

Feb. 23, 1954

L. E. ELKINS ET AL
APPARATUS FOR PUMPING WELLS

2,669,936

Filed May 7, 1952

2 Sheets-Sheet 1

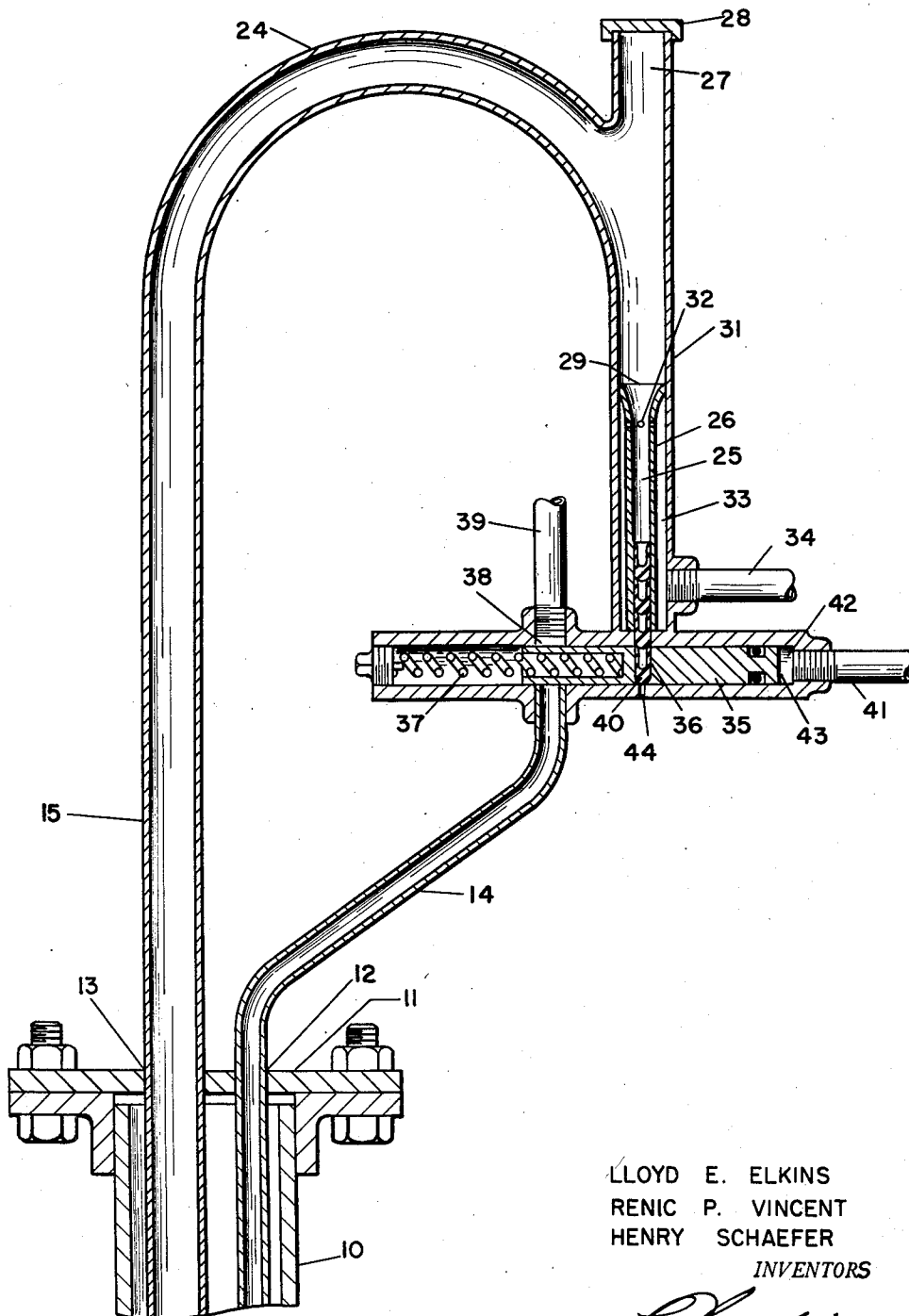


FIG. 1

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2 Sheets-Sheet 2

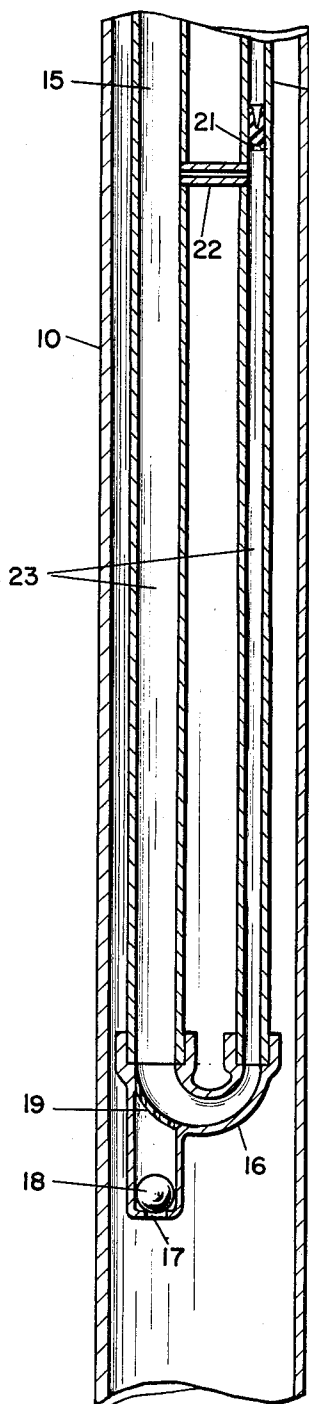


FIG. 2

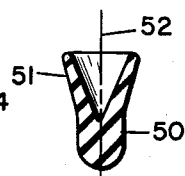


FIG. 3

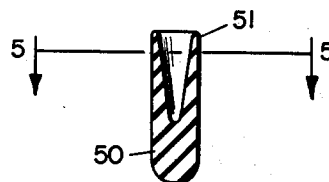


FIG. 4

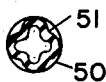


FIG. 5

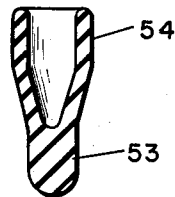


FIG. 6

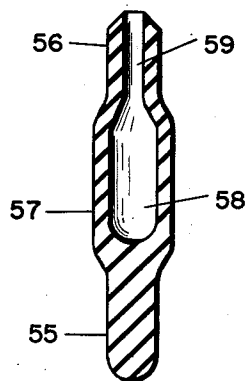


FIG. 7

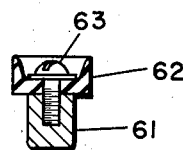


FIG. 8

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APPARATUS FOR PUMPING WELLS

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Application May 7, 1952, Serial No. 286,516

9 Claims. (Cl. 103—52)

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This invention pertains to a pumping system for wells employing gas lift cycling plungers. More particularly, this invention relates to an improved apparatus for producing wells employing a cycling gas lift plunger.

Various means have been proposed for producing a well by use of a cycling gas lift plunger. A system of this type is disclosed in U. S. Patent 1,932,496 Wellensiek. In a copending application, United States application, Serial Number 261,714 Vincent filed December 14, 1951, various improvements in the Wellensiek system have been proposed whereby the lifting gas/oil ratio of such pumping systems may be materially decreased. In the improved method and apparatus the power tubing string is temporarily plugged at the bottom once each cycle so that the gas remaining in the power tubing after the well fluids have been discharged from the production tubing is not wasted. That is, in this improvement, only about half of the gas in the system after a slug of well fluids is produced is wasted. By this means the pressure in the production tubing is periodically reduced to substantially atmospheric pressure, thereby facilitating the flow of well fluids into the production tubing without, at the same time, unnecessarily wasting gas.

It is an object of this invention to provide an improvement in the cycling gas lift plunger or free piston systems by which the capacity of such systems can be increased, particularly where a well is equipped with a small size casing. It is a more specific object of this invention to provide an improved cycling gas lift plunger system in which the quantity of gas in the gas accumulation chamber or power tubing can be varied over a wide range. It is still a more specific object of this invention to provide in a cycling gas lift plunger system, power tubing and production tubing strings of different sizes and to provide a cycling gas lift plunger which will operate in power tubing and production tubing strings of different size. These and other objects of this invention will become apparent from the following description. In this description reference will be made to the accompanying drawings in which:

Figure 1 is of a cross-sectional view of wellhead apparatus suitable for use in the herein-described cycling gas lift plunger system;

Figure 2 is a cross-sectional view of that part of the apparatus located in the well which is used in this system;

Figure 3 is a cross-sectional view of a typical gas lift plunger for use in a cycling gas lift plunger system employing power tubing and production tubing of different sizes;

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Figure 4 is a cross-sectional view of the plunger shown in Figure 3 having the skirt portion of the plunger compressed to the same outside dimensions as the solid head portion;

Figure 5 is a cross-sectional view taken on line 5—5 of Figure 4 showing the skirt portion of the plunger in its deformed position as it would be if passed through a conduit having a diameter of the same size as the head portion of the plunger;

Figure 6 is a cross-sectional view of a modification of the plunger shown in Figure 3 in which the skirt portion of the plunger is extended by the addition of a cylindrical sleeve;

Figure 7 is a cross-sectional view of a still further modification of the plunger shown in Figures 3 and 6 wherein the plunger is equipped with a head and tail portion and with a center skirt or body portion disposed between the head and tail;

Figure 8 is a cross-sectional view of an alternate plunger showing a head and skirt constructed of different materials.

In this invention which, as indicated above, is an improvement upon the cycling gas lift plunger system, the production and power tubing strings are of different nominal internal diameter and the gas lift plunger cycles down through the power tubing and up through the production tubing. The plunger provides a seal or divider in the larger tubing and preferably seals both tubing strings to prevent fluid from by-passing the plunger in either string. Referring now specifically to Figures 1 and 2 for a more detailed description of the invention, a well is equipped with a casing 10 having a tubing head 11. This tubing head has two openings 12 and 13 which are sealed as by welding around a power tubing 14 and a production tubing 15, respectively. Both power tubing 14 and production tubing string 15 extend down into the well and casing 10 to a depth below the working fluid level of the well. Typically, the two strings extend to the bottom of the well and are connected by a lower head 16 forming a continuous conduit within the well. At the lower end of the tubing, preferably in the head 16, this conduit is provided with a well fluid inlet 17. In some cases it is desirable to use a standing valve 18 in the well fluid inlet to prevent the well fluids in the conduit from being displaced back into the well when pressure is applied within the conduit to lift the well fluids. This standing valve may be of the removable type so that it can be fished out through the production tubing and replaced or repaired. A perforated plate 19 which is placed in head 16 and conforms to the

contour of the opening in the head may form part of the standing valve cage to facilitate removal of the standing valve. This perforated plate prevents plungers from falling into the standing valve opening in the head and directs the plunger up the production tubing. In some cases it may be desirable to leave out this perforated plate, and the system will operate satisfactorily, since the plunger tends to follow the well fluids around the U-bend in head 16 when standing valve 18 is used to prevent these fluids from flowing out through well fluid inlet 17.

As disclosed in the above-mentioned copending application Serial Number 261,714 Vincent, it is generally desirable to place a constriction 21 near the lower end of the power tubing. This constriction, as explained in greater detail hereinafter, holds the plunger in the power tubing as the gas pressure above the constriction and plunger increases up to a predetermined amount. By this means the lifting gas/oil ratio of the well may be decreased. While our gas lift system which employs power tubing and production tubing of different sizes may be operated without the constriction and retain some of the desirable characteristics of the system, we prefer such a constriction. This constriction is placed in the power tubing several joints above the lower end, preferably at about the working fluid level of the well. By this means the capacity of the conduit below the working fluid level is increased. An orifice 22 connecting the power tubing and the production tubing immediately below the constriction allows the liquid level in both tubing strings to equalize, thereby additionally increasing the capacity of the conduit below the working fluid level so that more fluid can be lifted each lifting cycle. The lower ends of power tubing 14 and production tubing 15 thus provide an accumulation chamber 23 in which well fluids accumulate between cycles of the plungers. Other means for providing a large volume accumulation chamber are disclosed in the above-mentioned copending application Serial Number 261,714 and can be incorporated in this system.

At the surface a plunger injector apparatus is provided to control the injection of gas into the power tubing and to insert plungers into the gas stream as desired. The plunger injector apparatus also separates plungers from the fluids produced from the well and reinjects them into the power tubing. The upper end of the production tubing 15 contains a U-bend 24 which directs well fluids and plungers down into a plunger hopper 25. The plungers may also be inserted into the hopper and withdrawn therefrom through an opening 27 which is plugged with a removable cap 28. The hopper 25 consists of a perforated tube 26 which has substantially the same internal diameter as the nominal diameter of the power tubing. This perforated tube has a flared top 29 which fits in riser 31. Riser 31 has the same nominal diameter as production tubing 15. Well fluids after displacing the plunger into perforated tube 26 pass through the perforations 32 into the annulus 33 between perforated tube 26 and riser 31 and thence into flow line 34. The well fluids and lifting gas flow into a tank or a separator or the like through this flow line. The lifting gas may be separated from the well fluids in the separator and the lifting gas may be returned to the well to be reinjected and lift additional well fluids. One of the plungers in tube 26 is driven down by the well fluids into a plunger injecting valve 35. This

valve comprises a long piston having a diametrical bore 36. The plunger injecting valve is urged to the right, the closed position, by a spring 37 so that the diametrical bore 36 is normally in registry with perforated tube 26. When the valve is in this normal position the gas inlet port 38 from gas supply line 39 is closed preventing gas from entering the power tubing 14. When the plunger injecting valve is in the left, the open position, the diametrical bore 36 registers with port 38 and power tubing 14 permitting lifting gas to flow from the gas supply line 39 into power tubing 14. As this valve moves to the left it carries the bottom plunger 40 in the plunger hopper with it in the diametrical bore 36. When this bore is in registry with gas inlet port 38 the lifting gas in gas supply line 39 drives the plunger into power tubing 14 ahead of the lifting gas charge and displaces the plunger down the power tubing.

The plunger injecting valve is opened periodically by applying a pressure fluid through line 41 to the chamber 42. This pressure fluid then acts on the valve head 43 to displace the valve to the left. As the valve is displaced to the left, the lower end of perforated tube 26 is covered by the long piston on the valve so that the plungers in the tube cannot move downwardly. The valve is held to the left against the force of spring 37 by the continued application of pressure in line 41 until a predetermined amount of gas pressure is built up in power tubing 14, until a predetermined amount of gas has been injected into that power tubing, or until a predetermined time has elapsed. Preferably, the injection of power fluid into chamber 42 is controlled by a time cycle injector. The valve can, of course, be controlled by hand-operated means or by any other means. When the pressure in line 41 is eventually removed, the valve returns to its normal or closed position causing diametrical bore 36 to register again with perforated tube 26 and at the same time closing gas inlet port 38 so that gas will not flow into power tubing 14. As diametrical bore 36 registers with perforated tube 26 an additional plunger is forced by the production tubing pressure down into diametrical bore 36. A perforation 44 may be provided in the valve housing to relieve the pressure in diametrical bore 36 so that well pressure will force the plunger into position. This perforation is then closed by the bottom plunger as it comes into position so that well fluids are not wasted. Obviously, the plunger injector and the gas injection may be controlled separately as by providing a separate control valve on the gas supply line 39 which may be operated by the same or some other control means.

In operation, gas supply line 39 is connected to a source of high pressure gas which may be a high pressure gas well or a gas compressor discharge line. A number of plungers 40 are then inserted into the plunger hopper through opening 27 and the plungers are forced down so that the bottom plunger is lodged in diametrical bore 36 and the other plungers are resting in series, one above the other, in perforated tube 26. Pressure is then applied through line 41 to valve head 43 displacing plunger injecting valve 35 to the left against compression spring 37 and injecting the bottom plunger into the power tubing ahead of the gas charge as above described. The flow of gas through diametrical bore 36 which registers with gas inlet port 38, continues by holding plunger injecting valve 35 in the left hand position

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until the first plunger reaches constriction 21. After the first plunger reaches the constriction, the pressure in the power tubing commences to rise, and gas injection into the power tubing is continued until the amount of gas in power tubing 14 is sufficient to raise a slug of the well fluids in the accumulation chamber to the surface. The amount of gas depends upon the pressure and the pressure may be varied over a considerable range depending upon the amount of fluid lifted per cycle, the relative sizes of the two tubing strings, and the like. In practice we have found that when about one barrel of liquid is raised in a 2-inch production tubing the pressure should be built up in a 1½-inch power tubing to about 200 p. s. i. regardless of well depth. As the ratio of production tubing diameter to power tubing diameter increases the pressure in the power tubing obviously must be increased to provide an adequate amount of gas to displace the same amount of well fluids to the surface. Alternatively, it will be apparent that in some cases the power tubing can be made larger than the production tubing for a more economic utilization of the lifting gas. As indicated above, the relative sizes of the two tubing strings may thus be adjusted in accordance with this invention to provide any variable operating condition required to produce a well with a minimum lifting gas/oil ratio. Obviously, also the sizes of the two tubing strings may be adjusted to provide a high capacity production tubing in a small casing which will not accommodate a power tubing of the same diameter as the production tubing. In 6½ inch O. D. 28 pound casing, for example, we have found that in order that the production tubing be 2 inch E. U. E., the power tubing must be reduced to 1½ inch E. U. E. tubing. The same size casing permits use of 2½ inch E. U. E. production tubing with 1½ inch E. U. E. power tubing.

When the first plunger reaches constriction 21 and the pressure in the power tubing has been increased to provide the amount of gas required to lift the well fluids in accumulation chamber 23, the pressure on line 41 is decreased allowing spring 37 to move plunger injecting valve 35 to the right and close gas port 38. At the same time, diametrical bore 36 is again placed in registry with perforated tube 26 allowing the next plunger to be driven by the flow line pressure down into the diametrical bore.

After sufficient time has elapsed for the well to fill accumulation chamber 23, another cycle is commenced by opening plunger injecting valve 35. When this valve is open the second plunger is injected into the power tubing. Additional gas is injected into the power tubing behind the plunger until the pressure in the power tubing is great enough to force the first plunger through constriction 21. The pressure in power tubing 14 required to displace the first plunger through the constriction depends upon a number of factors including the resiliency or hardness of the plunger, the cross-sectional area of the constriction, and the like. This constriction has an area great enough to permit the plunger to be driven through it by the gas pressure which is available at the gas supply. On the other hand, the constriction is made small enough so that a plunger will not be forced through it at the gas cutoff pressure, i. e., the pressure at which the volume of gas in the power tubing is adequate to lift a slug of well fluids to the surface. Typically, the area of the constriction may be in the range 0.5-0.9 times the area of the power tubing. When the gas pressure

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in the power tubing has been increased to a point at which the plunger is extruded through the constriction, the plunger is driven down through the power tubing side of the accumulation chamber displacing well fluids therefrom. The plunger is then displaced around the U-bend in head 16 where it expands to the larger area of the production tubing 15 and then upward through the production tubing to the surface. As indicated above, the volume of gas trapped in power tubing 14 between the first and second plunger is adequate to displace the first plunger together with its load of well fluids to the surface. When the well fluids and the plunger which follows arrive at the surface, the second plunger is preferably arriving at constriction 21. In some cases, it may be desirable to provide an excess supply of gas between the two plungers to insure that the first plunger with its load of well fluids reaches the surface.

At the surface the slug of well fluids in production tubing 15 flows around U-bend 24 through riser 31, perforations 32, annulus 33, flow line 34, and thence into a receptacle such as a separator or the like. The plunger following the slug of well fluid and separating it from the driving gas is driven down into perforated tube 26 where it is compressed to the diameter of the power tubing. The well fluids are thus discharged from the conduit and the plunger is placed in the supply hopper ready to make another trip. The number of plungers located in this hopper may be varied at will. Obviously, absent the restriction, one plunger is adequate for continued operation. With the constriction the minimum number of plungers required in the system is two. Even though in the preferred embodiment the system can be operated with two plungers, we prefer several more, typically, 10 or more. The greater number is preferred because we have found that there is some wear on the plungers. A plunger in continuous operation may run, for example, for thirty days and by supplying a large number of plungers, the wear on each plunger is reduced proportionately in a given length of time so that as the number of plungers is increased the period of time between replacement of the plungers is increased proportionately.

Referring now to Figure 3, an expansible plunger typically consists of a ball-like head portion 50 and a conical skirt portion 51. The head which may be a ball, as indicated, or a cylinder coaxial with the axis 52 of skirt 51 has a diameter substantially equal to the nominal diameter of the smaller of the power tubing and production tubing strings. In its normal or unstressed condition the skirt expands to the diameter of the larger of the power tubing and production tubing string. That is, the cross-sectional area of the expanded skirt at its greatest diameter is substantially equal to the cross-sectional area of the opening in the larger tubing. The skirt is desirably as large as or larger than the maximum diameter of the larger tubing. The cross-sectional area of the skirt 51 tapers, as indicated, so that at any plane along and perpendicular to the axis of the plunger the cross-sectional area of the skirt is no greater than the cross-sectional area of the head. In the preferred embodiment the cross-sectional area of the skirt portion at any such plane is less than the cross-sectional area of the head. This shuttle-cock-like plunger is preferably constructed in one piece of an elastic material such as synthetic rubber, typically, Hycar or neoprene.

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Referring now to Figures 4 and 5, the plunger is shown in its deformed position which is its condition as it is driven through the power tubing or the smaller of the two tubing strings. In this condition the skirt does not provide a seal in the tubing but the head portion does since it has the same diameter as the diameter of the smaller tubing. That is, the skirt portion of the plunger is folded as shown in Figure 5 and being folded it does not provide a continuous seal around the outside with the inside of the small tubing. A modification of the plunger above described is shown in Figure 6. In this alternate embodiment the head portion 53 is cylindrical, i. e., longer in the axial dimension of the plunger than the head portion of the plunger shown in Figure 3. This longer head is sometimes desirable in order to keep the plunger properly oriented in the production or larger tubing string. The skirt of this plunger is like the skirt in the above-described embodiment except that it is extended by a sleeve 54 which has an outside diameter substantially equal to the maximum diameter of the skirt 51 and which is also substantially equal to the maximum drift diameter of the larger tubing string. This additional length of skirt is sometimes desired to reduce the slippage of well fluids past the plunger as the plunger is raised through the production tubing. The maximum cross-sectional area of the cylindrical portion of the skirt on any plane perpendicular to the axis of the plunger is, like the conical portion, less than the cross-sectional area of the opening in the smaller tubing string.

Still another alternative plunger design is shown in Figure 7. In this embodiment the plunger has a head portion 55 and a tail portion 56. The diameter of the head and tail of this plunger embodiment is substantially equal to the diameter of the smaller tubing. A central expandible or body portion 57 of the plunger has an outside diameter substantially equal to the nominal diameter of the larger tubing string. The total cross-sectional area of the resilient material on any plane perpendicular to the axis within the central expandible portion is also preferably less than the cross-sectional area of the head or tail portion of the plunger. The thin walls of the central expandible portion form a cavity 58 which may be filled with air so that the outside diameter may be varied substantially to accommodate changes in the inside diameter of a conduit. Alternatively a passage 59 may be provided through the tail portion 56 so that when the plunger is placed in a well the cavity 58 becomes filled with well fluids. By inserting this plunger in the continuous conduit so that the tail portion 56 is exposed to gas pressure as the plunger rises through the production tubing, the pressure in cavity 59 becomes greater due to friction than the pressure on the outside of the body portion and thus this plunger produces a good seal with the inner surface of the production tubing and reduces the by-passing of well fluids around the plunger.

As indicated above, in the preferred embodiment, a constriction is placed in the lower end of the power tubing so as to reduce the lifting gas/oil ratio. However, this invention is not limited to the use of such a constriction. Without a constriction it is sometimes unnecessary to use a resilient material in the head portion of a plunger. Since the power tubing and the production tubing are of different sizes, however, a means is provided for a portion of the plunger to be expandible. As shown in Figure 8 a plunger for a cy-

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cling gas lift plunger system may be made of a hard head portion 61 and a resilient skirt 62. The head may be constructed of, for example, wood, metal, or the like. The skirt which is resilient, as discussed above, is then connected to the head by any suitable means such as a bolt 63. The skirt may be disc-like, as indicated, or it may be conical, as discussed above. The plunger embodiment, as indicated, is adapted for use normally only in a cycling gas lift plunger system which does not employ a constriction. It may be used in a system employing a constriction provided the constriction is made of resilient material such as synthetic rubber or the like.

From the foregoing it can be seen that we have shown by various examples how a cycling gas lift plunger system can be operated when the production tubing and power tubing are of different sizes. As stated, it is often considered desirable for a number of reasons to use power tubing and production tubing strings of different size. In the preferred embodiment this invention has been described with the larger string generally constituting the production string. It will be apparent that in some cases the reverse might be preferred. Various other modifications of the apparatus and system of operation will be apparent to those skilled in this art. This invention should not therefore be construed to be limited to the above description. It should be limited only by the scope of the appended claims.

We claim:

1. A pump for lifting well fluids from a well comprising parallel production tubing and power tubing extending into said well below the working fluid level therein, said production tubing and said power tubing being of substantially different sizes, means at each end for connecting said power tubing and said production tubing together as a continuous elongated conduit, a constriction in said power tubing at about said working fluid level of said well, an inlet for well fluids below said constriction for admitting well fluids into said conduit within said well, a standing valve in said inlet, a multiplicity of plungers in said conduit, a plunger injector for delivering said plungers in series into the upper end of said power tubing, means to inject lifting gas into said power tubing behind each of said plungers and means at the upper end of said elongated conduit for separating said plungers from said well fluids and discharging said well fluids from said conduit.

2. A pump according to claim 1 in which said plungers comprise a first relatively rigid part having a diameter about equal to the diameter of the smaller of said production tubing and said power tubing and a second relatively flexible part having a diameter about equal to the diameter of the larger of said production tubing and said power tubing.

3. An apparatus according to claim 1 in which the diameter of said constriction is in the range between about 0.5 and 0.9 of the nominal diameter of said power tubing.

4. In an apparatus for gas lifting a well with plungers including a relatively large production tubing and a relatively small power tubing extending into said well below the working fluid level therein, a constriction in said power tubing at about the working fluid level of said well, the diameter of said constriction being in the range between about 0.5 and 0.9 of the nominal diameter of said power tubing, a head at the lower end connecting said production tubing and said power tubing together, an inlet for admitting well fluids

into said head, a standing valve in said inlet, plunger injecting means comprising hopper and valve means at the upper end of said production tubing and said power tubing, said head and said plunger injecting means connecting said production tubing and said power tubing together and forming a continuous elongated conduit, said hopper means separating said plungers from the well fluids and discharging said well fluids from said conduit as said well fluids are lifted through said production tubing by said plungers, said valve means being adapted to admit lifting gas intermittently into said power tubing, and upon opening to discharge a plunger from said hopper into said power tubing ahead of said lifting gas, and a multiplicity of said plungers in said conduit, each of said plungers comprising a solid part having a diameter about equal to the diameter of said power tubing and a skirt part having a diameter about equal to the diameter of said production tubing.

5. In a cycling gas lift plunger pumping system for wells including a producing tubing and a power tubing of different sizes connected together at the bottom to produce a continuous conduit in a well, a plunger comprising a head having substantially the same diameter as the smaller of said production tubing and said power tubing and a skirt having substantially the same diameter as the larger of said production tubing and said power tubing, said skirt being adapted to be deformed so that it is as small as said head whereby said plunger may be cycled through said conduit and will seal both said production tubing and said power tubing.

6. In a pumping apparatus for wells including a production tubing, a power tubing, means at each end for connecting said production and said power tubing together as a continuous elongated conduit, an inlet for well fluids at the lower end of said elongated conduit, a plunger injector for delivering a series of plungers into the upper end of said power tubing, means for injecting lifting fluid behind each of said plungers, and means at the upper end of said elongated conduit for separating said plungers from said well fluids and discharging said well fluids from said conduit, the improvements comprising production tubing and power tubing of different nominal diameters and a plunger having a first part adapted to seal the smaller of said production tubing and said power tubing and a second part adapted to seal the larger of said production tubing and said power tubing.

7. In an apparatus for gas lifting a well with plungers including parallel production tubing and power tubing extending into said well below the working fluid level therein, said production tubing being larger than said power tubing, means at each end for connecting said power tubing and

said production tubing together as a continuous elongated conduit, a constriction in said power tubing, an inlet for well fluids at the lower end of said elongated conduit, a plunger injector for delivering a series of plungers into the upper end of said power tubing, means for injecting lifting fluid behind each of said plungers, means at the upper end of said elongated conduit for separating plungers from said well fluids and discharging said well fluids from said conduit, and a cycling gas lift plunger comprising a resilient head having substantially the same diameter as said power tubing and a skirt having substantially the same diameter as said production tubing, said skirt being adapted to be deformed to pass through said power tubing and to expand and seal said production tubing.

8. A plunger for lifting well fluids in a well equipped with a cycling gas lift plunger system having a relatively large production tubing and a relatively small power tubing comprising a cylindrical head having a diameter substantially equal to the nominal diameter of said power tubing and a skirt coaxial with the axis of said head and having a diameter substantially equal to the nominal diameter of said production tubing, said skirt being adapted to be deformed to pass through said power tubing and to expand and seal said production tubing.

9. In an apparatus for lifting well fluids in a well equipped with a cycling gas lift plunger system having a relatively large production tubing and a relatively small power tubing connected together at both ends to form a continuous elongated conduit with well fluid inlet means at the bottom and with well fluid discharge means and gas injection means at the surface, said power tubing having a constriction near the lower end, a plunger comprising a resilient cylindrical head having a diameter substantially equal to the nominal diameter of said power tubing and a conical skirt, the apex of said skirt being connected coaxially to said head, said skirt having substantially the same diameter as said production tubing and being adapted to be deformed to pass through said power tubing and to expand and seal said production tubing.

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