

[54] PUMPING APPARATUS AND METHOD

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[22] Filed: **Mar. 6, 1973**

[21] Appl. No.: **338,566**

[52] U.S. Cl. **417/403, 60/472, 91/165,**
166/68.5

[51] Int. Cl. **F04b 35/00, E21b 43/00**

[58] Field of Search 166/68.5, 75, 267;
417/327, 12, 403; 91/165, 166; 60/372

[56] **References Cited**

UNITED STATES PATENTS

3,212,406	10/1965	McDuffie	417/403
3,654,995	3/1972	Sizer	166/68.5
3,247,798	4/1966	Glasgow et al.	166/68.5
2,999,360	9/1961	Habernicht	60/372
2,560,676	7/1951	White	60/372
3,269,320	8/1966	Tilley et al.	417/12

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[57] **ABSTRACT**

A differential of gas pressure between the wellhead and another pressure is applied across each of a pair of power cylinders whereby such pistons drive a piston bracket. A pair of counterbalance cylinders powered by pressurized gas assist in support of the well rod string, are tied to the same piston bracket and are automatically maintained at an adjustable pressure created by the piston bracket motion. The piston bracket operates a reversing valve to change the direction of power cylinder piston travel as the piston bracket and the pump shaft attached thereto complete cycles of operation; the differential of gas pressure is developed between the wellhead operating pressure and sales line pressure so that substantially no loss of gas is usually effected from production while providing alternative differential gas pressure systems alternatively tied thereto to permit continued operation of this apparatus under unusual conditions.

8 Claims, 8 Drawing Figures

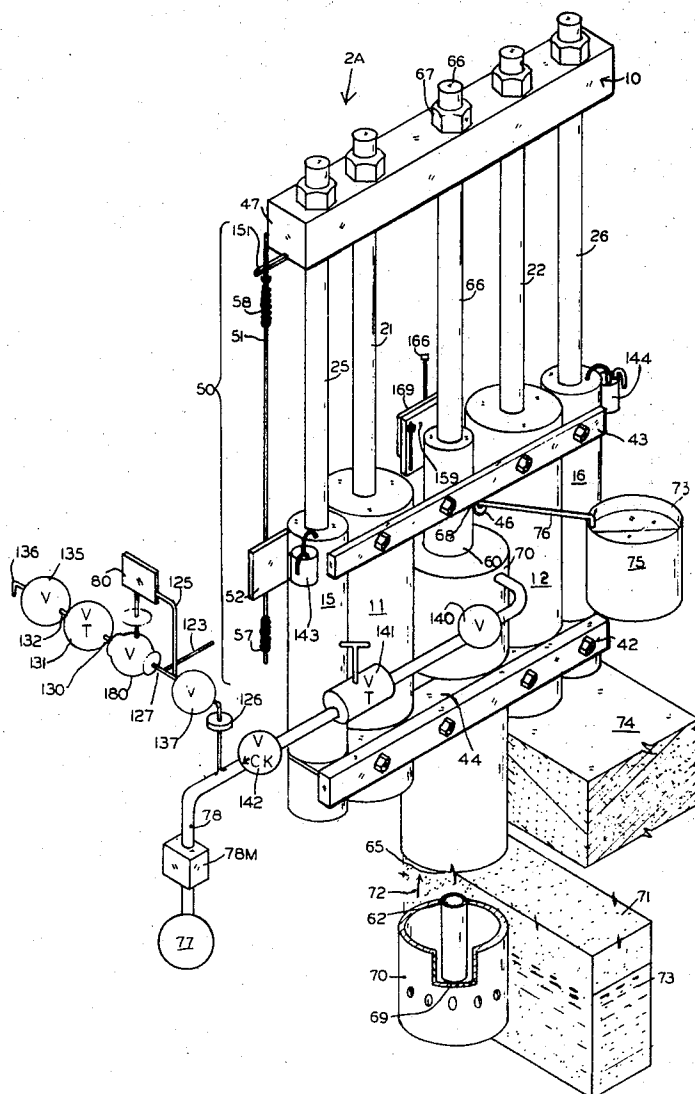


FIG. 2

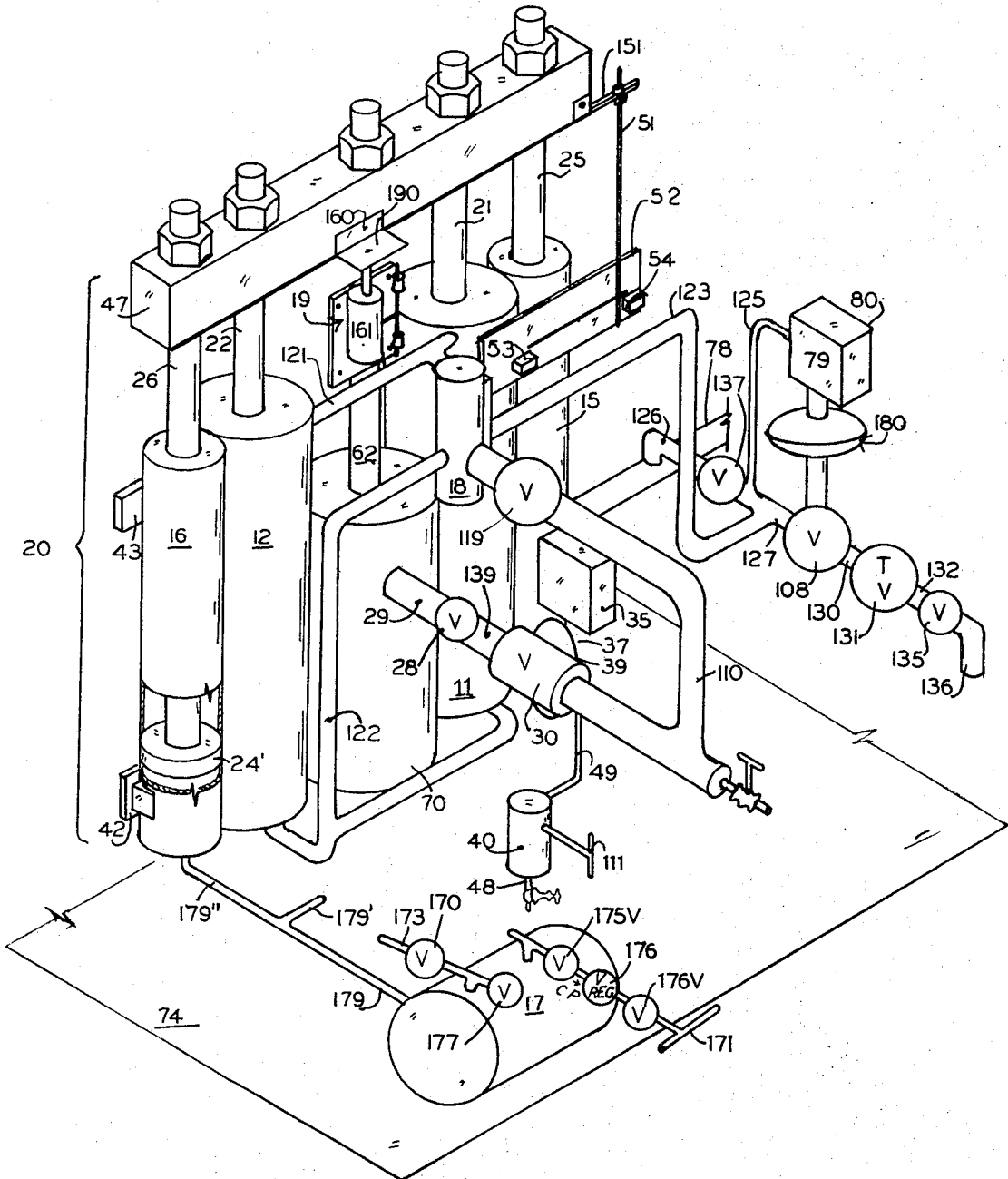


FIG. 3

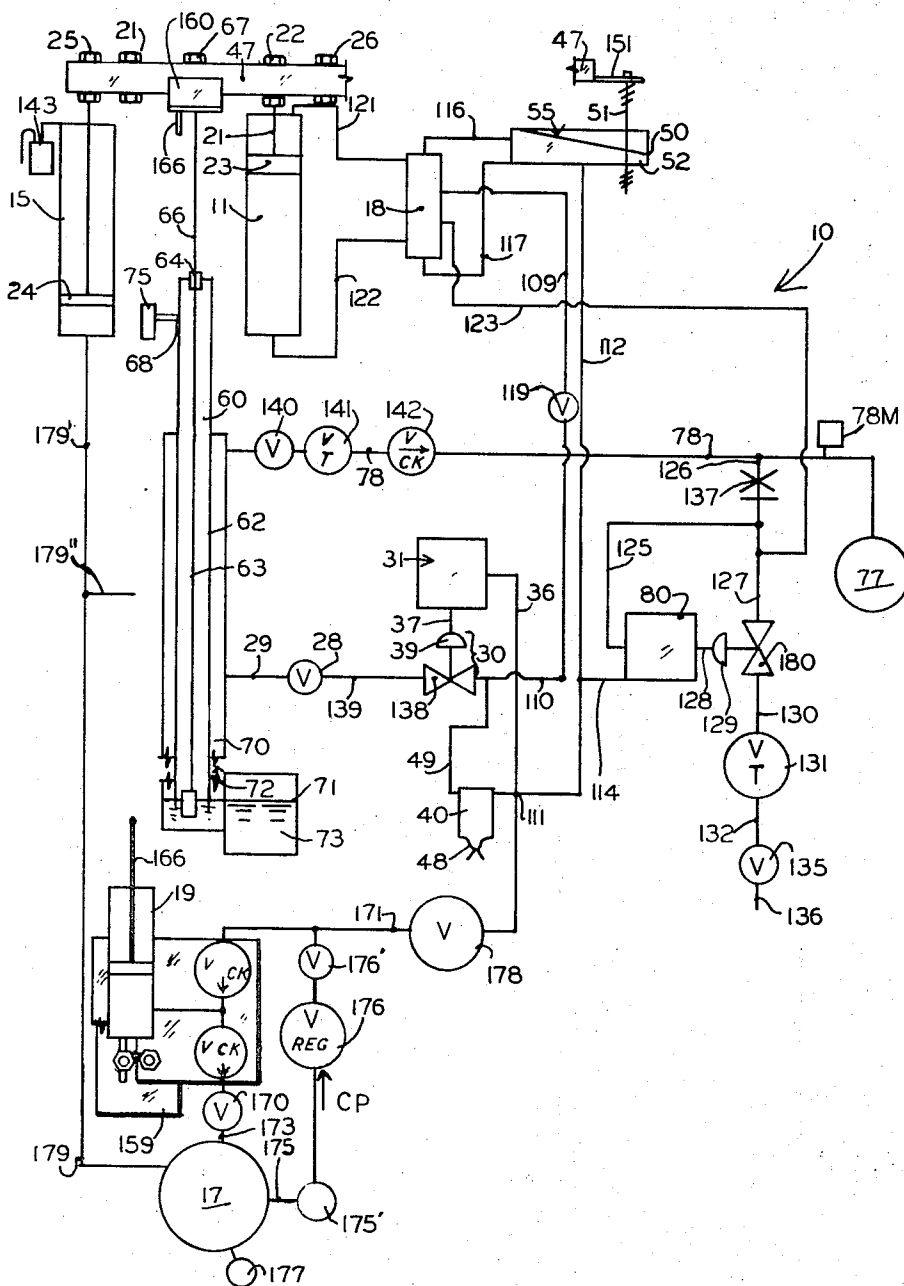


FIG. 4

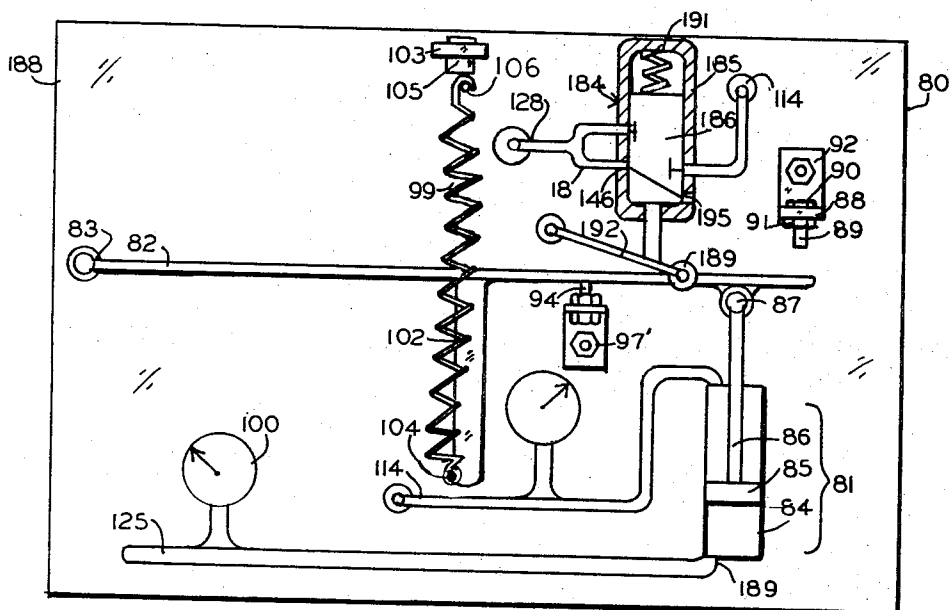
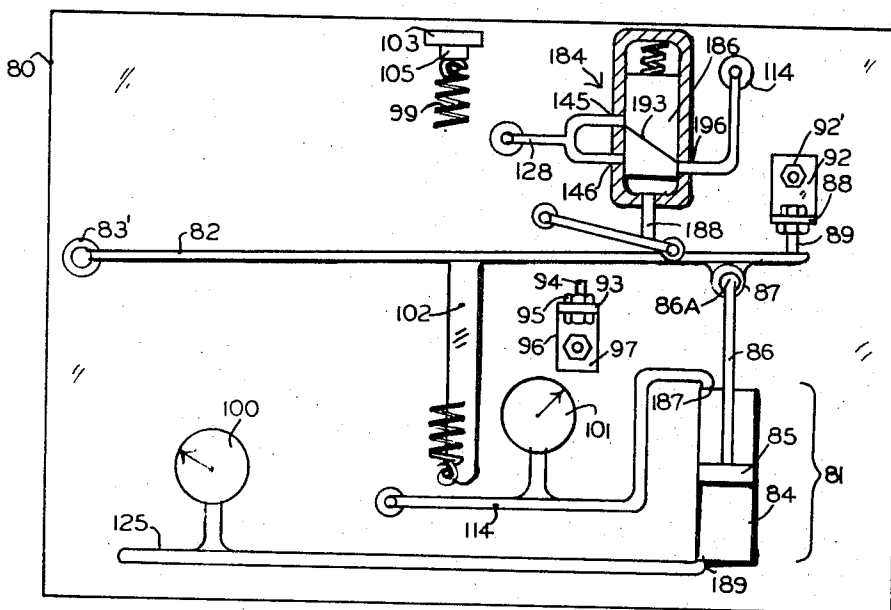
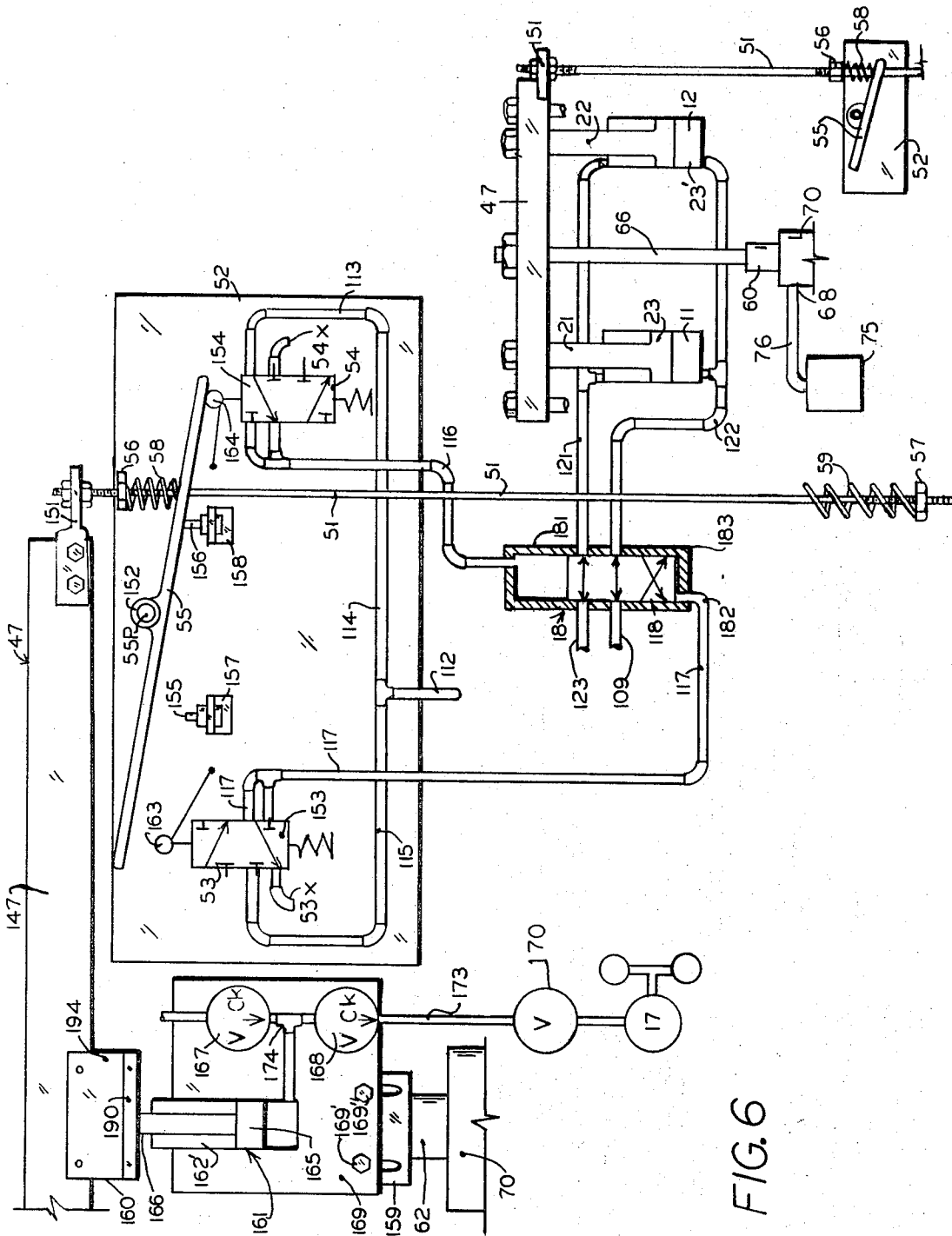
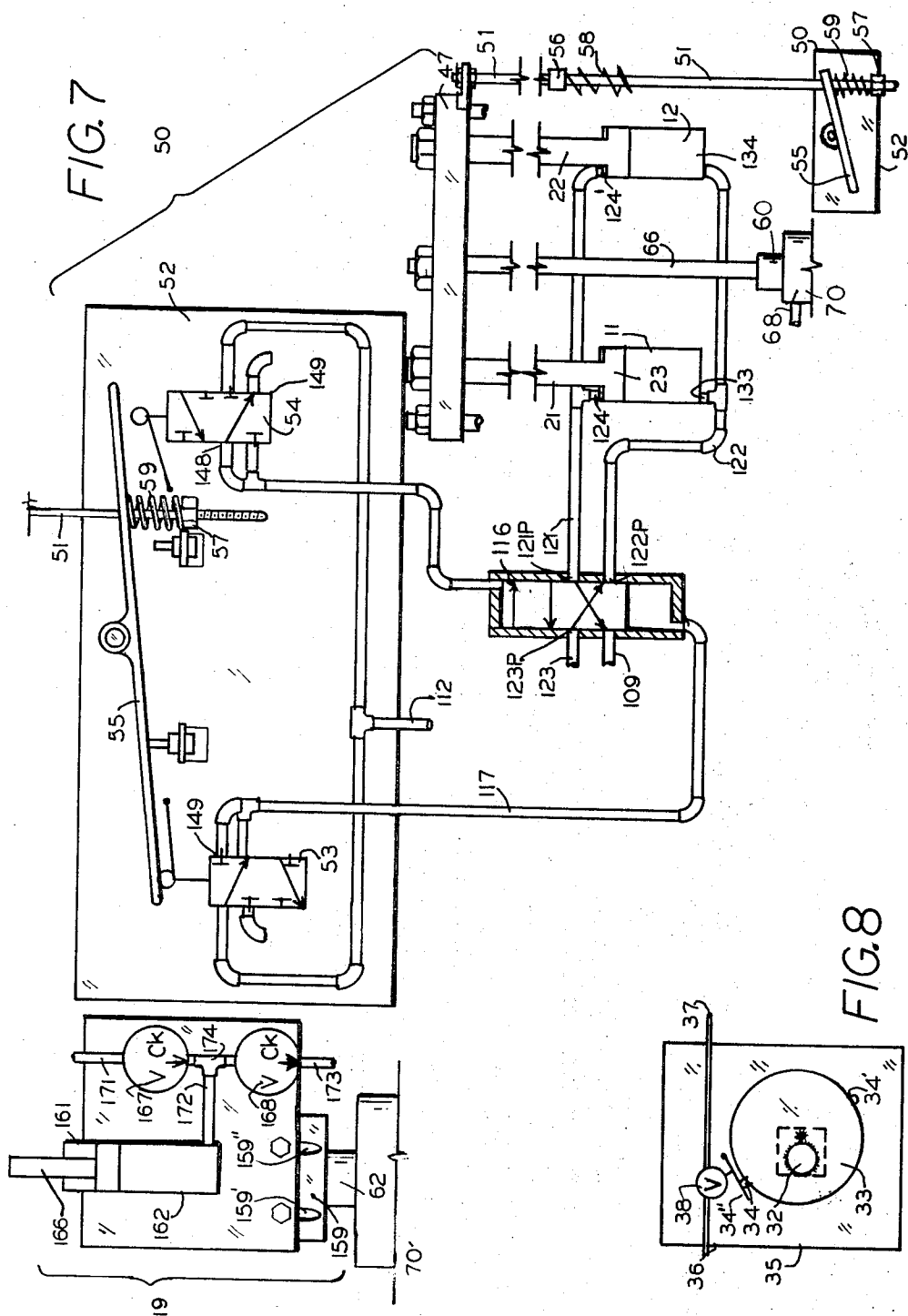


FIG. 5







PUMPING APPARATUS AND METHOD

BACKGROUND OF THE INVENTION:

1. THE FIELD OF THE INVENTION:

The field of art to which this invention pertains are pump and motor circuits for gas well pumping, and motors of expansible chamber type with application of motive fluid at different pressures to opposed working member faces and including a distributor reversal.

2. DESCRIPTION OF THE PRIOR ART:

As gas producing wells are usually in isolated locations, reliability of operation and ready adjustability as well as low operating cost are needed. Present apparatuses require power for pumping which is costly in a highly competitive field or are not flexible to meet varied conditions of weight of moving pumping apparatus, e.g., rod string, and varied liquid output requirements and/or are not readily kept in alignment and have need for auxiliary equipment to start operations and/or are wasteful of gas. The apparatus of this invention avoids these problems of the prior art by an apparatus and system that is readily installed, has substantially no operating cost, requires no auxiliary equipment to start and is flexible to meet varied load requirements, while in usual operations passes the gas used for pumping to the sales line.

BRIEF DESCRIPTION OF THE DRAWINGS:

FIG. 1 is a perspective and diagrammatic view from the front and left sides of the large units of an assembly 10 according to this invention with the piston shaft bracket 47 in its lowered position and the earth broken away to show the gas source; some components of this system are diagrammatically represented.

FIG. 2 is a diagrammatic perspective view of the larger units of apparatus 10 seen from its rear and right side showing above ground components only and with the piston bracket 47 in its raised position.

FIGS. 1 and 2 do not show the fluid conduits that carry the connecting control lines between the various components shown in these drawings. This omission is made for purposes of clarity of representation inasmuch as those connections are shown in FIG. 3.

FIG. 3 is a diagrammatic representation of the various units of assembly 10 with the connecting conduits between the units shown in FIGS. 1 and 2 represented therein.

FIG. 4 is a diagrammatic representation of the differential pressure sensor and control assembly 80 in the positions of its parts whereat the differential between wellhead operating pressure and pipeline pressure applied to the power operation cylinders 11 and 12 is adequate to effect the pumping operation.

FIG. 5 is a representation as in FIG. 4 wherein the differential from wellhead pressure to line pressure applied to the piston cylinders is not adequate to effect the pumping operation and a different differential pressure is applied to those power cylinders.

FIGS. 6 and 7 diagrammatically illustrate the position of parts in the reversing valve. FIG. 6 shows the position of parts of the reversing assembly 50 and its connections to related other units of apparatus 10 during the upward stroke of the power pistons while FIG. 7 shows the position of such parts of assembly 50 during the downward stroke of the pistons in the power cylinders.

FIG. 8 is a diagrammatic showing of parts of time cycle or intermitter assembly 31.

TABLE I is a tabulation of the dimensions and operating conditions of one apparatus 10 according to this invention.

TABLE II sets out the composition of gas used in the embodiment set out in TABLE I.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The apparatus 10 comprises, in cooperative combination a gas producing formation 71, a casing 70, a pair of power cylinders 11 and 12, a pair of counterbalance cylinders 15 and 16, a counterbalance reservoir 17 and counterbalance reservoir pump assembly 19, and a control assembly therefor. The control assembly comprises, in cooperative combination, a time cycle intermitter 31, mounting brackets as 42, a piston rod bracket 47, a reversing assembly 50 and a differential sensor and control assembly 80. In usual operation, the casing 70 extends below ground level 74 into a gas producing formation 71; gas 72, oil and water 73 are discharged from the formation 71 into the casing and therefrom gas, either by gas sales line 78 to gas storage 77 or via pumping tee 68 to liquid storage 75. The major assemblies and their operation are below described.

THE CYLINDER ASSEMBLY

Cylinders 11, 12, 15 and 16, casing 70, bracket 47, and tubing string 62 form a cylinder assembly 20, shown in FIGS. 1 & 2. The rigid vertically extending left power cylinder 11 and right power cylinder 12 are a pair of like cylinders; each is a rigid strong vertically elongated right circular holder cylinder located adjacent to and on either side of the vertically extending casing 70. The counterbalance left cylinder 15 and the right counterbalance cylinder 16 are a pair of like cylinders; each is a rigid, vertically elongated strong hollow cylinder and is located adjacent and lateral to a power cylinder as 11 and 12, respectively, for 15 and 16. The casing 70 locates and supports a string of tubing 62, of which the topmost portion extends above the top of casing 70 with tops of cylinders 11, 12, 15 and 16 at same vertical height.

A rigid bracket assembly 41 comprising a bottom front horizontally extending rigid mounting plate 42 and a like top plate 43 are firmly joined to each of the cylinders 11, 12, 15 and 16, as well as to the casing 70. A piston cylinder shaft 21 is firmly attached to a piston 23 in power cylinder 11 and a piston shaft 22 is similarly firmly attached to a piston 24 within the right power cylinder 12. Similarly, the left counterbalance cylinder shaft 25 is firmly attached to a counterbalance piston 24, located in the left counterbalance cylinder 15 and extending upward therefrom. A right counterbalance cylinder shaft 26 is attached to a similar piston in the counter-balance cylinder 16.

The casing 70 supports therein a tubing string 62 of which the topmost portion 60 extends beyond the top of the casing 70. A polish rod 66 is operatively connected to a rod string 65 therebelow which, in turn, is attached to a conventional pump 69 in the bottom of the tubing string. The polish rod passes through a stuffing box 64 at the top of the tubing portion 60.

A polish rod clamp 67 is firmly attached to the top of the polish rod 66 and is supported on the piston rod bracket 47.

The top ends of the power piston cylinder shafts 21 and 22 and counterbalance piston shafts 25 and 26 extend vertically and are firmly attached to a rigid horizontally extending mounting bracket 47 whereby these shafts 21, 22, 25 and 26 and polish rod 66 and rod string 65 rise and fall together.

A pumping tee 68 is operatively connected to the tubing string 62 and to a line 76 and provides for discharge of water and other liquids such as oil discharged from the well to a reservoir.

Such liquids, as water and oil, are discharged from well producing formation 71 by the pumping action of bracket 47 which is attached to rod string 63 and pump 69 which (63 and 69) are located in tubing string 62 and extend downwardly from the polish rod 66 to below the top level of the producing formation.

An adapter 44 is attached to the rear of the rigid bottom mounting plate 42 to firmly seat the cylinders 11, 12, 15 and 16 and casing 70 against the rear of the plate 42; a like adapter is provided for the top plate 43 for cylinders 11, 12, 15 and 16. The top mounting plate 43 is firmly attached to the upper ends of cylinders 11, 12, 15 and 16. A hanger 46 is firmly fixed to the plate 43 and pumping tee 68, which tee 68 is firmly attached to the top tubing string portion 60.

The frame members 42 and 43 thereby support and keep the central longitudinal axes of cylinders 11, 12, 15 and 16 parallel and co-planar and parallel and co-planar with the central longitudinal axes of the co-axial polish rod 66 and casing 70.

As all cylinders 11, 12, 15 and 16 and the controls attached thereto, except the reservoir tank 17, are attached to and supported by casing 70; there is no need for a separate base or foundation.

THE TIMER AND CONTROL POWERING ASSEMBLY

A gas drive outlet tee 29 from casing 70 connects to a cut off or gate valve 28, which is connected to a pipe 139. Pipe 139 is connected to the valve body 138 of a motor valve 30; the motor valve has a diaphragm casing and a diaphragm chamber 39 within the casing. The casing supports a timer assembly 31. A gas inlet line 36 enters the timer assembly 31; a timer motor valve control line 37 exists from the timer assembly and passes to the diaphragm 39 of motor valve 30.

The timer of intermitter assembly 31 comprises a spring wound clock 32 that drives a rotatable timer wheel 33 on the periphery of which lugs as 34 and 34' are located to initiate and maintain operation by contacting the arm 34'' of a normally closed valve 38. Valve 38, when open, passes gas under same pressure as tee 111 from line 36 to line 37.

A vertically elongated motor valve reservoir tank 40 is connected by control power line 49 to the outlet of time motor valve 30 and has, as its bottom, a drain valve 48 to separate liquid from the gas-liquid mixture usually passed thereunto and, at its top, an outlet tee 111 from which valve control lines 36, 171 and 112 extend. Chamber 40 has adequate volume to actuate the diaphragm of motor valve 30 and 180 and to operate reversing valve 18 by the pilots therefor provided in apparatus 10 or when manually operated. A motor line 110 extends from timer motor valve 30 to power con-

trol valve 119 for control of gas flow through line 109 to the reversing valve 18.

REVERSING ASSEMBLY

A reversing assembly 50 is firmly supported on the right power cylinder 11 and counterbalancing cylinder 15 generally as shown in FIG. 2. The reversing assembly 50 comprises a frame 52, valves 53 and 54, a reversing rod 51 and a reversing valve 18. Frame 52 is a rigid plate on which a left three-way valve 53 and a right three-way valve 54 are firmly supported. A rigid straight actuating arm 55 is pivotally supported at its center on a cylinder stud or pin 55P. The pin 55 is firmly attached to the plate 52. A reversing rod 51 is firmly supported at its top in a rigid bracket or ear 151; the ear is firmly attached to and located at the end of the piston rod bracket 47. The rod 51 is a straight rigid vertical cylindrical rod which passes through a hole therefor in the arm 55 near to one end thereof. The arm 55 is a stiff flat plate with a journal 152 for pivotal attachment to and support on the pin 55P.

Rod 51 is firmly supported at its top by a rigid rod bracket 151 that is firmly attached to the rear of bracket 47 at its right side. The rod 51 supports and locates a top reversing spring 58 and a bottom reversing spring 59. These springs are located, respectively, on the rod 51 by a top rod lug 56 fixed to the top of spring 58 and a bottom rod lug 57 fixed to the bottom of spring 59. Lugs 56 and 59 are fixedly attached to the rod 51 but may be located at any desired position therealong to adjust the length of the stroke of the piston shafts 21 and 22.

One end of the pilot control line 112 is also operatively connected to the tee 111 on tank 40. The other end of control line 112 is connected by up drive pilot branch line 114 to a right (in FIGS. 6 and 7) up drive valve 54, through its valve casing to its valve spool 154. A pilot output up drive line 116 connects the drive outlet port 148 of the valve 54 to top port 181 of the casing 118 of the reversing valve 18.

The pilot control line 112 is also connected by down drive pilot branch line 115 to a left (in FIGS. 6 and 7) down drive valve 53, through its valve casing to its valve spool 153. A pilot output down drive line 117 connects the drive outlet port 149 of the valve 53 to the bottom port 182 of the casing 118 of the valve 18. The reversing valves 53 and 54 are fixed to the reversing assembly frame 52 on opposite sides of the pivot 55P as shown in FIGS. 6 and 7. The actuating arm 55 is moved by springs on rod 51 and serves to move either the valve spool 153 of valve 53 or the valve spool 154 of valve 54 downward. The spring of the other valve then moves that other valve body downwards inasmuch as each such spool is a springloaded two position valve.

A threaded arm up rest adjustment screw 156 is located on the right side of the plate 52 between the pivot 55P and the casing of the right valve 54. This adjustment screw is firmly supported on a lug 158 which is firmly fixed to the plate 53. A threaded arm down rest adjustment screw 155 is adjustably and firmly supported on a rigid adjustment lug 157 which is firmly fixed on the left side of plate 52 on its left side, as shown in FIGS. 6 and 7, of the frame between pivot 55P and casing of the left valve 53.

The lines 114, 155, 117 and 116 and the valves 53 and 54 are firmly fixed to the plate 52. The adjustment

of the adjustment screws 155 and 156 provides that the motion of the arm 55 will not damage the valves. Each of the valves is provided with a roller cam, as 163 for valve 53 and 164 for valve 54, which is arranged to contact the arm 55 and is connected to the valve spool of such valve to provide for its movement, as shown in FIGS. 6 and 7.

A main reversing valve 18 is firmly supported by a bracket attached to the casing 70 or tubing portion 62 as well as by the sturdy motor line 110 (which is a large, 2 inch, pipe) and comprises a rigid vertically elongated cylindrical casing 183 and a vertically movable, two position, large heavy valve spool 118. The motor inlet line, a large diameter pipe, passes from outlet of timer or intermitter motor valve 30 to inlet or power control valve 119.

Control valve 119 is a manually adjustable throttle valve, also called a pinch valve, and may be an adjustably plug valve. Valve power line 109 passes from the outlet of valve 119 to the valve 18 and enters the valve casing 183 by an inlet port 181; A reversing valve top output line 121 passes from casing 183 to the top ports 124 and 124' of the power cylinders 11 and 12, respectively, while the casing 183 is also operatively connected at a port 122P spaced away from the port 122P leading to line 121, to a bottom reversing valve output line 122 which line passes to the bottom port 133 of power cylinder 11 and to the bottom port 134 of power cylinder 12.

A large main reversing valve exhaust line 123 is connected to casing 183 at discharge port of manifold thereof, as 123P, and to a reversing valve discharge manifold 127. Manifold 127 is a large pipe connected at one end to the valve body 180B of motor valve 180 and, at the other to a tee 126 (flanged) which is connected to sales line 78. As spool 118 is a heavy vertically movable spool, the normal resting position of the spool 118 is at bottom of its casing 183; in such position valve power line 109 operates to pass gas to cylinders 11 and 12 to drive the bracket 47 upward until gas is passed into valve 18 because of actuation of down valve 53 by arm 55.

THE COUNTERBALANCE ASSEMBLY

Counterbalance compressor assembly 19 comprises a counter-balance compressor pump top bracket 160, a counterbalance pump assembly 161 and a counterbalance pump assembly adjustment bracket 159.

The compressor top bracket 160 is an L-shaped rigid bracket with a rearwardly and horizontally projecting plate 190 and a vertical plate 194 firmly attached to the rear face 147 of the piston bracket 47.

The counterbalance pump assembly 161 comprises, in operative combination, as shown in FIG. 6, with a pump compressor chamber 162' therein, an inlet check valve 167 and an outlet check valve 168 and associated piping firmly fixed to a rigid vertical flat compressor assembly plate 169. Plate 169 is firmly yet adjustably attached to and supported on adjustment bracket plate 159. Plate 159 is firmly fixed to the upper tubing portion 60 of the tubing string 62. The plate 159 is a rigid flat vertical plate with vertically extending slots 159' and 159'' therein. Bolts 169' and 169'' pass through the slots as 159' and 159'' and fit in holes therefor in plate 169 and, with nuts on each bolt, provide for vertical adjustment of plate 169 to plate 159, and thereby

vertical adjustment of parts of assembly 161 relative to bracket 47 and the tubing string 62.

A pump piston 165 is movably located in the vertically elongated cylindrical pump body 162. The piston 165 is operatively connected to a rigid vertical shaft 166 vertically extending thereabove. Valves 167 and 168 are firmly held on the plate 169. A compressor inlet line 171 extends from the tee 111 to the inlet of inlet check valve 167. The outlet of valve 167 is connected to tee 174. Feedline 172 passes from tee 174 to the inlet and interior of the pump body 162 near to the bottom thereof and below the lowest point of travel of the bottom of piston 165.

Tee 174 is firmly supported on plate 169 and connected to the feedline 172, to the outlet of check valve 167, and to the inlet to the check valve 168. Outlet line 173 of valve 168 passes to an adjustable cut-off or gate valve 170 and therethrough to the counterbalance reservoir 17. A counterbalance pressure output line 179 operatively connects the reservoir 17 to the bottom of each of the counterbalance cylinders 15 and 16 by its branches 179' and 179'', respectively.

A pressure guage 177 is connected to the counterbalance reservoir 17 and a gate valve 170 is likewise connected to the reservoir 171 to hold the gas volume therein as needed when the pressure desired is reached.

The adjustable locations of lugs 57 and 59 provides that any desired travel of shaft 166 may be provided by control of length of downward travel of bracket 160 in contact with the top of compressor pump piston shaft 166. Also, vertical adjustment of plate 169 relative to the fixed plate 159 (which plate 159 is fixed to the tube string portion 60) provides that the bottom point of travel of the piston 165 may be at any desired fixed distance, e.g., 2 inches from the bottom of chamber 162, which distance (2 inches) is a predetermined portion of the total length of the pump chamber 162, e.g. 6 inches. Thereby, the movement of piston 165 produces only a predetermined and limited compression of the gas from the wellhead fed by line 172 into the compressor chamber 162 at wellhead pressure. The pressure in the counterbalance reservoir 17 is thereby held at a predetermined multiple of the wellhead pressure. Accordingly, when such an adjustment of the bracket 159 is utilized, the pressure in the counterbalance reservoir 17 may be held at any desired maximum pressure.

However, where manipulation of the bracket plate 159 relative to the plate 169 is desired to be avoided, or excessive temperature variations occur, counterbalance reservoir outlet line 175 passing from reservoir 17 via gate valve 175' to a constant pressure inlet valve 176 and operatively connected through a gate valve 176' to the compressor inlet line 171 may be used.

The use of valves 175, 176 and 176' maintains the pressure in tank 17 constant (to limit of the valve 186) independent of any variations in pressure in reservoir 17 due to local temperature changes.

THE DIFFERENTIAL SENSOR ASSEMBLY

The differential sensor assembly 80 comprises a rigid enclosure 79 with a movable door. The rear fixed wall 188 of such enclosure is firmly attached to the top of the frame of a motor valve 180 which valve the sensor unit 80 actuates and to which it is operatively connected.

A sensing arm 82, a differential piston cylinder assembly 81, a control spring 99 and a differential control valve 184 and a differential pressure cylinder assembly 81 are located on a rigid rear wall 188 of the enclosure 79. The sensing arm 82 is a flat rigid arm that extends horizontally substantially across the width of the rear wall 188 and has one pivotally fixed journal hinge 83' at one (left as shown in FIGS. 4 and 5) end and has a vertically movable journal hinge, 87, near its right end.

Arm 82 is pivotally supported on its journal 83' at one (left in FIGS. 4 and 5) end thereof on a horizontally extending pivot pin 83 which pivot pin is firmly fixed at the left (as shown in FIG. 4) portion of wall 188 and projects forwardly therefrom. A vertically extending long rigid ear 102 is firmly attached to the bottom face of the arm 82 between the journal 87 and journal 83'. It is provided with a spring holding horizontally extending pin 104 at its lower end for attachment to a vertically extending differential sensor spring 99. A spring holding lug 103 is firmly affixed to the rear wall 188 of the frame enclosure 81 above pivot pin 83 and to the right thereof and above and to left of the right hand end (as shown in FIGS. 4 and 5) of sensing arm 82.

The lug 103 has an adjustment screw 105 to which the sensor spring 99 is attached, whereby the tension across that spring 99 is adjustable. The upper end of the spring 99 is thus attached to a spring support lug 103 above arm 82 (as shown in FIG. 4) while the lower end of spring 99, which spring is normally in tension, is attached to the pin 104 at the bottom of the ear 102 of arm 82. Spring 99 urges the arm 82 upwardly.

The rigid cylindrical shell 84 of the piston differential cylinder assembly 81 is firmly fixed to the rear wall 188 of the enclosure 79. The bottom of the piston shell 84 has a port 189. One end of a control line 125 (which line is connected at its other end to reversing valve discharge manifold 127 to sense the pressure therein) is connected to that port 189. The line 125 is also connected to a gauge 100 with which to read the pressure of gas in sales line 78 through manifold 127. The top port 187 of the cylinder shell 84 is connected to the control line 114. Line 114 is a gas conduit (as are other lines herein referred to) and is operatively connected to the tee 111 which is connected to tank 40 and, when valve 30 is open, line 114 is provided with the gas pressure existing at the tee 29 and casing 70.

A differential pressure cylinder piston 85 is located slidably yet in gas-tight manner in the vertical shell 84 to slidably move therealong as the pressure on one side or another of such piston is greater than the pressure on the opposite side thereof. A rigid vertical differential pressure cylinder piston shaft 86 is attached to the upper end of the piston 85 and extends upwardly through a gas-tight seal in the shell 84 to a horizontal arm portion 86A that is pivotally held in a journal hinge 87. Hinge 87 is a journal that is firmly attached to the bottom of the sensing arm 82 at a point distant from the pivot pin 83 (generally as shown in FIGS. 4 and 5) vertically above the central longitudinal axis of the cylindrical shell 84. As arm 82 is horizontal, the movement of journal 87 is substantially vertical.

A gauge 101 is operatively connected to the line 114 to read the pressure in line 114. Gauges 100 and 101 are firmly fixed to the wall 188.

The position of the movable end of arm 82 is limited by a top limit adjusting screw 89 at the top thereof (as

shown in FIG. 4 and 5) and also a bottom limit adjusting screw 94 at the bottom. The top limit screw 89 is supported in an upper L-shaped rigid bracket or lug 88 which is firmly fixed at its rear to the wall 188; lug 88 is provided with an upper and lower adjusting screw lock nuts 90 and 91, respectively, in which the adjusting screw 89 is located. The rear portion of the lug 88 comprises a vertical lug plate 92 which is firmly fixed to the wall 188 by a nut therefore, as 92'.

The bottom adjusting screw 94 is located in a horizontally extending arm of a lower L-shaped bracket or lug 93, which is attached to a vertically extending rigid lug plate 97, which is firmly affixed to the wall 188 by a nut, as 97'; the adjusting screw lock nuts 95 and 96 are firmly affixed to the lug 93 and to the adjusting screw and fix the position of the screw 94.

The differential control valve 184 comprises a valve body 185 fixed to wall 188 and a movable valve spool 186 and, also, a valve spring 191 whereby the spool 186 is normally held in the downward position, as shown in FIG. 4.

The valve body 185 has an exhaust port 195 and an inlet port 196 to which (196) differential valve control line 114 is operatively connected. The valve body 185 also has a motor valve input port 145 and a motor valve output port 146, which ports are operatively connected to the diaphragm chamber 129 of motor valve 180 by line 128.

The screws 89 and 94 provide that movement and positioning of the spool of valve 184 is such as to provide accurately controlled gas flow from line 114 to line 128 or from line 128 (and motor valve diaphragm chamber 129) to exhaust port 195.

The position of arm 82 is determined by the difference between the pressure on the top of piston 85 and on the bottom thereof and by the tension in spring 99. When the pressure differential applied across the piston 85 in a downward (as shown in FIGS. 4 and 5) direction exceeds the upward force of the spring 99 applied at journal 87, the arm 82 and valve spool 186 are in the lowered position shown in FIG. 4 and no gas flows from line 114 to line 128 and motor valve 180 is closed.

When the pressure differential applied across the piston 86 in a downward (as shown in FIGS. 4 and 5) direction is less than the upward force of the spring 99 applied at journal 87, the spool 186 and arm 82 are located in the raised position shown in FIG. 5 and gas passes from line 114 to line 128 and motor valve 180 is opened.

For the valve 18, there is used a Model 5340-51, valve of Modernair Co. (1105 Williams Street, Angolo, Ind.) and described in drawing MQ 1669 of 11-2-70, but without a spring and with a top center tap for pilot operation, as shown in the FIGS. 5 and 6: it has 1 inch diameter ports and it is used because of the low pressure drop therethrough but any other valve of type suitable for gas passage, as shown in the figures and above described may be used.

OPERATION

In the usual series of steps of continuous operation of apparatus 10, gas passes continuously through gate valve 140, throttle valve 141, and check valve 142 to sales line 78 and gas in the casing 70 is passed by motor valve 30 at times and for periods determined by the lugs 34 and/or 34'' of intermitter assembly 31 to line

110. The pinch valve 119 is a throttle valve used to control the rate of flow of gas through line 110 at well head pressure to the reversing valve 18 and, there-through, to the pistons 23 and 23' in power cylinders 11 and 12 respectively in the position of parts shown in FIGS. 4 and 6. The pressure of the gas in reservoir tank 17 is concurrently applied against the bottom of the pistons as 24 and 24' in counter-balance cylinders 15 and 16. The pressure in the reservoir 17 is brought to or maintained at a pressure which serves to support the weight of the rod string 63 in its lowered position (FIGS. 2 and 4). The volume of the tank 17 is very large (9 feet long $\times$ 11 inches internal diameter) compared to the volume of the counterbalance cylinders (3-1/2 inches internal diameter and 42 inches long each).

On the lowest position or limit of downward motion of the bracket 47, as shown in FIGS. 2 and 6, the rod 51 is moved downwardly with bracket 47 and the spring 58 contacts the top of arm 55 and moves the right end of the arm 55 downwardly, as shown in FIG. 6. The downward force of the spring 58 on the right end or arm 55, as shown in FIG. 6, causes the spool 154 of the valve 54 to be urged downwardly, and, in such position of parts, to pass gas at well head pressure from the branch line 114 to the line 116 and thence to the reversing valve 18. This positioning of the reversing valve spool 118 permits passage of gas at well head pressure from the motor lines 109 and 110 to below the pistons 23 and 23' of power cylinders 11 and 12 at a rate determined by the positioning or opening, e.g., wide open or partly open, of the control valve 119 and at a rate reduced by (a) the back pressure at the other side of the pistons 23 and 23' created by the pressure in manifold 127 (which is the same as that in sales line 78) and (b) the load of liquid carried by the rod string 63 and pump 69. Thereby the piston bracket 47 is raised by shafts 21, 22, 25 and 26 for the length of the stroke set by the location of springs 58 and 57 on rod 51. On such raising of the bracket 47 the polish rod 66 is raised and with it the rod string; liquid carried by the tubing string is then passed into tee 68 and therefrom to line 76 and to container 75. On upward motion of pistons 23 and 23' the gas theretofore in cylinders 11 and 12 above pistons 23 and 23' is driven out of cylinders 11 and 12 via line 121 to valve 18 and therefrom via line 123, to manifold 127.

The tension in spring 99 is adjusted or set, in view of the diameter of power cylinders 11 and 12, to the value of differential of pressure between sales line 78 and the pressure at line 190 that is the minimum adequate to perform the pumping operation. This pressure difference may be as low as 15 pounds per square inch although in the embodiment herein described, there is a pressure drop of 50 psi and this is entirely adequate to drive the pump at 6 strokes per minute and return all gas used for pumping of liquid (to storage 75) to the sales line 78.

On reaching the upper end or limit of upward travel of the bracket 47, the rod 51 is, as shown in FIGS. 1 and 7, moved upwardly to such a degree that the top of bottom spring 59 contacts the right end (as shown in FIG. 6 and 7) arm 55 and moves it upwardly.

In the position of parts shown in FIG. 7, whereat the bracket 47 is in its fully raised position, as also shown in FIG. 1, the actuating arm 55 is raised on its right hand side and lowered as shown in FIG. 7 on its left

hand side and then moves the valve body 153 of the valve 53 downwards and thereby passes gas at well head pressure from the line 112 through the branch line 115 to the down output line 117 to the bottom of the reversing valve 18 and moves the valve spool 118 upwards and permits passage of gas from line 109 at well head pressure from the motor line 110 through the valve 18 to the top ports of power cylinders 11 and 12, as shown in FIG. 7, to drive the pistons thereof downwardly.

In the position of parts shown in FIG. 7, the gas on the bottom side of the pistons 23 and 23' is connected through line 122 to the reversing valve 18 and through the valve spool 118 thereof to line 123.

Line 123 then passes gas to the sales line 78 through a manifold line 127 while control sensor line 125 passes therefrom to the directional sensor and control assembly 80.

In operation where the differential between the line pressure and the well head pressure is adequate therefor valve 180, controlled by the assembly 80, is closed and the gas in line 123 is operatively connected to line 127, and via open connector cutoff valve 137 to the sales line 78 whereby all such gas as has been used to pump the power cylinders 11 and 12 is then passed into the sales line.

In operation where the pressure differential between the line pressure and the well head pressure is inadequate for pump operation, the motor valve 180 controlled by the assembly 80 is automatically opened by the differential sensor assembly as above described and the gas in line 123, which is also operatively connected to manifold 127, is serially connected through manifold 127 to a discharge line 130, a throttle valve 131 and past an open gate valve 135 to exhaust at 136. With such resultant increased differential in pressure across pistons 23 and 23' the pumping may be continued using the full well head pressure across pistons 23 and 23'. At the next period for pumping as determined by timer assembly 31, the differential of well head to sales line may be adequate. When the valve 180 is opened the drop in line pressure of line 78 as measured at meter 78M in a meter house about 50 yards from tee 126 of apparatus 10 is usually only 20 psi (drop from 150 psig to 130 psig) because of adjustment at discharge valve 131: a different setting could provide more drop if needed but usually a 20 psi added differential is all that is required to provide adequate differential pressure across pistons 23 and 23' usually.

The sensor assembly 80 provides for maintaining across the valve power line 109 and valve exhaust line 123 the minimum differential in pressure required for satisfactory operation of the pumping action effected by cylinders 11, 12, 15 and 16 while returning all gas used for pumping to the sales line. The reversing assembly 50 provides for automatically using only enough volume of the well head gas for completion of each cycle of pumping, each such cycle comprising a full upward and a full downward stroke of rod 66, i.e., the sequence of steps beginning at one position, e.g., the lowermost, of bracket 47 as in FIG. 6 and including its movement to the highest point of movement of that bracket 47 as in FIG. 1 and including the return of the bracket 47 to its lowest position. The speed of each such cycle is controlled by the setting of valve 119.

The sensor assembly 80 serves to compare the pressure differential available across the power cylinder

pistons with the minimum pressure desired thereacross and, when the minimum differential does not exist, automatically provides for providing a greater pressure differential across the power cylinder pistons. In operation of the assembly 80 the line 114 enters one side of the valve casing 184 and, in position of parts shown in FIG. 4, when the pressure at line 114 exceeds the pressure in the discharge line 78 by a predetermined minimum value, assembly 80 provides for no gas passage from line 114 to line 128 through valve spool 186. However, when the differential in pressure between line 125 and line 114 (which is the differential in pressure between the sales line 78 and the well head pressure at the tee 29) does not reach the predetermined minimum differential, the spring 99 contracts as diagrammatically shown in FIG. 5, because the force downward against piston 85 by the gas pressure in line 114 is then not adequate to overcome the force of gas pressure in line 125 (same as in manifold 127) plus that of the spring 99, and the arm 86 therefore moves upwardly. The hinge 87 of arm 82 permits the arm 82 to rotate counterclockwise from the position shown in FIG. 4 (held by adjusting screw 93) to the position shown in FIG. 5 (held by screw 94). The arm 82 then contacts the roller arm 192 and moves the valve body 186 upward so that passage 193 therethrough permits gas to pass from gas conduit line 114 to gas conduit line 128 and, therefrom, to the diaphragm chamber 129 of the motor valve 180. Motor valve 180 is normally spring urged to be in closed position. Valve 180, therefore, opens when the difference in pressure between line pressure 78 and the well head pressure in line 114 does not reach a valve sufficient to overcome the tension applied along spring 99 to arm 82. The tension along spring 99 passed to the arm 82 through the crank arm 102 may be adjusted at the adjustment screw 105. Accordingly, adjustment of spring 99 provides for determination of the pressure differential at which operative or flowing connection is made between conduit lines 114 and 128 and thereby opens the valve 180; the pressure in line 123 is then, but for the pressure drop across valve 131, reduced to atmospheric pressure whereupon the pressure differential across lines 121 and 122, which pressure is the pressure applied across the pistons in the power cylinders 11 and 12, is accordingly increased, usually 15 to 40 psi, so that the force of the pumping action applied to the pistons 23 and 23' and thence to bracket 47 and, from the bracket 47 through the polish rod 66 to the rod string 75 will be accordingly increased. Adjustment of the adjustment screw 105 is readily made to cause the piston 86 to move upward at any desired minimum differential in pressure between the line 114 and 125; such difference is readily determined by reading of the gauges 100 and 101. Usually, this differential minimum is set at only 30 pounds per square inch, depending upon the rod string weight and the rate of operation (strokes per minute) desired; a greater difference in pressure or a lesser difference in pressure may be used to activate the bracket 47 as determined by rod string weight, and weight of liquid to be lifted and strokes per minute needed for pumping. (30 p.s.i. was used for apparatus 10 as an example.)

Where the counterbalance reservoir 17 does not initially have adequate pressure to permit the differential between well head and sales line pressure alone to adequately operate the pump 69 and rod string, without

added power source, apparatus 10 provides that the arm 82 may be manually held upwards against top adjustment screw 89 and the movement of bracket 160 and compressor pump assembly 19 used to pump gas from line 29 into tank 17 until a desired pressure therein is reached whereat tank 17 does provide a pressure sufficient to support the rod string weight in the well.

Not only does this system of apparatus 10 return pumping gas to the sales line but also the use of a pressure differential across valve 18 that is less than the well head pressure avoids condensation and or freezing that otherwise occurs where usual gas that is highly saturated with water or other readily condensable vapors is used to power the pumping operation. Also, the use of a plurality of large diameter cylinders 11 and 12 as used herein, which cylinders operate parallel piston shafts attached to a common bracket, as 47, permits low pressure differential, as 15 p.s.i., in combination with the plural high pressure counterbalance cylinders, to be entirely adequate for many pumping operations. The counterbalance cylinders 15 and 16 have dust filters 143 and 144 respectively at their discharge ports. The use of plural units also permits a sufficiently low height of total unit that the apparatus 10 does not interfere with operation of conventional pivot irrigation systems: unit 10 is sufficiently low that the rotating irrigation pipe-assembly which is usually 8 to 10 feet high passes freely over the bracket 47 in its highest position (as in FIG. 1). The location and ready removal of bracket 47 allows the tubing string 62 to be readily pulled.

TABLE I—DIMENSIONS OF APPARATUS 10

35	Bracket 47		
	Width (left to right)		34"
	Height		5"
	Thickness		
	(front to rear)		¼"
	Stroke (exemplary)		25"
40	Cylinders 15, 16		
	Diameter		3½"
	Height		42"
	Internal Pressure		250 psi
	Shaft 25-26 Diameter		¾"
	11-12 Diameter		6"
	Height		42"
	Shaft 21-22 Diameter		1½"
45	Distance (centerline to outerline: Shafts 22-66, and 22-26		9½"
			3¼"
	Pipes 109, 110, 121, 122, 123, 127, 76 & 179	Pipe	i.d. 1"
			o.d. 1½"
50	Control conduit lines as 36, 37, 125, 128, 112, 114, 115, 116 and 117 tubing, i.d.		¼"
	Pressure in casing 70		130 psi
	Pressure in line 78 (at junction with line 126)		80 psi
	Capacity		100 bbl.
	Tank 75		1½"
55	Plate 52		
	Shaft 66, diameter		
	Length (left to right in FIG. 6)		13"
	Height (top to bottom)		3"
	Thickness		¼"
	Length		12"
	Width (front to rear)		¾"
	Rod 51		
	Length		40"
60	Diameter		¼"
	Spring 58		10"
	Spring 59		10"
	Length		
	Springs 58 & 59		
	Space between top of 59 and bottom of 58		15"
	Tank 40		
65	Diameter		5"
	Height		15"
	Tank 17		
	Diameter (i.d.)		11"
	Length		9"

Plate 159			
Width	6"		
Height	12"		
Thickness	¼"		
Cylinder			
Diameter	2"		
Height	10"	5	
Arm 166			
Diameter	¼"		
Height			
Plate 188			
Width (left to right as in FIG. 4)	12"		
Height	12"	10	
Arm 82			
Length	11"		
Thickness	¼"		
Cylinder 81			
Diameter	1½"		
Length	4"		
Spring 99			
Length	8"	15	
Diameter	½"		
Arm 102	Length	5"	
Diaphragm 129 and 39	Diameter	10"	
Location of Well	Morton County, Kansas		
	Depth of Well	3,100 ft.	20
	Liquids pumped	5 to 10 bbl/day	
	Stroke rate, average 6 per min.		
Line pressure, 78 (read at guage 100)		80 psi	
Well head pressure at 70 (read at guage 101)		120 to	
Schedule of Operations	On 2 hours, Off 2 hours	130 psi	

TABLE II

Analysis of Gas used in Apparatus of Table I

General description	natural gas	
Date Sampled	Jan. 29, 1973	
Well location	Sec. 9-35-32	
	Morton County, Kansas	
Component	Mol %	
Helium	0.61	
Hydrogen	—	
Carbon Dioxide	0.07	
Nitrogen	21.05	
Methane	65.35	35
Ethane	6.26	
Propane	3.92	
i-Butane	0.46	
n-Butane	1.29	
i-Pentane	0.27	
n-pentane	0.35	
Hexanes — Plus	0.37	40

About 10 cc of water are collected in tank 40 per 24 hours and some finely divided dust size solid particles are carried therein.

I claim:

1. A gas well pumping apparatus comprising, in cooperative combination, a cylinder assembly, a timer assembly, a reversing assembly, a counterbalance assembly,

said cylinder assembly comprising a plurality of rigid parallel vertical power cylinders and counterbalance cylinders, a well casing with a sales outlet line, a well tubing, a rod string and a rigid horizontally extending piston bracket, each of said power cylinders and counterbalance cylinders including a piston movable axially thereof and a vertical rigid shaft vertically and axially extending therealong and attached near its top to said bracket and at its bottom to said piston a polish rod shaft attached to said rod string and said piston bracket, the shafts attached to said bracket being parallel to and symmetrically arrayed about said polish rod shaft,

said reversing assembly comprising a reversing valve comprising a valve body and a valve spool, first conduits operatively connecting said well casing to each of said power cylinders and an adjustable reversing pilot means connected to said bracket and to said reversing valve whereby to move said reversing valve spool to different positions corre-

sponding to different positions of said bracket, a gas power source connected to said pilot means and, therethrough, to said reversing valve, a second conduit connected from said well casing to a motor valve inlet, the motor valve having an inlet and outlet and operatively connected to the timer assembly and controlled thereby, a third conduit from the motor valve outlet to an adjustable throttle valve, a fourth conduit from said motor valve outlet to said reversing valve, a fifth conduit leading from each of said power cylinders to the sales line;

the counterbalance assembly comprising a counterbalance pump assembly, a counterbalance reservoir and said counterbalance cylinders, said reservoir and pump assembly operatively connected by conduits to the bottom of said counterbalance cylinder, said reservoir having a volume which is a multiple of the volume of said counterbalance cylinders; said pump assembly comprising a pump actuation bracket attached to said piston bracket, and movable with said piston bracket in a vertical path, and counterbalance pump cylinder and piston, said counterbalance pump piston having a vertically extending shaft, said pump shaft extending in said vertical path, said pump attached to a vertically adjustable pump supporting means on said piston assembly, said pump being vertically adjustable on said support means.

2. Apparatus as in claim 1 wherein said adjustable reversing pilot means includes a vertically extending control rod with valve engaging means thereon attached to said bracket and extends to engage the pilot valve means located on said cylinder assembly and conduits operatively connected to said pilot valve from said well casing and conduits connected from said pilot valve to said reversing valve.

3. Apparatus as in claim 2 including also a differential sensor and motor assembly, said sensor and motor assembly comprising

a first conduit operatively connected to a top portion of said casing,

a second conduit attached to a manifold operatively connected to said sales line,

a pressure differential sensing means with said first and conduits leading thereinto,

a motor valve operatively attached to and actuated by said sensor means and attached to said manifold means, an inlet port of said motor valve means attached to said manifold and a discharge port of said motor valve open to a conduit which passes a throttle valve, said throttle valve having a discharge opening open to atmosphere.

4. Apparatus as in claim 3 wherein said sensor assembly comprises a conduit operatively connected to said well casing and to a pilot valve actuated by said sensing means, said pilot valve connected by another conduit to said motor valve.

5. Process of pumping liquid from an underground formation containing flowing gas, comprising the steps of

1. passing gas from said formation through a well casing extending upward to the ground surface and therefrom to a first, sales, line conduit through a manifold,

2. concurrently passing gas from said formation to a second, pump drive, conduit against one face of a motor means to the other face of which a manifold

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pressure is applied and driving said motor means in a vertical upward direction and applying the force of such motion to pump liquid from the formation and empty it at the surface,

3. exhausting the gas passed to said one face of said motor means to said manifold,
4. measuring the difference between the pressure in the first sales line and the pressure in the said casing near the ground surface and reducing the manifold pressure when the difference between the wellhead pressure and the manifold pressure falls below a predetermined value.
6. Process as in claim 5 wherein gas is passed from the well casing to a compressor and the pressure of such gas is raised and passed to a reservoir therefor,

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and the gas in said reservoir is applied continuously to said motor means to assist the gas passed to said one face of said motor means to support the pump means.

7. Process as in claim 6 wherein said pressure in said reservoir is maintained at a predetermined value.

8. Process as in claim 6 wherein the compressor reduces the volume of gas passed into said compressor to a predetermined fraction thereof whereby the pressure of said gas is raised to a predetermined multiple of the pressure of gas fed therinto from the well casing, and gas passed from said compressor to said reservoir is maintained at a maximum pressure that is a predetermined multiple of the wellhead pressure.

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