Jan. 23, 1940. H. E. GRAU ET AL 2,187,969

DRILLING SYSTEM

Filed March 21, 1938 3 Sheets-Sheet 1

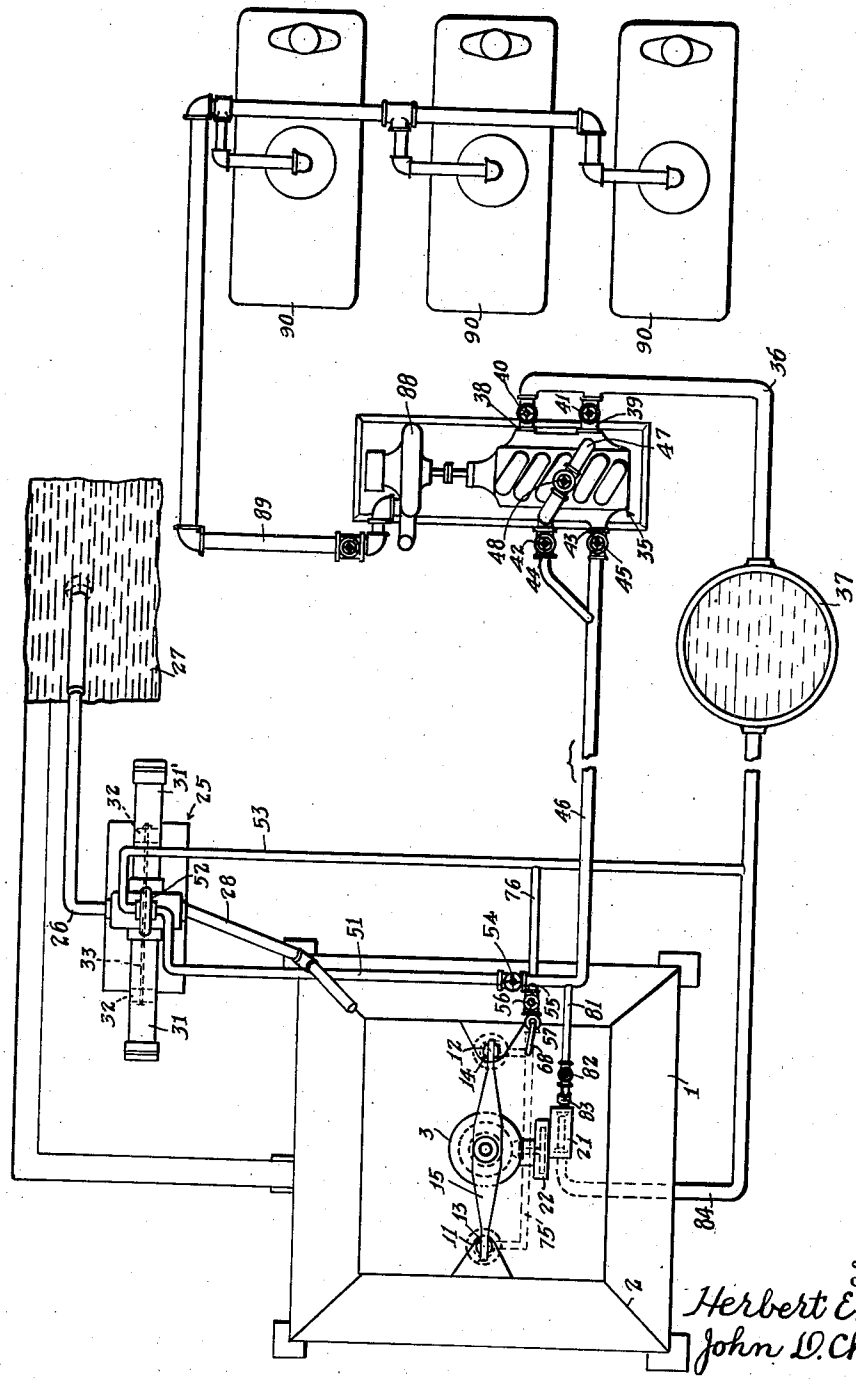


Fig. 1

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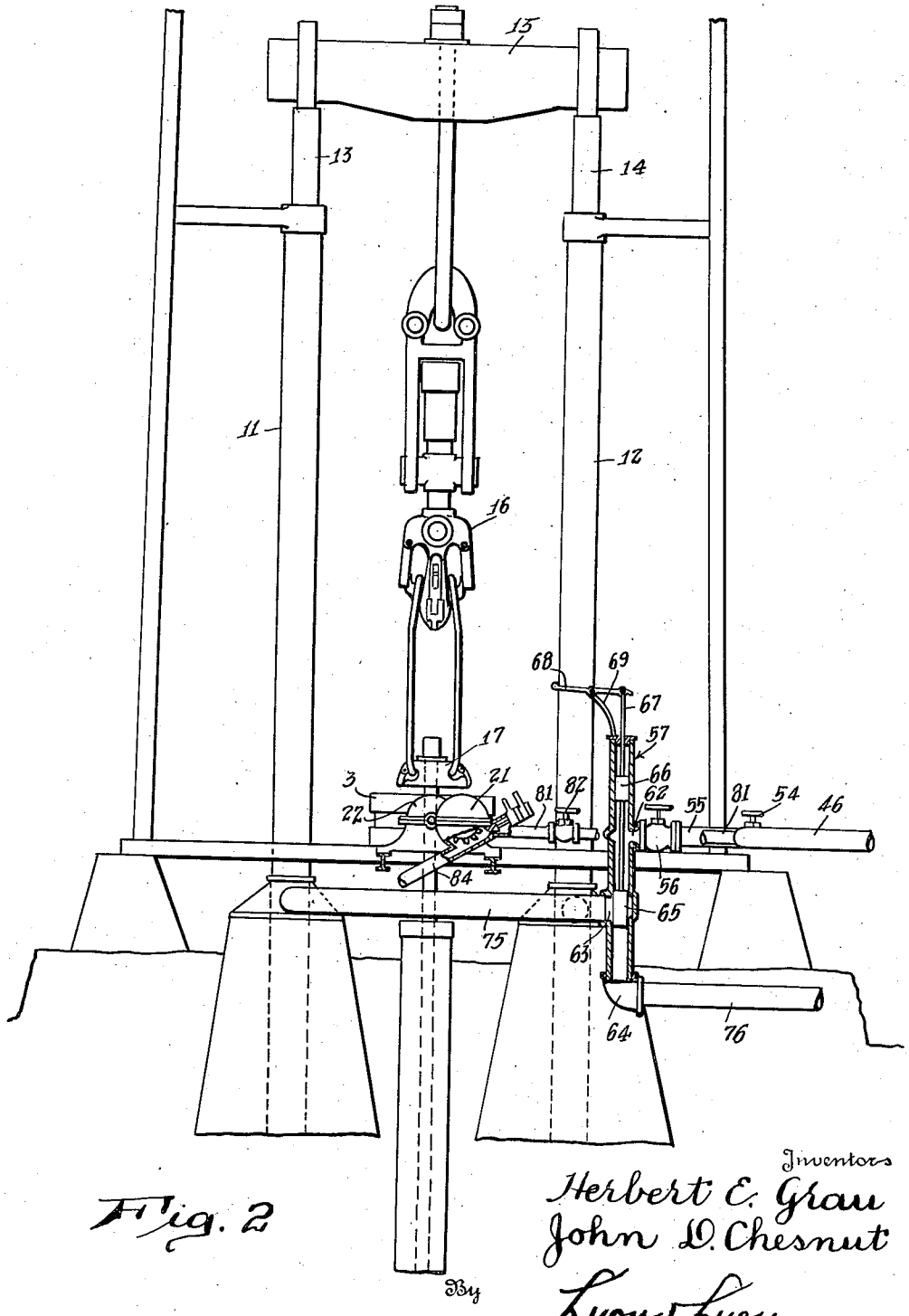


Fig. 2

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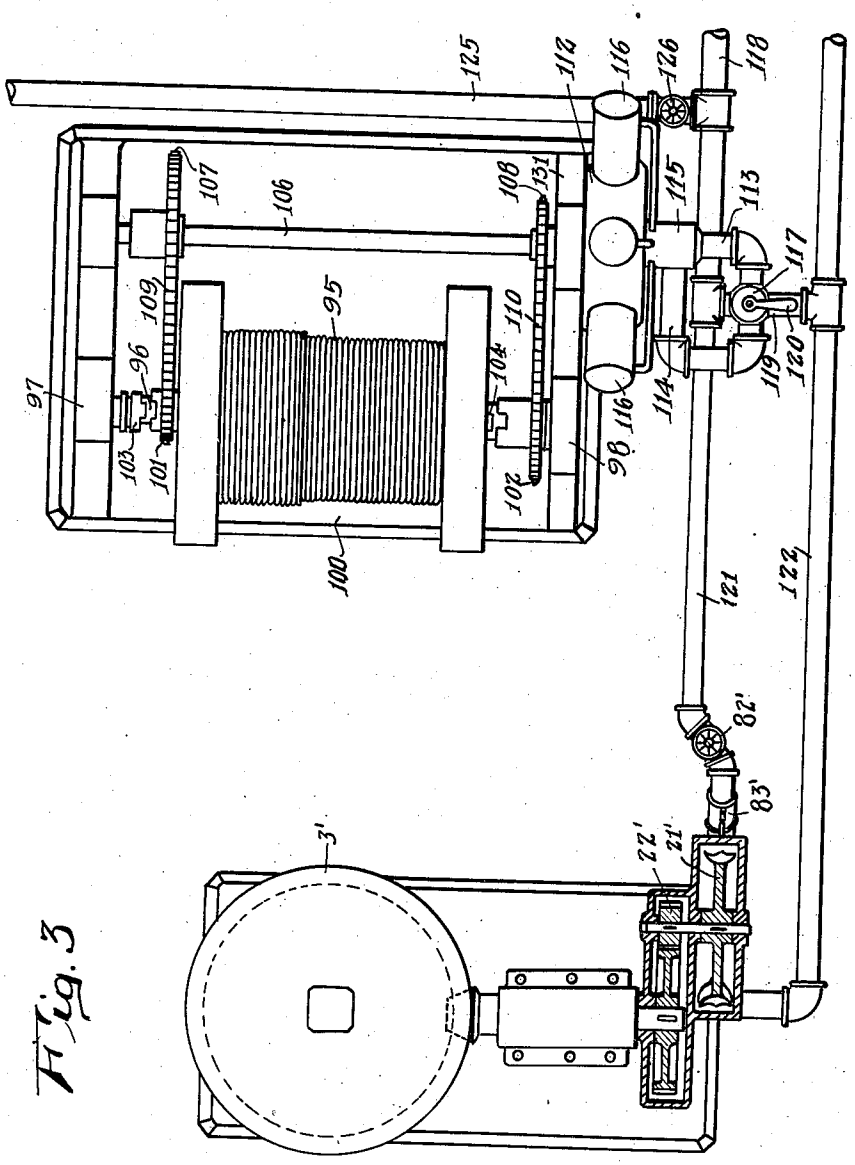


Fig. 3

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2,187,969

DRILLING SYSTEM

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Application March 21, 1938, Serial No. 197,102

7 Claims. (Cl. 255—19)

This invention relates generally to deep well drilling, and is directed particularly to an improved hydraulic well-drilling system.

In the constant search for more oil reserves, oil wells are being drilled to ever increasing depths. At the present time the limiting factors controlling the depths obtainable are the capacity of available equipment to withstand the increased weights and pressures incidental to deep drilling, and the operating cost. Various attempts have been made to provide equipment which will withstand the enormous stresses imposed on it, and which can be operated efficiently. The modern trend is toward so-called "power-units" driven by internal combustion engines mainly because of the inability of steam-driven mud pumps to provide the required pressures and volumes. It should be noted in this connection that for pumping the mud, substantially all modern drilling units include standard duplex, double-acting pumps, basically the same as those used since the advent of rotary drilling. Because of the pressure limitations of this type of pump, the mud pump is the chief factor limiting the depths obtainable with these drilling units.

Various types of power units and drives have been developed in attempts to increase the capacity and the operating range of the mud pumps, but it is a significant fact that whatever type of power unit previously employed was most satisfactory for driving the mud pumps was not best suited for operating the hoist and the rotary table. The flexibility desired in the rotary table drive and in the drive for the drawworks was not inherent in the power units capable of operating the mud pumps at the required capacity, and necessitated expensive and cumbersome auxiliary speed changing and speed control devices, if a common source of power was utilized.

As an alternative, separate power units for the various devices have been resorted to. However, although not always recognized, it happens that the hoist and the mud pumps require approximately the same horsepower, and are seldom, if ever, operated simultaneously. The rotary table and the mud pumps are operated simultaneously but the rotary table requires a relatively small amount of power, and a prime mover of sufficient capacity to handle these units will have adequate capacity for any load imposed thereon by the hoist. For this reason, the provision of separate sources of power for the mud pumps and the hoist and rotary table is from a power standpoint unnecessary, and could be avoided if there were available a common power source having operating characteristics suitable to mud pumping, hoisting, and driving the rotary table.

Hydraulic equipment is recognized as being admirably suited to hoisting and feeding of drill pipe, because of the ease and smoothness of manipulation and the nicety of control of the feed. However, heretofore hydraulic hoisting and feeding means have required extra equipment for providing the pressure liquid, in addition to the usual rotary table and mud pump drives.

A principal object of this invention is to eliminate the defects mentioned and provide a drilling equipment having a single common power source, that gives high desirable operating characteristics for each of the different units, and at the same is simple, efficient, and reliable.

In general, this object is achieved by employing a hydraulic system comprising a single prime mover driving a pump supplying power-liquid which actuates the rotary table, hoist, and mud pump hydraulically. The prime mover need be of a capacity only sufficient to handle the hoisting load, and this capacity will be sufficient to handle the rotary table and the mud pump.

A fully hydraulic system such as referred to herein is made possible by the development of a hydraulic mud pump, the operating characteristics of which are such as to make it well adapted to handling abrasive drilling mud in the wide range of volumes and high pressures required for deep drilling. It may be noted that a centrifugal pump would be ideal for handling drilling mud, from a standpoint of operating characteristics, but is not capable of standing up for any length of time if handling the abrasive mud directly, because of rapid abrasion of parts. However, by utilizing the centrifugal pump to supply a clear motive liquid in required volumes and at the required pressures, and by transmitting the volume displacement and pressure of the clear motive liquid to the drilling mud by means of a hydraulically actuated mud pump adapted to handle the abrasive mud, the advantages inherent in the centrifugal pump being made available without subjecting it to abrasion by the mud.

By the provision of a hydraulic mud pump, it is possible to employ a hydraulic hoist and hydraulically driven rotary table without requiring an additional prime mover or extra power liquid pumps. The centrifugal pump is not only ideal as a source of power-liquid for the mud pump, but also is well adapted to operate a hydraulic hoist and a hydraulic motor for operating the rotary table.

An inherent characteristic of centrifugal pumps which makes them especially well adapted to this service, is the ability to compound them either in series or in parallel, to provide a wide range of volumes and pressures, and a further feature of the invention is a hydraulic drilling system including a prime mover, a series-parallel multistage centrifugal pump or a plurality of centrifugal pumps connectible in series or in

parallel, and driven by the prime mover, with a hydraulic mud pump, a hydraulic hoist, and a hydraulically actuated rotary table driven by motive liquid supplied by the centrifugal pumps.

In drilling deep wells, the time elements is an important factor, and delays occasioned by failure of any of the equipment are very costly. Stand-by units are consequently considered essential in order to avoid cessation of operations while repairing equipment. It is usual practice to provide extra mud pumps, and, particularly when power units such as internal combustion engines are used as prime movers, a stand-by engine is considered necessary. However, the usual practice is to provide one engine for the hoist and rotary table, and one for the mud pumps, with provision for compounding them when necessary and for substituting either one for the other. In such arrangements, however, it will be evident that a full stand-by unit is not provided, since one of the units must cease its normal function in order to act as a substitute for the other in case of breakdown of the latter.

In a fully hydraulic system according to our invention, however, a single prime mover and centrifugal pump is provided having adequate capacity for operating each of the units of the rig at full capacity, and consequently a stand-by unit such as an additional steam turbine and centrifugal pump will be a full stand-by unit, capable of taking over all of the duties of the primary unit and permitting continuation of all of the drilling activities during shut-down of the primary unit. As stated previously, both the primary unit and the stand-by unit are of a type particularly well adapted to operating each of the units.

Another advantage of our system results from the fact that when a steam engine is employed as a source of power, the boiler must be located a substantial distance from the well to reduce the fire hazard. In existing systems in which the mud pump, hoist and rotary table are driven directly by steam engine, long steam lines to the boiler are required involving large heat losses. In our system, however, only one steam engine (driving the pump) is required and it may be positioned close to the boiler, the power being transmitted to the hydraulically actuated devices located at the well through the medium of the motive liquid, which may readily be conveyed through pipes of sufficient size to keep the pressure drop, and resultant power loss, small.

Other objects, features, and advantages will be apparent from the following description, taken in conjunction with the accompanying drawings, wherein

Fig. 1 is a lay-out, in plan, of a hydraulic drilling system, incorporating the invention;

Fig. 2 is an elevation of the hydraulic hoist and rotary table drive of Fig. 1; and

Fig. 3 is a plan view of a modified hydraulic hoist and a rotary table drive.

Referring to Fig. 1, the usual well derrick floor is indicated at 1, and a derrick is diagrammatically shown at 2. A conventional rotary table is shown at 3.

In the hydraulic drilling system of this form of the invention, the conventional drum-type drawworks is replaced by a plunger-type hydraulic hoist, preferably of the type disclosed in the patent to Herbert E. Grau and Andrew J. Colmerauer, No. 1,790,913, granted February 3, 1931. This hoist comprises generally a pair of unusually long hydraulic cylinders 11 and 12 (Fig. 2) disposed with approximately the lower halves thereof sunk within wells beneath the derrick floor, and with the upper halves projecting above the derrick floor. Piston rods 13 and 14 having pistons at their lower ends are reciprocable in the cylinders, the stroke of the pistons being preferably sufficiently long to handle a standard 80-foot stand of drill pipe at one stroke. A crosshead 15 connecting the upper ends of the piston rods supports the usual drilling hook 16 and other pipe-handling equipment such as the elevator 17.

The rotary table 3 is driven by a Pelton wheel 21 through reduction gearing 22.

The hydraulic mud pump indicated at 25 is provided with a mud suction inlet 26 extending to the usual mud pit 27, and a mud discharge pipe 28 extending to the usual mud connection on the rotary swivel (not shown). The mud pump may be of the specific form disclosed in the copending applications of Aladar Hollander and Waldemar F. Mayer, Ser. No. 197,140, filed concurrently herewith, or that disclosed in the copending application of Waldemar F. Mayer, Ser. No. 197,142, also filed concurrently herewith. It comprises generally a pair of aligned cylinders 31, 31' in which are reciprocable a pair of pistons 32, 32' connected to opposite ends of a common piston rod 33. Motive liquid is alternately admitted to the inner ends of the cylinders to reciprocate the pistons, and mud is alternately drawn in and forced out of the outer ends of the cylinders by the reciprocation of the pistons. As disclosed in the copending applications referred to above, a surge piston arrangement is provided for insuring continuous and steady flow of discharge mud and of motive liquid during reversal of the stroke of the pistons. The pressures of motive liquid and of mud on opposite sides of the pistons are substantially equal, with the motive liquid pressure only slightly higher than the discharge mud pressure. The displacement of motive liquid and mud is obviously equal. It will thus be seen that a hydraulic mud pump of this type transmits the pressure and volume characteristics of the motive liquid to the drilling mud, while acting as a barrier between the two fluids, preventing admixture thereof. Any slight leakage will be of motive liquid into the mud, because of the slightly higher pressure of the former, but this is not objectionable inasmuch as it is necessary to add make-up water to the drilling mud from time to time to compensate for that lost in the formations being penetrated.

The three hydraulic units mentioned above are selectively actuated by a motive liquid, preferably water, supplied by a centrifugal pump As shown in Fig. 1, the centrifugal pump, generally indicated at 35, is of the multi-stage series-parallel type, wherein the stages are divided into two groups capable of being connected either in series for high pressure, or in parallel for large volume at less pressure. A water supply line 36 leads from a water tank 37 to a pair of branch inlets 38, 39 controlled by cut-off valves 40, 41. Discharge outlets 42, 43, controlled by cut-off valves 44, 45 merge into a common discharge pipe 46. A cross-over 47 controlled by valve 48 extends from outlet 42 of one group of stages to inlet 39 of the other group. When valves 40, 41, 44 and 45 are open and valve 48 is closed, the two groups of stages pump in parallel to deliver a relatively large volume of water at relatively low pressure. When valves 44 and 41 are closed, however, and valve 48 is opened, the discharge

of the first group of stages enters the intake of the second group and the two groups pump in series to deliver a decreased volume of water at increased pressure.

A branch pipe 51 for high pressure water extends from the common discharge pipe 46 to the pressure water inlet 52 of the mud pump 25, and an exhaust conduit 53 extends from the water outlet of the mud pump to the tank 37. A cut-off valve 54 is interposed in the mud pump water supply line 51.

A branch conduit 55 also extends from discharge pipe 46 to the hydraulic hoist. A main cut-off valve 56 is interposed in conduit 55 in advance of a balanced three-way hoist control valve generally indicated at 57. As shown in Fig. 2, the control valve comprises a vertically disposed valve chamber 61 having an upper inlet connection 62 for pressure water, an intermediate port 63 leading to the hoist cylinders, and a lower discharge outlet 64 connected to the supply tank 37. A balanced valve comprising a pair of piston valves 65 and 66 are reciprocable on the chamber 61 by means of a valve stem 67. A hand lever 68 pivotally mounted on an upstanding bracket 69 on the valve chamber is pivotally connected to the valve stem for the reciprocation of the latter. The valves 65 and 66 are so disposed on the valve stem in relation to the inlet 62 and port 63 that either the inlet 62 or the port 63 may be closed, or these two ports may be placed in communication with each other to admit pressure water to the hoist cylinders, or port 63 and discharge outlet may be placed in communication with each other to vent water from the hoist cylinders to permit lowering of the pistons and the suspended load. A conduit 75 extends from the port 63 of the hoist control valve 57 to the lower ends of the cylinders 11 and 12, and an exhaust conduit 76 extends from the exhaust port 64 of the control valve to the water discharge conduit 53 of the mud pump.

A water supply conduit 81 extends from the main supply line 46 to the Pelton wheel 21, a cut-off valve 82 and a fluid-actuated needle control valve 83 being interposed in this conduit. An exhaust conduit 84 extends from the Pelton wheel back to the water tank 37.

It will be observed that the control valves 57 and 83 for the hoist and rotary table, and the cut-off valves 54, 56 and 82 are all located within easy reach of the driller, whose position is between the control valves 57 and 83.

In the form of the invention illustrated in Fig. 1, the centrifugal pump is driven by a steam turbine 88. A steam supply line 89 furnishes steam to the turbine from a battery of boilers 90.

In Fig. 3 there is shown a modified form of hydraulic hoist, embodying a simplified application of our completely hydraulic system to a conventional rig, embodying a drum-type drawworks. While it is true that one of the principal advantages of a completely hydraulic drilling system lies in the fact that it enables the use of a plunger-type hoist without the necessity of providing additional pumping equipment solely for operating the hoist, the application of such a system to a conventional drilling rig has in itself many distinct advantages. In its simplest form, this arrangement consists in the provision of a hydraulic motor connected to the drawworks for rotating the drum. The motor may be of any desired type of rotary hydraulic motor, such as a Pelton wheel or a radial piston motor, as shown.

For purpose of illustration, a simple form of two-shaft drawworks is shown. The usual cable drum 95 is secured to a drum shaft 96 journaled at its opposite ends in bearings 97, 98 mounted on pedestals formed on the base 100. A pair of sprockets 101, 102 are selectively connectible to the drum shaft by sliding jaw clutches 103, 104, the sprockets being of different diameters to provide two drum speeds. A line shaft 106 has keyed thereto a pair of sprockets 107, 108, connected to sprockets 101, 102 by chains 109, 110 whereby the drum shaft and drum may be driven by the line shaft at either of two speeds.

Connected directly to one end of the line shaft 106 is a hydraulic motor 112, shown herein as of the reversible, radial piston type. Intake and exhaust connections 113 and 114 are connected to a valve chamber 115 wherein suitable valve mechanism is provided for controlling the admission and exhaust of motive liquid to the cylinders 116 of the motor. A four-way reversing valve 117 selectively admits motive liquid to one conduit 113 or 114 from a supply pipe 118 and simultaneously connects the other conduit 114 or 113 to a return pipe 119. By suitable manipulation of the handle 120 of the valve 117 the hoisting drum 95 may be rotated in either direction at a wide range of speeds. With this type of hydraulic motor the lowering the drill pipe may be controlled by the motor, the latter functioning at such times as a brake.

The rotary table 3' is shown as being driven by a Pelton wheel 21' through reduction gearing 22', as in the form of the invention shown in Figs. 1 and 2. A control valve 83' and a shut-off valve 82' are interposed in the supply line 121 connected to supply line 118. The exhaust from the Pelton wheel returns to a water tank as at 37 in Fig. 1, through a return line 122. The exhaust line 119 of the motor 112 is also connected to the return line 122.

A supply line 125 branches off from the main supply pipe 118 and leads to the hydraulic mud pump 25 shown in Fig. 1. A shut-off valve 126 is interposed in line 125 within reach of the operator from his station near the hoist control valve 117. A return line (not shown) is provided from the mud pump to the water tank, as in Fig. 1.

In the form of the invention last described, the advantages of a fully hydraulic system are made available for use with a conventional drilling rig, although the full advantage inherent in the fully hydraulic system are not realized. As stated previously, the advantages of a plunger-type hoist over the drum type are many. In the latter the entire weight of the suspended drill string is carried by the derrick. Futhermore, in order to handle the long strings of drill pipe the number of reeves of the cable through the crown block and travelling block is so large that lifting speed is very slow and free lowering of the unloaded hock is almost impossible because of the cable friction in the blocks. The plunger-type hoist, on the other hand, supports the suspended weight independently of any derrick, and does away entirely with the blocks and wire lines. The raising and lowering speed may be varied as desired, and with a centrifugal pump supplying the power liquid, as the load decreases with shortening of the drill string when coming out of the well, the raising speed automatically increases. The operation is smooth and noiseless, whereas with the usual drum-type drawworks the manipulation of pipe is characterized by a series

of jerks and vibrations and the noisy operation of chain drives. Moreover, the hydraulic piston type of hoist permits accurate determination and control of the weight on the bit, there being no wire lines, travelling block or crown block with their attendant high friction loads to interfere with the determination of the true load on the drilling bit.

Furthermore, irrespective of whether or not the hydraulic hoist is employed, there are peculiar advantages to the use of the hydraulic motor drive for the rotary table and the balanced piston mud pump, both supplied by parallel connection from a common source of motive liquid. A difficulty frequently encountered when drilling through clayey formation, is that the clay "balls up" on the bit. This increases the torque required to rotate the bit, thereby tending to cause a decrease in rotative speed which, in turn, tends to aggravate the balling up. The balling up of the bit, however, also increases the resistance to circulation of drilling mud through the bit, thereby causing the mud pressure to increase. When applicant's balanced piston mud pump is employed, the motive liquid pressure increases in response to the mud pressure increase, and since the mud pump and rotary table are connected to the same source of motive liquid, the increased pressure of motor fluid produced by the decreased flow of mud, causes the rotary table to speed up and the balled up clay is thrown off the bit by centrifugal force.

It will be apparent from the foregoing description and remarks that a fully hydraulic drilling system is far superior to the conventional system now in use, and that such a system is made possible by the development of a hydraulic mud pump. The latter enables the use of a centrifugal pump as the power liquid source, which pump is not only highly efficient but is also particularly well adapted to operate each of the units of the system, because of its operating characteristic. Its flexible pressure and volume characteristics make it possible to employ a steam turbine as a prime mover and to obtain a wide pressure and volume range while operating the turbine at constant speed. The steam turbine is recognized as being by far the most efficient of any steam-driven prime mover, and since they operate efficiently within the same speed range as centrifugal pumps, the turbine and pump can be directly connected together, thus eliminating the necessity of costly reduction gears which are required with gas engine drives, or the expensive variable control systems required with A. C. electric motors.

We claim:

1. A hydraulic well drilling system comprising a rotary drill having mud passages therethrough and a hollow drill string for supporting and rotating said drill and conducting mud thereto, a rotary table for rotating the drill string and drill and a hydraulic motor for rotating the rotary table, said motor supplying a torque to said table which increases with an increase in pressure of motive liquid supplied to said motor, a hydraulically actuated mud pump for forcing drilling mud through said drill string and drill, said mud pump being of the variable speed piston type in which the volume of mud pumped bears a fixed relation to the volume of motive liquid consumed and the pressures of the mud and motive liquid are interdependent, and a common source of motive liquid supplying motive liquid to both said mud pump and said hydraulic motor in parallel connection, whereby an increase in resistance to flow of mud through said drill automatically increases the pressure of said motive liquid and the speed of rotation of said hydraulic motor, rotary table and drill.

2. A hydraulic well drilling system as described in claim 1, in which said source of motive liquid comprises a centrifugal pump driven by a prime mover.

3. A hydraulic well drilling system comprising: a hydraulically actuated rotary table, a hydraulically actuated hoist, a hydraulically actuated mud pump, a series parallel centrifugal pump and fluid connections from said pump to said rotary table, hoist and mud pump, all in parallel relation, whereby said motive liquid may be delivered under pressure selectively to the rotary table, hoist and mud pump, said centrifugal pump being operable in series connection to obtain increased pressure at lower volume, or in parallel to obtain increased volume at lower pressure.

4. A hydraulic well drilling system comprising a rotary drill having mud passages therethrough and a hollow drill string for supporting and rotating said drill and conducting mud thereto, a hydraulically actuated hoisting mechanism for supporting and feeding the drill string and drill, a rotary table for rotating the drill string and drill and a hydraulic motor for driving the rotary table, said motor supplying a torque to said table which increases with an increase in pressure of motive liquid supplied to said motor, a hydraulically actuated mud pump for forcing drilling mud through said drill string and drill, said mud pump being of the type in which the volume of mud pumped bears a fixed relation to the volume of motive liquid consumed and the pressures of the mud and motive liquid are interdependent, and a common source of motive liquid supplying motive liquid to said hoisting mechanism, rotary table motor, and mud pump in parallel connection.

5. A system as described in claim 4, in which the maximum power requirement of the hoisting mechanism is approximately equal to the combined power requirements of the rotary table and the mud pump, and in which said source of motive liquid comprises a pump having a motive liquid capacity substantially just sufficient to handle either the hoisting mechanism alone or the rotary table and mud pump simultaneously.

6. A system as described in claim 4, in which said source of motive liquid comprises a steam generator located a sufficient distance from the well to eliminate fire hazard, a steam-driven prime mover disposed relatively close to said steam generator and connected thereto by a steam supply pipe and a motive liquid pump disposed adjacent said prime mover and driven thereby, said hydraulic motor driving said rotary table, said hydraulic hoist and said hydraulic mud pump being all disposed closely adjacent said well.

7. A hydraulic well drilling system as described in claim 4, in which said source of motive liquid comprises a steam generator, a steam turbine connected to said generator, and a centrifugal pump directly connected in driven relation with said turbine.

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