United States Patent [19]

Elfarr

[11] **3,797,968**

[45] **Mar. 19, 1974**

[54] **APPARATUS FOR FLOWING LIQUID FROM A WELL**

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[73] Assignee: **William George, Jr.,** Palestine, Tex. ; a part interest

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[52] **U.S. Cl.** **417/138,** 417/145, 417/149

[51] **Int. Cl.** **F04f 1/02**

[58] **Field of Search** 417/118, 137, 138, 145, 417/149, 451, 452, 453

[56] **References Cited**

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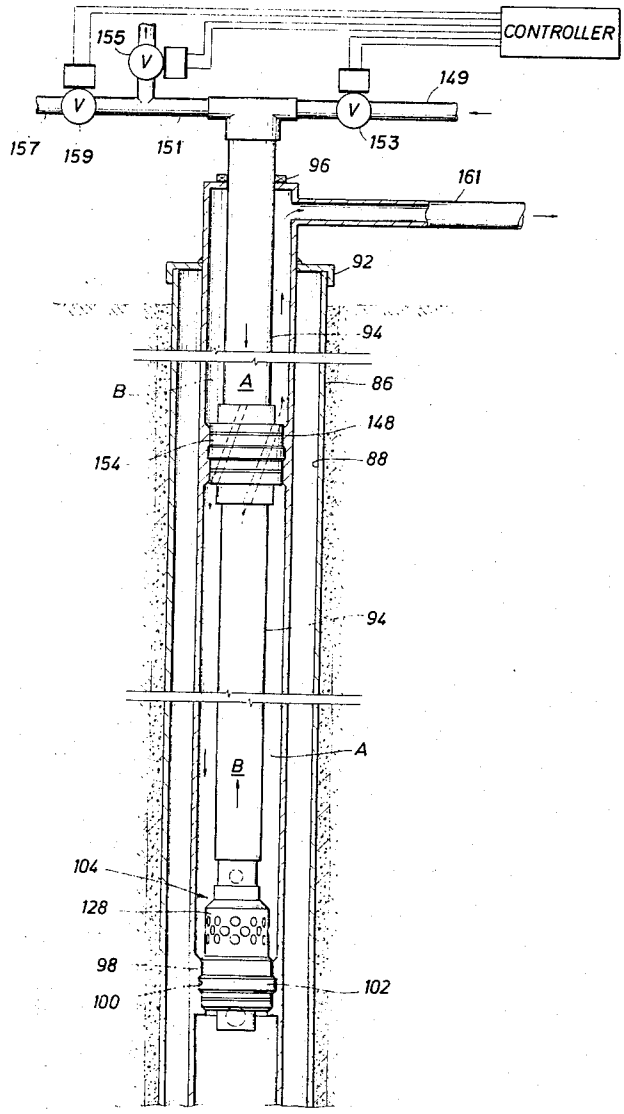
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Primary Examiner—Carlton R. Croyle
Assistant Examiner—Richard E. Gluck

[57] **ABSTRACT**

Apparatus for flowing fluid from wells such as oil wells and the like, utilizing gas displacement of fluid entering the well from an earth formation intersected by the well. Apparatus is utilized that enables the use of a simple downhole double check valve system that may be retrieved from the well for repair or replacement simply by removing the centermost conduit from the well thereby enabling the use of blowout proof safety mechanisms for such repair or replacement operations and eliminating the necessity of simultaneously removing all of the conduits or removing liquid filled tubing from the well.

14 Claims, 8 Drawing Figures



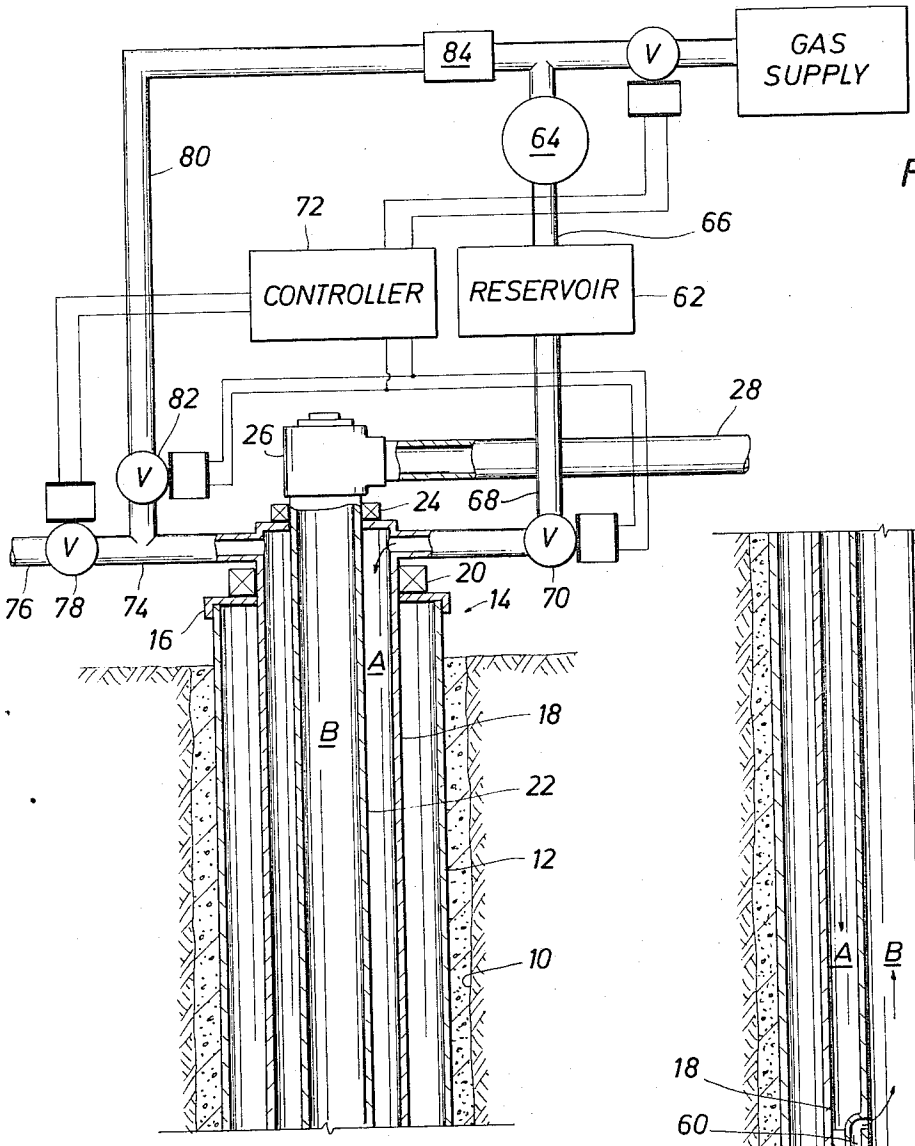
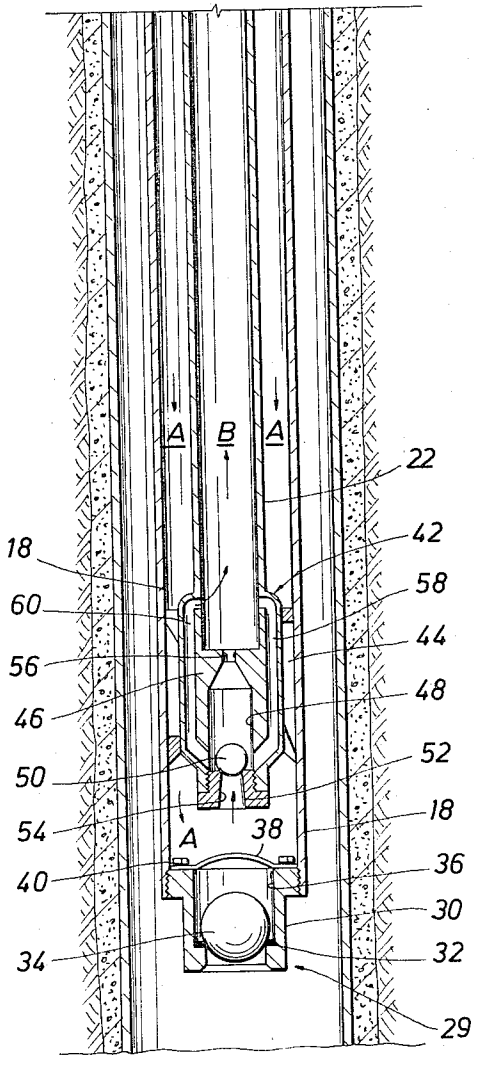


FIG. 1

FIG. 2



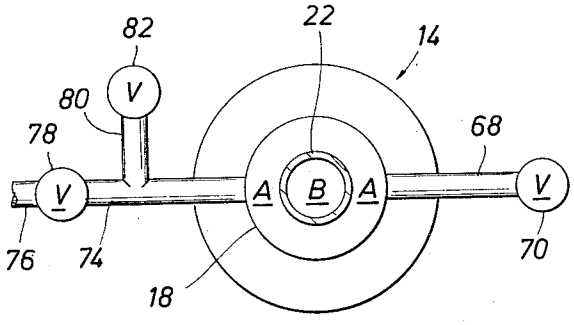


FIG. 3

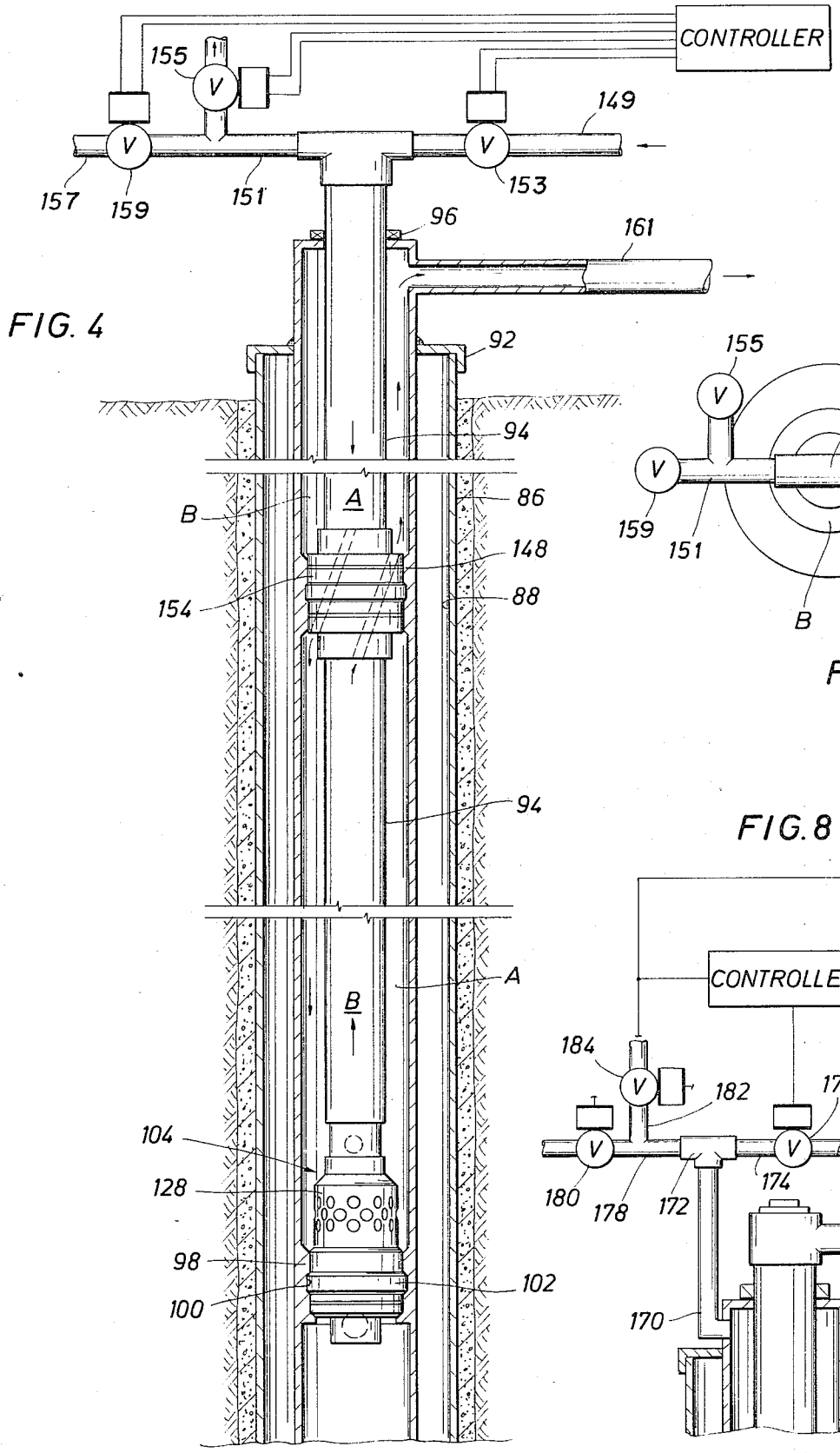


FIG. 4

FIG. 6

FIG. 8

FIG. 5

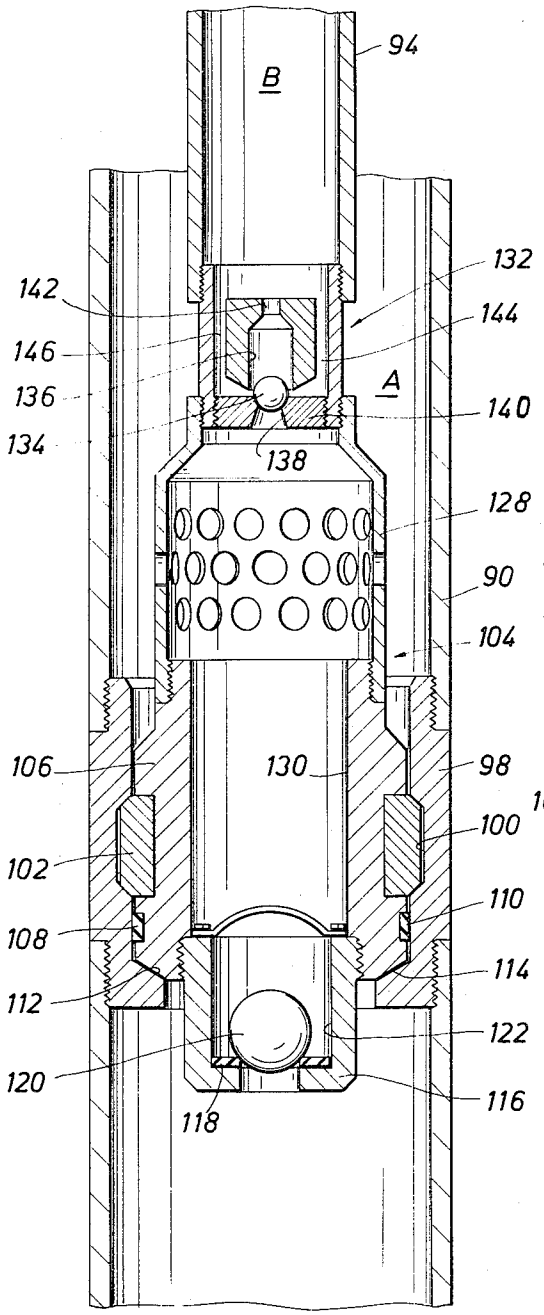
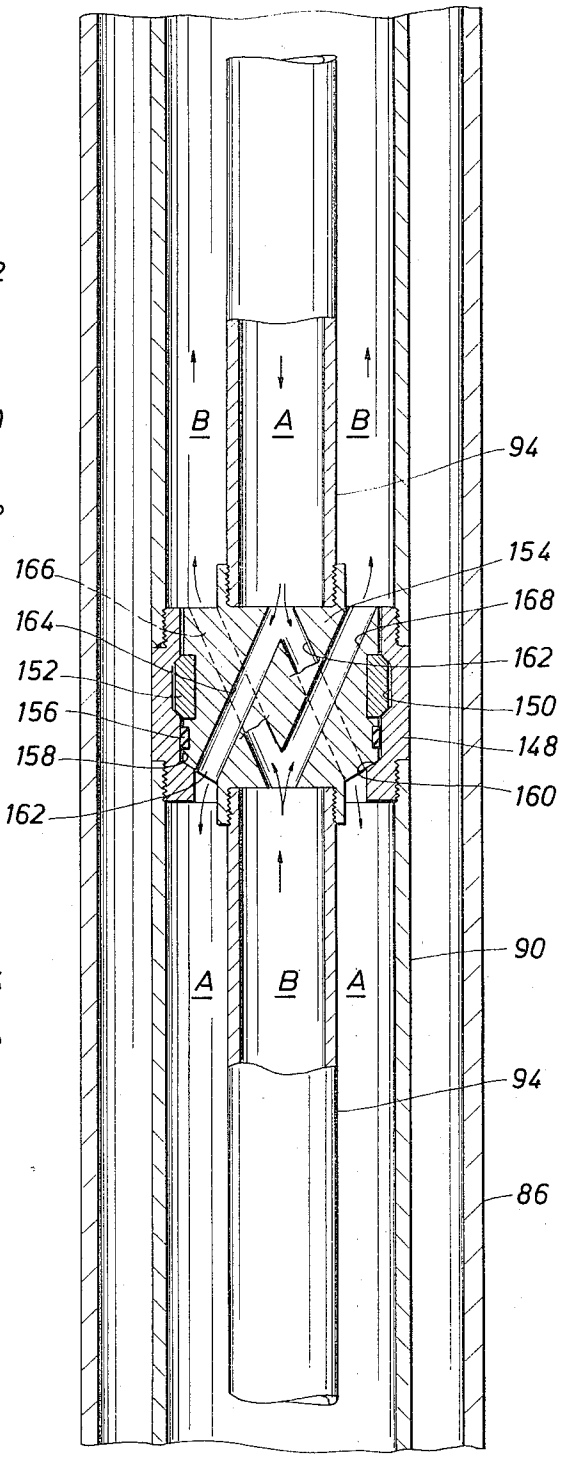

B
94
132
142
144
146
A
136
140
134
138
128
90
104
106
130
98
100
102
110
108
114
112
122
120
116
118

FIG. 7


B
A
B
94
154
166
168
164
162
152
150
156
148
158
160
162
A
B
A
90
94
86

APPARATUS FOR FLOWING LIQUID FROM A WELL

FIELD OF THE INVENTION

This invention is directed generally to apparatus for producing fluid such as oil from earth formations having insufficient formation pressure for raising the fluid to the surface of the earth. More particularly, the invention is directed to pneumatic displacement pump means incorporating a downhole valve mechanism and a surface-located control facility that cooperate to inject pressurized gas into the well for displacement of liquid production fluid such as petroleum therefrom.

BACKGROUND OF THE INVENTION

While the invention will be explained for purposes of simplicity with regard to its application to production of oil from oil-bearing earth formations having little or no formation pressure, it is considered obvious that the invention may be utilized effectively for displacement of other fluids that may or may not be located within earth formations. The present invention will be discussed in its application solely for the production of oil from oil-bearing earth formations for purposes of simplicity and to facilitate ready understanding of the invention.

When oil-bearing formations are discovered that have insufficient formation pressure for gas energized production of oil found in the formation, or when a pressurized oil-bearing formation loses a substantial amount of its formation pressure, it will become necessary to provide for recovery of the oil by methods other than production by formation pressure flowing. One acceptable method for producing low pressure or zero pressure oil-bearing formations has been the use of mechanically energized pumps but these pumps are generally restricted to production of oil from shallow oil-bearing formations. Another method, successfully utilized in production of otherwise unproducible oil wells, has been the use of pneumatic displacement pumps, which may also be referred to as "gaslift valves." These pumps or valves may be energized by compressed air, compressed inert gases, steam, or compressed natural gas and are effective to achieve production of oil-bearing formations that are of substantial depth. U.S. Pat. No. 1,326,338 to Gregory, 1,754,945 to Haskell, and 3,106,170 to Gray, each disclose pneumatic displacement type devices for flowing or pumping oil wells.

One problem presented by the use of pneumatic type fluid displacement pumps or flowing devices is the physical dimension of the well casing within which the pump mechanisms must be received. Because of the substantial physical size of most pneumatic displacement pumps, it is necessary to provide a well bore and well casing of substantial dimension to allow sufficient space within which the pump may be received. Well bores of substantial size are expensive to drill and quite obviously detract from the commercial effectiveness of the pumping system. Moreover, oil wells of relatively small dimension that have been previously produced by formation gas pressure and have ceased production because of loss of such formation pressure may be impossible to produce with conventional pneumatic displacement type pumping mechanisms because of the physical limitations of the well provide insufficient space for

conventional pneumatic displacement pumps. It may not be possible to obtain a pneumatic displacement type pump of sufficiently small dimension to be retained within a relatively small well bore and it may be impractical to increase the well dimension sufficiently to accept a conventional displacement pump.

Another problem frequently associated with pneumatic displacement type pumping mechanisms is the typical necessity of simultaneously removing multiple tubing strings from the well. The tubing weight that must be lifted may require the use of expensive heavy duty workover rigs thereby increasing the expense of the workover operation. More important however, it may be impossible to employ blowout proof well safety mechanisms during tubing retrieval operations. This feature, of course, presents safety hazards that are frequently very difficult and expensive to overcome.

Another problem typically associated with pneumatic displacement type pumping mechanisms is the frequent necessity of removing strings of tubing from the well that may be substantially filled with oil, which is disadvantageous not only because of the excessive weight of the tubing string but also because the entrapped oil frequently spills when the tubing is separated and presents a safety hazard because of the likelihood of fire and generally unsafe conditions presented by oil spills. It would be desirable, of course to remove tubing strings from the well that are not filled with oil or oil-water mixtures.

Accordingly, it is a primary object of the present invention to provide pneumatic displacement type pumping apparatus for flowing oil from a well that obviates any necessity for lifting oil filled tubing strings from the well during repair or replacement operations.

It is an even further object of this invention to provide novel pneumatic displacement type pumping apparatus having downhole valves that may be removed for repair or replacement simply by removing the innermost lightweight tubing string from the well.

Another object of the present invention involves the provision of novel pneumatic displacement type pumping apparatus for flowing wells, including valve apparatus and valve seat structures that may be completely removed from the well in a single operation simply by removing the centermost light-weight tubing string from the well.

Among the several objects of the present invention is contemplated the provision of novel pneumatic displacement type pumping apparatus that may be effectively utilized in oil wells of relatively small casing dimensions.

It is also an important object of the present invention to provide novel pneumatic displacement type pumping apparatus employing a simple crossover mechanism that promotes efficient pumping operation of the apparatus.

It is another object of the present invention to provide novel pneumatic displacement type pumping apparatus employing a gas control system enabling selective recirculation of uncontaminated gas or venting of contaminated gas, if desired, without altering the physical structure of the pumping apparatus.

It is an even further object of the present invention to provide novel pneumatic displacement type pumping apparatus for flowing oil from a well, which apparatus is simple in nature, reliable in use, and low in cost.

Other and further objects, advantages, and features of the present invention will become apparent to one skilled in the art upon consideration of the written specification, the attached claims, and the annexed drawings. The form of the invention, which will now be described in detail, illustrates the general principles of the invention, but it is to be understood that this detailed description is not to be taken as limiting the scope of the present invention.

SUMMARY OF THE INVENTION

A preferred embodiment of the present invention may comprise inner and outer conduits removably retained by a well-head and extending to the production zone within the well casing. Each of the tubing strings may be provided with a ball-and-seat-type check valve structure to allow the flow of oil from the production zone into the casings but to prevent flow in the opposite direction.

The inner and outer tubing strings cooperate to define a pressure-imposing chamber and a fluid flow chamber separated by the normally closed ball-and-seat valve of the inner tubing string. The outer tubing string is communicated with a source of pressurized actuating gas such as compressed air, compressed natural gas, or steam, which may be introduced into the annulus between the inner and outer tubing strings under control of a first solenoid actuated control valve.

An exhaust conduit may also be communicated with the annulus between the inner and outer tubing strings and may be communicated with a valve actuated recirculating conduit and a valve actuated vent conduit. The recirculating and venting valves may be selectively opened either to vent contaminated gas to a disposal facility or to recirculate uncontaminated gas in a closed loop to a reservoir for repressurization and reinjection into the pressure imposing chamber.

A controller mechanism is operative to selectively actuate the injection valve, the recirculation valve, and the venting valve to achieve cyclic operation of the pumping system for displacing oil or an oil-water mixture that may have bypassed the check valve of the outer tubing string and may have entered the annulus between the inner and outer tubing strings.

Another embodiment of the present invention may incorporate inner and outer tubing strings substantially as described above with the outer tubing string having landing nipples disposed intermediate the extremities thereof and at or adjacent the lower extremity thereof. The inner tubing string may be provided with a valve housing at or adjacent the lower extremity thereof that may be received by the lowermost landing nipple and may include upper and lower check valve mechanisms that cooperate with control valves and a controller mechanism to achieve cyclic pumping operation to displace fluid from within the valve structure to a flow line disposed in communication with the inner or outer tubing string, as the case may be. A crossover mechanism may be carried by the inner tubing string and may be received by the intermediate landing nipple in such manner as to define crossing over of both the injected gas and the displaced liquid from the inner to the outer tubing strings for the purpose of simplifying the necessary structure for the displacement pump mechanism and enhancing the physical dimension of the pressure imposing chamber to achieve substantial production.

The valve housing, along with the upper and lower check valve and valve seat mechanisms and the cross-over mechanism, may be removed from the well for repair or replacement simply by removing the inner tubing string from the well. This feature allows individual removal of the tubing string and allows the use of blow-out proof safety mechanisms as the well pumping mechanism is being removed or reinstalled during servicing operations.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited features, advantages and objects of the present invention, as well as others which will become apparent, are attained and can be understood in detail, more particular description of the invention, briefly summarized above, may be had by reference to the embodiments hereof which are illustrated in the appended drawings, which drawings form a part of this specification.

It is to be noted, however, that the appended drawings illustrate only typical embodiments of the invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

IN THE DRAWINGS

FIG. **1** is a sectional view of the upper portion of a pneumatic displacement type pumping apparatus constructed in accordance with the present invention.

FIG. **2** is a sectional view illustrating the lower portion of the pump structure of FIG. **1.**

FIG. **3** is a plan view of the pumping apparatus ,of FIGS. **1** and **2.**

FIG. **4** is a sectional view illustrating the upper portion of a modified displacement type pumping apparatus constructed in accordance with the present invention.

FIG. **5** is a sectional view of the lower portion of the pumping apparatus of FIG. **4.**

FIG. **6** is a plan view of the pumping apparatus of FIG. **4.**

FIG. **7** is a sectional view illustrating an intermediate portion of the pumping apparatus of FIG. **4** illustrating the cross-over mechanism in detail.

FIG. **8** is an elevational view of one typical well-head structure and illustrating connection thereto of a pressurized gas supply and control system for the pumping apparatus of this invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Now referring to the drawings and first to FIG. **1,** there is disclosed a well bore drilled in the earth from the surface to an oil-bearing formation, which well bore may be lined with a casing **12** that may be secured to the well bore by well cement or the like. At the upper extremity of the casing **12** is disposed a well-head illustrated generally at **14,** including a hanger assembly **16** secured to the upper extremity of the casing **12** in any desired manner. An outer conduit or tubing string **18** may be secured to the hanger assembly **16** and may be maintained in removable sealed relation with the hanger assembly and well-head structure by a packing or stuffing box **20.** In the alternative, the outer conduit **18** may be formed integrally with or may be fixed to the tubing hanger structure **16** thereby eliminating the necessity for provision of a stuffing box such as the stuffing box **20.** The outer tubing string may be removed

from the well simply by releasing the connection between the tubing hanger **16** and the casing **12** and lifting the outer conduit from the casing in conventional manner.

An inner conduit or tubing string **22** may be received within the outer conduit **18** in substantially concentric relation therewith and may extend downwardly to a position adjacent the lower extremity of the outer conduit and at or near the oil production zone or at a level below the maximum level to which liquid rises within the well. The inner conduit **22** may be supported by the outer conduit **18** or by other appropriate well-head structure, if desired, and may be maintained in removable sealed relation with the outer conduit by an upper stuffing box **24.** The inner conduit **22** may be provided with a conventional tee connection **26** at the upper extremity thereof that may be employed for connection of a flow line **28** in fluid communication with the inner conduit to conduct produced oil from the well-head to a storage facility pipeline or the like. The upper opening of the tee connection **26** may be plugged, if desired, or other well control or monitoring structure such as pressure gauge mechanisms may be connected to the tee connection in obvious manner if so desired.

With reference now to FIG. **2,** the outer casing **18** may be internally threaded at its lower extremity and may threadedly receive a lower or main valve housing **30** having a valve seat **32** retained therein. A valve ball **34** may be received within an axial bore **36** defined within the valve housing and may be normally seated against the valve seat **32,** thereby maintaining the main valve in a normally closed condition. The main or lower valve will therefore constitute a check valve that is opened by pressure differential created across the valve seat of sufficient force to raise the valve ball from its seat and allow the flow of oil from the casing into a pressure-imposing chamber A. The pressure-imposing chamber may be defined in part by the space above the seat **32** and below the lower extremity of the inner conduit and may be defined in part by the annulus between the inner and outer tubing strings. A retainer strap **38** which may take the form of a cage if desired may be secured to the valve housing **30** by means of bolts **40** and may serve to prevent the valve ball **34** from being ejected from the bore **36** by sudden pressure differential across the valve seat. It is readily seen that upon achieving sufficient pressure differential for opening of the main check valve **34,** fluid will enter the pressure-imposing chamber from the well casing and rise to a suitable level therein.

The inner conduit **22** may terminate in a valved plug, illustrated generally at **42,** that may be provided with a means for centering the valved plug within the outer casing **18.** If desired, the centering means may conveniently take the form of spiral fins **44** that extend exteriorly and longitudinally along the plug **42** and engage the inner wall of the outer conduit **18,** the fins with the adjacent portion of the wall of the casing **18** forming helical passageways for imparting a helical twist to the oil admitted to the pressure-imposing chamber A through the lower main check valve **29.** Imparting a helical twist to the flow of oil passing through the passageways creates substantial turbulence and prevents sediment such as sand and other foreign matter from accumulating within the valving mechanism.

The valved plug **42** may comprise a valve body portion **46** having a central passageway **48** formed therein and adapted to receive a valve ball element **50** cooperating with a seat to define an upper check valve. A valve seat element **42** may be threadedly received at the lower extremity of the housing **46** and may provide an appropriate spherical seat for engagement by the valve ball **50.** The seat element **52** may be provided with a central passageway **54** through which oil and other liquid may flow from the pressure-imposing chamber A past the upper check valve **50.** The passageway **48** through the valve structure may be restricted at the upper extremity thereof as shown at **56** in order to prevent ejection of the valve ball **50** from the passageway by fluid urging the valve ball from its seat. Divergent passageways **58** and **60** may be formed within the valve body **46** and may serve to bypass the valve ball after the valve ball has been lifted from its seat.

The upper and lower check valves effectively cooperate to allow well fluid such as oil or oil/water mixture to enter the valve structure and to allow pressure-imposing fluid to displace such fluid from the well. Assuming pressure within the pressure-imposing chamber to be lower than pressure existing below the lower or main check valve, pressure differential across the check valve may be sufficient to lift the valve ball **34** from its seat thereby allowing well fluid to flow past the valve ball and into the pressure-imposing chamber A. It may be desirable to communicate a source of subatmospheric pressure to the pressure-imposing chamber A under these circumstances to enhance the flow of well fluid into the pressure-imposing chamber.

After the pressure-imposing chamber has become sufficiently filled with liquid from the well bore, a source of pressurized gas such as compressed air, compressed natural gas, steam or the like may be communicated to the pressure-imposing chamber thereby pressurizing the same. When the pressure-imposing chamber has become so pressurized, the main valve ball **34** will be tightly seated by such pressure against its seat **32** and will prevent oil within the pressure-imposing chamber from flowing back into the well bore. The increased pressure within the pressure-imposing chamber will cause the upper valve ball **50** to become unseated from its seat element **52,** thereby allowing the well fluid to flow from the pressure-imposing chamber into an oil flow chamber B, defined within the inner conduit **22.** If the pressure differential across the valve ball **50** or the rate of flow of fluid within the passageway **46** is sufficiently great to lift the valve ball **50** to a position blocking the restricted aperture **56,** the flow of displaced well fluid will continue into the oil flow chamber B through the bypass passages **58** or **60.** The oil, so displaced, will flow through the flow chamber B to the flow line **28** where it will be conducted to a storage facility or to a pipe-line for ultimate transportation away from the production site.

Referring now to FIG. **1,** it will be appropriate to provide the pneumatic displacement type well pumping apparatus with means to supply pressurized displacement fluid to the well and to control cyclic injection and exhaust of such pressurized fluid from the pressure-imposing chamber of the pumping system. One such supply and control system may conveniently take the form illustrated in the upper portion of FIG. **1,** which discloses a reservoir **62** adapted to contain a gaseous medium such as air or natural gas that may be obtained from a gas supply and maintained under pressure by a compressor **64** communicated with the reser-

voir by a conduit **66.** A supply conduit **68** is connected to the reservoir and conducts the pressurized gaseous medium to the pressure-imposing chamber A under control of an automatically actuated valve **70** which, for simplicity, will be referred to herein as a solenoid valve although other automatically actuated valves may be employed with equal success. The valve **70** is normally closed and is opened and closed responsive to a controller system **72** that may be of electric, electromechanical, or electronic nature as desired and is capable of achieving controlled actuation of solenoid controlled valve.

An exhaust conduit **74** may also be connected to the outer conduit and may communicate used pressure-imposing fluid from the pressure-imposing chamber A for venting through a vent passage **76** under control of a normally open solenoid actuated vent valve **78.** A recirculation conduit **80** may be connected to the conduit **74** upstream of the valve **78** and may be controlled by a normally closed solenoid actuated valve **82** to recirculate used uncontaminated pressure-imposing fluid to the compressor **64** and reservoir **62** for reuse. A filter **84** of any suitable type may be disposed within the recirculation conduit **80** in order to separate any foreign matter that might have become entrained in the pressure-imposing fluid exhausted from the well.

Assuming that well fluid has entered the pressure-imposing chamber A in the manner discussed hereinbelow, and has risen to a suitable level within the pressure-imposing chamber, the conroller **72** operating in timed sequence, or operating in response to the level of liquid within the pressure-imposing chamber, will cause simultaneous opening of the injection valve **70** and closing of the vent valve **78** and will allow the normally closed valve **82** to remain closed. Pressurized fluid is thereby communicated from the reservoir **62** into the pressure-imposing chamber A resulting in pressurization of the liquid within the pressure-imposing chamber, thereby causing the liquid to flow past the upper check valve into the flow chamber B where it is conducted to the flow line **28** as discussed above.

In response to timed sequence of the controller **72,** or in response to a predetermined low level of fluid within the pressure-imposing chamber A, the controller **72** will actuate the valve **70** to its closed position, thereby, terminating injection of pressure-imposing gas and will cause opening of either of the vent or recirculation valves **78** or **82,** depending upon the nature of the pressure-imposing gas exhausted from the chamber A. If the pressure-imposing gas is contaminated or is otherwise no longer usable for liquid displacement purposes, the controller will actuate the valve **78** to its open position, thereby venting the pressure-imposing gas through conduit **76** to a gas disposal system. In the event natural gas or other combustible gas is utilized for liquid displacement purposes, the natural gas may be burned or it may be transported to any suitable facility or utilization thereof.

In the event the pressure-imposing gas exists from the chamber A in an uncontaminated condition, the controller **72** will actuate the recirculation valve **82** to its open position and will allow valve **78** to remain closed, thereby causing exhausted gas from the exhaust conduit **74** to enter the recirculation conduit **80** where it is conducted through the filter **84** and is recompressed by the compressor **64** and stored in the reservoir **62** in compressed condition for use in subsequent cycles of the pumping operation. If desired, the uncontaminated gas may be otherwise used to do other useful work.

As indicated above, the controller **72** may be operative responsive to liquid levels within the pressure-imposing chamber or may be operative responsive to a suitable timing mechanism for cyclic actuation of the control valves in the manner discussed above. One acceptable controller system is disclosed in U.S. Pat. No. 3,106,170.

It would be desirable to provide a pneumatic displacement type pumping mechanism that may be simply and inexpensively removed from the well in order to promote simple replacement or repair of the valve mechanism. It would also be desirable to provide a pumping mechanism that promotes the use of blow-out proof safety mechanisms during work over operations. One such pneumatic displacement type pumping mechanism may conveniently take the form illustrated in FIGS. **4** through **7** where a well casing **86** is shown to be extended downwardly into a well bore **88** from the surface of the earth to a production zone from which oil may be produced. An outer tubing or conduit string **90** may be received within the casing **86** and may also extend downwardly to the production zone or at least to a position below the maximum liquid level within the casing. The outer conduit **90** may be secured to the well-head structure and may be maintained in sealed relation with the well-head structure by a packing assembly stuffing box **92.** If desired, connection between the casing **86** and the outer conduit **90** may take a similar form as illustrated in FIG. **1.**

An inner conduit **94** may be received within the outer conduit **90** and may be supported at the upper extremity of the outer conduit by any suitable tubing hanger structure. Alternatively, the inner conduit may be supported by seating devices typically employed in well-head structures. A stuffing box **96** may be employed to maintain sealed relation between the inner and outer conduits.

With reference now to FIG. **5,** the outer conduit **90** may be provided with a landing nipple **98** that may be connected into the outer conduit at a level within the well bore that is substantially below the liquid level within the well. If desired, the landing nipple **98** may be disposed at the lower extremity of the outer conduit **90.** The landing nipple **98** may be provided with an internal locking groove **100** within which may be received a releasable locking mechanism **102** defining a part of a valve assembly illustrated generally at **104.**

The valve assembly may incorporate a plug element **106** adapted to carry an annular seal **108** that may be disposed in sealed engagement with a generally cylindrical inner peripheral surface **110** of the landing nipple **98.** The landing nipple may be provided with an internal tapered landing flange **112** adapted to receive a correspondingly tapered support shoulder **114** defined on the plug thereby supporting the plug in the position illustrated in FIG. **5,** but allowing the plug to be moved upwardly as desired. The landing flange and support shoulder cooperate to center the valve assembly relative to the landing nipple and thereby centering the inner conduit within the outer conduit. Although a specific landing nipple and locking mechanism is illustrated in FIG. **5,** it is not intended to limit the present invention to use of these particular structures, it being obvious that other landing nipple structures and locking mechanisms may be incorporated into the present

invention without departing from the spirit or scope thereof.

A main valve housing **116** may be threadedly received within the lower extremity of the plug **106** and may incorporate a valve seat against which is normally seated a ball-type check valve **120** that may be retained within a passage **122** formed in the valve housing. A retainer element **124** may be secured to the valve housing by bolts **126** or by any other acceptable means to prevent the valve ball **120** from being completely displaced from the passage **122** of the valve housing **116** by fluid through the valve.

The upper extremity of the plug **106** may be provided with external threads that may be threadedly received by a perforated connection element **128** that establishes fluid communication between an interior passage **130** of the plug structure **106** and the pressure-imposing chamber A. If desired the connection element **128** may be provided with a plurality of elongated slots instead of the circular perforations or the connection element may conveniently take the form of a plurality of elongated connection elements serving merely to maintain structural connection between the upper and lower check valve assemblies while at the same time defining fluid communication between the valve chamber between the check valve assemblies and the pressure-imposing chamber A. The perforated connection element **128** may be threadedly received at the upper extremity thereof by external threads formed on the valve housing portion **130** of an upper check valve illustrated generally at **132.** The valve housing **130** may be provided with external threads at the upper extremity thereof for threaded connection of the valve housing to the lower extremity of the inner conduit **94.** A valve ball **134** may be retained within a central opening **136** formed in the valve housing **130** and may be normally disposed in sealing engagement with a complimentary seat defined about an orifice **138** extending through a valve seat element **140** secured to the valve housing **130.** The passage **136** may be restricted at its upper extremity to define a flow orifice **142** through which liquid may flow. The restricted passage is effective to prevent ejection of the valve ball **134** from the valve housing upon imposition of substantial pressure differential across the valve ball or upon substantial flow of produced fluid past the valve ball. By-pass passages **144** and **146** may be defined within the valve housing and may conduct fluid past the raised valve ball **134** as liquid flows from the pressure-imposing chamber A through the perforations of the connection element **128** and through orifice **138** past the valve ball.

Referring now to FIG. **7,** it will be desirable to provide a pressure-imposing chamber that is as large as possible in order to facilitate substantial production during each operative cycle of the pump structure. Accordingly, means for providing a pressure imposing chamber of substantial dimension may conveniently take the form illustrated in FIG. **7** where an intermediate landing nipple **148** is shown to be threadedly connected into the outer conduit **94.** The landing nipple **148** may be provided with an internal locking groove **150** adapted to releasably receive a locking mechanism **152** carried by an intermediate crossover plug that may be threadedly connected into the inner conduit.

An annular sealing element may be retained by the crossover plug **154** and may establish sealed engagement with a generally cylindrical surface **158** defined internally of the landing nipple **148.** The landing nipple **148** may be provided with a tapered internal landing flange **160** that may be engaged by a complimentary tapered support surface **162** formed on the plug to provide support for the crossover plug and to positively locate the releasable locking mechanism **152** in juxtaposition with the annular locking groove **150.**

The crossover plug **154** may be provided with downwardly diverging passages **162** and **164** that serve to conduct pressurized gas from the upper part of a pressure-imposing chamber A within the inner conduit **94** to the lower part of pressure-imposing Chamber A disposed in the annulus between the inner and outer conduits. Likewise, diverging passageways **166** and **168** may be defined within the crossover plug to conduct flowing oil from the lower portion of the oil flow chamber B, within the inner conduit **94,** to the upper portion of oil flow chamber B, disposed within the annulus between the inner and outer conduits above the crossover plug. This feature effectively allows the use of the smaller dimensioned inner conduit for conducting the pressurized gaseous medium downwardly into the well for displacement purposes and allows utilization of the substantially larger dimensioned chamber, defined by the annulus between the inner and outer conduits, to receive the volume of oil or other well fluid that is to be displaced during a given actuation cycle of the pumping mechanism.

If it should become desirable to increase the volume of the pressure-imposing chamber A below the crossover plug **154** the inner conduit **94** may be removed from the well and the cross-over plug may be connected into the conduit at a greater distance from the bottom of the well. The landing nipple **148** however, must also be relocated within the outer conduit **90** in corresponding manner. Likewise, reduction in the volume of the pressure-imposing chamber A may be achieved by lowering the effective level of the crossover plug and landing nipple with respect to the outer casing **86.**

The inner conduit **94** extends through the upper stuffing box **96** and may be communicated with a gas injection conduit **149** and an exhaust conduit **151.** Flow of pressurized gas for injection into the well may be controlled by means of a solenoid actuated injection control valve **153** while exhaust of used pressure-imposing fluid is either recirculated in the manner discribed above in regard to FIG. **1** under control of a recirculation valve **155** actuated by a control mechanism, or is vented to a suitable disposable facility through a vent conduit **157** under control of a solenoid actuated vent valve **159,** also energized by the control system. The conduit **80** may, if desired, transport used but uncontaminated gas to another facility for commercial use.

Cyclic actuation of the pumping system may be achieved by closing the normally open vent valve **158** and allowing the normally closed recirculation valve **154** to remain closed while the injection valve **152** is opened to admit pressurized gas from the reservoir to the inner conduit **94** where it is conducted downwardly through the pressure-imposing chamber A to the crossover plug **154** where it diverges through the passages **162** and **164** into the annulus defining the lower part of the pressure-imposing chamber A below the crossover plug. Oil, that has bypassed the lower check valve **120**

and has become entrapped within the pressure-imposing chamber below the crossover plug, will become pressurized and will flow through the perforations of the connection element **128**, unseat the upper check valve ball **134** and flow through the orifice **142** and through the bypass passages **144** and **146** into the lower part of the flow chamber B, within the inner conduit **94** and below the crossover plug. The displaced oil responding to pressure created by the injected gas will flow upwardly through the diverging passages **166** and **168** of the cross-over plug and into the annulus between the inner and outer conduits defining the upper portion of the flow chamber B above the crossover plug. The displaced oil will continue to flow upwardly through the annulus where it will be conducted away from the well head structure by a discharge conduit **160** to an appropriate storage facility or any other appropriate system for handling of the oil so produced.

With reference now to FIG. **8**, there is illustrated a typical well head to which may be connected a pressurized gas supply and a control system for a downhole gas displacement type pumping system according to the present invention. It may be deemed practical to provide a dual purpose gas supply and exhaust conduit **170** that may be disposed in fluid communication with the annulus between the inner and outer conduits. The gas supply and exhaust conduit **170** may be provided with a tee connection **172** to which may be connected a supply conduit **174** controlled by a solenoid actuated valve **176** for communicating pressurized fluid such as compressed gas from a reservoir into the annulus. A discharge conduit **178** may also be connected to the tee **172** and may be controlled by a solenoid actuated valve **180** to achieve venting of contaminated pressure-imposing fluid from the well head pumping system following a pumping cycle. A recirculation conduit **182** may be disposed in fluid communication with the discharge conduit **178** and may be controlled by a solenoid valve **184** to return uncontaminated pressure-imposing fluid back to the reservoir for repressurization and reuse in subsequent pumping cycles. A controller mechanism may control cyclic pumping by sequentially actuating the solenoid valves in the manner discussed above in connection with FIGS. **1** and **4**.

In the pumping systems illustrated in both FIGS. **4** and **8**, it may be appropriate to utilize only two valves at any one time. For example, the gas supply valve **153** may be actuated in timed sequence with either the vent valve **159** or the recirculation valve while the remaining automatic valve remains idle.

It is therefore apparent that I have provided a novel pneumatic displacement type pumping system for oil wells and the like that may be effectively utilized in relatively narrow well bores. My fluid displacement pumping system is effectively adapted for use in wells having relatively high fluid levels without sacrificing the fluid production capability thereof. My invention also enables the development of a fluid displacement type system that may have substantial fluid capacity even though the well bore and tubing structures utilized therein may be of relatively small dimension. My invention also enables the use of simple and inexpensive repair and replacement techniques that may be accomplished through the use by work-over rigs of relatively low lifting capacity. Each of the modified embodiments of my invention enable work-over rigs to extract a single string of tubing during each lifting operation thereby promoting the use of lightweight work-over rig equipment. My invention also effectively prevents the necessity for lifting tubing strings that are filled with liquid thereby effectively limiting the weight that is necessary to be raised by work-over rig equipment. My invention also enables the recirculation of used uncontaminated gas for reinjection purposes or, in the event such gas should become contaminated by the displacement process, such gas may be automatically vented for suitable disposition.

In the event it should become necessary to repair or replace either the check valve mechanisms or the crossover mechanism, such can be accomplished simply by removing a single light-weight tubing string from the well thereby promoting simple and efficient repair and replacement operations and restricting the cost of conducting such operations. It is therefore seen that this invention is one well adapted to attain all the objects and advantages hereinabove set forth together with other advantages which will become obvious and inherent from a description of the apparatus itself. It will be understood that certain combinations and sub-combinations are of utility and may be employed without reference to other features and sub-combinations. This is contemplated by and is within the scope of the present invention.

As many possible embodiments may be made of this invention without departing from the spirit or scope thereof, it is to be understood that all matters herein above set forth or shown in the accompanying drawings are to be interpreted as illustrative and not in any limiting sense.

I claim:

1. Apparatus for flowing liquid from a well, comprising:

casing means extending into said well;

outer conduit means being removably supported by said casing means, said outer conduit means extending through said casing means inner conduit means extending into said outer conduit means and cooperating therewith to define a pressure imposing chamber;

a landing nipple having fixed to said outer conduit means below the level of liquid within said casing and defining an internal locking groove;

normally closed first valve means defining a closure for said pressure imposing chamber and being opened by pressure differential created between said casing and said pressure imposing chamber; said inner conduit means being supported by said outer conduit means, said inner conduit means defining a fluid flow chamber, said inner conduit means being movable through said outer conduit means;

flow conduit means being communicated with said flow chamber;

normally closed second valve means defining a lower closure for said fluid flow chamber and being opened responsive to predetermined pressure differential created between said pressure imposing chamber and fluid flow chamber;

locking means carried by said first and second valve means and being disposed in releasable engagement with said locking groove;

a source of pressurized gas being communicated with said pressure imposing chamber;

first control valve means for controlling introduction of pressurized gas from said source into said pressure imposing chamber;

exhaust conduit means being disposed in communication with said pressure imposing chamber and including recirculation conduit means connected to said source and vent conduit means;

second control valve means for controlling flow of gas to said source from said exhaust conduit means;

third control valve means for controlling the flow of gas to said vent conduit means from said exhaust conduit means; and

controller means for selectively and automatically actuating said first, second and third control valve means to achieve cyclic actuation of said apparatus.

2. Apparatus as recited in claim **1**:

first packing means establishing sealed relation between said outer conduit means and said casing; and

second packing means establishing sealed relation between said outer conduit means and said inner conduit means.

3. Apparatus as recited in claim **1**:

said first and second valve means being check valves disposed to allow flow of liquid into said pressure imposing chamber and said flow chamber respectively, and to prevent flow of liquid in the opposite direction.

4. Apparatus as recited in claim **1**:

said first, second and third control valve means being automatic valves; and

said controller means being electrically connected to said automatic valves and being operative to actuate said valves in cyclic sequence to achieve gas pressure imposed displacement of liquid from said well.

5. Apparatus for flowing liquid from a well, comprising:

casing means extending into said well and defining a well head at the upper extremity thereof;

outer conduit means being supported by said well head and extending into said casing, said outer conduit means terminating at a level below the level of liquid within said casing;

a landing nipple being fixed to said outer conduit defining an internal groove; inner conduit means extending into said outer conduit means;

locking means being fixed to said inner conduit means and being disposed in releasable engagement with said locking groove;

a second landing nipple being fixed to said outer conduit means and defining a second internal locking groove;

said inner and outer conduit means cooperating to define a pressure imposing chamber and a liquid flow chamber;

valve means carried by said inner conduit means and being releasably received in locked engagement with said second internal locking groove, said valve means being removable along with said inner conduit means upon extraction of said inner conduit means from said outer conduit means said valve means comprising a valve housing; upper and lower check valves being disposed within said housing and being opened by predetermined pressure differential developed thereacross, said lower check valve controlling communication of well liquid into said pressure imposing chamber and said upper check valve controlling communication between said pressure imposing chamber and said liquid flow chamber; and second locking means being fixed to said inner conduit means and being disposed in releasable engagement with said second locking groove.

6. Apparatus as recited in claim **5**:

said fluid imposing chamber being disposed downstream of said lower valve and upstream of said upper valve; and

perforated wall means forming a part of said valve housing and establishing communication between said outer and inner casing means intermediate said valves.

7. Apparatus as recited in claim **5**, including:

crossover means being defined in said locking means of said inner conduit means and communicating said inner conduit means above said crossover means with said outer conduit means below said crossover means and communicating said inner conduit means below said crossover means with said outer conduit means above said crossover means.

8. Apparatus as recited in claim **5**, including:

a source of pressurized gas being disposed in communication with said pressure imposing chamber;

first control valve means for controlling introduction of pressurized gas from said source into said pressure imposing chamber;

exhaust conduit means being disposed in communication with said pressure imposing chamber and including reuse conduit means and vent conduit means;

second control valve means for selectively controlling flow of gas from said exhaust conduit means through said reuse conduit means;

third control valve means for selectively controlling the flow of gas from said exhaust means through said vent conduit means; and

controller means for selectively and automatically actuating said first, second and third control valve means to achieve cyclic actuation of said apparatus.

9. Apparatus for flowing liquid from a well, comprising:

casing means extending into said well and defining a wellhead at the upper extremity thereof;

outer conduit means being supported by said wellhead and extending into said casing means, said outer conduit means terminating at a level below the level of liquid within said casing means;

inner conduit means extending into said outer conduit means, said inner conduit means cooperating with said outer conduit means to define a pressure imposing chamber and a liquid flow chamber;

lower check valve means carried by said inner conduit means and defining a closure for said outer conduit means and being opened by pressure differential to allow flow of liquid from said casing means into said pressure imposing chamber;

upper check valve means carried by said inner conduit means and separating said pressure imposing chamber from said flow chamber;

a landing nipple being fixed to said outer conduit means and defining an internal locking groove;

locking means carried by said upper and lower check valve means and being disposed in releasable engagement with said locking groove;

said inner conduit means, said lower check valve means and said upper check valve means being removable as a unit from said outer conduit means;

means controllably communicating pressurized gas into said pressure imposing chamber to displace liquid from said pressure imposing chamber into said liquid flow chamber; and

means conducting liquid so displaced from said flow chamber.

10. Apparatus as recited in claim **9**, including:

connector means securing said upper and lower check valve means in assembly and defining a valve chamber therebetween, said connector means establishing fluid communication between said valve chamber and said pressure imposing chamber.

11. Apparatus as recited in claim **9**:

said upper check valve means being fixed to said inner conduit means and defining closure means separating said pressure imposing chamber and said flow chamber; and

connector means being secured to said upper check valve means and supporting said lower check valve means, said connector means defining valve chamber means between said upper and lower check valve means, said connector means defining fluid communication between said valve chamber means and said pressure imposing chamber.

12. Apparatus as recited in claim **11**:

said connector means being of tubular configuration and having perforations formed therein to establish said fluid communication between said valve chamber means and said pressure imposing chamber.

13. Apparatus as recited in claim **9**, said means controllably communicating pressurized gas into said pressure imposing chamber, including:

a source of pressurized gas being disposed in communication with said pressure imposing chamber;

first control valve means for controlling introduction of pressurized gas from said source into said pressure imposing chamber;

exhaust conduit means being disposed in communication with said pressure imposing chamber and including reuse conduit means connected to said source and vent conduit means;

second control valve means for selectively controlling flow of gas to said source from said exhaust conduit means;

third control valve means for selectively controlling flow of gas to said vent conduit means from said exhaust means; and

controller means for selectively and automatically actuating said first, second and third control valve means to achieve cyclic actuation of said apparatus.

14. Apparatus as recited in claim **9**:

upper support means being defined intermediate the extremities of said outer conduit means; and

crossover means being carried by said inner conduit means and being releasably received in locked engagement with said upper support means, said crossover means communicating said inner conduit means above said crossover means with said outer conduit means below said crossover means and communicating said inner conduit means below said crossover means with said outer conduit means above said crossover means.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,797,968 Dated March 19, 1974

Inventor(s) Johnnie A. Elfarr

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 6, line 3, "42" should read --52--.

Col. 7, line 30, "conroller" should read --controller--.

Col. 10, line 29, the following paragraph was omitted
--When a pumping valve mechanism and crossover mechanism are removed from the casing of a well, it is desirable that such be accomplished free of the well fluid because of the physical weight that must be raised and because of the danger and/or inconvenience that must be accommodated if liquid is allowed to spill from the tubing as the sections of tubing are disassembled For example, where secondary oil recovery procedures are employed, the gas injected into the well may be superheated steam and the well fluid produced may be at a temperature in the order of 250° F. It is considered very dangerous to allow hot liquid to spill when workmen are in the area where the disassembly operations are taking place. The valve crossover mechanisms effectively allow both the inner and outer tubing strings to be extracted from the well with the liquid drained therefrom. The only remaining liquid will be disposed between the valve assembly and the crossover assembly and this can be removed when the last section of the inner tubing is removed simply by unseating the check valve 134.--

Col. 12, line 17, after "conducting such operations." the following was omitted
--Moreover, the inner tubing string will not be filled with liquid when it is removed from the outer tubing string, thereby allowing the tubing sections to be readily disassembled in safe, clean and efficient manner. Also, removal of the inner tubing string allows the outer tubing string to be extracted from the casing free of liquid.--

Col. 12, line 43, "having" should read --being--.

Signed and sealed this 22nd day of October 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents