Title: FLUID POWERED SUBTERRANEAN PUMP SYSTEM

Abstract: The present invention includes a subterranean pump assembly (100) in fluid communication with a production zone (150). The assembly includes a body (110) defining a cavity (190) therein and an elastic, collapsible bladder (155) suspended longitudinally within the cavity. The flexible bladder is in one-way communication at a lower end (125) with production fluid (165) from the well and in one-way communication at an upper end (120) with a collection line for transportation of the production fluid to the surface of the well. After the bladder fills with production fluid due to hydrostatic pressure in the well, control fluid in the annular area therearound is pressurized, causing the bladder to collapse. In this manner, production fluid in the bladder is forced upwards through the valve at the upper end thereof and into the collection line.
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FLUID POWERED SUBTERRANEAN PUMP SYSTEM

The present invention relates to a fluid pumping system for moving fluid from one location to another. More particularly, the invention relates to a submerged pumping system with no subsurface mechanical, moving parts, for elevating production fluids from an underground formation to the well surface.

A variety of types of pumps and artificial lift systems are in use for producing oil and other liquids from wells where the liquids flow slowly or will no longer flow at all by natural lift. The type of pump selected for use with a particular well is dictated by a number of factors, including the formation pressure and the liquid to be pumped. For example, submerged mechanical displacement pumps, operated from the surface by a reciprocating sucker rod, are conventionally employed to elevate oil to the well surface. However, mechanical pumping systems are undesirable to the extent that they entail substantial movement of metal parts which corrode and abrade. Mechanical pumps also produce a relatively limited volume of oil during each pumping cycle and require relatively large amounts of power for their operation. The close tolerances required in most system-cylinder type mechanical pumps also make such pumps expensive to produce and maintain.

Flexible displacement member or bladder pumps have been used in various installations for bringing underground oil to the surface. These pumps, which use a distendable diaphragm, bladder or bellows to displace the pumps liquid from a confined area, are particularly useful in wells where the moving parts of a pump come into contact with corrosive or abrasive liquids, gases or particles that can damage the inner portions of a conventional pump. Prior art flexible member pumps are usually powered by a mechanically driven piston-cylinder assembly in which the piston acts against a liquid which in turn controls movement of the flexible member. The piston itself is either operated through a mechanical linkage extending from the surface or is operated by a motor located adjacent the pump. Such systems therefore suffer to a degree from many of the same short comings which exist in a conventional mechanical displacement pump. Specifically, both systems require a submerged motor, making them subject to wear and mechanical failure. Also, when used with high viscosity oil, conventional
mechanical linkage pumps are inefficient since the density and the viscosity of the oil make it difficult to raise the mechanical linkage on the up stroke and prevent the linkage from falling freely during the down stroke.

There is a need therefore, for a subterranean pump with no mechanical moving parts below the surface of the well. There is a further need therefore, for a subterranean pump that can displace and recover liquid in an environment including particles and other contaminants. There is yet a further need for a subterranean pump that can operate in the presence of corrosive gases and liquids without failing due to damage of components.

In accordance with one aspect of the present invention there is provided an apparatus for recovering production fluid from a well, comprising:

- a cavity of a defined volume in a wellbore;
- an elastic, collapsible member within the cavity, the member in communication with the production fluid at a first end and in communication with a recovery member at a second end, the collapsible member fillable with production fluid; and
- a source of control fluid supplied to the cavity which, when pressurised, causes the collapsible member to collapse, thereby urging the production fluid in the collapsible member into the recovery member.

Further preferred features are set out in claims 2 to 10.

In one aspect of the invention, a subterranean pump assembly is in fluid communication with a production zone in a well. The assembly includes a body defining a cavity therein and an elastic, collapsible bladder suspended longitudinally within the cavity. Formed between the outer surface of the bladder and the cavity walls is an annular area in fluid communication with a source of control fluid. The flexible bladder is in one-way communication at a lower end with production fluid from the well and in one-way communication at an upper end with a collection line for transportation of the production fluid to the surface of the well. After the bladder fills with production fluid due to hydrostatic pressure in the well, control fluid in the annular area therearound is pressurised, causing the bladder to collapse. In this manner, production
fluid in the bladder is forced upwards through the valve at the upper end thereof and into the collection line. As the control fluid is depressurised, the bladder returns to its original shape due to elastic forces of the bladder material, refilling with additional production fluid to be subsequently forced into the collection line during the next pumping cycle.

Some preferred embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of the subterranean pump of the present invention;
Figure 2 is a schematic view showing a second embodiment of the subterranean pump;
Figure 3 is a schematic view showing a third embodiment of the subterranean pump; and
Figure 4 is a schematic view showing a fourth embodiment of the subterranean pump.

Figure 1 is a schematic view of a first embodiment of the subterranean pump 100 of the present invention. The pump 100 as depicted is adjacent a production zone 150 of a well. However, the pump will operate effectively above or below a production zone of a well. The well includes wellbore 165 which is lined with casing 160 including perforations 171 formed therethrough. The perforations allow production fluid from the production zone 150 to migrate into the wellbore 165 and into the annular area 170 formed between the inside of the casing wall and the outside surface of the pump 100. The level of production fluid in the wellbore 165 illustrated in Figure 1 is at a level 175. While Figure 1 illustrates the pump in a cased wellbore, the pump may also be effectively used in an open hole well.

In the embodiment of Figure 1, the pump 100 includes a body 110, an upper, one-way valve 120, a lower, one-way valve 125, end cap 135 and control fluid line 130. At an upper end, pump body 110 is threadedly attached to the end of a conventional, retrievable tubular member 145 which conducts production fluid to the surface of the well. Upper valve 120 is housed at the upper end of the pump body and provides the sole path of fluid communication between the pump body and the tubular member 145. At a bottom end of the pump body, end cap 135 is threadedly attached to the body and
lower valve 125 is housed therein so as to provide a sole path of fluid communication between production fluid in wellbore 165 and the pump body 110. Valves 120 and 125 are conventional ball valves allowing fluid to flow in one direction unhindered but preventing flow in the opposite direction. In the pump of Figure 1, lower valve 125 is arranged to permit flow of production fluid in an upward direction into the pump body 110. The floating ball 121 of valve 125 prevents the fluid from exiting back out the valve into the wellbore 165. Similarly, upper valve 125 is arranged to allow fluid to pass in an upward direction from the pump body 110 into the tubular member 145 but prevents the return of the fluid back into the pump body.

Pump body 110 defines a cavity 190 therein. An aperture 195 formed in a wall 180 of pump body 110 permits fluid to enter and exit the cavity 190. In the preferred embodiment, an externally located control fluid line 130 supplies a control fluid to the cavity 190. A fitting, in this embodiment, an elbow-shaped connector 131 provides an entry and exit means for control fluid from the supply line 130 to the cavity 190. A reservoir of control fluid is located at the surface of the well (not shown) with a source of control fluid adequate to fill the control fluid line and cavity 190. A means of pressurising the control fluid, like a mechanical piston, is also provided at the well surface.

Suspended longitudinally within the cavity 190 of pump body 110 is a flexible, collapsible bladder 155. The bladder 155 is sealingly attached at an upper end to the inflow side of upper valve 120 and at a lower end to the outflow side of lower valve 125. With the bladder attached at each end to the valves and with the interior of the bladder isolated from the cavity 190, the only flow path of fluid through the pump body is via the bladder 155. The flexible bladder described herein may be constructed of natural or synthetic rubber or other leak-proof, non-corrosive flexible materials which are capable of being repeatedly expanded and collapsed. In each case, the material forming the bladder has excellent memory characteristics ensuring that the bladder will return to its original extended position after collapsing due to pressure on its outside surface.

The connection between each end of the bladder and the valves is made using
any suitable means. For example, each end of the bladder could be flared outward and held by a sealing ring at the opening of each valve 120, 125. Another method of attachment between the bladder and valves includes a thermal connection whereby the edge of the bladder material is cured and fused at each end to a valve during the curing process. Also possible is adhesion of the bladder ends to the valve surfaces using an epoxy designed for use with dissimilar materials. Because the bladder is connected at each end to a valve, the valve/bladder assembly is removable from the pump body and replaceable in the event the bladder becomes damaged or worn or a pump with different bladder characteristics is required.

The pump 100 is made-up to the tubular member 145 at the well surface by attaching the pump to the end of the tubular member 145. Separately, control line 130 is attached to fitting 131 which in turn is connected to aperture 195 in wall 180 of pump body 110. The pump 100 is then run-into the well at the end of tubular member 145 to a pre-selected depth. Typically, as depicted in Figure 1, the level 175 of production fluid in the well will extend well above the installed pump. In such a case, hydrostatic pressure will tend to equalise the level of fluid inside and outside of the tubular member 145. For example, as the pump is lowered into the wellbore 165, fluid will flow into lower valve 125, through bladder 300 and through upper valve 120, partially filling the tubular member 145 to a level 176, substantially equal to the level of fluid 175 in the annulus 170 between the tubular member 145 and the wall of casing 160. In every case, the pump will be located at some depth in the well where at least the bottom portion of pump housing 110, including lower valve 125 will be submerged in fluid and the bladder will at least partially fill due to hydrostatic pressure.

When the pump 100 has been inserted into the well, control fluid is introduced into the control line 130 and allowed to fill the annular area formed in the cavity 190 of the pump body 110. Control fluid will typically be some fluid having a higher weight than the production fluid. For example, in the case of an oil well, water might be chosen as a control fluid because water is heavier than oil and will be more effective than oil in the collapsible bladder 155. The bladder is designed so that the pressure of the control fluid around it is not adequate to collapse the bladder without additional pressure exerted on the column of control fluid from the earth's surface.
After the bladder 155 is filled with production fluid, pressure is exerted on the column of fluid in the control line 130 and the bladder 155 is collapsed within cavity 190. As the bladder collapses, the fluid contained therein is forced through upper valve 120 and into the tubular member 145 where it joins the column of fluid therein. The design of the upper valve 120 prevents the fluid from flowing back into the bladder. Thereafter, the pressure exerted on the control line is released and the bladder returns to its original shape. The return of the bladder to its original shape causes additional fluid to be pulled into the bladder through lower valve 125. Thereafter, the bladder is again ready to be collapsed and its contents transferred to the tubular member 145 thereabove. In this manner, a volume of production fluid substantially equal to the volume of the bladder is moved towards the surface of the well with each cycle of the pump. As the tubular member 145 above the pump 100 fills with production fluid, the fluid is collected at the surface of the well and transferred to a remote collection location or refinery (not shown).

Figure 2 is a second embodiment of the invention. In this embodiment, a control fluid line 210 is housed within a tubular member 245. Control fluid communicates with the pump cavity 205 via an aperture 207 formed in the second end of the pump body 215. Because the control fluid line 210 is internally housed, the pump 200 is more compact and the control line 210 is less likely to be damaged in the annulus of the well. In this embodiment, the control line 210 is preferably constructed of coiled tubing. The coiled tubing extends from the well surface and terminates at fitting 212 thereby providing a flexible, isolated flow path for the control fluid. The description of operation of the pump of Figure 1 is equally applicable to the embodiment of the invention depicted in Figure 2.

Figure 3 is a third embodiment of the invention. In this embodiment, a packer 310 is installed in the annulus 370 between the pump 300 and the wall of casing 320. By placing the packer 310 between the pump 300 and well casing 320, that portion of the annulus above the packer 310 is isolated from production fluid. Two apertures 378a,b are formed in the side walls of the pump body 312 thereby providing fluid communication between annulus 305 and pump cavity 330. Fluid communication
between the annulus 305 and the cavity 330 of the pump makes it possible for the annulus to be filled with control fluid which can then be pressurised and can collapse the bladder member 360 evacuating its contents upwards through valve 375 and into the tubular member 380, as in the previous embodiments. This embodiment simplifies the pump of the present invention because no external or internal control fluid line is required for carrying the control fluid. While the packer 310 may be installed at the bottom end of the pump 300, the packer is sufficiently high enough to ensure that production fluid will still migrate into the bladder 360 through lower valve 374. The bladder 360 can then be completely filled as the bladder returns to its original shape after being collapsed in the first pump cycle.

Figure 4 shows yet another embodiment of the subterranean pump of the present invention. In this embodiment, like the embodiment shown in Figure 3, the annulus above the pump 400 between the pump and well casing 455 is isolated from production fluid by a packer 405. However, in this embodiment bladder 410 is designed to expand, rather than to collapse and the bladder displaces, rather than holds production fluid. The pump 400 is threadably engaged to the end of tubular member 445. A source of control fluid is located at the surface of the well and includes a reservoir large enough to fill member 445 and expandable bladder 410 to its expanded shape shown with dotted lines in Figure 4. Additionally, means are provided to pressurise the control fluid in the column of member 445. The expandable bladder 410 is mounted in cavity 450 of the pump body 402 and is attached only at the upper end of the pump body where it is in direct communication with the pipe 445. Two one way valves 425a, b are mounted in the side walls of pump body 402. A lower, single direction valve 435 is mounted in the bottom of the pump body -402 and is in fluid communication with the pump body cavity 450.

In this embodiment, production fluid enters valve 435 and fills the annular area created by the deflated bladder and the cavity 450 of the pump body 402. When the cavity has been filled with the migrating production fluid, the expandable member is inflated with control fluid pressurised from the well surface through the tubular member 445. As the inflatable bladder 410 is expanded, the production fluid present in cavity 450 is forced through at least one of the two valves 425a, b and into the annular area
455 above the packer 405. With successive cycles of the pump, the annular area 455 fills with production fluid which is collected at the well surface.

While foregoing is directed to the preferred embodiment of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.
CLAIMS:

1. An apparatus for recovering production fluid from a well, comprising:
   a cavity of a defined volume in a wellbore;
   an elastic, collapsible member within the cavity, the member in communication
   with the production fluid at a first end and in communication with a recovery member at
   a second end, the collapsible member fillable with production fluid; and
   a source of control fluid supplied to the cavity which, when pressurised, causes
   the collapsible member to collapse, thereby urging the production fluid in the
   collapsible member into the recovery member.

2. An apparatus as claimed in claim 1, whereby the collapsible member is
   suspended longitudinally in the cavity and connected at a first end to a first one-way
   valve and connected at a second end to a second one-way valve.

3. The apparatus of claim 2, whereby the first one-way valve permits production
   fluid to pass into the collapsible member and the second one-way valve permits
   production fluid to pass from the collapsible member into the recovery member.

4. The apparatus of claim 1, 2 or 3, whereby the control fluid is supplied to the
   cavity through a conduit in fluid communication with the cavity.

5. The apparatus of claim 4, wherein the conduit extends from the well surface to
   the cavity in the annular area formed by a wall of the wellbore and the outside surface
   of the recovery member.

6. The apparatus of claim 4, whereby the conduit extends from the well surface and
   is housed within the recovery member.

7. The apparatus of claim 4, whereby the conduit is the annular area between the
   wall of the wellbore and the outside surface of the recovery member, the annular area in
   fluid communication with the cavity and isolated from the production fluid.
8. A subterranean pump for recovering production fluid from a well, the pump comprising:
   a housing mountable at an end of a tubular member and locatable in a well bore in the presence of production fluid;
   a first reservoir formed inside the housing;
   a second, collapsible reservoir formed within the first reservoir;
   a valve providing communication between the second reservoir and the production fluid, the valve constructed and arranged to allow pressurised production fluid to enter but not exit the second reservoir;
   an inlet in communication with the first reservoir and a source of pressurised control fluid, the control fluid injectable into an annular area defined by the inside of the first reservoir and the outside of the second reservoir; and
   a second valve in communication with the second reservoir and a recovery pipe, said valve constructed and arranged to allow production fluid only to enter the recovery pipe, whereby:
   when the control liquid is injected into the first reservoir, the second reservoir is collapsed, forcing the production liquid into the recovery pipe.

9. An apparatus for recovering production fluid from a well comprising:
   a cavity having a defined volume located within a wellbore;
   an inflatable member located within the cavity and constructed and arranged to reduce the volume of the cavity;
   a source of control fluid in communication with the inflatable member causing the inflatable member to inflate and the volume of the cavity therearound to be reduced;
   the first valve permitting the production fluid to enter the volume; and
   a second valve permitting fluid to exit as the inflatable member is inflated and volume is reduced.

10. A method of pumping fluid from a well, comprising the steps of:
   running a submersible pump into a wellbore to a point wherein the pump is at least partially covered with production fluid;
   allowing production fluid to migrate into a collapsible member;
   pressurising a control line to control fluid surrounding the collapsible member;
forcing the production fluid out of the bladder and into a tubular collection member disposed thereabove;

releasing pressure on the control line thereby allowing the bladder to return to its original shape to refill with production fluid; and

repeating the cycle.
INTERNATIONAL SEARCH REPORT

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B F04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Name and mailing address of the ISA

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