Feb. 26, 1929. 1,703,234

E. P. HALLIBURTON

METHOD AND APPARATUS FOR DRILLING WELLS, SUCH AS OIL WELLS

Filed Nov. 4, 1920 2 Sheets-Sheet 1

Fig. 1

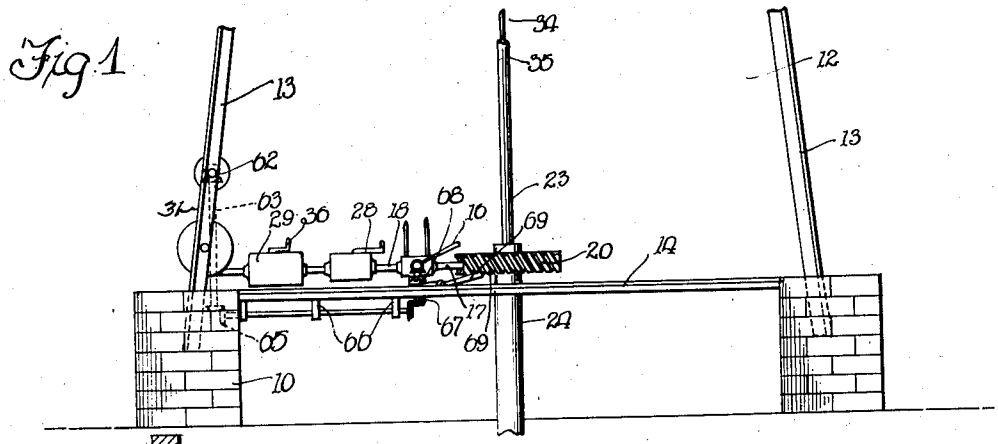


Fig. 2

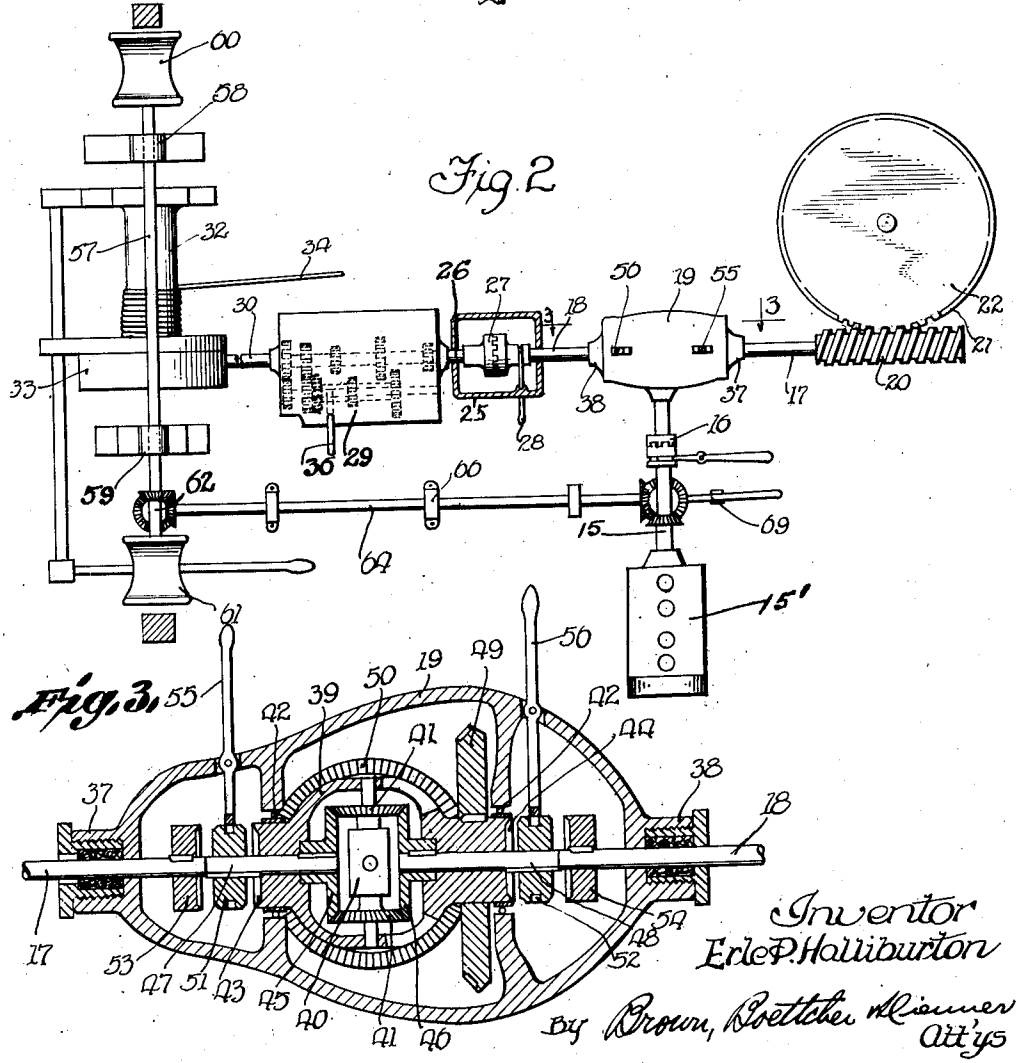


Fig. 3.

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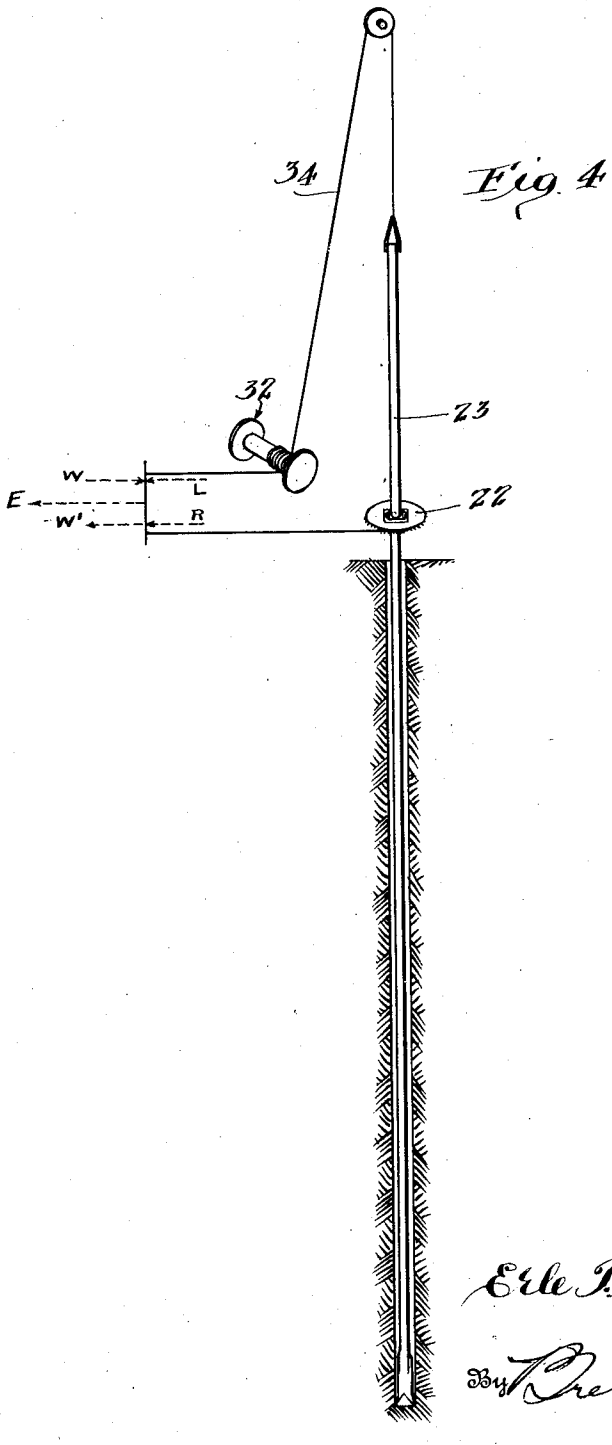


Fig. 4

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UNITED STATES PATENT OFFICE.

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METHOD AND APPARATUS FOR DRILLING WELLS, SUCH AS OIL WELLS.

Application filed November 4, 1920. Serial No. 421,663.

This invention relates to oil well and other well drilling apparatus and methods, and the primary aim of the invention is to provide improved power transmission mechanism for the drill whereby to obviate the difficulties and reduce the expenses incidental to drilling oil wells with the methods and apparatus thus far employed.

Heretofore, great difficulty has been encountered in drilling in hard formations, or in which heavy stone or other hard objects are met, it being quite impracticable to feed the drill bit manually with an even load. The lack of suitable means for coping with obstructions encountered often results in jamming the drill to such an extent that the bit or drill pipe or stem carrying the drill bit is twisted off and dropped into the bore. In other words, there is no outlet for the power applied to the drill stem, consequently the drill is subjected to a greater torsional strain than it is designed for, resulting in fracture. This necessitates the expenditure of needless time and labor in fishing for the part twisted off, and very often means abandonment of the bore.

Therefore, this invention embodies in a simple and inexpensive, yet thoroughly efficient structure, mechanism for controlling the feed pressure on the drill bit, automatically compensating for changes in the resistance to rotation due to the progress of the bit or due to obstructions in the bore of the well, or due to the changes in the character of the formation encountered. The device further compensates for unevenness in the load on the drill bit and draw works, the latter being employed as a "bleeder" for the power, that is, an outlet for the power which would otherwise be applied directly to the work of rotating the drill stem with the undesirable result referred to hereinbefore. Furthermore, distribution of power is obtained by an improved method of and apparatus for transmission whereby the unreliable parts, such as chains, pulleys, sprockets, and other adjuncts to well drilling machinery heretofore employed may be, if desired, to a large extent eliminated although it is not intended to limit the invention to apparatus in which such parts are eliminated. This transmission also permits of adjustment relatively of the parts driven, and thus places within the hands of the operator a protective measure not heretofore available.

Furthermore, the present invention embodies features in the nature of accessories which all cooperate to speed up and facilitate the process of drilling a well. For instance, the arrangement of gearing is such that when desired the drill may be quickly and easily extracted from the well, during or after the process without stopping the source of power or prime mover. A very important or commercial feature of the mechanism is its flexibility, permitting the use of an internal combustion engine as a prime mover; which has not heretofore been found practicable with machinery now employed in the fields.

Briefly, the transmission mechanism preferably consists of a pair of shafts connected to a power shaft through the medium of a differential gearing, one of the first said shafts being connected to the rotary table and the other connected to the draw works through a clutch and suitable transmission mechanism.

All the elements, such as shafting, gearing, etc., are controlled by suitable clutches, permitting of independent or collective, synchronous or relative movement of the parts.

I desire to emphasize the fact that the invention resides in the system of driving the various parts of the drilling machinery and not necessarily to any of the detail construction which will be described, I reserving the right to vary the details without materially departing from the spirit of the invention or the scope of the same as covered by the claims.

Other objects and advantages of this invention will appear upon reference to the following detailed description of a preferred example of a well drilling apparatus embodying the invention and by which a preferred method of drilling wells may be carried out.

In the drawings:

Figure 1 is a side elevation, partly broken away, showing a well drilling machine with the improvements of the present invention embodied therein;

Figure 2 is a top plan of the power transmission mechanism and associated parts;

Figure 3 is a detail section of the differential; and

Figure 4 is a force diagram illustrating the preferred mode of operation of the invention.

Referring now in detail to my invention and to the accompanying drawings, wherein similar characters of reference designate similar parts throughout the various views, the apparatus may include as elements various standard parts of a well drilling appara-

tus, the details of construction of which are well understood in the art and hence but diagrammatically herein illustrated. A form of foundation is provided consisting of the brick or concrete pillars 10 and 11 on which the frame 12 usually of wood stringers 13—13 is supported. A floor 14 supports the boring machinery and this floor is mounted on the foundation pillars 10 and 11.

In accordance with the teachings of my invention, the boring machinery derives power from a power shaft 15, suitably connected to a steam or internal combustion engine or other prime mover 15', this shaft having a clutch 16 therein for disconnecting the source of power from the drilling mechanism and draw works. The shaft 15 drives jack-shafts 17 and 18 through the medium of a conventional form of differential gears contained in the housing 19. The details of this gear are well known to those skilled in the art, the construction being but slightly modified to accommodate two clutches as will be described presently. The shaft 17 carries a worm 20 on the free end thereof, this worm engaging with a worm gear 21 which is mounted on the rotary table 22. The rotary table drives the drill bit which is carried by the usual drill pipe or stem 23 and may be of the conventional type and has, therefore, been shown but generally. In the usual practice, a drill casing 24 extends into the ground as shown in Figure 1 and serves to prevent the walls of the well caving in on the bit and drill stem 23.

The jack shaft 18 is broken in a housing 25, and is connected normally with a countershaft 26 by means of a clutch 27 arranged within the housing 25, said clutch being operable from without the housing by means of a lever 28. The shaft 26 extends into a housing 29 containing a transmission gearing, in other words, a gear change mechanism for changing the relation of speed between the shaft 26 and the shaft 30, this shaft 30 extending to "draw works" 31 consisting of the drum 32, and serving to drive said drum through a suitable worm gearing contained in the housing 33 as pointed out in the description of the mode of operation of the apparatus, the draw works 31 at times must drive the shaft 18 as well as be driven at other times by such shaft. Hence this worm gearing must obviously be of suitable reversible type. As pointed out, the "draw works" may be of any customary construction and is supplied as usual with brake drums 70 at both ends controlled by a common lever 71. A cable 34 is wound upon the drum and extends upwardly on the framework 12, over a sheave and is connected to the upper end of the drill stem 23 at 35. It is, of course, to be understood that while a single purchase fall in the nature of the cable 34 is shown, the necessary block and tackle (usually six-part) may be interposed between the end of the drill stem and the cable so as to obtain the necessary power when withdrawing the drill bit from the well. The gear change mechanism is operable by means of a lever 36 so that the desired power ratio between the draw works 31 and the rotary table 22 may be adjusted at will.

The detail construction of the differential is best shown in Figure 3. The section view in Figure 3 has been taken from the rear in order that the driving pinion carried on the shaft 15 will not hide the construction. The shafts 17 and 18 are mounted in suitable bearings 37 and 38, respectively, said bearings being carried by the casing 19.

A housing 39 carries the spider 40 on which the bevel pinions 41 are mounted, said housing being mounted in suitable anti-friction bearings 42 formed on the casing 19. The opposite ends of the housing 39 are reduced and provided with clutch faces 43 and 44 for a purpose which will be described presently. A pair of bevel gears 45 and 46 are carried by the stub-shafts 47 and 48, respectively, and receive power from the pinions 41, the housing being rotated and said spider by the ring gear 49 which in turn receives motion from the driving gear 50 carried on the inner end of the shaft 15. The stub-shafts 47 and 48 abut the shafts 17 and 18, respectively, and a pair of clutches 51 and 52 serve to connect the respective stub-shafts and abutting shafts, or to lock the stub-shafts to the housing. This is accomplished either by engaging the clutches 51 and 52 with their respective housing clutch faces or with the clutch face members 53 and 54 carried on the inner ends of the shafts 17 and 18. Suitable levers 55 and 56 project from the casing 19 for manual actuation of said clutches 51 and 52, respectively. The clutches shown are of the friction type, but if necessary, may be made toothed.

In the course of drilling a well and in handling heavy objects it is desirable that an independent hoisting means be associated with the drilling mechanism and draw works, and for this reason I have provided the shaft 57 mounted in suitable bearings 58 and 59 in the vertical stringers which support the draw works on the frame 12. The shaft 57 is provided with drums 60 and 61 on its free ends and said shaft is driven through a bevel gearing 62 from a vertical jack shaft 63, which latter in turn is driven from the counter shaft 64 through a suitable bevel gearing 65. The shaft 64 is mounted in suitable bearings 66 beneath the floor 14 so as to be out of the way of the operator, the shaft 64 being driven from the shaft 15 through a suitable bevel gearing and vertical jack shaft 67, the latter having a suitable clutch 68 therein operated by a lever 69 whereby to connect and disconnect said shaft 57 from the power shaft 15. Of course, under normal conditions the

shaft 57 is stationary, but in the event that it is desired to lift heavy objects on the floor the drums 60 or 61 may be conveniently employed for this purpose.

In the operation, power is applied to the shaft 15, this power being transmitted through the differential gearing to the shafts 17 and 18. Normally when drilling the shaft 18 is held stationary by virtue of the fact that all the power is applied to the work of rotating the drill stem, the weight of the drill stem tending to cause the drill bit to descend into the ground pursuant to its boring operation, this descent being regulated automatically by the draw works 31 as the hole is deepened. However, should the drill bit strike an obstruction, instead of continuing to descend causing excess torsional strain to be imposed on the drill stem, the moment that the resistance to the drill bit becomes greater than a predetermined amount regulated by the transmission gearing, the shaft 18 begins to reversely rotate. This usually takes place the moment the drill tends to jam and because excessive torque is placed on the drill stem, the power, by virtue of the differential gearing, now being delivered to the shaft 26, through the clutch 27, transmission gearing and to the draw works 31, thus elevating the upper end of the drill stem and, if the excess resistance to rotation continues, elevating the drill bit, thus preventing fracture of the drill stem due to an application of excess power to the drill stem when the same is unable to rotate. It will be obvious that as the sections are connected thereto in the course of drilling into the well, this weight will be compensated for by the draw works, the change speed transmission having been set to a position predetermined for this purpose. In other words, any tendency for the drill bit to feed too fast will be compensated for by the differential gearing and transmission so that if the drill bit tends to become jammed or to feed too fast there is a resulting effect on the draw works to cause the same to regulate the drilling operation throughout. It will also be apparent that should the force applicable on the rotary table from the prime mover, such as an internal combustion engine, be insufficient to overcome the resistance to drilling, the change gearing or transmission may be shifted to compensate for this necessary alteration in relation of the drilling apparatus to the draw works. I am not prepared to state just what relative proportion the gearing of the various parts of my invention should be, but believe that this is a matter which can be easily determined when the device is developed for actual reduction to practice. Another feature of the operation which I desire to point out is that performed by the two clutches 51 and 52. In the event that it is desired to raise the drill stem and bit without rotating the same and at the same time to apply all of the power to this process, which becomes necessary in many cases, the lever 55 is moved so that the clutch member 51 disengages from the clutch face member 53 on the shaft 17, the lever being moved until the clutch member 51 engages the clutch face 43 of the housing 39. In this manner the stub-shaft 47 will be locked to the housing and caused to rotate therewith. If this were not done, the stub-shaft 47 having no resistance whatsoever would rotate alone and the shaft 18 would, of course, cease to rotate. Under these conditions, the transmission gearing may be shifted as found necessary in order to deliver the desired power ratio to the drum 32 whereby to hoist the drilling bit out of the well. This is particularly valuable wherein the drill will often become jammed by earth falling down in the well.

When it is desired to apply all of the power to the shaft 17 the lever 56 is moved so that the clutch member 52 locks the housing 39 to the stub-shaft 48 and disconnects the shaft 18. By placing the levers 55 and 56 in the neutral position power may be cut off from both of the shafts 17 and 18, but it is rare that such will be necessary as that can be taken care of by the clutch 16.

In order to more clearly demonstrate how the before described results are obtained by the apparatus herein described and how the method of drilling wells can be carried out in the described apparatus, a description will now be given of the different forces set in action during operation. In this connection, it should be pointed out that as the drill stem 23 is described and shown as vertically disposed, and having part of its weight suspended, by the draw works 31, and part of its weight resting upon its attached drill bit, that the portion of the weight which is not supported from the draw works will be the effective feeding pressure applied to the bit. The drill stem is enabled to accomplish this variable division of its weight because it is capable of longitudinal compression, due to the fact that it is made up of many different joints, is of great length and hence possesses considerable elasticity, and also because it tends to assume a sinuous form in the well hole, all of which is well understood and appreciated in this art. It will thus be seen that when the prime mover 15′ is placed in operation so as to apply power to the main shaft 15, the power is transmitted through differential gearing to the jack shafts 17, 18, respectively, neither of which is in consequence rigidly connected to the main shaft 15. In place thereof, the differential gearing directs the force and power from the source or sources of original energy through two paths by which such forces pass to the common point or place of application, i. e., the drill stem; and by such differential gearing the ratio of power delivered to the rotary

table 22 and to the draw works or lift control mechanism 31 is automatically adjusted to effect automatic control operation.

In the preferred mode of operation of the invention, with reference to Fig. 4, there is a force derived from the main shaft 15 and applied upon the jack shaft 17 which is equal to the force applied upon the jack shaft 18 since the differential gearing, as described, is of equal ratio between these shafts. In Fig. 4 the force derived from the main shaft 15 is indicated by arrow E; that applied therefrom to jack shaft 17 by arrow R, and that applied therefrom to jack shaft 18 by arrow L. The force R which is applied to the jack shaft 17 is exerted as a driving force through the rotary table to perform the work of rotating the drill stem and automatically applies to the drill stem a substantially constant torque after the drilling apparatus is set in operation. The force L applied to the jack shaft 18 exerts through the medium of the draw works 31 driven thereby a lifting tendency upon the drill stem.

Any weight of the drill stem supported by the draw works exerts a force tending to unreel the draw works and is opposed by force L thereon. The magnitude of this force is in direct proportion to the suspended weight of the drill stem and also dependent upon the gear ratio between the drill stem and shaft 18. This ratio can be varied at will by the selective change speed transmission but once this gearing is set the ratio is fixed until again changed in the gearing. The force proportional to the weight of the drill stem suspended, which is applied to shaft 18, is indicated by arrow W in Fig. 4. This force W also acts through the differential upon shaft 17 to exert thereon a force W′ tending to rotate the drill stem.

Owing to its longitudinal elasticity any variation in the over-all length of the drill stem will correspondingly change the vertical position of its center of gravity and will change the ratio between that portion of the weight of the drill stem that will be supported by the draw works and that which rests upon the bit. Any change in the vertical position of the bit, therefore, which is not accompanied by an equal motion of the upper end of the drill stem where the tackle is attached, will result in a variation in the value W and vice versa.

The equality of the lengths of arrows L, W, W′ and R indicates that such forces are of equal value and illustrate that condition which exists when the apparatus is in equilibrium. The suspended weight of the drill stem W is balanced by the lifting force L exerted through the jack shaft 18 thus holding that shaft stationary and the total energy derived from the prime mover exerted through the rotation of the shaft 17 applied to the work of rotating the jack shaft, and the force E exerted by the prime mover, just balancing and overcoming the opposing load of the resistance of the drill stem to rotate. Any change in R or W will of course destroy the equilibrium. The torque force applied to the work of rotating the drill stem, is of course opposed by and in operation equals the resistance opposed to the rotation of the drill stem inasmuch as action and reaction must be equal. Hence any change in the resistance to rotation of the drill stem will change the force R applied to the work of rotating the drill stem. Inasmuch as force R cannot change without accompanying change of lifting force L due to the inherent action of the differential, any such variation in resistance to the rotation of the drill stem will unbalance the condition of equilibrium above described and by such unbalancing there will be a resultant force on shaft 18 tending to create lineal motion in the end of the drill stem to which the tackle is attached.

During the normal process of drilling, the bit operates to remove material from the bottom of the well hole with the consequent lowering of the lower end of the drill stem. This elongation of the drill stem tends to increase the suspended weight, tends to decrease the feeding pressure, tends to decrease the resistance to rotation, and tends to decrease the driving torque required to rotate the drill stem. These tendencies all tend to vary the forces applied to the jack shaft 18 and jack shaft 17. The tendency to increase the force W and decrease the force L thus unbalances the force to the draw works causing the fall and tackle to play out. This motion of the draw works decreases the suspended weight and the force W increases the resistance to rotation of the bit (by application of increased feeding pressure), and increases the driving torque which must be applied to the drill stem, thus tending to again cause R to equal W.

The summation of these foregoing tendencies is that there is ever present a tendency to automatically maintain the mechanism in a state of equilibrium, to maintain the required driving torque at the chosen optimum value and to cause continuous regulated rectilinear forward movement of the bit to compensate for the drilling action.

If the resistance to the rotation varies, for reasons induced by the variable conditions encountered in drilling, and not caused by the variations in the feeding pressure which proceed from the normal progress in drilling, the ratio will remain standing between the portion of the weight on the bit and the portion held suspended through the draw works. Hence W will remain constant but W will be unbalanced in regard to L with the result that rectilinear motion of the suspended end or top of the drill stem will take place. For example, in case such resistance decreases

also requiring a decrease in the force R, there will be a corresponding decrease in the lifting force L applied on the jack shaft 18. The lifting force L is no longer able to counterbalance the static force W applied thereto. This, therefore, allows the tackle to play out, lowering the center of gravity of the drill stem, decreasing the suspended weight and imposing additional feed pressure on the bit, this later effect in operation tending to increase the resistance of the bit to rotation with a corresponding increase of R. W tends to decrease to equal L and R tends to again return to its former value. Thus there is again re-established a condition of equilibrium with its resultant torque force R substantially equal to, but somewhat below, the predetermined optimum value.

In case the resistance to rotation increases from the above, or any uncontrollable causes, R increases, L increases and a series of tendencies is set up, the reverse of those above described with the final resultant of the re-establishment of a condition of equilibrium with the force R in excess of the predetermined optimum but substantially that optimum and well below the factor of safety of the mechanism. Such slight variation from the optimum torque being due to the inability of feed pressure changes to always exactly counteract the changes in specific resistance of the material drilled.

It is here pointed out that, at the times when the resistance to the rotary motion of the drill stem varies from the predetermined optimum, the upward rectilinear motion which is automatically imparted to the drill stem thereby, is imparted only to the upper end of the drill stem and is first utilized to remove compression or slack therefrom and hence does not necessarily withdraw the drill bit from the work-engaging position. The drill bit is withdrawn from work-engaging position only when there is a continuous application of excessive resistance to the rotation of the drill stem for such a duration of time as to permit all of the slack to be removed from the drill stem.

Even under conditions of resistance so severe as to positively prevent the rotation of the drill stem the prime mover does not apply hazardous torque load upon the drill stem as under these circumstances all the power is diverted in the differential from the work of rotating the drill stem and applied to the work of hoisting the drill stem.

It is therefore seen that whenever the forces L and W are unbalanced there follows a transfer of energy through the path including the draw works, the direction depending upon whether the center of gravity of the drill stem is lowered or raised and thereby yields or absorbs energy. Hence it is seen that the drill stem in operation not only acts as a support and a driver for the attached drill bit but as a reservoir for receiving and delivering energy in order to maintain the correct forces upon the apparatus to effect automatic continuous drilling action.

In the early stages of drilling, the total weight of the short drill stem employed may be insufficient to produce sufficient force W on the jack shaft 18 to enable the maintenance of sufficient torque on R at 17. At such times by the employment of artificial resistance to the rotation of the shaft 18 applied by the customary brakes 70 of the draw works, or by other brakes, the desired additional resistance to the rotation of jack shaft 18 may be imposed thereon to enable the differential to apply the desired torque through shaft 17 upon the rotary table. The customary brake 70 of the draw works 31 of course may be also utilized for effecting finer adjustments of the torque load than may be effected by the change speed transmission.

I desire to lay particular stress on the compactness of the device and the various parts thereof. By the arrangement shown, alignment of the parts may be conveniently arranged, it being possible to carry the transmission, clutch 27, differential, and associated parts on a single plank which may be set in the flooring of the rig. If necessary, universal joints may be employed in order to secure alignment in the shafts, but in view of the obvious mechanical expediency of such an arrangement in some cases, the same has not been shown in the drawings.

If desired, when an internal combustion engine is employed a reverse gear or series of gears may be embodied in the transmission.

I reserve the right to make changes in the detailed construction and arrangement of the parts. Of course, it may be desirable in some instances to arrange the shafts 17 and 18 in different relations, that is, owing to the construction of the supporting framework, it may be desirable to break the shafts 17 and 18 and connect the parts by universal joints, but I consider this within the purview of the ordinary mechanic. These are features which I consider variable without departing from the spirit and scope of the claims.

While the method of drilling wells and the drilling apparatus herein described is well adapted to accomplish the purposes of this invention, it is understood that various modifications may be made in the specific form of the method and apparatus without departing from the spirit of the invention, and that the invention includes all such modification and substitutions as defined within the appended claims.

I claim:

1. In combination, a source of power, a shaft having two sections, differential gearing normally driving one only of said shaft sections from said source of power, a speed

change gear mechanism on one of the shafts, a rotary table driven from the other shaft, and a drum driven by said change gear mechanism.

2. In combination, a source of power, a shaft having two sections, differential gearing normally driving one only of said shaft sections from said source of power, a speed change gear mechanism in one of said shaft sections and an actuating mechanism driven thereby, and a second actuating mechanism driven from the other shaft section and controlled by the first said actuating mechanism.

3. In combination, a source of power, a power shaft, differential gearing, a jack-shaft, a rotary table driven by said jack-shaft, a second jack-shaft, a drum driven thereby, said gearing connecting said jack-shafts with the power shaft, and means connecting said second jack-shaft to hoisting mechanism.

4. In combination, a source of power, a power shaft, differential gearing connected with said power shaft, a jack-shaft, a rotary table driven by said jack-shaft, a second jack-shaft, both of said jack-shafts being connected to said differential gearing, first said jack-shaft being normally driven by the differential gearing, a drum driven from the second jack-shaft, a clutch in said second jack-shaft, means for changing the power and speed ratio of said jack-shafts, and means connecting said power shaft to a hoisting mechanism.

5. A well drilling machine including a power shaft, a differential gearing driven therefrom, a pair of jack-shafts connected with said gearing, a rotary table connected with one of said jack-shafts, a draw-work connected with the other jack-shaft, and speed change mechanism between the draw-work and said jack-shaft.

6. In combination, a source of power, a power shaft, a pair of jack-shafts, differential gearing driving said jack-shafts from said power shaft, means for disconnecting one or both of said jack-shafts from said gearing, and for locking said gearing to deliver all the power to one of said shafts, and drilling and hoisting mechanism associated with said jack-shafts.

7. In combination, a source of power, a power shaft, a pair of jack-shafts, differential gearing driving said jack-shafts from said power shaft, means for disconnecting one or both of said jack-shafts from said gearing, and for locking said gearing to deliver all the power to one of said shafts, drilling and hoisting mechanism associated with said jack-shafts, and a change gear transmission in one of said jack-shafts.

8. The method of controlling the drilling of a well, which comprises applying a predetermined torque to a vertically disposed drill stem, suspending a portion of the weight of the drill stem, and employing the fluctuations of the resistance to such torque induced in the drilling operations to vary the percentage of the weight of the drill stem suspended, thereby tending to maintain substantially uniform torque applied to the drill stem.

9. A well drilling apparatus, comprising a drill stem, means for rotating the drill stem, means for suspending a portion of the weight of the drill stem, and means interposed between and connected to said suspending means and rotating means for regulating said suspending means and rotating means, and operative to automatically control the feed pressure and torque applied to the drill stem.

10. A well drilling apparatus, comprising a drill stem, a drill bit attached to the drill stem, means for suspending a portion of the weight of the drill stem, means for rotating the drill stem, a common source of power for said suspending means and rotating means, and means for adjusting the ratio of power applied from said source of power to said suspending means and rotating means through means regulated by fluctuations of the resistance to said rotating means induced in drilling operations, thereby effecting automatic control of the torque applied to the drill stem and feed pressure applied to the drill bit.

11. In a rotary well drilling apparatus, a vertically disposed drill stem, means for suspending part of the weight of said drill stem, means for rotating said drill stem, driving means for said rotating means, means for actuating said suspending means to govern the percentage of the weight of said drill stem supported thereby, and a differential gearing connecting said last two mentioned means and operative to cause the suspending means to vary the percentage of the weight supported thereby in accordance with the fluctuations in the resistance to the rotation of said drill stem.

12. A well drilling apparatus, comprising a drill stem, means for rotating the drill stem, means for suspending a portion of the weight of the drill stem, said means including a falls and tackle, and means interposed between and connected with said suspending means and rotating means for regulating said suspending means and rotating means and operative to automatically control the feed pressure and torque applied to the drill stem.

13. A well drilling apparatus, comprising a drill stem, a drill bit attached to the drill stem, means for suspending a portion of the weight of the drill stem, said means including a falls and tackle connected to said drill stem, means for rotating the drill stem, a common source of power for said suspending means and rotating means, and means for adjusting the rate of power applied from said source of power to said suspending means and rotating means through means regulated by fluctuations of the resistance to said rotating

means induced in drilling operations, thereby effecting automatic control of the torque applied to the drill stem and feed pressure applied to the drill bit.

14. In a rotary well drilling apparatus, a vertically disposed drill stem, means for suspending a part of the weight of said drill stem, said means including a falls and tackle connected to said drill stem, means for rotating said drill stem, means for driving said rotating means, means for actuating said suspending means to govern the percentage of the weight of said drill stem supported thereby, and a differential gear connected to said last two mentioned means and operative to cause the suspending means to vary the percentage of the weight supported thereby in accordance with the fluctuations in the resistance to the rotation of said drill stem.

15. A well drilling apparatus, comprising a drill stem, means for rotating the drill stem, means for suspending a portion of the weight of the drill stem, means interposed between and connected to said suspending means and rotating means for regulating said suspending means and rotating means, and operative to automatically control the feed pressure and torque applied to the drill stem, and means in the connection between said suspending means and rotating means to vary the feed pressure and torque to be automatically controlled by said regulating means.

16. In a rotary well drilling apparatus, a vertically disposed drill stem, means for suspending a part of the weight of said drill stem, means for rotating said drill stem, driving means for said rotating means, means for actuating said suspending means to govern the percentage of the weight of said drill stem supported thereby, a differential gearing connecting said last two mentioned means and operative to cause the suspending means to vary the percentages of the weight supported thereby in accordance with the fluctuations in the resistance to the rotation of said drill stem, and means for disconnecting the differential gearing from one of said means for locking the gearing to deliver all the power to the other means.

17. A well drilling apparatus, comprising a drill stem, means for rotating the drill stem, means for suspending a portion of the weight of the drill stem, a differential, means connecting one sun gear of the differential to the suspending means, means connecting the other sun gear of the differential to the rotating means, and means for driving the planetary gear of the differential.

18. A well drilling apparatus, comprising a drill stem, means for rotating the drill stem, means for suspending a portion of the weight of the drill stem, a single source of power, and a single differential connecting said source of power through said differential to said rotating means and suspending means for regulating the same to automatically control the feed pressure and torque applied to the drill stem.

19. In combination, a drilling mechanism, rotating means therefor, feeding means for said drilling mechanism, a differential having one sun gear connected to said feeding means and the other sun gear connected with said rotating means, and means for connecting the planetary gears to be driven by a source of power.

In witness whereof I hereunto subscribe my name this 23rd day of October, 1920.

ERLE P. HALLIBURTON.