

Aug. 23, 1960

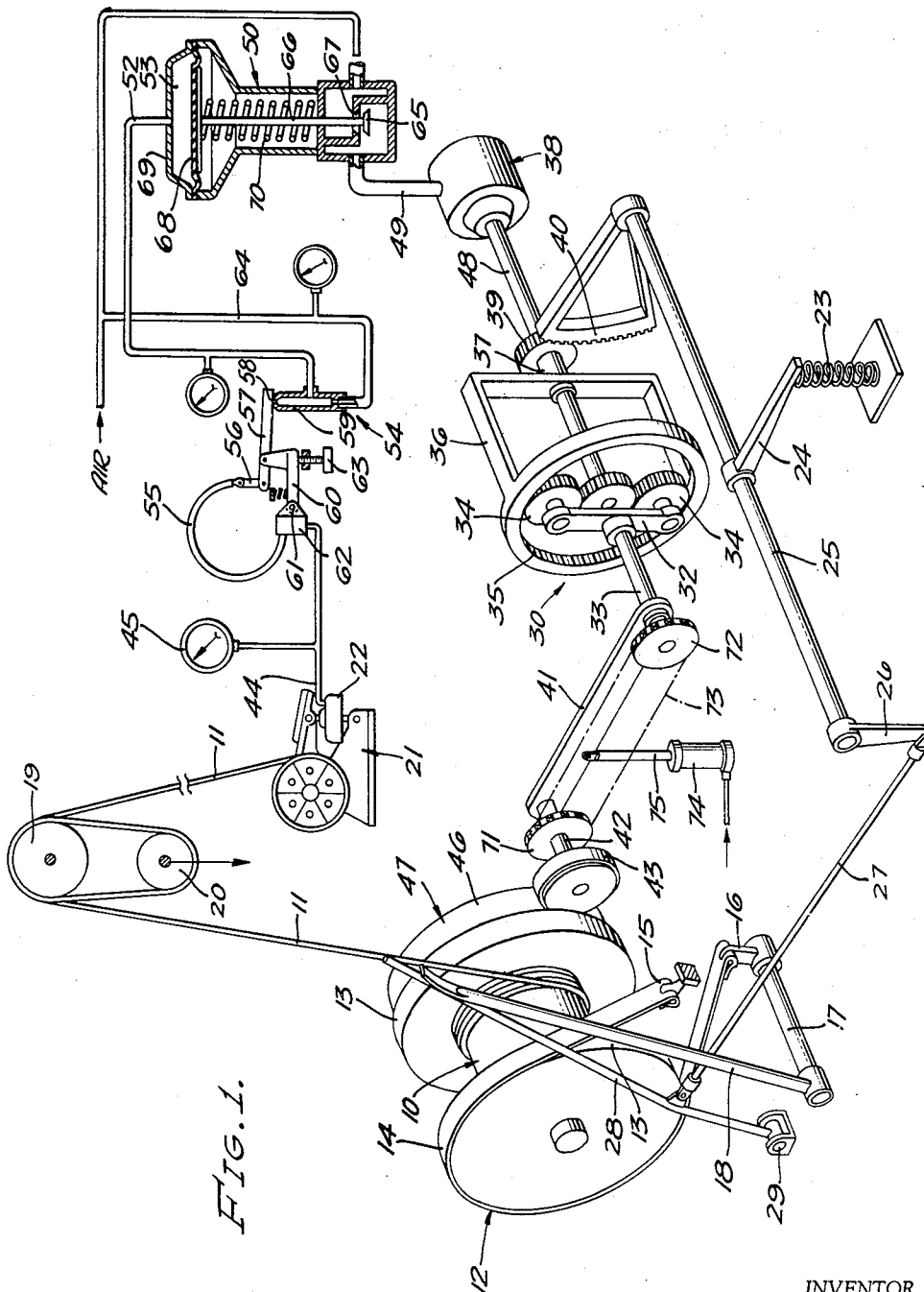
J. G. ABRAHAM

2,950,086

DRILLING CONTROL

Filed Dec. 9, 1957

7 Sheets-Sheet 1



INVENTOR.
JAMES G. ABRAHAM

BY

Lyons Lyons
ATTORNEYS

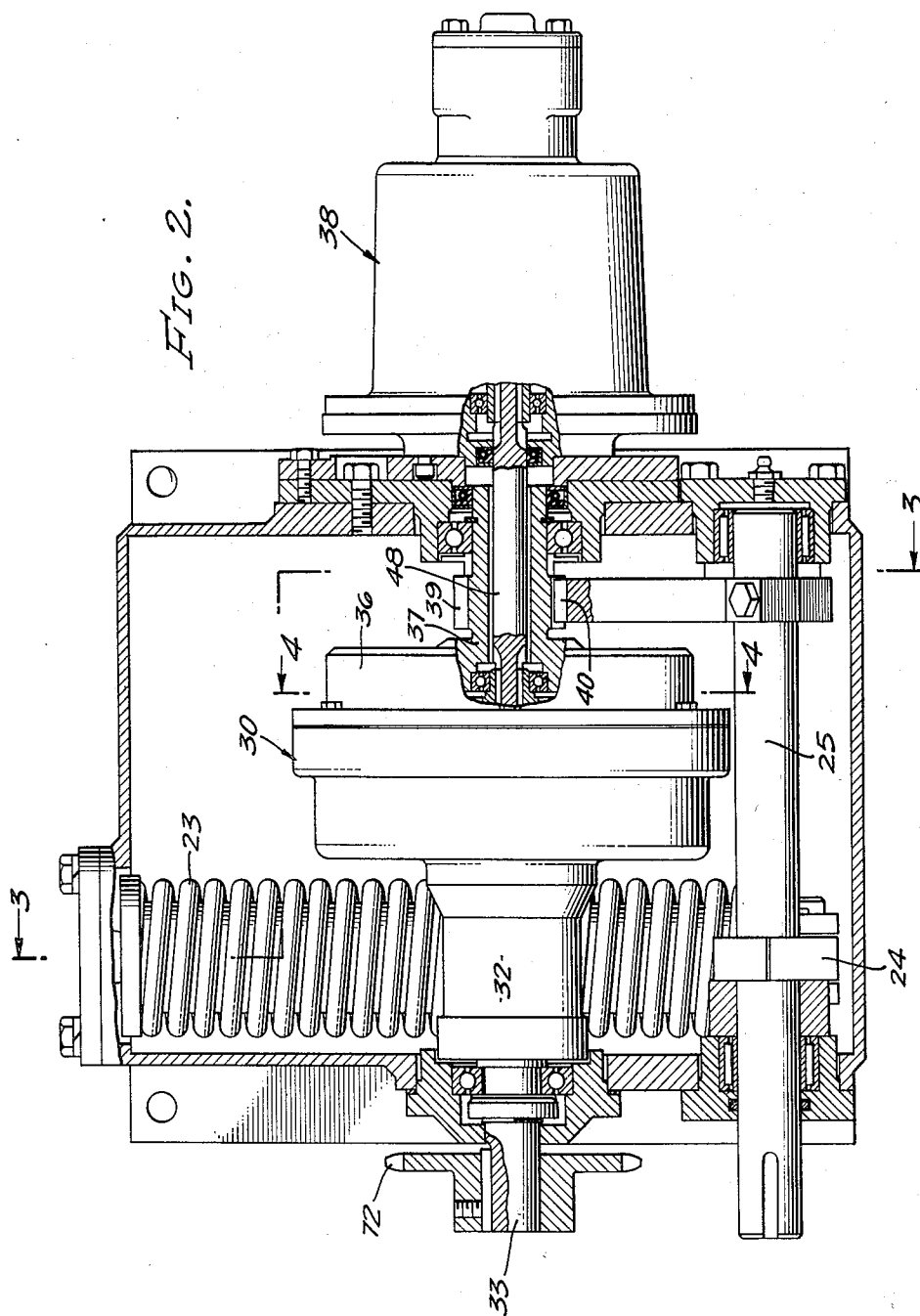
Aug. 23, 1960

J. G. ABRAHAM
DRILLING CONTROL

2,950,086

Filed Dec. 9, 1957

7 Sheets-Sheet 2



INVENTOR.
JAMES G. ABRAHAM

BY

Lyon & Lyon
ATTORNEYS

Aug. 23, 1960

J. G. ABRAHAM

2,950,086

DRILLING CONTROL

Filed Dec. 9, 1957

7 Sheets-Sheet 3

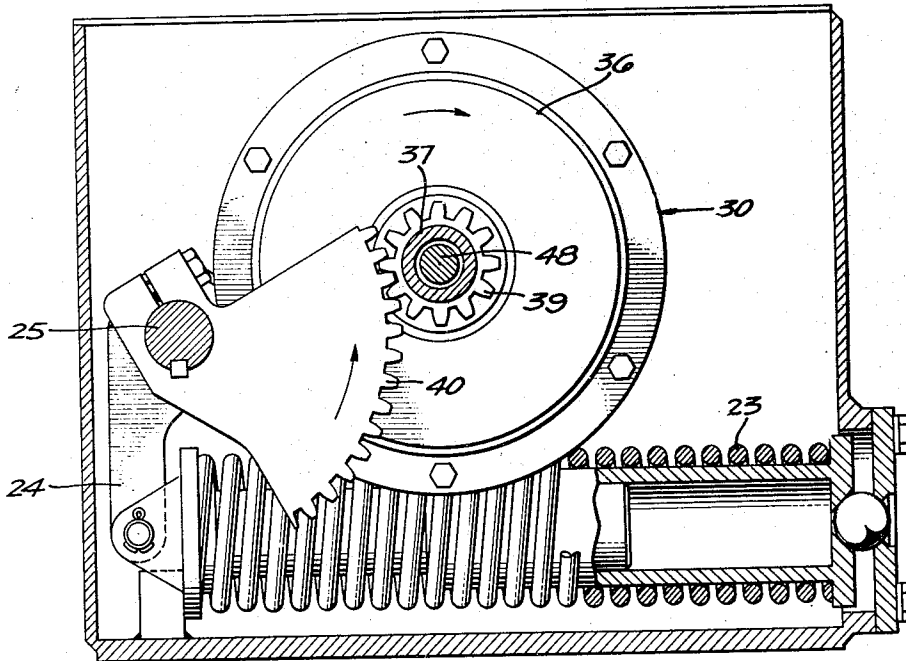


FIG. 3.

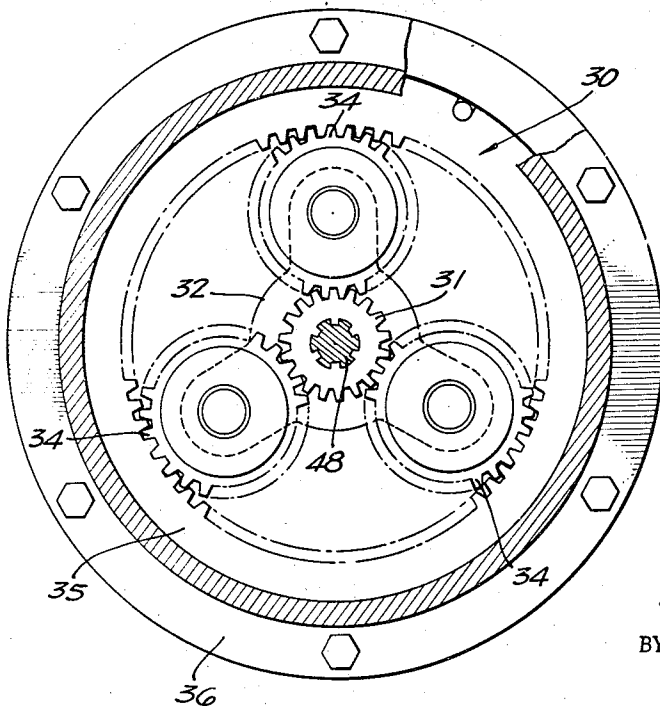


FIG. 4.

INVENTOR.
JAMES G. ABRAHAM
BY *Lyon & Lyon*
ATTORNEYS

Aug. 23, 1960

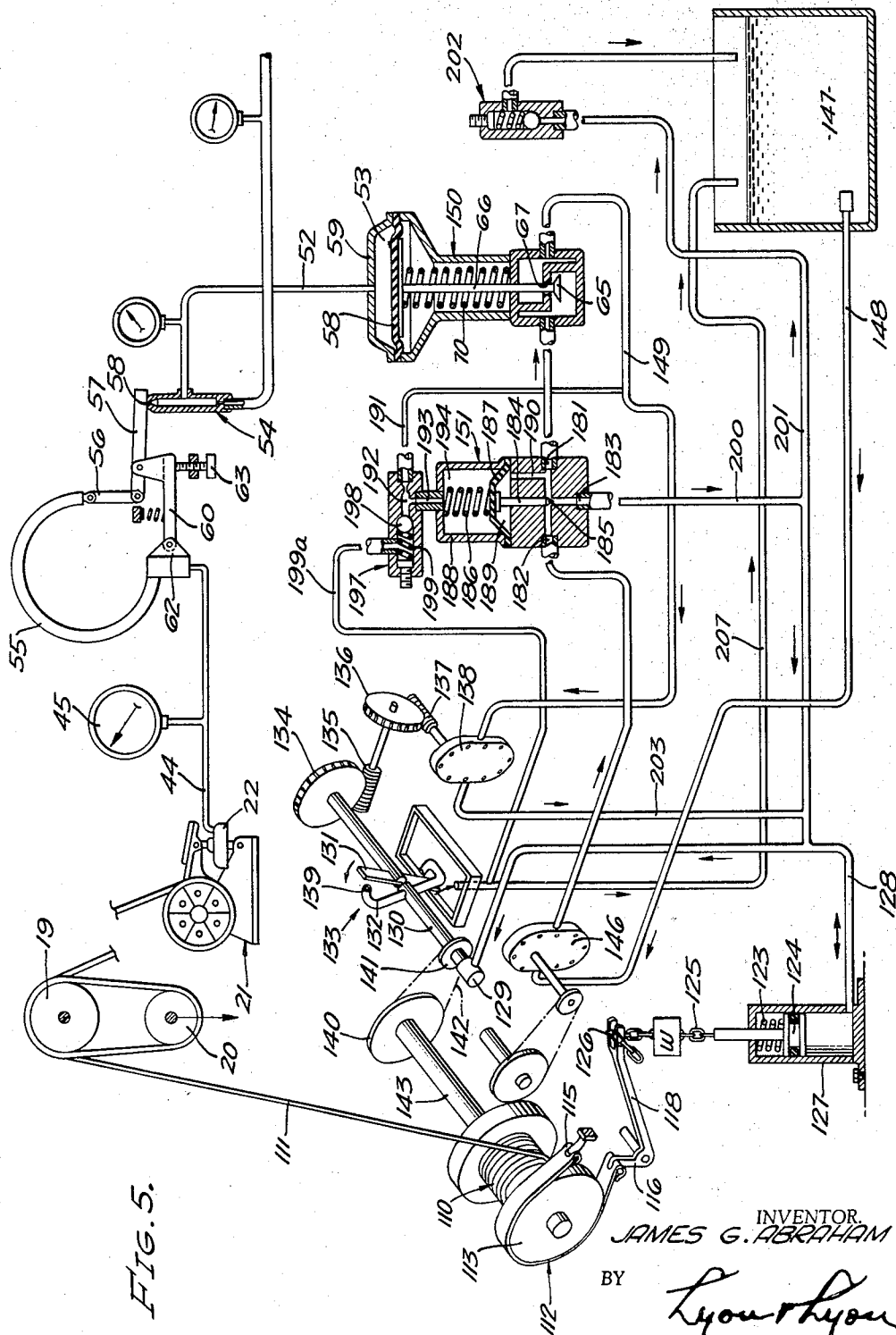
J. G. ABRAHAM

2,950,086

DRILLING CONTROL

Filed Dec. 9, 1957

7 Sheets-Sheet 4



INVENTOR.
JAMES G. ABRAHAM
BY
Lyon & Lyon
ATTORNEYS

J. G. ABRAHAM
DRILLING CONTROL

Filed Dec. 9, 1957

7 Sheets-Sheet 5



INVENTOR.
JAMES G. ABRAHAM

BY

ATTORNEYS

Aug. 23, 1960

J. G. ABRAHAM
DRILLING CONTROL

2,950,086

Filed Dec. 9, 1957

7 Sheets-Sheet 6

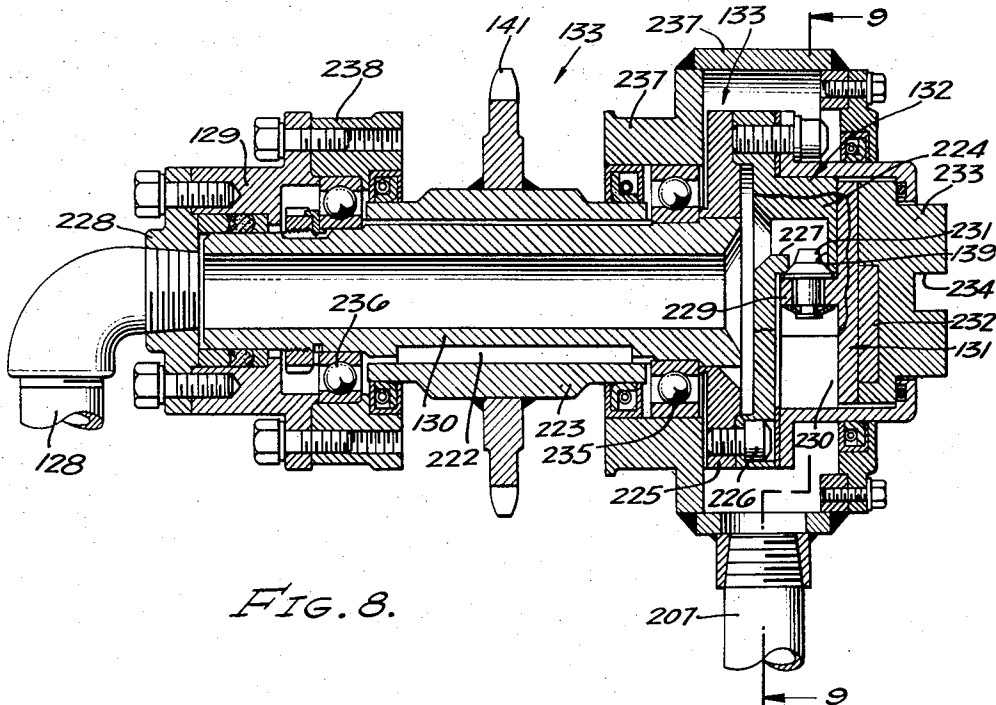


FIG. 8.

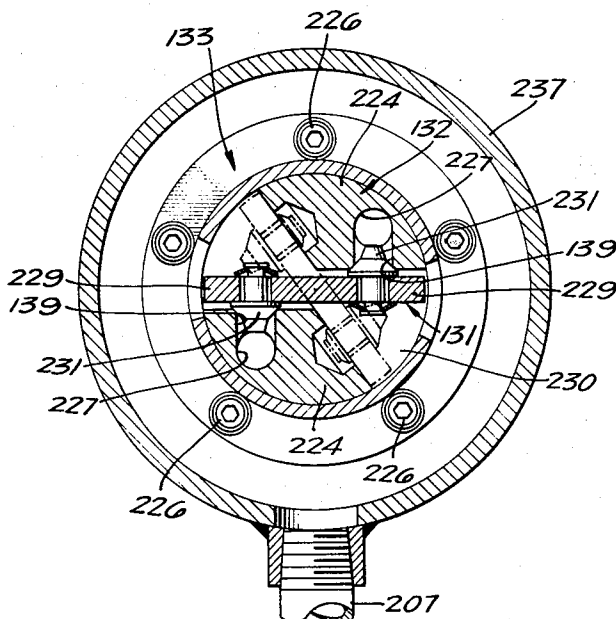


FIG. 9.

INVENTOR
JAMES G. ABRAHAM
BY *Lyon & Lyon*
ATTORNEYS

Aug. 23, 1960

J. G. ABRAHAM
DRILLING CONTROL

2,950,086

Filed Dec. 9, 1957

7 Sheets-Sheet 7

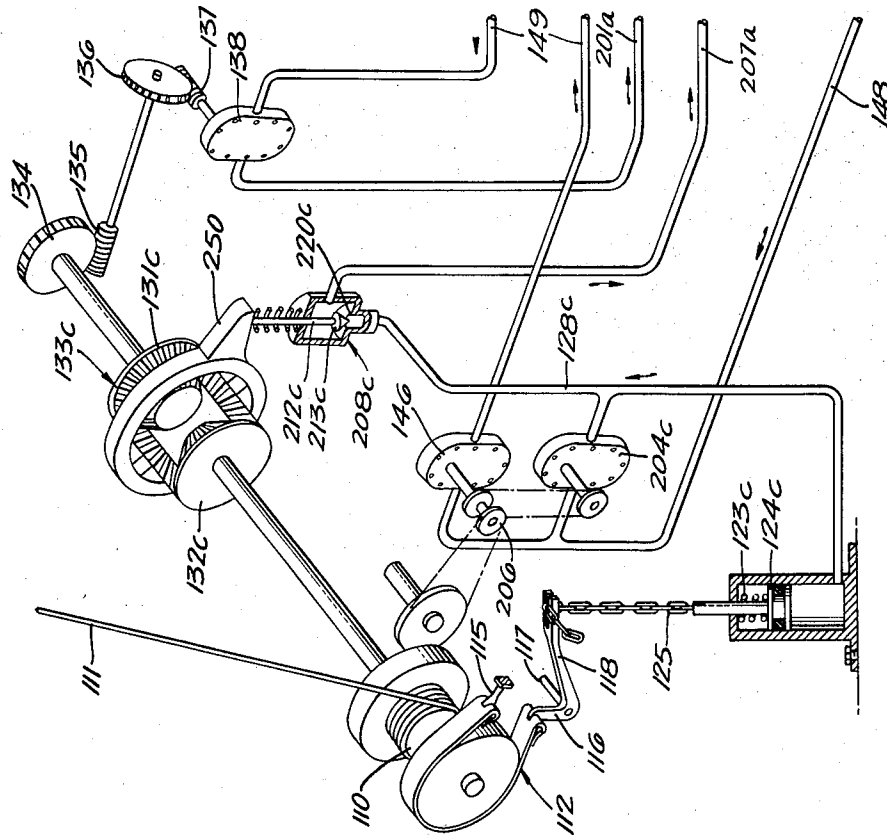


FIG. 11.

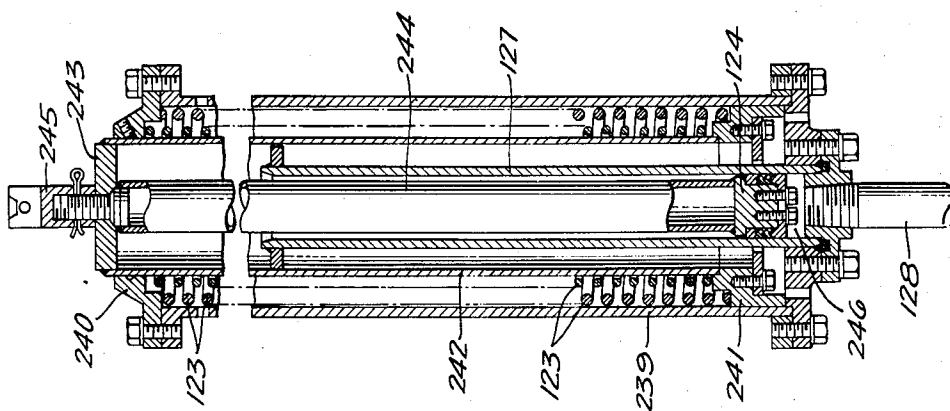


FIG. 10.

INVENTOR.
JAMES G. ABRAHAM

BY

Lyons Lyons
ATTORNEYS

1

2,950,086

DRILLING CONTROL

James G. Abraham, Rolling Hills, Calif., assignor, by mesne assignments, to The National Supply Company, Pittsburgh, Pa., a corporation of Ohio

Filed Dec. 9, 1957, Ser. No. 705,468

20 Claims. (Cl. 254—173)

This invention relates to apparatus for controlling the rate of feed of the drill string and bit in a well drilling rig.

This application is a continuation-in-part of my co-pending application for Drilling Control, Serial No. 476,254, now abandoned, filed December 20, 1954.

In the drilling of wells by the rotary method, it is customary to support the major portion of the weight of the rotary drill string at the top of the well and to allow only a minor portion to rest on the bit. As the bit turns, the formation is cut away and the rotary drill string is fed downward from the surface to maintain proper weight on the bit.

The rotary drill string is ordinarily supported from a swivel suspended from a traveling block. The traveling block is in turn supported by several line parts of a cable which passes over the crown block at the top of a derrick or mast. One end of the cable is wound on a spooling drum and the other may be secured to an anchor device. Unspooling of the cable from the drum allows the traveling block to move downward under the load imposed by the weight of the rotary drill string. Feeding of the bit into the formation is therefore conventionally accomplished by periodically releasing the brake on the spooling drum so that a short length of cable may be unspooled from time to time. When the rotary drill string is suspended so that the bit is just off bottom and not in contact with the formation, the tension in the cable serves as a measure of the total suspended weight. The drill string is then lowered by paying out cable from the spooling drum until reduction in cable tension indicates that the desired amount of weight is supported on the bit.

In conventional practice the driller manually operates the drawworks brake and allows the cable to unspool from the drum at the proper rate to maintain the desired weight on the bit. A weight indicating instrument is located adjacent the driller's position and this instrument responds to changes in tension at the anchor device. Various types of feed control devices have been proposed to relieve the driller of the tedious and monotonous duty of constantly watching the weight indicator and manually operating the brake control lever during the long hours while the bit is "on bottom." Such feed control devices have not met with universal acceptance however because the devices are not foolproof and experience has shown that they do not always operate as efficiently as a driller who manually operates the brake lever.

In one aspect, the problem is to pay out cable from the spooling drum at a rate which precisely equals the rate of penetration of the bit under desired loading. In accordance with my invention I provide improved means for automatically paying out cable from the spooling drum at a rate which maintains substantially constant weight on the bit as reflected by the tension in the cable. I provide a first member which moves at a rate controlled by variations in tension in the cable. A second cooperating member is provided which moves at a rate proportional to the unspooling movement of the cable drum, and hence the rate of penetration of the bit. When the first

2

member moves more rapidly than the second member, means are provided for releasing the brake to increase the rate of unspooling of the cable, thereby causing the second member to increase its speed of movement to equal that of the first member.

This result is accomplished by employing bias means such as a weight or a spring normally acting in a direction to apply the brake. Brake releasing means oppose the action of the bias means so that the spooling drum turns under the torque load applied by the tensioned cable whenever an increase in the cable tension causes the brake releasing means to overpower the bias means. In one form of my invention, a first member rotates at a rate controlled by variations in the tension in the cable, and a second member turns at a rate proportional to the unspooling rotary movement of the cable drum. The said members comprise two elements of a differential or planetary gear device, and the third element of such device moves in a direction to oppose the bias means. When the first member rotates too rapidly with respect to the second member, the action of the differential or planetary gear device is to permit the bias means to apply the brake, thereby arresting or decreasing the unspooling movement of the cable drum. Conversely, when the second member rotates too rapidly with respect to the first member the action of the differential or planetary gear device is to oppose the action of the bias means, thereby releasing the brake to permit the cable drum to increase its rate of turning in an unspooling direction.

In another form of the invention, fluid operated brake releasing means oppose the action of the bias means so that the spooling drum turns under the torque load applied by the tensioned cable whenever the pressure of the fluid reaches a value sufficiently high to overcome the force of the bias means. The "second member" mentioned above may be provided with a discharge port communicating with the pressure supply conduit for the brake releasing means. The discharge port is closed by an element of the "first member." So long as the discharge port is closed, pressure in the conduit energizes the brake releasing means, thereby allowing the drum to turn in a direction to pay out the cable. However, if relative movement occurs between the first and second members, the discharge port is open and fluid pressure in the conduit is relieved. The bias means then overcome the action of the brake releasing means and applies the brake to prevent rotation of the spooling drum.

The principal object of my invention is to provide an improved form of feed control device for a well drilling rig. A related object is to provide such a device in which resilient means normally apply the brake and wherein the brake is released when relative movement occurs between two members, one of the members moving at a rate controlled by variations in cable tension and the other moving at a rate proportional to the turning movement of the spooling drum.

Another object is to provide such a device in which the two members comprise two of the elements of a differential or planetary gear assembly, the third element of such assembly being connected to oppose the action of the brake-setting bias means.

Another object is to provide a feed control device in which the two members comprise coaxial rotary members forming a follower valve assembly.

Other and more detailed objects and advantages will appear hereinafter.

In the drawings:

Figure 1 is a diagrammatic illustration showing a preferred form of my invention.

Figure 2 is a plan view partly broken away and partly in section, showing a portion of the apparatus illustrated diagrammatically in Figure 1.

Figure 3 is a sectional end view taken substantially on the lines 3—3 as shown in Figure 2.

Figure 4 is a transverse sectional view taken substantially on the lines 4—4 as shown in Figure 2.

Figure 5 is a diagrammatic illustration showing a first modification.

Figure 6 is a diagrammatic illustration showing a second modification.

Figure 7 is a diagrammatic illustration showing a third modification.

Figure 8 is a sectional elevation showing a preferred form of follower valve assembly.

Figure 9 is a sectional view taken substantially on the lines 9—9 as shown in Figure 8.

Figure 10 is a longitudinal sectional elevation partly broken away, showing details of a fluid driven brake actuator employed with apparatus shown in Figures 5, 6, 7, 8, 9 and 11.

Figure 11 is a diagrammatic illustration showing a fourth modification.

Referring to the drawings and particularly to Figures 1-4:

The cable drum generally designated 10 has one end of a cable 11 spooled thereon. A friction brake assembly 12 is used to prevent rotation of the drum under torque load applied by the cable 11. This brake assembly 12 includes a brake drum 13 having a brake band 14 in contact therewith. One end 15 of the brake band 14 is held stationary and the other end is connected to a crank 16 on the brake shaft 17. The brake lever 18 is fixed to the shaft 17. When the brake lever 18 moves counterclockwise as viewed in Figure 1 the brake band 14 is released from contact with the brake drum 13 to permit the drum 10 to turn in a direction to pay out cable from the drum.

The cable 11 passes over the crown block 19 at the top of a derrick, not shown, then passes around a traveling block 20 which supports the suspended weight of the rotary drill string, not shown. A number of line parts of the cable 11 extend between the crown block 19 and traveling block 20. The other end of the cable 11 is secured relative to the anchor device generally designated 21. This anchor device is preferably of the type disclosed in the Spalding Patent No. 2,488,070 and includes a capsule 22 containing a fluid body under pressure. The pressure of the fluid body is proportional to the tension in the cable 11. This pressure is reflected through hydraulic line 44 to the weight indicator instrument 45. In effect this instrument is a pressure gage calibrated as a weight indicator and the instrument is ordinarily located adjacent the driller's position. When the drum 10 turns in a direction to pay out cable 11 the travelling block 20 moves down under the load imposed by the weight of the rotary drill string. The bit at the lower end of the drill string contacts the formation and when the desired amount of weight rests on the bit the brake 12 must be reapplied to prevent further unspooling movement of the drum 10. Excessive weight on the bit could damage the bit or even cause "twist-off" of the rotary drill string.

In accordance with my invention, I provide means for automatically actuating the brake 12 to maintain the desired weight of the bit. As shown in Figure 1, I provide bias means such as a weight (not shown) hanging from the upper end of the brake lever 18, or the spring 23 for moving the brake lever 18 in a direction to apply the brake. The spring 23 acts against the crank 24 fixed to rock shaft 25. The crank 26 also fixed to shaft 25 is connected by pivoted link 27 to the actuating arm 28. This arm is pivoted to a stationary support 29, and the upper portion thereof is positioned to contact the brake lever 18. Accordingly, the action of the spring 23 is to rotate the rock shaft 25 to cause the arm 28 to act on the brake lever 18 in a direction to apply the brake 12.

A differential or planetary gear mechanism generally designated 30 includes as a first member the sun gear 31 fixed on the motor shaft 48. As a second member the mechanism 30 includes the planet carrier 32 fixed on the driven shaft 33. Planet gears 34 are rotatably mounted on the carrier 32 and mesh with the sun gear 31. The third member of the mechanism 30 comprises a ring gear 35 concentric with the sun gear 31 and meshing with the planet gears 34. A gear carrier 36 is fixed to the ring gear 35 and is also fixed to the hub 37 of drive gear 39.

The hub 37 is rotatably mounted coaxially of the motor shaft 48 and the shafts 33 and 48 are coaxial. A gear segment 40 is fixed on the rock shaft 25 and meshes with the drive gear 39. Accordingly, turning movement of the ring gear 35 causes gearing 39 and 40 to turn the rock shaft 25.

A spacer arm 41 is mounted to turn about the axis of the driven shaft 33 and in turn rotatably supports the stub shaft 42 at its outer end. A roller 43 is fixed on the stub shaft 42 and this roller frictionally contacts the peripheral surface 46 of the member 47 which rotates with the spooling drum 10. Sprockets 71 and 72 connected by chain 73 drive the shaft 33 in accordance with the rotation of the stub shaft 42. A power cylinder assembly 74 is provided with an extensible rod 75 pivotally connected to the arm 41 for swinging the arm 41, shaft 42 and roller 43 upward into operative position. From this description it will be understood that the shaft 33 and planet carrier 32 are driven in accordance with rotation of the spooling drum 10, and that the motor shaft 48 and sun gear 31 are driven by the fluid motor 38.

The speed of the fluid motor 38 is accurately controlled by regulating the rate of flow of fluid through the pressure line 49. A metering valve assembly 50 controls the rate of flow of fluid through the line 49 to the fluid motor 38. The opening through the metering valve 50 is regulated by the pressure in the control pipe 52 leading to the diaphragm chamber 53. The control pipe 52 extends to a control mechanism 54. The purpose of this control mechanism 54 is to vary the pressure supplied to the control pipe 52 in accordance with hydraulic pressure within the capsule 22. The hydraulic pressure in the line 44 causes the Bourdon tube 55 to move the link 56 in a direction to swing the pivoted flapper valve 57 toward the orifice 58 in the nozzle 59. The flapper valve 57 may be conveniently supported on a bracket 60 pivoted at 61 to the stationary piece 62. The position of the bracket 60 may be regulated by means of the adjustable stop screw 63.

Pneumatic pressure is supplied to the nozzle 59 through the line 64. When the flapper valve 57 closes the orifice 58, pneumatic pressure within the nozzle 59 is transmitted through the control pipe 52 to the diaphragm chamber 53. When the flapper valve 57 swings upward away from the nozzle 59, pneumatic pressure is bled from the nozzle 59 through the orifice 58 thereby reducing the pressure within the control pipe 52. From this description it will be understood that an increase in pressure in the hydraulic line 44 is effective to increase the pneumatic pressure within the control pipe 52. Conversely a reduction in hydraulic pressure within the line 44 serves to vent the control pipe 52 to atmosphere.

The metering valve assembly 50 includes a valve head 65 carried on the lower end of a stem 66 and positioned to control the rate of flow through the port 67. The diaphragm 68 cooperates with the valve body 69 to define the chamber 53. Pneumatic pressure within the chamber 53 acts to oppose the action of the coil spring 70. The coil spring raises the valve stem 66 to restrict flow through the port 67 whenever the control pipe 52 is vented to atmosphere.

In the operation of that form of my invention shown

in Figures 1-4, the tension in the cable 11 increases when the bit "drills off" and this results in a corresponding pressure rise in the hydraulic capsule 22. The increase in hydraulic pressure in the line 44 acts through the control mechanism 54 to increase pressure in the control pipe 52 and thereby move the valve stem 66 in the direction to increase flow through the port 67 and through pressure line 49 to the fluid motor 38. This increases the speed to the fluid motor 38 and sun gear 31. An increase in the speed of rotation of the sun gear 31 in a clockwise direction, as viewed in Figure 1, results in turning movement of the ring gear 35 in a counter-clockwise direction. This motion, transmitted through gearing 39 and 40, turns the rock shaft 25 in a clockwise direction to relax the brake 12 and to permit an increase in the speed of unspooling movement of the drum 10. This latter increase in turning speed is reflected through the roller 43 and chain drive to shaft 33 and planet carrier 32, with the result that a new balance in speed is obtained between the planet carrier 32 and the sun gear 31, and accordingly the ring gear 35 comes to rest in a new position.

Should the cable 11 be payed out from the spooling drum 10 at too great a speed, the weight on the bit becomes excessive and the tension in the cable 11 decreases. Accordingly, the hydraulic pressure in the capsule 22 and hydraulic line 44 also decreases with the result that the stem 66 of the valve 50 moves upward to decrease the rate of fluid flow through the port 67. The speed of the fluid motor 38 therefore decreases and the corresponding decrease in the speed of the sun gear 31 causes the ring gear 35 to turn in a clockwise direction as viewed in Figure 1, thereby turning the rock shaft 25 in a direction to apply the brake 12.

In the modified form of my invention shown in Figures 5, 8, 9 and 10, I provide bias means such as the weight "W" or the spring 123 which acts against the piston 124 to move the tension element 125 in a direction to apply the brake. This tension element is connected to the swinging end of the brake lever 118 at 126. The hydraulic cylinder 127 which receives the piston 124 is connected to a fluid pressure conduit 128. This conduit 128 connects through stuffing-box 129 and hollow shaft 130 to one of a pair of relatively movable members 131 and 132 which are the principal parts of the follower valve assembly generally designated 133.

The members 131 and 132 are mounted for coaxial relative turning movement and the member 131 is driven through speed reduction gearing 134, 135, 136, and 137, by a hydraulic motor 138. The speed of rotation of the hydraulic motor 138 is regulated by the pressure of the fluid body within the capsule 22 as set forth below.

The member 132 of the follower valve assembly 133 is provided with one or more discharge ports 139 which are closed by engagement with the member 131. The member 132 is turned at a rate proportional to the rate of turning of the spooling drum 110 and this is accomplished by means of the aligned sprockets 140 and 141 connected by chain 142. Sprocket 140 is driven from the drum shaft 143 and the sprocket 141 is connected to drive the member 130.

Pressure fluid from any convenient source is admitted into the conduit 128. This pressure fluid escapes through ports 139 unless the ports are closed by contact with the member 131. When the ports 139 are open the pressure in the conduit 128 is relieved so that the piston 124 cannot overcome the force of the spring 123 and consequently the spring 123 applies the brake 112. When the ports 139 are closed by the member 131 pressure in the conduit 128 acts on the piston 124 to overcome the force of the spring 123 and thereby release the brake 112. A pump 146 driven from any convenient source of power draws hydraulic fluid from a reservoir 147 through a suction line 148 and delivers it through pressure line 149 to the hydraulic motor 138. The speed of the hydraulic

motor 138 is controlled by regulating the rate of flow of fluid through the pressure line 149. The metering valve assembly 150 controls the rate of flow of fluid through the line 149 in the same manner as described above in connection with the fluid motor 38, with the exception that a pressure differential valve assembly 151 is provided to maintain a constant pressure drop across the metering valve 150. The action of the Bourdon tube 55 and flapper valve 57 is the same as that previously described.

The differential pressure valve 151 is provided with an inlet 182, an outlet 181, and a bypass outlet 183. A stem 184 is shown schematically with a pointed lower end 185 for regulating the amount of hydraulic pressure permitted to escape through the bypass outlet 183. A coil spring 186 acts to move the stem 184 downward. A diaphragm 187 cooperates with the valve housing 188 to define an expansible pressure chamber 189 which communicates with the pressure supply pipe via passage-way 190. Pressure in the chamber 189 serves to raise the diaphragm 187 and the stem 184 against the action of the coil spring 186. The bypass line 191 is connected at one end to the pressure supply pipe 149 at a location downstream from the metering valve assembly 150. The other end of the bypass line 191 is connected through passages 192 and 193 with the space 194 above the diaphragm 187. From this description it will be understood that if the pressure in the line 149 downstream from the valve assembly 150 should fall more than a desired amount below the pressure upstream from the valve assembly 150, this lower pressure is reflected through bypass line 191 to the space 194. Diaphragm 187 then raises slightly against the action of the spring 186 thereby raising the stem 184 and consequently lowering the pressure in the line 149 between valves 151 and 150 by allowing a larger proportion of hydraulic fluid to escape through the bypass outlet 183. Since the pressure drop across the metering valve assembly 150 is kept substantially constant, the rate of flow of hydraulic fluid through the metering valve 150 is accurately determined by the vertical position of the stem 66. A relief valve 197 is connected with the bypass line 191 and may include a ball element 198 seated by means of a spring 199. If the pressure in the bypass line 191 exceeds a predetermined value, the ball element 198 is unseated to allow flow to occur through the piping 199a and 207 to the sump 147.

In this form of my invention, the source of pressure for the conduit 128 is taken from the discharge pipes 200 and 203, the latter being the discharge pipe for the hydraulic motor 138. The pressure in these discharge pipes and in the pipe 201 is regulated by the relief valve 202. In this way a convenient source of fluid under pressure is available for use in the conduit 128 but it is recognized that any other source of fluid under pressure may be used if desired.

The modified form of the apparatus shown in Figure 6 uses a separate pump 204 for supplying the fluid under pressure to the conduit 128a. One branch of this conduit 128a connects with the stuffing-box 129 as previously described and the other branch connects to the hydraulic cylinder 127. The pump 204 may be driven from any convenient power source and as shown in the drawings is connected by chain 205 to a driving sprocket 206 on the shaft of the pump 146. In this form of my invention, escape of fluid under pressure from ports 139 to the follower valve assembly 133 reduces the pressure to the conduit 128a and permits the spring 123 to set the brake 112. The control of the speed of the member 131 is the same as that previously described. The back pressure valve 202 is omitted and the pipe 201a connects directly to the reservoir 147. As in the form of the invention previously described, the drain line 207 connects the follower valve assembly 133 directly with the reservoir 147.

The operation of the form of the invention shown in

Figure 6 is substantially the same as that previously described with the exception that the pressure fluid supplied to the conduit 128a is derived from a separate pump 204 instead of from the back pressure line 201. Turning movement of the member 132 at a rate exceeding the rate of turning movement of the member 131 causes the discharge ports 139 to be opened and thereby bleed down pressure in the conduit 128a thus serving to set the brake 112. So long as the member 131 remains in sealing contact with the member 132 the discharge ports 139 are closed and hence pressure in the conduit 128a acts against the piston 124 to overcome the action of the spring 123 and thereby release the brake 112.

In the modified form of the invention shown in Figure 7, the follower valve assembly 133 is replaced by the valve assembly 208. A roller or sprocket 209 is rotatably mounted on the swinging end of an arm 210 which oscillates about a stationary pivot pin 211. A valve stem 212 is pivotally connected to the arm 210 and carries a valve head 213 at its lower end. The roller or sprocket 209 engages one reach of the chain 214 at a location between the sprockets 215 and 216. The sprocket 215 turns with the drum 110 and the sprocket 216 turns with the output gear 134 of the reduction train driven by the hydraulic motor 138. When the sprockets 215 and 216 remain stationary or turn at equivalent rates of speed the tension in the chain 214 remains the same. However if the sprocket 216 attempts to lag the sprocket 215 in the direction indicated by the arrow 217 then the tension in the reach 218 of the chain 214 is reduced. The spring 219 then raises the arm 210 and lifts the valve head 213 away from the stationary seat 220. Pressure fluid in the conduit 128b therefore escapes through the port 221 and returns to the reservoir 147 through the pipe 207b. The reduction in pressure within the conduit 128b permits the spring 123 to set the brake 112. Conversely, when the rate of rotation of the sprocket 216 tends to lead the equivalent rate of rotation of the sprocket 215 the tension in the reach 218 of the chain 214 increases in magnitude with the result that the arm 210 moves downward against the action of the spring 219 to close the valve head 213 against the seat 220. Pressure then builds up in the conduit 128b and acts against the piston 124 to release the brake 112 against action of the spring 123.

In Figure 8 I have shown a preferred form of follower valve assembly. The sprocket 141 is fixed relative to the hollow shaft 130 by means of the key 222 which engages the hub 223. The member 132 which is fixed to this hollow shaft 130 includes the block 224 which carries the discharge ports 139. The block 224 is connected in solid driving relationship with the flange 225 by means of threaded fastenings 226. Passageways 227 within the block 224 connect each port 139 with the interior of the hollow shaft 130. The conduit 128 connects to the stuffing-box 129 by means of the stationary threaded flange ring 228. Pressure fluid in the conduit 128 is therefore conducted through the hollow shaft 130 to the discharge ports 139 within the block 224.

As shown in Figure 8 the member 131 is positioned adjacent the member 132 and has quadrant portions 229 extending into cooperating recesses 230 provided in the block 224. Each of these quadrant portions 229 carries a valve head 231 which serves as a closure for one of the discharge ports 139. The member 131 is driven through an angular lost motion connection provided by the cooperating jaws 232. These jaws are provided on the member 131 and on the drive ring 233. The tongue of a driving member, not shown, enters the transverse slot 234 on the ring 233 for transmitting rotary movement to the member 131.

Axially spaced anti-friction bearings 235 and 236 rotatably support the hollow shaft 130 within the stationary housing supports 237 and 238.

So long as the valve heads 231 on the member 131

remain in sealing contact with the ports 139, pressure of fluid in the hollow shaft 130 and within the conduit 128 can be maintained at a relatively high value. When relative rotary movement occurs between members 131 and 132, however, the valve head elements 231 move away from the ports 139 to permit pressure fluid to pass from the hollow shaft 130 to passages 227 and discharge ports 139 into the recesses 230 and out through the drain line 207. As pointed out above this serves to reduce the pressure in the conduit 128 with the result that the spring 123 acts to set the brake 112.

The fluid driven actuator shown in Figure 10 includes the piston 124 acting within the cylinder 127. A stationary shell 239 encloses the cylinder 127 and serves as a housing for the relatively long concentric coil springs 123. At one end these springs engage the stationary flange 240 and at the other end they engage the moving ring 241 which is fixed to the tube 242. The tube 242 is fixed to the closure flange 243 and this is in turn fixed to the hollow piston rod 244. A clevis 245 at the forward end of the piston rod 244 is provided for connection to the tension element 125. When fluid pressure is supplied through conduit 128 to the chamber 246 the piston 124 moves upwardly as viewed in Figure 7 against the action of the concentric springs 123. The relatively long concentric springs 123 used in this construction provide an actuator having a very low spring rate. This is desirable for the intended service since it enables a relatively long travel to be obtained by relatively small percentage change in the fluid pressure supplied to the piston.

The particular form of follower valve assembly and fluid driven actuator shown in Figures 8, 9, and 10 are presented by way of illustration and it is recognized that other forms of these devices may be used. It may be pointed out that in certain aspects this invention is not limited to the provision of a follower valve assembly but on the contrary may use other means for sensing relative movement between two members and then employing this sensing means to release the brake for the spooling drum. For example, Figure 11 shows a differential gear or planetary gear assembly which is employed instead of the follower valve assembly 133. In such construction the members 131c and 132c would comprise two of the three elements of the differential gear or planetary gear, generally designated 133c. Any relative movement between these two elements would necessarily cause movement of the third element and such movement is made effective to release the brake 112. The third element 250 acts on the stem 212c of the valve assembly 208c closing the head 213c against the stationary seat 220c. Pressure in the line 128c is developed by the pump 204c and acts on the piston 124c, causing it to move against the action of the spring 123c and thereby release the brake 112c. In all other respects the operation of that form of my invention shown in Figure 8 is similar to that form shown in Figure 3.

Having fully described my invention, it is to be understood that I do not wish to be limited to the details herein set forth but my invention is of the full scope of the appended claims.

I claim:

1. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: resilient means acting in a direction to apply the brake, brake-releasing means acting to oppose said resilient means, a rotary member, means for turning said member, a cable tension measuring device connected to the cable, control means operated by said tension measuring device for regulating the rate of turning movement of said rotary member in accordance with variations in the magnitude of the cable tension, and means actuated by relative rotary movement of the drum and said rotary member

and operative to render the brake releasing means ineffective and thereby permit the resilient means to apply the brake.

2. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: resilient means acting in a direction to apply the brake, brake-releasing means opposing the action of said resilient means, a pair of cooperating relatively movable members, means for moving the first of said members, a cable tension measuring device connected to the cable, control means operated by said tension measuring device for regulating the rate of movement of said first member in accordance with variations in the cable tension, means for moving the second member at a speed proportional to the turning movement of the spooling drum, and means whereby relative movement of said members serves to render the brake-releasing means ineffective and thereby permit the resilient means to apply the brake.

3. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: resilient means acting in a direction to apply the brake, brake-releasing means opposing the action of said resilient means, a pair of coaxial relatively rotatable members, means for turning the first of said members, a cable tension measuring device connected to the cable, control means operated by said tension measuring device for regulating the rate of turning movement of said first member in accordance with variations in the cable tension, means for turning the second member at a speed proportional to the turning movement of the spooling drum, and means whereby relative turning movement of said members serves to render the brake-releasing means ineffective and thereby permit the resilient means to apply the brake.

4. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: resilient means acting in a direction to apply the brake, fluid-actuated brake-releasing means opposing the action of said resilient means, means including a conduit for supplying fluid under pressure to said brake-releasing means, a pair of relatively movable members, means for moving the first of said members, a cable tension measuring device connected to the cable, control means operated by said tension measuring device for regulating the rate of movement of said first member in accordance with variations in the magnitude of the cable tension, means for moving the second member at a speed proportional to the turning movement of the spooling drum, and means whereby relative movement of said members serves to reduce the pressure in said conduit and permit the resilient means to apply the brake.

5. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: resilient means acting in a direction to apply the brake, fluid-actuated brake-releasing means opposing the action of said resilient means, means including a conduit for supplying fluid under pressure to said brake-releasing means, a pair of cooperating relatively movable members, means for moving the first of said members, a cable tension measuring device connected to the cable, control means operated by said tension measuring device for regulating the rate of movement of said first member in accordance with variations in the magnitude of the cable tension, the second of said members having a discharge port in communication with said conduit and adapted to be closed by said first member, and means for moving the second member at a speed proportional to the turning movement of the spooling drum, whereby relative movement of said members in a direction to open said port serves to reduce

the pressure in said conduit and permit the resilient means to apply the brake.

6. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: resilient means acting in a direction to apply the brake, fluid actuated brake-releasing means opposing the action of said resilient means, means including a conduit for supplying fluid under pressure to said brake-releasing means, a pair of coaxial relatively rotatable members, driving means for turning the first of said members, control means for regulating the rate of turning movement of said first member, the second of said members having a discharge port in communication with said conduit and adapted to be closed by said first member, and means for turning the second member at a speed proportional to the turning movement of the spooling drum, whereby relative movement of said members in a direction to open said port serves to reduce the pressure in said conduit and permit the resilient means to apply the brake.

7. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: resilient means acting in a direction to apply the brake, fluid-actuated brake-releasing means opposing the action of said resilient means, means including a conduit for supplying fluid under pressure to said brake-releasing means, a pair of coaxial relatively rotatable members, means for turning the first of said members, a cable tension measuring device connected to the cable, control means operated by said tension measuring device for regulating the rate of turning movement of said first member in accordance with variations in the magnitude of the cable tension, the second of said members having a discharge port in communication with said conduit and adapted to be closed by said first member, and means for turning the second member at a speed proportional to the turning movement of the spooling drum, whereby relative turning movement of said members in a direction to open said port serves to reduce the pressure in said conduit and permit the resilient means to apply the brake.

8. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: resilient means acting in a direction to apply the brake, fluid-actuated brake-releasing means opposing the action of said resilient means, means including a conduit for supplying fluid under pressure to said brake-releasing means, a pair of relatively rotatable members, means including a fluid motor for rotating the first of said members, control means for regulating the rate of flow of fluid to said fluid motor to control the speed of rotation of said first member, the second of said members having a discharge port in communication with said conduit and adapted to be closed by said first member, means for pressurizing said conduit with fluid discharged from said pump, and means for turning the said second member at a speed proportional to the turning movement of the spooling drum, whereby relative movement of said members in a direction to open said port serves to reduce the pressure in said conduit and permit the resilient means to apply the brake.

9. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: a cable tension measuring device employing a fluid body under pressure proportional to the cable tension, resilient means acting in a direction to apply the brake, fluid-actuated brake-releasing means opposing the action of said resilient means, means including a first pump and a conduit for supplying fluid under pressure to said brake releasing

11

means, a pair of cooperating relatively movable members, means for moving the first of said members, including a second pump driving a fluid motor, control means responsive to the pressure of said fluid body for regulating the rate of flow of fluid to said fluid motor to control the speed thereof, the second of said members having a discharge port in communication with said conduit and adapted to be closed by said first member, and means for moving the said second member at a speed proportional to the turning movement of the spooling drum, whereby relative movement of said members in a direction to open said port serves to reduce the pressure in said conduit and permit the resilient means to apply the brake.

10. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: a cable tension measuring device employing a fluid body under pressure proportional to the cable tension, resilient means acting in a direction to apply the brake, fluid-actuated brake-releasing means opposing the action of said resilient means, means including a first pump and a conduit for supplying fluid under pressure to said brake-releasing means, a pair of cooperating relatively movable rotary members, means for rotating the first of said members, including a second pump driving a fluid motor, control means responsive to the pressure of said fluid body for regulating the rate of flow of fluid to said fluid motor to control the speed thereof, the second of said rotary members having a discharge port in communication with said conduit and adapted to be closed by said first member, and means for turning the said second member at a speed proportional to the turning movement of the spooling drum, whereby relative rotary movement of said members in a direction to open said port serves to reduce the pressure in said conduit and permit the resilient means to apply the brake.

11. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: resilient means acting in a direction to apply the brake, fluid-actuated brake-releasing means opposing the action of said resilient means, means including a conduit for supplying fluid under pressure to said brake-releasing means, a movable member, means for moving said movable member, a cable tension measuring device connected to the cable, control means operated by said tension measuring device for regulating the rate of movement of said movable member in accordance with variations in the magnitude of the cable tension, an element having a discharge port in communication with said conduit, a closure for said port, and means responsive to relative movement between said drum and said movable member acting to move said closure from said port to reduce the pressure in said conduit and permit said resilient means to apply the brake.

12. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: resilient means acting in a direction to apply the brake, fluid-actuated brake-releasing means opposing the action of said resilient means including a conduit for supplying fluid under pressure to said brake-releasing means, a first rotary member, means for turning said member, a cable tension-measuring device connected to the cable, control means operated by said tension-measuring device for regulating the rate of turning movement of said member in accordance with variations in the magnitude of the cable tension, a second rotary member mounted to turn with said drum, and means actuated by relative rotary movement of the drum and the first said rotary member, said means including an endless flexible connection trained over said rotary

12

members, a roller element engaging one reach of said flexible connection, a stationary element having a discharge port in communication with said conduit, and a closure for said port connected for operation by said roller element, whereby changes in relative rates of rotation of said members are operative to render the brake-releasing means ineffective and thereby permit the resilient means to apply the brake.

13. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: means including resilient means acting in a direction to apply the brake, means acting to oppose the action of said resilient means, including a rotary member, means for turning said member, a cable tension measuring device connected to the cable, control means operated by the tension measuring device for regulating the rate of turning of said member in accordance with variations in the magnitude of the cable tension, a second rotary member driven at a speed proportional to the turning movement of the drum, and means actuated by relative rotary movement of said members and operative to render the said opposing means ineffective and thereby permit the resilient means to apply the brake.

14. The combination set forth in claim 13 wherein the said rotary members each comprise one element of a differential gear assembly, and wherein the third element thereof constitutes a portion of the latter said means.

15. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: means including resilient means acting in a direction to apply the brake, a differential gear assembly having three relatively rotatable members, fluid motor means for driving a first of the members, a cable tension measuring device connected to the cable, control means operated by the tension measuring device for regulating the rate of turning of said fluid motor means in accordance with variations in the magnitude of the cable tension, means driving the second of the rotary members at a speed proportional to the turning movement of the drum, means whereby relative movement of said first two rotary members causes the third rotary member to release the brake, and resilient means acting to apply the brake.

16. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: means including bias means acting in a direction to apply the brake, brake releasing means acting to oppose said bias means, a rotary member, means for turning said member, a cable tension measuring device connected to the cable, means operated by said tension measuring device for regulating the rate of turning movement of said rotary member in accordance with variations in the magnitude of the cable tension, and means actuated by relative rotary movement of said drum and said rotary member and operative to render the brake-releasing means ineffective and thereby permit the bias means to apply the brake.

17. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: means including bias means acting in a direction to apply the brake, brake-releasing means acting to oppose said bias means, a pair of relatively rotatable members, means for turning the first of said members, a cable tension measuring device connected to the cable, means operated by said tension measuring device for regulating the rate of turning movement of said first member in accordance with variations in the cable tension, means for turning the second member at a speed proportional to the turning movement

13

of said drum, and means whereby relative turning movement of said member serves to render the brake-releasing means ineffective and thereby permit the bias means to apply the brake.

18. The combination of claim 17 in which the rotary members are co-axial.

19. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned cable and having a brake for said drum, the improvement comprising, in combination: means including bias means exerting a force to apply the brake, a pair of relatively rotatable members, means for turning the first of said members, a cable tension measuring device connected to the cable, means operated by said tension measuring device for regulating the rate of turning movement of said first member in accordance with variations in the cable tension, means for turning the second member at a speed proportional to the turning movement of said drum, and differential means responsive to relative turning movement of said members for modifying the force of said bias means upon the brake.

20. In a feed control device for a rotary drilling rig, the rig having a drum for spooling one end of a tensioned

14

cable and an anchor for the dead end thereof, the rig also having a brake for said spooling drum, the improvement comprising, in combination: means including bias means acting in a direction to apply the brake, a rotary member, means for turning said rotary member, a cable tension measuring device connected to the dead end of the cable, means operated by said tension measuring device for controlling the rate of turning movement of said rotary member in accordance with changes in the cable tension, and means operatively interposed between said member and said bias means whereby relative turning movement of the spooling drum and said member is effective to oppose the said bias means to release the brake.

References Cited in the file of this patent

UNITED STATES PATENTS

1,919,611	Besigk	July 25, 1933
1,926,119	Smith	Sept. 12, 1933
2,455,917	Crake	Dec. 14, 1948
2,657,011	Slonneger	Oct. 27, 1953
2,759,702	Abraham	Aug. 21, 1956
2,783,968	Bell	Mar. 5, 1957