Feb. 24, 1942. W. A. LOOMIS 2,274,339

MEANS FOR AUTOMATIC WEIGHT CONTROL IN WELL DRILLING

Filed Jan. 5, 1939 3 Sheets-Sheet 1

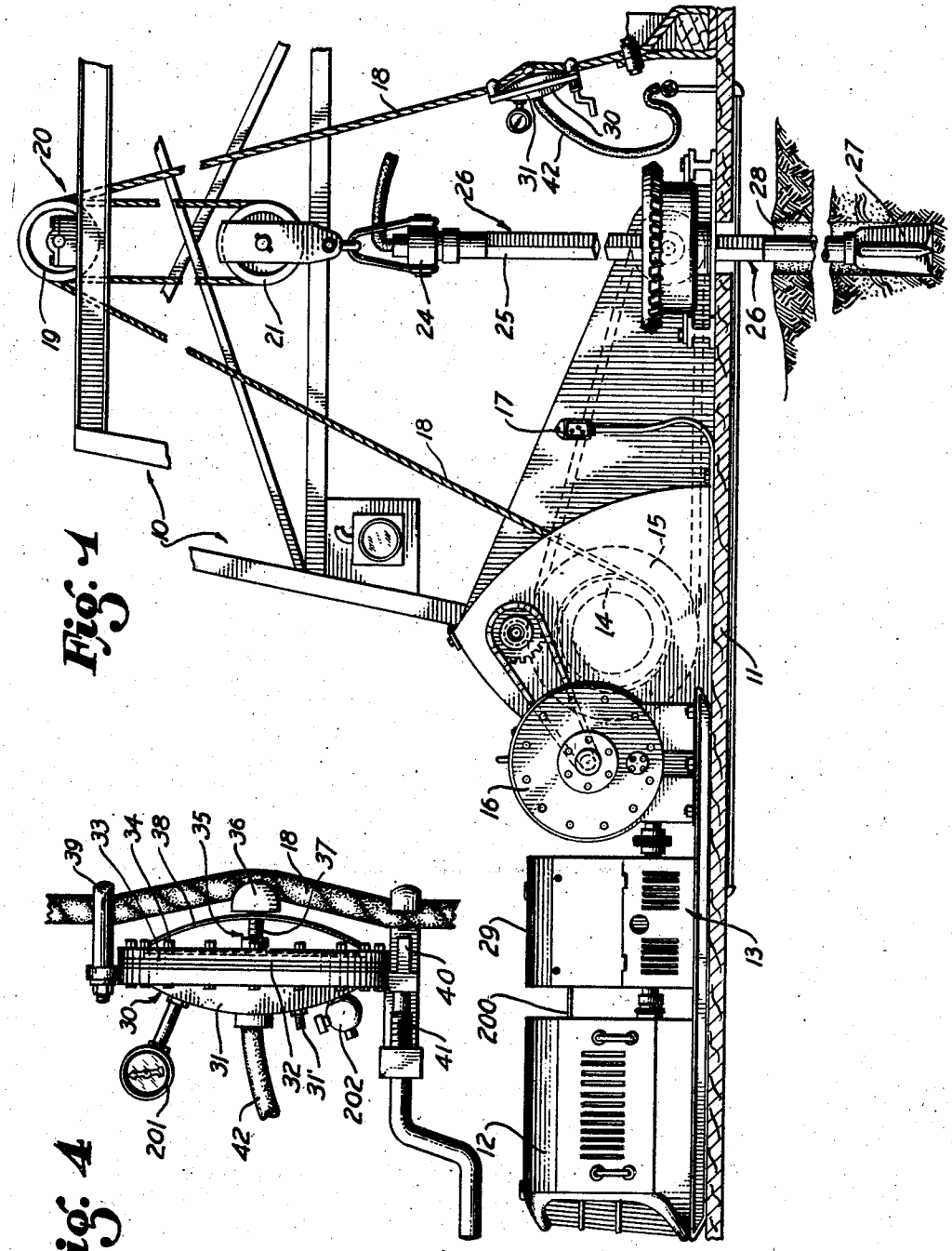

Fig. 1

Fig. 4

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MEANS FOR AUTOMATIC WEIGHT CONTROL IN WELL DRILLING

Filed Jan. 5, 1939 3 Sheets-Sheet 2

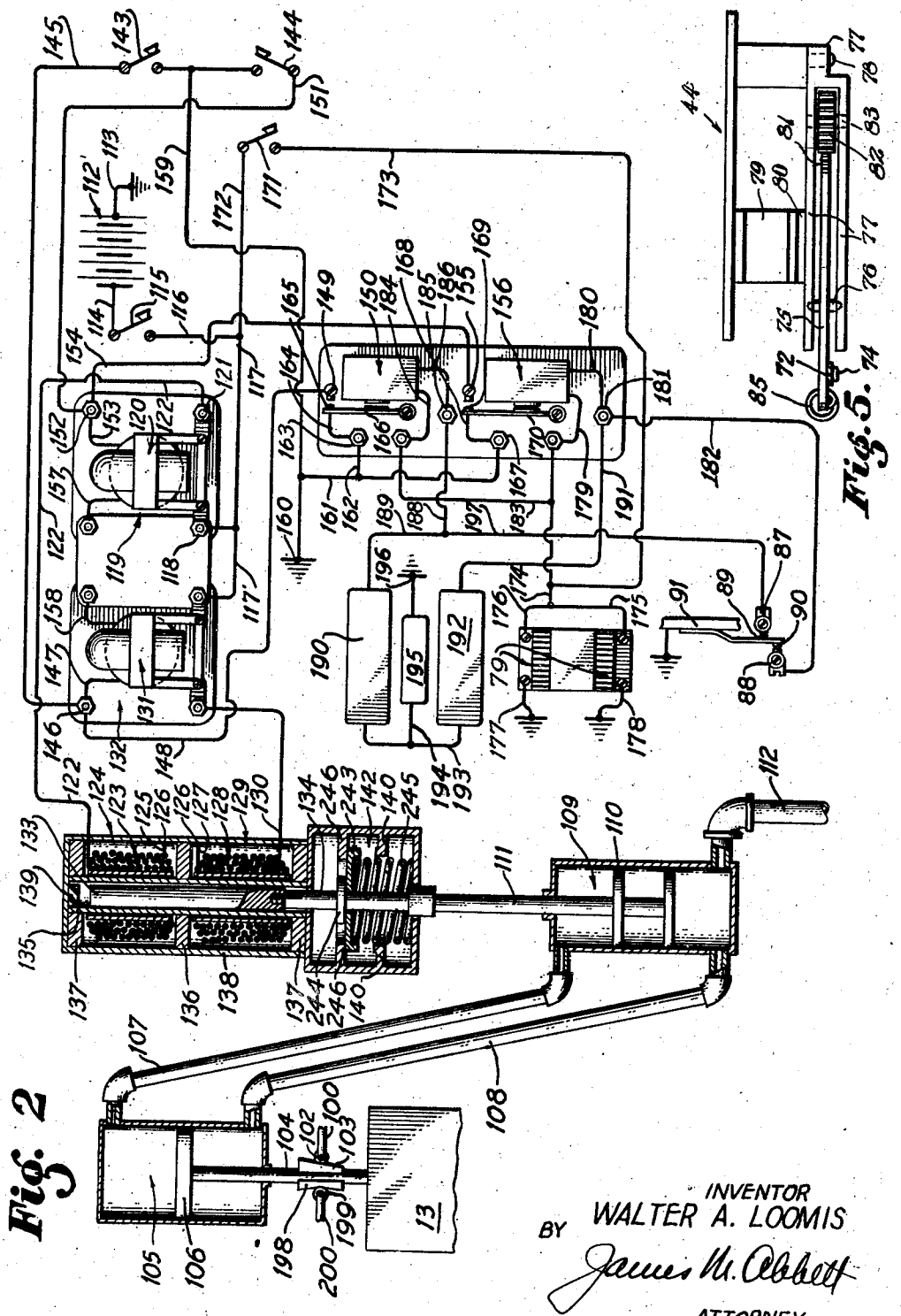

Fig. 2

Fig. 5.

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MEANS FOR AUTOMATIC WEIGHT CONTROL IN WELL DRILLING

Filed Jan. 5, 1939 3 Sheets-Sheet 3

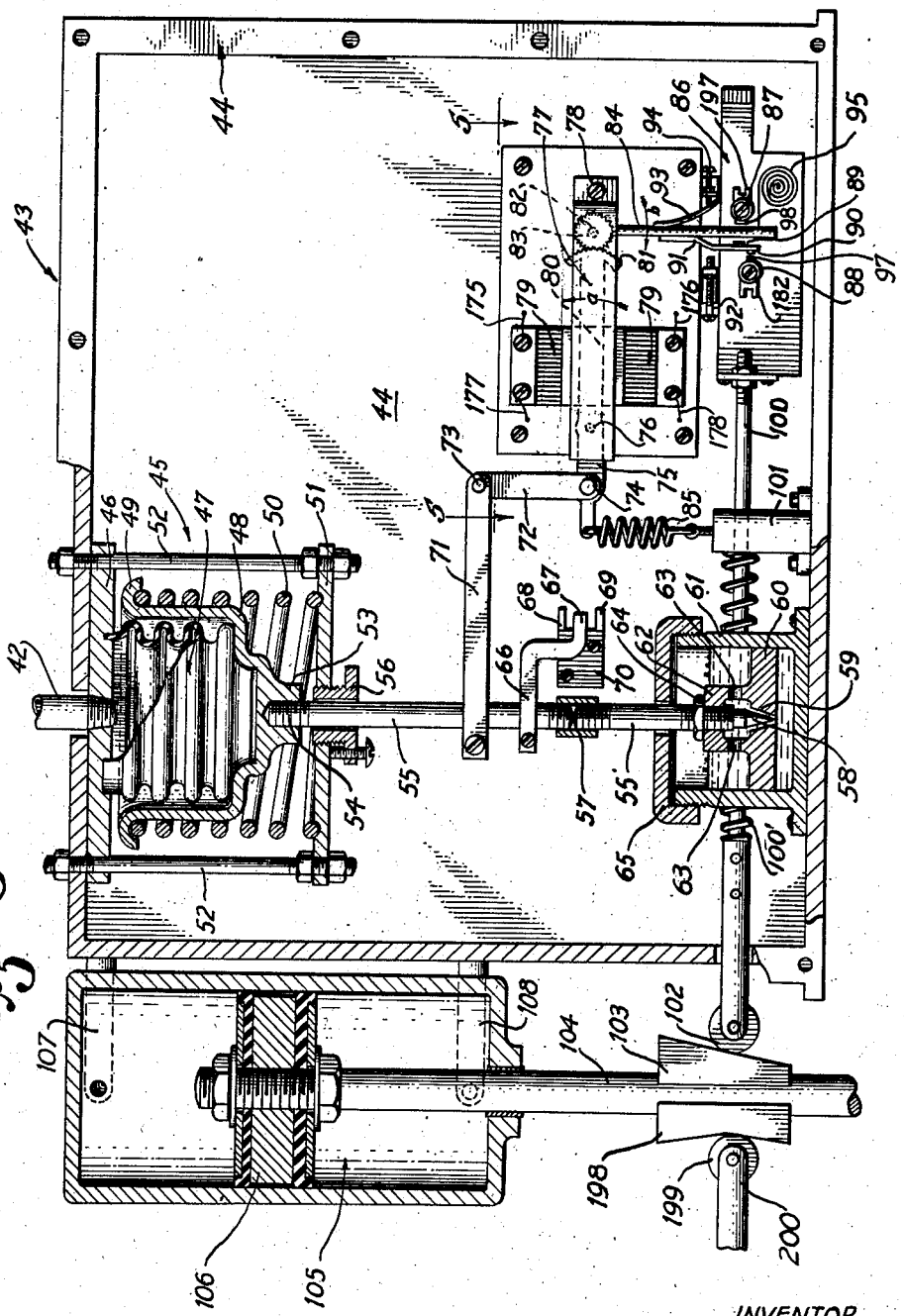

Fig. 3

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UNITED STATES PATENT OFFICE

2,274,339

MEANS FOR AUTOMATIC WEIGHT CONTROL IN WELL DRILLING

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Application January 5, 1939, Serial No. 249,398

2 Claims. (Cl. 255—19)

This invention relates to oil well drilling equipment and particularly pertains to a means for automatic weight control in well drilling.

In the drilling of wells, and particularly oil wells, great difficulty is experienced in drilling a well in a manner to produce a straight well bore. This is due to the fact that the formation being penetrated varies in character both as to material and as to hardness, and furthermore, for the reason that some formations are disposed at an inclination to the horizontal plane being penetrated with the result that at different depths the drilled hole may deviate from the vertical. These conditions are aggravated when the drill is not fed into or through formations at a speed appropriate to their physical character and hardness, as for example when a hard stratum is encountered and the drilling speed is not retarded, the drill will produce a condition known as overfeeding which will cause the drill to tend to drill in a plane at right angles to the angle of inclination of the hard stratum, and in thus being deflected will deviate the well bore from the vertical. Attempts have been made to apprise the driller of the condition of the geological formation being encountered by the drill so that he could vary the feed of drilling appropriately. Such operations have usually involved the use of a weight indicator which measures the tension on the drill cable, and thus indicates the proportion of the weight of the drill-string which is imposed upon the drilling cable and the corresponding proportion of weight resting on the formation being drilled. This requires that the driller constantly watch the weight indicator and attempt to adjust the feed appropriately as more or less weight is indicated as being imposed upon the supporting cable. This often necessitates a relatively slow driving speed of the rotary table in order to cautiously proceed. It sometimes happens that such a method of procedure with manual regulation is inaccurate so that at times the drill will be over-feeding and at other times it will be under-feeding when it could be advancing rapidly into the formation. When over-fed deviation of the drill bit takes place; when underfed the bit will drill off bottom and spin. With some types of bits excessive wear will then occur both on the bit itself and in the roller bearings. Under certain circumstances of drilling it becomes necessary to retract the drill and drill while attempting to come out of the hole. The tension imposed upon the drilling cable is important under such circumstances.

In most instances of attempted automatic weight control the pressure responsive means acted upon by variation of the weight has been applied to the "live end" of the drill supporting cable and attempts have been made to initiate and interrupt the feeding movement in response to tension variation in the live end of the cable. It has been found that the friction set up in the traveling block tends to reduce the tension in the live end of the cable over the actual value of tension created by the weight imposed upon the cable. This produces an over-sensitive condition when the tension responsive means is placed on the live end of the cable and thus acts to render the device unsatisfactory in its operation. When the tension responsive means is placed on the dead end of the cable the friction of the traveling block tends to increase the tension on the dead end of the cable so that all of the friction of the traveling block is thrown to the dead end of the traveling block. For that reason it is desirable to apply the tension responsive means to the dead end of the cable since the action will be less violent due to the damping effect of the friction in the traveling block. It has, however, been found to be necessary to set the tension responsive means so that the drill will be at all times feeding downwardly so that under no circumstances the drill feed will be interrupted entirely since this insures a more accurate feed operation and prevents subsequent inoperation after the feed of the drill string has once been stopped.

It is the principal object of the present invention, therefore, to provide a weight control for drill rigs which is fitted with means whereby accurate manual operation and adjustment of drilling equipment may be made, and whereby after a desired adjustment and setting of the drill feed is effected the apparatus will act automatically to maintain a continuous drill feed with direct reference to the degree of resistance of the formation being penetrated to the cutting action of the drill bit.

The present invention contemplates the provision of an automatic weight control for oil well drilling rigs which may be used in connection with any type of rotary drilling apparatus now in use and which when set will feed the drill-string downwardly to act to maintain this feed constantly downwardly while appropriately varying the feeding speed with direct reference to the character of the formation being penetrated, the structure including adjusting means to determine and set the normal rate of feed either downwardly or upwardly and automatic means for controlling the rate of feed and tending to restore

the feed from variation to the predetermined set speed.

The invention is illustrated by way of example in the accompanying drawings, in which:

Figure 1 is a view in side elevation illustrating a commercial type of oil well drill rig and disclosing the application of the present invention thereto.

Fig. 2 is a view in diagram showing the general layout of the apparatus.

Fig. 3 is an enlarged view in vertical section showing the automatic weight control unit.

Fig. 4 is an enlarged view of the fluid responsive means applied to the drilling cable.

Fig. 5 is an enlarged view in plan as seen on the line 5—5 of Fig. 3 and discloses the construction of the control lever arrangement.

Referring more particularly to the drawings, 10 indicates a derrick used in oil well drilling. This derrick has the usual floor 11 with relation to which it is suitably anchored and upon which a power unit 12 is mounted. This power unit may be of any desired type, such for example as those commonly used in connection with draw-works drives either employing electric, steam or gas engine power. In connection with such units a speed varying transmission 13 is provided by which the direction of rotation of the draw-works may be controlled and the speed of rotation may be determined.

The transmission mechanism is suitably connected with the drum 14 of the draw-works and may be fitted with a worm wheel 15 in mesh with a worm gear 16 driven by the speed varying transmission 13. One end of a drilling cable 18 is mounted to pass around the winding drum 14. The drilling cable 18 is led upwardly and over the sheaves 19 of a crown block 20 and after being led around the traveling block 21 the dead end of the cable is properly anchored, as indicated at 22 in Fig. 1 of the drawings. Connected to the traveling block 21 is the swivel 24 carrying the upper end of a kelly bar 25 and to which bar the usual drill string 26 is attached. Mounted at the lower end of the drill-string 26 is a drill bit 27 which operates in a well bore 28. The well bore 28 penetrates the geological formation of the earth and it is the prime object of this invention to control the feed of the drill 27 in and through the formation at appropriate speeds with relation to the character of the formation being penetrated.

Associated with the power unit 12 of the rotary drilling equipment is an automatic control 29 with which the present invention is concerned and which acts to control the feed of the driving mechanism automatically. This control is in direct response to variation of the tension in the drilling cable 18 and is a hydraulic structure mounted upon the cable and generally indicated at 30 in the drawings. This structure is of the general type of device known as a Martin-Decker weight indicator, shown particularly in Fig. 4 of the drawings.

The weight indicator includes a bowl 31 across which a diaphragm 32 is disposed and is held by a cover plate 33. A suitable pressure plate 34 rests against the diaphragm to deflect the same and has associated with it a post 35 carrying a saddle 36 across which the cable 18 lies. This post has a threaded mounting 37 with relation to the pressure plate for purposes of adjustment, as will be hereinafter set forth. A guide for the post is indicated at 38. Carried upon the body member is a relatively fixed stirrup 39 which hooks over the cable 18 at one side of the saddle 36, and carried at the diametrically opposite side of the body member 30 is an adjustable hook structure 40 which operates on the border of a C clamp and may be tightened or loosened by an adjusting screw 41. Connected with the bowl 31 is a pressure tube 42 which leads to the automatic weight control unit 43.

Referring more particularly to Fig. 3 of the drawings, it will be seen that the automatic weight control unit comprises an outer housing 44 within which a pressure responsive device 45 is positioned. This device is in communication with the bowl 31 through the tube 42. The pressure responsive device includes an upper mounting plate 46 to which a sylphon bellows 47 is mounted. The bellows 47 extend vertically and downwardly from the plate 46 and rest within a cup 48. The cup 48 is formed with an annular lip 49 around its upper outer edge to provide a seat for an expansion spring 50 which rests upon a plate 51. The plate 51 is secured with relation to the top plate 46 and the top wall of the housing 43 by a plurality of bolt hangers 52. The lower end of the cup 48 is formed with a central boss 53 which extends downwardly and is threaded to receive the threaded end 54 of a thrust rod 55. This rod extends through a tubular adjusting nut 56 which is mounted through a threaded opening in the plate 51 and stands in the path of the lower face of the boss 53 so as to limit downward movement of the cup and also limit downward movement of the thrust rod 55. The thrust rod 55 is formed in two pieces which are longitudinally aligned and threaded at their contiguous ends so that they may be coupled together by a nut 57 and may be adjusted as desired. The lower section of the rod is indicated at 55' and it is shown as terminating in a needle valve 58 which extends into a valve seat 59 formed in a plunger 60. The plunger 60 reciprocates within a dash pot cylinder 61 by which violent movement of the thrust rod 55 is resisted. The needle valve is threaded through a boss 62 formed on the top of the dash pot and controls the flow of an incompressible fluid from above the plunger 60 through ports 63 and the valve seat 59 to the space within the dash pot and below the plunger, and vice versa. A nut 64 is provided to lock the needle valve 58 in its set position while a cap 65 is detachably mounted over the dash pot to close and protect the same.

The dash pot structure acts to damp out vibrations from the pump and also vibrations occasioned by rough digging. It is necessary to properly adjust the thrust rod for a particular operation and for that purpose an indicating finger 66 is adjustably secured on to the thrust rod 55. This indicating finger has a horizontally extending portion 67 which assumes an indicating relation with regard to fixed fingers 68 and 69 carried by a plate 70 and rigidly secured to the housing 44.

An automatic control is actuated by the thrust rod 55. This includes a horizontal arm 71 adjustably mounted upon the thrust rod 55 and carrying a link 72 at its free end. The upper end of the link 72 is secured to the arm 71 by a pivot pin 73. The lower end of the link is provided with a pivot pin 74 connected to a control lever 75. The lever 75 has a pivot pin 76 intermediate its ends which is carried by an auxiliary lever 77. The auxiliary lever 77 is pivoted at the opposite end from the pin 76 upon a pivot pin

78 by which it is mounted to the housing and around which it may oscillate in a vertical plane. Carried beneath the free end of the auxiliary lever 77 is a pair of magnets 79 mounted on the wall of the housing 44. The magnets are spaced from each other and disposed upon the opposite sides of the longitudinal center of the lever 77, while an armature plate 80 is carried upon the lever 77. The free end of the lever 75 is fitted with an arcuate gear segment 81 which is in mesh with a gear pinion 82 mounted upon a pivot 83 carried by the auxiliary lever 77. Extending downwardly from and rigidly secured with relation to the pivot pin 83 is a contact arm 84. This arm will oscillate in a plane parallel to that of the levers 75 and 77 under circumstances to be hereinafter pointed out.

The lever arm 75 is acted upon by a tension spring 85 to tend to move the gear segment 81 upwardly since the weight of the lever arm would normally cause it to swing downwardly. The spring also takes lost motion out of the linkage. The contact arm extends downwardly to swing over the vertical face of a mounting plate 86 which carries adjustable contacts 87 and 88. These contacts are disposed upon opposite sides of the arm and may engage contact elements 89 and 90 carried by a spring finger 91 mounted upon the arm 84. An adjusting screw 92 limits movement of the spring finger in one direction, and a spring 93 limits movement of the contact arm in its opposite direction. An adjusting screw 94 is provided to vary the tension of the spring 93 for purposes to be hereinafter described. Attached to the free end of the contact arm 84 and on the same side thereof as occupied by the spring 93 is a hair spring 95 which tends to hold the contact arm in proper equilibrium since it is necessary to accurately balance the spring finger 91 and its contacts between the contacts 87 and 88 carried by the mounting block 86.

The block 86 is adjustably mounted at 99 to an operating rod 100. This rod is horizontally slidable through a bearing 101 and through the side wall of the housing 44. Mounted at the outer end of the rod 100 is a roller 102 which bears against a cam 103 carried upon a piston rod 104. This piston rod 104 is connected with the tilting block structure 13 by which speed variation and direction of transmission of power is controlled in a transmission of the hydraulic type. The piston rod extends into a hydraulic operating cylinder 105 and is connected with a piston 106 reciprocating therein. The opposite ends of the operating cylinder 105 are fitted with fluid conduits 107 and 108 which lead to the opposite ends of a pilot valve cylinder 109. The pilot valve cylinder 109 is fitted with a piston 110 carrying a piston rod 111. An oil well pressure line 112 leads into the pilot valve cylinder. The pilot valve cylinder, by which speed and direction of the draw-works transmission are controlled, is operated indirectly through the control structure generally indicated as being enclosed in housing 43 and shown in Fig. 3 of the drawings.

In addition to the control structure shown in Fig. 3 of the drawings it is necessary to provide an electrical unit indicated in Fig. 2 and comprising relays and solenoids. In this structure 112 indicates a source of electrical supply, one pole of which is connected with a ground wire 113 and the opposite pole of which is connected with a power lead wire 114. A switch 115 is provided to establish electrical communication between the wire 114 and the wire 116. The conductor 116 is connected with a lead wire 117. This leads to pole 118 of a relay 119. A circuit is completed from the conductor 116 through a relay switch 120, here shown as a double break single pole switch, the opposite pole 121 of which connects with a conductor 122. This wire leads to a coil 123 of a "down" solenoid 124. A conductor 125 leads from the coil 123 to a ground connection 126. A conductor 127 leads from said ground connection to coil 128 of "up" solenoid 129. This has a conductor 130 which connects with switch 131 of relay switch 132. Other details of the solenoids 124 and 129 will be explained hereinafter.

The relay 132 agrees in construction and function with the relay 119. This includes the double break single pole switch 131 controlling a circuit from a conductor 117' to conductor 130. The conductor 130, as explained, leads to coil 128 of the "up" solenoid 129.

The solenoid structure including the up and down solenoids 124 and 129 is of particular construction and embodies the use of two coils and a single plunger. The plunger is indicated at 133 and is connected to an extension member 134. The plunger slides through a bushing 135 around which the coils 123 and 128 are wound. Mounted between the two coils is a collar 136 and at the ends thereof are collars 137, upon which are mounted an outer metal sleeve 138. The plunger 133 is of a length shorter than the length of the bushing 135 and stands midway the length of this bushing under normal conditions. A bumper disc 139 of resilient material is secured at the outer end of the structure and against which the plunger 133 may strike. Stop lugs 140 mounted within a cage 142 are engaged by a stop washer 243 mounted upon the plunger extension 134 beneath the shoulder 244 and limit opposite movement of the plunger. The washer 243 is held in its uppermost position by a spring 245 and it is limited in its upper movement by stop lugs 246 carried by the cage 142.

By this arrangement it will be seen that the plunger 133 may move in either direction a limited distance as influenced by the coil of a particular solenoid. It is to be understood that the extension member 134 is made of non-magnetic material so that when either of the solenoid coils is energized there will be a tendency for the plunger to move toward that particular end of the solenoid to close the gap normally occurring in the magnetic field. The plunger extension 134 is connected to the piston rod 111 of the pilot valve 110.

The relays 119 and 132 are intended to control the solenoids 124 and 129 by manual action and by automatic action. The control of the relays for manual action includes an up switch 143 and a down switch 144. The switch 143 is provided with a conductor 145 which leads to binding post 146 of the relay. A conductor 147 leads from the binding post to the coil of relay 132. A conductor 148 leads from this binding post to contact post 149 of automatic relay 150. The down switch 144 is provided with a conductor 151 which leads to binding post 152 of relay 119. A conductor 153 leads from this binding post to the coil of relay 119 while another conductor 154 connects with the binding post 152 and leads to contact post 155 of an automatic control relay 156. The opposite sides of the relay magnets

119 and 132 are provided with conductors 157 and 158.

The up switch 143 and the down switch 144 are provided with a common lead wire 159 which is shown as being provided with a ground connection at 160. Extending from the ground connection 160 and being a continuation of wire 159 is wire 161. This wire has a connection 162 secured to a binding post 163 of automatic control relay 150. The connection 164 leads from the binding post 163 to a contact 165 carried by an armature 166 of the relay 150 and is adapted to engage the contact post 149 of that relay. The end of conductor 161 is secured to binding post 167 to which a conductor 168 is connected. This conductor is secured to a contact 169 carried by the armature 170 of the relay 156. Thus, when electrical contact is made between the contact post 149 and 165 a ground circuit will be completed to the ground connection 160 from conductor 148, and when electrical contact is made between contact post 155 and 169 a ground circuit is completed from the ground connection 160 to the wire 154. It will thus be seen that the conductor 159 provides a common ground connection for both the up and down switches 143 and 144, and that a separate ground connection is provided for the two relays 119 and 132 as controlled by the relays 150 and 156.

The magnets of the relays 150 and 156 are energized when an automatic control switch 171 is closed. This switch is provided with a conductor 172 which connects with the feed wire 116. The other side of the switch 171 is provided with a conductor 173 which is connected with a distributing wire 174. One end of the distributing wire is provided with conductors 175 and 176 which lead to the two coils 79 of the structure shown in Fig. 3 of the drawings. The other sides of these coils are provided with ground connections 177 and 178. The distributing wire 174 connects to one side of the magnet coil of relay 156 by a wire 179. A wire 180 connects to the opposite side of the coil of the relay 156. This wire is secured to a binding post 181. A conductor 182 leads from the binding post to contact 88 of the automatic control switch, as shown in Fig. 3 of the drawings.

The relay 150 connects with the wire 174 through conductors 183 and 184. The wire 184 connects to one side of the magnet of relay 150. A wire 185 connects to the opposite side of the magnet and to a binding post 186. The wire 188 leads from the binding post 186 to a conductor 189 connected to a condenser 190.

The binding post 181 of the relay 156 is provided with a conductor 191 which leads to one side of a condenser 192. The condensers have a common lead wire 193 attached by a wire 194 to a suitable resistance 195. The opposite side of the resistance is provided with a ground connection 196. The wire 188 also connects with a wire 197 which leads to contact member 87 of the control mechanism shown in Fig. 3 of the drawings.

The contact finger 91 carried by the arm 84 is, as has been previously described, provided with contacts 89 and 90 which may be moved into electrical engagement with the contacts 87 and 88, respectively. By this arrangement it will be seen that one side of the circuit of each of the relays 150 and 156 is completed by movement of the contact finger 91 in an appropriate direction, and that across these circuits is placed the condensers 190 and 192 and the resistance 195.

By reference to Fig. 3 of the drawings attention is directed to the fact that the rod 104 of the operating piston not only carries the cam 103 but a double faced cam 198 over which a roller 199 may move. This roller is mounted upon a connecting link 200 leading to the throttle of the engine or other prime mover. This acts to accelerate the engine speed as the control apparatus advances the feed. By this means it is insured that the engine will not stall under increased loads.

In operation of the present invention the entire structure is assembled as generally indicated in Fig. 1 of the drawings, after which the pressure responsive unit 30 is mounted upon the dead end of the drilling cable 18. The bowl of the unit 30 is pumped up to a desired pressure through the stem 31' as is the usual practice when using weight indicators of this general type. The adjustment of the weight indicator upon the drilling cable 18 is, however, somewhat different due to the fact that the control apparatus including its switch operates in response to a substantially constant pressure intermediate the extreme pressures regardless of the weight imposed upon the drilling cable 18 by the drill-string suspended thereon. It is, therefore, necessary to vary the amount of deflection of the cable 18 occurring between the members 39 and 40 and the intermediate saddle 36. This is done by adjusting the saddle on its threaded mounting 35 and by appropriate adjustment of the screw 41 attached to the clamp 40. When light loads are imposed upon the drilling cable 18 such as when drilling at the top of the hole the saddle 36 is moved outwardly and the clamp 40 is drawn inwardly. This produces a relatively great deflection in the portion of the drilling cable 18 occurring between the hook 39 and the clamp 40. It will be recognized that correspondingly a greater pressure will be imposed upon the diaphragm 33 and the fluid within the bowl 30 than would have otherwise been the case. When, however, the depth of the drilled hole has materially increased the saddle 36 is adjusted so that the member 37 is shortened and at the same time the clamp 40 with its threaded member 41 are loosened. This will produce less deflection in the portion of drilling cable occurring between members 39 and 40 and will restore the effective fluid pressure within the bowl 31 to substantially the same pressure as when a lesser amount of pipe was suspended on the drilling cable 18 so that a pressure gauge 201 would be maintained at practically the same indication all the time, and the pressure upon the fluid within the conduit 42 would be substantially constant. This fluid pressure is transmitted from the unit 30 through the conduit 42 to the sulphon 47 within the automatic control unit 43. The result will be that the pressure will distend the sulphon 47 against the tension of the spring 50 and will tend to force the thrust rod 55 downwardly. This will act against the member 55' and the plunger 60 to displace the fluid within the dash pot 61 through the valve seat 59 and the ports 63 as controlled by the adjustment of the needle valve 58. The limit of downward movement of the sulphon and its cup 48 is set by adjustment of the threaded bushing 56. It is intended, however, that the sulphon and the thrust rod 55 may have a desired movement above this limit, and that the movement of the pressure rod may be upwardly as well as downwardly. The intermediate position of the pressure rod at the mean

pressure of the fluid within the line 42 is intended to maintain the indicator finger 67 at a point midway between the members 68 and 69.

When the apparatus is thus adjusted it is desired to set it with relation to the pressure created by a particular amount of weight imposed upon the drilling cable 18 and with the remaining weight resting upon the formation being penetrated. As drilling proceeds it is to be understood that the apparatus is so set as to insure that a continuous substantially constant drilling feed is maintained, although this feed varies in either direction from a mean feed rate as produced by drilling conditions. As the structure reaches a position of excessive hydrostatic fluid pressure in the pipe 42, the fluid may be bled off from the bowl 31 of the pressure responsive means 30 to restore the pressure to the normally set pressure for feeding. When, however, excessive pressures are reached then the saddle 36 and the clamp 40 must be readjusted. It has also been found that when large temperature differentials occur the pressure should be relieved by the valve 202 to correct the pressure, and that under freezing conditions a non-freezing pressure fluid should be used in the hydraulic system.

When drilling is started the power unit 12, here indicated in Fig. 1 as being an internal combustion engine, should be started to see that the transmission is in proper gear. The power unit may then be set to operate at a determined rate of speed, after which the clutch may be thrown in on the draw-works by letting the suspended load down upon the formation with the line shaft clutch out. The clutch on the machine may then be put into engagement by letting the load further down. When this clutch supports the load the brake commonly present on the draw-works is released. Care should be taken to never tie the brake down with the clutch in engagement. A constant feed is now taking place on the drum 14 to pay out the cable 18 at a predetermined constant rate of speed. The switch 144, which is the down manual control switch is then closed, so that the draw-works will pay out the drill cable 18 at a rate of speed at which the drill bit will cut properly. The indicator 201 may be observed on the pressure responsive means 30 so that the amount of drill pipe weight supported on the cable will be indicated. When the drill reaches the bottom of the hole the control switches 143 and 144 are set to maintain a proper feeding adjustment so that the drill will dig at an efficient rate of speed. It is to be understood that in setting the mechanism to drill at a desired rate of speed opening and closing of the down switch 144 and the up switch 143 may be brought about manually to effect operation of the relays 119 or 132, and thus appropriately actuate solenoids 124 and 129, whereby the pilot valve structure 109 will be moved to control operation of the operating cylinder 105 and the piston therein. In the event, however, that automatic operation is required the switch 171 is closed after the pilot valve has been set by manipulation of the solenoids 124 and 129. Prior to the closing of this switch it will be understood that the auxiliary lever 77 may oscillate freely on its pivot 78 since the magnets 79 are not energized. When, however, the automatic switch 171 is closed the electric circuits through the magnets 79 will be energized to lock the arm 77 in rigid relation to the housing. The lever 75 then swings on pivot 76 and its segment 81 acts with the pinion 83 to swing arm 84. At the same time the relays 150 and 156 and the relays 119 and 132 will be properly connected so that they may operate the respective relays controlling the appropriate down solenoid 124 or the up solenoid 129 as relay circuits are completed from the contact finger 91 carried by the arm 84 and as the contacts 89 and 90 carried by this finger move into or out of electrical contact with the contact members 87 and 88, respectively. It is understood that these conditions of contact may be brought about by movement of the thrust rod 55 acting through the arm 71 and the link 72 to the lever 75, or by movement of the member 100 as shifted by the cam 103 on the piston rod 104 of the operating piston 106. Thus, feeding speed and drilling weight are correlated to produce automatic regulation of the apparatus and to maintain the apparatus under efficient drilling conditions. It may be also necessary to adjust the spring 98 and also the hair spring 95 to a particular set of conditions.

In further analysis of the structure here disclosed it will be evident that since the automatic feed mechanism is at all times acting to maintain a constant feed of the drill string although at varying rates and that the cable tension creating this variation is damped due to the friction of the traveling block, the automatic control must be set to feed the drill string downwardly constantly at pressures varying from a set minimum. Thus, as tension increases, due to the penetration of a less resistant cutting material, the thrust rod 59 moves downwardly in turn swinging the lever 75 to swing upwardly in the direction of the arrow *a* in Fig. 3 of the drawings, and will at the same time act through the gear elements 81 and 82 to swing the contact arm 84 in the direction of the arrow *b*. This will produce contact between the members 91 and 88 completing the circuit, which would cause the downward feed of the drill to be accelerated. As this takes place the piston rod 104 moves upwardly and carries the cam 103 with it to relieve pressure on the roller 102 of the operating rod 100. The spring 100' will then act to move the rod 100 outwardly so that the roller 102 will follow and maintain contact with the inclined face of the cam 103. This will bodily move the mounting block 86 until contact is broken between the members 91 and 88, at which time it will be recognized that the tension of the dead end of the cable and the pressure produced through the tension responsive means 30 will have reached the predetermined tension for the minimum rate of feed of the drill string, after which drilling operations will continue with the lever 75 set at its new angle and the piston 106 set at its new control speed. At the same time the mounting block 86 will be disposed at a new position and the spring 93 will be out of contact with the lever 84. If still lighter cutting material is encountered the lever 75 will swing upwardly farther and the lever 84 and the mounting block 86 will move farther to the left, with reference to Fig. 3. When, however, a formation is encountered which would cause over-feeding at the set speed, the tension on the dead end of the cable 18 will be decreased and the fluid pressure in the Sylphon bellows 47 will be proportionately decreased. At such a time the lever 84 will tend to swing to the right and when its member 91 makes electrical contact with the member 87 a readjustment of th

speed control will be produced through the automatic structure shown in Fig. 2. This will in due course cause the piston rod 104 to move in a reverse manner from that previously described so that the cam 103 will force the roller 102 and the rod 100 toward the right, as considered in Fig. 3, so that the mounting block 86 will shift to the right until the desired relationship between the fluid pressure and the bellows 47 and the feeding speed, as represented by the position of the cam 103, will be restored and contact between the members 91 and 87 broken. When, however, this readjustment has taken place until an exceedingly low rate of speed of downward feed is produced the lever 84 will again encounter the spring 93, which will tend to resist further swinging movement of the lever 84 counter to that indicated by the arrow *b*. This will act to prevent the feed mechanism from completely interrupting downward feed of the drill.

Attention is also directed to the fact that by the use of the automatic mechanism indicated in Figs. 2 and 3 and the magnetic setting of the levers 75 with relation to lever 77 the magnet acts as a clutch to cause the automatic control to dominate and maintain substantially the same condition in the apparatus as existed at the moment automatic control is initiated. This makes it possible for the automatic control structure, including the levers 75 and 77 and the magnet 79, to be utilized in various settings other than those indicated in the drawings.

When all of the adjustments on the apparatus have been properly made the machine will act automatically with a negligible amount of error in either direction from the adjusted position. It will also be recognized that since the feed is constant the drill pipe never stops moving in the selected direction so that the structure becomes much more sensitive than would be the case when feeding is interrupted by hand adjustment. This makes it possible for drilling operations to be carried on at a relatively high rate of speed.

It will thus be seen that the structure here disclosed comprises a simple operating mechanism having a convenient manual control operable at a remote point from the apparatus and a convenient automatic control which includes the manipulation of only one control switch or button. It will be seen that by this arrangement a desired rate of speed may be manually controlled in either direction, after which the structure may be instantly set to maintain a speed of feed selected. When a desired speed of feed has been selected the automatic control may be thrown in so that the machine will continue to feed at substantially the selected speed although varying appropriately to maintain the necessary weight which was resting on the bottom of the hole at the moment the automatic control was set up. When it becomes necessary to vary these conditions for any purpose the automatic control may be interrupted instantly and readjustments made, after which the drilling will continue in a manner to insure the drilling of a straight hole at a maximum cutting speed and by automatic means.

While I have shown the preferred form of my apparatus and method of operating the same, it will be understood that various changes may be made in the combination, construction and arrangement of parts by those skilled in the art, without departing from the spirit of my invention as claimed.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. A rotary well drilling apparatus comprising a rotary table, a drill string fed downwardly therethrough and driven thereby, a drill bit at the lower end of said string, means for supporting the drill string whereby a determined proportion of the weight of the drill string may be permitted to rest upon the formation being penetrated, feed means associated with the drill string support, means connected therewith to feed the drill string downwardly continuously at a rate of speed above a set minimum, speed varying means associated with said feed means and responsive to variation in the amount of weight of the drill string being supported by the formation being penetrated and whereby the rate of speed may be accelerated or decelerated above the set minimum speed until a predetermined proportion of weight is supported by the formation, a power unit for driving said feed means, and means automatically accelerating the speed of said power unit when a feed adjustment is made by the apparatus.

2. A control device of the character described including a prime mover and a responsive member, constantly linked intermediate levers between said prime mover and responsive member for translating movement from the prime mover to the responsive member, said intermediate levers being normally ineffective in translating movement, and optionally controlled means for rendering said intermediate means effective in translating movement, said optionally controlled means including a member adapted to act magnetically in holding parts of the intermediate means rigid with relation to each other.

WALTER A. LOOMIS.