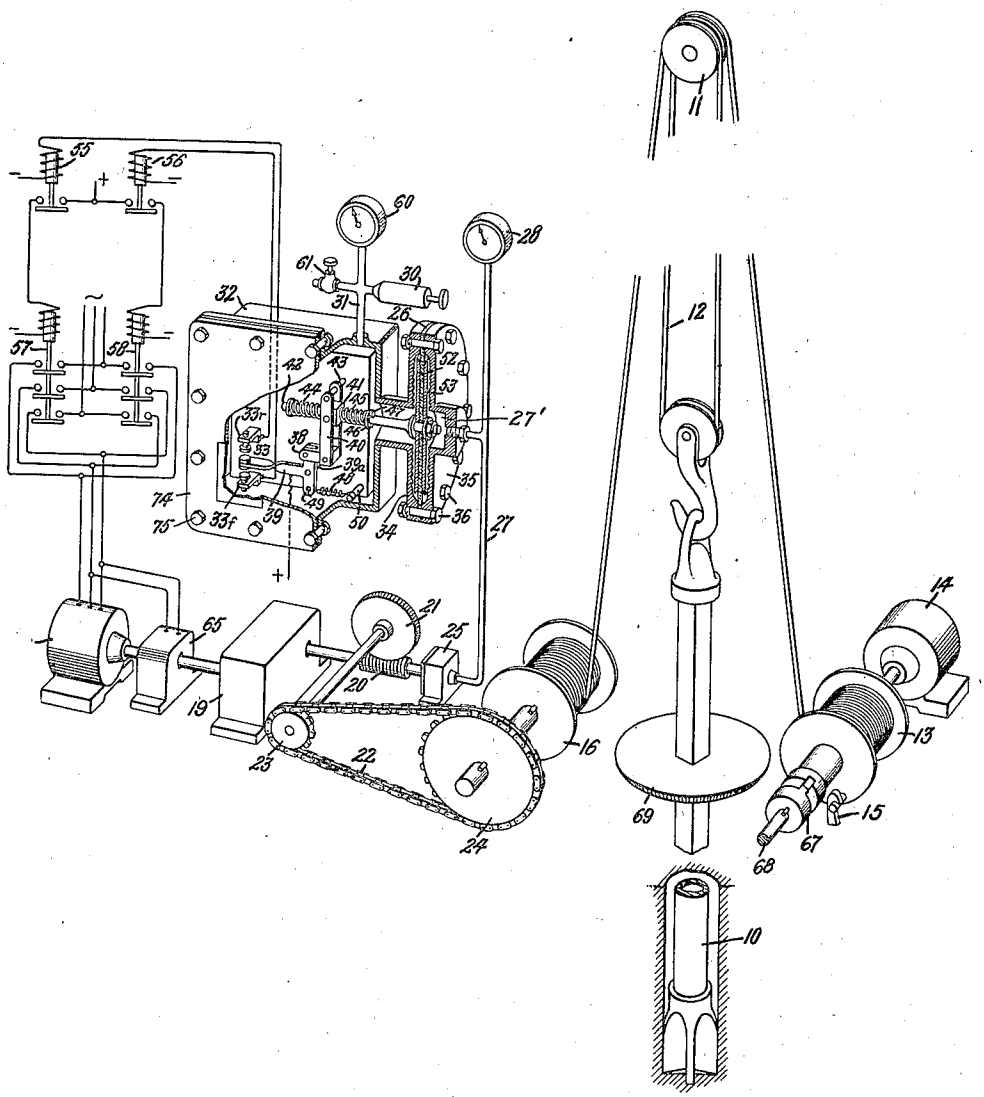
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CONTROL SYSTEM FOR ROTARY DRILLING

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CONTROL SYSTEM FOR ROTARY DRILLING

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My invention relates to control systems suitable for well drilling equipment, more particularly to the automatic weight control for oil well rotary drilling equipment, and has for an object the provision of a simple and reliable system of this character.

In drilling oil wells it is generally recognized that straight holes are needed for the best results in finishing the well and in producing the oil. Furthermore, the accurate and positive control of the weight carried on the drill, or, in other words, the pressure of the drill on the earth formation, is one of the chief requirements for the rapid drilling of straight holes. More specifically, my invention relates to improvements in well drilling apparatus of this type.

In the past it has been proposed to utilize hydraulic pressure proportional to the weight on the drill against one side of a diaphragm and fluid pressure in an amount proportional to the weight desired on the drill on the other side of a second diaphragm, the inner faces of the diaphragms being connected by a rigid member and exposed to atmospheric pressure. By means of stationary contacts cooperating with a movable contact mounted on the rigid member between the two diaphragms, the energization of a feeding motor was controlled so that a substantially predetermined pressure was maintained on the drill. Though such a system is entirely operative and represents a distinct advance in the art, something remains to be desired in improved control. It is an object of my invention to provide pressure responsive control means for a system of this type having greater sensitivity.

In carrying out my invention in one form thereof I provide for the joint application of the hydraulic pressure and of the fluid pressure to the respective faces of a single diaphragm with a control switch mounted within the fluid pressure chamber. More specifically, I provide a sealed container for a switch arranged to control the energization of the feeding motor in such a manner as to increase or decrease the weght on the drill. The diaphragm is secured to the container with one face responsive to air pressure within the container, while hydraulic means is provided for applying pressure on the other face of the diaphragm proportional to the weight on the drill. Between the diaphragm and the switch there are connected levers to amplify the movements of the diaphragm. As long as the pressures are equal the feeding motor remains deenergized but as soon as either the fluid pressure or the hydraulic pressure becomes greater than the other the switch operates to energize the motor in a direction to shift the weight to or from the drill until the diaphragm is balanced and a given weight is established on the drill.

For a more complete understanding of my invention, reference should now be had to the drawing in which the single figure shows diagrammatically my invention as applied to an oil well drilling apparatus.

Referring to the drawing, I have shown my invention in one form as applied to the control of the weight on a drill 10 supported from a crown-block 11 by means of a supporting cable 12, and operated in connection with the usual mud circulatory system (not shown) as employed in rotary drilling practice. One end of this cable is wound upon a drum 13 normally restrained from rotation by a latch 15, and arranged to be driven by a draw-works motor 14. The other end of the cable is wound about a hoisting drum 16 arranged to be driven by a feeding motor 18. This motor drives the drum 16 through a gear reduction box 19, a worm gear 20, a cooperating gear 21 and a driving chain 22 carried by the sprocket gears 23 and 24. The worm gear 20 and cooperating gear 21 are non-reversible as to transfer of power, and therefore will hold a load without the assistance of a brake.

In order to measure the weight of the drill string which includes the total weight suspended from the crown block 11, a diaphragm is mounted in a container 25 so as to create a hydraulic pressure proportional to the tension in the cable 12 and consequently proportional to the weight which may be applied on the drill 10. This hydraulic pressure is obtained by connecting the diaphragm within the container 25 so as to be responsive to the end thrust on the worm gear 20. The hydraulic pressure is applied to one side of a balanced diaphragm 26 by means of a pipe 27, connected to a pressure chamber 27', filled with an incompressible liquid such as glycerin or the like. A pressure gauge 28 is connected to the pipe 27. The diaphragm 26 may be balanced by reason of fluid pressure which may be produced by an air pump 30 connected by a pipe 31 to the sealed enclosing casing 32. Within the casing 32 there is mounted the control switch 33 operated by movements of the diaphragm 26. This diaphragm is secured between an extension 34 of the casing 32 and a closure member 35 by the bolts 36. The switch 33 is operated in accordance with movement of the diaphragm 26 by reason of a link 38 pivotally connecting the armature 39 of the switch and the lever 40. The

lever 40 is pivotally secured to a member 41 slidably carried by a stud bolt 42 which bolt is secured to the diaphragm 26. The lever 40 is pivoted at its upper end by a pin 43 suitably secured to the casing 32. The switch armature 39 is pivotally carried by a pin 39a secured to the casing 32.

As long as the diaphragm is balanced a pair of compression springs 44 and 45 encircling the bolt 42 on opposite sides of the member 41 operate to hold the armature 39 of the switch 33 in its neutral position between the stationary contacts. As shown, the spring 45 is restrained from end movement by a washer 46 and a cotter pin 47 which extends through a hole provided in the bolt 42. The corresponding end of the spring 44 is similarly held in place. A tension spring 48 secured at 49 to the armature 39 and to a pin 50 carried by the casing normally biases the armature in engagement with the lower switch contact.

In order to secure maximum effective area, thereby insuring lateral movements of the bolt 42 with changes in pressure, annular metal face plates 52 and 53 are secured to the respective sides of the diaphragm. These plates also serve to protect the diaphragm from abnormal changes of pressure in a well understood manner.

The switch 33 selectively controls the energization of the feeding motor 18 by means of a pair of sensitive relays 55 and 56 and a pair of direction switches 57 and 58.

In explaining the operation of my invention in the form shown it will be assumed that the supply lines are energized as indicated by the well understood symbols for direct and alternating currents and that the draw-works motor 14 has been energized until the drill 10 has been lowered to substantially the depth of the well. The latch 15 on the drum 13 will then be engaged to prevent rotation of the drum 13.

An indication of the weight suspended from the cable 12 may be read on the hydraulic pressure gauge 28. The air pump 30 is then operated until a fluid pressure gauge 60, connected to the pipe 31, indicates a pressure equal to that shown on the gauge 28. Under these conditions it will of course be seen that equal amounts of pressure are exerted on opposite sides of the diaphragm 26 so that it is balanced and the armature 39 of the switch 33 is in its neutral position. An air valve 61 is then opened until the air pressure within the switch enclosing casing 32 is reduced a predetermined amount.

The exact amount of the reduction of pressure corresponding to a desired weight on the drill will depend upon the constants of each particular apparatus. For example, the ratio of the gearing between the drum 16 and the worm gear 20, and the ratio between the diaphragms in the hydraulic pressure transmitting means may be selected so that the ratio for the apparatus is 300:1. Therefore, one pound gauge differential, multiplied by 300, multiplied by the number of weight supporting lines in the derrick gives the weight on the drill.

If 3000 pounds of weight is desired on the drill, the fluid pressure is reduced until the gauge 60 reads five pounds less than the gauge 28. As shown, there are two weight supporting lines so that $5\times300\times2=3000$, the weight desired. Of course, as the length of the drill string increases more supporting lines are added. For example, six weight supporting lines are required for the support of a six inch drill pipe in a well 1000 feet in depth. The weight of such a drill string is approximately 16 tons while only 3600 pounds may be a desirable weight for drilling. For this weight on the drill 10, the fluid pressure is reduced until the gauge 60 reads two pounds less than the gauge 28. $(2\times300\times6=3600)$

Consequent to the reduction of fluid pressure in the switch casing 32, the hydraulic pressure causes the diaphragm 26 to move the stud bolt to the left thereby rotating the lever 40 about its pivot 43. The result is an amplified movement of the diaphragm as applied by link 38 to the switch armature 39 which armature is rotated about its pivot 39a in a counter-clockwise direction until it engages the lower stationary contact 33f.

The relays 55 and 56 preferably are operated by direct current and are very sensitive so that the slightest contact between the switch armature and a stationary contact will cause the positive operation of a relay.

Continuing with the operation of my invention, as soon as the armature 39 touches the "feed" contact 33f, an energizing circuit is completed for the operating coil of the relay 55 which relay closes its contacts. An energizing circuit is thereby completed for the operating coil of the direction switch 57 which switch is operated to its closed position to energize the motor 18 in a direction to rotate the drum 16 in a direction to pay out cable. At the same time an electric brake 65 connected across the motor supply terminals is energized and operates to release itself from the motor driving shaft. The drill 10 is lowered until it comes into engagement with the earth formation at the bottom of the drill hole. As soon as the drill strikes the bottom of the hole, there is a transfer of weight from the crown block 11 which weight is applied to the drill 10. This transfer of weight continues until the tension in the cable 12 and consequently the thrust of the worm gear 20 are reduced an amount sufficient to reduce the hydraulic pressure applied to the diaphragm 26 until this pressure equals the fluid pressure applied to the other side of the diaphragm. As the hydraulic pressure becomes equal to the fluid pressure the switch 33 is opened thereby deenergizing the motor 18 and the brake 65, causing the latter to set and absorb the energy stored in the moving parts of the drill, so that the tendency of the system to over-regulate the weight on the drill is substantially eliminated.

The draw-works motor 14 may be used to impart rotary movement to the drill 10 by means of the clutch 67, the shaft 68, suitable connecting gearing (not shown) and the gear 69.

As the bit drills the hole, the weight applied by it to the earth formation is gradually transferred back to the cable 12. The result is an increase in hydraulic pressure applied to the diaphragm 26 and the operation of the switch 33 to energize the motor in a direction to increase the weight on the drill 10. It will, therefore, be seen that the weight on the drill is maintained substantially constant during the drilling of the well.

In a typical application of my invention to a well drilling equipment, a change in tension in the portion of the cable between the hoisting drum 16 and the crown block 11 of only ten pounds was sufficient to operate the switch 33 irrespective of the weight of the drill string.

Inasmuch as the diaphragm 26 is balanced by the equal pressures on its respective sides whenever the desired weight is applied to the drill, it will be apparent that for this condition there are no unbalanced forces applied to the disphragm. Consequently, it may be constructed of relatively

light weight material, such as rubber or the like, thereby to increase the sensitivity of the system. For example, the diaphragm operated switch 33 may be operated by a differential of pressure of a small fraction of a pound.

If the switch 33 had not been placed within the pressure chamber, packing would have been necessary for the switch lever operated by the movement of the diaphragm. Such a packing in order to withstand the high pressures encountered would introduce sufficient mechanical resistance to reduce very materially the sensitivity of the system. The importance of insuring operation of the feeding motor 18 in response to small pressure changes on the diaphragm, aside from securing a substantially straight oil well, may be seen by examining the operation of the system during an abnormal condition.

For example, when the drill 10 enters a clay formation, it often happens that the clay will form a ball on the drill and the pressure of the circulatory system will then be exerted against the under side of the ball. The effect, of course, will be a reduction in the cutting action of the drill and the transfer of weight from the crown block 11 to the drill 10. A resultant decrease in hydraulic pressure permits the fluid pressure within the switch casing to move the diaphragm to the right. The switch 33 therefore completes an energizing circuit through its upper contact 33r for the operating coil of the relay 56. The relay 56 thereupon closes its contacts to energize the operating coil of the direction switch 58 which switch closes to energize the feeding motor 18 in a direction to retrieve the drill 10. The motor 18 will continue to retrieve the drill until the pressures on the diaphragm 26 are again balanced. As soon as the mud ball is removed from the drill an unbalanced weight appears and the drill is quickly lowered until the pressures are again balanced. The reversals may be repeated several times, the operation being known in oil field parlance as " spudding off a balled bit ". By thus restoring the cutting action of the drill, the penetration of the drill through the clay is greatly facilitated.

Should there be a large or sudden reduction of pressure on either side of the diaphragm causing the switch armature 39 to be quickly driven against a stationary contact, injury to the switch is prevented by the slidable mounting of the member 41 between the compression springs 44 and 45. After the contacts are engaged, further movement of the stud bolt 42 is absorbed by one or the other of the springs. The effect on the contacts is merely the increase of the contact pressure.

The life of the contacts themselves is materially lengthened due to the action of the fluid pressure in suppressing arcing at the contacts. Due to the long life of the contacts, instead of securing the face plate 74 to the casing 32 by the bolts 75, it will be understood that this plate may be welded to the casing.

Inasmuch as the weight on the drill is determined with reference to cable tension, my invention may be used to prevent overloading of the derrick under abnormal retrieving operations. If for example the drill pipe becomes stuck, the force applied in retrieving may be limited to the load the derrick will withstand by pumping up the air pressure until the product of the constant 300, the number of weight supporting lines in the derrick, and the difference in pressures indicated on the gauge equals the desired force applied. The system will function to maintain this force constant which is a valuable aid, aside from the protective feature, for the operations preceding the final retrieval of the " stuck pipe ".

While I have shown a particular embodiment of my invention, it will be understood, of course, that I do not wish to be limited thereto, since many modifications may be made, and I therefore contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I desire to claim and secure by Letters Patent of the United States, is:

1. In a well drilling equipment, a motor for paying out and taking up a cable which is subject to a variable tension, means for controlling the energization of said motor so as to maintain substantially constant a predetermined tension in said cable comprising a control switch, a diaphragm, means responsive to the cable tension for applying a pressure to one face of said diaphragm, means for applying fluid pressure directly to the other face of said diaphragm to balance said pressure for said predetermined tension in said cable and connecting means between said switch and diaphragm.

2. In combination with a well drilling equipment, provided with a drill and a drill string including a supporting cable for said drill, of a motor for paying out and retrieving said cable so as to vary the weight applied to said drill, a pair of pressure chambers, a diaphragm separating said chambers, a switch mounted within one of said chambers for selectively controlling the energization of said motor, operating means therefor conected to the armature of said switch and to said diaphragm, means responsive to the weight applied to said drill for producing a pressure in one of said chambers, and means for producing fluid pressure in the other of said chambers whereby said diaphragm is actuated to operate said switch so that said motor is energized in a direction to vary the weight on said drill.

3. In combination with a well drilling equipment having a drill and supporting cables therefor, of a motor for paying out and retrieving said cable so as to vary the weight applied to said drill, a switch for controlling the energization of said motor, a diaphragm, means for connecting said diaphragm to said switch, a pressure chamber, means for producing fluid pressure within said chamber, means for supporting said switch in said chamber, means for applying said pressure to one side of said diaphragm, means responsive to the weight on said drill for applying hydraulic pressure to the other side of said diaphragm, whereby any difference in the pressures applied to the respective sides of said diaphragm actuates said diaphragm and said switch so that said motor is energized in a direction to vary the load on said drill.

4. Means for maintaining a predetermined weight on the drill of a well drilling apparatus comprising a diaphragm operated switch, means for applying hydraulic pressure proportional to the actual weight on the drill on one side of said diaphragm, means for applying fluid pressure proportional to a desired weight on said drill to the other side of said diaphragm, means connected between said diaphragm and said switch for multiplying the motion of said diaphragm, a motor arranged to control the weight on said drill and means responsive to the operation of said switch for controlling the energization of said motor.

5. In a well drilling equipment including a drill string, a cable for supporting the string, said cable being under a tension the magnitude of which is determined by the weight of the string and the character of the earth formation upon which the drill is acting, a motor for controlling the tension of said cable, a switch for controlling the energization of said motor, the said switch comprising a pair of stationary contacts and a movable switch member arranged for the selective engagement of said contacts, an enclosing casing for said switch, a diaphragm having one side exposed to the interior of said casing, means responsive to said cable tension for applying hydraulic pressure to the other side of said diaphragm, means for producing fluid pressure within said casing proportional to a desired cable tension, and means connecting said diaphragm and said movable switch member for amplifying the movement of said diaphragm whereby said motor is operated to maintain said predetermined tension in said cable.

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