United States Patent Application Publication 20250257728
Kind Code A1
Publication Date August 14, 2025
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PUMP WITH CONDUIT SYSTEM FLUIDLY COUPLED TO CYLINDERS

Abstract

A pump includes a cylinder and a piston disposed within the cylinder to define a first chamber and a second chamber within the cylinder. The piston is configured to move within the cylinder to reduce a size of the first chamber to discharge material from the first chamber. The pump also includes a conduit system configured to direct fluid into the first chamber to aerate material in the first chamber.

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Family ID: **94637693**

Appl. No.: **19/047533**

Filed: **February 06, 2025**

Related U.S. Application Data

us-provisional-application US 63553371 20240214

Publication Classification

Int. Cl.: **F04B53/16** (20060101); **F04B1/0408** (20200101); **F04B1/0421** (20200101); **F04B53/00** (20060101)

U.S. Cl.:

CPC **F04B53/16** (20130101); **F04B1/0408** (20130101); **F04B1/0421** (20130101); **F04B53/006** (20130101);

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION [0001] This patent application claims priority to and the benefit of, and is a non-provisional application of, U.S. Patent App. No. 63/553,371, filed Feb. 14, 2024, entitled “PUMP WITH CONDUIT SYSTEM FLUIDLY COUPLED TO CYLINDERS”, having Attorney Docket No. 5020.0251P/P381186.US.01, the entire disclosure of which is incorporated by reference herein in its entirety.

TECHNICAL FIELD
[0002] The present disclosure is directed to pumps and more specifically to a pump with a conduit system that fluidly couples cylinders to one another to direct fluid (e.g., gas) between the cylinders.
BACKGROUND
[0003] Pumps can be used to drive movement of certain materials. For example, the pump may include multiple cylinders, as well as pistons movable within each cylinder. Movement of the pistons within their respective cylinders directs materials through the cylinders. In some embodiments, the material being directed includes a powdered material. Unfortunately, powdered material is susceptible to settling within the cylinder, and settling of the powdered material may obstruct or choke a flow of the powdered material and/or impede movement of the pistons. Thus, settling of the powdered material may reduce an efficiency or an effectiveness of operation of a pump moving powdered material.
SUMMARY
[0004] In one embodiment, the present application is directed to a pump. The pump includes a cylinder and a piston disposed within the cylinder to define a first chamber and a second chamber within the cylinder. The piston is configured to move within the cylinder to reduce a size of the first chamber to discharge material from the first chamber. The pump also includes a conduit system configured to direct fluid into the first chamber to aerate material in the first chamber.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0005] To complete the description and provide a better understanding of the present disclosure, a set of drawings is provided. The drawings form an integral part of the description and illustrate an embodiment of the present disclosure, which should not be interpreted as restricting the scope of the disclosure, but just as an example of how the disclosure can be carried out.
[0006] FIG. **1** is a perspective side view of a pump system, in accordance with an embodiment of the present disclosure.
[0007] FIG. **2** is an exploded view of the pump system of FIG. **1**.
[0008] FIG. **3** is a perspective side view of a pump drive system of a pump system, in accordance with an embodiment of the present disclosure.
[0009] FIG. **4** is a cross-sectional view of the pump drive system of FIG. **3**.
[0010] FIG. **5** is a perspective view of the pump drive system of FIG. **3**.
[0011] FIG. **6** is a graph illustrating timing of piston strokes for a pump drive system, in accordance with an embodiment of the present disclosure.
[0012] FIG. **7** is a schematic diagram of a pump drive system, in accordance with an embodiment of the present disclosure.
[0013] FIG. **8** is a schematic diagram of a pump drive system, in accordance with an embodiment of the present disclosure.
[0014] FIG. **9** is a schematic diagram of a pump drive system, in accordance with an embodiment of the present disclosure.

[0015] FIG. **10** illustrates a pump drive system that includes a distributor for directing fluid into cylinders, in accordance with an embodiment of the present disclosure.

[0016] FIG. **11** is a schematic diagram of a pump drive system, in accordance with an embodiment of the present disclosure.

[0017] FIG. **12** is a schematic diagram of a method for operating a pump system, in accordance with an embodiment of the present disclosure.

[0018] Like numerals have been used throughout the Figures.

DETAILED DESCRIPTION

[0019] The present disclosure is directed to directing fluid (e.g., gas) between cylinders of a pump system to aerate material within the cylinders. It is to be understood that particulate, such as powdered material, may be present in the fluid that is directed between cylinders of a pump system. In other words, the fluid that is directed is not solely a fluid, such as a gas. Operation of the pump system drives movement of the material into and out of the cylinders. For example, each cylinder of the pump system defines a chamber, and movement of a piston within the chamber draws material into the chamber and directs material out of the chamber, such as at a desirable speed and/or pressure. By way of example, the material driven by the pump system includes a powdered material that contains small, solid particles.

[0020] Unfortunately, powdered material may settle within the chambers. Settled powdered material may be relatively more difficult to move via the pistons. For example, the settled powdered material may adhere to the walls of the cylinder and may be difficult to remove it from the walls with pumping pressure. The adhered powder may then increase friction in the chamber, reducing the effectiveness of the pump, further diminishing pumping effectiveness. Thus, a substantial portion of the powdered material may remain within the chambers instead of being directed out during movement of the pistons. For this reason, settling of the powdered material in the chambers may reduce an efficiency of operation of the pump system to direct the powdered material. Additionally or alternatively, powdered material may adhere with one another and compact. Consequently, during operation of the pump, the compacted powdered material may impact and collide with the pump to impart an excessive amount of force onto the pump, thereby affecting a structural integrity of the pump and of other components of the pump system (e.g., the cylinder wall against which the pump may move the powdered material) and potentially reducing a useful lifespan of the pump system.

[0021] Increasing movability of the powdered material may improve efficiency of operation of the pump system and/or increase a useful lifespan of the pump system. Therefore, in accordance with embodiments of the present disclosure, the pump includes a conduit system configured to aerate and/or agitate the powdered material within the chambers to prevent or at least discourage settling of the powdered material in the cylinders. For instance, the pump may include a first cylinder and a first piston disposed in the first cylinder to define a first pumping chamber and a first containment chamber. The pump may also include a second cylinder and a second piston disposed in the second cylinder to define a second pumping chamber and a second containment chamber. The first piston is configured to move within the first cylinder to discharge powdered material from the first pumping chamber, and the second piston is configured to move within the second cylinder to discharge powdered material from the second pumping chamber.

[0022] Movement of the first piston to draw powdered material into the first pumping chamber reduces a size of the first containment chamber to direct fluid from the first containment chamber to the second pumping chamber via the conduit system. The fluid directed into the second pumping chamber aerates the powdered material in the second pumping chamber to improve movability of the powdered material. As an example, the fluid causes the powdered material to be suspended within the second pumping chamber instead of adhering to the cylinder in the second pumping chamber. As such, the powdered material is more readily movable such that movement of the second piston can more efficiently discharge the powdered material from the second pumping chamber. That is, powdered material may flow more easily through the pump system and avoid compacting and/or settling. For this reason, the conduit system directing fluid flow from the first containment chamber to the second pumping chamber may improve operation of the pump and maintain a desirable structural integrity of the pump. Although the present disclosure primarily discusses usage of fluid to facilitate movement of powdered material, it should be noted that fluid may be directed between cylinders to facilitate movement of any other suitable material, including a fluid that does not contain substantial amounts of solid material.

[0023] FIG. **1** is a perspective side view of a pump system **50**. The pump system **50** includes, among other components, a diaphragm pump **10** that is operably coupled to a control system **12** and a drive or driver **14**. While embodiments discussed herein are primarily discussed in terms of diaphragm pump systems, at least certain features can also be applicable to a variety of other types of pump systems, including, but not limited to, other types of pumps and positive displacement pumps.

[0024] According to certain embodiments, the control system **12** can include, for example, an external embedded controller **11** that is communicatively coupled to a human-machine interface **13**, among other components. The external controller **11** is configured to automate the operation of the diaphragm pump **10**. For example, the external controller **11** can be configured to correlate speed of a driver **14**, such as, for example, a motor speed, with a flow rate of a material being pumped by the diaphragm pump **10**. The external controller **11** can also include an override for extended periods of a stall event. Further, the control system **12** may be optional to supplement a motor drive, such as a variable frequency drive (VFD) **15** that is configured to operate the driver **14**.

[0025] As shown in at least FIG. **1**, the diaphragm pump **10** is mechanically coupled to the driver **14**. The driver **14** is operably coupled to a timing device with a mechanical output, such as a crankshaft, **40** (FIG. **2**) of the pump system **50** such that operation of the driver **14** facilitates rotational displacement of at least the crankshaft **40** about a crankshaft axis (or “rotational axis”) **100** (FIG. **4**). Further, as shown in at least FIG. **1**, according to certain embodiments, operable coupling of the driver **14** to the crankshaft **40** includes a gearbox **16** that is configured to adjust and/or control the relative speeds and torque transmitted from the driver **14** to the crankshaft **40**.

[0026] The diaphragm pump **10** includes a crankcase **17** and a plurality of cylinders **18**. During operation of the pump system **50**, the diaphragm pump **10** directs powdered material into and out of each cylinder **18**. For example, referring to FIGS. **1** and **2**, powdered material can enter each cylinder **18** through an inlet **22**, and powdered material can exit each cylinder **18** through an outlet **24**. The driver **14** may drive rotation of the crankshaft **40** to direct the powdered material in a particular manner, such as at a particular speed and/or at a particular pressure.

[0027] The diaphragm pump **10** also includes a conduit system **150** extending between the cylinders **18**. The conduit system **150** is configured to direct a fluid, such as air (e.g., compressed air), between the cylinders **18**. The fluid flow between the cylinders **18** may aerate or agitate the powdered material within the cylinders **18** to prevent or at least discourage settling of the powdered material within the cylinders **18**, thereby facilitating movement of the powdered material through the cylinders **18**. Thus, the conduit system **150** may improve operation of the pump system **50**.

[0028] FIG. **2** is an exploded view of the pump system **50** that includes the diaphragm pump **10** with an associated stand **30**. The pump system **50** includes a common inlet manifold **20** and a common outlet manifold **38**, among other components. The common inlet manifold **20** introduces powdered material into the cylinders **18** via the inlets **22**, and the common outlet manifold **38** directs the powdered material out of the cylinders **18** via the outlets **24**. The crankshaft **40** protrudes from the crankcase **17** and is coaxially coupled with a drive shaft **19** of the driver **14** to direct the powdered material through the cylinders **18**. While three cylinders **18** are primarily provided herein, any quantity of cylinders **18** can be implemented in additional or alternative embodiments.

[0029] According to at least certain embodiments, each of the cylinders **18** can have generally similar components. For example, each cylinder **18** can include an outer housing **42** (e.g., a fluid cap), an inner housing **44**, and a diaphragm **80** positioned between the outer housing **42** and the inner housing **44**. In the depicted embodiment, each diaphragm **80** is secured within its cylinder **18** via a mechanical fastener **74**, such as a bolt. Other couplings may be used to secure the diaphragms in other embodiments. The conduit system **150** is coupled to the outer housing **42** and to the inner housing **44** of each of the cylinders **18**.

[0030] Additionally, according to certain embodiments, one-way check valves **48** can be functionally positioned proximate to both the inlet **22** and the outlet **24** of each of the cylinders **18**. While a variety of types of one-way check valves can be utilized, according to certain embodiments, the one-way check valves **48** are ball valves. In some embodiments, such ball valves may be gravity operated. In additional or alternative embodiments, the one-way check valves **48** may include a biasing element, such as a spring, among other forms of biasing elements.

[0031] FIG. **3** is a perspective side view of a pump drive system **200** of the diaphragm pump **10**. As shown in FIG. **3**, the crankcase **17** includes a lower crankcase **26** and an upper crankcase **28**. Each cylinder **18** is mounted to the lower crankcase **26** via a shoulder **61**. The crankshaft **40** extends from the upper crankcase **28**, and the upper crankcase **28** includes a seal **114** that extends around a portion of the crankshaft **40** to sealingly engage the upper crankcase **28** with the crankshaft **40**. Also shown in FIG. **3** are the outlets **24**, the outer housings **42**, and the inner housings **44** for cylinders **18**.

[0032] FIG. **4** is a cross-sectional view of the pump drive system **200** taken along line **4-4** in FIG. **3**. As shown in FIG. **4**, each outer housing **42** defines at least a portion of a pumping chamber **46** of its respective cylinder **18**. The pumping chamber **46** is in fluid communication with the inlet **22** and the outlet **24** of the respective cylinder **18**. As such, powdered material enters the pumping chamber **46** via the inlet **22** and exits the pumping chamber **46** via the outlet **24**. Further, each diaphragm **80** within its cylinder **18** is coupled to an adjacent piston **68** of a slider crank mechanism **21**. In addition to a plurality of pistons **68**, the illustrated slider crank mechanism **21** includes connecting rods **62** coupled to the pistons **68**. The connecting rod **62** extends from the piston **68** to connect to the crankshaft **40**, such as by a bearing ring or journal bearing **84**. Such connection between the connecting rods **62** and the crankshaft **40** enables movement (e.g., rotation) of the crankshaft **40** to drive movement of the connecting rods **62** and therefore movement of the pistons **68** coupled to the connecting rods **62**. For instance, rotation of the crankshaft **40** causes each piston **68** to move reciprocally (e.g., back and forth) within a corresponding piston housing **60** extending between the crankcase **17** and the inner housing **44** to drive corresponding movement of the diaphragm **80** in the particular cylinder **18**.

[0033] At least certain components of the slider crank mechanism **21** that are associated with a particular cylinder **18** have the same configuration as other similar components of the slider crank mechanism **21** that are associated with another cylinder **18**. For instance, each of the piston **68**, the piston housing **60**, and/or the connecting rod **62** of the slider crank mechanism **21** that is used with a particular cylinder **18** can have similar configuration and features as a similar component that is used with another cylinder **18**. Indeed, similar elements and associated features for those elements can exist for each of the cylinders **18** and the associated slider crank mechanism **21**, whether or not such similar elements and features are actually viewable in certain drawings of this disclosure. Notably, since the cylinders **18** of the embodiments depicted in FIG. **4** are longitudinally (e.g., vertically) offset, different portions of each cylinder **18** are visible in FIG. **4**.

[0034] Operation of the slider crank mechanism **21** and movement of the crankshaft **40** causes each piston **68** to reciprocate along a piston axis that extends through a cylinder bore **59** of the piston housing **60**. Each piston **68** extends between a first end **92** that is coupled to one of the connecting rods **62** and a second end **94** that is coupled to one of the diaphragms **80**. Thus, reciprocation of the pistons **68** along the piston axes drives movement of the diaphragms **80** within the cylinders **18**. The portion of each piston **68** proximate to the crankcase **17**, namely the first end **92** of the piston

68, includes a wrist pin cavity in which a wrist pin **64** is positioned that attaches the piston **68** to the connecting rod **62**.

[0035] A corresponding cylinder axis **116** extends through the center of each cylinder **18**. Each cylinder axis **116** for the cylinders **18** is perpendicular to the crankshaft axis **100** of the crankshaft **40**, and the cylinder axes **116** are distributed circumferentially around the crankshaft axis **100**. However, in additional or alternative embodiments, the cylinder axes **116** may be oriented in a different manner relative to the crankshaft axis **100**, such as extending along (e.g., parallel to) the crankshaft axis **100**. Each piston **68** is configured to move along a corresponding cylinder axis **116**. That is, the piston axis along which each piston **68** reciprocates is aligned with the corresponding cylinder axis **116**. In some embodiments, the cylinders **18** are offset from one another along the crankshaft axis **100**. That is, the cylinder axes **116** are offset from one another along the crankshaft axis **100**. Thus, each piston **40** is connected to a different portion of the crankshaft **40**.

[0036] Movement of the pistons **68** within the cylinders **18** causes the diaphragms **80** to change a volume, and thus a pressure, within their respective pumping chamber **46**. For instance, each diaphragm **80** may be coupled to the outer housing **42** and/or to the inner housing **44** via an annular flexible portion **83**, which can flex to adjust the positioning of the diaphragms **80** within the cylinder **18**, thereby changing the volume within the pumping chamber **46**. The change in volume effectuated by the diaphragms **80** may move powdered material into and out of the pumping chambers **46**. For example, displacing or flexing at least a portion of the diaphragm **80** (e.g., via the annular flexible portion **83**) to increase a volume and therefore decrease a pressure within the pumping chamber **46** may draw powdered material into the pumping chamber **46** through an inlet **22**. Additionally, displacement or flexing of the diaphragm **80** (e.g., via the annular flexible portion **83**) to decrease the volume of the pumping chamber **46** and therefore increase a pressure within the pumping chamber **46** may force at least a portion of the powdered material out of the pumping chamber **46** through an outlet **24**.

[0037] The diaphragm **80** within the cylinder **18** can be designed as a replaceable wear component. For example, in the illustrated embodiment, the diaphragm **80** is mechanically coupled to the second end **94** of an associated piston **68** via a mechanical fastener **74**. The mechanical fastener **74** extends through an inner washer **76** and an outer washer **78** that are positioned on, and support, opposing sides of the diaphragm **80**. By way of example, the radially inner portion of diaphragm **80** can be secured between the inner washer **76** and the outer washer **78**. The washers **76** and **78** are configured to provide stabilizing and rigid support to at least the adjacent portion of the diaphragm **80**. Additionally, the annular flexible portion **83** extends radially outward from the washers **76** and **78** and can be securely fitted between opposing sealing surfaces of the inner housing **44** and the outer housing **42**. In additional or alternative embodiments, either or both of the washers **76** and **78** may be integrated into the diaphragm **80** to form a monolithic structure.

[0038] The illustrated embodiment includes a containment chamber **81** defined on the backside of each diaphragm **80**. Each diaphragm **80** provides a seal that fluidly separates a containment chamber **81** and a corresponding pumping chamber **46** from one another. During operation of the pump drive system **200**, the containment chamber **81** includes a fluid, such as ambient air and/or a dedicated process fluid. The conduit system **150** fluidly couples the containment chamber **81** of one of the cylinders **18** with the pumping chamber **46** of another of the cylinders **18**. Thus, fluid may pass between the cylinders **18**. For instance, during an intake stroke in which a diaphragm **80** is forced axially toward the crankcase **17**, the volume of the containment chamber **81** is reduced to force fluid out of the containment chamber **81** and into the conduit system **150**. The conduit system **150** then directs the fluid to the pumping chamber **46** of another cylinder **18**. As a result, the fluid may interact with the powdered material in the pumping chamber **46** of the other cylinder **18** to aerate the powdered material, thereby discouraging settling of the powdered material within the other cylinder **18**. As a result, movement of the piston **68** within the other cylinder **18** (e.g., to reduce a volume of its pumping chamber **46**) may direct the powdered material out of the other cylinder **18** more effectively.

[0039] Moreover, the containment chamber **81** is substantially sealed from a lubricant bath that is within at least a portion of the crankcase **17**, such as, for example, lubricant that is within the crankcase **17** and is utilized to reduce wear and distribute heat of the crankshaft **40** and the connecting rods **62**. A seal assembly **72** bears against the outer surface of the piston **68**. The seal assembly **72** can include, for example, one or more oil facing seals and one or more containment chamber facing seals including, but not limited, to bellows seals and bi-directional seals. According to certain embodiments, the containment chamber facing seal can be a bellow design (not shown) that spans between the second end **94** of the piston **68** and the piston housing **60**. The seal assembly **72** is configured and positioned to prevent or discourage lubricant from mixing with fluid in the containment chamber **81**.

[0040] Furthermore, sensors **152** are used to monitor amounts of powdered material in the containment chambers **81**. For example, presence of powdered material in the containment chambers **81** may indicate leakage of powdered material through the diaphragms **80** (e.g., caused by an undesirable change in structural integrity of the diaphragms **80**). Thus, the sensors **152** may be used to determine whether operation of the pump drive system **200** is desirable to direct powdered material and avoid buildup of powdered material in the containment chambers **81**. By way of example, the sensors **152** may include optical sensors configured to visually determine a presence of powdered material in the containment chambers **81** (e.g., by capturing an image within the containment chambers **81**). However, any other suitable type of sensors **152** may be utilized to monitor a parameter, such as a weight, indicative of presence of powdered material in the containment chambers **81**. In certain embodiments, a control system **154** is communicatively coupled to the sensors **152**. The control system **154** includes a memory **156** and a processor **158** (e.g., processing circuitry). The memory **156** includes read only memory (ROM), random access memory (RAM), magnetic disk storage media devices, optical storage media devices, flash memory devices, electrical, optical, or other physical/tangible (e.g., non-transitory) memory storage devices. Thus, in general, the memory **156** includes one or more computer-readable storage media (e.g., a memory device) encoded with software with computer executable instructions that may be executed to effectuate the operations described herein. The processor **158** includes a collection of one or more microcontrollers and/or microprocessors, for example, each configured to execute respective software instructions stored in the memory **156**. The processor **158** is configured to, for example, execute the instructions stored in the memory **156** to operate the pump drive system **200**.

[0041] For instance, the control system **154** may receive data from the sensors **152** and determine an amount of powdered material in the containment chambers **81** based on the data. In response to a determination that the amount of powdered material in the containment chambers **81** is above a threshold amount (e.g., to indicate sufficient leakage of powdered material), the control system **154** may output a signal. As an example, the signal may provide a notification, such as a visual output (e.g., via a display **160**), an audio output, and/or a notification sent to a user device. Thus, the signal may prompt a user to inspect the pump drive system **200** and address buildup of powdered material in the containment chambers **81**. As another example, the signal may suspend or reduce operation of the pump drive system **200** to avoid further leakage of powdered material into the containment chambers **81**.

[0042] FIG. **5** is a perspective side view of the pump drive system **200** illustrating a first cylinder **18**A fluidly coupled to a second cylinder **18**B via the conduit system **150**. In particular, a conduit of the conduit system **150** is fluidly coupled to the containment chamber **81** of the first cylinder **18**A and to the pumping chamber **46** of the second cylinder **18**B. More specifically, a first end of the conduit is coupled to an opening of the inner housing **44** of the first cylinder **18**A and a second end of the conduit is coupled to an opening of the outer housing **42** of the second cylinder **18**B. Thus, axial movement (e.g., translation) of the piston **68** in the first cylinder **18**A toward the crankcase **17**, as effectuated by the driver **14**, reduces the volume of the containment chamber **81** of the first cylinder **18**A and drives fluid flow from the containment chamber **81**. This fluid flow moves through the conduit and into the pumping chamber **46** of the second cylinder **18**B. Consequently, the fluid may aerate powdered material within the pumping chamber **46** of second cylinder **18**B to allow the piston **68** in the second cylinder **18**B to efficiently pump powdered material. For example, axial movement of the piston **68** in the second cylinder **18**B away from the crankcase **17** may discharge the aerated powdered material more efficiently from the pumping chamber **46** of the second cylinder **18**B than embodiments without aeration/agitation. In some embodiments, such movement of the piston **68** in second cylinder **18**B may also drive movement of the fluid received from the conduit out of the pumping chamber **46**. That is, a mixture of the powdered material and the fluid may be discharged out of the pumping chamber **46**.

[0043] In the illustrated embodiment, the conduit is coupled to the outer housing **42** at a portion (e.g., a lower portion) coupled to the common inlet manifold **20**. Thus, the conduit is positioned adjacent to the inlet **22**, which is configured to direct powdered material into the pumping chamber **46**. Accordingly, powdered material directed into the pumping chamber **46** via the inlet **22** may immediately be aerated by the fluid directed from the conduit as it enters pumping chamber **46** to avoid settling of the powdered material.

[0044] In some embodiments, as described above, a first one-way valve (e.g., a first check valve) may be implemented at the conduit between the pumping chamber **46** of the second cylinder **18**B and the containment chamber **81** of the first cylinder **18**A. For instance, the first one-way valve may be positioned at a first end of the conduit adjacent to the pumping chamber **46** of the second cylinder **18**B or at a second end of the conduit adjacent to the containment chamber **81** of the first cylinder **18**A. The first one-way valve blocks flow of fluid from the pumping chamber **46** of the second cylinder **18**B toward the containment chamber **81** of the first cylinder **18**A, thereby forcing fluid flow from the containment chamber **81** of the first cylinder **18**A to the pumping chamber **46** of the second cylinder **18**B. The first one-way valve may also prevent or at least discourage powered material from exiting the pumping chamber of one cylinder and moving into the containment chamber of another cylinder. Thus, the first one-way valve improves fluid flow to aerate powdered material in the pumping chamber **46**.

[0045] Additionally or alternatively, a second one-way valve (e.g., a second check valve) may be implemented on the first cylinder **18**A to enable flow of fluid into the containment chamber **81** of the first cylinder **18**A and block flow of fluid from the containment chamber **81** of the first cylinder **18**A into a surrounding environment (e.g., an ambient environment, an external environment). Thus, during a discharge stroke in which the volume of the containment chamber **81** of the first cylinder **18**A is increased, fluid is directed from the surrounding environment into the containment chamber **81** of the first cylinder **18**A. Similarly, a third one-way valve (e.g., a third check valve) may be implemented on the second cylinder **18**B to enable flow of fluid into the containment chamber **81** of the second cylinder **18**B and block flow of fluid from the containment chamber **81** of the second cylinder **18**B into the surrounding environment. As such, a discharge stroke that increases the volume of the containment chamber **81** of the second cylinder **18**B directs fluid from the surrounding environment into the containment chamber **81** of the second cylinder **18**B.

[0046] In some embodiments, a valve (e.g., a flow control valve) is used to adjust the flow rate of fluid through the conduit, such as by adjusting an opening within the conduit through which the fluid is directed. Thus, the valve adjusts the flow rate of fluid directed into the pumping chamber of the second cylinder **18**B. For example, the valve may be adjusted for various operating modes that may include different rates of powdered material to be directed and, therefore, demand different corresponding flow rates of fluid to be directed into the pumping chambers to aerate the powdered material.

[0047] FIG. **6** is a graph illustrating movement of different pistons within their respective cylinders. In particular, a first line **600** corresponds to movement of a first piston within a first cylinder (e.g., the first cylinder **18**A), and a second line **610** corresponds to movement of a second piston within a second cylinder (e.g., the second cylinder **18**B). A conduit system is configured to direct fluid from the containment chamber **81** of the first cylinder **18**A to the pumping chamber **46** of the second cylinder **18**B to aerate powdered material in the pumping chamber **46** of the second cylinder **18**B. The lines **600** and **610** indicate a size of the pumping chamber in the respective cylinders resulting from movement of the pistons therein. For example, a decrease in the value of a line is associated with decreasing a volume in the pumping chamber and, therefore, indicates a stroke of the piston to discharge powdered material in the particular cylinder. An increase in the value of a line is associated with increasing the volume in the pumping chamber and, therefore, indicates a stroke of the piston to draw powdered material in the particular cylinder. An increase of a line is also associated with decreasing the volume in the containment chamber **81** to discharge fluid from the containment chamber **81**.

[0048] The illustrated graph shows that the first line **600** begins to increase at T**1**, whereas the second line **610** begins to decrease at T**2**, which occurs after T**1**. That is, the first piston begins to move to increase the size of the pumping chamber **46** of the first cylinder **18**A and to decrease the size of the containment chamber **81** of the first cylinder **18**A before the second piston begins to move to decrease the size of the pumping chamber **46** of the second cylinder **18**B. Accordingly, the first piston begins to discharge fluid from the containment chamber **81** of the first cylinder **18**A as a result of the decrease in the size of the containment chamber **81** of the first cylinder **18**A before the second piston begins to discharge powdered material from the pumping chamber **46** of the second cylinder **18**B as a result of the decrease in the size of the pumping chamber **46** of the second cylinder **46**. As such, by the time the second piston moves to discharge powdered material, the powdered material is sufficiently aerated by the fluid. In other words, a piston of one cylinder moves to direct fluid into the pumping chamber **46** of another cylinder prior to the piston of the other cylinder moving to discharge powdered material from the pumping chamber **46** to readily enable increased movement of the powdered material. Consequently, the timing of movement (e.g., an intake stroke) of the first piston relative to the movement (e.g., a discharge stroke) of the second piston helps improve operation of a pump drive system.

[0049] It should be noted that the first line **600** stops increasing at time T**3** and the second line **610** stops decreasing at a time T**4**, which occurs after T**3**. For example, a first duration of time in which the first line **600** increases may be substantially similar to a second duration of time in which the second line **610** decreases. That is, movement of the first piston to increase the size of the pumping chamber **46** of the first cylinder **18**A takes about as long as movement of the second piston to decrease the size of the pumping chamber **46** of the second cylinder **18**B. However, it should be noted that a duration of time in which the first piston moves to increase the size of the pumping chamber **46** of the first cylinder **18**A may be greater than or less than that in which the second piston moves to decrease the size of the pumping chamber **46** of the second cylinder **18**B in alternative embodiments. In any case, the termination of the increase of the first line **600** prior to the termination of the decrease of the second line **610** indicates that the fluid flow from the containment chamber **81** of the first cylinder **18**A to the pumping chamber **46** of the second cylinder **18**B is suspended prior to completed movement of the second piston to discharge powdered material from the pumping chamber **46** of the second cylinder **18**B. However, the powdered material in the pumping chamber **46** of the second cylinder **18**B may remain aerated for a duration of time after fluid flow into the pumping chamber **46** of the second cylinder **18**B has been suspended. Therefore, despite fluid flow into the pumping chamber **46** of the second cylinder **18**B being suspended prior to completed movement of the second piston to discharge powdered material, the second piston may still effectively discharge powdered material from the pumping chamber **46** after T**3** (e.g., until movement of the second piston is completed at T**4**).

[0050] Alternatively, in other embodiments, other timing schemes may be utilized. For example, aeration of a pumping chamber may occur simultaneously with start of a powder discharge stroke or after the start of a powder discharge stroke. The timing scheme may also shift over the course of a pumping operation if desired. Still further, while FIG. **6** illustrates two cylinders, the timing sequence of FIG. **6** or variations thereof described herein may be applied to pumps with any number of chambers, with identical sequences applied across all cylinders, and/or with different timing sequences used between different pairs of cylinders (and/or changing over time). Indeed, the timing scheme between one pair of the cylinders may be different from the timing scheme between another pair of the cylinders implemented in the same pump drive system.

[0051] The techniques discussed herein may also be implemented in other configurations of pump drive systems, such as a different pump drive system having a different arrangement of cylinders and pistons. For example, FIG. **7** is a schematic diagram of pump system (e.g., a diaphragm pump or another suitable type of pump system) **700** that includes a first cylinder **710** and a second cylinder **740**. A first piston **712** is disposed in and configured to move (e.g., translate) within the first cylinder **710**, and a second piston **742** is disposed in and configured to move (e.g., translate) within the second cylinder **740**. For example, the first piston **712** defines a first pumping chamber **720** and a first containment chamber **722** in the first cylinder **710**, and the second piston **742** defines a second pumping chamber **750** and a second containment chamber **752** in the second cylinder **740**. Movement of the first piston **712** within the first cylinder **710** adjusts a size of the first pumping chamber **720** and of the first containment chamber **722**, and movement of the second piston **742** within the second cylinder **740** adjusts a size of the second pumping chamber **750** and of the second containment chamber **752**.

[0052] In the illustrated embodiment, the first piston **712** is coupled to a driver **704** via a first rod **714**, and the second piston **742** is coupled to the driver **704** via a second rod **744**. The driver **704** is configured to move within a housing **702** to drive corresponding movement of the first piston **712** and of the second piston **742**. For example, movement of the driver **704** in a first direction “A” may move the first piston **712** and the second piston **742** in the first direction “A” to reduce the sizes of the first pumping chamber **720** and the second containment chamber **752** while increasing the sizes of the first containment chamber **722** and the second pumping chamber **750**. Thus, movement of the driver **704** in the first direction “A” may cause the first piston **712** to discharge powdered material from the first pumping chamber **720** while also causing the second piston **742** to draw powdered material into the second pumping chamber **750**. Movement of the driver **704** in a second direction “B”, opposite the first direction “A”, may move the first piston **712** and the second piston **742** in the second direction “B” to increase the sizes of the first pumping chamber **720** and the second containment chamber **752** while reducing the sizes of the first containment chamber **722** and of the second pumping chamber **750**. As such, movement of the driver **704** in the second direction “B” may cause the second piston **742** to discharge powdered material from the second pumping chamber **750** while also causing the first piston **712** to draw powdered material into the first pumping chamber **720**. The driver **704** may reciprocate to alternate movement between the first direction “A” and the second direction “B”.

[0053] The pump drive system **700** also includes a conduit system **760** having a first conduit **762** and a second conduit **764**. The first conduit **762** is fluidly coupled to the first containment chamber **722** and the second pumping chamber **750**, and the second conduit **764** is fluidly coupled to the first pumping chamber **720** and the second containment chamber **752**. As such, movement of the first piston **712** in the second direction “B” causes fluid to flow through the first conduit **762**, from the first containment chamber **722** to the second pumping chamber **750**, and aerate powdered material in the second pumping chamber **750**. On the other hand, movement of the second piston **742** in the first direction “A” causes fluid to flow through the second conduit **764**, from the second containment chamber **752** to the first pumping chamber **720**, and aerate powdered material in the first pumping chamber **720**. Therefore, reciprocating motion of the driver **704** alternately pumps powdered material from the first pumping chamber **720** and the second pumping chamber **750** while also alternately moving fluid into the first pumping chamber **720** and the second pumping chamber **750** to aerate powdered material in the cylinders **710** and **740**. Consequently, the pump drive system **700** may more effectively and efficiently pump powdered material.

[0054] In the depicted embodiment, a first one-way valve (e.g., a first check valve) **770** is configured to block fluid flow from the second pumping chamber **750** to the first containment chamber **722**. To this end, the first one-way valve **770** is positioned between the second pumping chamber **750** and the first containment chamber **722**, such as adjacent to the first containment chamber **722** or adjacent to the second pumping chamber **750**. Meanwhile, a second one-way valve (e.g., a second check valve) **772** is configured to block fluid flow from the first pumping chamber **720** to the second containment chamber **752**. To this end, the second one-way valve **772** is positioned between the first pumping chamber **720** and the second containment chamber **752**, such as adjacent to the first pumping chamber **720** or adjacent to the second containment chamber **752**. With these one-way valves **770** and **772**, the powdered material being pumped may not contaminate or clog the containment chambers **722** and **752** or the conduit system **760**. However, other embodiments might also achieve similar advantages with various quantities of check valves.

[0055] Furthermore, a third one-way valve (e.g., a third check valve) **774** is configured to block fluid flow from the first containment chamber **722** into a surrounding environment while allowing fluid flow from the surrounding environment into the first containment chamber **722**. Additionally, a fourth one-way valve (e.g., a fourth check valve) **776** is configured to block fluid flow from the second containment chamber **752** into the surrounding environment while allowing fluid flow from the surrounding environment into the second containment chamber **752**. With these one-way valves, respective discharge strokes that increase the volume of the first containment chamber **722** and of the second containment chamber **752** direct fluid flow into the containment chambers **722** and **752** and enable fluid flow via the conduit system **760**.

[0056] Still referring to FIG. **7**, the illustrated pump drive system **700** includes two cylinders **710** and **740** in which each conduit is fluidly coupled to the cylinders. However, the pump drive system may include any suitable quantity of cylinders (e.g., multiple pairs of cylinders coupled to respective drivers) and/or the conduit system may include conduits that fluidly couple to cylinders in a different manner (e.g., a conduit is fluidly coupled to cylinders of different pairs, such as a daisy-chain arrangement) in additional or alternative embodiments. In such embodiments, movement of the respective pistons in the cylinders drives fluid flow between cylinders to aerate material in different cylinders to facilitate pumping of powdered material.

[0057] FIG. **8** is a schematic diagram of a pump drive system **800** which includes several similar structural features to pump system **700**. Pump drive system **800** includes a fluid source (e.g., a tank, a reservoir) **805** that is fluidly coupled to a first containment chamber **822** and to a second containment chamber **852**. The fluid source **805** is configured to store a fluid (e.g., air, nitrogen), such as low pressure fluid, and direct fluid into the containment chambers **822** and **852** via a conduit system **880** (e.g., a first conduit **882** fluidly coupling the first containment chamber **822** and the fluid source **805** to one another, and a second conduit **884** fluidly coupling the second containment chamber **852** and the fluid source **805** to one another). For instance, the fluid source **805** may be configured to fill the containment chambers **822** and **852** with fluid such that movement of pistons **812** and **842** to reduce the size of the containment chambers **822** and **852**, respectively, may readily discharge fluid from the containment chambers **822** and **852** to a corresponding pumping chamber **820** or **850**. Thus, the fluid source **805** facilitates sufficient fluid flow into the pumping chambers **820** and **850** to aerate powdered material and improve operation of the pump drive system **800** to discharge powdered material.

[0058] In some embodiments, the fluid source **805** includes a pump configured to direct air (e.g., ambient air) from the surrounding environment of the pump drive system **800** into the containment chambers **822** and **852**. In additional or alternative embodiments, the fluid source **805** includes a tank or reservoir that stores fluid separate from air in the surrounding environment, and the fluid source directs fluid from the tank into the containment chambers **822** and **852**.

[0059] FIG. **9** is a schematic diagram of another pump system **900** in which a fluid source **905** is fluidly coupled to the first pumping chamber **920** and to the second pumping chamber **950**. The fluid source **905** is configured to supply fluid directly into the pumping chambers **920** and **950** via a conduit system **980**, such as a first conduit **982** fluidly coupling the fluid source **905** to the first pumping chamber **920** and a second conduit **984** fluidly coupling the fluid source **905** to the second pumping chamber **950**. Thus, fluid may be directed into cylinders **910** and **940** to aerate powdered material without having to pass fluid between the cylinders **910** and **940**. In certain embodiments, the fluid source may direct fluid at particular time intervals, such as near or during respective discharge strokes to aerate the powdered material and facilitate pumping of powdered material.

[0060] FIG. **10** includes a perspective view of a pump system that includes a fluid source configured to store and output a fluid (e.g., air, nitrogen). The pump system also includes a distributor (e.g., a pneumatic distributor) coupled to a crankcase and configured to enable fluid flow from the fluid source into the pumping chambers at particular time intervals, such as near or during respective discharge strokes. By way of example, the distributor may include a first component (e.g., a stator) having supply channels, and each supply channel is fluidly coupled to a respective pumping chamber via the conduit system, such as by connecting each supply channel to a respective conduit using a connector disposed in or coupled to the distributor. The distributor may also include a second component (e.g., a rotor) with an inlet channel fluidly coupled to the fluid source, as well as a passage fluidly coupled to the inlet channel. The fluid source may be pressurized and therefore configured to fill the inlet channel and the passage of the second component with fluid.

[0061] However, the second component moves relative to the first component to alternately enable and block fluid flow from the passage through the different supply channels and into the pumping chambers. For instance, the second component may be coupled to the crankshaft of the pump system and therefore configured to sequence movement to adjust positioning of the passage relative to each supply channel. Alignment of the passage with a supply channel enables fluid flow from the fluid source through the supply channel and into the corresponding pumping chamber. Misalignment of the passage with a supply channel (e.g., the passage is aligned with another supply channel, the passage is aligned with a wall of the first component) blocks fluid flow from the fluid source through the supply channel. Therefore, the corresponding pumping chamber does not receive fluid from the fluid source. As such, sequential movement of the second component, such as rotation thereof, as driven by rotation of the crankshaft, may selectively supply fluid to the pumping chambers, such as at the particular time intervals to improve pumping of powdered material. In alternative embodiments, the sequential movement of the second component can be a movement other than rotation.

[0062] The first component may also be rotated relative to the crankcase to move the supply channels relative to the second component and change the timing in which fluid is directed into the pumping chambers. For example, in a first orientation of the first component (e.g., a first rotational position of the first component relative to the crankcase), a first rotational position of the second component aligns the passage with the supply channel configured to direct fluid into a pumping chamber of a cylinder. The first rotational position of the second component may correspond to a first rotational position of the crankshaft at which movement of a piston to discharge powdered material from the pumping chamber of the cylinder is initiated. Thus, in the first orientation of the first component, the second component is configured to direct fluid from the fluid source into the pumping chamber of the cylinder as the crankshaft initiates movement of the piston to discharge powdered material from the pumping chamber.

[0063] However, in a second orientation of the first component (e.g., a second rotational position of the first component relative to the crankcase), the first rotational position of the second component no longer aligns the passage with the supply channel. As such, in the second orientation of the first component, the second component is not configured to direct fluid from the fluid source into the pumping chamber of the cylinder as the crankshaft initiates movement of the piston to discharge powdered material from the pumping chamber. Instead, in the second orientation of the first component, a second rotational position of the second component aligns the passage with the supply channel. The second rotational position of the second component may correspond to a second rotational position of the crankshaft that is in place prior to initiation of the movement of the piston to discharge powdered material from the pumping chamber (i.e., the piston does not move to discharge powdered material from the pumping chamber until the crankshaft has moved from its second rotational position to its first rotational position). Therefore, in the second orientation of the first component, the second component is configured to direct fluid from the fluid source into the pumping chamber of the cylinder before the crankshaft initiates movement of the piston to discharge powdered material from the pumping chamber (e.g., to preemptively aerate the powdered material such that the powdered material may be moved more easily upon initiating movement of the piston to discharge powdered material). Accordingly, the first component may be rotated and positioned to change the timing of when fluid is directed into the pumping chamber relative to movement of the piston.

[0064] Although the passages of the distributor are uniformly distributed around a rotational axis of the first component (i.e., the respective angles formed between each adjacent passage are equal to one another) in the illustrated embodiment, in alternative embodiments, the passages may not be uniformly distributed around the rotational axis. For instance, a passage may be more adjacent to one of the other passages than to another of the passages. In other words, the respective angles formed between each adjacent passage may be different form one another (e.g., a first angle formed between a first passage and a second passage is greater than a second angle formed between the first passage and a third passage. Such distribution of the passages may adjust a timing in which fluid is directed into each cylinder (e.g., to correspond more suitably to movement of the respective pistons within the cylinders).

[0065] To enable rotation of the first component relative to the crankcase, the first component includes slots or openings. A fastener is inserted through each slot to fix to the crankcase and secure the first component to the crankcase. In addition, the slots enable the first component to rotate relative to the fastener and therefore relative to the crankcase. For example, the fastener may be loosened to reduce compression of the first component against the crankcase and enable movement of the first component relative to the crankcase, and the fastener may be tightened to compress the first component securely against the crankcase and block movement of the first component relative to the crankcase, thereby securing the orientation of the first component. As such, the timing of directing fluid into the pumping chamber may be readily adjusted (e.g., manually adjusted) and set (e.g., manually set) as desired. Although the distributor is configured to direct fluid into the pumping chambers via a rotating mechanism in the illustrated embodiment, the distributor may direct fluid into the pumping chambers using any other suitable mechanism in additional or alternative embodiments.

[0066] A size of the passage and/or of the supply channels may establish a flow rate of fluid directed into the various pumping chambers. For instance, to provide fluid at different flow rates into the pumping chambers, the distributor may be manufactured to have supply channels with different sizes. Additionally or alternatively, a valve (e.g., a flow control valve) disposed in or at the conduit may control flow rate directed into a pumping chamber. By way of example, the valve may be adjustable to readily increase or decrease the flow rate, such as regardless of the manufactured size of the supply channels. In further embodiments, the fluid source may be operated to control the flow rate directed into the distributor and toward the pumping chambers, such as to adjust the flow rate of fluid discharged by the fluid source to adjust the flow rate of fluid directed into each pumping chamber.

[0067] One or more one-way valves (e.g., a respective one-way valve for each supply channel) may also be implemented to block fluid flow from the pumping chambers toward the distributor. For instance, the one-way valves may be positioned between the distributor and the pumping chambers, such as along the conduits, at the distributor, and/or at the pumping chamber. Thus, undesirable fluid flow into the distributor (e.g., and toward the fluid source) may be avoided, such as during operation of the pump system during which the pumping chambers are pressurized and/or upon suspending operation of the pump system during which the fluid source does not operate to direct fluid into the pumping chambers.

[0068] Moreover, in certain embodiments, the containment chamber of each cylinder is fluidly coupled to a surrounding environment to enable fluid flow between the containment chambers to the and the surrounding environment. For instance, a discharge stroke that increases the volume of the containment chamber may direct fluid into the containment chamber from the surrounding environment, and a suction stroke that reduces the volume of the containment chamber may discharge fluid from containment chamber into the surrounding environment. Additionally or alternatively, the containment chamber of each cylinder is fluidly coupled to one another. Consequently, fluid may be transferred between containment chambers of different cylinders. That is, a suction stroke that reduces the volume of a containment chamber discharges fluid from the containment chamber to another containment chamber, and a discharge stroke that increases the volume of a containment chamber directs fluid from another containment chamber into the containment chamber. In either case, fluid flow into and out of the containment chambers reduce or limit undesirable pressure levels within the containment chamber that otherwise would impede movement of the pistons. Consequently, the pistons move more easily and readily to direct powdered material.

[0069] Although the distributor is incorporated into the pump system that moves pistons within corresponding cylinders via a crankshaft in the illustrated embodiment, the distributor may be incorporated in a pump system (e.g., any of the pump systems shown in FIGS. **7-9**) that utilizes a reciprocating shaft that moves multiple pistons in an alternating manner in other embodiments. Indeed, the distributor or any other suitable timing mechanism may be incorporated into any of the pump systems disclosed herein to adjust fluid flow directed into the pumping chamber of different pistons relative to one another.

[0070] FIG. **11** is a schematic diagram of a pump system (e.g., a diaphragm pump or another suitable type of pump system) **1100** that includes a single cylinder **1110**. A piston **1112** is disposed in and configured to move (e.g., translate) within the cylinder **1110** to define a pumping chamber **1120** and a containment chamber **1122** in the cylinder **1110**. The piston **1112** includes one or more diaphragms that define the pumping chamber **1120** and the containment chamber **1122** in the cylinder **1110**. Movement of the piston **1112** within the cylinder **1110** adjusts a size of the pumping chamber **1120** and of the containment chamber **1122**. The piston **1112** is coupled to a driver **1104** via a rod **1114**, and the driver **1104** is configured to move within a housing **1102** to drive corresponding movement of the piston **1112**. For example, movement of the driver **1104** in a first direction may move the piston **1112** in the first direction to reduce a size of the pumping chamber **1120** while increasing a size of the containment chamber **1122**. Thus, movement of the driver **1104** in the first direction may cause the piston **1112** to discharge powdered material from the pumping chamber **1120**. Movement of the driver **1104** in a second direction, opposite the first direction, may move the piston **1112** in the second direction to increase the size of the pumping chamber **1120** while reducing the size of the containment chamber **1122**. As such, movement of the driver **1104** in the second direction may cause the piston **1112** to draw powdered material into the pumping chamber **1122**.

[0071] The pump drive system **1100** also includes a conduit system **1180** having a conduit **1182** fluidly coupled to the containment chamber **1122** and the pumping chamber **1120**. As such, movement of the piston **1112** in the second direction causes fluid to flow through the conduit **1182**, from the containment chamber **1122** to the pumping chamber **1120**, and aerate powdered material in the pumping chamber **1120**. On the other hand, movement of the piston **1112** in the first direction causes fluid to flow through the conduit **1182**, from the pumping chamber **1120** to the containment chamber **1122**, and replenish fluid to the containment chamber **1122**. Therefore, reciprocating motion of the drive **1104** alternately directs fluid between the containment chamber **1122** and the pumping chamber **1120**.

[0072] FIG. **12** is a flowchart **1200** of a method for operating a pump system, such as any of the pump systems discussed herein. The pump system includes a cylinder and a piston disposed in the cylinder to define a pumping chamber and a containment chamber in the cylinder. In some embodiments, a single entity (e.g., the external controller **11**) may perform the operations of the method. In additional or alternative embodiments, the operations of the method may be performed by separate entities. It should also be noted that the method may be performed differently than depicted. For example, an additional operation may be performed, and/or any of the depicted operations may be performed differently, in a different order, and/or not be performed.

[0073] In step **1210**, a shaft operates to draw powdered material into the cylinder. That is, the shaft drives the piston to increase a size of the pumping chamber to enable intake of powdered material. In some embodiments, the shaft may rotate about an axis to drive movement of the piston. Alternatively, the shaft may translate to drive movement of the piston.

[0074] In step **1220**, a fluid is directed into the pumping chamber of the cylinder to aerate the powdered material, thereby preventing or at least discouraging settling of the powdered material in the pumping chamber. In certain embodiments, fluid is directed from a containment chamber of an additional cylinder into the pumping chamber of the cylinder via a conduit system. For example, movement of the shaft to drive the piston to increase a size of the pumping chamber may drive an additional piston of the additional cylinder to reduce a size of the containment chamber of the additional cylinder to direct fluid from the containment chamber of the additional cylinder into the pumping chamber of the cylinder. Additionally or alternatively, a fluid source is configured to direct fluid directly into the pumping chamber via the conduit system. For instance, a distributor may move to enable fluid flow from the fluid source to the pumping chamber. In either case, fluid may be directed into the cylinder before powdered material is discharged from the pumping chamber and/or while powdered material is drawn into the pumping chamber (e.g., during movement of the piston within the cylinder to increase a size of the pumping chamber).

[0075] In step **1230**, the shaft then operates to discharge aerated powdered material from the pumping chamber of the cylinder. The aerated powdered material may be more readily movable as compared to settled powdered material. As such, aeration of the powdered material may improve operation of the pump system to discharge powdered material.

[0076] In some embodiments, similar operations of the method may be performed for an additional cylinder. By way of example, operation of the shaft to drive movement of the piston to draw aerated powdered material into the pumping chamber of the cylinder may direct fluid from the containment chamber of the cylinder into an additional pumping chamber of the additional cylinder to aerate powered material in the additional pumping chamber. The shaft may then operate to drive movement of an additional piston in the additional cylinder to discharge aerated powdered material from the additional pumping chamber. Additionally or alternatively, the distributor may move to enable fluid flow from the fluid source to the additional pumping chamber of the additional cylinder. Such movement of the distributor may block fluid flow from the fluid source to the pumping chamber. As such, the distributor may alternately enable and block fluid flow to different pumping chambers.

[0077] As used herein, unless expressly stated to the contrary, use of the phrase ‘at least one of’, ‘one or more of’, ‘and/or’, variations thereof, or the like are open-ended expressions that are both conjunctive and disjunctive in operation for any and all possible combination of the associated listed items. For example, each of the expressions ‘at least one of X, Y and Z’, ‘at least one of X, Y or Z’, ‘one or more of X, Y and Z’, ‘one or more of X, Y or Z’ and ‘X, Y and/or Z’ can mean any of the following: 1) X, but not Y and not Z; 2) Y, but not X and not Z; 3) Z, but not X and not Y; 4) X and Y, but not Z; 5) X and Z, but not Y; 6) Y and Z, but not X; or 7) X, Y, and Z.

[0078] Additionally, unless expressly stated to the contrary, the terms ‘first’, ‘second’, ‘third’, etc., are intended to distinguish the particular nouns they modify (e.g., element, condition, node, module, activity, operation, etc.). Unless expressly stated to the contrary, the use of these terms is not intended to indicate any type of order, rank, importance, temporal sequence, or hierarchy of the modified noun. For example, ‘first X’ and ‘second X’ are intended to designate two ‘X’ elements that are not necessarily limited by any order, rank, importance, temporal sequence, or hierarchy of the two elements. Further as referred to herein, ‘at least one of’ and ‘one or more of’ can be represented using the ‘(s)’ nomenclature (e.g., one or more element(s)).
[0079] Each example embodiment disclosed herein has been included to present one or more different features. However, all disclosed example embodiments are designed to work together as part of a single larger system or method. This disclosure explicitly envisions compound embodiments that combine multiple previously-discussed features in different example embodiments into a single system or method.
[0080] One or more advantages described herein are not meant to suggest that any one of the embodiments described herein necessarily provides all of the described advantages or that all the embodiments of the present disclosure necessarily provide any one of the described advantages. Numerous other changes, substitutions, variations, alterations, and/or modifications may be ascertained to one skilled in the art and it is intended that the present disclosure encompass all such changes, substitutions, variations, alterations, and/or modifications as falling within the scope of the appended claims.

Claims

1. A pump, comprising: a cylinder; a piston disposed within the cylinder to define a first chamber and a second chamber within the cylinder, wherein the piston is configured to move within the cylinder to reduce a size of the first chamber to discharge material from the first chamber; and a conduit system configured to direct fluid into the first chamber to aerate material in the first chamber.
2. The pump of claim 1, wherein the cylinder is a first cylinder and the piston is a first piston, and the pump comprises: a second cylinder; and a second piston disposed within the second cylinder to define a third chamber and a fourth chamber within the second cylinder, wherein the second piston is configured to move within the second cylinder to reduce a size of the third chamber to discharge material from the third chamber, wherein the conduit system fluidly couples the fourth chamber and the first chamber to one another and is configured to direct fluid from the fourth chamber to the first chamber to aerate material in the first chamber.
3. The pump of claim 2, wherein the second piston is configured to move within the second cylinder to reduce a size of the fourth chamber to draw material into the third chamber and to direct fluid from the fourth chamber to the first chamber via the conduit system.
4. The pump of claim 3, comprising a shaft configured to drive movement of the first piston within the first cylinder and movement of the second piston within the second cylinder, wherein the shaft is configured to drive movement of the second piston within the second cylinder to reduce the size of the fourth chamber to direct fluid from the fourth chamber to the first chamber via the conduit system prior to the first piston moving within the first cylinder to reduce the size of the first chamber to discharge material from the first chamber.
5. The pump of claim 2, comprising a crankshaft extending along a crankshaft axis and configured to rotate about the crankshaft axis during operation of the pump, wherein the first cylinder and the second cylinder are distributed circumferentially around the crankshaft axis, and rotation of the crankshaft drives movement of the first piston within the first cylinder and movement of the second piston within the second cylinder.
6. The pump of claim 5, wherein the first piston is configured to move within the first cylinder

along a first cylinder axis, the second piston is configured to move within the second cylinder along a second cylinder axis, and the first cylinder axis and the second cylinder axis are offset from one another along the crankshaft axis.

7. The pump of claim 2, wherein the conduit system comprises a check valve configured to block fluid flow from the first chamber to the fourth chamber.

8. The pump of claim 2, comprising: a third cylinder; and a third piston disposed within the third cylinder to define a fifth chamber and a sixth chamber within the third cylinder, wherein the third piston is configured to move within the third cylinder to reduce a size of the fifth chamber to discharge material from the fifth chamber, and the conduit system fluidly couples the second chamber and the fifth chamber to one another and is configured to direct fluid from the second chamber to the fifth chamber to aerate material in the fifth chamber.

9. The pump of claim 8, wherein the conduit system comprises: a first conduit fluidly coupled to the first chamber and to the fourth chamber; and a second conduit fluidly coupled to the second chamber and to the fifth chamber.

10. The pump of claim 1, wherein the cylinder comprises an inlet that introduces material into the first chamber, and the conduit system is configured to direct fluid to the first chamber adjacent to the inlet to aerate material received via the inlet.

11. The pump of claim 1, comprising a fluid source configured to direct fluid into the first chamber via the conduit system.

12. The pump of claim 11, comprising a distributor configured to alternately enable and block fluid flow from the fluid source to the first chamber via the conduit system.

13. The pump of claim 12, wherein the distributor comprises: a first component comprising a supply channel fluidly coupled to the first chamber via the conduit system; and a second component comprising: an inlet channel fluidly coupled to the fluid source; and a passage fluidly coupled to the inlet channel, wherein the second component is configured to rotate relative to the first component to adjust positioning of the passage relative to the supply channel, alignment of the passage with the supply channel enables fluid flow from the fluid source into the first chamber via the supply channel, and misalignment of the passage with the supply channel blocks fluid flow from the fluid source into the first chamber via the supply channel.

14. A pump, comprising: a cylinder having an inlet; a piston disposed within the cylinder to define a first chamber and a second chamber within the cylinder, the piston being movable within the cylinder to reduce a size of the first chamber to discharge material from the first chamber and to increase a size of the second chamber; and a conduit system that directs fluid into the first chamber to aerate material in the first chamber, wherein conduit system is configured to direct the fluid adjacent to the inlet.

15. The pump of claim 14, wherein the cylinder is a first cylinder and the piston is a first piston, and the pump comprises: a second cylinder; and a second piston disposed within the second cylinder to define a third chamber and a fourth chamber within the second cylinder, the second piston being configured to move within the second cylinder to reduce a size of the third chamber to discharge material from the third chamber, wherein the conduit system fluidly couples the fourth chamber and the first chamber to one another and is configured to direct fluid from the fourth chamber to the first chamber to aerate material in the first chamber.

16. The pump of claim 15, wherein the second piston is configured to move within the second cylinder to reduce a size of the fourth chamber to draw material into the third chamber and to direct fluid from the fourth chamber to the first chamber via the conduit system.

17. The pump of claim 15, comprising: a crankshaft extending along a crankshaft axis and configured to rotate about the crankshaft axis during operation of the pump, wherein the first cylinder and the second cylinder are distributed circumferentially around the crankshaft axis, and rotation of the crankshaft drives movement of the first piston within the first cylinder and movement of the second piston within the second cylinder.

18. The pump of claim 14, comprising a fluid source configured to direct fluid into the first chamber via the conduit system.

19. A pump, comprising: a first cylinder; a first piston disposed within the first cylinder to define a first chamber and a second chamber within the first cylinder, the first piston being configured to move within the first cylinder to reduce a size of the first chamber to discharge material from the first chamber and to increase a size of the second chamber; a second cylinder; a second piston disposed within the second cylinder to define a third chamber and a fourth chamber within the second cylinder, the second piston being configured to move within the second cylinder to reduce a size of the third chamber to discharge material from the third chamber and to increase a size of the fourth chamber; and a conduit system that fluidly couples the fourth chamber to the first chamber, wherein the conduit system is configured to direct fluid from the fourth chamber to the first chamber to aerate material in the first chamber.

20. The pump of claim 19, wherein the second piston is configured to draw material into the third chamber and to direct fluid from the fourth chamber to the first chamber via the conduit system when the second piston moves within the second cylinder to reduce the size of the fourth chamber.