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(54) **PUMPING SYSTEM HAVING REMOTE VALVE BLOCKS**

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E21B 43/26 (2006.01)
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(58) **Field of Classification Search**
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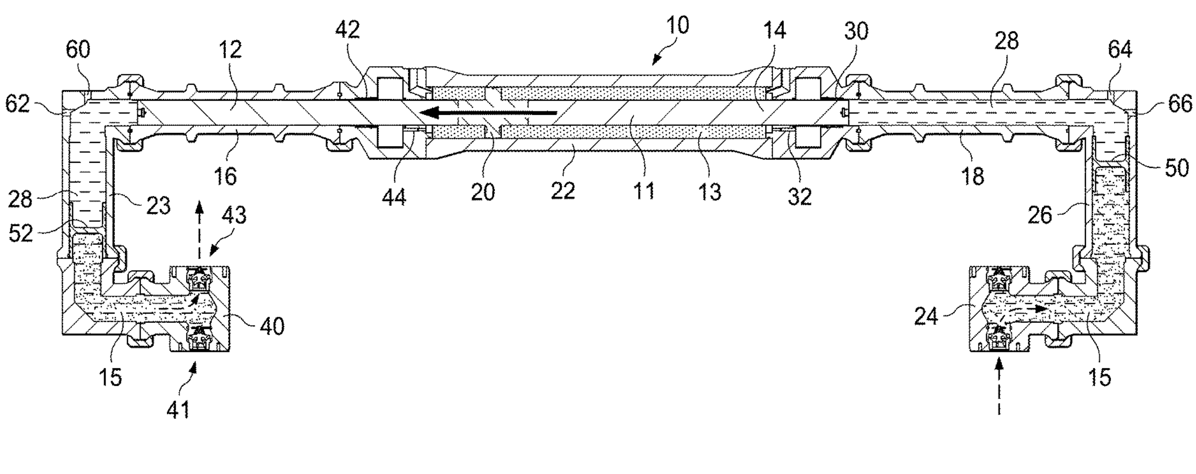
(57) **ABSTRACT**

This disclosure presents a pumping system that includes a plunger disposed in a pressure cylinder that is operable to be displaced in a suction and a discharge stroke. A packing seal is disposed between the plunger and the pressure cylinder. A valve block is disposed separate from the pressure cylinder and houses a suction valve and a discharge valve. A conduit fluidly couples the pressure cylinder with the valve block.

20 Claims, 3 Drawing Sheets



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F04B 47/04 (2006.01)
F04B 49/03 (2006.01)

(58) **Field of Classification Search**
USPC 417/383–389
See application file for complete search history.

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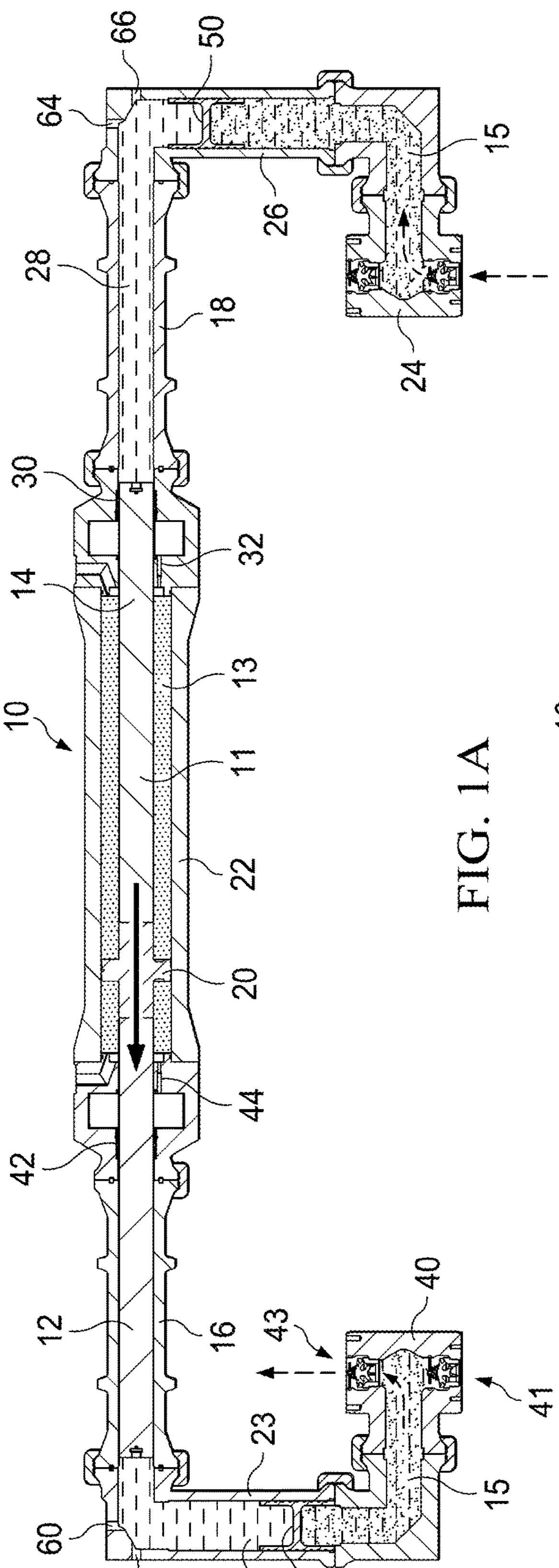
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FIG. 1A

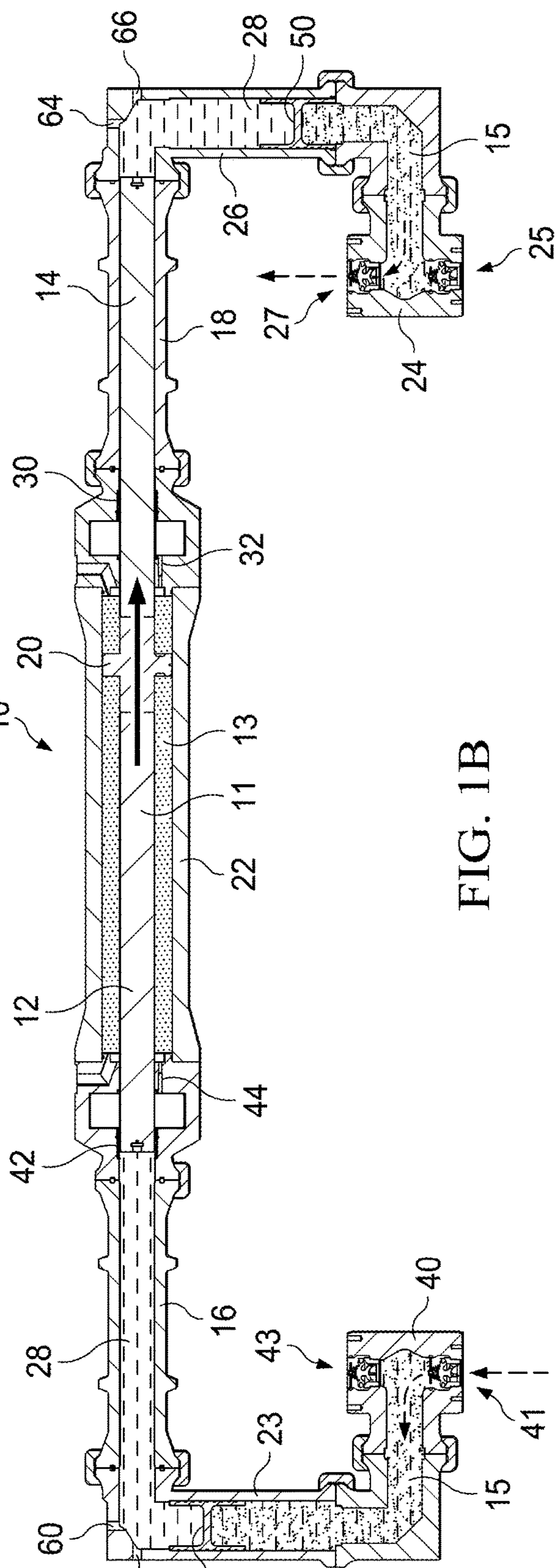
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FIG. 1B

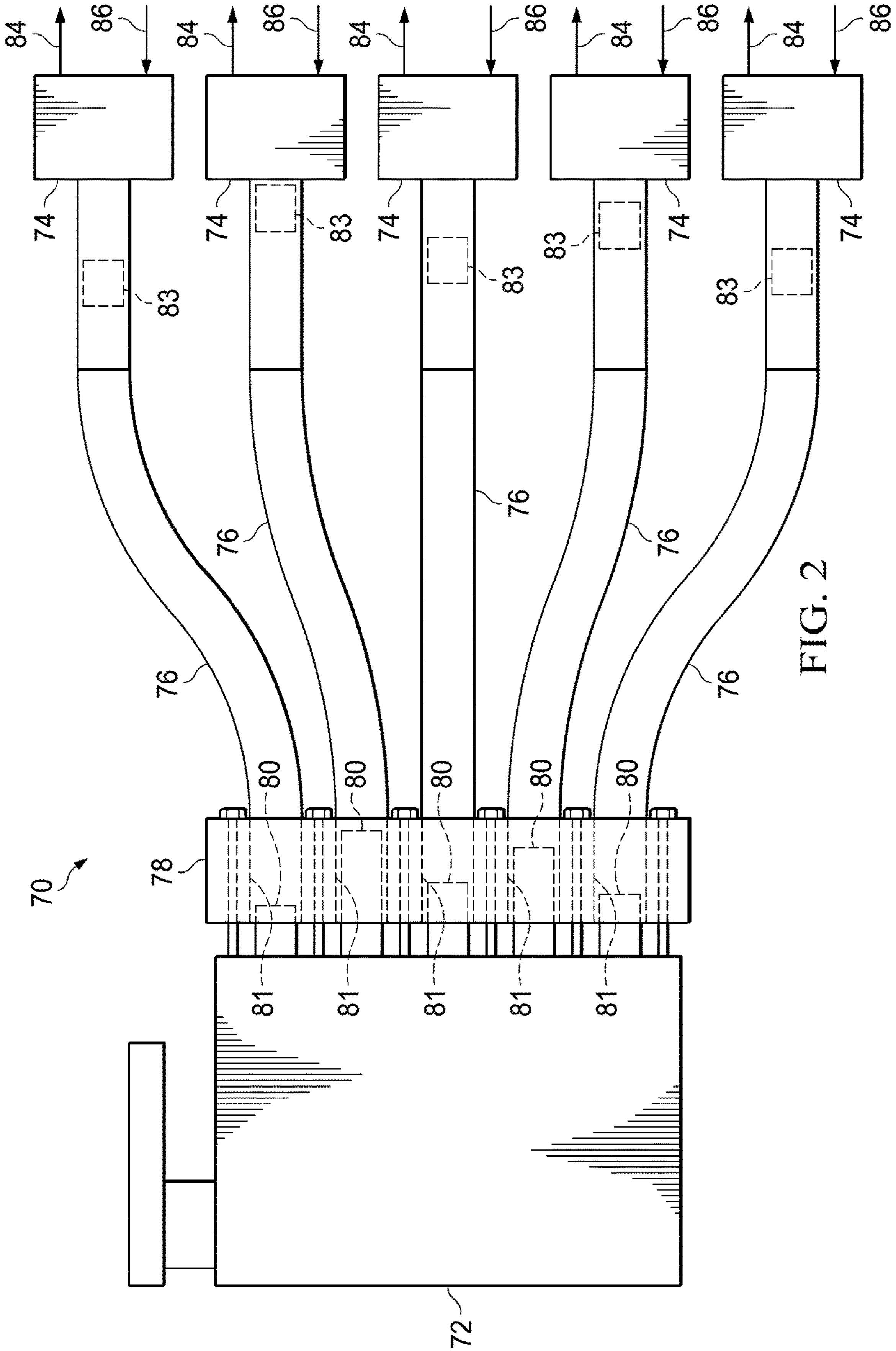

FIG. 2

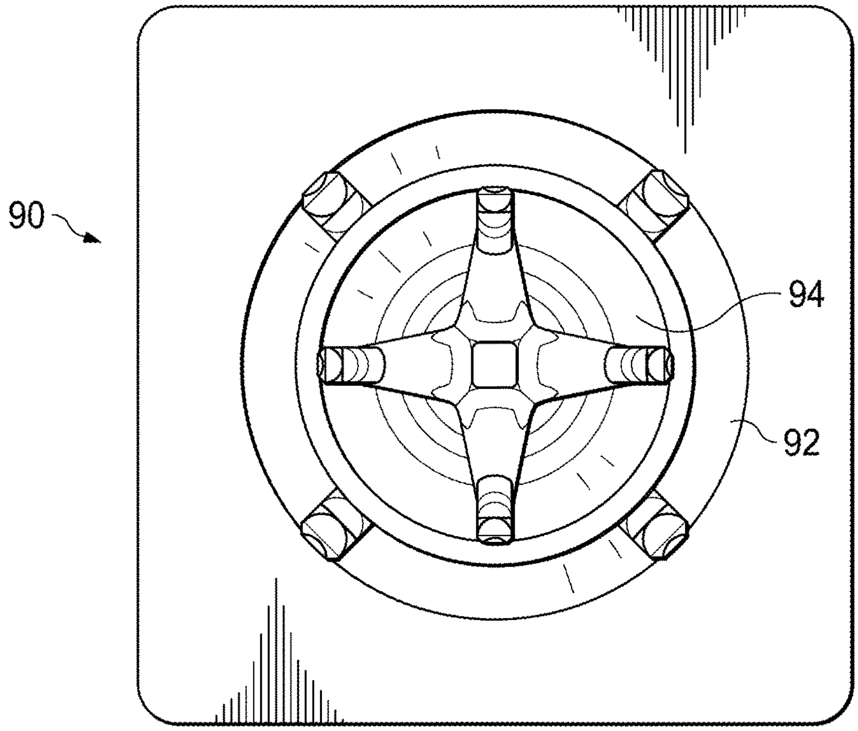

FIG. 3A

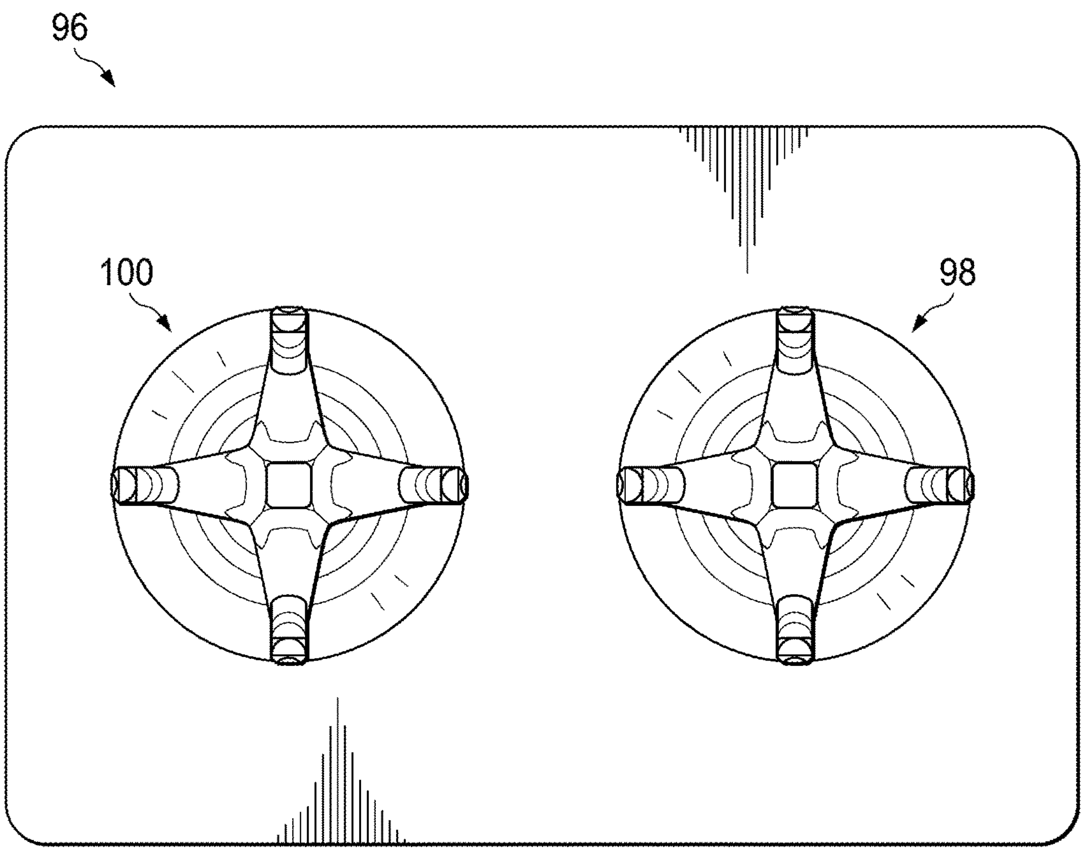

FIG. 3B

PUMPING SYSTEM HAVING REMOTE VALVE BLOCKS

PRIORITY CLAIM

This application is a 371 national stage application of PCT Application No. PCT/US2021/026898 filed on Apr. 12, 2021, entitled "PUMPING SYSTEM HAVING REMOTE VALVE BLOCKS," which claims priority to U.S. Provisional Application for Patent No. 63/009,348 filed on Apr. 13, 2020 the disclosures of the prior Applications are considered part of and are incorporated by reference into this Patent Application.

FIELD

This disclosure relates in general to pumping systems used in oilfield applications, such as hydraulic fracturing, and more particularly to positive displacement pumping systems with remote valve blocks that are separate from a pressure cylinder.

BACKGROUND

Large pumps are commonly used for mining and oilfield applications, such as, for example, hydraulic fracturing. During hydraulic fracturing, fracturing fluid (i.e., cement, mud, frac sand and other material) is pumped at high pressures into a wellbore to cause the producing formation to fracture. One commonly used pump in hydraulic fracturing is a high pressure reciprocating pump, like the SPM® Destiny™ TWS 2500 frac pump or the SPM® QEM 3000 Continuous Duty Frac Pump, manufactured by S.P.M. Flow Control, Inc. of Fort Worth, Texas In operation, the fracturing fluid flows into and out of a pump fluid chamber as a result of one or more reciprocating piston-like plungers moving away from and toward the fluid chamber. As the plunger moves away from the fluid chamber, the pressure inside the chamber decreases, creating a differential pressure across an inlet valve, drawing the fracturing fluid through the inlet valve into the chamber. When the plunger changes direction and begins to move towards the fluid chamber, the pressure inside the chamber substantially increases closing the inlet valve increasing the differential pressure across an outlet valve and opening the outlet valve, enabling the highly pressurized fracturing fluid to discharge through the outlet valve into the wellbore.

A typical frac unit is powered with a diesel engine driving a frac pump through a multispeed transmission. The rotational energy transferred to the reciprocating frac pump is channeled to horizontal plungers for pumping via a crankshaft and connecting rods. The operating conditions are often extreme involving high fluid flow and high operating pressures (oftentimes up to 15,000 psi).

In conventional pumps used in hydraulic fracturing operations, suction and discharge valves are integrated into the fluid chambers that are mounted to the pump power end. The suction and discharge valves are integrated into a fluid end of conventional linear and reciprocating pumps. Conventional linear pumps (also known as hydraulic intensifiers) and conventional reciprocating pumps include suction and discharge valves proximate their pressure cylinders. This integration results in complex designs and limited design freedom for the overall package size and configuration of conventional pumps. Also, the fluid chambers of conventional fracking pumps are difficult to machine and manufacturer, and the fluid chambers with integrated suction and discharge valves are subjected to high stresses and multiple stress risers. In reciprocating hydraulic fracturing pumps there is a high risk of early cyclic fatigue failure.

Conventional hydraulic fracturing pumps are expensive to fabricate in material and labor, and they are heavy and bulky. They also require frequent valve and valve seat replacements, so they can be difficult and expensive to maintain. Moreover, conventional pumps with integrated suction and discharge valves may also present challenges in servicing the valves because a ladder or service platform may be required to access the suction and discharge valves to perform service.

Conventional reciprocating hydraulic fracturing pumps include plunger packings. Plunger packings form a seal around the reciprocating plunger and are also referred to as seals. Conventional plunger packings in reciprocating pumps and linear hydraulic fracturing pumps operate in a slurry of sand and water, which can damage the seals and reduce the useful life of the plunger packings. The slurry is also abrasive and causes the plunger to wear. In certain applications, the plungers are hard-coated to reduce wear, but the hard coating can wear the packing seals.

With respect to conventional linear pumps used in hydraulic fracturing applications, the pumping is typically performed using multiple axes. Using multiple axes reduces the long dwell time in order to maintain the consistency of the slurry in the suction manifold. In other words, to prevent the sand particles from separating from the liquid of the slurry (to avoid the sand falling out of suspension), conventional linear pumps cluster the suction and discharge ports together such that they serve multiple axes at the same time and thereby lower the dwell time to be equal to the stroke time divided by the number of axes. These constraints limit the design and application flexibility of linear pumps when used in a slurry application, such as for hydraulic fracturing.

SUMMARY

This disclosure presents a pumping system that includes a plunger disposed in a pressure cylinder that is operable to be displaced in a suction and a discharge stroke. A packing seal is disposed between the plunger and the pressure cylinder. A valve block is disposed separate from the pressure cylinder and houses a suction valve and a discharge valve. A conduit fluidly couples the pressure cylinder with the valve block.

The pumping system of the present disclosure may be used with a working fluid, for example a fracking fluid or a slurry, that is commonly used in hydraulic fracturing or other oilfield operations.

According to certain embodiments, a barrier fluid protects the packing seals in the fluid cylinder that would otherwise be exposed to the harsh slurry.

Technical advantages of the present disclosure include reduced design complexity for the overall design of the pumping system. Also, by remotely locating the valve block that houses the suction and discharge valves, greater freedom of design and freedom of package size and configurations are enabled. The pumping system fluid end according to the disclosed embodiments is also easier to machine and manufacture than conventional reciprocating or linear pumps.

In a linear actuated pump embodiment, the longer pump stroke reduces the risk of early cyclic fatigue failure of certain pump components. The fluid cylinder for the linear pumping system is less expensive in material and labor to manufacture. It may also be designed to be lighter and have a smaller profile than conventional reciprocating or linear pumps. Also, a stress induced fracture in a conventional fluid end renders the whole fluid end inoperable resulting in the loss of 2 to 4 other cylinders.

An additional technical advantage is that the valves and seats are more easily and conveniently located, which makes valve and seat replacement easier.

Using a single conduit to plumb the slurry from the remote valve block to the pressure cylinder allows a linear pump according to the teachings of the present disclosure to operate without clustered suction and discharge ports. It also eliminates the concern of sand falling out of suspension in the slurry because there is no dwell time for the slurry in a single axis linear pump. The slurry is in constant motion. It is sucked in to the system, and once it is fully sucked in the discharge stroke forces the slurry out of the system and into the wellbore.

The pressure cylinders may be designed without accommodating valves and seats, which simplifies the design of the pressure cylinder. Also with a smaller and lighter pressure cylinder, the cantilevered weight on the pump frame can be significantly reduced.

Other aspects, features, and advantages will become apparent from the following detailed description when taken in conjunction with the accompanying drawings, which are a part of this disclosure and which illustrate, by way of example, principles of the inventions hereof.

DESCRIPTION OF THE FIGURES

The accompanying drawings facilitate an understanding of the various embodiments.

FIGS. **1**A and **1**B are schematics of a cross-section of a linear pump with remote valve blocks housing suction and discharge valves according to the teachings of the present disclosure;

FIG. **2** is a schematic of a reciprocating pump with remote valve blocks housing suction and discharge valves;

FIGS. **3**A and **3**B are schematics of remote valve blocks housing suction and discharge valves for a working fluid.

Like numerals refer to like elements.

DETAILED DESCRIPTION

This disclosure presents embodiments of pumping systems suitable to be employed in hydraulic fracturing applications. According to one embodiment, the pumping systems may include a reciprocating pump with remote valve blocks that house suction and discharge valves. A working fluid is sucked into a suction valve and discharged at a high fluid pressure through the discharge valve. A remote valve block is disposed separate from a pressure cylinder. A conduit fluidly couples the remote valve block with a pressure cylinder.

According to another embodiment, a pumping system includes a linear pump that operates in a single axis and a remote valve block that houses suction and discharge valves. Other axes could be employed in parallel in a similar manner to make a multi-axis pumping unit. Also, embodiments disclosed herein are shown and described with respect to a double acting linear pump (where motion of the plunger pumps both sides of a hydraulic shell), but the teachings of the present disclosure are also applicable to a single acting linear pump (motion of the plunger pumps on one side of the hydraulic shell).

According to certain embodiments, the pump moves a clean barrier fluid (also referred to herein as a clean fluid) through the conduits. The clean barrier fluid is moved through the pressure cylinders of either a linear or a reciprocating pump. According to one embodiment, the clean barrier fluid moves through conduits that fluidly couple a cylinder block of a reciprocating pump to one or more remote valve blocks. In either the linear pump or the reciprocating pump embodiments, packing seals that conventionally would be exposed to harsh working fluid, such as a hydraulic fracturing fluid, are instead exposed to a clean barrier fluid, such as water. According to an alternate embodiment, the packing seals are disposed in a pressure cylinder and are isolated from the harsh working fluid. Because the seals do not operate in the harsh environment of the fracking fluid, they will wear less and last longer.

A valve block that houses suction and discharge valves is disposed remote from the pump and is fluidly connected to the pump through a conduit or line. Remotely locating the suction and discharge valves allows easier access to the valves and relieves design constraints associated with the footprint of the pump mechanism. Also, the remote suction and discharge valves may be incorporated into a manifold, which offers greater design flexibility and easier access for replacement or repair.

According to the teachings of the present disclosure, the suction and discharge valves associated with the pressure cylinders of reciprocating and linear pumps are not integrated with the respective pressure cylinders. Rather, the suction and discharge valves associated with each pressure cylinder are disposed separate from and remote with respect its respective pressure cylinder.

Among other advantages, by locating the suction and discharge valves remotely, the length of a linear pump can be reduced because the overall length does not include the suction and discharge valves positioned at each end of the pressure cylinders. Also, in order to avoid the solid particles falling out of the slurry mix during longer suction and discharge strokes of the plungers in a linear pumping system, each valve block may be fluidly coupled to its respective pressure cylinder by a single conduit. Thus, there is no dwell time, as is common with multiple pumping axes employed in conventional linear pumping systems. Dwell occurs in the suction and discharge lines of linear pumps. The fluid in the suction line feeding one end of a conventional linear pump must stop and wait for the previous suction stroke to be discharged. Likewise, frac fluid in the discharge line must stop and wait for the next discharge stroke while the suction stroke is active.

In contrast, according to the teachings of the present disclosure, the working fluid drawn in by the linear pumping system according to the teachings of the present disclosure is in constant motion—it is discharged as soon as it is fully sucked into the system.

FIGS. **1**A and **1**B are cross-sections of a linear pumping system **10** according to the teachings of the present disclosure. The linear pumping system **10** employs remote suction and discharge valves that are connected to their respective pressure cylinders by a single conduit. A plunger **11** moves within a pressure cylinder to create suction and discharge pressure. The plunger **11** includes a first plunger portion **12** and a second plunger portion **14**. The first plunger portion **12** moves through a first pressure cylinder **16**, and the second plunger portion **14** moves through a second pressure cylinder **18**. The depicted embodiment shows the first plunger portion **12** and the second plunger portion **14** moving through a hydraulic fluid and through the fluid disposed in the pressure cylinder **16**, **18**. This disclosure also contemplates longer plunger portions **12**, **14** that do not operate in the hydraulic fluid.

The plunger **11** may be a single part integrating the first plunger portion **12** and the second plunger portion **14**. According to an alternate embodiment, each of the plunger portions **12** and **14** may be separate parts that are joined using any suitable connector to form the plunger **11**. The plunger **11** is powered by hydraulic pumps driven by a prime mover, such as a diesel engine or an electric motor. The prime mover pumps hydraulic fluid **13** to circulate it within a hydraulic shell **22**. The illustrated drive force for the linear pumping system **10** is hydraulic. However, an electrical drive may be used in lieu of the hydraulic force.

An increased diameter portion **20** extends radially from the plunger **11** and is acted on by the hydraulic fluid **13**, for example a hydraulic oil. According to known hydraulic power transmission principles, the hydraulic fluid **13** intensifies and increases the pressure with which the plunger **11** delivers a working fluid **15** to a wellbore. For example, in certain embodiments the hydraulic fluid **13** acting on such an increased diameter portion **20** can multiply a hydraulic oil pressure of 5000 psi to create a wellbore pressure of 15,000 psi.

FIG. **1**A shows the first plunger portion **12** in a compression stroke and simultaneously the second plunger portion **14** is in a suction stroke. FIG. **1**B shows the first plunger portion **12** in a suction stroke and the second plunger portion **14** in a discharge stroke. As shown in FIG. **1**A, the working fluid **15**, such as a frac fluid, is drawn through a remote valve block **24** and into a working fluid conduit **26**. The remote valve block **24** houses a suction valve **25** and a discharge valve **27**. The working fluid conduit **26** generally extends from the pressure cylinder **18** to the remote valve block **24**.

The working fluid **15** is drawn through the suction valve **25** and discharged through the discharge valve **27** corresponding to the suction and compression motion of the plunger portion **14**. Each of the suction valve **25** and discharge valve **27** are check valves that only permit fluid flow in one direction. Thus, when fluid is flowing through the suction valve **25**, the discharge valve **27** is closed. Similarly, when fluid is flowing through the discharge valve **27**, the suction valve **25** is closed.

In the double-acting linear pumping system **10** illustrated, the pressure cylinder **16** depicted on the left side of the pumping system **10** is also fluidly coupled to a remote valve block **40**. The working fluid **15**, such as a frac fluid, is drawn through the remote valve block **40** and into a working fluid conduit **23**. The remote valve block **40** houses a suction valve **41** and a discharge valve **43**. The working fluid conduit **23** generally extends from the pressure cylinder **16** to the remote valve block **40**. The working fluid **15** is drawn through the suction valve **41** and discharged through the discharge valve **43** corresponding to the suction and compression motion of the plunger portion **12**. Each of the suction valve **41** and discharge valve **43** are check valves that only permit fluid flow in one direction. Thus, when fluid is flowing through the suction valve **41**, the discharge valve **43** is closed. Similarly, when fluid is flowing through the discharge valve **43**, the suction valve **41** is closed.

According to certain embodiments, a clean barrier fluid **28** is disposed in either one or both of the working fluid conduits **23** and **26**. For example, the barrier fluid **28** disposed in the working fluid conduit **26** separates the working fluid **15** from the pressure cylinder **18**. Alternatively, the linear pumping system **10** may be operated without the barrier fluid **28**. With the barrier fluid **28** disposed between the working fluid **15** and the pressure cylinder **18**, the pressure cylinder **18** and the second plunger portion **14** are not operating in a harsh working fluid. Rather, the second plunger portion **14** compresses the clean barrier fluid **28** that is disposed in the second pressure cylinder **18**. This allows flexibility in the design of the plunger **11** and the pressure cylinder **18** because these components are not be required to withstand the abrasive working fluid **15**, for example fracking fluid. When barrier fluid **28** is disposed in the working fluid conduit **23**, the plunger portion **12** and the pressure cylinder **16** are protected from the abrasive working fluid **15** and operate in the clean barrier fluid **28**.

With continuing reference to FIG. **1**A, the linear pumping system **10** includes annular seal assemblies (also referred to as plunger packers) that surround the plunger **11** and form a fluid-tight seal between the plunger portion and the corresponding pressure cylinder. The seal assemblies facilitate the stroke of the plunger without the fluid (frac fluid or clean barrier fluid) leaking between the plunger and the pressure cylinder. For example, an annular plunger packing seal assembly **30** is disposed within the pressure cylinder **18** and surrounds the plunger portion **14**. Similarly, an annular plunger packing seal assembly **42** is disposed in the pressure cylinder **16** and surrounds the plunger portion **12**. According to the teachings of the present disclosure, the seal assemblies **30** and **42** are isolated from the harsh working fluid **15**. In certain embodiments, the seal assemblies **30** and **42** are primarily exposed to only the clean barrier fluid **28**, which will allow the seal assemblies **30** and **42** to last longer than they otherwise would if they were constantly exposed to the harsh working fluid **15**. Seal failure is a common issue in conventional frac pumps, so extending the working life of the packing seals **30**, **42** according to the teachings of the present disclosure can be advantageous and also provide a motivation to improve other components of the pumping system to increase the working life of the overall pumping system.

An example of a packing seal assembly that may be used with the disclosed pumping systems including the linear pumping system **10** and the reciprocating pumping system **70** (see FIG. **2**) is disclosed in U.S. Pat. No. 9,534,691 to Miller et al. and assigned to UTEX Industries, Inc., and hereby incorporated by reference.

The linear pumping system **10** also includes hydraulic fluid seals that are disposed within the hydraulic shell **22** and surround the plunger **11**. The hydraulic fluid seals maintain the hydraulic fluid **13** within the hydraulic shell **22**. The hydraulic fluid seals **32** may be a seal assembly with at least one elastomeric ring. The hydraulic fluid seals **32** surround the plunger **11** and form a fluid-tight seal between the plunger **11** and the hydraulic shell **22**. The hydraulic seals **32** facilitate the stroke of the plunger without the hydraulic fluid **13** leaking between the plunger **11** and the hydraulic shell **22**. For example, a hydraulic seal **32** is disposed within the hydraulic shell **22** and surrounds the plunger **11**. Similarly, a hydraulic seal **44** is also disposed at an opposite side of the hydraulic shell **22** and surrounds the plunger **11**. The hydraulic fluid seals **32** and **44** are exposed to the hydraulic fluid **13** in the hydraulic shell **22**.

As shown in FIG. **1**A, the motion of the plunger to the left simultaneously sucks working fluid **15** through the second remote valve block **24** and into the working fluid conduit **26**. This plunger motion also draws the clean barrier fluid **28** into the pressure cylinder **18**. In this position, the pump is prepared to discharge the working fluid **15** through the remote valve block **24** into the well when the prime mover drives the plunger **11** to the right as shown in FIG. **1**B. FIG.

1B shows the right side of the linear pumping system **10** in its discharge position and the left side of the linear pumping system **10** in its suction position.

On the left side of the linear pumping system **10**, the first plunger portion **12** advances through the first pressure cylinder **16** and creates a pressure to move the clean barrier fluid **28** that in turn applies pressure to the working fluid **15** to discharge the working fluid **15** at an elevated pressure, for example 15,000 psi through the remote valve block **40** into the wellbore. As discussed above, the remote valve block **40** includes a first suction valve **41** and a first discharge valve **43**. Each of the first suction valve **41** and discharge valve **43** are check valves that only permit fluid flow in one direction. Thus, when fluid is flowing through the suction valve **41**, the discharge valve **43** is closed. Similarly, when fluid is flowing through the discharge valve **43**, the suction valve is closed **41**.

With continuing reference to FIG. **1**A, the linear pumping system **10** may include an isolator **50** disposed in the working fluid conduit **26**. The isolator **50** moves freely within the working fluid conduit **26** with the flow of the working fluid **15** in the working fluid conduit **26**. The isolator **50** separates the working fluid **15** from the clean barrier fluid **28**. An isolator **52** is disposed in the working fluid conduit **23** to separate the working fluid **15** from the clean barrier fluid **28** that is driven by the first plunger portion **12**. The isolator **50**, **52** may also be referred to as a pig, a shuttle, a ball, or a cartridge. Devices similar to the isolator **50**, **52** are used to clean the inside of pipes, for example an oil pipeline. According to an embodiment, the isolator **50**, **52** includes a mid-portion separating two cup portions. The open end of each cup portion faces opposite the other cup portion, and the mid-portion forms a floor for each cup portion. Absolute separation by the isolators **50** and **52** may not be required because a small volume of the working fluid **15** mixing with the barrier fluid **28** may be tolerated. For example, the barrier fluid **28** may be flushed between fracking jobs or at other periodic intervals.

According to an alternate embodiment with reference to the right side of the pumping system shown in FIGS. **1**A and **1**B (with the same applying to the left side), the barrier fluid **28** may separate the pressure cylinder **18**, the plunger portion **14**, and the packing seals **30**, without an isolator disposed in the working fluid conduit **26**. In this embodiment, the working fluid **15** may gradually blend with the barrier fluid **28**, but the pumping system **10** may be operated for periods of time such that the packing seals **30**, plunger portion **14**, and pressure cylinder **18** have limited exposure to the working fluid **15**. For example, the pumping system **10** may be operated for approximately two hours without an isolator separating the barrier fluid **28** from the working fluid **15** in the working fluid conduit **26**. After the period of operation, the barrier fluid **28** may be flushed from the system **10** and replaced with clean barrier fluid.

Alternatively, when the barrier fluid is not used, the isolator **52** may be omitted because there is no barrier fluid **28** to maintain separate from the working fluid **15**.

According to an embodiment, the linear pumping system **10** is fluidly coupled to one or more cooling fluid circuits that are operable to cool the barrier fluid **28**. The motion of the barrier fluid **28** in the pressure cylinders and the working fluid conduits **23**, **26** will cause the temperature of the barrier fluid **28** to increase. A cooling inlet port **60** and a cooling outlet port **62** are formed in the working fluid conduit **23**. According to an embodiment, the cooling inlet port **60** and the cooling outlet port **62** are disposed proximate a junction of the pressure cylinder **16** and the working fluid conduit **23**. The cooling inlet port **60** and the cooling outlet port **62** are disposed upstream of the isolator **52**, for example on the barrier fluid side of the isolator **52**.

Similarly, in a double-acting linear pump, a cooling inlet port **64** and a cooling outlet port **66** are formed in the working fluid conduit **26**. According to an embodiment, the cooling inlet port **64** and the cooling outlet port **66** are disposed proximate a junction of the pressure cylinder **18** and the working fluid conduit **26**. The cooling inlet port **64** and the cooling outlet port **66** are disposed upstream of the isolator **50**, for example on the barrier fluid side of the isolator **50**. The barrier fluid **28** may be discharged through the cooling fluid outlet ports **62** and **66** due to the motion of the plunger **11**. This barrier fluid **28** may be cycled through a respective fluid cooling circuit (not shown) that includes a radiator or other suitable fluid cooling device. The cooled barrier fluid **28** is received from the respective fluid cooling circuit by the linear pumping system **10** through the cooling fluid inlet ports **60** and **64**. Communicating fluid to and from the cooling circuit may correspond to the suction stroke of the respective plunger portion **12** and **14**.

According to certain embodiments, inlet and outlet valves are in fluid communication respectively with the cooling inlet port **60** and the cooling outlet port **62** such that barrier fluid is circulated through the cooling outlet port **62**, through the cooling circuit, and received in the cooling inlet port **60** on the suction stroke of the plunger **12**. Similarly, inlet and outlet valves are in fluid communication respectively with the cooling inlet port **64** and the cooling outlet port **66** such that the barrier fluid is circulated sequentially through the cooling outlet port **66**, through the fluid cooling circuit, and then received by the cooling inlet port **64**.

This valve arrangement allows the barrier fluid **28** to circulate through the cooling circuit at fluid pressures that are significantly lower than the discharge pressure of the working fluid **15** generated by the plunger portions **12** and **14** during their respective discharge strokes. Thus, the barrier fluid **28** flows through the cooling circuit at manageable pressures, as opposed to the high pressures that are generated with respect to discharge of the working fluid **15**. As a result, the fluid cooling circuit may be designed to withstand lower fluid pressures. The valves fluidly coupling the cooling circuits to the linear pumping system **10** may be closed during the discharge stroke of the respective plunger portion **12**, **14**.

Reference is made to FIG. **2**, which is a schematic illustration of a reciprocating pumping system with remote valve blocks **74**. The system **70** includes a reciprocating pump **72** in fluid communication with one or more remote valve blocks **74** through one or more working fluid conduits **76**. The reciprocating pump **72** may be any reciprocating pump power end operable to inject a working fluid into a wellbore. According to one embodiment, the reciprocating pump **72** is the power end of a SPM® QEM 3000 Continuous Duty Frac Pump, manufactured by S.P.M. Flow Control, Inc. of Fort Worth, Texas with a simplified cylinder block **78**. In one embodiment, a crankshaft within the reciprocating pump **72** is driven by a prime mover. The crankshaft is coupled to connecting rods that each in turn is coupled to a plunger **80**. The plungers **80** reciprocate within respective pressure cylinders **81** that are formed in the cylinder block **78**.

A remote valve block **74** is fluidly coupled to each pressure cylinder **81** and is disposed separate and remote from the pressure cylinder **81** and the plunger **80**. As a result, the cylinder block **78** and each pressure cylinder **81** may be simplified. The simplified cylinder block **78** does not include suction and discharge valves that would otherwise be part of an integrated fluid end of a conventional reciprocating pump. According to certain embodiments, the cylinder block **78** also does not include a dedicated access port to allow servicing of the plunger **80**. Also, the bore size of the pressure cylinders **81** formed in the cylinder block **78** may be increased, which may facilitate increased pumping pressure and/or pumping volume. According to certain embodiments of the cylinder block **78**, the center-to-center limitation of pressure cylinders of conventional reciprocating pumps with integral valve blocks is reduced significantly because each pressure cylinder **81** does not have to accommodate suction and discharge valves.

A packing seal may be disposed in the pressure cylinder and surround the plunger **80**. The packing seal may include the features and the function described above with respect to the packing seals **30** and **42** of the linear pumping system embodiment. According to an embodiment, the packing seals may be exposed to a clean barrier fluid, as described with respect to FIGS. **1**A and **1**B. The barrier fluid disposed in the pressure cylinders **81** and the working fluid conduits **76** separates the packing seals and the plungers **80** from the harsh working fluid. Thus, the packing seals and the plungers **80** will wear less and last longer.

Each pressure cylinder **81** is coupled to a working fluid conduit **76** that fluidly couples a respective pressure cylinder **81** with a remote valve block **74**. The working fluid conduit **76** may be a flexible hose or a rigid pipe, or the working fluid conduit **76** may have portions that are flexible and portions that are rigid. The rigid pipe portions may accommodate the motion of an isolator **83**. An isolator **83** may be disposed in each of the working fluid conduits **76**. It may include the structure and function as described above with respect to FIGS. **1**A and **1**B. For example, the isolator **83** may move freely in the working fluid conduit **76** with the suction and the discharge of the working fluid. The isolator **83** separates the working fluid from the barrier fluid and a respective pressure cylinder **81**, plunger **80**, and packing seals (not shown). The remote valve blocks **74** may be easier to manufacture, transport, and service than conventional valve blocks that are integrated into a reciprocating pump. According to some embodiments, the remote valve blocks **74** may be supported by a trailer that is commonly found on fracturing job sites.

Each remote valve block **74** houses a suction valve represented by arrow **86** and a discharge valve represented by arrow **84**. The remote valve block **74** may be supported by the ground or a trailer and may be supported independent of the reciprocating pump **72**.

According to certain embodiments of the remote valve block **74** the suction valve may be disposed above or below the discharge valve similar to conventional reciprocating pumps with integral valve blocks. According to an alternate embodiment of a remote valve block **90** shown in FIG. **3**A, the suction valve **92** may be nested in the discharge valve **94** or the discharge valve may be nested in the suction valve. According to yet another alternate embodiment of a remote valve block **96** illustrated in FIG. **3**B, a suction valve **98** may be disposed beside a discharge valve **100**. This embodiment differs from the valve-over-valve arrangement because the valves are disposed on the same face of the remote valve block **96**. In the valve-over-valve embodiment, the valves are disposed on opposite faces of the remote valve block. Other suction and discharge valve arrangements are contemplated by this disclosure.

In the foregoing description of certain embodiments, specific terminology has been resorted to for the sake of clarity. However, the disclosure is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes other technical equivalents which operate in a similar manner to accomplish a similar technical purpose.

In the specification and claims, the word "comprising" is to be understood in its "open" sense, that is, in the sense of "including", and thus not limited to its "closed" sense, that is the sense of "consisting only of". A corresponding meaning is to be attributed to the corresponding words "comprise", "comprised" and "comprises" where they appear.

In addition, the foregoing describes only some embodiments of the invention(s), and alterations, modifications, additions and/or changes can be made thereto without departing from the scope and spirit of the disclosed embodiments, the embodiments being illustrative and not restrictive.

Furthermore, invention(s) have described in connection with what are presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not to be limited to the disclosed embodiments, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the invention(s), as defined solely by the appended claims. Also, the various embodiments described above may be implemented in conjunction with other embodiments, e.g., aspects of one embodiment may be combined with aspects of another embodiment to realize yet other embodiments. Further, each independent feature or component of any given assembly may constitute an additional embodiment.

What is claimed is:

1. A pumping system for delivering a working fluid into a wellbore, the pumping system comprising:

- a pressure cylinder coupled to a first valve block and a second valve block;
- a plunger disposed in the pressure cylinder, the plunger operable to be displaced in a suction stroke and a discharge stroke;
- a packing seal disposed between the plunger and the pressure cylinder;
- the first valve block and the second valve block are disposed separate from the pressure cylinder, wherein each valve block is coupled to an opposing respective end of the pressure cylinder by a respective conduit, and each valve block includes a suction valve and a discharge valve; and
- an isolator disposed within each respective conduit, each isolator having two opposing cup portions, and each isolator slideably engaged with a respective interior surface of each respective conduit to separate a barrier fluid from the working fluid, wherein an entirety of each isolator is freely moveable with respect to the respective interior surface of each respective conduit.

2. The pumping system of claim **1** wherein the plunger is a portion of a double-acting plunger rod.

3. The pumping system of claim **1** further comprising a hydraulic shell containing a hydraulic fluid operable to displace the plunger.

4. The pumping system of claim **1** wherein the pressure cylinder is one of a plurality of pressure cylinders formed in a cylinder block.

5. The pumping system of claim **4** wherein the plunger is one of a plurality of plungers each operable to reciprocate within a respective one of the plurality of pressure cylinders.

6. The pumping system of claim **1**, wherein the barrier fluid is disposed in each respective conduit, and wherein the packing seal is exposed to the barrier fluid.

7. The pumping system of claim **6**, wherein each isolator is operable to isolate the packing seal from the working fluid.

8. The pumping system of claim **7** wherein each respective conduit defines a cooling outlet port configured to communicate the barrier fluid to a fluid cooling circuit and a cooling inlet port configured to receive the barrier fluid from the fluid cooling circuit.

9. The pumping system of claim **1** wherein each of the first valve block and the second valve block comprise a first face associated with the suction valve and a second face different from the first face associated with the discharge valve.

10. The pumping system of claim **1** wherein each of the first valve block and the second valve block comprise a first face associated with both the suction valve and the discharge valve.

11. The pumping system of claim **1** wherein each respective conduit comprises a rigid pipe.

12. The pumping system of claim **11** wherein each respective conduit comprises a flexible hose.

13. A pumping system for delivering a working fluid into a wellbore, the pumping system comprising:

a pressure cylinder coupled to a first valve block and a second valve block;

a plunger disposed in the pressure cylinder, the plunger operable to be displaced in a suction stroke and a discharge stroke;

a barrier fluid disposed in the pressure cylinder;

the first valve block and the second valve block disposed separate from the pressure cylinder, wherein each valve block is coupled to an opposing respective end of the pressure cylinder by a respective conduit;

a suction valve for the working fluid disposed within each valve block;

a discharge valve for the working fluid disposed within each valve block, the working fluid being different from the barrier fluid; and

an isolator disposed within each respective conduit, each isolator having two opposing cup portions, and each isolator slideably engaged with a respective interior surface of each respective conduit to separate the barrier fluid from the working fluid, wherein an entirety of each isolator is freely moveable with respect to the respective interior surface of each respective conduit.

14. The pumping system of claim **13** wherein the plunger is a portion of a double-acting plunger rod.

15. The pumping system of claim **13** further comprising a hydraulic shell containing a hydraulic fluid operable to displace the plunger.

16. The pumping system of claim **13** wherein the pressure cylinder is one of a plurality of pressure cylinders formed in a cylinder block.

17. The pumping system of claim **13** further comprising packing seals disposed between the plunger and the pressure cylinder.

18. A method for delivering a working fluid to a wellbore, comprising:

displacing a plunger through a packing seal and within a pressure cylinder in a first direction, the pressure cylinder coupled to a first valve block and a second valve block, wherein each valve block is coupled to an opposing respective end of the pressure cylinder by a respective conduit, and each valve block includes a suction valve and a discharge valve;

drawing the working fluid through the suction valve and into the respective conduit, the suction valve being disposed in the first valve block;

displacing the plunger through the packing seal within the pressure cylinder in a second direction opposite the first direction;

discharging the working fluid from the respective conduit through the discharge valve disposed in the first valve block; and

displacing an isolator within each respective conduit, each isolator having two opposing cup portions, and each isolator slideably engaged with a respective interior surface of each respective conduit to separate a barrier fluid from the working fluid, wherein an entirety of each isolator is freely moveable with respect to the respective interior surface of each respective conduit.

19. The method of claim **18** further comprising pressurizing the barrier fluid disposed within each respective conduit.

20. The method of claim **19**, each isolator being disposed between the barrier fluid and the working fluid.

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