Aug. 9, 1938. O. B. GOLDMAN 2,126,189

MEANS FOR DRILLING WELLS

Filed Dec. 30, 1935 3 Sheets-Sheet 1

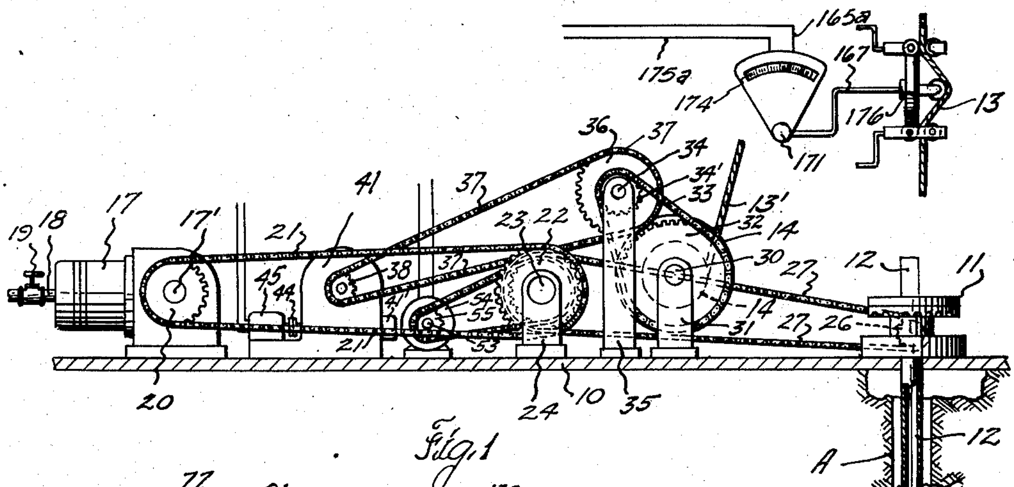

Fig. 1

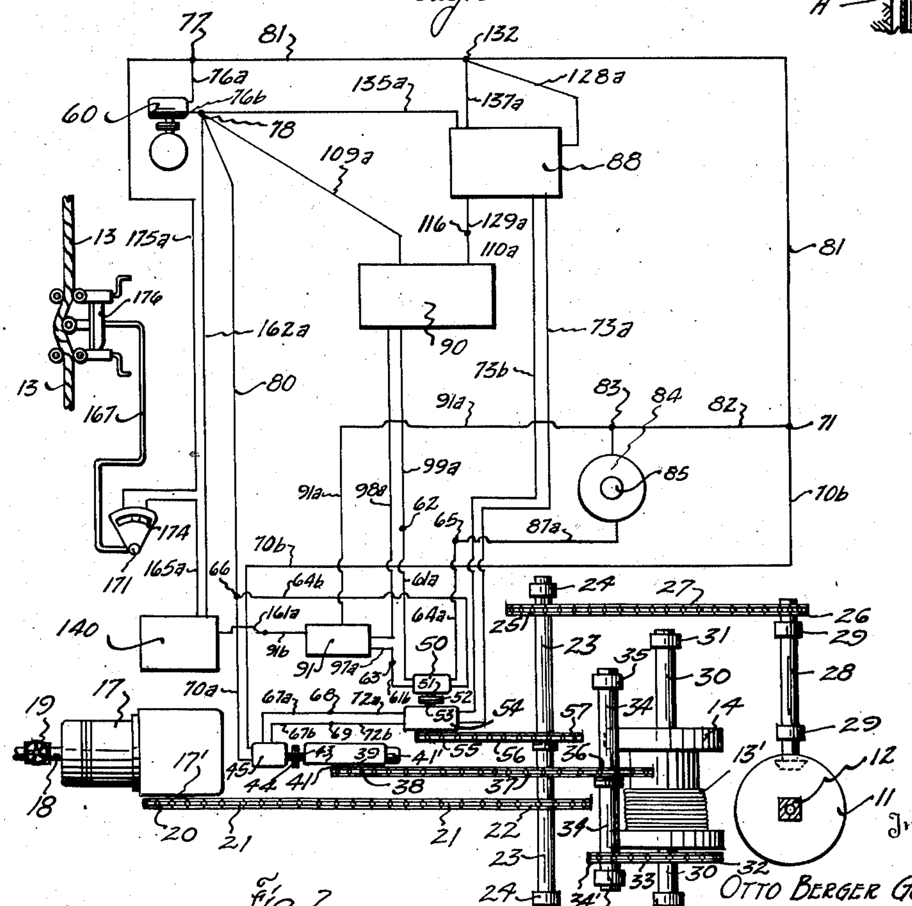

Fig. 2

Inventor

OTTO BERGER GOLDMAN

By Jack A. Ashley

Attorney

Aug. 9, 1938. O. B. GOLDMAN **2,126,189**

MEANS FOR DRILLING WELLS

Filed Dec. 30, 1935 3 Sheets-Sheet 2

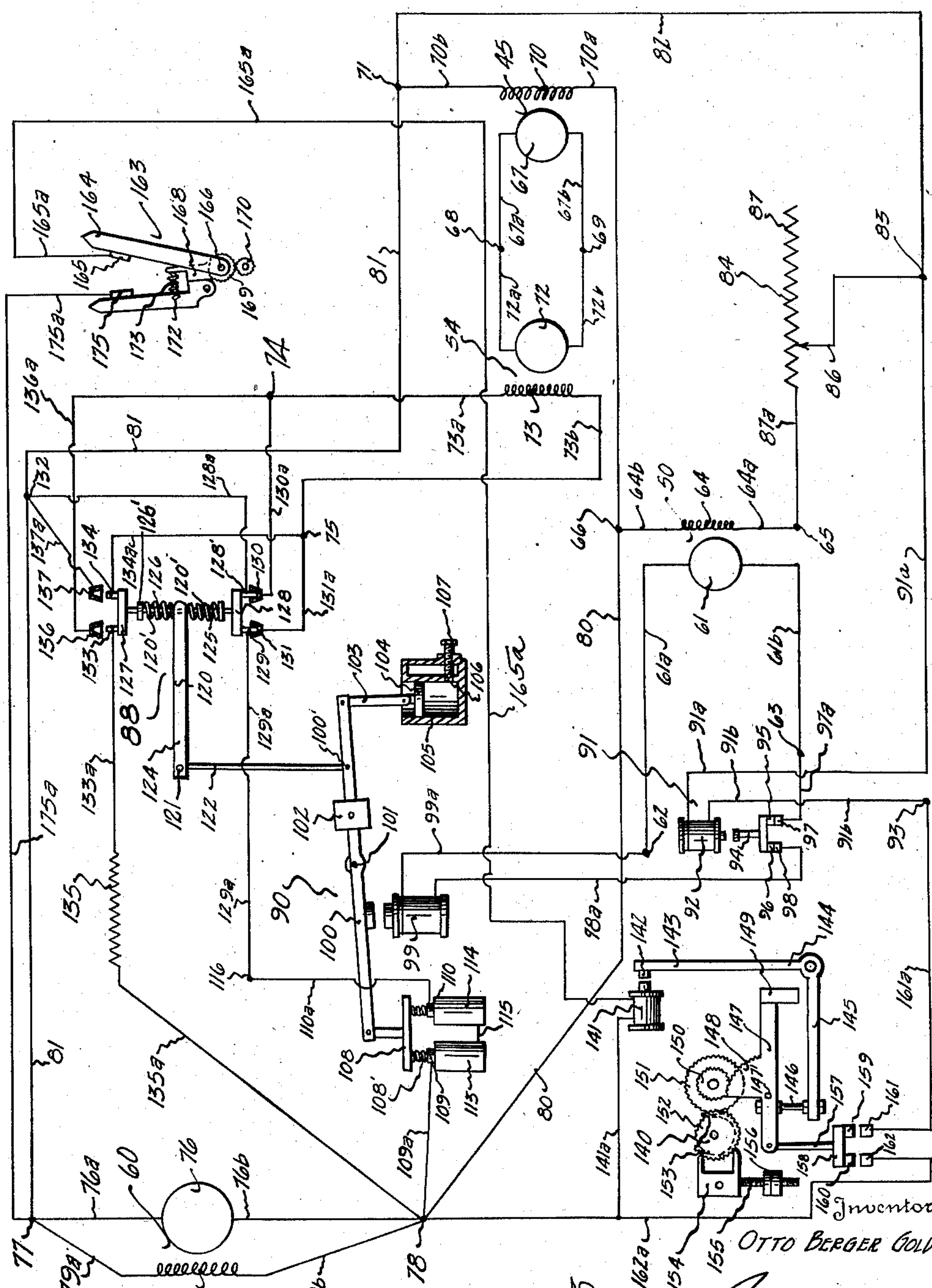

Fig. 3

Inventor

Otto Berger Goldman

By Jack A. Ashley

Attorney

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MEANS FOR DRILLING WELLS

Filed Dec. 30, 1935 3 Sheets-Sheet 3

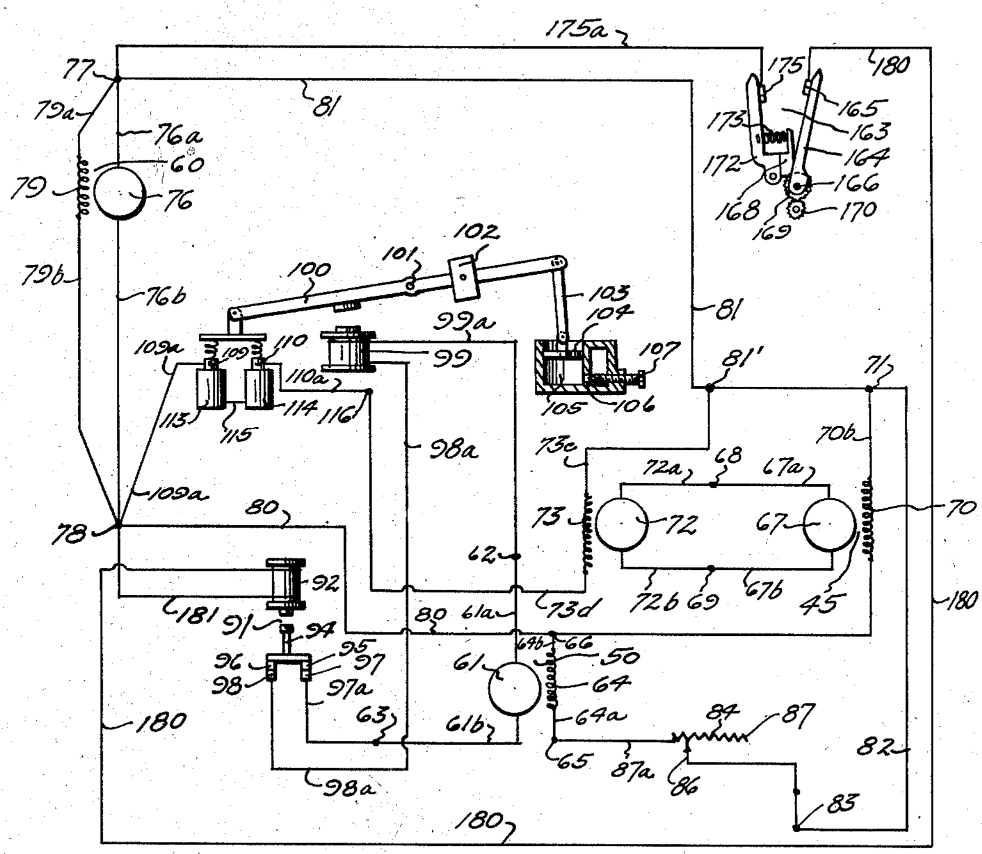

Fig. 5

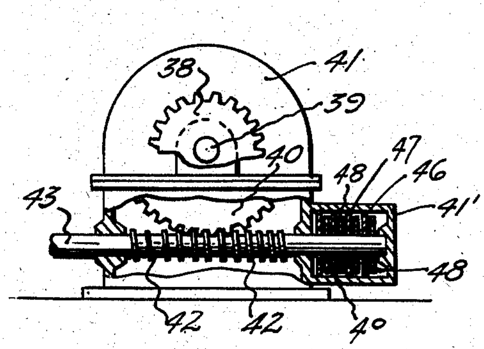

Fig. 4

Inventor

OTTO BERGER GOLDMAN

By Jack Ashley

Attorney

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2,126,189

UNITED STATES PATENT OFFICE

2,126,189

MEANS FOR DRILLING WELLS

Otto Berger Goldman, Dallas, Tex.

Application December 30, 1935, Serial No. 56,607

3 Claims. (Cl. 255—19)

This invention relates to new and useful improvements in methods of and means for drilling wells.

The invention is an improvement upon the method and means for well drilling set forth in my Letters Patent No. 1,913,752, issued June 13, 1933.

One object of the invention is to provide an improved method of drilling, wherein the drill bit is rotated at a substantially constant speed and preferably at the maximum allowable speed, which makes for the fastest possible, and thus most economical, drilling.

An important object of the invention is to provide an improved method of drilling which involves constant speed of rotation of the drill bit, and wherein variations in the speed of rotation of the bit, due to variations in the character of formation being drilled, are reflected in proportional variations in the operation of the drill stem driving means and in the feeding means for the drill stem, whereby the speed of rotation of the drill bit is maintained substantially constant regardless of the character of the formation being drilled and thereby a faster drilling speed may be attained than has heretofore been possible.

Another object of the invention is to provide an improved drilling method wherein the weight of the drill bit on the bottom of the hole is automatically varied inversely with the hardness of the formation being drilled and wherein the maximum allowable power is delivered to the bit at all times.

Still another object of the invention is to provide an improved method of rotary drilling wherein the operation of the feeding means for the drill stem is automatically controlled by the speed of rotation of the drill bit, whereby said means is operated to provide a continuous feed of said drill stem.

A further object of the invention is to provide improved means for drilling, coring and reaming of wells, wherein the speed of rotation of the drill bit is maintained substantially constant, irrespective of the character of formation being drilled, while the drilling speed progresses in proportion to the variations in the character of the formation.

A still further object of the invention is to provide an improved rotary drilling mechanism which includes a prime mover for rotating the drill stem and bit, and a feeding means connected with and controlled by the speed of said prime mover for feeding the drill stem into the hole, the prime mover being governed only by the load imposed upon the bit in passing through the various formations being drilled, the connection between the prime mover and the feeding means being such that variations in the speed of rotation of the drill stem and bit, due to variations in the character of formation being drilled, will be compensated by an immediate adjustment in the feeding means, whereby a substantially constant speed of rotation of the drill stem and a substantially continuous feed thereof will be maintained.

Another object of the invention is to provide improved means for rotary drilling which includes a feeding means connected to the drill stem and a counterbalance or compensating means connected to said feeding means and exerting a torque equal to, or preferably greater, than the torque resulting from the weight of the drill stem load, whereby said drill stem is counterbalanced; a motor connected with the feeding means for the operation of the same and serving to control the feed of the drill bit into the formation being drilled, thereby eliminating the building up of a great momentum due to the weight of the drill stem load and thus eliminating the danger of overfeed.

A construction designed to carry out the invention will be hereinafter described, together with other features of the invention.

The invention will be more readily understood from a reading of the following specification and by reference to the accompanying drawings, in which an example of the invention is shown, and wherein:

Figure 1 is a side elevation of an apparatus for carrying out the improved method constructed in accordance with the invention,

Figure 2 is a plan view and electromechanical diagram of the complete device,

Figure 3 is an enlarged electromechanical diagram, and showing schematically the construction of the various portions of the electrical apparatus.

Figure 4 is an enlarged view, partly in elevation and partly in section of the worm, gear and brake, which control the feed of the draw works, and

Figure 5 is a view, similar to Figure 3, of a modified form of apparatus.

In the drawings, the numeral **10** designates the derrick floor on which the conventional drilling rig is mounted. The rig includes the usual rotary table **11**, through which the drill stem or string of pipe **12** extends. The drill bit (not shown) is carried on the lower end of the drill stem and engages, or bears on, the bottom of the hole A. The connection between the rotary table and drill stem is such that rotation of the rotary table will rotate the drill stem and the drill bit carried thereby. The drill stem is freely movable vertically through the rotary table and has its upper end secured to the usual travelling block (not shown) which is suspended by several runs of cable, the dead end of which is shown at 13. The live end 13' of the cable is wound on the ordinary draw works drum 14, and it will be seen that as said drum is rotated to pay out the cable, the drill stem will be lowered into the hole A.

For rotating the table 11 so as to rotate the drill stem and bit to perform the drilling operation, a suitable drilling engine 17 is provided. The engine has the usual admission or feed pipe 18 in which the throttle valve 19 is connected. It is obvious that adjustment of the valve 19 controls the power of the engine. The engine is provided with a driving sprocket 20 mounted on the engine shaft 17', and an endless chain 21 passes over this sprocket. The chain also passes over a sprocket 2 secured on a transverse jack shaft 23 which is mounted in bearing brackets 24. As shown in Figures 1 and 2, the shaft 23 is located substantially midway between the engine 17 and rotary table 11, but it is noted that the invention is not to be limited to any particular location of any of the parts.

When the engine 17 is operated, the sprocket 20 is rotated, causing rotation of the jack shaft 23 through the medium of the chain 21 and sprocket 22. The jack shaft also carries a second sprocket 25 secured at one end, and this sprocket is connected to the driven sprocket 26 of the rotary table 11 by an endless chain 27. The driven sprocket 26 is keyed on one end of the rotary drive shaft 28, which is supported in suitable bearing brackets 29. The opposite end of the shaft 28 is operatively connected to the rotary table by means of bevel gears (not shown), so that rotation of said shaft will rotate said table. It will be seen that motion is transmitted from the engine 17 to the jack shaft 23, and from this shaft to the rotary drive shaft 28 through the endless chain 27 and sprockets 25 and 26, whereby rotation of the rotary drive shaft 28 and the resultant rotation of the rotary table and of the drill stem and bit is caused by the engine 17. It is pointed out that the engine 17 has no governor and its speed is controlled by the load imposed upon it which load results from the engagement of the drill bit with the formation being drilled and the resistance offered to the rotation by such formation.

The draw works drum 14 is fastened on a transverse shaft 30 which is journaled in bearing brackets 31. A sprocket 32 is keyed on the drum shaft. This sprocket has connection through an endless chain 33 with a sprocket 34' on a transverse line shaft 34, which is rotatably supported in bearing brackets 35. It will be obvious that rotation of the line shaft 34 will rotate the drum shaft to rotate said drum 14, or rotation of said drum will impart rotation to said line shaft.

A second sprocket 36 is secured to the line shaft 34 and an endless chain 37 passes over this sprocket and also over a sprocket 38 which is fastened on the end of the shaft 39 of a worm gear 40. The gear 40 is mounted within a suitable case 41 which also has a worm 42 mounted on a worm shaft 43 in its lower end. The worm is in constant engagement with said worm gear 40. One end of the worm shaft 43 extends outwardly from the case 41 and is connected by a coupling 44 with an electric feed motor 45. It will be obvious that when the motor 45 is operated, the worm 42 is rotated to drive the worm gear 40 and rotate the gear shaft 39. Rotation of this shaft will rotate the line shaft 34 through the sprockets 36 and 38 and endless chain 37. The line shaft 34 will, in turn, impart rotation to the drum 14 through the chain 33 and sprockets 32 and 34'.

For counterbalancing the weight of the drill stem and its associate parts, a suitable compensating means or counterbalance may be mounted at any point between the feed motor 45 and drum 14. This compensating means has been shown in the form of a multiple disk brake 46 which is mounted in an extension 41' formed on the worm and gear casing 41. The brake comprises a plurality of disks 47 rigidly attached to the inside of the extended portion 41' of the case, and a plurality of revoluble disks 48 which are secured on the extended end of the worm shaft 43 which is free to undergo axial movement. It is noted that the stationary disks are alternately mounted with relation to the rotating disks.

Since the drill stem is carried by the cable wound on the drum 14, the weight of said stem will tend to rotate the drum 14, whereby the worm will tend to be rotated by said drum. With the mounting of the multiple disk brake on the worm shaft, it will be seen that the torque resulting from the weight of the drill stem and its associate parts will cause the worm shaft 43 to move axially to press the disks 48 on the worm shaft against the stationary disks 47 secured within the casing. The brake is so constructed that the torque of its friction is sufficient to more than neutralize that resulting from the weight of the stem and its associate parts, whereby said brake acts as a counterbalance. Therefore, since the stem is counterbalanced, the rotation of the draw works drum 14 to pay out the cable 13' and lower the drill stem 12 into the hole is controlled entirely by the feed motor 45. The weight of the stem is not depended upon to feed the same in the hole.

It has been the usual practice, in hand drilling, to apply a brake to the drum 14 and to intermittently release the brake, thereby permitting the drum to be rotated to pay out the cable by the weight of the drill stem. An automatic brake of this type is fully disclosed in my former patent, hereinbefore referred to. In such structure, the weight of the stem is depended upon to lower the same, and due to the intermittent release of the brake, the feed of the stem into the hole is intermittent. Also, when the brake is released, the weight of the stem and its associated parts give an active acceleration to the down feed of the stem, which results in a high velocity and great momentum. Therefore, when the brake is again applied, immediate stopping of the downward movement of the drill stem is impossible, the result being that the drill stem over-feeds.

This active acceleration and resultant overfeed is overcome with the structure herein disclosed by the counterbalancing of the drill stem. The multiple disk brake 46 is of such size that it serves to not only reduce the downward acceleration of the drill stem to zero, but preferably to make the same negative. Further, by overcoming the downward acceleration, it is possible to accomplish a continuous feed of the drill stem in the hole which is positively controlled by the electric feed motor 45. The rate of the feed may be faster or slower, but is nevertheless continuous.

From the foregoing, it will be seen that the engine drives the rotary table 11 through the chains 21 and 27, jack shaft 23 and drive shaft 28. The engine has no governor and its speed is controlled only by the load imposed upon the drill bit, which load results from the resistance offered by the formation to the rotation of the bit. The downward movement of the dril stem 12, or the feed of said stem into the hole, is controlled by the electric feed motor 45. If said motor operates at a faster speed, the drum 14 is rotated faster to pay out cable at a faster rate. Similarly, if the feed motor slows, then the cable pay-out is lessened and the stem is fed into the hole at a slower rate. The weight, or pressure, of the bit on the bottom of the hole is, of course, regulated by the rate of feed of the stem, relative to the rate at which the bit digs off.

For varying the speed of the electric feed motor 45, which positively controls the draw works drum 14, an electrical control generator 50 is provided (Figure 2). The armature shaft 51 of this generator is connected by a coupling 52 and driven by the shaft 53 of a feed generator 54. This shaft 53 of this latter generator has a sprocket 55 on its outer end and this sprocket has a driving connection through an endless chain 56 with a sprocket 57 secured on the jack shaft 23.

As has been explained, motion to the rotary table 11 and drill stem 12 from the drilling engine 17 is transmitted through the jack shaft 23. Therefore, since the armature shaft 53 of the feed generator is connected with the jack shaft, it will be seen that the speed of the feed and control generators are controlled by the engine 17. The feed generator 54 is electrically connected with and drives the feed motor 45, whereby the speed of said motor is controlled thereby. The worm 42, which is driven by said motor 45, regulates the paying out of the cable, and therefore, due to the connection of the parts as shown, it will be seen that the speed of the feed motor 45 and resultant pay out of the cable to feed the drill stem, is regulated according to the speed of rotation of the bit and stem, as transmitted to the jack shaft 23.

In drilling, the drill bit must perform two functions, first, it must penetrate the formation and, second, is must remove the material by a shearing or cutting action. The penetration of the bit is caused by the weight of the bit on the bottom of the hole, while the cutting or shearing is produced by the rotative power applied to the bit. If the penetration of the bit is too deep, the resistance offered by the formation to the rotation of the bit is so great that the speed of rotation of the drill bit is reduced, thereby reducing the power input to the bit, with a corresponding retarded rate of drilling, or else the rotation of said bit and stem may be stopped altogether by the deep penetration, and a "hang-up" results. On the other hand, if the penetration is not deep enough, there is not sufficient resistance to the rotation and the bit will rotate without properly performing its cutting or shearing action, which results in a reduction in the rate of drilling. Thus, it is evident that for maximum speed of drilling, the penetration of the bit must be neither too great nor too small.

Due to the various characters of formations through which the drill must pass, it is obvious that no fixed weight on bottom can be maintained. That is, as the character of the formation changes, the weight on bottom must change to attain the proper penetration. When drilling in a hard formation, the weight on bottom must be greater than in a soft formation and vice versa; therefore, the weight on bottom must vary according to the formation being drilled, and this weight must be more or less inversely proportional to the hardness of the formation. In addition to the proper penetration, it is imperative, in order to attain the maximum rate of drilling, that the power input to the drill bit be maintained substantially constant and preferably at the maximum allowable, irrespective of the character of the formation through which it is passing. Since the power of the drilling engine, at a fixed position of the throttle, varies with its speed, it is obvious that constant speed of rotation of the bit, together with proper penetration is necessary to fastest drilling.

As above explained, the feed of the drill stem 12 and bit is controlled by the electric feed motor 45, which in turn is actuated according to the speed of rotation of the drill stem and bit through the jack shaft. In describing the operation of the electrical apparatus employed, reference is made to Figures 2 and 3, wherein a wiring diagram is shown. The several pieces of electrical apparatus which are employed are, with slight modification, standard equipment, and therefore, they have not been illustrated in detail. However, their main working parts have been illustrated and a brief description thereof is herewith given. For the sake of clarity the entire electrical hook-up will first be described, after which the various circuits will be set forth.

As has been stated, an electric feed motor 45, feed generator 54 and control generator 50 are provided. For exciting the fields of the motor and generator, a constant voltage direct current excitor generator 60 is provided, (Figure 3). This generator may be either engine or motor driven.

Referring now in detail to Figure 3, it will be seen that the control generator 50 has an armature 61 which has one of its terminals connected to a binding post 62 by a lead wire 61*a*, and its other terminal connected with a binding post 63 by a wire 61*b*. The field 64 of this generator has one side connected by a conductor 64*a* with a binding post 65, while its other side is connected by a wire 64*b* with a post 66.

The feed motor 45 is provided with an armature 67, one terminal of which is connected by a wire 67*a* with a post 68, while its other terminal is connected by a wire 67*b* to a terminal 69. The field 70 of this motor has one side connected with the binding post 66 by a wire 70*a*. The other side of the feed motor field is connected by a conductor 70*b* with a binding post 71.

The feed generator 54 has one side of its armature 72 connected by a wire 72*a* to the post 68, while its other side is connected by a wire 72*b* with the post 69. With such arrangement, it is obvious that the armatures 67 and 72 of the feed motor and feed generator are electrically connected. The field 73 of the feed generator has one terminal connected by a wire 73*a* to a binding post 74, and its other terminal connected by a wire 73*b* with a binding post 75.

The exciter generator 60 is provided with an armature 76, one side of which is connected by a wire 76a with a binding post 77, the other side of said armature being connected with a post 78 by a wire 76b. The field 79 of this generator has one of its terminals electrically connected by a wire 79a to the post 77 while the other terminal thereof connects by a wire 79b with the binding post 78. A conductor 80 extends from the binding post 78 to the post 66, whereby one side of the exciter generator is electrically connected to one side of the field of the control generator through the wire 64b, and also to one side of the field of the feed motor through the wire 70a. The other side of the exciter generator is connected to the other side of the field 70 of the feed motor by a conductor 81 which leads from the post 77 to the post 71, to which the field 70 is connected by a wire 70b.

In order to connect this side of the exciter with the other side of the field 64 of the control generator, a conductor 82 leads from the binding post 71 to a binding post 83. A variable resistance 84 is arranged to connect the post 83 and binding post 65 which latter is connected by a wire 64a with the field 64 of said control generator. The resistance includes a handle 85 (Figure 2) rigidly attached to a pivoted lever 86, which is adapted to move along an electrical resistance 87. The inner end of the lever is electrically connected with the post 83, while the resistance 87 has one end connected to the post 65 by a wire 87a. Thus, it will be seen that current passing through the conductor 82 must pass through the resistance to reach the field of the control generator 50.

From the above, it will be seen that opposite sides of the fields 64 and 70 on the control generator and feed motor are electrically connected to opposite sides of the exciter generator, whereby said fields are excited thereby. The field 73 of the feed generator is also connected with and excited by said exciter generator but is connected through a reversing switch 88, and controller 90 the details of which will be described later.

As has been hereinbefore stated, the armature 72 of the feed generator 54 is rotated by its shaft which carries the sprocket 55 (Figure 2), whereby said generator is operated by the rotation of the jack shaft 23. The operation of the control generator 50 is, of course, also controlled by the jack shaft because its armature shaft 51 is connected by the coupling 52 with the armature shaft of the feed generator. The actuation of the feed motor 45 is controlled by the feed generator 54, the power output of which is regulated by an electrical controller 90.

The controller 90 is with slight modification in assembly, the same as the General Electric automatic voltage adjuster, type G 4. This controller is electrically connected with the armature 61 of the control generator through a solenoid switch 91. This switch consists of a solenoid 92, one terminal of which is connected by a wire 91a to the binding post 83 which has connection by wires 82 and 81 to post 77 which connects to one terminal of the exciter generator 60. The other terminal of the solenoid is connected to a binding post 93 by a wire 91b. When the solenoid is energized, it attracts an armature bar 94 which carries contacts 95 and 96. These contacts are arranged to normally engage contacts 97 and 98, whereby when the solenoid is de-energized the contacts 97 and 98 are electrically connected. Of course, energization of said solenoid electrically disconnects the contacts.

The contact 97 has a lead wire 97a which is connected with the binding post 63 to which one side of the armature 61 of the control generator is connected. A conductor 98a leads from the contact 98 to one side of a solenoid 99 which forms a part of the controller 90. The opposite side of the solenoid 99 is connected by a conductor 99a with the binding post 62 to which the other side of the armature of the control generator 50 is connected. From the above, it will be seen that with the solenoid 92 de-energized, current will flow from the armature 61 of the control generator to the solenoid 99 of the controller, and as the output of said generator varies according to the speed of the jack shaft 23, the magnetic attraction of said solenoid 99 is varied to correspond.

When the solenoid 99 is energized, it is adapted to attract one end of an armature bar 100 which is pivotally mounted on a pivot pin 101. The other end of the bar carries a counterweight 102 which is adjustable thereon. This end of the bar also has a rod 103 pivoted thereto and the lower end of the rod carries a piston 104 which is slidable within a cylinder 105, so as to form a dash pot and suitably dampen the movement of the bar. The cylinder has an opening 106 in its lower end and the size of this opening may be varied by a needle valve 107, whereby the speed of movement of the piston may be regulated.

The end of the bar which is arranged to be attracted by the solenoid 99, has an insulated bar 108 pivoted thereto. The lower end of this bar carries a pair of coiled springs 108' which engage terminals 109 and 110 which rest on the carbon pile resistances 113 and 114. The lower ends of these resistances are connected to each other by a wire 115. The resistances 113 and 114 are arranged to decrease when the solenoid 99 attracts the bar 100 so as to increase the pressure on said resistances. Similarly, the resistances increase as said bar moves away from the solenoid 99 to relieve the pressure. The contact 109 carried by the resistance 113 is connected by a wire 109a with the post 78 which is connected with one side of the exciter generator, while the contact 110 is connected by a wire 110a with a binding post 116.

It will be evident that the power output of the control generator 50 regulates the energization of the controller solenoid 99. This solenoid controls the swinging of the armature bar 100, which in turn increases or decreases the resistances 113 and 114.

As was above stated, the field 73 of the feed generator is excited by the exciter generator through an electrical reversing switch 88. Also the resistances 113 and 114 are connected in the feed generator circuit so that variation of these resistances will vary the power output of the feed generator 54 to vary the rate of feed of the bit into the formation.

The reversing switch 88 includes an actuating arm 120 which is pivoted to swing on a pin 121. The upper end of a rod 122 is pivoted to one end of the arm 120, while the lower end of the rod 122 is pivoted to the end 100' of the armature bar 100 of the controller, whereby when said bar is swung, through energization of the solenoid 99, the actuating bar 120 is also swung.

The opposite end of the actuating bar 120 has a rod 126 slidable therethrough and the bar has insulated cross bars 127 and 128 at its upper and lower ends. The rod is provided with collars 126' thereon, and coiled springs 120' surround the rod above and below the arm 120, between said arm and the collars, whereby connection between the arm and rod is had. It is noted that the springs are balanced and exert an equal pressure above and below the arm. The lower bar 128 carries contacts 128' and 129 arranged to frictionally engage contacts 130 and 131. The contact 128' is connected by a wire 128a, with the conductor 81 at a point 32. It is noted the conductor 81 leads from one side of the exciter generator 60. The contact 129 is connected by a wire 129a with the post 116, which post is connected to the contact 110 of the carbon pile resistance 114. The contact 130 is connected by a wire 130a with the binding post 74 which has connection with one side of the field 73 of the feed generator. A wire 131a connects the contact 131 with the post 75, which post is connected to the other side of the field of the generator 54.

The upper bar 127 of the rod 126, carries a pair of contacts 133 and 134. The contact 133 is connected by a lead wire 133a with one side of a resistance 135, and the opposite side of this resistance is connected by a wire 135a to the binding post 78 which leads to one side of the exciter generator. The contact 134 is directly connected by a lead wire 134a with the post 75. The contacts 133 and 134 are arranged to frictionally engage contacts 136 and 137, the former having connection by a wire 136a with the binding post 74, while the latter is connected by a wire 137a with the conductor 81 at the point 132.

Under normal operation, the rod 126 is in a lower position with the contacts 128' and 129 frictionally engaging the contacts 130 and 131. However, if the armature bar 100 is swung, it will be seen that the arm 120 is also swung. Due to the frictional engagement of the contacts 128 and 129 with the contacts 130 and 131, and also due to the springs 120', the arm 120 must move a predetermined distance, that is until the upper spring 120' is under sufficient pressure to break the frictional engagement of the contacts. When this occurs, the arm is swung to the opposite direction to engage the upper contacts 133 and 134 with the contacts 136 and 137. A similar action takes place on the reverse actuation of the arm 120.

Assuming the contacts 128' and 129 are in engagement with the contacts 130 and 131, the field 73 of the feed generator is excited by the exciter generator 60. The current flows from the generator 60, through the conductor 81, to the point 132, through the wire 128a, through contacts 128' and 130, wire 130a, post 74, wire 73a to the field 73. The current then passes through the wires 73b and 131a to contacts 131 and 129, then through wire 129a, post 116, wire 110a, contact 110, through the resistance 114, wire 115 and resistance 113, contact 109, wire 109a, post 78 and then through wire 76b to the other side of the exciter generator 60. Since the resistances 113 and 114 are connected directly in this circuit, it is obvious that an increase or decrease thereof will affect the excitation of the field 73 of the feed generator to increase or decrease the power output of said generator. Since this feed generator controls the feed motor, it is obvious that the speed of said motor is regulated by the resistances 113 and 114 which, in turn, are controlled by the energization of the solenoid 99 of the controller. This solenoid is energized by the power output of the control generator 50, which is actuated by the jack shaft 23. Therefore, it is obvious that the speed of the jack shaft regulates the speed of the feed motor, and since the speed of the jack shaft varies in accordance with the load imposed on the drill bit passing through the formation, it is manifest that the speed of the feed motor 45, which regulates the feed of the cable from the draw works drum 14, is regulated in accordance with the formation being drilled.

As has been stated, in normal operation the rod 126 of the reversing switch is lowered as shown and the field 73 of the feed generator is excited as above set forth. However, when the actuating arm 120 is swung oppositely by increased swinging of the armature bar 100, then the contacts 128' and 129 at the lower end of the rod are disengaged from the contacts 130 and 131, while the contacts 133 and 134 at the upper end of said rod engage the contacts 136 and 137. In such event, the electrical current flowing from the exciter generator 60, passes through the conductor 81 to the point 132, then through the wire 137a, through the contacts 137 and 134, through the wire 134a to the post 75, and then through the wire 73b to one terminal of the field 73 of the feed generator. The current then flows through the field, through wire 73a, post 74, wire 136a, contacts 136 and 133, then through wire 133a, resistance 135, wire 135a, post 78 and finally through wire 76b to the opposite side of the generator 60. Thus, it is seen that the terminals of the generator 60 are connected to the reverse sides of the field 73 to cause the generator to reverse the direction of its current output, thereby operating the feed motor in a reverse direction to cause the motor to rotate the draw works drum 14 so as to wind, instead of unwind, the cable 13' around said drum and thus lift the drill stem.

To control energization of the solenoid switch 91, which latter interrupts the flow of current between the control generator 50 and the solenoid 99 of the controller 90, a time delay device 140 is employed. This device includes a solenoid 141 which when energized, attracts an armature 142 carried on one arm 143 of a pivoted bell crank 144. The other arm 145 of said crank is connected by a link 146 with a pivoted bar 147. This bar carries a gear segment 148. It is obvious that when the solenoid is energized, the bell crank is swung which actuates the bar 147 to swing the segment. When the solenoid 141 is de-energized, a counterweight 149 returns the bar 147 to its normal position.

The segment 148 is in constant engagement with a gear wheel 150 which is attached to a larger gear 151 by a ratchet connection (not shown) which permits the wheel 150 to rotate reversely without rotating the large gear 151. The gear 151 is in constant engagement with a smaller gear 152 which is rigidly attached to a ratchet wheel 153. An escapement mechanism 154 engages the ratchet wheel and this escapement carries a pendulum 155 which has weights 156 adjustably secured thereon. By adjusting these weights, the periodicity of the swinging movement may be varied, which varies the length of time required for the segment to swing from one extreme position to another. The intricate details of the time switch are intentionally omitted as this is a standard switch which may be purchased on the open market. The General Electric switch bearing catalogue number Cr 2953–3 has been found suitable.

The pivoted bar 147 has a non-conductor rod

157 connected to one of its ends as shown and this rod carries a conductor plate 158 at its lower end. The plate has a pair of contacts 159 and 160 which are arranged to engage contacts 161 and 162. It is noted that when the solenoid 141 is energized, and the bell crank 144 has been swung after actuation of the time delay mechanism, the contacts 159 and 160 engage the contacts 161 and 162 to close an electrical circuit between the latter two contacts. Of course, when the solenoid 141 is de-energized, the counterweight 148 has raised the rod 157 to disengage said contacts.

The contact 161 is connected by a wire 161*a* with the binding post 93, which, it will be remembered, is connected to one side of the solenoid 92. The other contact 162 is connected by a wire 162*a* to the binding post 78 which is connected with the exciter generator. Therefore, when the solenoid 141 is energized to engage the contacts 159 and 160 with the contacts 161 and 162, an electrical circuit to the solenoid 92 is completed to energize this solenoid. Energization of the solenoid 92 will attract its armature 94 to disengage the contacts 95 and 96 from the contacts 97 and 98 which breaks the circuit between the control generator and solenoid 99 of the controller to render both inactive. When the solenoid 99 is de-energized the armature bar 100 is swung away from the solenoid which causes the resistances 113 and 114 to increase to stop the feed motor 45 and thereby stop the feed of the drill stem 12. It is noted that under normal conditions, the solenoid 141 of the time delay is de-energized, in which case, the solenoid switch 91 is holding the circuit to the solenoid 99 closed.

For energizing the solenoid 141 of the time delay, a pressure controller 163 is provided. This is a conventional apparatus and includes a pointer 164 which has an electrical contact 165, said contact being insulated from the pointer. This contact is connected by a wire 165*a* with one side of the solenoid 141. The other side of the solenoid is connected by a wire 141*a* to the wires 162*a* which leads to the post 78.

The pointer 164 is rigidly secured on a pivot pin 166 which is operatively attached to a Bourdon tube (not shown) so as to be rotated by pressure variations in a tube 167 (Figure 2) which communicates with the Bourdon tube. A block 168 has a toothed segment 169 concentric with the pivot pin 166, and this segment is in constant engagement with a pinion 170 which is secured on a pin having a hand knob 171 on its outer end. On one side of the block 168, an arm or second pointer 172 is pivoted and a coil spring 173 has one end secured to the pointer and its other end fastened to the block, whereby said spring exerts its tension to hold the pointer in engagement with the block. Thus, the position of the arm or pointer 172 with relation to the dial 174 may be readily varied by rotating the knob 171 and changing the position of the block. The arm 172 is provided with an insulated contact 175 which is arranged to engage the contact 165 of the pointer 164 when said pointers move into engagement with each other. The contact 175 is connected by a wire 175*a* with the binding post 77 which has connection with the exciter generator 60. It is obvious from the above that the pointer 172 is manually adjustable while the pointer 164 is moved or swung by the pressure within the tube 167. When the contacts of the pointers are in engagement with each other, electrical current flows from the exciter generator 60, through the post 77, through wire 175*a*, through the contacts 175 and 165, and then through the wire 165*a* to one side of the solenoid 151. Then from the other side of the solenoid through the wire 141*a* through the wire 162*a*, post 78, and then through wire 76*b* to the other side of the generator 60, whereby the solenoid 141 is energized. Therefore, this solenoid is energized only when the pointers 164 and 172 have their contacts engaging.

For varying the pressure in the tube 167 to swing the pointer 164, the tube 167 is connected to a translating device 176 (Figure 2) which is engaged with the dead end 13 of the cable carrying the drill stem and which device is responsive to the variations in the tension of said cable. The details of the translating device are clearly shown in my former Patent No. 1,766,782, issued on June 24, 1930. Suffice it to say, therefore, that as the tension on the cable decreases, the pressure in the tube 167 decreases, which causes the movable needle 164 to move toward the adjusted or stationary needle 172. If this tension decreases sufficiently, the pointers will move to engage their contacts, which will close the electrical circuit to the solenoid 141, as has been explained.

In operation, the power to be delivered by the drilling engine 17 is determined by the adjustment or setting of the admission valve 19 in the line 18. Operation of the engine rotates the jack shaft 23, which, in turn, drives the rotary table 11 to rotate the drill stem 12 and bit, as has been explained. The engine is ungoverned except by the load imposed on the drill bit, and therefore, a fixed amount of power is delivered by said engine so long as its speed remains constant.

The exciter generator 60 excites the fields of the feed motor 45, feed generator 54 and control generator 50. The jack shaft 23 drives the feed generator 54 and since its field is excited by the exciter generator, said feed generator delivers power to the feed motor because of its connection with said motor through the leads 72*a* and 67*a* and 72*b* and 67*b*. Thus, the feed motor is actuated which drives the worm 42, and therefore, the draw works drum 14 is rotated to pay out the cable and thereby lower the drill stem 12 into the hole, which feeds the bit into the formation.

The resistance offered by the formation to the rotation of the bit determines the load on the engine 17 and thus, governs its speed. If the resistance increases, thereby increasing the load, the speed of rotation of the bit will decrease, whereby the engine speed is decreased. This decrease will cause a decrease in the speed of rotation of the jack shaft 23, which decrease will be transmitted to the feed generator 54 and the control generator 50 to slow up the same.

Reduction in the speed of the feed generator 54 will reduce its power output, and this will result in a decrease of the speed of the feed motor; also, the reduction in the speed of the control generator 50 will reduce the energization of the coil 99 of the controller 90 and thereby increase the resistances 113 and 114 in series with the field 73 of the feed generator 54, thus further decreasing the speed of the feed motor 45. As a result, the draw works drum 14 will be rotated at a slower rate which reduces the rate of down feed of the drill stem. This reduction in the rate of down feed will reduce the load on the drill bit, which reduction will be reflected by a decreased load on the engine. As soon as the engine load is decreased the jack shaft 23 will again be speeded up, so that the speed of rotation of the bit will be again brought up to its original speed. Thus, it will be seen that if the bit enters a formation which increases the load, the feed motor is immediately slowed down to reduce the rate of feed of the drill stem until such time as the drill bit again attains its original speed of rotation.

If, on the other hand, the drill enters a formation where the load on the drilling engine is reduced, said engine will be speeded up. This increased speed of the engine increases the speed of the jack shaft **23** which increases the power output of the feed generator **54** to increase the speed of the feed motor **45**; also, this increases speed of the control generator **50** which causes increased energization of the solenoid **99**, whereby the resistances **113** and **114** in series with the field **73** of the feed generator are decreased, which further causes speeding up of the feed motor. The resultant increase in the speed of the motor increases the rate of down feed of the drill stem **12** which immediately increases the load on the engine **17**, whereby said engine is slowed down to its original normal speed. Therefore, it is manifest that irrespective of the character of formation through which the drill is passing, the speed of the drill bit is maintained substantially constant by varying the rate of feed of the drill stem.

In drilling, part of the weight of the drill stem **12** is supported from above by the travellling block (not shown) while the remainder of this weight is supported on the bottom of the hole. Thus, the upper part of the stem is in tension, but the lower part having a length whose weight is equal to the weight with which the bit presses on the bottom of the hole is in compression. As the weight of the bit on bottom increases, the length of drill stem which is in compression increases, until finally a length so great is had that this portion of the stem buckles, in which case a crooked hole results. The revolution of the drill stem in a crooked hole results in fatigue failure, or "twist-offs" due to the back and forth bending which follows when said stem is rotated in a crooked hole. To remove from the well parts which have been so broken off involves a great deal of expense and often results in the loss of the well.

To avoid this expense, and hazard, it is necessary to limit the weight of the bit on the bottom to such extent that the drill stem **12** will not buckle. This is automatically accomplished by means of my controller and its associate parts.

With the bit off the bottom of the hole, the movable pointer **164** of the pressure controller **163**, indicates the total weight of the drill stem. The stationary pointer **172** is then set at an amount less than this total weight, this difference being equal to the maximum weight of the bit on bottom that will be allowed. For example, if the pointer **164** indicates 50 tons with the bit off of bottom and the maximum weight of the bit on bottom is to be limited to 3 tons, then the pointer **172** is set at 50 less 3 tons or at 47. The drilling equipment is then put into operation and the bit feeds down. As the bit presses on bottom, the weight on the hook is reduced and as a result the pointer **164** lowers on the dial. Should it ever lower as much as three points, the contact **165** goes into circuit closing engagement with the contact **175** of the pressure controller with the result that the solenoid **141** is energized drawing the armature **142** towards it and causing the contacts **159** and **160** to move towards the contacts **161** and **162** at a rate determined by the adjustment of the timing mechanism indicated therein and after a certain interval, the contacts **159** and **160** engage the contacts **161** and **162** and thus cause the solenoid **92** to be energized. The energizing of the coil **92** causes the contacts **95** and **96** to separate from the contacts **97** and **98** opening the circuit which energizes the solenoid **99** of the controller **90** and causing the switch **88** to go into the reversing position to cause the feed motor **45** to lift the drill stem and thus to relieve the weight of the bit on the bottom of the hole. But as soon as the weight of the bit on the bottom of the hole is again less than the limit set, the contacts **165** and **175** again separate, deenergizing the coil **141** and the contacts **159** and **160** and contacts **161** and **162** again separate due to the action of the counterweight **149** of the timing mechanism with the result that the solenoid **99** is again energized, which returns the reversing switch **88** to its original position so that the feed motor operates to feed the stem downwardly. It is pointed out that when the switch **88** is in a reverse position, the resistances **113** and **114** are not in the circuit of the field **73** of the feed generator but the fixed resistance **135** is in the circuit. The purpose of this resistance is to cause the feed motor to operate at a predetermined rate of speed whereby the drill stem is lifted at a predetermined rate. It is pointed out that the time delay prevents the solenoid **92** from being energized by the momentary engagement of the contacts **165** and **175** which may be caused by "bouncing" of the bit.

The construction of the controller **90** and its associated parts is such as to prevent the bit from hanging up. When the load of the engine reaches a predetermined amount, due to reduction in speed of the drill stem, the solenoid **99** of the controller is not energized sufficiently to overcome the weight **102**, because of the reduced power output of the control generator **50**, due to the reduced rotation of the jack shaft **23**. Thus, the bar **100** is swung sufficiently to increase the resistance of the carbon pile to the maximum, whereby the speed of the feed motor **45** is reduced to zero. Any further reduction in the speed of the stem **12** permits further swinging of the armature bar **100**. This additional swing of the bar, swings the actuating bar **120** to swing the switch **88** to a reverse position so that the feed motor is operated in the opposite direction. It is noted that the springs **120'** and the frictional engagement of the contacts permits the bar **100** to be swung a predetermined distance before actuating the reversing switch, after which time the switch is snapped into reverse position.

When the motor **45** is operated in the reverse direction, the drill stem is hoisted whereby the bit is freed sufficiently from its engagement with the formation so as to permit the speed of rotation of the bit to again increase. As soon as this increase occurs the reversing switch is returned to its normal position to operate the motor **45** so as to again feed the stem **12** downwardly. It is pointed out that the switch **88** may be operated either by the pressure controller **163**, or by the controller **90**. In either case, it serves to hoist the drill stem.

From the above, it will be obvious that with the improved method herein set forth, the speed of rotation of the drill bit is maintained substantially constant, irrespective of the character of formation through which said bit is drilling. The feed of the drill stem downwardly in the hole is controlled in accordance with the load imposed on the drill bit in rotation, and since this feed is positively controlled by the feed motor 45, a continuous feed is had. All danger of the bit "hanging up", or being stopped in rotation due to too great a resistance, is eliminated by means of the reversing mechanism. By means of the pressure controller 163, excess weight which causes the drill stem to buckle, resulting in crooked holes and twist-offs, is prevented. By means of the time delay apparatus, it will be obvious that bouncing of the bit which may occur during drilling will not affect the normal operation of the entire apparatus. Therefore, it will be seen that the improved method permits constant speed of rotation of the drill bit, whereby the maximum allowable power may be delivered to the bit which greatly increases the speed and economy of the drilling.

It is pointed out that the reversing switch 88, which raises the drill stem 12 in the event that there is an excess weight on bottom of the bit, or too deep penetration, may be eliminated. In such case, the electrical hook-up would be as shown in Figure 5. By observing this figure and comparing it with the wiring diagram Figure 3, the differences in the hook-up may be readily seen. When the switch is eliminated, the field 73 of the feed generator 54 has one terminal connected by a wire 73*c* to the conductor 81 at the point 81′. The other terminal of the field 73 is connected by a wire 73*d* with the terminal or binding post 116, which post is connected by the wire 110*a* with the contact 110 which is carried by the resistance 114. With this arrangement, it will be obvious that the reversing switch and its associate wiring is entirely eliminated. The field 73 of the feed generator is then energized in the following manner: The current flows from one side of the exciter generator 60 through the conductor 81 to the point 81′, then through the wire 73*c* to the field 73. From the field 73 the electrical current passes through the wire 73*d* to the binding post 116, through a wire 110*a*, contact 110, through the resistance 113, wire 115 and resistance 114, then through contact 109, through wire 109*a* to the binding post 78, from which post the current passes through the wire 76*b* to the opposite side of the exciter generator 60. In this way it will be obvious that the field 73 of the feed generator is constantly excited by the exciter generator. The operation of the other parts when the reversing switch has been eliminated, is exactly as has been described.

It is further noted that although it is most desirable to utilize the time delay switch 140, it is possible to eliminate this switch. For purposes of illustration, this switch has been eliminated in Figure 5. In such case, the solenoid 92 of the solenoid switch 91 is directly connected and arranged to be energized by the engagement of the contacts 165 and 175 on the pointers 164 and 172 of the pressure controller 91. A lead wire 180 has one end connected to the contact 165 and leads to one side of the solenoid 92. The other side of the solenoid is connected by a wire 181 with the binding post 78 which leads to one side of the exciter generator. When the contacts 165 and 175 move into engagement with each other, it will be seen that the current will flow from one side of the excitor through the wire 76*b*, post 78 and through the wire 181 to the solenoid. From the solenoid the current will flow through the wire 180 to the contact 165, through the contact 175, through a wire 175*a*, and finally through the post 77 and wire 76*a* to the other side of the exciter generator. Thus, it will be seen that when the time delay switch 140 is omitted, the energization of the solenoid 92 is controlled directly by the contact on the pointer of the pressure controller 163. It has been found that this structure will operate, but it is more desirable to have the time delay switch because many times the contacts of the pointer move into engagement with each other due to bouncing of the bit and in such case it would not be desirable to actuate the solenoid 92. However, such cases are not very frequent and the apparatus will operate without said switch.

What I claim and desire to secure by Letters Patent is:

1. A well drilling apparatus including, a restrainedly suspended drill stem having a drill bit at its lower end in the well, a prime mover for rotating the drill stem and governed by the load imposed upon it by the drill bit rotating through the formation, means actuated by the prime mover for releasably feeding the drill stem downwardly as the hole is drilled, drill stem weight self-applied brake means associated with the feeding means for counterbalancing the weight and decelerating the downward movement of the drill stem so as to prevent said stem over feeding by gravity, and time controlled means for automatically reversing the operation of the feeding means to hoist the drill stem and bit when the drilling load on said bit exceeds a predetermined point.

2. A well drilling apparatus including, a hoisting and lowering drum having a cable wound partially thereon from one end, the cable carried movably over a support, and a drill stem suspended from the opposite end of the cable, said stem having a bit at its bottom to drill the hole, a prime mover for continuously rotating the drill stem, a retainable feeding device including a worm wheel geared to said drum whereby the one is rotatable by the other, a worm screw engaging said worm wheel, a brake on the shaft of said worm screw and constantly set in effective braking condition by endwise movement of the shaft brought about by the weight of the drill stem tending to unwind its supporting cable from the drum, and a feed motor for continuously rotating said worm screw shaft, said motor being actuated by electrical controlling elements coordinated with the prime mover whereby variations in the speed of the drill stem is reflected in the feed controlling means and the feeding of the drill stem is continuous but varied proportionately to the change in character of the formation being drilled and the stem is rotated continuously at substantially a constant speed.

3. The apparatus as set forth in claim 2 and further including means time delayed in operation for automatically reversing the feed motor to operate the drum to lift the drill stem when the drilling load on said bit in the formation reaches a predetermined point.

OTTO BERGER GOLDMAN.