Oct. 20, 1964 G. H. SADOUET 3,153,387

PUMPING UNIT

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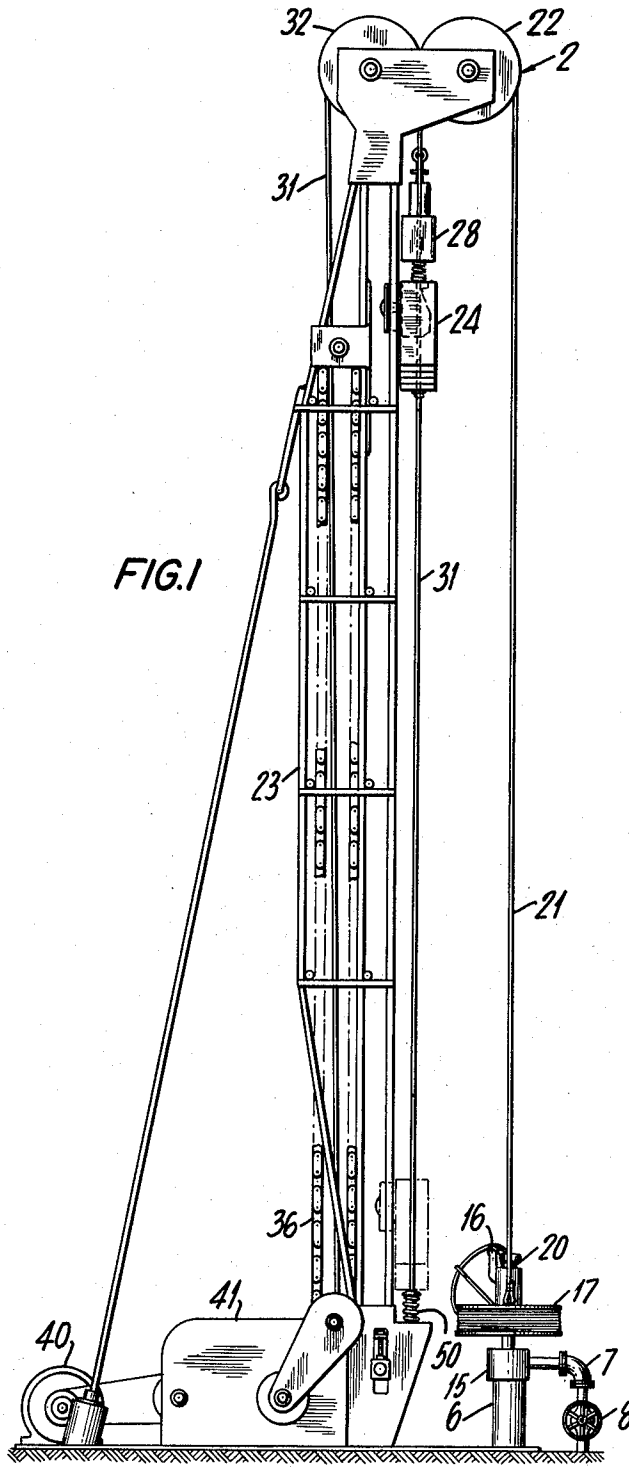


FIG.1

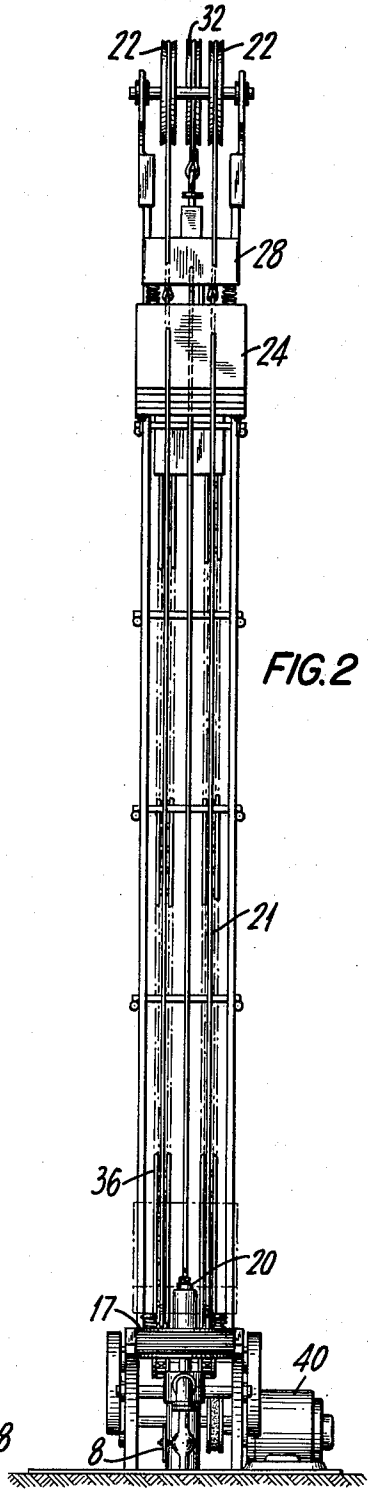


FIG.2

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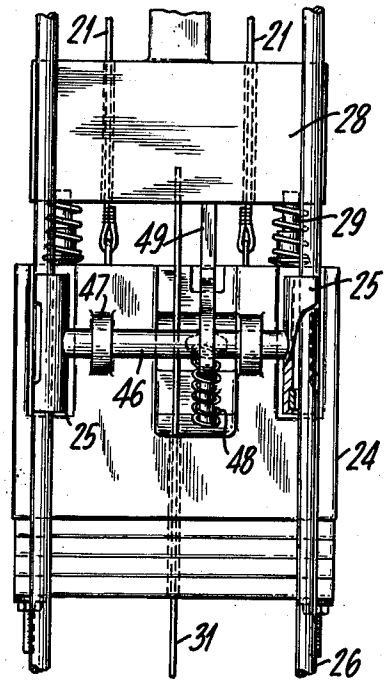


FIG.4

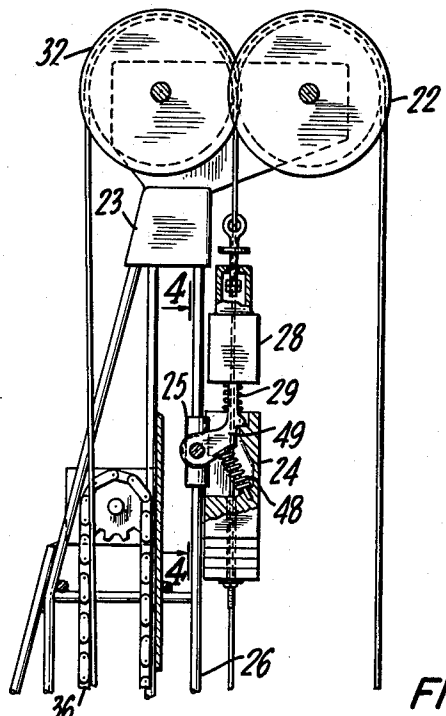
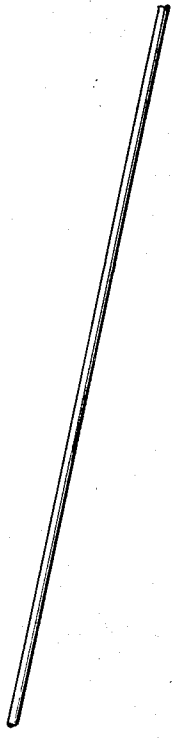
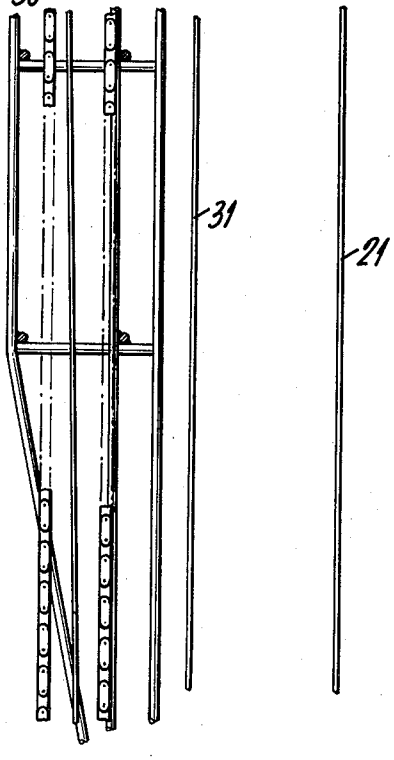


FIG.3A

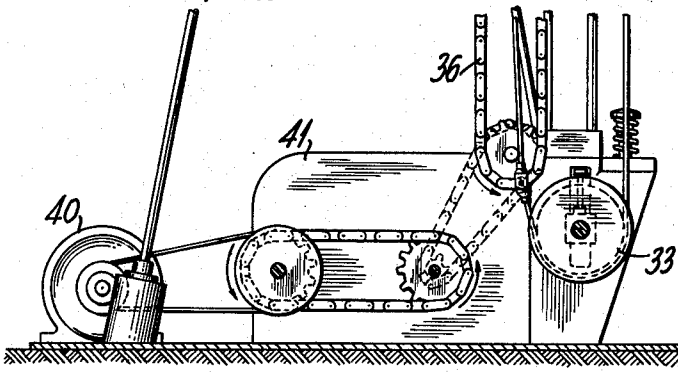


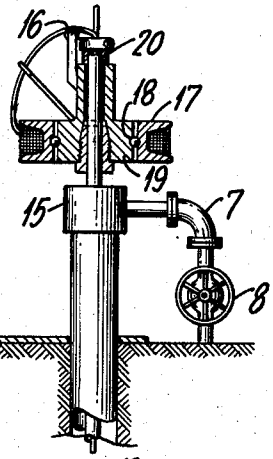


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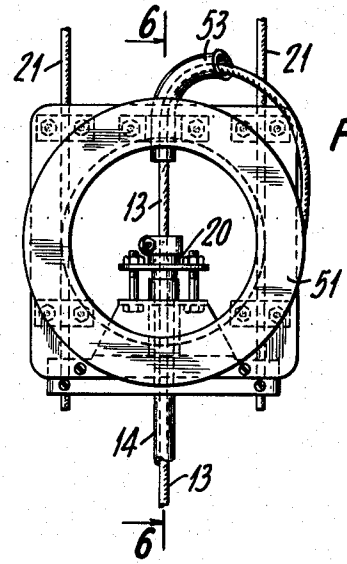


FIG.5

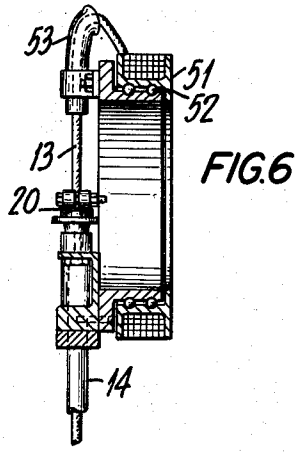


FIG.6

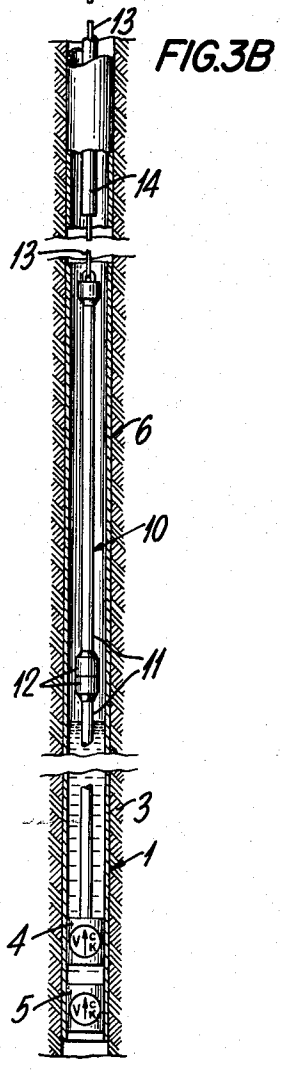


FIG.3B

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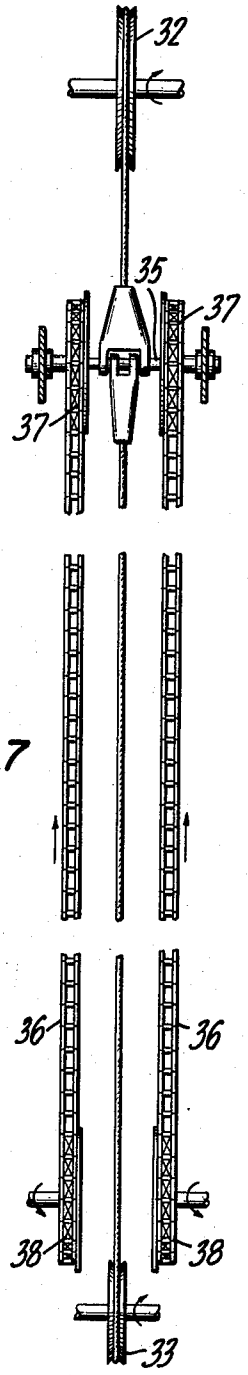


FIG.7

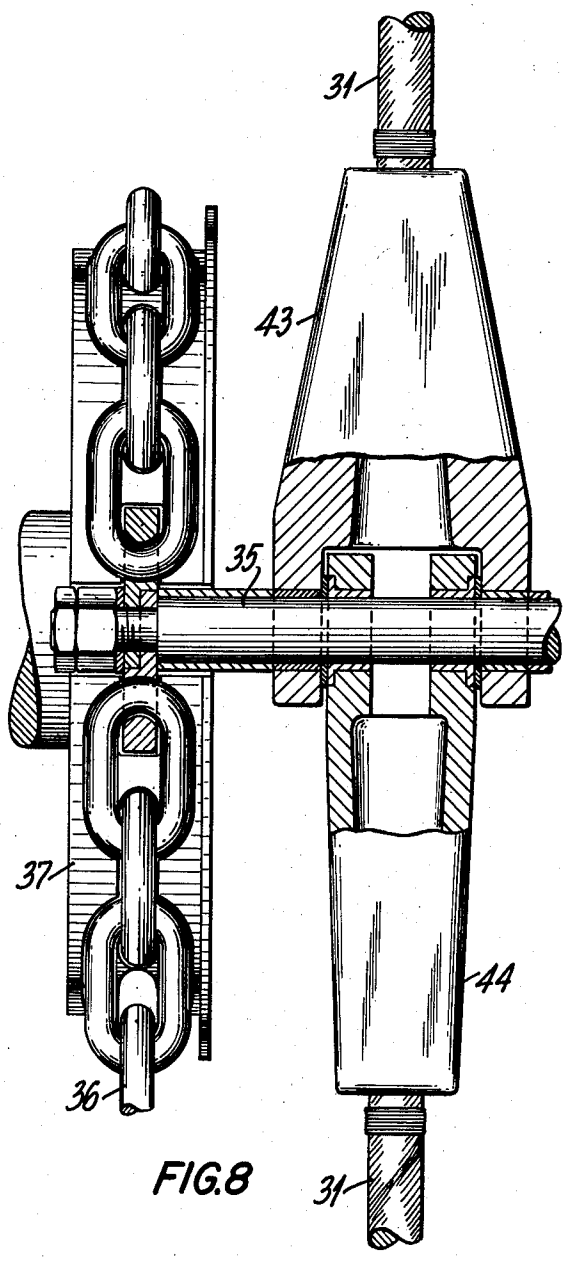


FIG.8

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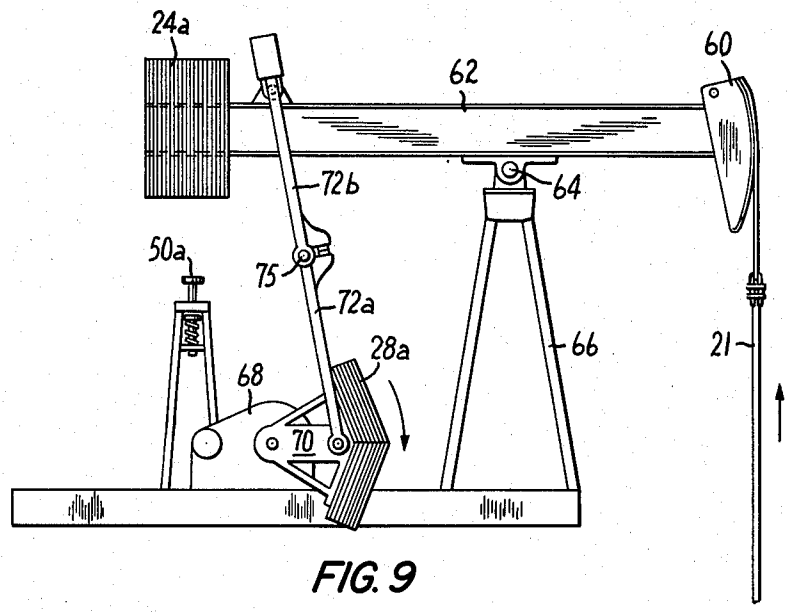
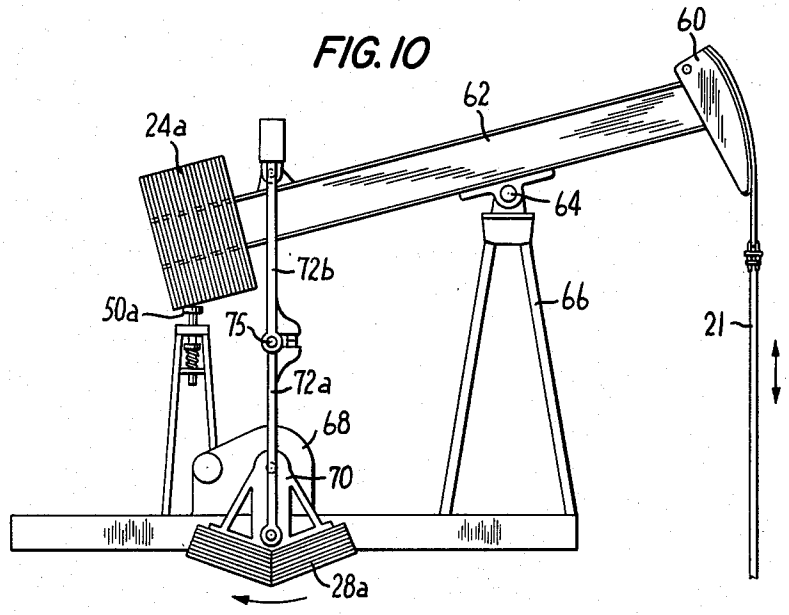


FIG. 9

FIG. 10



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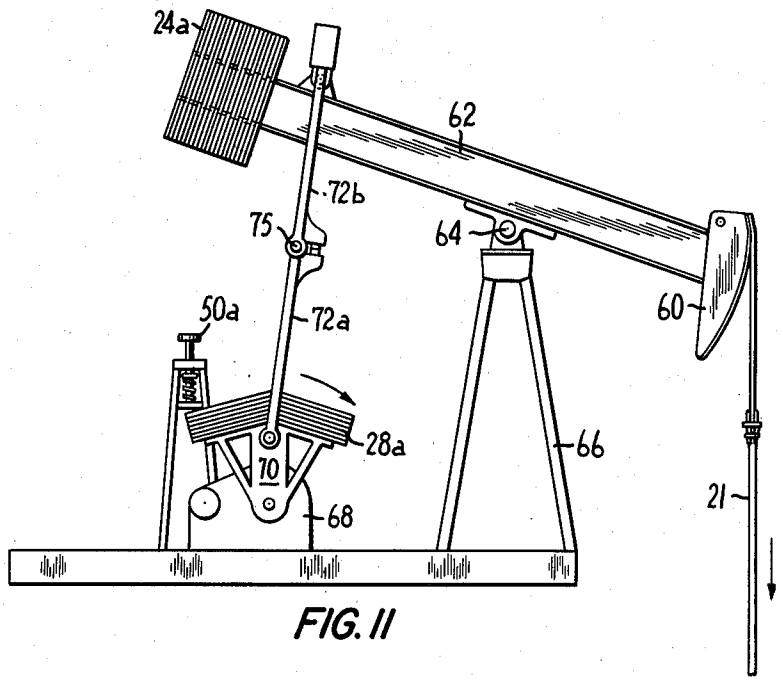


FIG. 11

FIG. 12

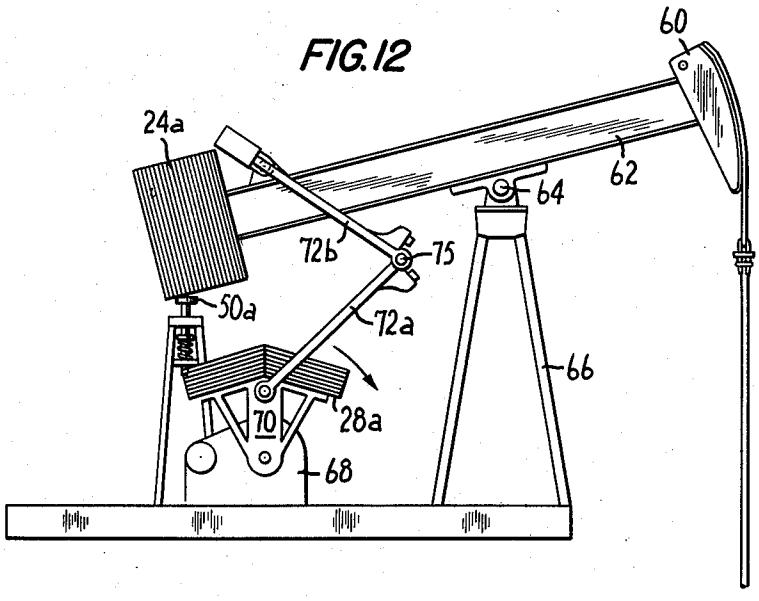
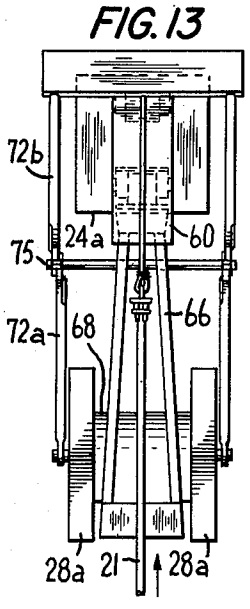


FIG. 13



United States Patent Office 3,153,387 Patented Oct. 20, 1964

3,153,387

PUMPING UNIT

Georges H. Sadouet, Buenos Aires, Argentina, assignor to E.V.A.G. Sociedad di Responsabilidad Limitada, Buenos Aires, Argentina, a corporation of Argentina

Filed Mar. 14, 1963, Ser. No. 265,290
14 Claims. (Cl. 103—206)

The present invention relates to pumping units and more particularly to pumping units for oil and other wells of the kind in which a pump comprising a cylinder and a piston are located in the well and operated by means of a pumping string which connects the piston to an operating mechanism located above ground.

It is an object of the invention to provide an improved pumping unit having a long pumping stroke and constant speed throughout a major portion of the travel of the piston by means of a fully mechanical transmission system.

In accordance with the invention there is provided, in combination with a well pump having a cylinder, and a piston movable therein, and a casing extending upwardly from the cylinder for receiving liquid discharge from the pump, a pumping string connected to said piston and extending up through said casing, first counterweight means connected to the upper end of said pumping string to counterbalance the weight of said pumping string, drive means for moving said pumping string upwardly, second counterweight means connected with said drive means, and means connecting said drive means and said second counterweight means to said pumping string and first counterweight means to transmit force to move said pumping string in an upward direction only, downward movement of said pumping string being effected solely by gravity, said first counterweight means having an effective weight less than the weight of said pumping string, and the combined effective weight of said first and second counterweight means being approximately equal to the weight of said pumping string plus half the weight on said piston of liquid in said casing.

It is thus a feature of the invention that the total counterweight force which acts to raise the pumping string during the up-stroke of the pump piston is divided into two parts which can act separately or in combination.

It is a further feature of the invention that constant tension is applied to the pumping string so that wire rope can be used in the string, if desired, in place of sucker rods. This not only decreases the cost of installation, but makes it possible readily to adjust the length of the pumping string and facilitates withdrawal and reinstallation of the pumping string in the event it becomes necessary to pull the pump for servicing.

The invention further reduces maintenance costs by limiting forces applied to the pumping string and to the power unit and other portions of the equipment in the event of jamming of the pump. The advantages of pumping units in accordance with the invention include higher mechanical efficiency, lower installation and operating costs, and long trouble-free operation with a minimum of maintenance.

The objects, characteristics and advantages of the invention will be more fully understood from the following description and claims in conjunction with the accompanying drawings in which are shown by way of example illustrative embodiment of the invention. In the drawings,

FIG. 1 is a side elevation of the above-ground portion of a pumping installation embodying features of the invention;

FIG. 2 is a front elevational view of the installation shown in FIG. 1;

FIGS. 3A and 3B are, taken together, a side view, partially in section, showing the installation of FIGS. 1 and 2 and including portions of the pump and pumping string on an enlarged scale;

FIG. 4 is a partial front elevation on a still larger scale showing a counterweight system and associated portions of the mechanism;

FIG. 5 is a fragmentary front elevation showing an alternative form of reel used for holding a variable supply of wire rope or cable for the pumping string;

FIG. 6 is a section taken approximately on the line 6—6 in FIG. 5;

FIG. 7 is a schematic view illustrating a portion of the operating mechanism;

FIG. 8 is a magnified detail view corresponding to a portion of FIG. 7, with portions broken away and shown in section;

FIG. 9 is a side elevational view of another form of pump embodying features of the present invention, the parts being shown midway in the course of the upward stroke;

FIG. 10 shows the installation of FIG. 9 at the end of the upward stroke;

FIG. 11 is another view of the apparatus of FIG. 9 at the end of the downward stroke;

FIG. 12 shows the device of FIGS. 9–11 as it appears at the end of the downward stroke when the sucker rods become jammed; and

FIG. 13 is an end elevational view of the embodiment of FIGS. 9–12.

The pumping installation shown by way of example in FIGS. 1 to 8 of the drawings comprises a pump 1 located in a well, and an operating mechanism 2 located above-ground. The pump is shown schematically in simplified form as comprising a pump cylinder 3 and a reciprocating piston 4. A foot valve 5 is provided below the piston to admit liquid to the cylinder when the piston moves up but to check the flow of liquid in the opposite direction. The piston is also constructed to provide check valve action permitting liquid to flow up through or past the piston as the piston moves downwardly in the cylinder. A casing 6 extends upwardly from the pump cylinder to the surface of the ground and is provided at its upper end with a discharge pipe 7 having a valve 8. The casing 6 ordinarily comprises a conduit pipe extend- up inside an outer casing of the well. The pump piston 4 is operatively connected to the operating mechanism above surface by a pumping string 10 which is shown as comprising a plurality of sucker rods 11 connected by screw joints 12. A wire rope or cable 13 is connected to the uppermost sucker rod and extends up through a hollow polished rod 14 which projects up through a sealing gland 15 at the upper end of the casing 6. An upper end portion of the cable 13 extends over a pulley 16 and is wound on a reel 17 which is rotatably supported by bearings 18 on a head 19 secured to the upper end of the polished rod 14. A gland 20 on the upper end of the polished rod 14 clamps the cable 13 and also provides a fluid-tight seal. The construction shown makes it possible to vary the effective length of the cable 13 as desired while providing a reserve portion of the cable reeled on the reel 17.

The operating mechanism comprises a flexible line shown as a pair of cables 21 running over coaxial pulleys or sheaves 22 rotatably supported on a tower or mast 23. One end of each of the cables 21 is connected to the head 19 on the upper end of the polished rod 14 while the other ends are secured to a lower counterweight 24. The counterweight 24 is suspended by the cables 21 and is guided for vertical movement by sleeves 25 slidable on vertical guide rods 26. An upper counter-

weight 28 rests on the lower counterweight through suitable cushion means illustrated as spring shock absorbers 29. The cables 21 on which the lower counterweight 24 is suspended extends through holes in the upper counterweight 28 and are not attached to the upper counterweight. A flexible loop comprising a cable 31 runs over a pulley or sheave 32 at the top of the mast 23 and a second pulley or sheave 33 near the bottom of the mast. Opposite ends of the cable 31 are secured to the upper counterweight 28 so as to form a closed loop. The lower counterweight 24 is provided with a hole through which the cable 31 passes freely without attachment to the lower counterweight. At a point approximately midway its length, i.e., approximately opposite the point of attachment of the cable to the upper counterweight 28, the cable 31 is pivotally attached to a cross bar 35 (FIGS. 7 and 8) extending between two parallel endless chain belts 36. Each of the chain belts runs over an upper sprocket wheel 37 and a lower sprocket wheel 38. The upper sprockets 37 are coaxial with one another and are rotatably mounted on the mast 23 near its upper end. They are preferably vertically adjustable in order to adjust the tension on the chain belts 36 and also to provide for lengthening and shortening the chain belts. The lower sprockets 38 are likewise coaxial and are rotatably mounted near the lower end of the mast. The two sprockets 38 are driven in synchronism with one another by a motor 40 and gear reduction transmission 41. As will be seen from FIG. 7, the cross bar 35 is carried around by the chain belts 36 as the driven sprockets 38 are rotated. By its connection to the cross bar 35, the cable loop 31 is caused to run first in one direction and then in the other over the pulleys 32 and 33. Thus, as the cross bar 35 is carried downwardly by the chain belts 36, the cable loop 31 runs over pulleys 32 and 33 in a counterclockwise direction. As the cross bar 35 is carried upwardly by the chain belts 36, the cable loop 31 runs in a clockwise direction over the pulleys 32 and 33. The upper counterweight 28 is thereby moved upwardly and downwardly by the cable 31, with the vertical movement or stroke of the upper counterweight being equal to the vertical extent of the chain belts 36.

The weight of the lower counterweight 24 is selected so as to be substantially less than the weight of the pumping string 10. Preferably, the weight of the lower counterweight 24 is approximately equal to 7/8 the weight of the pumping string minus a value "F" which represents a selected downward force required to overcome friction and the viscosity of the liquid being pumped to move the piston downwardly. The proportion 7/8 takes into account the buoyancy effect of the liquid being pumped upon the pumping string immersed in it, the total weight (WP) of the pumping string being the weight in air. The weight of the upper counterweight 28 is preferably equal to the value F plus one half the weight or pressure on the piston 4 of the column of liquid in the casing 6. This can, of course, be readily determined in relation to the particular liquid being pumped and the height of the casing through which the liquid is lifted. Hence the total weight of the counterweights 24 and 28 is approximately equal to seven-eighths the weight of the pumping string plus one half the weight of the liquid column on the piston. In other words, the effective weight CW1 of the first counterweight is approximately

$$CW1=\frac{7WP}{8}-F$$

and the effective weight CW2 of the second counterweight is approximately

$$CW2=F+\frac{WL}{2}$$

where:

WP is the weight of the pumping string in air,

WL is the weight on the piston of the liquid column in the casing, and

F is a selected force required to overcome friction and the viscosity of the liquid when the piston moves in a downward direction. The additional force required to lift the pumping string will, of course, be provided by the motor or other prime mover. It will, of course, be understood that a greater part of the lifting load may be transferred to the prime mover. Thus, in the above formulae CW2 can be equal to

$$\frac{F}{2}+\frac{W1}{2}$$

so that the prime mover provides a force equal to

$$\frac{F}{2}+\frac{W1}{2}$$

These two definitions of CW2 are, therefore, essentially equivalent and are similarly susceptible of further equivalent variation.

The operation of the unit will be readily understood from the foregoing description of its construction. Starting with the two counterweights in their uppermost position as shown in FIG. 1, and with the cross bar 35 between the chain belts 36 in its lowermost position, the counterweight 28 is moved downwardly by the pull of the cable 31 as the cross bar 35 is carried upwardly by the chain belts. Engagement of the upper counterweight 28 through the shock absorbers 29 with the lower counterweight 24 forces the lower counterweight downwardly and thereby pulls the pumping string 10 upwardly by means of cables 21. The piston 4 is thereby moved upwardly in the cylinder 3. After reaching the bottom of its downward movement, the upper counterweight 28 is moved upwardly through the driving mechanism comprising the cable 31, cross bar 35 and chain belts 36. Since the weight of the pumping string is substantially greater than that of the lower counterweight, the action of gravity on the pumping string causes the lower counterweight 24 to follow the upward movement of the upper counterweight 28. However, since the two counterweights are not attached to one another the upward movement of upper counterweight 28 does not force the lower counterweight 24 to move upwardly. Hence, if the pumping string should happen to jam in the casing so as to prevent its downward movement, the lower counterweight 24 will remain in its lowermost position and the upper counterweight 28 will be moved freely upwardly and downwardly by the driving mechanism without exerting strain on the pumping string. Excessive strain on the motor 40, reduction gears 41, and chain belts 36 is also avoided.

It will be noted that the pumping unit in accordance with the invention provides a long pumping stroke limited only by the height of the mast 23 and the length of the chain belts 36. A pump stroke 30 feet long is readily obtainable. Throughout a major portion of its stroke the piston moves at a uniform optimum speed, thereby assuring maximum pumping efficiency.

While the chain belts 36 are, for convenience, shown schematically as link belts in certain of the figures, they are preferably of the kind shown in more detail in FIG. 8. The driving sprockets 38 have a peripheral configuration to receive and drive the chain 36. The upper sprockets 37 may be of like configuration, as shown in FIG. 8, or may be simple sheaves. FIG. 8 also illustrates a preferred method of attachment of the cable 31 to the cross bar 35. The cable is cut and its ends are secured in fittings 43 and 44 which have aligned apertures in which the cross bar 35 is rotatably received.

Suitable safety means are provided to retard downward movement of the lower counterweight 24 in case of cable breakage. As illustrated by way of example in FIGS. 3A and 4, the safety means comprises mounting the guide

sleeves 25 of the lower counterweight on a transverse shaft 46 rotatably supported on the counterweight 24 by bearings 47. A strong spring 48 acts on an arm 49 on the shaft 46 to tend to turn the shaft and thereby to twist the guide sleeve 25 so as to bind on the guide rods 26. An upward extension of the arm 49 normally engages the upper counterweight 28 and holds the sleeves 25 in axial alignment with the guide rods. However, if cables 21 should break, permitting the lower counterweight to fall away from the upper counterweight, the arm 49 would be released and the shaft 46 would be turned by the action of the strong spring 48 so as to cause the sleeves 25 to bind on guide rods 26 and thereby provide a braking action to retard further downward movement of the counterweight. Spring bumpers 50 (FIG. 1) are also preferably provided on a base portion of the mast below the counterweight.

FIGS. 5 and 6 illustrate an alternative arrangement of a reel for securing an upper reserve portion of the cable 13 which constitutes a portion of the pumping string. In this embodiment, a reel 51 is mounted vertically so as to be rotatable about a horizontal axis on bearings 52. A guide tube 53 guides the cable 13 to the reel. As in the embodiment illustrated in FIG. 3B, the reel is mounted on a suitable head secured to the upper end of the polished rod 14.

It will, of course, be understood that the invention may be embodied in other operating mechanisms for the pumping string. Indeed, in a preferred form of the invention, the two-part counterweight system which is characteristic of this invention are advantageously embodied in a pump operating mechanism of the walking-beam type. Thus, referring to the embodiment of the invention illustrated in FIGS. 9 to 12, inclusive, the upper end of the cables 21 are attached to the head 60 of a walking beam 62 pivoted at 64 upon a supporting frame 66. The free end of the beam 62 has mounted upon it a counterweight 24*a* corresponding to the lower counterweight of the embodiment of FIGS. 1 to 8 and having the value CW1. Driving the walking beam 62 is a motor or engine 68, corresponding to the motor 40, which is connected to the walking beam through crank arms 70 and articulated pitman rods each comprising a lower rod section 72*a* pivoted to a crank arm 70 and an upper rod section 72*b* pivoted to the walking beam. The two pitman rod sections are interconnected at a hinge joint 75 which is constructed to pivot when resistance to upward movement of the upper rod section is encountered during the up-stroke of the crank arms. In accordance with the invention, the crank arms 70 are provided with counterweight means 28*a* corresponding to the upper counterweight 28 of the embodiment of FIGS. 1 to 8 and having the value CW2. An adjustable spring bumper 50*a* is provided to limit the counterclockwise pivoting of the walking beam, particularly when it is free of connection with the crank 70 as shown in FIG. 12.

The operation of the embodiment of FIGS. 9 to 12 will be apparent from the drawings and from the foregoing description of the operation of the embodiment of FIGS. 1 to 8. Thus, as seen in FIGS. 9 and 10, during the pumping stroke of the crank arms 70 as they move downwardly in the direction F and the pumping spring moves upwardly, the two counterweights 24*a* and 28*a* act in combination in lifting the pumping string. On the other hand, when the crank arms move upwardly from the position shown in FIG. 10 to the position shown in FIG. 11, the counterweight 28*a* does not necessarily act to lower the pumping string as the walking beam pivots counterclockwise. If, for example, as shown in FIG. 12, the pumping string jams or otherwise resists downward movement at the rate corresponding to the speed of rotation of the crank arms, the hinged connection between the two portions of the pitman rods open up and the force of the motor and the counterweight 28*a* are not transferred to the walking beam.

By reason of its simple and rugged construction, the pumping unit in accordance with the present invention provides trouble-free operation with a minimum of maintenance. Moreover, the long piston stroke and uniform piston speed not only provide high efficiency of operation, but also further avoid the need of maintenance by keeping forces acting on the several components of the unit well below safe maximum values.

While illustrative embodiments of the invention have been shown by way of example in the drawings and have been particularly described, it will be understood that the invention is in no way limited to these embodiments, but may be modified within the scope of the appended claims.

It is intended, therefore, that all matter contained in the foregoing description and in the drawings shall be interpreted as illustrative only and not as limitative of the invention.

This is a continuation-in-part of my copending application Serial No. 126,761, filed June 19, 1961, now abandoned.

I claim:

1. In combination with a well pump having a cylinder and piston and a casing extending up from said cylinder and receiving liquid discharged from said pump, a pumping string connected to said piston and extending up through said casing, first counterweight means connected to the upper end of said pumping string partially to counterblance the weight of said pumping string, drive means for moving said pumping string upwardly , second counterweight means connected with said drive means, and means for transmitting force from said drive means and said second counterweight means to said pumping string and first counterweight means to move said pumping string in an upward direction only, downward movement of said pumping string being effected solely by gravity, said drive means and second counterweight means being movable through a complete stroke without movement of said pumping string and first counterweight means when said pumping string is held in uppermost position, said first counterweight means having an effective weight less than the weight of said pumping string and the combined effective weight of said first and second counterweight means being approximately equal to the weight of said pumping string plus half the weight on said piston of liquid in said casing.

2. In well-pumping apparatus comprising a cylinder and piston, a casing extending up from said cylinder and receiving liquid discharged from said cylinder, a pumping string extending up through said casing, and driving means for operating said piston through said pumping string, the improvement comprising first counterweight means connected to said pumping string partially to counterbalance the weight of said pumping string, second counterweight means connected to and movable with said drive means, and means for transmitting force from said drive means to said pumping string and first counterweight means to move said string in an upward direction only, downward movement of said pumping string being effected solely by gravity, said drive means and second counterweight means being movable through a complete stroke without movement of said pumping string and first counterweight means when said pumping string is held in uppermost position, said first counterweight means having an effective weight less than the weight of said pumping string and the combined effective weight of said first and second counterweight means being greater than the weight of said pumping string.

3. Apparatus according to claim 2, wherein the effective weight CW1 of said first counterweight means is approximately

$$CW1=\frac{7WP}{8}-F$$

and the effective weight CW2 of said second counterweight means is approximately

$$CW2=F+\frac{WL}{2}$$

where:

WP is the weight of said pumping string in air

WL is the weight on said piston of the liquid column in said casing, and

F is a selected force required to overcome friction and the viscosity of said liquid when the piston moves in a downward direction.

4. In combination with a well pump having a cylinder and piston, pulley means rotatably supported above said pump, a flexible line running over said pulley, a pumping string connecting said flexible line on one side of said pulley with said pump piston, a lower counterweight suspended on said flexible line on the other side of said pulley and having a weight less than that of said pumping string, an upper counterweight disposed over said lower counterweight and normally resting thereon but free to move upwardly therefrom, and drive means for imparting up and down reciprocatory movement to said upper counterweight, said drive means being connected with said upper counterweight only, whereby downward movement of said upper counterweight by said drive means forces said lower counterweight downwardly and thereby moves said pumping string and pump piston upwardly, while upward movement of said upper counterweight permits upward movement of the lower counterweight by the weight of said pumping string.

5. Apparatus in accordance with claim 4, wherein said upper counterweight is secured to one run of a flexible loop running over additional upper and lower pulley means and wherein said drive means is connected with the opposite run of said loop.

6. Apparatus in accordance with claim 5, wherein said drive means comprised vertically-spaced pulley means, endless belt means running over said pulley means, means driving at least one of said pulley means, and thereby driving said belt means, and means providing a driving connection between a selected point on said belt means and said flexible loop.

7. Apparatus in accordance with claim 4, wherein said pumping string consists in part of cable.

8. Apparatus in accordance with claim 7, wherein means is provided for varying the effective length of said cable and wherein reel means carried by said pumping string is adapted to receive a portion of said cable.

9. In combination with a well pump having a cylinder and piston, and a casing extending up from said cylinder and receiving liquid from said pump, pulley means supported above said pump for rotation on a horizontal axis, a flexible line running over said pulley means and having two ends, a pumping string extending through said casing and connecting one end of said line with said pump piston, a lower counterweight suspended on the other end of said line, an upper counterweight disposed over said lower and normally resting thereon, and drive means for imparting up and down movement to said upper counterweight, said drive means being connected with said upper counterweight only, said lower counterweight having a weight less than the weight of said pumping string, and said counterweights together having a combined weight

approximately equal to the weight of said pumping string plus half the weight on said piston of liquid in said casing.

10. Apparatus according to claim 9, wherein sealing means is provided at the upper end of said casing and wherein said pumping string comprises a hollow rod extending through said sealing means, and a cable extending through said hollow rod.

11. Apparatus according to claim 10, further comprising reel means mounted on said hollow rod and adapted to receive a portion of said cable, a variable portion of said cable being connected in said pumping line and the balance being reeled on said reel means.

12. A pump as defined in claim 1, wherein said first counterweight means is connected to the upper end of said pumping string through a walking beam, and said means connecting said drive means to said pumping string to transmit force to move said pumping string in an upward direction only comprises an articulated pitman rod.

13. Well-pumping apparatus as defined in claim 2, wherein said first counterweight means is connected to the upper end of said pumping string through a walking beam, and said means connecting said drive means to said pumping string to transmit force to move said pumping string in an upward direction only comprises an articulated pitman rod.

14. In combination with a well pump having a cylinder and piston and a casing extending up from said cylinder and receiving liquid discharged from said pump, a pumping string connected to said piston and extending up through said casing, a walking beam pivotally supported for oscillation about a horizontal axis and having one end connected to said pumping string, a first counterweight carried at the other end of said walking beam and having an effective weight less than that of said pumping string partially to counterbalance the weight of said pumping string, drive means for moving said pumping string upwardly, second counterweight means connected with said drive means, and means for transmitting force from said drive means and said second counterweight means to said walking beam, pumping string and first counterweight means to move said pumping string in an upward direction only, downward movement of said pumping string being effected solely by gravity, said drive means and second counterweight means being movable through a complete stroke without movement of said walking beam, pumping string and first counterweight means when said pumping string is held in uppermost position, said first and second counterweight means being in additive relation to one another and the combined effective weight of said first and second counterweight means being approximately equal to the weight of said pumping string plus half the weight on said piston of liquid in said casing.

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