March 20, 1945. W. ST. M. E. CRAKE 2,371,953

DRILLING WEIGHT CONTROL SYSTEM

Filed July 24, 1942 2 Sheets-Sheet 1

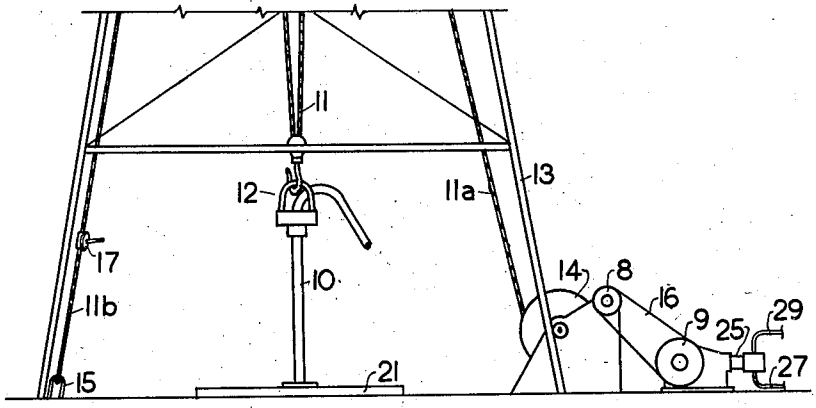


Fig. I

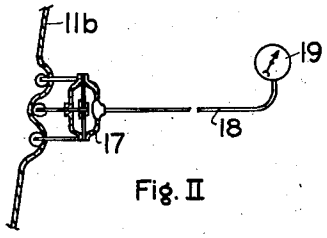


Fig. II

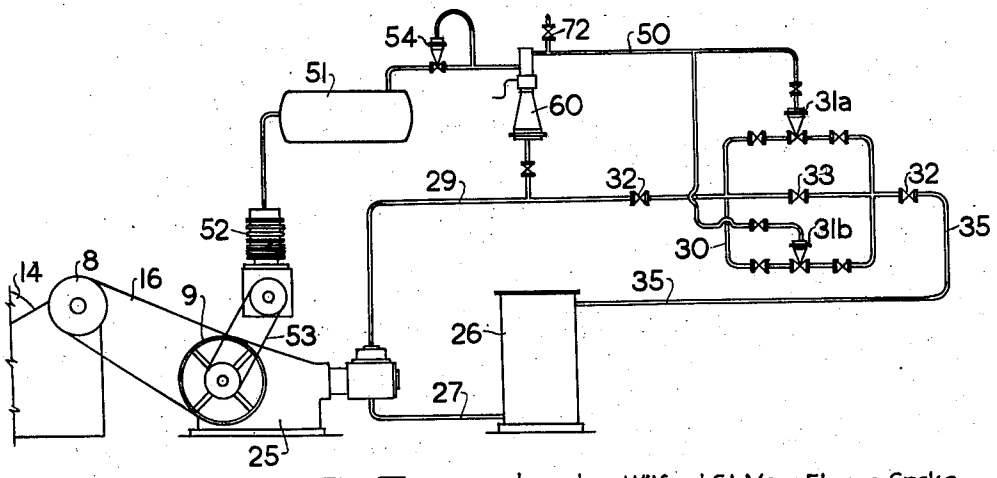


Fig. III

Inventor: Wilfred St. Maur Elmore Crake

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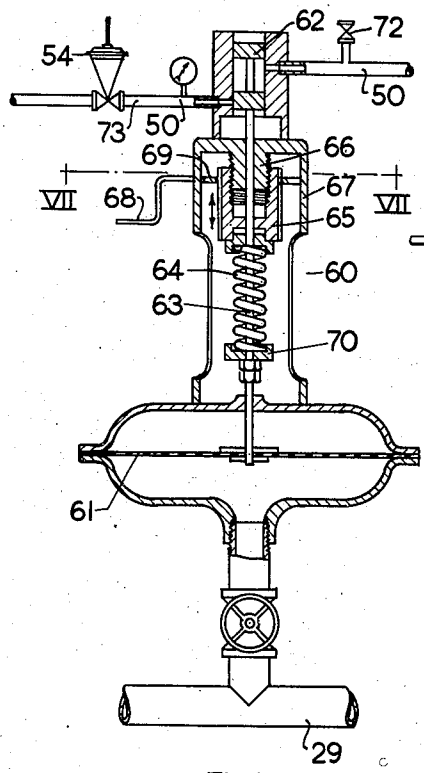


Fig. IV

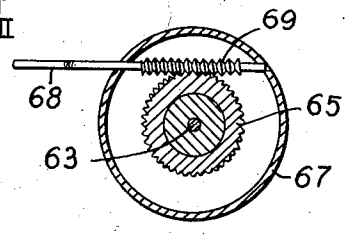


Fig. VII

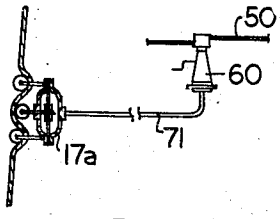


Fig. VI

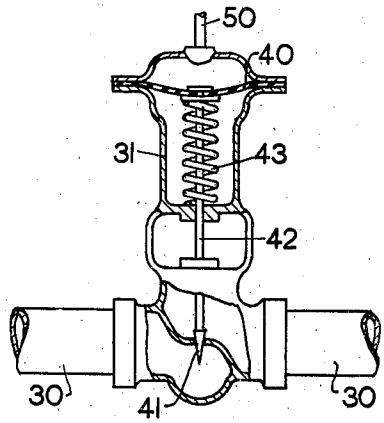


Fig. V

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By his Attorney: [signature]

Patented Mar. 20, 1945

2,371,953

UNITED STATES PATENT OFFICE

2,371,953

DRILLING WEIGHT CONTROL SYSTEM

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2 Claims. (Cl. 255—19)

The present invention relates to well drilling control systems by which the drill bit feed into the formation being drilled is controlled in accordance with the weight supported on the bit, and pertains more particularly to an improvement over the control apparatus described in U. S. Patent 2,133,016 issued on October 11, 1938 to Brantley.

The Brantley device operates by causing the weight of the drill stem to motivate a pump, the discharge of which pump may be throttled by means of a plurality of valves in the fluid circuit of the pump, whereby the downward speed, or the rate of penetration, of the drill bit is controlled. In a homogeneous formation, a constant setting of the throttling valves will give a constant bit feed rate, and therefore a constant weight on the drill bit, with constant and pump flow and rotary table speed. However, any change in rotary table speed or mud pump speed, or any variation in formation hardness, will increase or decrease the weight on the drill bit, and maintenance of a constant pressure or weight on the bit can in such case be achieved only by manual control of the throttle valves.

It is therefore an object of this invention to provide a control system for automatically maintaining a constant pressure or weight on the drill bit, irrespective of changes in rotary table speed, or mud pump speed, or variations in earth formation hardness. Since an increase in bit pressure over a predetermined value detracts from the useful cutting life of the bit considerably, such an automatic control system, in eliminating variations in pressure due to the inherent shortcomings of the manual control, increases the bit life and gives a faster rate of penetration of the drill bit into the formation due to the increased percentage of total drilling time during which the drill bit is engaging the earth formation at the optimum pressure. The present automatic control system likewise yields straighter and better gauge boreholes.

With the above and other objects and advantages in view, the invention has particular relation to certain novel features of construction, operation, and arrangement of parts, an example of which is given in this specification and illustrated in the accompanying drawings, wherein:

Figure I is a schematic view showing the relation of the drag pump and winding drum as well as the weight indicator to the derrick and drill stem.

Figure II is an enlargement of the weight indicator detail from Figure I, showing also the indicating dial.

Figure III is a schematic view showing the cable drum and control system including the drag pump.

Figure IV is an enlarged vertical sectional view of the pilot valve detail of the control system.

Figure V is an enlarged vertical sectional view of the diaphragm motor valve detail of the control system.

Figure VI is a schematic view showing an alternate arrangement of the pilot valve part of the control system.

Fig. VII is a cross-sectional view taken along the line VII—VII of Fig. IV.

Referring to Figures I and II of the drawings, a drill string 10 is suspended in the usual manner by a cable 11 attached to the upper end of the drill string 10 by means of the usual blocks, hook and swivel arrangement generally shown at 12. The drill string 10 may be of any suitable type, such as used for rotary drilling, and any of the suitable drilling rigs may be employed. The cable 11 passes over the crown pulley (not shown) on derrick 13 and the live hoisting portion 11a of the cable 11 is wound on a drum 14, while the dead end 11b of the cable 11 is fastened to the derrick by means of suitable clamps 15. The dead end portion 11b of the cable carries a suitable weight measuring device, such as the commonly used hydraulic diaphragm device 17 connected by tube 18 to a weight indicating dial 19 (Figure II) arranged in a convenient position for inspection by the driller.

The drill bit (not shown) on the lower end of the drill string 10 is rotated, together with said drill string by a rotary table 21. As the drill bit bores into the earth formation, the live end 11a of the cable 11 is gradually unwound from the cable drum 14 to lower the drill string 10. The unwinding of the cable 11 rotates the drum 14, and develops a considerable torque which is opposed and restrained by pumping or otherwise driving water or other suitable liquid against a predetermined back pressure. The driving connections between the drum 14 and a pump 25 may be of any suitable type, including pulleys 8 and 9 connected by belt 16 as shown in Figures I and III, and preferably having a speed-multiplying or power reducing transmission with clutching means or the like for selectively connecting the pump 25 to the drum 14.

The pump 25, which may, for example, be a multi-cylinder double acting pump, obtains fluid,

such as water, oil, or the like, as shown in Figure III, from a reservoir or storage tank 26 through a pipe 27 and discharges it through a pipe 29 to a manifold 30, containing control valve means, such as diaphragm motor valves 31*a* and 31*b*, preferably in parallel, together with suitable auxiliary shut-off valves 32 and by-pass valve 33. A return pipe 35 from the manifold 30 returns to the tank or reservoir 26. A preferred form of diaphragm motor valves 31*a* and 31*b* is shown in detail in Figure V and comprises a diaphragm 40 connected to the valve 41 by means of a valve stem 42 and a spring 43 acting against the lower side of the diaphragm 40 and tending to open the valve 41 which may suitably be a needle valve, as shown, a balanced type valve, etc. Preferably, the motor valve 31*a* has a small diameter flow channel and is thus adapted for low feeding rates or high pressure feeding while the other motor valve 31*b* has a large diameter flow channel for high feeding rates or low pressure feeding. The valves 31*a* and 31*b* may be used singly or in parallel as desired.

The weight of the drill string 10 on the cable 11*a* rotates the drum 14 and thus causes the pump 25 to pump fluid from the reservoir 26, which is at atmospheric pressure, through the pipe 29 and through at least one of the control valves 31*a* and 31*b*. By controlling the back pressure held on the pump 25 in the pipe line 29 by closing the by-pass valve 33 and partially opening at least one of the control valves 31*a* and 31*b*, the load, or portion of the weight of the drill string 10, carried by the cable 11*a* can be controlled. If the valves 31*a* and 31*b* and 33 are shut off completely, the pump will be stopped and the load will hang without descending. The tendency of the pump 25 to operate due to the load applied thereto through the cable 11*a* on the drum 14 will cause a certain blocked pressure in the pipe line 29. If the control valves 31*a* and 31*b* are opened so that the back pressure on the pump 25 in the line 29 is a predetermined amount lower than the closed in or blocked pressure, and maintained at this differential, the weight which is thus relieved remains constant and is transferred to the bit of the lower end of the drill string 10.

The pressure fluid, such as air, oil, or the like, which actuates the motor valves 31*a* and 31*b*, passes through pipe or line 50 to the diaphragms 40 of the motor valves 31*a* and 31*b* from a suitable source of pressure fluid, such as a reservoir 51, into which, for example, air is pumped by means of an air pump 52 having a power take-off, such as a chain 53, from the pump 25. A pressure regulator 54 of any suitable type, such as a spring-loaded diaphragm-actuated valve in which the diaphragm is exposed to the pressure in the conduit on the downstream side of the valve, is preferably arranged in the line 50 from the reservoir 51 to maintain the actuating pressure fluid at a constant pressure. The passage of actuating pressure fluid through the line 50 to the diaphragms 40 of the motor valves 31*a* and 31*b* is controlled by pressure-responsive means, such as a suitable pilot valve 60 in the line 50 between the motor valves 31 and the pressure regulator 54. A preferred form of pilot valve 60 is illustrated in Figure IV and comprises a diaphragm 61 connected to the valve 62 in the line 50 by means of a stem 63, and a spring 64 acting at one end against a bracket 70 on the valve stem 63 and tending to close the valve 62, which may be of any suitable type, such as a balanced valve, as shown in Figure IV, a tapered needle valve, or the like. The tension on the spring 64 and therefore the pressure on the diaphragm 61 at which the valve opens is adjusted by means of an axially movable sleeve 65 surrounding the valve stem 63 and against which the other end of the spring 64 acts. The sleeve 65 is internally threaded and thereby engaged with an externally threaded coaxial tubular member 66 carried by the housing 67 of the pilot valve 60. The sleeve 65 is moved downwardly to increase the tension on the spring, and likewise upwardly for the opposite effect, by rotating the sleeve 65 on the threadably engaging member 66 either by hand directly or by means of a crank 68 and gear means 69 engaging the sleeve 65, as shown in Fig. VII.

Valve 72 continuously bleeds pressure from line 50 at a predetermined slow rate in order to prevent excessive build-up of pressure from line 73 and also to exhaust the pressure from line 50 when valve 62 is closed off.

In one preferred embodiment of the present invention, the weight supported by the drill bit is maintained constant by holding the back pressure on the pump 25 in the line 29 at a predetermined constant value. This is achieved by exposing the diaphragm 61 of the pilot valve 60 to the pressure in line 29. An increase in the back pressure acting on the diaphragm 61 of the pilot valve 60 closes the valve 62 and the decreased pressure on the diaphragm 40 of the motor valves 31*a* and 31*b* caused by bleeding of pressure from line 50 through valve 72, causes the valve elements 41 of said throttling valves 31*a* and 31*b* therein to be opened further, releasing the excess pressure in line 29 and allowing the drum 14 to rotate faster. Likewise a decrease in the back pressure on line 29 acting on the diaphragm 60 of the pilot valve 61 opens valve 62 and permits pressure fluid from line 73 to enter line 50 and increase the pressure on diaphragm 40 in valves 31*a* and 31*b*. This causes the motor valves 31*a* and 31*b* to close, permitting the back pressure to increase and further restraining the unwinding of the cable 11*a* from the drum 14, so that the drill string is lowered at a decreased rate.

In operation of the above described embodiment of the control system of the present invention, the drill string 10 is lowered into the borehole until the drill bit reaches within a few feet of the bottom. The circulation of drilling fluid and rotation of the rotary table are started at whatever operating speeds are desired and then the weight supported by the cable 11 indicated on the weight indicator 17, which may be called the full hanging load, is noted. The drag or restraining pump 25 is then suitably brought into operative connection with the cable drum 14 while the throttling valves 31 and by-pass valve 33 are in closed position. The pilot valve 60 is adjusted by means of parts 64—69 inclusive so that the back pressure on the pump 25 in the line 29 acting on diaphragm 61, which actuates the valve 62, causes the valve 62 to just close. The supply of pressure fluid through line 50 acting on the diaphragm 40 of the throttling valves 31*a* and 31*b* being cut off, the valve elements 41 of said throttling valves 31*a* and 31*b* open slightly due to action of the spring 43, allowing the fluid to circulate through the fluid circuit comprising the pump 25, pipe 29, motor valves 31*a* and 31*b*, return line 35, reservoir 26, etc. The pump 25 is thus able to operate slowly and the load, comprising the drill string 10, on the cable, starts to move downward very slowly, while the back pressure on the pump 25 is practically equal to the

blocked pressure under full hanging load conditions. The compression in the spring 64 of the pilot valve 60 is further released by slowly moving the sleeve 65 upwardly until a lowered reading on weight indicator 17 shows that the back pressure has been reduced sufficiently to allow the load or weight of the drill string 10 on the suspending cable 11 to be reduced from the previously noted full hanging load by the amount of weight desired to be maintained on the drill bit.

It will be seen that the back pressure held on the pump 25 by the throttling valves 31a and 31b will be reduced by an amount proportional to the load or weight supported on the drill bit, and the control system will maintain this pressure constantly. Thus, in case the back pressure tends to decrease due to a slower rate of penetration of the earth formation by the bit as a result, for example, of increased hardness of formation, the diaphragm 61 of the pilot valve 60 will be forced downwardly by the action of the compressed spring 64 and the valve 62 thereby caused to open. The increased pressure on the diaphragms 40 of the throttling valves 31a and 31b by the fluid pressure through line 50 and opened valve 62 causes the valves 41 connected to diaphragms 40 to be moved toward closed position, whereby the fluid circuit is more tightly throttled, that is, fluid circulates therethrough more difficulty, and thus the back pressure on pump 25 is raised by the required increment back to the predetermined normal value. The weight on the drill bit will thus be controlled automatically to a constant value, regardless of the speed of circulation of drilling fluid, the rotary table speed, both of which have a buoyant effect, or the hardness of the earth formation being penetrated.

In order to prevent a rapid falling of the load, i. e. the drill string 10, etc., in case the drill bit penetrates into a cavity, either or both of the auxiliary values 32 are set by hand prior to the setting of the pilot valve 60 so that with the throttling valves 31a and 31b wide open, the auxiliary valves 32 throttle the flow so that the rate of fall of the load is fixed to a reasonable maximum greater than the maximum at which it is expected to drill.

It will be seen that in the above described embodiment the control system will maintain a constant load on the drill bit as long as the cable 11a on the hoist drum 14 unreels from the constant drum radius at which the back pressure is set. In the event that the cable 11a unwinds a whole layer during the drilling for a depth equal to the length of one section or stand of drill pipe and thus drops to a smaller radius, the torque on the hoist drum 14 which is connected to the pump 25 is reduced and the weight on the drill bit will be reduced unless corrected by re-setting the pilot valve 60 which controls the back pressure on the pump 25.

This contingency is overcome by using a modification of the present invention illustrated by Figure VI. Instead of the diaphragm 61 of the pilot valve being exposed to the back pressure in the line 29, the pilot valve 60 is controlled directly by the weight or load on the cable 61, preferably by the weight on the dead end 11b of the cable. For this purpose, a pipe 71 communicates from the pressure-responsive side of the diaphragm 61 of the pilot valve 60 to the fluid pressure side of the diaphragm of a weight indicator, such as an auxiliary indicator 17a, attached to and actuated by the dead end 11b of the cable 11 in parallel and identical to the regular weight indicator 17. If desired, the pipe 71 may be tapped into the pressure fluid line 18 of the weight indicator shown in Figure II.

When the back pressure on the pump 25 is set by adjustment of the pilot valve 60 to give the desired weight on the drill bit, as shown by the weight indicator, the back pressure on the pump 25 will be automatically controlled by the cooperating effects of weight indicator 17a and pilot valve 60 to give a constant load or pressure on the drill bit regardless of the radius of the cable 11a on the hoist drum 14, since the unwinding speed of the cable 11a and thus the downward speed of the drill string 10 is directly controlled by the weight on the dead end 11b of cable 11 through the weight indicator 17a.

It will be apparent that the above described embodiments of the control system of the present invention may undergo various modifications and variations without departing from the scope of the invention as defined by the appended claims. For example, instead of diaphragms 40 and 61 in the pressure-responsive valves 31a and 31b, and 60, respectively, spring-controlled plungers or pistons, or the like, may be used.

I claim as my invention:

1. A control system for well drilling apparatus comprising a drill stem adapted to penetrate the ground, a rotatable drum, a cable suspending said stem and wound around said drum, whereby said drum is rotatably driven as the stem penetrates the ground, a pump, a speed multiplying mechanism to drive said pump by the rotation of said drum, a closed fluid circuit between the high and the low sides of said pump, diaphragm controlled valve means in said fluid circuit adapted to throttle the fluid flow therein, thereby maintaining on the pump a back pressure to oppose the unwinding of said cable from said drum, and a pressure fluid control system comprising a source of pressure fluid; means for adjusting the pressure in said control fluid to a predetermined value, and means responsive to variations in the suspended weight of said drill stem and cooperating with the dead end of said drill stem-supporting cable for applying the pressure of the control fluid to the diaphragms of the valve means in the pump circuit, thereby throttling the fluid flow in said circuit and maintaining the back pressure in said circuit at a predetermined value.

2. A control system for well drilling apparatus comprising a drill stem adapted to penetrate the ground, a rotatable drum, a cable suspending said stem and wound around said drum, whereby said drum is rotatably driven as the stem penetrates the ground, a pump driven by the rotation of said drum a closed fluid circuit between the high and low sides of said pump, pressure-responsive valve means in said fluid circuit adapted to throttle the fluid flow therein, thereby maintaining on the pump a back pressure to oppose the unwinding of said cable from said drum, a fluid control circuit, means for adjusting the pressure in said control circuit to a predetermined value, and means responsive to variations in the suspended weight of said drill stem for applying the pressure of the control circuit to the pressure-responsive valve means in the pump circuit, thereby throttling the fluid flow in said closed fluid circuit.

WILFRED ST. MAUR ELMORE CRAKE.