

May 18, 1937.

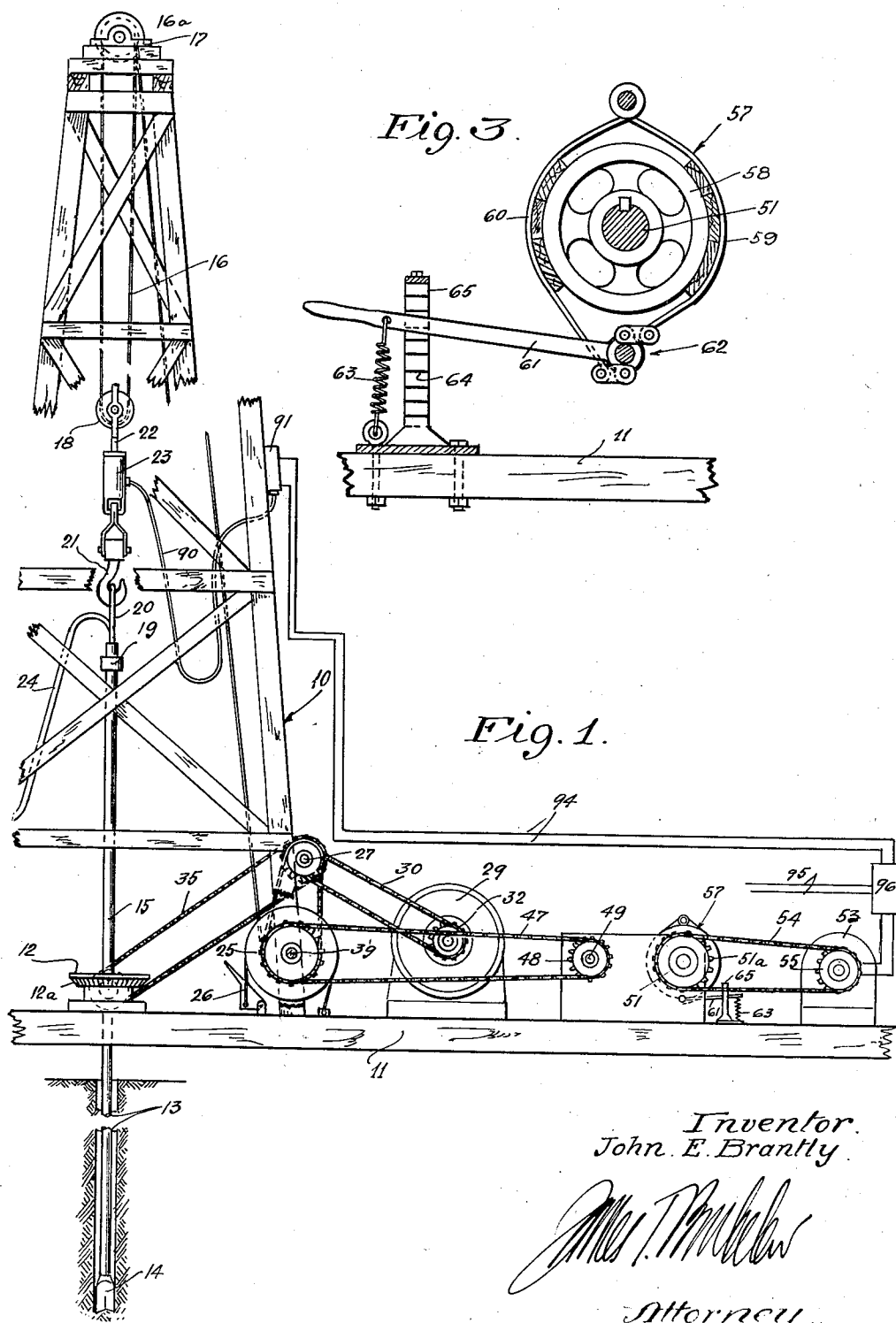
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2,080,804

WELL DRILLING CONTROL SYSTEM

Filed April 30, 1935

3 Sheets-Sheet 1



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WELL DRILLING CONTROL SYSTEM

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3 Sheets-Sheet 2

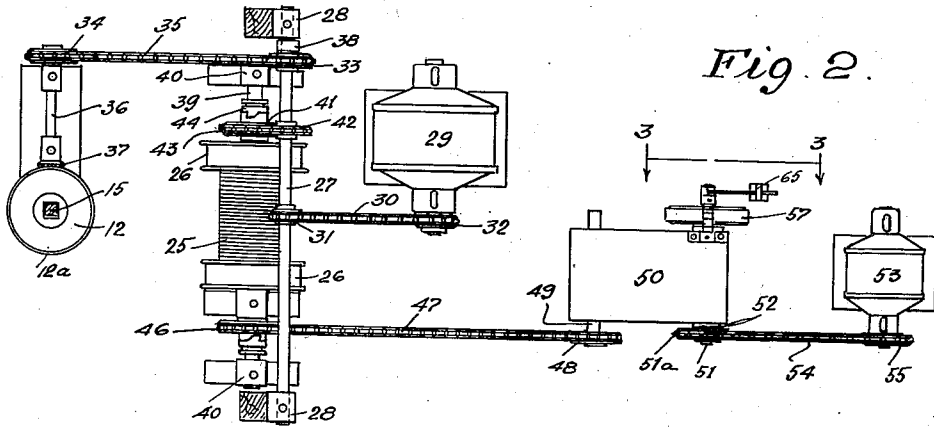


Fig. 2.

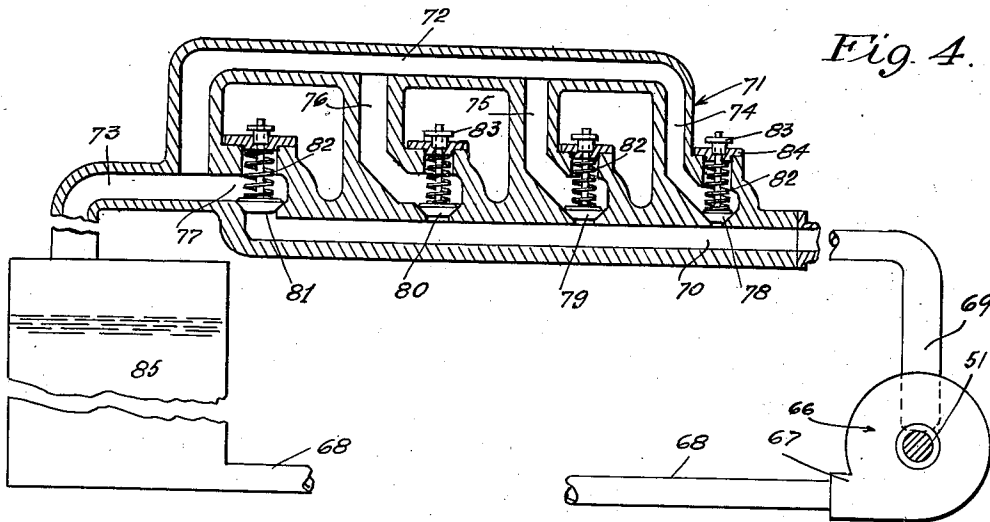


Fig. 4.

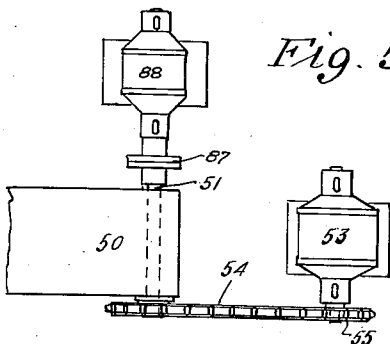


Fig. 5.

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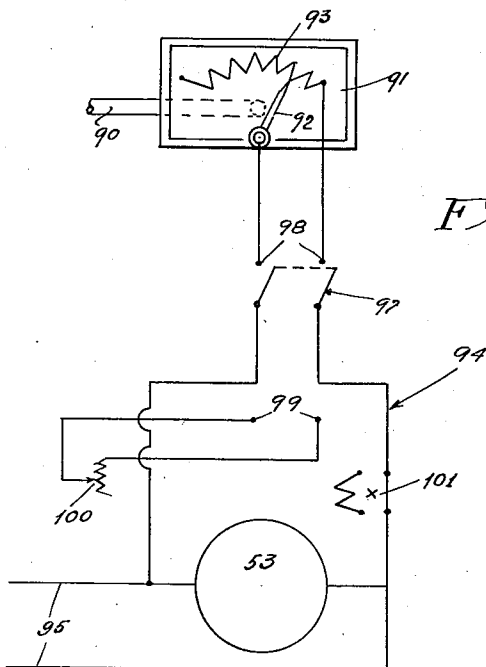
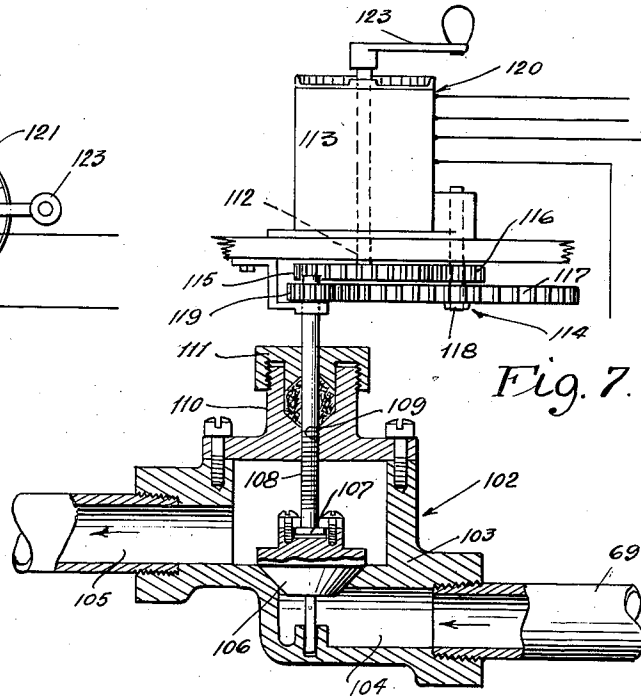
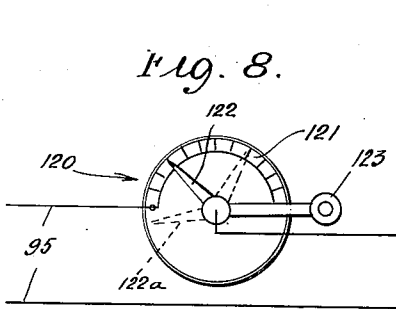
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3 Sheets-Sheet 3



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2,080,804

WELL DRILLING CONTROL SYSTEM

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Application April 30, 1935, Serial No. 19,017

15 Claims. (Cl. 255—19)

This invention relates generally to well drilling control systems of the type operating to regulate the bit feed into the formation being drilled, or to control the feed in accordance with the weight on the bit, and has for its principal object to provide a drilling control system whereby the bit may be fed or lowered at a substantially more uniform rate and under a much smoother acting control, than has heretofore been possible with known types of drilling control systems.

Several methods have in the past been proposed and used with varying degrees of success, that aim generally at the idea of controlling the rate of drilling or rate of bit feed in accordance with variations in the weight on the bit, by decreasing or increasing the rate of feed as the weight on the bit correspondingly increases or decreases, with a resultant approximation of a uniform pressure on the bit at all times and regardless of variations in the hardness of the formation. In some cases these systems have been made to operate automatically; the bit feeding mechanism responding automatically to variations in the bit pressure.

In all instances however, these prior methods have involved a common and characteristic principle, the departure from which by the present invention is primarily responsible for its superiority. That principle, briefly, consists in placing a drilling pressure on the bit by supporting or suspending a portion only of the entire weight of the drill string, and utilizing the unsupported weight to apply pressure to the bit to force it into the formation. As harder or softer formations are encountered, greater or lesser portions of drill string load have been taken from the bit, but always, during drilling, a portion of the weight of the drill string will remain unsupported except by the bit. It will readily be seen therefore that in varying the rate of drilling or the pressure on the bit, the practice has been to control and vary the unsupported part of the total weight of the drill string.

Experience has shown that while theoretically it is possible to maintain that control, in actual practice it has not been possible to control the rate of feed or pressure on the bit within the close limits most to be desired, or to a degree where practically absolute uniformity in either of these conditions can be maintained. By the present invention I am able to achieve such uniformity, primarily as a result of the departure from the common principle of former methods, as discussed in the foregoing.

The novel and characteristically different mode

of operation employed in the present system consists in the method of controlling the bit feed by first suspending the pipe string by a force or means sufficient to support the entire weight thereof, as distinguished from a portion only, and lowering the pipe string to feed the bit during drilling by partially overcoming that force or means, but while maintaining it, by a second independent force. Thus during drilling there is always a force being applied that is sufficient to support substantially the entire drill string load, but which is constantly being overcome by an independent force. In contrast to prior methods wherein the element of control comes about by varying the unsupported load on the bit, I control the rate of bit feed or the pressure on the bit by controllably varying the described independent overcoming force. The result is that by virtue of the presence of the two forces, one acting to support the entire drill string, and the other to partially overcome that force, I am able to obtain a smoothness of feed and sensitivity of control that heretofore could not be even closely approximated. As will hereinafter appear, the present method lends itself particularly adaptably to automatic control to maintain an accurately uniform pressure on the bit, although this feature is additive and need not necessarily be employed since the system is fully responsive to manual control.

The invention embodies various additional features and objects, and includes a novel and improved apparatus for performing the operations described above. All these however will be further and completely explained in the description to follow, and throughout which reference is made to the accompanying drawings, in which:

Fig. 1 is a general view, diagrammatic in parts, showing a typical well drilling and control system embodying the invention;

Fig. 2 is a plan view of the draw works and drilling control apparatus shown in Fig. 1;

Fig. 3 is an enlarged view in the aspect of line 3—3 of Fig. 2 showing the drill string supporting brake in side elevation;

Fig. 4 is a partly sectional view illustrating the variational and hydraulic type brake;

Fig. 5 is a fragmentary plan illustrating a sectional variational form of brake, in this instance of an electric or motor generator type;

Fig. 6 is a line diagram showing the motor circuit and control switches;

Fig. 7 is a view, partly in section, showing a valve controlled tube used in conjunction with a hydraulic type brake; and

Fig. 8 is a plan view of the rheostat control of Fig. 7.

Referring first to Fig. 1, numeral 10 indicates the usual derrick having a floor or platform 11 which supports the rotary table 12, the latter operating to rotate the drill pipe string 13 and bit 14 via the usual square-section kelly 15 extending through the rotary table. The drill string is supported by cable 16 trained over sheave wheel 16a on crown block 17, and around the travelling block 18. The latter is connected to the usual swivel 19 attached to the upper end of kelly 15, by way of the swivel bail 20, hook 21 and ball 22 of a weight indicator 23, the purpose of which will hereinafter appear. Circulating fluid is discharged down through the kelly and drill string from the ordinary pipe or hose 24 connected to swivel 19. The drill pipe supporting cable 16 is wound around a winding drum 25 which rotates to let off cable during lowering of the pipe string, or, reversely, to take up the cable for the purpose of pulling the drill string from the well. The usual type of manually operated brake 26 applied to drum 25, preferably is used to lower the drill string in the well to drilling depth, but thereafter, during normal drilling operations, this brake will be released and remain out of operation. In other words, it is intended solely as a pipe lowering brake.

As best illustrated in Fig. 2, the draw works and drilling control apparatus comprise a shaft 27 journaled in bearings 28 and driven from a suitable power source, such as an engine or motor 29, by way of chain 30 passing around sprockets 31 and 32 on shaft 27 and the motor shaft, respectively. Rotary table 12 is driven from shaft 27 by way of sprockets 33 and 34, chain 35, and shaft 36 carrying a bevel gear 37 meshing with the rotary table ring gear 12a. The rotary table drive may be disconnected by manually operating clutch 38 to release shaft 27 from driving connection with sprocket 33. Winding drum 25 is mounted on a shaft 39 journaled in bearings 40, and may be driven from motor 29 by way of chain 41 carried on sprockets 42 and 43 on shafts 27 and 39, respectively, the winding drum however being disconnectible from motor 29 by means of a manually operated clutch 44 which, when released, leaves sprocket 43 floating on the drum shaft. It will be unnecessary to refer further to the driving connections between motor 29 and the winding drum, other than to state that ordinarily the drum will be driven by motor 29 only for the purpose of pulling the pipe string from the well. As will later appear, the drilling control apparatus also operates to elevate the pipe string, although at a slower rate due to the particular gear system employed, so that a separate hoisting drive for the winding drum is desirable in order to save time in pulling the pipe string.

Operating in conjunction with the draw works mechanism described thus far, is a drilling control apparatus which, as previously observed, serves to feed the bit into the formation at a uniform, even rate as a result of the adoption of a novel principle in the application of forces governing the lowering of the drill string. Broadly speaking, the drilling control system may be regarded as acting to impose sufficient force resisting rotation of winding drum 25 in a cable releasing direction, as to overcome the tendency of the cable tension imposed by the entire weight of the drill string, to rotate the drum in that direction; or in other words, to impose

sufficient resistance to drum rotation as to support substantially the entire weight of the drill string. Then in conjunction with this force acting to resist rotation of the winding drum, I employ a second, controllably variable force which partially overcomes the drum rotation resisting force, causing the drill string to be lowered and the bit to be fed into the formation as a result of the unsupported portion of the drill string load. The relative amount of the second mentioned force therefore determines the weight on the bit. Provision is made whereby this force may be controllably varied to increase or decrease the rate at which the bit is fed into the formation and, if desired, to controllably vary the drilling pressure on the bit.

While it is realized that the two forces just referred to may be applied directly to the winding drum 25, I prefer to apply the control forces indirectly through a speed increasing mechanism of the character later described, due to the fact that at normal drilling rates, drum 25 rotates so slowly in letting off cable as to render it difficult, if not impossible, to obtain the desired precision and smoothness of operation in the drilling control if the said forces were to be applied directly to the drum. Accordingly, I apply the forces to a rotating element operated in accordance with the rotation of the winding drum 25, but at a substantially greater speed, and as a result, I am able to obtain much greater smoothness and sensitiveness of control than would be possible were it attempted to apply the forces directly to the slow moving winding drum.

A second sprocket 46 on the winding drum shaft 39 is connected by chain 47 with sprocket 48 carried on the low speed shaft 49 of a speed increasing or multiplying unit 50. The latter is illustrated diagrammatically only, since speed increasers operating to multiply, in a high speed driven shaft, the rotative speed of a low speed driving shaft, or vice versa as regards the driving and driven shafts, are commonly known and require no detailed explanation or illustration. In this case shaft 49 is operatively connected by the speed increasing mechanism with a shaft 51, the latter rotating at a substantially greater speed than shaft 49. Winding drum shaft 39 and the speed increasing mechanism 50 may be operatively disconnected by manually disengaging the clutch 52. One end of the speed increaser shaft 51 carries a sprocket 51a which is driven by a suitable power source, preferably a reversible and variable speed motor 53, via chain 54 and sprocket 55 on the motor shaft.

Broadly speaking, any suitable means may be applied to or connected with high speed shaft 51 of the speed increaser, that will impose sufficient resistance to rotation of the shaft to hold winding drum 25 against rotation under the full load of the drill string. As a typical means whereby such rotation resisting force may be applied to shaft 51, I show in Fig. 3 a suitable friction brake 57 illustrated conventionally as comprising a drum 58 keyed to shaft 51, and a pair of friction bands 59 and 60 operated by lever 61 and linkage 62 to apply a braking force to drum 58 and the shaft. A tension spring 63 is connected to the handle, and the latter may be held in fixed position to apply any desired braking force to the drum, by engagement with ratchet teeth 64 on post 65.

In Fig. 4 I show a variational mechanism in the form of a hydraulic brake, for applying any predetermined rotation resisting force to shaft

51. In this instance the shaft is connected to a pump 66, which may be of any suitable type, having an inlet 67 connecting with line 68, and an outlet 69 discharging into passage 70 of a multiple valve device 71. Passage 70 is communicable with discharge passages 72 and 73 by way of separate passages 74, 75, 76 and 77, the flow of high pressure fluid through these passages from passage 70 being controlled by valves 78, 79, 80 and 81, of progressively increasing size in the order designated. Each of the valves is seated by a compression spring 82, the thrust of which, and therefore the resistance to opening of its valve, may be adjusted by nut 83 engaging a washer 84 against which the upper end of the spring bears. The fluid is discharged from passage 73 into a supply chamber 85 from which pump 66 takes suction through line 68.

When under the full load of the drill string, winding drum 25 tends to rotate shaft 51, via the speed increaser 50, in such direction as to cause pump 66 to discharge fluid into passage 70. Valves 78 to 81, however, will be set to remain closed under the fluid pressure in passage 70, thereby imposing a back pressure holding the pump rotor (not shown) and shaft 51 against rotation. The valves thus impose a resistance to fluid flow sufficient to hold shaft 51 and winding drum 25 against rotation with cable 16 under the full load of the drill string 13.

The pipe string supporting resistance presented by valves 78 to 81 is overcome by driving shaft 51 and pump 66 from motor 53 to increase the discharge pressure in passage 70 to the point where one or more of the valves will become unseated to allow fluid circulation and rotation of shaft 51 of the winding drum at a controlled rate. The valves will be set to open successively at suitable predetermined increments pump discharge pressure; valve 78 opening first, and then valves 79, 80 and 81 as the pump discharge pressure increases in response to increases in the speed of motor 53.

Instead of resisting rotation of shaft 51 by a mechanical friction or hydraulic type brakes, I may utilize a suitable electric brake. Thus in Fig. 5, shaft 51 is shown to be connected through coupling 87 with an electrically operated brake 88, for example of the motor generator type. It may be mentioned that in many instances the electric type brake may be preferred because of its capacity for extreme smoothness in operation. In the following, reference will be made only to brake 57, however with the understanding that any of the described types of brakes may be used interchangeably.

In the operation of the system, starting with the lowering of the pipe string into the well, and with clutches 38, 44 and 52 disengaged, the pipe string will be lowered in the usual manner under control of the winding drum brake 26 to substantially drilling depth. Clutch 38 is then engaged to transmit the drive from motor 29 to the rotary table 12, and clutch 52 thrown in and brake 57 adjusted and set to hold shaft 51 against rotation by the weight of the drill string transmitted through winding drum 25, chain 47 and the speed increaser 50. In this condition, the entire drill string will be suspended by virtue of the rotation resisting force applied by brake 57 to shaft 51. Motor 53 is now started into operation, driving shaft 51 against the resistance to rotation imposed by the brake, and overcoming that resistance proportionate to the speed of operation of the motor, modified by the resist-

ance of the formation to penetration by the bit. As the motor speed is increased or decreased, the rate of bit feed increases or decreases accordingly. Always, however, there is maintained by the brake 57 a force sufficient to indirectly support the entire drill string, but this force is constantly being partially overcome by the force applied by the motor. The rate of drilling may be manually controlled by varying the speed of motor 53, or the motor operation may be automatically controlled, as I shall now explain.

In some cases it may be desirable to provide an automatic control for the system whereby a substantially uniform pressure may be at all times maintained on the bit during drilling, and for this purpose I have provided, in conjunction with the described mechanism, a control whereby the operating speed of motor 53 is automatically regulated in accordance with variations in the pressure on the bit. A suitable weight indicator 23, which may be one of a number of types in common use, is shown to be connected into the drill string suspension, for example between the travelling block 18 and the hook 21, so that the weight of the drill string is transmitted through the indicator. Using a weight indicator of the fluid pressure type, the regulator 23 may be connected via pressure hose 90 with a suitable meter 91 having an indicator arm 92 actuated in response to variations in the fluid pressure in hose 90 and, accordingly, in accordance with variations in the suspended weight of the drill string. Arm 92 controls the variable resistance 93 placed in the motor circuit 94 to which current is supplied from power lines 95.

The motor circuit is controlled for drilling under automatic or manual regulation, from a switch box 96 which may be placed at any convenient location. As shown in Fig. 6, the motor circuit control comprises a double-throw switch 97 which when brought into contact with poles 98, places the variable resistance 93 in the motor circuit for drilling under automatic control. As previously observed, arm 92 moves in response to variations of pressure on the bit, to control the operating speed of motor 53. As the pressure on the bit increases above normal, arm 92 moves to increase the resistance in the motor circuit and proportionately decrease the motor speed, and consequently the rate of bit feed, until normal drilling pressure on the bit has been restored. Conversely, the control operates automatically to increase the motor speed and rate of bit feed when the pressure on the bit falls below normal.

In case it is desired to control the rate of drilling by manual regulation, switch 97 is thrown into contact with poles 99 to bring the manually variable resistance 100 into the motor circuit. By manually controlling the resistance 100, the motor speed may be increased or decreased, as desired. If for any reason it becomes desirable to elevate the drill string by motor 53, as for example for the purpose of drilling or reaming upwardly, rotation of the motor may be reversed by switch 101 acting to reverse the motor field. Switch 101 of course operates to reverse the motor operation whether the system be under automatic control with switch 97 in contact with poles 98, or under manual control from the variable resistance 100.

In Figs. 7 and 8 I have illustrated a valve mechanism adapted to be installed in the discharge line of a hydraulic type brake, and operated to vary the braking force or resistance of the hydraulic brake. The valve operating mechanism

comprises means whereby movement of the valve is synchronized with a rheostat control for the motor 53, so that the valve is caused to open from fully closed position, when the motor circuit is open, progressively to fully open position as the rheostat control comes into operation the motor reaches full speed.

As illustrated in Fig. 7, the valve proper, generally indicated at 102, may be installed in the discharge line 69 of pump 66, see Fig. 4, and, it may be observed, this valve may be used either in lieu of or in addition to the automatic valve control 71 which I have previously described. The use of both the manually operated valve 102 and the automatic valve control 71 would have an advantage however in that the former provides an additional safety factor against failure of the valves in the mechanism 71 to properly function. The valve device 102 comprises a body 103 having inlet and outlet passages 104 and 105, and a valve 106 having a swivel connection at 107 with stem 108 threaded at 109 through the cap portion 110 of the body. Fluid leakage along the valve stem is prevented by a suitable stuffing box, as indicated at 111.

The valve 106 is opened and closed by rotation of stem 108, the latter in turn being actuated from manually rotated shaft 112 of the rheostat motor control 113. Shaft 112 drives the valve stem 108 through a speed increasing gear train 114 comprising gear 115 carried on shaft 112, and gears 116 and 117 keyed to shaft 118, gear 117 meshing with gear 119 on the upper end of the valve stem. The gear ratio of the speed increaser 114 may be selected so as to give shaft 112 and valve stem 108 a rotation ratio of around 1 to 6, so that for a half turn of the motor control shaft, the valve stem will make three complete turns or revolutions, moving the valve from closed to wide open position.

The motor control, generally indicated at 120, comprises a rheostat having a variable resistance 121 in series with one of the power lines 95 leading to the motor 53, the rheostat being thrown into the circuit by rotating arm 122 from the dotted position 122a into contact with the resistance 121, arm 122 being carried on shaft 112 and the latter rotated by a suitable hand control 123. When arm 122a is in the dotted line position illustrated, with the motor circuit open and the motor not in operation, valve 106 is then in closed position. As the motor is brought into operation and its speed progressively increased by rotating the rheostat arm 122 in a clockwise direction as viewed in Fig. 8, valve 106 is progressively raised a distance proportionate to the speed of operation of the motor. When the motor is operated at maximum speed the valve is wide open.

It will be understood of course that when the rheostat motor control 120 is being used, then the previously described motor control operated in accordance with the weight on the bit, will not be employed. If desired, however, the two controls may be connected into the motor circuit and used selectively or alternately, as desired.

I claim:

1. In a rotary well drilling employing a bit carried by a rotatably driven pipe string whose length and weight are increased as drilling progresses, and means rotatable to lower the pipe string; the method of smoothly feeding the bit that includes, suspending the pipe string by continuously applying to said rotatable means a controllably variable rotation resisting force sufficient to support substantially the entire weight

of any length thereof during drilling, and lowering the pipe string and continuously exerting downward pressure on the bit to drill the formation by partially overcoming said force by a second force independent of the pipe suspending and rotating forces, while at the same time maintaining the first mentioned force.

2. In rotary well drilling employing a bit carried by a rotatably driven pipe string whose length and weight are increased as drilling progresses, and means rotatable to lower the pipe string; the method of smoothly feeding the bit that includes, suspending the pipe string by continuously applying to said rotatable means a controllably variable rotation resisting force sufficient to suspend substantially the entire weight of any length thereof during drilling, lowering the pipe string and continuously exerting downward pressure on the bit to drill the formation by partially overcoming said force by a second force independent of the pipe suspending and rotating forces, and controllably varying said second force while at the same time maintaining the first mentioned force.

3. In rotary well drilling employing a bit carried by a rotatably driven pipe string lowered in the well by an attached suspension means, and means rotatable to release said suspension means, the length and weight of said pipe string increasing as drilling progresses; the method of smoothly feeding the bit that includes, continuously applying to said rotatable means a controllably variable rotation resisting force sufficient to suspend substantially the entire weight of any length of the pipe string during drilling, and lowering the pipe string and continuously exerting downward pressure on the bit to drill the formation by partially overcoming said force by applying to said means a rotation producing force independent of the pipe suspending and rotating forces, while at the same time maintaining the first mentioned force.

4. In rotary well drilling employing a bit carried by a rotatably driven pipe string whose length and weight are increased as drilling progresses, and means rotatable to lower the pipe string; the method of smoothly feeding the bit that includes, suspending the pipe string by continuously applying to said rotatable means a controllably variable rotation resisting force sufficient to suspend substantially the entire weight of any length thereof during drilling, lowering the pipe string and continuously exerting downward pressure on the bit to drill the formation by partially overcoming said force by a second force independent of the pipe suspending and rotating forces, while at the same time maintaining the first mentioned force, and continuously applying said second mentioned force to advance the bit through the formation.

5. In rotary well drilling employing a bit carried by a rotatably driven pipe string lowered in the well by an attached suspension means, and means rotatable to release said suspension means, the length and weight of said pipe string increasing as drilling progresses; the method of smoothly feeding the bit that includes, continuously applying to said rotatable means a controllably rotation resisting force sufficient to suspend substantially the entire weight of any length of the pipe string during drilling, lowering the pipe string and continuously exerting downward pressure on the bit to drill the formation by partially overcoming said force by applying to said means a rotation producing force independent of the pipe

suspending and rotating forces, while at the same time maintaining the first mentioned force, and continuously applying and controllably varying said second mentioned force to advance the bit through the formation.

6. In rotary well drilling employing a bit carried by a rotatably driven pipe string lowered in the well by a cable released from a rotatable winding drum, the length and weight of said pipe string increasing as drilling progresses; the method of smoothly feeding the bit that includes, restraining rotation of said winding drum by applying thereto a continuous and controllably variable force sufficient to support substantially the entire weight of any length of the pipe string from the drum by way of said cable, and lowering the pipe string and continuously exerting downward pressure on the bit to drill the formation by partially overcoming said force by a second independent force, while at the same time maintaining the first mentioned force.

7. In rotary well drilling employing a bit carried by a rotatably driven pipe string lowered in the well by a cable released from a rotatable winding drum, the length and weight of said pipe string increasing as drilling progresses; the method of smoothly feeding the bit that includes, restraining rotation of said winding drum by applying thereto a continuous and controllably variable force sufficient to support substantially the entire weight of any length of the pipe string from the drum by way of said cable, lowering the pipe string and continuously exerting downward pressure on the bit to drill the formation by partially overcoming said force by a second independent force, while at the same time maintaining the first mentioned force, and continuously applying and controllably varying the second mentioned force to advance the bit through the formation.

8. In rotary well drilling employing a bit carried by a rotatably driven pipe string whose length and weight are increased as drilling progresses, and means rotatable to lower the pipe string; the method that includes, suspending the pipe string by applying to said rotatable means a continuous and controllably variable rotation resisting force sufficient to suspend substantially the entire weight of any length thereof during drilling, lowering the pipe string and continuously exerting downward pressure on the bit to drill the formation by partially overcoming said force by a second independent and continuously applied force, while at the same time maintaining the first mentioned force, and automatically varying the second mentioned force in accordance with variations in the weight on said bit.

9. In rotary well drilling employing a bit carried by a rotatably driven pipe string lowered in the well by an attached suspension means, and means rotatable to release said suspension means, the length and weight of said pipe string increasing as drilling progresses; the method that includes, continuously applying to said rotatable means a controllably variable rotation resisting force sufficient to suspend substantially the entire weight of any length of the pipe string during drilling, lowering the pipe string and continuously exerting downward pressure on the bit to drill the formation by partially overcoming said force by applying to said means a rotation producing force independent of the pipe suspending and rotating forces while at the same time maintaining the first mentioned force, and automatically varying the second mentioned force in

accordance with variations in the weight on said bit.

10. In rotary well drilling employing a bit carried by a rotatably driven pipe string lowered in the well by a cable released from a rotatable winding drum, the length and weight of said pipe string increasing as drilling progresses; the method that includes, restraining rotation of said winding drum by applying thereto a continuous and controllably variable force sufficient to support substantially the entire weight of any length of the pipe string from the drum by way of said cable, lowering the pipe string and continuously exerting downward pressure on the bit to drill the formation by partially overcoming said force by a second independent and continuously applied force, while at the same time maintaining the first mentioned force, and automatically varying the second mentioned force in accordance with variations in the weight on said bit.

11. In combination with a rotary well drilling pipe string carrying a bit, a rotatable winding drum, and a drill pipe suspension cable released from said winding drum; a speed multiplying mechanism, a shaft connected via said mechanism with said winding drum so as to rotate at substantially greater speed than the drum, a brake for applying a rotation resisting force to said shaft to restrain rotation of said winding drum, and a motor for driving said shaft and winding drum, both said brake and motor being located at the high speed side of said speed multiplying mechanism.

12. In combination with a rotary well drilling pipe string carrying a bit, a rotatable winding drum, and a drill pipe suspension cable released from said winding drum; a speed multiplying mechanism, a shaft connected via said mechanism with said winding drum so as to rotate at substantially greater speed than the drum, means at the high speed side of said speed multiplying mechanism for continuously applying a rotation resisting force to said shaft to restrain rotation of said winding drum, and a motor connected to and driving said shaft.

13. In combination with a rotary well drilling pipe string carrying a bit, a rotatable winding drum, and a drill pipe suspension cable released from said winding drum; a speed multiplying mechanism, a shaft connected via said mechanism with said winding drum so as to rotate at substantially greater speed than the drum, means continuously applying a rotation resisting force directly to said shaft to restrain rotation of said winding drum, and a motor connected to and driving said shaft, said motor operating to partially overcome the shaft rotation resisting force applied by said means.

14. In combination with a rotary well drilling pipe string carrying a bit, a rotatable winding drum, and a drill pipe suspension cable released from said winding drum; a speed multiplying mechanism, a shaft connected via said mechanism with said winding drum so as to rotate at substantially greater speed than the drum, a brake connected directly to said shaft and operable to resist rotation of the shaft and said winding drum, and a motor connected to said shaft and operable to rotate said drum.

15. In combination with a rotary well drilling pipe string carrying a bit, a rotatable winding drum, and a drill pipe suspension cable released from said winding drum; a speed multiplying mechanism, a shaft connected via said mechanism with said winding drum so as to rotate at

substantially greater speed than the drum, a brake connected directly to said shaft and resisting rotation of the shaft and said winding drum sufficiently to enable substantially the entire weight of the pipe string to be supported from the drum by way of said cable, an electrically driven motor connected to said shaft and operat-

ing to partially overcome the shaft rotation resisting force applied by said brake, and means automatically controlling the speed of said motor in accordance with variations in the weight on said bit.

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