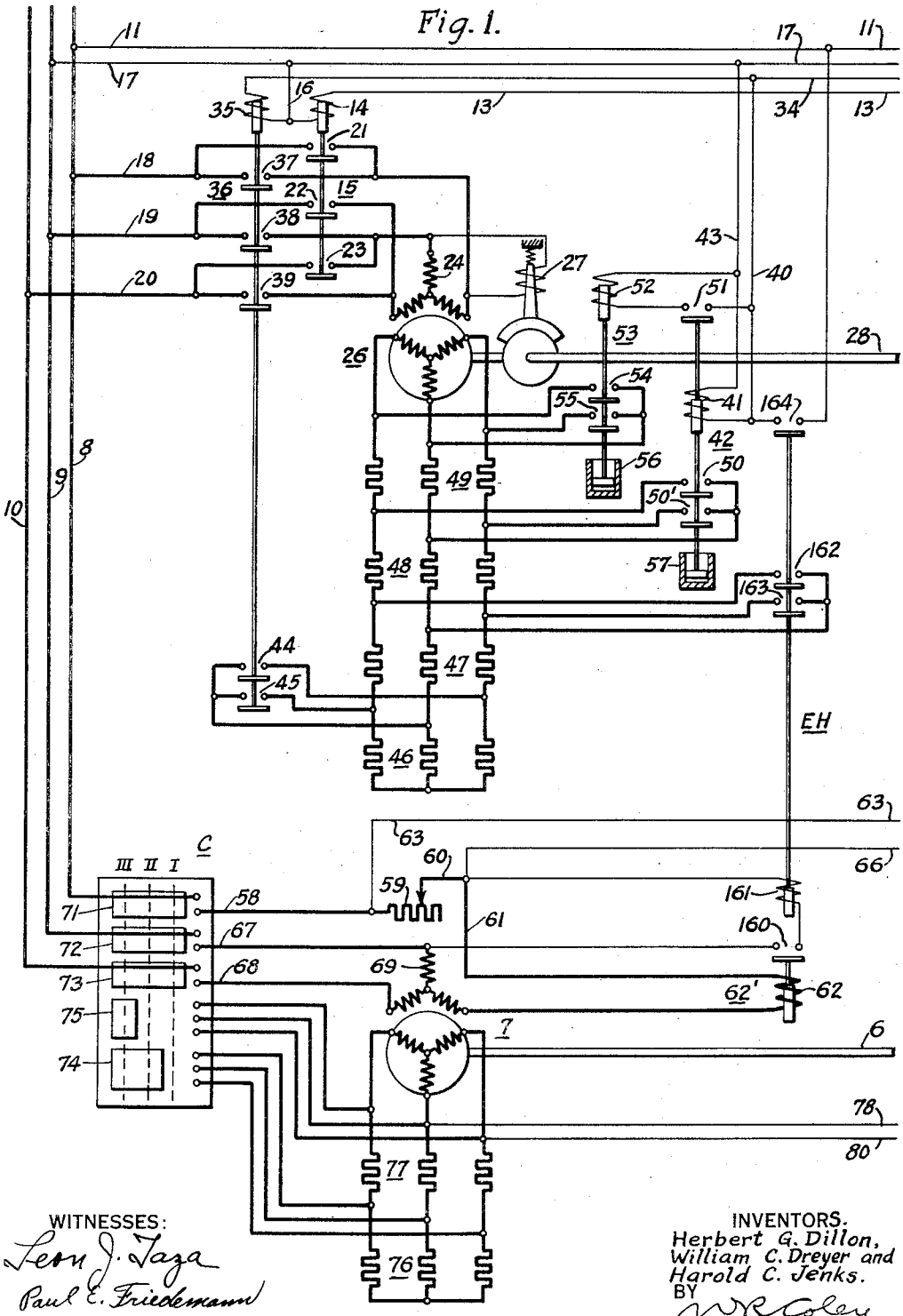
June 25, 1935. H. G. DILLON ET AL 2,005,889

AUTOMATIC DRILLING SYSTEM FOR ROTARY DRILLING EQUIPMENT

Filed Nov. 12, 1932 3 Sheets-Sheet 1

Fig. 1.



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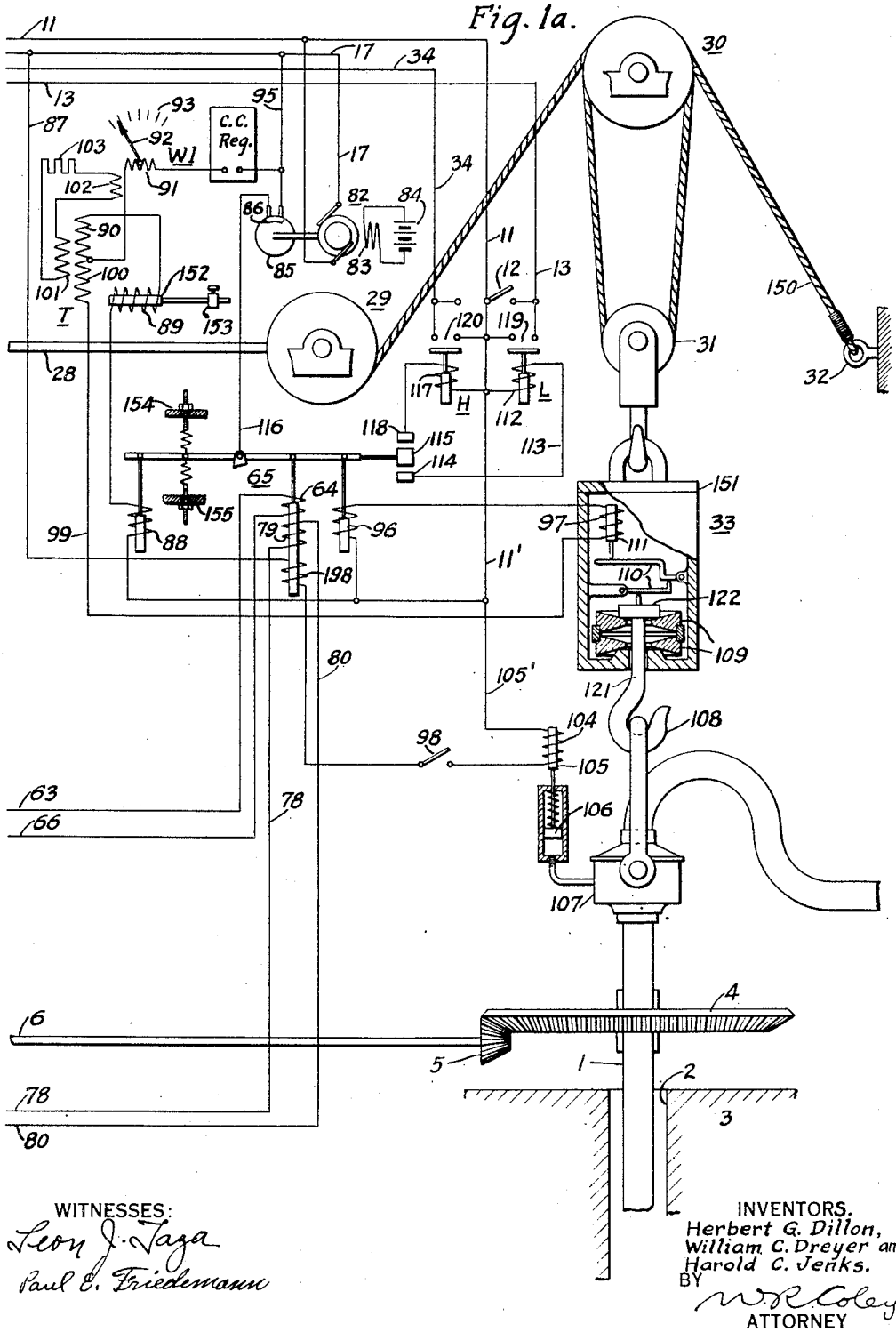
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AUTOMATIC DRILLING SYSTEM FOR ROTARY DRILLING EQUIPMENT

Filed Nov. 12, 1932 3 Sheets-Sheet 2

Fig. 1a.



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AUTOMATIC DRILLING SYSTEM FOR ROTARY DRILLING EQUIPMENT

Filed Nov. 12, 1932 3 Sheets-Sheet 3

Fig. 2

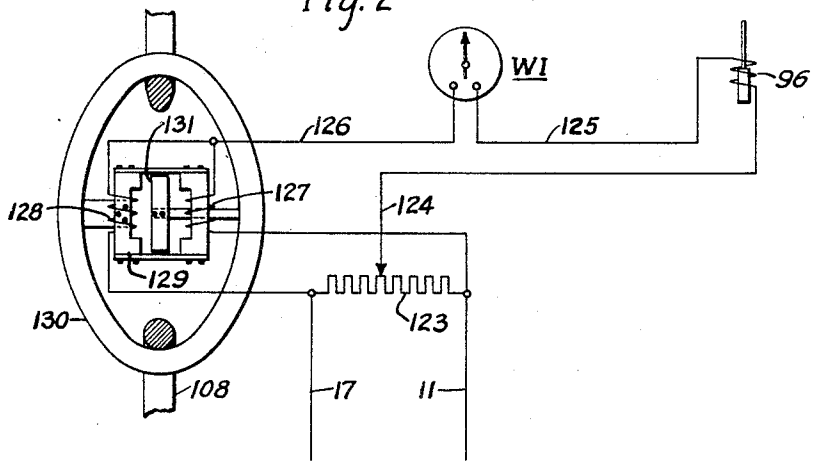
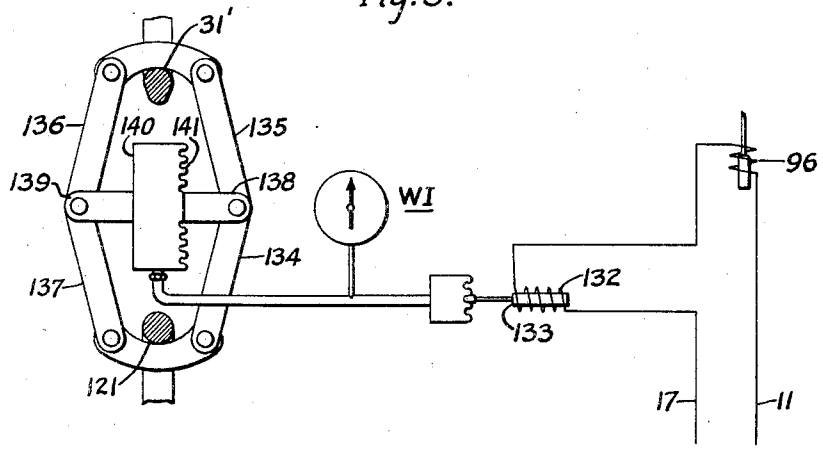


Fig. 3.



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UNITED STATES PATENT OFFICE

2,005,889

AUTOMATIC DRILLING SYSTEM FOR ROTARY DRILLING EQUIPMENT

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Application November 12, 1932, Serial No. 642,416

26 Claims. (Cl. 255—19)

This invention relates to rotary well drilling systems.

Various attempts have heretofore been made with devices of the prior art to control the hoisting motor as a function of the load of the drilling motor in drilling the strata upon which the bit operates. To this end, tension responsive devices, cooperating with the cable, have been mounted at the dead end. Such practice has not proved successful commercially. From the forces involved, it is obvious that such devices must be unsatisfactory, because scientific tests have shown that the tension in the shank of the hook supporting the drill stem may vary over a range of 5000 lb. without any variation in the tension of the cable at the "dead" or fixed end. To take measurements and to actuate control devices from operating characteristics in the cable at the fixed end may apparently be very simple and cheap, but if such measurements are in error by a value much greater than the value to be controlled, then such control devices are clearly unsatisfactory from the standpoints of accuracy and reliability.

In working on the invention herein presented, we were fully apprised of the problem and had as an object of this invention the provision of a simple, practical, inexpensive, and above all, accurate system of control whereby the drilling motor is not overloaded, crooked holes are avoided, broken and twisted-off drill stems are prevented, and the drilling operation proceeds with the maximum of speed at which a given formation can be properly drilled.

It is also an object of this invention to control the feeding of the drill stem as a function of the pressure or weight of the drill stem on the bottom of the well, that is, on the strata being drilled.

Another object of this invention is to control the feeding of the drill stem in response to the operations of electro-mechanical means disposed to directly indicate the tension in the supporting hook for the drill stem.

Another object of this invention is to provide for automatically retrieving the drill stem when the weight of the drill resting on the bottom of the well, or the load on the drilling motor, or both, exceeds a predetermined amount.

A further object of this invention is to provide for electrically indicating and controlling the tension in the hook supporting the drill stem.

A still further object of this invention is to provide for controlling the movement of the drill stem as a function of tension in the drill-stem-supporting hook, the load on the drilling motor, the speed of the drilling motor, and the pressure of the fluid pumped by the mud pump, or any one, or any combination of these factors.

It is also an object of this invention to provide hydraulic means combined with electric means to indicate and control the weight supported by the hook of the traveling block of a well-drilling equipment.

A further object of this invention is to mechanically and electrically amplify the changes in the extensions of a tension responsive device, mounted directly between the drill stem and the traveling block, of a well drilling equipment, as a result of the variations in the supported weight of the drill stem, and to provide for controlling the vertical movements of the drill stem in response to such extensions.

Other objects and advantages will become apparent from a study of the following specification when studied in conjunction with the accompanying drawings, in which:

Figs. 1 and 1*a* diagrammatically illustrate a well drilling system organized in accordance with this invention, including a disk spring type of weight indicator disposed between the traveling block and the drill stem;

Fig. 2 is a schematic showing of a modified weight or tension-responsive device to be connected between the traveling block and the drill stem; and

Fig. 3 is a schematic showing of a further modification of a weight-responsive device that may be utilized as one of the essential parts of the control system shown in Figs. 1 and 1*a*.

Referring more particularly to Figs. 1 and 1*a*, the reference character **1** designates a drill stem depending in the well **2**. A drill table **4** is disposed to operatively engage the stem and may be rotated by the drilling motor **7**, through shaft **6** and a beveled pinion **5** cooperating with the usual gear portion of the drill table.

A traveling block **31** is disposed to support the drill stem by the coaction of the hoisting motor **26**, brake **27**, shaft **28**, hoist drum **29**, crown block **30** and the cable **150** associated therewith. The cable is connected to the fixed or "dead" end **32** and after traversing the traveling block **31** and crown block **30** is secured to the hoist drum **29**. A weight-responsive, or tension-responsive device **33** is disposed directly between the traveling block **31** and the hook **108** for the drill stem.

In this invention, several modifications of the weight or tension responsive devices are shown.

The modification 33 shown with the entire system in Figs. 1 and 1a, embodies a case 151, a hook 108 having a shank 121 and a lug 122 and a plurality of disk springs 109. Only two disk springs are shown, for the sake of simplicity, but in actual practice more than two may be used, so that a considerable deformation or elongation between the traveling block 31 and the lug 122 may be had. Since the entire drill stem will be supported by the disk springs 109, these springs are designed to be very rugged and, in consequence, even great variations in the weight of the drill stem supported on the bottom of the well will not produce very appreciable deflections.

To take advantage of the small elongations or deformations of the springs, mechanical multiplying levers 110 are provided and these levers actuate the iron core 111 of a reactor coil 97 thereby changing mechanical movements into electrical phenomena. A more detailed description of the weight-measuring means may be had from a study of application, Serial No. 651,668, filed January 14, 1933, relating to Drill stem weight measuring devices, and assigned to the Westinghouse Electric & Manufacturing Company.

The reactor coil 97 is associated with an adjustable reactor coil 89 having an iron core 152 that may be manually fixed in different adjusted positions by the screw mechanism 153. A balancing or control mechanism 65 and a weight indicator WI are also associated with the reactor coils 97 and 89 and aid in the control of the hoisting motor 26 in a manner discussed more in detail hereinafter.

Assuming that the desired number of drill stem lengths are connected and the drill has been lowered to the bottom of the well, but does not touch the bottom, then the entire weight of the drill stem is supported through tension responsive device 33. The total weight of the drill stem deflects the disk springs 109 above the hook a certain maximum amount, thereby causing the iron core 111 of the reactor coil 97 to assume a certain position corresponding to the total weight of the drill stem. The iron core 152 of the reactor coil 89, located as a rule at the control station on the derrick, is adjusted by hand to balance its reactance against that of coil 97, thereby balancing out the total weight of the drill stem so that the weight indicator WI has a zero reading. The weight indicator WI is usually a watt meter and has a stationary coil 102, and a movable coil 91, the movable coil having a hand or other indicator 92 connected thereto. The scale 93 is calibrated in pounds of the drill stem resting on or supported by the bottom of the well or on the strata being drilled.

The drill stem is then lowered until a certain amount of weight is resting on the bottom. The desired value of the weight on the strata depends upon the type of bit used, the formation to be drilled and the speed of the drill table 4. This weight on the strata is read directly by the watt meter, because the reactor coil 97 in the device 33 is upset from its balanced condition an amount proportional to the weight resting on the bottom of the well.

With the desired weight or pressure on the strata being drilled, it is necessary to start the drilling and maintain the pressure within certain limits. The weight on the strata is automatically maintained within the desired limits by means of the balancing or control mechanism 65. The control mechanism is provided with spring adjustments 154 and 155. The tensions of the springs are so adjusted that contact member 115 is not in contact with either contact member 114 or contact member 116 when the weight indicator WI indicates the desired weight on the bottom of the well. Any change in the weight on the bottom of the well will change the reactance of the reactor coil 97 which, if such change is beyond certain limits, will upset the state of balance for the control mechanism 65 sufficiently to cause it to close a circuit at either contact member 116 for hoisting the drill stem or at contact member 114 for lowering the drill stem. The stem will thus be hoisted or lowered, as the case may be, to reestablish a balanced condition and, in consequence, a proper load of the drill stem on the strata will be maintained.

A more complete understanding of this invention may be had from a study of the sequence of operation of the elements thereof. Assume that conductors 8, 9 and 10 are fully energized, that controller C is in the position shown, that the number of pipe lengths desired have been connected to the drill stem, and that switch 12 is in open circuit position. To lower the drill stem 1 into the well 2, switch 12 is closed toward the right, thereby establishing a circuit from conductor 8 through conductor 11, switch 12, conductor 13, actuating coil 14 of the directional contactor 15 and conductors 16 and 17 to the energized conductor 9. It will be noted that switch 12 may be utilized to shunt the contact members 119 and 120, so that both the lowering operation and the hoisting operation may be effected independently of the balancing mechanism 65.

With the operation of the directional contactor 15, the hoisting motor 26 is energized through conductors 18, 19 and 20, and contact members 21, 22 and 23, whereby the primary winding 24 is connected directly to the energized conductors 8, 9 and 10. The hoist motor is of the wound rotor type and is provided with a plurality of resistor sections 46, 47, 48, 49, etc. During the lowering operation, most of the resistor sections in the secondary winding of the motor 26 are not shunted, but merely act to give the motor a proper speed torque characteristic.

To release the hoisting drum 29 for the lowering operation, the brake coil 27 is connected directly across the leads of the primary winding 24 and is thus energized whenever either one of the directional contactors 15 or 36 have operated. With the motor energized, the hoist drum, by virtue of the operation of the brake 27 is released, the operation being effected through the shaft 28. The drill stem 1 is thus lowered as the cable is paid out by the drum 29 and traverses the crown block 30 and the traveling block 31.

Before explaining the normal drilling operation, it will be pointed out how the system functions when it is desired to hoist the drill stem 1. In this case, the switch 12 is moved toward the left, thereby establishing a circuit from the energized conductor 11 through switch 12, conductor 34, actuating coil 35 of the directional contactor 36, and conductors 16 and 17 to the energized conductor 9. With the operation of the directional contactor 36, contact members 37, 38, 39, 44 and 45 are closed. The brake coil 27 is energized as heretofore explained and, since contact members 44 and 45 are closed, a number of resistor sections, such as 46, are immediately shunted when the motor 26 is connected to hoist the drill stem. It is thus obvious that the speed

torque characteristic of the motor will be modified to suit hoisting conditions. Furthermore, if the weight of the drill stem is excessive, means are provided to increase the torque and thus to accelerate the motor to provide for a rapid hoisting operation. This is accomplished by the following arrangement.

With the energization of conductors 17 and 34, a circuit is established from conductor 34 through conductor 40, actuating coil 41 of the accelerating contactor 42 and conductor 43 to conductor 17. The accelerating contactors 42 and 53 as herein shown are of the time limit type, however, very frequently these accelerating contactors are of the current limit type. The specific type of accelerating contactor in itself does not constitute a part of this invention, but any type of accelerating contactor in combination with the remaining system is satisfactory. The accelerating contactors, as stated, have the time control means 56 and 57, and after a predetermined interval of time, contact members 50, 50' and 51 close, thereby shunting resistor sections 46, 47 and 48 and establishing an energizing circuit for the accelerating contactor 53 which effects the shunting of the resistor section 49 after the lapse of a definite interval of time by the closing of the contact members 54 and 55.

If the controller C be now shifted to the first drilling position, position I, in which position segments 71, 72 and 73 bridge the necessary contact fingers, conductors 58, 67 and 68 are energized, thereby energizing the primary winding 69 of the drilling motor 7. One leg of the primary winding is, however, not directly energized, but is energized through resistor 59, conductors 60 and 61, and actuating coil 62 of the excess current relay 62'. The portion of the resistor section 59 included in this circuit just traced is shunted by a coil 64 associated with the balancing mechanism 65. The circuit for this coil may be traced from conductor 58 through conductor 63, coil 64 and conductor 66 to the conductor 60. It is, therefore, obvious that the balancing mechanism 65 will be influenced by a force proportional to the current of the drilling motor.

The drilling motor 7 is provided with a plurality of accelerating resistors 76, 77, etc. for varying the speed of the drilling table 4. A second coil 79 associated with the balancing mechanism is connected across two of the leads of the secondary winding of the drilling motor 7. This circuit may be traced through conductor 78, coil 79 and conductor 80. It is, therefore, obvious that the balancing mechanism is also influenced by a force proportional to the voltage and frequency of the secondary winding of the drilling motor, or, in short, the balancing mechanism 65, aside from the other forces acting upon this device and discussed more in detail hereinafter, is influenced by a factor proportional to the power delivered by the drilling motor 7.

The drilling motor 7 may be accelerated in a conventional manner by shifting the controller to the remaining operating positions to successively shunt resistor sections 76, 77, etc. by the controller segments 74 and 75, etc.

After the drill stem 1 has been lowered into the well 2 and is suspended just above the strata to be drilled, the springs 109 will be deflected a maximum amount and the iron core 111, through the mechanical multiplying levers 110, will have shifted with reference to the reactor coil 97 a maximum amount. The iron core 152 of the adjusting reactor coil 89 is then shifted, as heretofore explained, until the reactances of the two reactor coils balance each other. The screw mechanism 153 is then utilized to fix the position of the iron core 152. The circuit for these coils may be traced from the energized conductor 11 through conductor 11', coil 96, reactor coil 97, conductor 99, primary winding 100 of the transformer T, movable coil 91 of the weight indicator WI, constant current regulator, CC Reg., and conductor 95 to the energized conductor 17. Another circuit is established from the energized conductor 11' through coil 88, adjustable reactor coil 89, and primary winding 90 to the movable coil 91 of the weight indicator WI. The stationary coil 102 of the weight indicator WI is energized from the secondary winding 101 of the transformer T. A variable resistor 103 is connected in the circuit of the stationary winding 102 and the secondary winding 101 to control the relative effect of the stationary winding 102.

The weight indicator WI has its scale 93 calibrated to read in pounds of the drill stem resting on the bottom of the well or the strata being drilled. As the stem is lowered, pointer 92 will indicate the portion of the weight resting on the strata, and when the indication is of the desired value, the balancing means 154 and 155 of the balancing mechanism 65 are so adjusted that contact member 115 is in the position shown.

For controlled operation of the drilling, the knife switch 12 will be in the position shown and, in consequence, the hoist drum 29 will hold the stem in a fixed vertical position for any given loading. As the drill stem 1 is rotated, more and more of the strata is being drilled away and more and more of the weight of the stem is supported through the tension-responsive device 33. The balanced condition of the reactor coils 89 and 97 is thus disturbed at the coil 97 with the result that the effect of the coil 96 is minimized and contact members 114 and 115 close a circuit. This circuit may be traced from conductor 11 through actuating coil 112 of the lowering control relay L, conductor 113, contact members 114 and 115, conductor 116, contact segment 86 on the circuit interrupter 85 and conductor 95 to the energized conductor 17. With the energization of coil 112, contact members 119 of relay L are closed and the directional contactor 15 is energized to lower the drill stem exactly as heretofore explained when manual control was assumed.

To prevent hunting, a circuit interrupter 85 is provided which is rotated by the motor 82 connected to conductors 11 and 17 and having a field winding 83 energized from a source of energy 84. As the circuit interrupter 85 rotates at a fairly rapid rate the coil 112 of relay L will be energized, but intermittently, so that the lowering operation for each unbalanced condition is effected by rapidly recurring steps and the drill stem comes to rest when the desired weight of the stem again rests on the strata being drilled. The constant-current regulator shown is for the purpose of balancing out variations in the line voltage so that the controlling operations effected by the system herein disclosed are not affected by variations in the voltage of the energy supplied.

If, for any cause, a moderately excessive amount of the weight of the drill stem has been lowered upon the strata, the balancing mechanism 65 will be unbalanced by the action of the reactor coil 97 and contact members 115 and 118 close, thereby energizing the coil 117 of the hoist control relay H. Contact members 120 are thus closed and

the hoisting directional contactor 36 is energized as heretofore explained in connection with the manually controlled hoisting operation.

From the foregoing discussion, it is obvious that the combined action of the balancing mechanism 65, the manually adjustable reactor coil 89 and the reactor coil 97 effect an automatic control of the weight of the drill stem resting on the strata being drilled, and that this control, in view of the position of the tension-responsive device 33, is very accurate, exceeding in accuracy, and flexibility any of the devices heretofore known in the prior art.

Scientific tests of the various factors influencing the load on the drill stem show that the pressure of the fluid in the system of the mud pump, particularly for some types of formation being drilled, is of importance. This factor may also very readily be taken care of merely by operating the knife switch 98 to the circuit closing position to thus energize the coil 104. The pressure of the mud pump is transmitted from the housing 107 to the piston 106 which, in coaction with a spring moves the position of the iron core 105, thereby varying the reactance of the reactor coil 104. It is, of course, obvious that when coil 104 is interconnected, as shown, the effect of coil 98 will also be impressed on the balancing mechanism. The circuit for coil 104 may be traced from conductor 11 through conductors 11' and 105', coil 104, switch 98, coil 98 and conductor 87 to conductor 17.

Since the pressure of the fluid in the pumping system is usually not a very appreciable factor, the operation of this system would more often proceed with the switch 98 in the position shown. In some instances it may even be desirable not to utilize coils 64 and 79, in which case these coils may be disconnected by switching mechanism not herein shown.

It sometimes happens that the drill stem gets stuck or, for some cause or other, a dangerously excessive weight is placed upon the strata being drilled, in which case the load on the drilling motor becomes greatly excessive. The drilling motor, however, is usually of sufficient capacity to carry any load demanded by the stem with the result that the drill stem 1 may be twisted off, necessitating a very expensive fishing operation. To prevent injury to the drill stem 1, excess current relay 62' is provided. When this relay operates, contact members 160 are closed thereby energizing coil 161 of the emergency hoist contactor EH. When this contactor EH operates contact members 162, 163 and 164 are closed. The first two contact members effect the shunting of a considerable number of the accelerating resistors such as 46 and 47, etc. thereby effecting a very rapid hoisting of the drill stem. Furthermore, the closing of the contact members 164 starts the operation of the accelerating contactors, and the hoisting motor 26 effects its hoisting operation with increasing speed so that there is no danger of breaking the drill stem. If the closing of the contact members 162 and 163 be insufficient to effect immediate hoisting, that is, when the stem is stuck quite tightly, the torque of the hoisting motor 26 by the operation of the accelerating contactors rapidly rises and the drill stem is cleared at any event.

The tension- or weight-responsive device 33 shown in Fig. 1a is but a preferred showing of the tension-responsive devices that may be utilized with this system of control. However, Figs. 2 and 3 show other modifications of tension-responsive devices which may be utilized in the position shown for the tension-responsive device 33.

In Fig. 2 a ring 130 is shown which is connected respectively to the traveling block 31 and the loop of the hook 108. Any deformations of this ring will cause a shifting of the armature 131 with reference to the magnetic core 129 of the reactor coils 127 and 128. An unbalanced condition will thus be produced and the coil 96 of the balancing mechanism 65 will thus be actuated to operate as heretofore explained. The energization for this coil is of course, effected from conductor 11 through a portion of the resistor 123, conductor 124, coil 96, conductor 125, weight indicator WI, conductor 126 and coil 128 to the energized conductor 17.

In the modification shown in Fig. 3, a plurality of links 134, 135, 136 and 137 are disposed between the hook 31' of the traveling block and a portion of the shank 121 of the hook 108. The variations in weight on the strata being drilled are transmitted to the flexible chamber or "sylphon" 140 by plungers 138 and 139. As the diaphragm 141 deflects, the weight indicator, which is pressure responsive in this instance, indicates the weight of the drill stem on the bottom of the well and also varies the reactance of reactor coil 132 by the shifting of the iron core 133. The balancing mechanism 65 is thus caused to operate in a well-known manner.

The system of control and the particular weight or tension responsive devices hereinbefore discussed are deemed merely illustrative of this invention, because it is obvious that any one skilled in the art, after having had the benefit of the teachings of this invention, can devise other means of accomplishing the novel results herein specified. It is thus apparent that this invention is only to be limited by the appended claims and the pertinent prior art.

We claim as our invention:

1. In a rotary well-drilling system, in combination, a drill table, a drill stem, a drilling motor for rotating said table and stem, a hoisting device, a hoisting motor for operating the hoisting device, a mud pump, control devices for controlling the operation of the hoisting motor, load-responsive means operable in response to the load on the drilling motor, tension indicating means for indicating the tension in the drill stem, and means responsive to the load-responsive means, the pressure in the mud pump, and the tension indicating means, respectively, to control the operation of said control devices.

2. In a rotary well-drilling system, in combination, a drill table, a drill stem disposed to be rotated by the table, supporting means for the stem, operating means for reciprocating said supporting means to hoist and lower said stem, a weight-responsive device disposed intermediate the stem and the stem-supporting means, said device comprising a housing, a plurality of disk springs acted upon by the unsupported weight of the stem, adjustable reactor means adjustable for different weights of the drill stem, mechanical multiplying means disposed intermediate the springs and the reactor means to vary the reactance of the reactor means, and means controlled by the variations of reactance to control the operation of the operating means.

3. In a rotary well-drilling system, in combination, a drill table, a drill stem disposed to be rotated by the table, supporting means for the stem, operating means for reciprocating said supporting means to hoist and lower said stem, a weight-

responsive device disposed intermediate the stem and the stem-supporting means, said device comprising a toggle mechanism, a diaphragm containing a fluid disposed to be compressed by the toggle mechanism, adjustable reactor means adjustable for different weights of the drill stem, means responsive to variations of the fluid pressure in the diaphragm to vary the reactance of the reactor means, and means controlled by the variations of reactance to control the operation of the operating means.

4. In a rotary well-drilling system, in combination, a drill table, a drill stem disposed to be rotated by the table, supporting means for the stem, operating means for reciprocating said supporting means to hoist and lower said stem, a weight-responsive device disposed intermediate the stem and the stem-supporting means, said device comprising a ring, adjustable reactor means having an adjustable magnetic circuit and a variable magnetic circuit, means for changing the position of elements of the variable magnetic circuit in response to deformations in the ring caused by variations in the weight of the stem supported by the ring to vary the reactance of the reactor means, and means controlled by the variations of reactance to control the operation of the operating means.

5. In a well drilling system, in combination, a drill table, a vertically disposed drill stem, a support for the stem, a tension-responsive device disposed directly intermediate the support and the drill stem, a reactor associated with the tension device, means for varying the reactance of the reactor in response to changes in tension in the tension device, a control reactor and circuit connections cooperating therewith, said control reactor being adapted to balance the effective reactance of said first-named reactor when a predetermined proportion of the weight of the stem rests on the strata being drilled, a motor for reciprocating said support to hoist and feed said stem, as desired, electro-mechanical control mechanisms adapted to control the operation of said motor, and means responsive to a predetermined unbalance of said reactors to cause predetermined operations of said control mechanisms to thus effect predetermined operations of said motor.

6. In a well drilling system comprising a drill table, a vertically disposed drill stem, a support for the stem, in combination with a device for indicating the weight of the drill stem supported on the bottom of a well by the strata being drilled, said device comprising, a case, a plurality of disc springs disposed in the case, a hook, a shank on the hook having disk-engaging means associated with the shank, whereby all of the disks in the case are acted upon by the tension in the shank, mechanical multiplying means for multiplying the total deflection of the springs, a reactor, an iron core for varying the reactance of the reactor, means for actuating said core by said multiplying means, a variable reactor for balancing the reactance of the first-named reactor for a given tension in the shank, and means for indicating the unbalance of the reactors to thus indicate the unsupported weight of the drill stem.

7. In a rotary well-drilling system, in combination, a drill table, a drill stem passing through the table to be rotated thereby, a motor for rotating the table, a hoisting hook, a hoist motor and means associated therewith for vertically reciprocating the hook to hoist and lower the stem, and electric control means for controlling the operation of the hoist motor, said means including an electro-mechanical scale mechanism connected directly between the hook and stem, electric reactor means, and adjustable reactor balancing means adapted to balance said electric reactor means for different weights of drill stem all coacting to make said scale mechanism responsive to variations of weight of the stem supported on the bottom of the well.

8. In a rotary well-drilling system, in combination, a drill table, a drill stem passing through the table to be rotated thereby, a motor for rotating the table, a hoisting hook, a hoist motor and means associated therewith for vertically reciprocating the hook to hoist and lower the stem, a motor operated mud pump and electric control means for controlling the operation of the hoist motor, said means including an electro-mechanical scale mechanism connected directly between the hook and stem, a pressure device responsive to the fluid pressure produced by the pump and means responsive to excessive loads on the motor operating the drill table.

9. In a rotary well-drilling system, in combination, a drill table, a drill stem passing through the table to be rotated thereby, a motor for rotating the table, a hoisting hook, a hoist motor and means associated therewith for vertically reciprocating the hook to hoist and lower the stem, a motor-operated mud pump and electric control means for controlling the operation of the hoist motor, said means including an electro-mechanical scale mechanism connected directly between the hook and stem and a pressure device responsive to the fluid pressure produced by the pump.

10. In a rotary well-drilling system, in combination, a drill table, a drill stem passing through the table to be rotated thereby, a motor for rotating the table, a hoisting hook, a hoist motor and means associated therewith for vertically reciprocating the hook to hoist and lower the stem, a motor-operated mud pump and electric control means for controlling the operation of the hoist motor, said means including an electro-mechanical scale mechanism connected directly between the hook and stem, electric reactor means, and balancing means coacting to make said scale mechanism responsive to the weight of the stem supported on the bottom of the well, and a pressure responsive device responsive to the fluid pressure produced by the pump to also influence the reactor means.

11. An automatic well drilling apparatus, in combination, a drill stem, a bit thereon, means for rotating the drill stem, means for suspending a portion of the weight of the drill stem to decrease or increase the feeding pressure upon the bit, control means sensitive to the torque in the drill stem, which means controls the operation of the suspending means to regulate the feeding pressure upon the bit and thus upon the strata being drilled in accordance with predetermined torque limits of safety and efficient drilling, weight responsive means operable simultaneously with said control means, adapted to also control the pressure of the bit on the strata being drilled, and torque responsive means, responsive to a torque above a predetermined value in the drill stem to control said stem suspending means independently of said control means and said weight responsive means to retrieve the stem comparatively rapidly.

12. An automatic well drilling apparatus, in combination, a drill stem, a bit thereon, means for rotating the drill stem, means for suspending

a portion of the weight of the stem to decrease or increase the bit feeding pressur against the formation being drilled, control means for controlling the pressure of the bit simultaneously in response to the variations in weight of the supported portion of the stem, and the torque in the stem, and means responsive to a torque above a given value to retrieve said stem independently of the action of said control means.

13. An automatic well drilling apparatus, in combination, a drill stem, a bit thereon, means for rotating the drill stem, means for suspending a portion of the weight of the drill stem to decrease or increase the bit feeding pressure on the formation being drilled, control means for controlling said drill stem weight suspending means to maintain a substantially predetermined feeding pressure upon the said bit, and safety means for causing substantially instantaneous lifting of the said drill stem in the event of an excessive torque demand regardless of the control effect of said control means, said control means comprising simultaneously operable drill stem weight sensitive means, and drill-stem-torque sensitive means.

14. In a system of control for well drilling apparatus embodying a drill stem and bit, in combination, means for suspending a portion of the weight of the drill stem, a power drive for said weight suspending means; power drive control means comprising an electric control circuit which when closed causes the power drive to increase the suspended drill stem weight, and contactor means subject simultaneously to actuation in accordance with instant factors of torque upon the stem rotating means and suspended drill stem weight, which contactor means normally control the continuity of said electric control circuit simultaneously in accordance with both of said factors to normally maintain the feeding pressure upon the bit and the torque on the stem within certain selected limits, and means responsive to a torque on the drill stem in excess of said selected limits for controlling the means for suspending the drill stem independent of the controlling effect of said power drive control means.

15. In a system of control for earth drilling equipment utilizing a drill stem and bit, means for operating the drill stem, means for suspending a portion of the weight of the drill stem, and a power drive for said weight suspending means; control means comprising an electric control circuit which when closed causes the power drive to increase the suspended drill stem weight and contactor means subject simultaneously and jointly to the instant factors of torque upon the stem rotating means and suspended drill stem weight whereby a normal drilling pressure on the formation being drilled is maintained, and means responsive to a predetermined abnormal torque for retrieving the drill through the control of said suspending means independent of the controlling action of said control means.

16. In a system of control for controlling the operation of earth drilling equipment utilizing a drill stem, a bit, means for rotating the drill stem, means for suspending a portion of the weight of the drill stem, and a reversible electric motor drive for said suspending means; control means for said reversible drive comprising an electric circuit for said motor drive, and contactor means governing said circuit to effect an increase in suspended drill stem weight upon a predetermined effective joint variation of the torque on the drill stem and the suspended weight of the stem and to effect a decrease in suspended drill stem weight upon a different predetermined effective joint variation of the torque on the drill stem and the suspended weight of the stem, and torque responsive means independent of said control means for selectively controlling the operation of said motor drive when the torque on said drill stem is in excess of a predetermined value.

17. In a system of control for controlling the operation of earth drilling equipment utilizing a drill stem, a bit mounted thereon, means for operating the drill stem, means for suspending a portion of the weight of the drill stem, and a reversible electric motor drive for said suspending means; control means for said motor drive comprising a pair of electric circuits, one of which when closed causes said motor drive to increase the suspended drill stem weight, the other of which when closed causes the motor drive to decrease the suspended drill stem weight, contactor means rendered operative by a predetermined effective joint variation in a given sense of the torque on the stem and feeding pressure of the stem on the strata being drilled for closing the first of said mentioned control circuits, and contactor means rendered operative by a predetermined effective joint variation in a different sense of the torque on the stem, and feeding pressure of the stem on the strata being drilled for closing the second of said mentioned control circuits, and torque responsive means responsive to a predetermined abnormal torque on the stem for controlling said motor drive independent of said control means.

18. An automatic well drilling apparatus, in combination, a drill stem, a bit thereon, means for rotating the drill stem, means for suspending a portion of the weight of the drill stem to decrease or increase the feeding pressure upon the bit, a mud pump, control means sensitive to the torque in the drill stem, which means controls the operation of the suspending means to regulate the feeding pressure upon the bit and thus upon the strata being drilled in accordance with predetermined torque limits of safety and efficient drilling, pressure responsive means responsive to the pressure in the pump and weight responsive means both operable simultaneously with said control means, adapted to also control the pressure of the bit on the strata being drilled, and torque responsive means, responsive to a torque above a predetermined value in the drill stem to control said stem suspending means independently said control means and said weight responsive means to retrieve the stem comparatively rapidly.

19. An automatic well drilling apparatus, in combination, a drill stem, a bit thereon, means for rotating the drill stem, a mud pump, means for suspending a portion of the weight of the stem to decrease or increase the bit feeding pressure against the formation being drilled, control means for controlling the pressure of the bit simultaneously in response to the variations in weight of the supported portion of the stem, the pressure in the pump, and the torque in the stem, and means responsive to a torque above a given value to retrieve said stem independently of the action of said control means.

20. An automatic well drilling apparatus, in combination, a drill stem, a bit thereon, means for rotating the drill stem, a mud pump, means for suspending a portion of the weight of the drill stem to decrease or increase the bit feeding pressure on the formation being drilled, control means

for controlling said drill stem weight suspending means to maintain a substantially predetermined feeding pressure upon the said bit, and safety means for causing substantially instantaneous lifting of the said drill stem in the event of an excessive torque demand regardless of the control effect of said control means, said control means comprising simultaneously operable drill stem weight sensitive means, drill-stem-torque sensitive means, and pressure responsive means responsive to the pressure in the pump.

21. In a system of control for well drilling apparatus embodying a drill stem, bit, and mud pump, in combination, means for suspending a portion of the weight of the drill stem, a power drive for said weight suspending means; power drive control means comprising an electric control circuit which when closed causes the power drive to increase the suspended drill stem weight, and contactor means subject simultaneously to actuation in accordance with instant factors of torque upon the stem rotating means, suspended drill stem weight, and pressure of said pump, which contactor means normally control the continuity of said electric control circuit simultaneously in accordance with both of said factors to normally maintain the feeding pressure upon the bit and the torque on the stem within certain selected limits, and means responsive to a torque on the drill stem in excess of said selected limits for controlling the means for suspending the drill stem independent of the controlling effect of said power drive control means.

22. In a system of control for controlling the operation of earth drilling equipment utilizing a drill stem, a bit mounted thereon, a mud pump, means for operating the drill stem and pump, means for suspending a portion of the weight of the drill stem, and a reversible electric motor drive for said suspending means; control means for said motor drive comprising a pair of electric circuits, one of which when closed causes said motor drive to increase the suspended drill stem weight, the other of which when closed causes the motor drive to decrease the suspended drill stem weight, contactor means rendered operative by a predetermined effective joint variation in a given sense of the torque on the stem, the pressure in the pump and feeding pressure of the stem on the strata being drilled for closing the first of said mentioned control circuits, and contactor means rendered operative by a predetermined effective joint variation in a different sense of the torque on the stem, the pressure in the pump, and feeding pressure of the stem on the strata being drilled for closing the second of said mentioned control circuits, and torque responsive means responsive to a predetermined abnormal torque on the stem for controlling said motor drive independent of said control means.

23. An automatic control apparatus for use with drilling equipment employing a drill stem, a bit, a mud pump, means for rotating the drill stem, and means for suspending a portion of the drill stem weight to regulate the bit feeding pressure, which comprises means sensitive to the weight suspended, pump pressure responsive means and means sensitive to the torque demand upon said stem rotating means, a reversible motor operating the weight suspending means, a switch for the motor, and relay means responsive to and energized by said weight, said pump pressure and said torque sensitive means for actuating said switch in accordance with variations in torque demand, pump pressure and suspended weight.

24. In a system of control for earth drilling equipment utilizing a drill stem and bit, a mud pump, means for operating the drill stem and pump, means for suspending a portion of the weight of the drill stem, and a power drive for said weight suspending means; control means comprising an electric control circuit which when closed causes the power drive to increase the suspended drill stem weight and contactor means subject simultaneously and jointly to the instant factors of torque upon the stem rotating means, pressure in the pump and suspended drill stem weight whereby a normal drilling pressure on the formation being drilled is maintained, and means responsive to a predetermined abnormal torque for retrieving the drill through the control of said suspending means independent of the controlling action of said control means.

25. In a system of control for controlling the operation of earth drilling equipment utilizing a drill stem, a bit, a mud pump, means for rotating the drill stem, means for suspending a portion of the weight of the drill stem, and a reversible electric motor drive for said suspending means; control means for said reversible drive comprising an electric circuit for said motor drive, and contactor means governing said circuit to effect an increase in suspended drill stem weight upon a predetermined effective joint variation of the torque on the drill stem, the pressure in the pump, and the suspended weight of the stem and to effect a decrease in suspended drill stem weight upon a different predetermined effective joint variation of the torque on the drill stem, the pressure in the pump, and the suspended weight of the stem, and torque responsive means independent of said control means for selectively controlling the operation of said motor drive when the torque on said drill stem is in excess of a predetermined value.

26. In a rotary well drilling system, in combination, a drill table, a drill stem, tension means responsive to the tension in the drill stem, a drilling motor for rotating said table and stem, a hoisting device, a hoisting motor for operating said hoisting device, motor control means for controlling the operation of the hoisting motor, control means responsive to the joint and simultaneous effect of the torque on the stem and the tension in the stem to control the operating character of said control means, the tension means of said control means including an elliptical ring, a reactor the reactance of which may be varied with variations of the shape of the ring resulting from a change of the tension in the stem, an adjustable balancing reactor adapted to balance the effect of said first reactor for different tensions in the drill stem, a source of electrical energy interconnected with said reactors and circuit connections for interconnecting the reactors and said control means.

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