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(54) ANTI GAS-LOCK PUMPING SYSTEM

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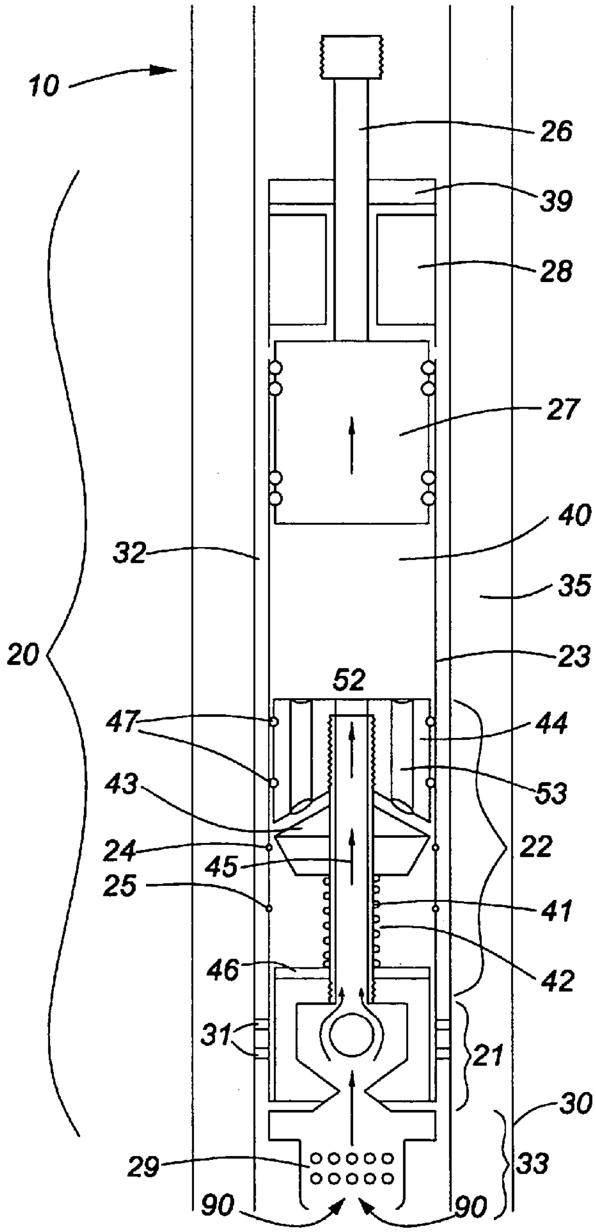
(57) ABSTRACT

An improved fluid pumping system is described. The pump is designed such that any gas present in the fluid being pumped is completely displaced from the pumping chamber with each downstroke of a pump plunger. This prevents pump failure due to gas-locking by preventing gas build-up within the pump, thereby improving long-term pumping efficiency and increasing pump life.



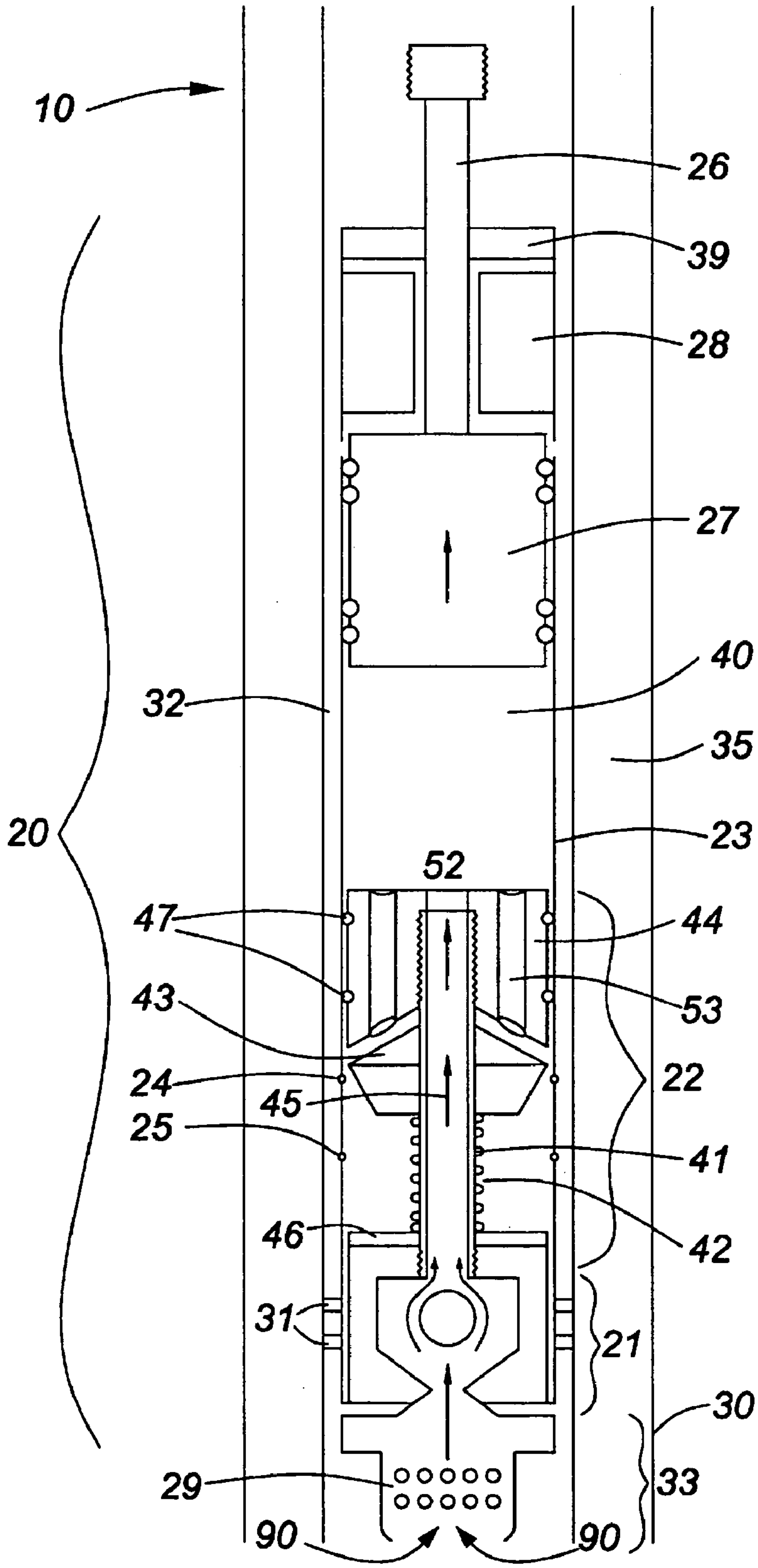

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FIG. 1

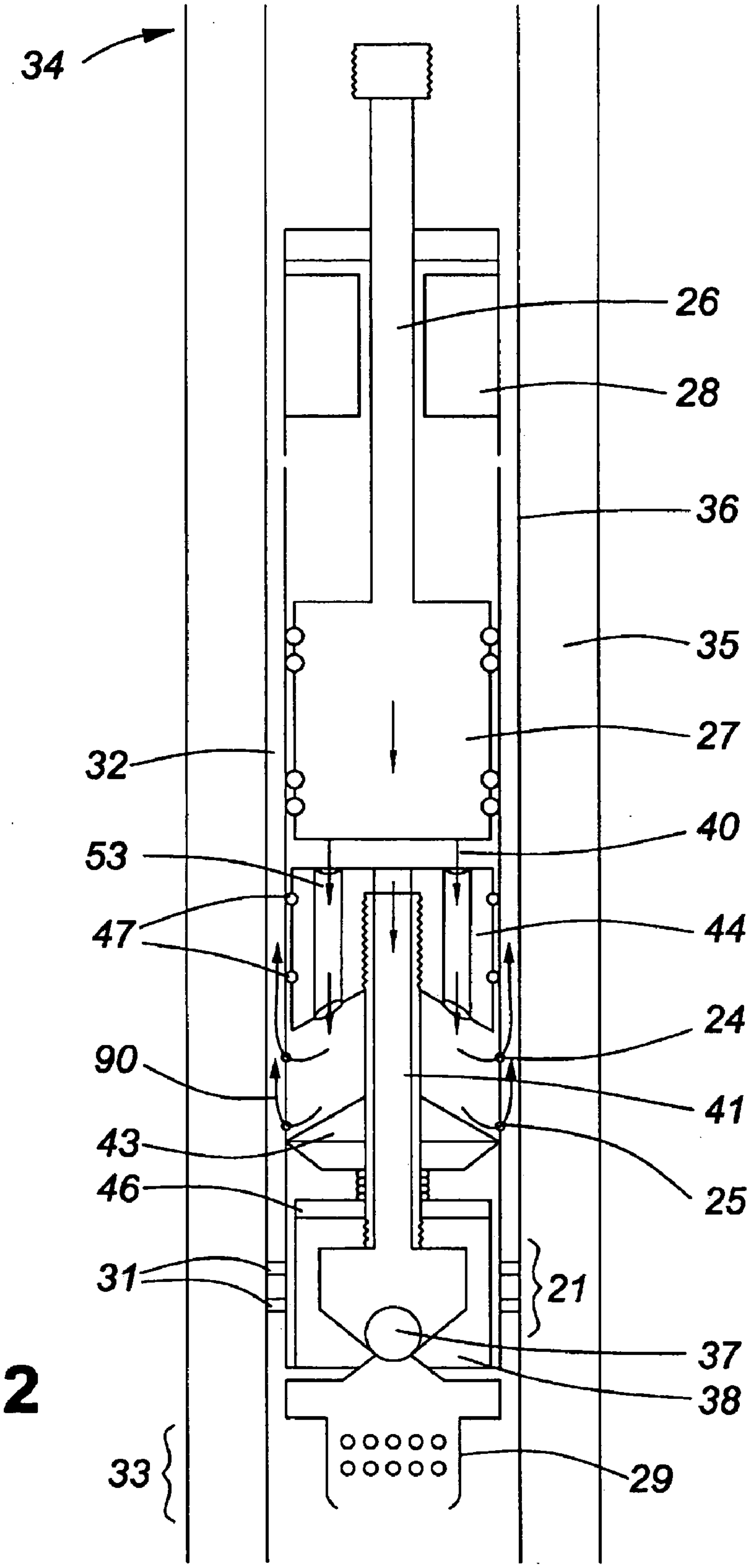

FIG. 2

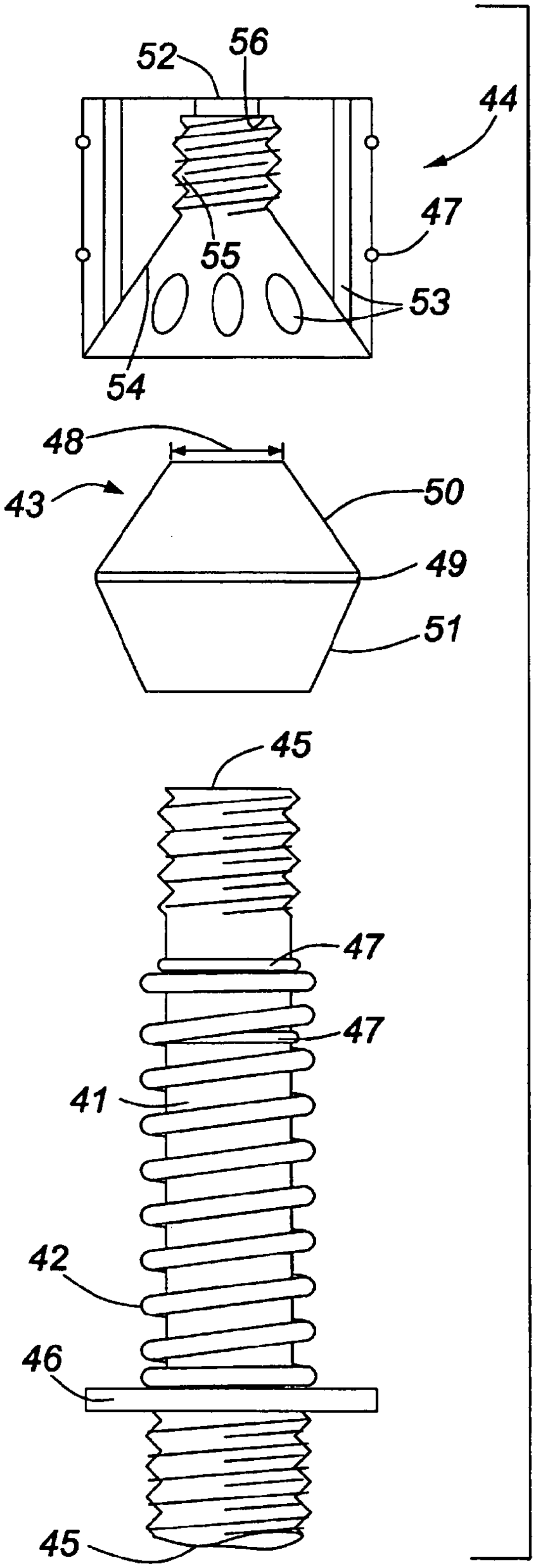

FIG. 3A

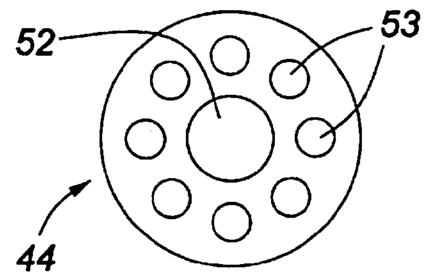

FIG. 3B

ANTI GAS-LOCK PUMPING SYSTEM

FIELD OF THE INVENTION

[0001] The present invention relates to anti gas-lock fluid pumping systems, and more specifically, to a valve which prevents gas-locking of a downhole pump.

BACKGROUND OF THE INVENTION

[0002] Piston pumps are commonly used in many applications, such as the pumping of water, air, and other fluids. Piston pumps are well adapted for use in an oil well, as they have linear mechanical parts, are relatively simple in their operation, and are of a size and shape easily accommodated within a downhole well.

[0003] Conventional downhole piston pumps have both a lower standing valve, and an upper travelling valve which is generally attached to the piston and plunger of the pump. During plunger upstroke, a pumping chamber is expanded, creating a negative pressure cavity. The negative pressure unseats the lower standing valve, allowing fluid from the well to be drawn into the pumping chamber. As the plunger is drawn up, the travelling valve is closed due to the build-up negative pressure in the chamber between the travelling valve and the standing valve, thereby creating a head of fluid to be expelled on downstroke. During downstroke, the piston/plunger moves downward, increasing the pressure between travelling and standing valves. The lower standing valve is forced closed, and the travelling valve opens to release fluid upward, either through or around the plunger.

[0004] In such a conventional pumping system, if gas is present in the well and fills the pumping chamber defined between the valves, it may cause gas-lock of the pump. Gas-lock occurs when the hydrostatic pressure of fluid above the plunger (already pumped), is greater than the pressure required to compress the gas in the pumping chamber, with the result that the travelling valve cannot open, and the gas is simply compressed on downstroke of the plunger. Subsequently, on upstroke, the pump has reduced efficiency, as gas remains in the chamber, preventing it from completely filling with fluid. Over time, gas build-up may lead to gas-locking and failure of the pump.

[0005] Various attempts have been made to address the gas-locking problem in downhole pumps. Generally such pumps have been designed to allow passive removal of the gas from the pumping chamber by mechanically opening the travelling valve during at least part of the downstroke to allow gas to be passively released from the pumping chamber, as taught, for example, in U.S. Pat. No. 5,249,936; U.S. Re. 33,163; and U.S. Pat. No. 5,139,398. One disadvantage of such systems is their reduced efficiency when the pump is not placed vertically, as the efficiency of travelling valves is generally reduced by positioning. In addition, gas may not fully escape from the pumping chamber if the position is not vertical. Further, such systems may alow pumped fluid to re-enter the pumping chamber as the gas is escaping.

[0006] Other anti gas-lock valves are complex in their operation, requiring rotating or otherwise intricate parts, as taught in U.S. Pat. No. 4,531,896 and U.S. Pat. No. 4,629,402; or alter the conventional piston-type pumping mechanism, as taught in U.S. Pat. No. 5,139,398.

[0007] It is therefore desirable to provide a fluid pump that is not susceptible to gas-lock, is simple in operation, and is suited for use in current downhole pumping.

[0008] It is further desirable to provide a fluid pump in which gas present is actively removed from the pumping chamber, avoiding the unreliability of systems which allow the gas to escape passively.

SUMMARY OF THE INVENTION

[0009] According to one aspect of the invention, there is provided an anti gas-lock valve for operative mounting within a pump having a pump housing with at least one outflow port, the pump having a plunger for upstroke and downstroke motion within the housing, the anti gas-lock valve comprising a valve shaft having an inlet port, for allowing fluid inflow in a first direction towards the plunger, the valve shaft oriented within the pump housing such that a first end of the valve shaft is proximal to the plunger and a second end of the valve shaft is distal to the plunger; and a valve head attached to the first end of the valve shaft, the valve head having at least one outlet port for allowing fluid outflow in a second direction away from the plunger; and a valve plug slidably engaged with the valve shaft for reversible seating against the at least one outlet port of the valve head to permit fluid flow through the at least one outlet port during downstroke of the plunger, and out through the outflow port.

[0010] In one embodiment of the first aspect of the invention, the valve head of the anti gas-lock valve has a top surface proximal to the plunger and a bottom surface distal to the plunger, and includes a plurality of outlet ports arranged circumferentially around the valve shaft for communication of fluid from the top surface to the bottom surface of the valve head.

[0011] In a second embodiment, the valve plug of the anti gas-lock valve is maintained in seating relationship to the at least one outlet port of the valve head by a compression spring mounted slidably along the valve shaft below the valve plug.

[0012] In other embodiments, the valve plug may have a diameter less than the diameter of the pump barrel and/or the lower surface of the valve plug may be tapered for allowing particulate matter to flow around the valve plug and settle below the outflow ports of the pump housing.

[0013] In a further embodiment, the valve shaft may include a one-way valve assembly at the second end of the valve shaft to prevent backflow and/or may include a steel ring at the second end of the valve shaft.

[0014] In a second aspect of the invention, there is provided an anti gas-lock fluid pump comprising a longitudinal pump barrel having at least one pump discharge port; a plunger and piston slidably and sealingly engaged within the pump barrel for reciprocal movement within the pump barrel; a valve shaft having at a first end a valve head in sealable contact with the pump barrel, located proximally to the plunger, and defining a pumping chamber between the valve head and the plunger; the valve shaft and the valve head having an inlet port for allowing fluid into the pumping chamber on upstroke of the plunger, and the valve head also having at least one valve head outlet port through which fluid may be expelled from the pumping chamber on plunger downstroke; and a valve plug in sliding engagement with the valve shaft for reversible seating with the valve head on upstroke, and unseating with the valve head on downstroke to allow fluid to be expelled from the pump barrel through at least one pump discharge port.

[0015] In one embodiment, the valve head of the anti gas-lock fluid pump comprises a plurality of valve head outlet ports arranged circumferentially around the valve head inlet port.

[0016] In a second embodiment, the valve plug of the anti gas-lock valve is maintained in seating relationship to the at least one outlet port of the valve head by a compression spring mounted slidably along the valve shaft below the valve plug.

[0017] In other embodiments, the valve plug may have a diameter less than the diameter of the pump barrel and/or the lower surface of the valve plug may be tapered for allowing particulate matter to flow around the valve plug and settle below the outflow ports of the pump housing.

[0018] In a further embodiment, the valve shaft may include a one-way valve assembly at the second end of the valve shaft to prevent backflow and/or may include a steel ring at the second end of the valve shaft.

[0019] In an additional embodiment, the pump plunger may include at least one seal around its circumference for preventing fluid flow between the plunger and the pump barrel.

[0020] In a further embodiment, the pump may have a plurality of pump discharge ports located circumferentially around the pump barrel at its end distal to the plunger

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The invention is described with reference to the following drawings wherein:

[0022] **FIG. 1** is a longitudinal cross sectional view of a fluid pumping system in accordance with the present invention, illustrating fluid flow and the position of the valve assembly during upstroke of the fluid pumping system.

[0023] **FIG. 2** is a longitudinal cross sectional view of a fluid pumping system in accordance with the present invention, illustrating fluid flow and the position of the valve assembly during downstroke of the fluid pumping system.

[0024] **FIG. 3A** is an exploded side view of a valve assembly in accordance with the present invention.

[0025] **FIG. 3B** is a top view of the valve head shown in **FIG. 3A**.

DETAILED DESCRIPTION OF THE INVENTION

[0026] Overview

[0027] In accordance with the invention and with reference to the Figures, a fluid pumping system having an anti gas-lock valve is described. As shown in **FIG. 1**, a fluid pumping system **10** is shown to generally include a fluid pump **20**, operatively containing a slidable plunger **27**, and one-way lower **21** and upper **22** valve assemblies, within a pump barrel **23**. The fluid pump **20** is lowered downhole into a well **30** and is anchored within the well **30** by hold down cups **31**, thereby defining an annulus **32** between the pump **20** and the well **30**.

[0028] Generally, a fluid **90** is pumped from the bottom **33** of well **30** by reciprocating motion (upstroke and downstroke) of plunger **27** within the pump barrel **23**. During upstroke, as shown in **FIG. 1**, fluid **90** is drawn in through the lower valve assembly **21**, and as shown in **FIG. 2** during downstroke, the lower valve assembly **21** is closed allowing the upper valve assembly **22** to open, and allowing fluid **90** to exit the fluid pump **20** through discharge ports **24** and wash ports **25** into annulus **32**, where it will be forced by continued pumping to the top **34** of the well **30**.

[0029] For purposes of illustration, the well **30** includes well wall **35**, which is lined by tubing **36**. Hold down means **31** are generally known in the field as hold down cups, or anchors.

[0030] Description of Fluid Pump

[0031] As noted above, the fluid pump **20** includes a pump barrel **23**, a plunger rod **26**, a plunger **27**, a lower valve assembly **21**, and an upper valve assembly **22**. The plunger rod **26** has a plunger/piston **27** at its distal end, the plunger **27** having a diameter sufficient to fit within the pump barrel **23**.

[0032] The coaxial position of the plunger rod **26** within the pump barrel **23** is maintained by a plunger rod guide **28**, which is threadably attached to the pump barrel **23**. The plunger is moved in upstroke and downstroke by a motor (not shown) at the top **34** of the well **30**, which drives a sucker rod (not shown) threadably attached to the plunger rod **26** at its proximal/upper end. A tap block **39** may be threadably attached to the plunger rod **26** to precisely set the maximum downstroke. On upstroke, the plunger moves away from the upper valve assembly **22**, thereby defining a pumping chamber **40**, into which the pumped fluid **90** will be drawn by negative pressure and thereby opening the lower valve assembly **21**, and closing the upper valve assembly **22**. On downstroke, the plunger is moved downward towards the upper valve assembly **22**, causing closure of the lower valve assembly **21**, fluid **90** is pumped through the upper valve assembly **22**, to exit the pump **20** at discharge ports **24**.

[0033] Lower Valve Assembly

[0034] Referring again to **FIG. 1**, the lower valve assembly **21** is threadably connected to the upper valve assembly **22**, and permits fluid flow **90** into the pump **20** from the bottom **33** of the well **30**. Generally, on plunger upstroke, fluid **90** will flow upward through a strainer nipple **29** to the lower valve assembly **21**, shown as a standing ball **37** and seat valve **38**. The negative pressure created by plunger upstroke will unseat the ball, allowing fluid passage past the standing valve and upwards into the pumping chamber **40** through the interior of the upper valve assembly **22**. On downstroke of the plunger, the positive pressure created in the pumping chamber **40** will force the lower standing valve to close, thereby preventing fluid backflow.

[0035] Upper Valve Assembly (Anti Gas-Lock Valve)

[0036] Valve Shaft **41**

[0037] The upper valve assembly **22** of the present invention is shown in **FIG. 3** as having four separable steel parts, namely a valve shaft **41**, a compression spring **42**, a valve plug **43**, and a valve head **44**. The valve shaft **41** is preferably a cylinder having valve shaft inlet port **45** defined through its longitudinal axis, which is of a size sufficient to permit fluid flow. Preferably, the diameter of the inlet port **45** is in the order of 0.5 inches. The valve shaft **41** is threaded at its uppermost end for attachment to the valve head **44**, and threaded at its base for attachment to the lower valve assembly **21**. The base of the valve shaft **41** is defined by a steel seal ring portion **46** immediately above the threaded base. The steel seal ring portion **46** of the valve shaft **41** serves to support the compression spring **42**, which seats the valve plug **43** against the valve head **44** when fully assembled. The compression spring is of slightly larger diameter than the valve shaft **41**, and should be biased with enough force to minimize backflow of fluid from the annulus **32** through the discharge ports **24** due to hydrostatic pressure created by the head of pumped fluid present in the annulus **32**. Preferably, the compression spring **42** is biased with 50 pounds of force.

[0038] The valve shaft **41** is fitted with at least one ring seal **47**, located inferior to the upper threaded portion of the valve shaft **41**. The seals are of sufficient diameter to ensure that a seal is formed between the valve shaft **41** and the valve plug **43**, thereby preventing fluid movement through valve plug **43**.

[0039] Valve Plug **43**

[0040] The valve plug **43**, as shown in **FIG. 3**, is preferably a steel cylinder with an inner bore **48**, the outer surface of the valve plug **43** being bilaterally tapered outwardly from the central bore at each longitudinal end. Such tapering defines an outer diameter **49**, and upper and lower tapered surfaces **50** and **51**, respectively. The diameter of the inner bore **48** of the valve plug **43** should be sufficient to permit passage of the valve plug **43** around the valve shaft **41**, while ensuring adequate sealing with ring seals **47**. In a preferred embodiment, the diameter of the inner bore **48** of the valve plug **43** is 0.750 inches. The outer diameter **49** of the valve plug **43** is preferably slightly smaller than that of pump barrel **23**, allowing any particulate matter present in the pumped fluid to fall between the valve plug **43** and the pump barrel **23**.

[0041] The upper **50** and lower **51** tapered surfaces may or may not be identical in height and degree of taper, and may be modified depending on the characteristics of the fluid to be pumped. In the preferred embodiment, illustrated herein for use in a downhole pump, the characteristics of the upper and lower tapered surfaces **50** and **51** are configured as detailed below. The upper tapered surface **50** should maximize the surface area available for fluid flow while minimizing the resistance to fluid flow as the fluid is pumped. Preferably, the upper taper **50** is a 30 degree taper. The lower tapered surface **51** should be sufficient to facilitate the fall of particulate matter between the valve plug **43** and the pump barrel **23**. Preferably, the lower taper **51** is a 20 degree taper.

[0042] Valve Head **44**

[0043] The valve head **44** of the valve assembly **21**, as shown in the embodiment of **FIGS. 3A and 3B**, may comprise a steel cylinder containing inlet and discharge ports **52**, **53**. The lower inner surface **54** of the valve head **44** is tapered to mate with the upper tapered surface **50** of the valve plug **43**, and the remainder of the inner surface of the valve head **44** is threaded **55**, save for an upper flange **56** that serves as a stop for the threaded attachment to the valve shaft **41**, and defines a central inlet port **52** through the valve head **44**. When the valve head **44** is threadably attached to the valve shaft **41**, a continuous inlet port **45**, **52** is defined to permit fluid flow through the valveshaft **41** and valve head **44**. It is understood that the central inlet port shown is the preferred embodiment of the valve head **44**, however other configurations or layouts may be designed in accordance with the invention.

[0044] The discharge ports **53** are shown in their preferred embodiments as eight 0.250 ports spaced diametrically around the inlet port. The discharge ports **53** serve to permit fluid flow **90** on plunger **27** downstroke from the pumping chamber **40**, through the valve head **44**.

[0045] The valve head **44** also preferably contains at least one ring seal **47**, of sufficient diameter to effectively seal any space between the valve head **44** and the pump barrel **23**, thus necessitating that all fluid to be expelled from the pumping chamber **40** passes through the valve head **44**.

[0046] Fluid Flow During Pump Operation

[0047] With reference to **FIG. 1**, on upstroke of the plunger rod **26**, the plunger **27** will rise, increasing the size of the pumping chamber **40**, thereby creating negative pressure within the chamber **40**, causing the lower standing valve **21** to become unseated. Fluid **90**, will be drawn upwards through the strainer nipple **29** and lower standing valve **21**, to pass through the inlet port **45**, **52**, filling the pumping chamber **40**.

[0048] With reference to **FIG. 2**, on downstroke of the plunger rod **26**, the plunger **27** will be forced towards the valve head **44** of the upper valve assembly, decreasing the size of the pumping chamber **40**, and increasing the pressure within pumping chamber **40**. This downward pressure will cause the lower standing valve **21** to close. As the pressure within the pumping chamber **40** increases, the pressure of the fluid **90** within the discharge ports **53** of the valve head **44** of the upper valve assembly **22** will also increase. This increase in pressure will translate to a downward pressure upon the valve plug **43** of the upper valve assembly **22**. The force within the pumping chamber **40** and discharge ports **53** will overbias the upward pressure of the compression spring **42** against the valve plug **43**, and valve plug **43** will be forced downward towards the steel seal ring **46**. Thus, fluid will flow through valve discharge ports **53**, and through the plurality of discharge ports **24** in the pump barrel **23** into the annulus **32**, where continued pumping will force the pumped fluid **90** to exit the top **34** of the well **30**.

[0049] As the downstroke proceeds, and fluid is pumped from the pumping chamber **40**, and exits to the annulus **32** of the well **30**, the pressure within the pumping chamber **40** will decrease to the point that it is unable to overbias the upward pressure of the compression spring **42** against the valve plug **43**. Therefore, as downstroke is completed, the valve plug **43** will move towards its initial seated position within the valve head **44**, preventing backflow of fluid from the annulus **32** into the pumping chamber **40**.

[0050] Prevention of Gas-Lock

[0051] It is apparent that the present pumping system will not be susceptible to gas-lock. Should gas enter the fluid pump **20**, it will likewise be drawn into the pumping chamber **40** with the fluid. Due to the complete positive displacement of the pumping chamber by the plunger **27** against the valve head **44**, gas will not be permitted to remain in the pumping chamber **40**. Further, although the compression spring is biased to ensure complete seating of the valve plug **43** within the valve head **44**, the force required to compress the spring is less than that required to compress the gas within the pumping chamber. Thus the gas will be forced out of the pumping chamber **40**, through the discharge chamber **54**, and into the annulus **32** of the well **30**, rather than being compressed within the pumping chamber **40** and causing gas-lock failure of the pump **20**.

[**0052**] Movement of Particulate Matter

[**0053**] The present pumping system **10** will also prevent the build-up of particulate matter within the pump **20**. Any particulate matter that is drawn into the pumping chamber **40**, will exit through the discharge ports **53** in the valve head **44** and enter the discharge chamber **54**. The upper tapered surface **50** of the valve plug **43** is designed to allow particulate matter to fall towards the central outer diameter **49** of the valve plug **43**. As the central outer diameter **49** of the valve plug **43** is less than the diameter of the pump barrel **23**, the particulate matter will fall between the valve plug **43** and the pump barrel **23**, to rest on the steel seal ring **46**. Thus the particulate matter is prevented from remaining in the functional portion of the pump **20**, prolonging the life of the pump **20**.

[**0054**] When pumped fluid is present within the annulus **32** of the well **30**, a hydraulic pressure is created within the annulus **32**, causing a tendency for backflow of fluid into the pumping barrel **23**. The presence of a plurality of wash ports **25** about the pump barrel **23** accommodates this, allowing fluid to re-enter the fluid pump **20**, to wash the area of the upper valve assembly **22** occupied by the compression spring **42**. This washing serves to remove any particulate matter from the compression spring **42** and the steel seal ring **46**.

EXAMPLE

[**0055**] The anti gas-lock valve described above was placed within a pump into a downhole production well in Central Alberta, and was operated for 14 days. The pump produced 1000 L/h of oil, and maintained this efficiency for the entire duration of the test, indicating that the pump did not experience gas-lock. It was observed that both oil and gas were pumped into the annulus exterior of the pump barrel, to the top of the well. It was further evident that the entire contents of the pumping chamber was fully displaced with each downstroke of the plunger, this was also indicative that the pump would not be subject to gas locking.

What is claimed is:

1. An anti gas-lock valve for operative mounting within a pump having a pump housing with at least one outflow port, the pump having a plunger for upstroke and downstroke motion within the housing, the anti gas-lock valve comprising:

a. a valve shaft having an inlet port, for allowing fluid inflow in a first direction towards the plunger, the valve shaft oriented within the pump housing such that a first end of the valve shaft is proximal to the plunger and a second end of the valve shaft is distal to the plunger; and

b. a valve head attached to the first end of the valve shaft, the valve head having at least one outlet port for allowing fluid outflow in a second direction away from the plunger; and

c. a valve plug slidably engaged with the valve shaft for reversible seating against the at least one outlet port of the valve head to permit fluid flow through the at least one outlet port during downstroke of the plunger, and out through the outflow port.

2. An anti gas-lock valve according to claim 1, wherein the valve head has a top surface proximal to the plunger and a bottom surface distal to the plunger, and wherein the valve head includes a plurality of outlet ports arranged circumferentially around the valve shaft for communication of fluid from the top surface to the bottom surface of the valve head.

3. An anti gas-lock valve according to claim 1, wherein the valve plug is maintained in seating relationship to the at least one outlet port of the valve head by a compression spring mounted slidably along the valve shaft below the valve plug.

4. An anti gas-lock valve according to claim 1, wherein the valve plug has a diameter less than the diameter of the pump barrel for allowing particulate matter to flow around the valve plug.

5. An anti gas-lock valve according to claim 1, wherein the lower surface of the valve plug is tapered for facilitating settling of any particulate matter present in the pumped fluid.

6. An anti gas-lock valve according to claim 1, wherein the valve shaft has at its second end a one-way valve assembly for allowing fluid entry into the inlet ports of the valve shaft on plunger upstroke, and preventing fluid backflow from the inlet port of the valve shaft on plunger downstroke.

7. An anti gas-lock valve according to claim 1, wherein the valve shaft has at its second end a base, the base being defined by a steel ring.

8. An anti gas-lock valve according to claim 2, wherein the valve plug is maintained in seating relationship to the outlet ports of the valve head by a compression spring mounted slidably along the valve shaft below the valve plug.

9. An anti gas-lock valve according to claim 8, wherein the valve plug has a diameter less than the diameter of the pump barrel for allowing particulate matter to flow around the valve plug.

10. An anti gas-lock valve according to claim 9, wherein the lower surface of the valve plug is tapered to facilitate settling of any particulate matter present in the pumped fluid.

11. An anti gas-lock fluid pump comprising:

a. a longitudinal pump barrel having at least one pump discharge port;

b. a plunger and piston slidably and sealingly engaged within the pump barrel for reciprocal movement within the pump barrel;

c. a valve shaft having at a first end a valve head in sealable contact with the pump barrel, located proximally to the plunger, and defining a pumping chamber between the valve head and the plunger; the valve shaft and the valve head having an inlet port for allowing fluid into the pumping chamber on upstroke of the plunger; and the valve head also having at least one valve head outlet port through which fluid may be expelled from the pumping chamber on plunger downstroke; and

d. a valve plug in sliding engagement with the valve shaft for reversible seating with the valve head on upstroke, and unseating with the valve head on downstroke to allow fluid to be expelled from the pump barrel through at least one pump discharge port.

12. An anti gas-lock fluid pump according to claim 11, wherein the valve head comprises a plurality of valve head outlet ports arranged circumferentially around the valve head inlet port.

13. An anti gas-lock fluid pump according to claim 11, wherein the valve plug is maintained in seating relationship to the at least one outlet port of the valve head by a compression spring mounted slidably along the valve shaft below the valve plug.

14. An anti gas-lock fluid pump according to claim 11, wherein the valve plug has a diameter less than the diameter of the pump barrel for allowing particulate matter to flow around the valve plug.

15. An anti gas-lock fluid pump according to claim 11, wherein the lower surface of the valve plug is tapered for facilitating settling of any particulate matter present in the pumped fluid.

16. An anti gas-lock fluid pump according to claim 11, wherein the valve shaft has at its second end a one-way valve assembly for allowing fluid entry into the inlet port of the valve shaft on plunger upstroke, and preventing fluid backflow from the inlet port of the valve shaft on plunger downstroke.

17. An anti gas-lock fluid pump according to claim 11, wherein the plunger includes at least one seal around its circumference for preventing fluid flow between the plunger and the pump barrel.

18. An anti gas-lock fluid pump according to claim 11, wherein the valve shaft has at its second end a base, the base being defined by a steel ring.

19. An anti gas-lock fluid pump according to claim 12, wherein the valve plug is maintained in seating relationship to the outlet ports of the valve head by a compression spring mounted slidably along the valve shaft below the valve plug.

20. An anti gas-lock fluid pump according to claim 19, wherein the valve plug has a diameter less than the diameter of the pump barrel for allowing particulate matter to flow around the valve plug.

21. An anti gas-lock fluid pump according to claim 20, wherein the lower surface of the valve plug is tapered to facilitate settling of any particulate matter present in the pumped fluid.

22. An anti gas-lock fluid pump according to claim 12, wherein the pump has a plurality of pump discharge ports located circumferentialy around the pump barrel at its end distal to the plunger.

* * * * *