Our invention relates to means for transmitting power from the ground surface to a pump located a great distance below the surface of the ground or at a very substantial distance away from the motive force. A usual field of installation is in connection with the pumping of petroleum products, such as oil together with some gas, from relatively great depths.

The patent literature contains a number of disclosures of arrangements incorporating positive displacement pumps located at the bottom or adjacent the bottom of oil wells and connected by a length, usually several thousand feet—for example, 5,000 to 12,000 feet, of pump rod, to a motor or engine adjacent the surface of the ground. One of the great problems involved in such an installation arises out of the elasticity of the relatively long pump rod, which is sufficient to render inexact, both in magnitude and in phase, the correspondence between the pump stroke at the bottom of the well and the engine stroke at the surface of the ground. It happens in practice that the reciprocatory pumping motion results in the transmission of wave vibration along the pump rod so that local stresses are not only very great but are sometimes in excess of the capacity of the material and pump rod breakage occurs. Such breakage not only results in a discontinuance of the pumping operation and some damage to the pump rod which must be replaced, but often results in very serious damage to the motive machinery which tends to disrupt itself when suddenly relieved of the pumping load.

It is therefore an object of our invention to provide an improved hydraulic pumping jack. Another object of our invention is to provide a pumping jack which is protected against damage due to pump rod or other operating failure.

Another object of our invention is to provide a pumping jack in which the stresses in the pumping rods are maintained below maximum amounts.

A further object of our invention is to provide a pumping jack which is versatile in its capabilities so as to minimize installation difficulties of a relatively standard unit under different environmental conditions.

An additional object, of our invention is to provide a hydraulic pumping jack which is susceptible of precise adjustment, not only to accord with the original installation conditions but also to accommodate variations in such conditions from time to time.

The foregoing and other objects are attained in the embodiment of the invention illustrated in the drawings, in which—

Fig. 1 is a schematic diagram of a hydraulic pumping jack in accordance with our invention;

Fig. 2(a) is a cross-section on a vertical transverse plane, of the actuating unit of our hydraulic jack, a portion of the balancing unit being shown, while

Fig. 2(b) is a continuation of Fig. 2(a), being a cross-section vertically on the stated transverse plane but showing the lower portion of the balancing mechanism and the connection of the pumping jack to the casing head;

Fig. 3 is a plan of a base plate on which the electric motor and the main pump are mounted;

Fig. 4 is a side elevation of the structure shown in Fig. 3;

Fig. 5 is a cross-section, to an enlarged scale, the plane of which is shown by the line 5-5 of Fig. 4;

Fig. 6 is a cross-section the plane of which is indicated by the line 6-6 of Fig. 5; and

Fig. 7 is a detail cross-section the plane of which is indicated by the line 7-7 of Fig. 6.

In its preferred form, the hydraulic pumping jack of our invention includes an actuating structure adapted for installation at the head of a well and for connection by a pump rod to a displacement pump adjacent the bottom of the well, the pump rod itself being connected to a balancing piston and to an actuating piston which are located respectively in a balancing cylinder and in an actuating cylinder, these being provided with hydraulic connections to a balancing tank and to a controlled supply and discharge of actuating fluid. For the control of the actuating fluid there is provided a hydraulically actuated valve responsive to the position of the actuating piston within the actuating cylinder, in accordance with a predetermined but variable selection thereof, the valve also being regulable to afford various rates of acceleration and deceleration of the actuating cylinder piston. In addition, there are various means for checking or arresting the operation of the structure in the event of unusual conditions or breakage.

Although the hydraulic pumping jack of our invention is not so restricted, it is typically installed in connection with a subterranean oil well which is provided with an outer casing extending from the surface of the ground to a point many feet therebelow, usually a point in the neighborhood of from five to twelve thousand.
feet below the surface of the ground. Within and coaxial with the casing 6 there is an interior pipe 7 which houses a pump rod or polish rod 8 extending to the actuating element of the positive displacement pump (not shown) located adjacent the bottom of the well. The casing 6 is provided with a flange 9 having a terminus 11 which receives a ring 12 on which a supporting collar 13, in threaded engagement with the interior pipe 7, rests. The ring 12 is retained in place by an adapter section 14 clamped in position to the terminus 11 by fastening means 15. Extending from the chamber 16 defined by the tubes 6 and 7 and capped by the ring 12, is an outlet conduit 17 for conducting gas emanating from the well to any convenient place. Somewhat similarly, above the collar 12 and having a chamber 18 defined by such collar, the adapter 14 and a diaphragm 19 extending across and forming part of the adapter, is a conduit 21 for conducting pumped oil to any suitable location.

The adapter section 14 is continued in a skeleton manner above the diaphragm 19 to be open to the atmosphere. The diaphragm is pierced by the polish rod 8 which also pierces a base 22 incorporated in the adapter 14 and designed to receive a motor or driving structure. Leakage into the open adapter section is prevented by a lower packing 23 and an upper packing 24. The skeleton construction of the upper portion of the adapter facilitates access to the packings 23 and 24.

Immediately surrounding the adapter 14 is the lower head 26 of a balancing cylinder the principal portion of which is formed by a circular-cylindrical shell 27 coaxial with the polish rod 8 and encompassing such rod. The balancing cylinder 27 is spanned at its upper end by a balancing piston 28 provided with a connection 29 or coupling to the polish rod 8 and having a packing or sealing rings 31 to minimize leakage. By this construction there is formed beneath the balancing piston 28 a balancing chamber, generally designated 32, communication with which is had by a conduit 33 of considerable diameter, which is joined to an adapter opening 34 integrally formed with the head 26. The conduit 33 is connected to a balancing tank 37, conveniently mounted upon a base plate 38, in turn mounted on a foundation 39, and comprising a generally closed metallic vessel having operating fluid 41, in its lowermost portion and having in its upper portion a gas 42, such as ordinary air or an inert gas such as nitrogen which is capable of being repeatedly compressed and decompressed. In effect, the balancing tank 37 acts somewhat as a surge chamber for alternate flow from such tank into the balancing chamber 32 and from such balancing chamber 32 back to the balancing tank 37, the flow through the conduit 33 being generally unrestricted and having but slight frictional retardation. The amount of fluid 41 maintained in the balancing chamber and the pressure therein are preferably arranged so that a predetermined portion of the load upon the polish rod 8, due to external factors, is substantially or entirely balanced. Likewise, so if any, which is permitted to remain varies with different installations and can be established at any desired value by appropriately regulating the characteristics of the balancing tank 37 with respect to the remaining parts of the structure.

At its bottom the balancing chamber shell 21 is fitted into an upper head 43 which is secured with respect to the remaining part of the structure by through-bolts 44 paralleling the shell 27 and engaging the upper part of the adapter 14 to afford a rigid assembly. The head 43 defines an enclosed chamber 45 encompassing a polish rod 47 which is, to all intents and purposes, an extension of the polish rod 8. The chamber 46 is terminated at its upper portion by a transverse diaphragm 48 containing a packing 49 to preload leakage. It is intended that normally the chamber 46 be subject to a pressure tending to minimize interconnection with the neighborhood of atmospheric pressure, preferably below the actual pressure of the atmosphere and perhaps considerably below actual atmospheric pressure. This range of pressure in the neighborhood of atmospheric pressure is referred to herein as substantially atmospheric. To prevent the accumulation of leakage oil in the chamber 46, it is provided at one side with a scavenger outlet 51 which is connected by a pipe 52 to the inlet 53 of a scavange pump 54 which is of sufficient capacity normally to maintain the desired pressure within the chamber 46. The pump 54 is of the positive displacement gear type and includes a drive shaft 55 which is coupled to any suitable source of power, such as an electric motor 57, mounted on the base plate 38, so that during the operation of the mechanism accumulated leakage oil within the chamber 46 is withdrawn through the pipe 52 and returned to the scavange pump 54 from the outlet 58 of which it passes through a return pipe 59 to the balancing tank 37, joining the mass 41 of fluid therein.

The section 43 above the diaphragm 48 serves as the lower head for an acting chamber 61 defined not only by the head 48 but by a circular-cylindrical shell 62 coaxial with the polish rod 47 and held in place with respect to such rod not only by the member 43 but by an upper head 63 positioned by through-bolts 64 engaging the member 43. Operating within the chamber 61 is an actuating piston 66 having rings 67 therein to reduce leakage and suitably secured to the polish rod 47 for reciprocatory movement within the cylindrical shell 62. Leakage past the piston 66 is removed from the chamber 61 by a scavange port 71 leading into the chamber 46 from whence the leakage oil can flow through the pipe 52 as previously described. In addition to the port 71, another pipe connection 68, the head 63 is provided with a lifting boss 72 to assist in dismantling or moving the attached structure.

Since the piston 66 is designed to be lifted by fluid pressure, and since its stroke is variable without mechanical restraint thereupon except what is due to the weight of the load upon the polished rod 8, we provide for precluding severe damage in the event the polish rod 8 should break and suddenly relieve the actuating piston 66 of its load. Under these conditions, the actuating piston 66 would ascend very rapidly within the cylinder 62 until such time as it uncovered, beyond its maximum normal stroke or above the end of such maximum normal stroke, a relatively large port 73 which is connected by a large port 74 to the conduit 71 which itself has a considerable diameter and conduit of large diameter communicates through a large opening with the chamber 46 from which there is but the small opening of the port 51 for scavange purposes. Hence, when the load is suddenly relieved from the rod 8 and the piston 66 rises above the port 73, the increasing fluid beneath the piston, which is tending to press it upwardly, flows out through the port 73 through the large pipe 11 and into
the chamber 45 above the balancing piston 28, This piston is consequently subjected to the full pressure of the actuating fluid, which port 58 is much too small to carry off more than a fraction of the entering fluid. Since the balancing piston 28 is somewhat larger in diameter than the actuating piston 66, as soon as the port 73 is uncovered and a transfer of fluid takes place, there is an immediate and equal large arresting force exerted upon what remains of the polish rod 8, so that, instead of damage ensuing, the reciprocating mechanism, after it passes its maximum normal stroke, is quickly arrested without damage.

In the event of sudden imposition of excess load in the opposite direction, for instance if the supply of actuating fluid to the chamber 61 should suddenly fall when the polish rod 8 is fully loaded, then the piston 66 descends rapidly to its normal lower stroke limit. But shortly below this point the piston 28 enters the bore of the lower head section 25 the outlet 34 from which is spaced above the bottom thereof and communicates therewith through a decreasingly tapered channel 76. The piston 28 and the section 26 therefore act together as an arresting dashpot, progressively damping the stroke of the piston 28 in emergency.

If desired, the lower end of the chamber 61 can also be constructed as is the lower end of the section 26, so that, by co-operating therewith, the piston 66 will augment the dashpot effect of the piston 28 in emergency.

The normal entrance of motive fluid to the actuating cylinder 61 is through a relatively large conduit 76 opening into the upper portion of the structure 43 and extending into communication with a valve casing 71, so that actuating fluid alternately flows in the conduit 16 in opposite directions to and from the valve casing to lift and lower the actuating piston 66 and its attached mechanisms. Conveniently, the valve casing 71 is disposed as a part of the housing 76 surrounding and supporting a main gear pump 79 which is mounted on the base plate 35 and which includes the drive shaft 56, so that not only is the scavenge pump 54 driven by the electric motor 57 but likewise the main pump 79 is simultaneously driven thereby. The main pump 79 includes bearings 61 for the drive shaft 56 as well as bearing 62 for the pump idler gear 83. The pump gears are disposed within an interior pump casing 84 and their direction of rotation is such that a port 86 in the interior casing 84 serves as a discharge port into a chamber 87 enclosed between the interior casing 84 and the exterior housing 78.

Within the valve casing 71, which is integral with the outer pump housing 78, there is disposed a sleeve 91 which has various ports therein for regulating flow to and from the pump. Thus, there is centrally disposed a low-pressure port 92 for the pump inlet and adjacent the ends of the sleeve, a pair of high-pressure ports 93 and 94 which latter communicate with the chamber 87. Also piercing the sleeve 91 is a port 96 forming the outlet of the pipe 76 which leads to the actuating chamber, as well as a port 97 which is provided for the equally communicating with the balancing tank 37 through a pipe 98 extending from the port to a junction with the transfer pipe 33.

Adapted to operate within the sleeve 91 to govern the fluid flow between the various ports, there is provided a piston 101 which includes an axial stem 102, a center land 103, and end lands 104 and 105. When the piston valve 101 is in one extreme position, as shown in Fig. 6 of the drawings, the pipe 98 is placed in communication with the low-pressure side 92 of the pump, while the conduit 76 is placed in communication with the high-pressure chamber 87 thereof. Thus, fluid is extracted from the balancing tank 37 by the pump and is forced into the actuating chamber 46 thereby lifting the piston 66 therein and effectuating an oil pumping stroke. But, when the piston valve 101 is in its opposite extreme position, as shown in Fig. 1 of the drawings, then the conduit 76 is in communication with the low-pressure port 92, while the conduit 98 is placed in communication with the high-pressure chamber 87, and the pump is effective to withdraw fluid from the chamber 61 and to transfer or discharge it into the balancing tank 37, thus permitting the piston 66 to lower by gravity but at the rate of withdrawal of the actuating fluid by the pump 79. Thus, if the piston valve 101 is made to reciprocate between its extreme positions, there will be a corresponding reciprocation of the piston 66 and a resulting pumping action.

The maximum downward acceleration is normally limited by the liquid withstanding or evacuating capacity of the main pump 79 acting through the pipe 76, and the maximum upward acceleration may be similarly limited or may be established by a by-pass valve 107 set to allow flow through a pipe 108 from the pipe 76 directly to the conduit 98 leading to the tank 42 whenever the pressure within the pipe 76 is twice the pressure within the tank 42, for example.

We preferably provide means for controlling the piston valve 101 in accordance with several factors, some at least of which are definite or variable. For example, under variable conditions at one installation, or even under varying conditions in different installations, it is desirable to vary the length of stroke of the piston 66. This is for several reasons, one of which is that different stroke pumping units may be disposed at the bottom of the well to which the operating structure is to be connected, and another of which is that the amount of stretch or yield of the long pumping rod. That is, under some conditions, a required stroke of eight feet in a pump at the bottom of the well, because of the elongation of the rod, requires a considerably greater stroke of the actuating unit. Furthermore, conditions of pumping change; for example, the relative proportion of gas and oil in the pumped fluid, which render a variation in stroke desirable. While a normal stroke is in the neighborhood of approximately ten feet, and any fraction of that or a similar quantity can be utilized, we have illustrated herein an arrangement in which five various strokes are possible in accordance with the operator's selection. We therefore provide means which are responsive to a selected position of the piston 66 within the cylinder 82, for affecting the piston valve 101 to end the upstroke of the piston 66.

At appropriately spaced intervals along the walls of the cylinder 82, we provide a plurality of conduits 111, 112 and 113 which preferably extend to a ported casing 113 where in a selector 114 is disposed. The selector is always connected by a duct 116 to the piston valve 101, albeit sometimes indirectly, so that by appropriately positioning the selector 114 the device can be made responsive to a selected portion of the piston 66. That is, when the piston
in rising uncovers the selected one of the conduits 111, 112 and the like, the pressure fluid within the cylinder 62 then flows through the connected one of the conduits 111, 112 and the like and, through the selector 114, into the conduit 118.

Usually it is not necessary to have any stroke variation at the bottom portion of the piston travel, and but a single control point is necessary there. At the same time, if desired, the plurality of ports utilized at the upper end of the cylinder and their selector valve can be substantially duplicated at the lower end. As illustrated, however, there is a single lower control port 118 which is uncovered when the piston approaches the lower portion of its stroke, so as to subject such port to substantially atmospheric pressure.

When the piston is above such port it is subjected to the same pressure that exists within the line 176 for example, which is considerably above atmospheric. In order that the higher pressure will not be effective upon the control instrumentality as the piston in rising uncovers the port 118, but will be effective only as the piston in rising uncovers the selected one of the ports 111 or 112, we provide a pipe 119 connecting the port 118 with the pipe 116 but interposes a check valve 121 in the pipe 119 which is closed by higher pressure in the chamber 61, and also interposes a check valve 122 in the pipe 116 between the selector valve 114 and the junction of the pipe 116, which check valve is closed by higher pressure on the side of the pipe 119. Thus, whether or not the high pressure in the pipe 116 drops to its lower value depends upon the uncovering of the port 118 by the descending piston 66 adjacent the lower part of the cylinder 62 while the increase of pressure within the pipe 116 from the lower value to the higher value depends only upon the uncovering of the selected one of the ports 111 and 112 by the ascending piston 66 adjacent the upper portion of the stroke.

In accordance with our invention, we do not actuate the piston valve 101 directly but utilize a pilot valve or servo mechanism for this purpose in order to increase the sensitivity of response of the mechanism. For that reason the pipe 116 is connected to a chamber 123 formed in a pilot valve body 124 secured to one end of the housing 177. Within the chamber 123 is a differential piston plunger 126 which has a relatively large piston head 127 operating within the chamber 123 and subject to the pressure variations in the line 116. Acting upon the opposite side of the piston head 127 is pressure fluid within a chamber 128 which is in communication through a duct 129 with the high-pressure chamber 87 of the main pump. But the entire face of the piston 127 is not effective within the chamber 128 since there merges therewith a smaller piston 131 operating within a cylinder 132 of reduced diameter, which cylinder is then enlarged for communication through a pipe 133 with the inlet 53 of the scavenge pump 54. Leading from the cylinder 132, along a port 141 is a duct 142 the pressure in which is utilized to control the piston valve 101.

To determine the particular pressure from time to time existing within the duct 142 in cooperation with the piston 131, there is a piston head 143 on the stem of the plunger 126 of substantially the same diameter as the head 131. The relationship of the piston heads 131 and 143 is such that in one extreme position thereof the high-pressure conduit 129 communicates through the cylinder 132 with the pipe 142 and consequently subjects the pipe 142 to the relatively high pressure of the discharge of the main pump; whereas in the other extreme position the piston heads 131 and 143 the pipe 142 is in communication through the cylinder 132 with the pipe 133 extending to the scavenge pump 54, thus subjecting the pipe 142 to a relatively low pressure.

The action of the differential piston plunger 126 in occupying either of its extreme positions is subject to the pressure existing within the duct 116. For example, when the duct 116 is substantially at atmospheric pressure, then the much higher pressure from the pump 87 through the pipe 129 is effective to displace the head 121 within the chamber 123 toward the left in Fig. 1 and to permit immediate communication between the duct 129 and the pipe 142. When, however, the pressure in the pipe 116 is increased due to uncovering of the selected one of the ducts 111, 112 and the like by the ascending piston 66, then such superior pressure is effective upon the entire face of the head 127 to displace the differential piston valve toward the right, as seen in Fig. 1, within the chamber 123, not only to cut off communication between the duct 129 and 142 by the action of the piston head 131 but also to uncover direct communication between the pipe 142 and the pipe 133 by displacement of the piston head 143, so that the pressure within the pipe 142 is immediately varied from its maximum value to its minimum value. When the pressure in the pipe 116 drops, the reverse action of the plunger 124 occurs and the pressure in the pipe 142 is immediately increased to the higher value. The extreme pressure variation in the pipe 142 occurs almost instantly despite the relatively gradual uncovering of the ducts 111 and 112 or 116, is effective to produce a corresponding operation of the main piston valve 101, although, in the event a slower operation of the main valve is indicated—which it usually is to afford a smooth reversal of stroke—we provide in the duct 142 a reguilaible needle valve 148 for governing the rate of flow through to the conjoined portion of the pipe 142.

The regulated flow into and from the pipe 142 is utilized differentially to actuate the piston valve 101. The valve at this point within the sleeve 91 to define a chamber 148 in communication with the duct 142 so that the entire cross-sectional area of the valve piston is subjected to the pressure transmitted by the pipe 142 to the chamber 148. Extreme movement of the valve 101 toward one end of the chamber 148 is regulated by an adjustable set-screw 149 enclosed in a cap 151 to preclude external leakage. At its opposite end, the valve 101 is likewise limited in stroke by a similar adjustable set-screw 152 which is enclosed in a leakage-preventing cap 153 and which is effective against a reduced stem 154. This stem is part of the valve 101 and is slidable within a chamber 156 always in communication with the high-pressure chamber 81 of the main pump through a conduit 157. A chamber 158, intake valve 102 in communication between the differential area of the land 156 and the body 159 within which the stem 154 operates, is connected to the scavenge pump 54 by a pipe 161 extending from the chamber 158 to a junction with the pipe 52.

When the relatively high pressure from the main pump is solely effective within the chamber 156 upon the stem 154, the valve 101 is translated to an extreme position against the stop-
screw 149, and this is the case when the pressure within the pipe 142 is relatively low, which occurs just after the rising piston 66 has uncover ed one of the ports, such as 112, for example. This is the condition illustrated in Fig. 1, in which the valve 101 places the actuating cylinder 62 in communication with the low-pressure side of the main pump so as to return the piston. But, although the high pressure continues to act within the chamber 156 against the stem 154 during most of the descent of the piston 66, when the piston 66 approaches the lower end of its stroke and uncovers the port 118 to the atmospheric pressure existing above the piston 66, then the pressure within the chamber 123 drops, and the pilot valve 126 is translated so as to connect the high-pressure pipe 129 through the pipe 142 to the chamber 148, thus subjecting the relatively large end of the piston valve 101 to high pressure. This pressure is substantially the same as that in the chamber 156, but since the area of the end of the piston 101 is considerably greater than the effective area of the stem 154, the valve 101 is translated into a position connecting the pipe 76 with the high-pressure chamber 87 of the main pump. Consequently, again there is exerted an upward pressure on the piston 66 to begin a new stroke in an upward direction.

Since the rate of translation of the main valve 101 from one extreme position to the other is dependent upon the rate at which fluid can flow into and out of the chamber 148 through the pipe 142, and since this rate of flow is under the control of the needle valve 146, the rate of reversal of the piston 66 at the top and at the bottom of its stroke can be set at any desired value, thereby precluding the occurrence of excessive stresses in the polished rod 8. None of the various valves is balanced in any intermediate position but all are positively impelled from one extreme position to the other so that they cannot stick or balance in any intermediate location to stall operation. Thus, the ordinary operation of the structure is very smooth and exactly as adjusted and regulated, although the length of the stroke can readily be altered by changing the selector valve position. Yet if an accident should occur and the polished rod 8 should break, the structure is automatically arrested at the upper extremity of the stroke by virtue of by-passing of the actuating fluid to form an arresting cushion; or, if there should be a sudden actuating fluid failure, the construction of the lower part of the actuating cylinder is such as to arrest the piston if it should move accidentally in that direction beyond its maximum stroke.

We claim:

A hydraulic pumping jack comprising a polished rod, a balancing cylinder of predetermined diameter coaxial therewith, a balancing piston in said balancing cylinder and fast on said rod to provide a balancing chamber below said piston and retarding chamber above said piston, an actuating cylinder of smaller diameter coaxial with said rod, an actuating piston in said actuating cylinder to provide an actuating chamber below said actuating piston and another chamber above said actuating piston, means for supplying working fluid under pressure to said actuating chamber and means for supplying fluid under a lower pressure to said balancing chamber, means including a restricted conduit for withdrawing fluid from said retarding chamber, a conduit having a diameter relatively large with respect to said first-mentioned conduit and connecting said retarding chamber and said other chamber and means for connecting said working chamber with said retarding chamber and said other chamber upon an upward stroke of said actuating piston above the normal maximum stroke thereof, said restricted conduit constituting the sole outlet for fluid from said retarding chamber and said other chamber during said upward stroke above said normal maximum stroke.

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