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.
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 allow 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. 4,620,402; 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.

SUMMARY OF THE INVENTION

[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.

[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 reciprocative 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 slideable 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 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 valve shaft 41 and valve head 44. It is understood that the central inlet port 45, 52 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 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 üzer 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 to 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 override 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 outlet 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
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 circumferentially around the pump barrel at its end distal to the plunger.

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