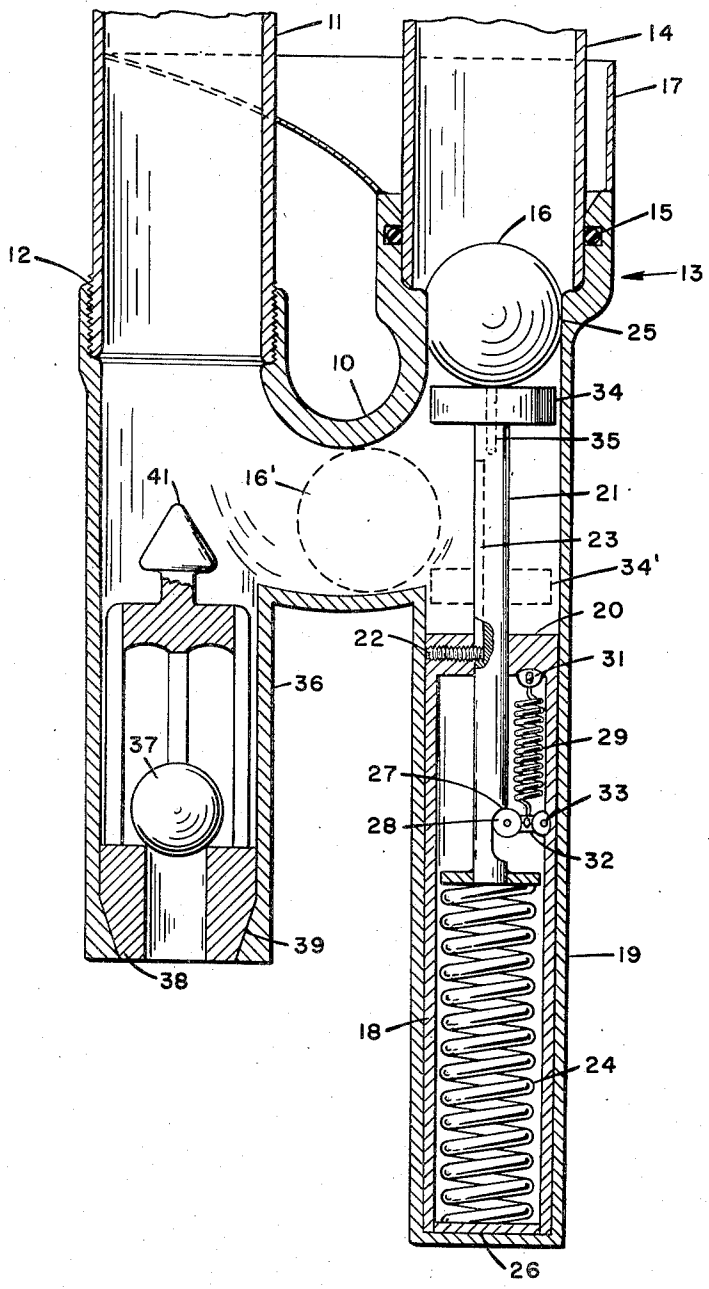
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APPARATUS FOR PUMPING WELLS

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APPARATUS FOR PUMPING WELLS

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This invention relates generally to a well pump. More particularly, this invention relates to an improvement in the cycling free piston pumping system described in a number of places, including U. S. Patent 1,932,497 Wellensiek and U. S. Patent 2,698,582 Vincent.

In the cycling free piston pumping system, sometimes referred to as the ball pump, free pistons such as rubber balls are fed automatically into the upper end of a power tubing string and driven to the bottom by injecting gas behind the free piston. At the bottom of the power tubing, the free piston is constrained to prevent the wasting of lifting gas. After a predetermined amount of liquid has built up in the production tubing which is placed in the well in parallel with the power tubing or after a predetermined time interval, the free piston is forced past the constraint by the injection of additional gas which builds up a great differential pressure across the free piston sufficient to force it past the constraint. The lifting gas then displaces any liquid in the production tubing to the surface with the free piston disposed between the two fluids to avoid intermingling of the lifting gas with the produced liquid. The above-mentioned Vincent patent discloses one type of apparatus for constraining the free piston at the bottom of the well. This involves as a preferred embodiment a constriction having a substantially smaller cross-sectional area than the minimum cross-sectional area of the free piston, this minimum cross-sectional area being about equal to the cross-sectional area of the production tubing. In that pumping apparatus, it has been found that with rubber balls as the free pistons, the differential pressure between the power tubing and the production tubing required to displace the ball through the constriction varies as the age and wear of the ball vary so that the pumping system never becomes completely stabilized. That is, when the ball pop-through pressure changes, the amount of fluid lifted per cycle and the gas/oil ratio change so that the pump does not operate at maximum efficiency for a long period of time.

It is, therefore, an object of this invention to provide an improved well pump. It is a further object of this invention to provide an improved free piston restriction at the bottom of the well. It is still a more specific object of this invention to provide a bottom hole free piston restriction for a cycling free piston pumping system that maintains a substantially constant pop-through differential pressure for the free piston. Other objects and advantages of this invention will become apparent as the following detailed description proceeds. In this description reference will be made to the accompanying drawing which is a cross-sectional view of the lower end of a cycling free piston pumping system.

This invention may be described briefly as an improved free piston restriction for a cycling free piston pumping system, the free piston being restrained by a mechanical snap-action means which permits the free piston to be displaced through the restriction at a substantially constant differential pressure. For a more detailed description, reference is now made to the accompanying drawing.

A tubular U-bend **10** is connected to the bottom of a production tubing **11** which may be suspended in a well. The two are connected together as by threads **12** at the production outlet of the U-bend so that the U-bend may be lowered into the well on the bottom of the production tubing. The other end of the U-bend, the lifting fluid inlet **13**, may be connected to a power gas conduit **14**. In one embodiment the power gas conduit and the production tubing may both be fixed to the U-bend and lowered into the well together as shown in the above-mentioned Vincent patent. Alternatively, the U-bend may be lowered into the well on the production tubing and the power gas conduit may be lowered into position subsequently. In this embodiment, the embodiment illustrated, the U-bend and power gas conduit may be provided with an O ring slip joint **15** to provide a fluid-sealed remotely coupled joint between the power gas conduit and the U-bend. It will also be apparent that the power gas conduit is not required in some instances, as shown, for example, in copending application S. N. 468,033, now Patent No. 2,755,742 in the name of Renic P. Vincent. In that embodiment, the free piston **16** is dropped into the well in the annular space surrounding the production tubing, caught at the bottom by the funnel **17** and thereby directed into the U-bend inlet **13**. In any case, the free piston **16** is restrained in the U-bend inlet by a snap-action mechanism which controls the differential pressure between the power gas conduit and production tubing at which the free piston is displaced through the U-bend and into the production tubing. This restraining mechanism may be integral with the U-bend, but, in the preferred embodiment, it includes a housing **18** which may be either dropped into position in the U-bend extension **19** or run in on a wire line. The housing has an upper guide member **20** through which the free piston stop **21** reciprocates. This free piston stop is aligned and constrained both axially and rotatably by a set screw **22** fixed in upper guide member **20** and extending into a groove **23** in the stop. The stop is urged to its uppermost position, as shown by compression spring **24**. In this position it restrains the free piston within the throat **25**. This spring is in compression between the bottom end **26** of the housing **18** and the lower end of the stop **21**. The stop has a shoulder **27** near the lower end against which the snap-action roller **28** is held by spring **29**. This spring is connected in tension between an anchor **31** in the upper end of the housing and an arm **32** on which the roller rotates vertically about a fulcrum **33** which is also connected to the housing. The upper end of the stop may have a head **34**. It also may be drilled, as indicated in the dotted outline **35**, to permit an internal fishing tool to be attached so that the complete snap-action mechanism may be removed from the U-bend and the well without pulling the tubing.

The throat **25** is preferably smaller in cross-sectional area than the cross-sectional area of the production tubing and the power gas conduit and also smaller than the minimum cross-sectional area of the free pistons used. Typically, the power gas conduit and the production tubing have about the same diameter and cross-sectional area. When a free piston is first installed, it generally has about the same diameter and cross-sectional area. Continuous use of rubber balls as free pistons tends to wear these balls so that they do not fit closely in either conduit. Consequently, even though a close fit is not required in the tubing strings, in order that the balls may be used for a long time in the system, it is generally desirable to constrict the inlet to the U-bend so that a worn ball will provide a fluid seal. The constriction may be provided either in the U-bend itself, as above described, or, alternatively, the housing **18** may be extended into and sealed to the

U-bend inlet to provide a removable constriction. The amount of constriction is not particularly critical but a cross-sectional area from about 5 to about 25 percent smaller than the cross-sectional area of the production tubing is considered desirable.

The U-bend has a production inlet below the liquid level in a well. This may be provided by leaving the U-bend power gas inlet **13** open, as above described. In the illustrated embodiment, the U-bend **10** has a production inlet **36** on the lower side which is preferably coaxial with the production tubing **11**. This inlet may be substantially extended and may include a tubing packer. A standing valve **37** in a cage **38** may be lowered into this production inlet and seated on the tapered shoulder **39**. A fishing neck **41** is provided on the standing valve cage so that a fishing tool can be lowered through the production tubing to remove the standing valve, if desired.

In operation, the U-bend, standing valve and snap-action restraining mechanism are placed in position in a well. The power gas conduit is then seated in the U-bend inlet. The free piston restraining mechanism and standing valve may alternatively be dropped into the power gas conduit or tubing and the production tubing respectively or they may be lowered thereinto on a wire line after the tubing is run. After all of this well equipment is in place, free pistons are injected one at a time into the upper end of the power gas conduit or into the annular space in accordance with the process described in the above-mentioned copending application S. N. 468,033. Gas is injected behind each free piston, driving it to the bottom. At the bottom of the well, the free piston is caught in the U-bend inlet and held in throat **25** by stop **21**. Fluid production from the well then enters the pumping system through the production inlet and standing valve **37**. After a predetermined time interval, another free piston and additional gas are injected into the upper end of the power gas conduit. The injection of additional gas builds up a high differential pressure across the free piston stationed in the throat and eventually the differential pressure across the fluid seal is great enough to displace the stop **21** downwardly against the force of springs **24** and **29**. Before the free piston emerges from the throat **25**, the snap-action roller **28** which is rotating about fulcrum **33** rides up over shoulder **27** reducing the force required to lower the stop. With this reduction in force, the free piston and stop are accelerated downwardly until the head **34** is in the position **34'** indicated in dotted outline. This permits the free piston to pass through the U-bend inlet and throat and pass through the tubular U-bend as shown in dotted outline **16'**, and thence into the production tubing **11**. After the free piston **16** has passed into position **16'**, spring **24** returns rod **21** to the original position. At the same time, roller **27** is likewise returned to the original position by spring **29** in readiness to stop the next free piston. Gas in the power conduit passes either around or through perforations in the head **34** until the next free piston arrives and is stopped by the restriction. The pressure of the gas behind the free piston being substantially greater than the bottom hole pressure in the production tubing due to the hydrostatic head of produced liquid, the slug of liquid and the free piston are displaced up the production tubing to the surface. Due to the greater pressure in the production tubing after the ball passes through the U-bend, the standing valve **37** is closed until the pressure in the tubing decreases to less than bottom hole well pressure. At the surface the production and the free piston are separated, the production going to storage and the free piston being retained in a hopper for reinjection into the power gas conduit.

The invention has been described by reference to specific and preferred embodiments. It will be apparent, however, that many modifications can be made without departing from the spirit of the invention. For example,

while in the preferred embodiment the free piston restriction has been actuated by the differential pressure between the power gas conduit and the production tubing, it can be seen that other means of actuation, such as a bottom hole timing mechanism or a surface-actuated electrical mechanism, can be substituted for the differential pressure-actuated device. Accordingly, this invention should be construed not to be limited to the embodiment herein described but should be limited only by the scope of the appended claims.

I claim:

1. A free piston restriction for a cycling free piston pumping system comprising a tubular U-bend having a lifting fluid inlet and a production outlet substantially in parallel, a production inlet to said U-bend, said lifting fluid inlet being adapted to form a fluid seal with a free piston, resilient means to position said free piston in said lifting fluid inlet, and snap-action means between said U-bend and said resilient means to release said resilient means upon application of a predetermined force to permit said free piston to pass through said lifting fluid inlet and into said production outlet.

2. A free piston restriction for a cycling free piston pumping system comprising a tubular U-bend having at one end a lifting fluid inlet and at the other end a production outlet, a production inlet to said U-bend substantially coaxial with said production outlet, a throat in said lifting fluid inlet adapted to form a fluid seal with a free piston, resilient means to position a free piston in said throat, and snap-action means between said U-bend and said resilient means initially to restrain said free piston in said throat and finally to release said resilient means upon the application of a predetermined force and permit a free piston to pass through said throat and into said production outlet.

3. A free piston restriction for a cycling free piston pumping system comprising a tubular U-bend having a lifting fluid inlet and a production outlet substantially in parallel, a production inlet to said U-bend, said lifting fluid inlet being adapted to form a fluid seal with a free piston, a stop initially to restrain a free piston in said lifting fluid inlet, snap-action means between said U-bend and said stop to release said stop under a predetermined condition and permit a free piston to pass through said lifting fluid inlet and into said production outlet, and means to return said stop to its initial position.

4. A free piston restriction according to claim 3 including a standing valve in said production inlet.

5. A free piston restriction according to claim 4 including means to remove said standing valve through said production outlet.

6. A free piston restriction according to claim 3 including means to remove said stop through said lifting fluid inlet.

7. A free piston restriction according to claim 3 including a throat within said fluid inlet, said throat being substantially smaller than a free piston.

8. In a cycling free piston pumping system including a lifting fluid conduit, a production tubing, a tubular U-bend connecting said conduit and said tubing, at least one cycling free piston, and a free piston constraint in said lifting fluid conduit, the improvement in said constraint comprising a stop initially to restrain said free piston in said constraint, snap-action means between said U-bend and said stop to release said stop under a predetermined force and permit said free piston to pass through said constraint and into said production tubing, and means to return said stop to its initial position.

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UNITED STATES PATENTS

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