March 23, 1943. C. C. SCHARPENBERG 2,314,560

TORQUE CONTROL IN ROTARY WELL DRILLING

Filed May 5, 1941

Fig. 2.

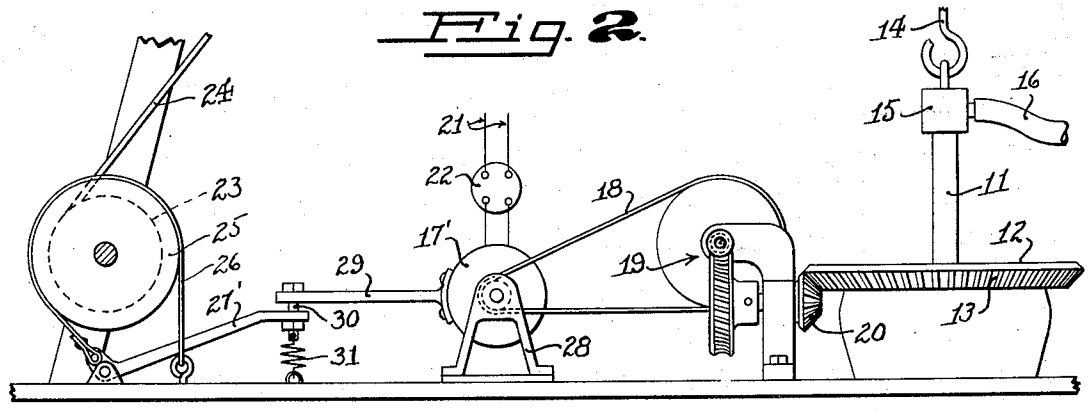


Fig. 1.

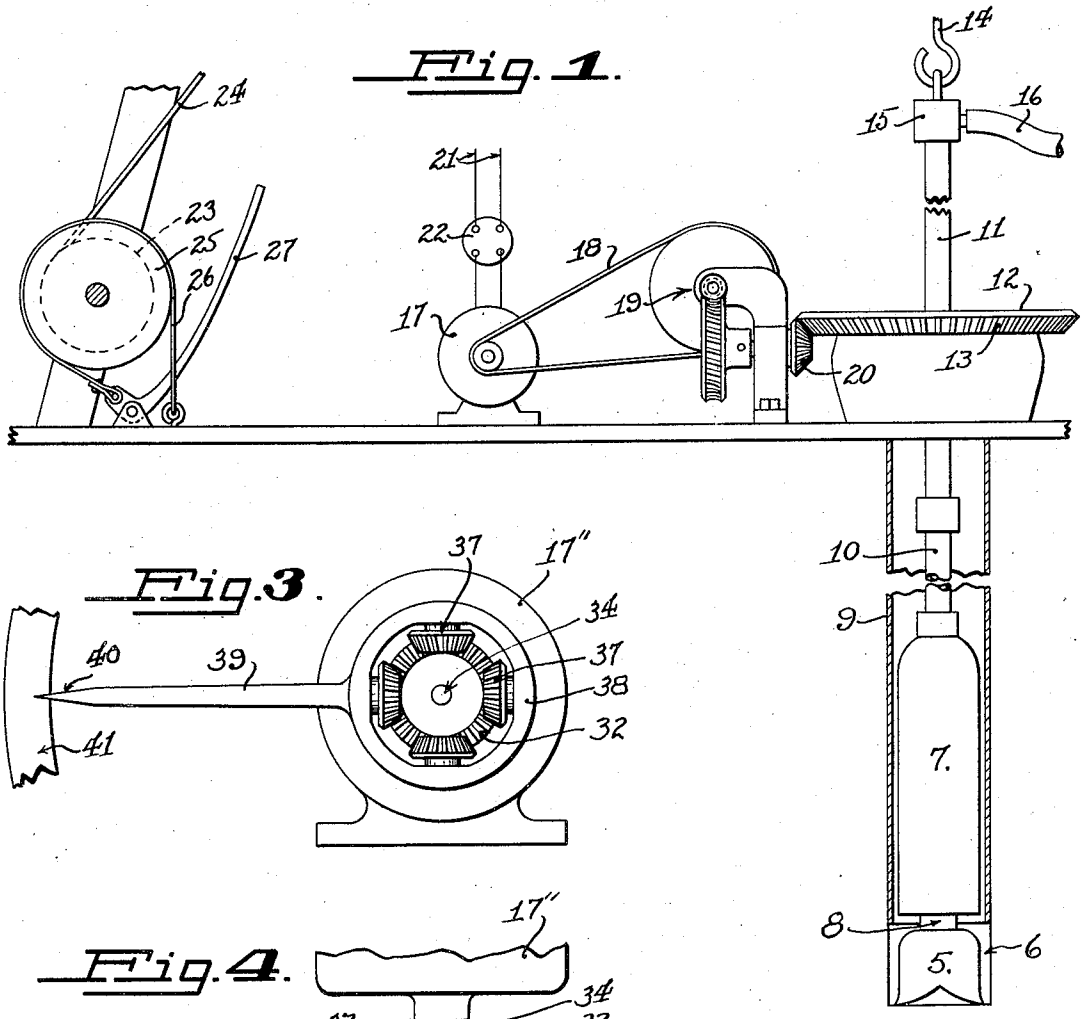
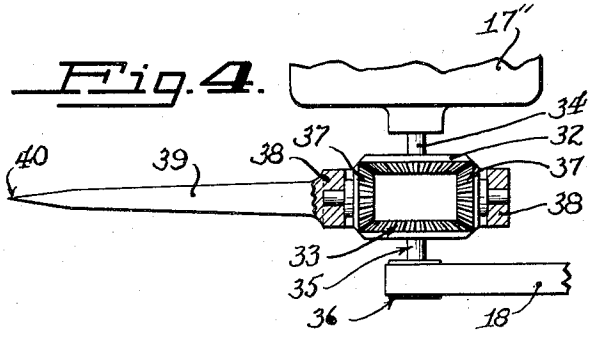


Fig. 3.

Fig. 4.



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TORQUE CONTROL IN ROTARY WELL DRILLING

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4 Claims. (Cl. 255—19)

The present invention relates to the art of drilling wells with rotary drilling rigs in which the drill bit is rotated by a motor suspended in the well.

The principal object of the invention is to enable the driller to feed the bit downwardly at the optimum rate for most rapid drilling. In operating a rotary drill bit driven by a motor suspended in the well by a non-rotating drilling string, it is impossible to gauge the rotative speed of the bit, and hence practically impossible to feed it downwardly at the proper rate. If the feed is too slow, the bit will run free and fail to drill properly, whereas if the feed is too rapid, the bit will either stall or will turn too slowly for effective cutting.

Attempts have been made to regulate the feed automatically by the reactive torque in the drilling string, as disclosed in U. S. Patent No. 1,786,173, issued December 23, 1930, upon my application. Such attempts have not been wholly successful, principally because the drilling string is not constantly rotating, or is rotating at widely varying speeds depending upon the reactive torque of the bit motor. The weight and inertia of the drilling string is very great, and the friction between it and the drilling mud which fills the well is considerable. As a consequence, any change in rotative speed of the drilling string is affected not only by the torque reaction of the drill motor but also by the inertia and friction of the drilling string.

The specific object of my present invention is to provide means for indicating the reactive torque set up in the drilling string by the drill bit motor without having such indication affected by inertia and friction due to changes in rotative speed of the string. The torque indication thus provided, which reflects accurately any change in the torque reaction of the drill bit, can be used as a guide by the driller in regulating manually the rate of feed of the bit, or it can be used, by appropriate mechanism, to regulate the rate of feed automatically.

I achieved the object described above by positively rotating the drilling string at a constant slow speed, by means of a prime mover entirely separate from the drill bit motor, and by using either the power input of said prime mover or its torque as a relative indication of the reactive torque of the drill bit, as will be explained more fully hereinafter. It will at once be appreciated that since the rotative speed of the drilling string is constant, its inertia has no effect, and its friction against the drilling mud and against the walls or lining of the wall is constant. Hence the power or torque required to rotate the drilling string at constant speed is affected only by variations in the torque reaction of the drill bit.

A further object of the invention is to provide a method for controlling the deviation from the vertical of the drill bit in its downward course. I have found by actual experience that, in certain formations, the drill bit tended to deviate approximately 3 degrees from the vertical when the drilling string was rotated at 4 R. P. M., but that when the speed of the string was increased above 6 R. P. M., the deviation was much reduced and could easily be corrected by ordinary methods. The deviation will be affected, of course, by the formation of the ground and by the shape of the bit, as well as by the speed of rotation of the drilling string, but in most cases it can be effectively controlled by selecting the proper speed at which to rotate the string. In general, with the bit rotating at a theoretically optimum speed of 600 R. P. M. (its actual speed is unknown) a speed of from 3 to 6 R. P. M. of the drilling string gives best results. The string may be rotated in either direction.

It is to be understood that changes, within the scope of the claims hereto appended, may be made in the construction, arrangement and operation of the apparatus herein described, without departing from the spirit of the invention as set forth in said claims.

In the accompanying drawing,

Fig. 1 is a partly diagrammatic and partly sectional elevation of a portion of a drilling rig showing a simple form of my invention adapted for manual control of the drill bit feed.

Fig. 2 is a similar view showing one means for automatically controlling the feed.

Fig. 3 is an end view of the drilling string motor illustrating r eans for indicating its torque.

Fig. 4 is a part sectional plan of the same.

In the drawing, the reference numeral 5 designates the drill bit at the bottom of the well 6. 7 is a drill bit motor of any usual type, herein indicated as a hydraulic motor, whose output shaft 8 is directly connected with the bit 5. The motor 7 is suspended within the well casing 9 by a string of drill pipe 10 extending to the surface and connected with a square kelly section 11 which passes through, with a sliding fit, a suitable bushing in a rotary table 12 having bevel gear teeth 13 around its periphery. The kelly 11 is suspended by the usual means indicated at 14 from the derrick, and is provided with a swivel mud connection 15 connected with a mud

supply hose 16, through which the drilling mud is supplied to the drill pipe.

The table 12 is rotated at slow speed by a suitable prime mover, indicated as an electric motor 17, through a belt 18 and suitable speed reducing gearing indicated at 19 as a worm and worm wheel, said gearing driving a bevel pinion 20 meshing with the teeth 13 of the table. The motor 17, which is designed to operate at constant speed, is supplied with electric power from a line 21, and the power input to the motor is indicated by an ammeter 22 (or a watt meter if the voltage is not constant).

The drill pipe 10, and the drill bit, are raised and lowered by the usual hoisting mechanism, a portion of which is indicated as a drum 23 upon which the hoisting cable 24 is wound, the other end of said cable being connected, through appropriate pulley blocks, not shown, with the suspension member 14 at the top of the kelly 11. The drum 23 is provided with a brake drum 25, having a brake band 26 operated by a hand lever 27.

In operating the apparatus illustrated in Fig. 1, the drill pipe is set in rotation at a selected constant speed, preferably between 3 and 6 R. P. M. While the bit 5 is raised above the bottom of the well, and is not being driven by its motor 7, i. e. with no mud supplied, the power input of the drill pipe motor 17 is read at the meter 22. The mud pump (not shown) is then started, and another reading taken of the meter 22. The drill pipe is then lowered, with full power applied to the drill bit motor 7, and said lowering is continued until the bit stalls, when a third reading of the meter 22 is taken. The second and third readings will give respectively the minimum and maximum power input necessary to turn the drill pipe at constant speed under all operating conditions, ranging from a free turning bit to a stalled bit. The variation in power input as indicated at the meter 22 is directly proportional to, and an accurate measure of, the variation in the reactive torque of the drill bit and its motor 7, because the drill pipe is rotating at constant speed, and its inertia and friction are constant.

Some value between the observed minimum and maximum readings of the meter 22 will be an indication of the optimum torque reaction of the bit, i. e. the torque reaction at which it will progress most rapidly through the formation. By regulating the downward feed of the bit by means of the brake lever 27, the operator can hold the torque reaction at its optimum value, and therefore secure the most rapid drilling. The optimum value of the torque reaction, as indicated by the meter 22, must be determined by trial and experience, and will vary for different types of bit, different formations, and other drilling conditions. But once learned, the optimum rate of feed can be continued as long as drilling conditions remain the same, merely by keeping the indication of the meter 22 at a constant value. As previously stated, the direction of rotation of the drill pipe 10 and the motor 17 is immaterial, the important consideration being a constant speed in order to eliminate inertia and hold friction to a constant value.

In Fig. 2 I have illustrated a simple means for automatically controlling the rate of feed by means of the torque reaction of a constantly rotated drill pipe.

All parts indicated are the same as in Fig. 1 except that the electric drill pipe motor 17' is mounted in trunnions 28, so that its frame or stator can oscillate in response to variations in its power input and torque reaction. An arm 29 extends from the motor frame, and is connected with the brake lever 27' by suitable coupling means 30. A spring 31 balances the torque reaction of the motor 17'. With proper proportioning and adjustment of the connections between the motor frame 17' and the brake lever 27', variations in the torque reaction of the motor, which are directly proportional to variations in the torque reaction of the drill bit, will control the operation of the brake in such a manner that the optimum rate of feed will be maintained. For example, assuming that the shaft of the motor 17' is turning counterclockwise, an increase in the torque reaction of the drill bit coincident with a decrease in its speed will cause an increase in the torque reaction of the motor 17', which will raise the torque arm 29 and the brake lever 27', increasing the friction of the brake upon the drum. This will slow down the feed of the bit into the formation, thereby increasing its speed and decreasing its torque reaction, whereupon the torque reaction of the motor 17' will decrease and the spring 31 will release the brake until a balance is attained. In this form of apparatus, as illustrated in Fig. 2, the direction of rotation of the shaft of motor 17' must be counter-clockwise, although it could be reversed by reversing the position or action of the spring 31. As this would be merely an obvious reversal of parts, it has not been illustrated in the drawing.

It will be appreciated that any means can be employed for indicating the torque of the drill pipe motor 17. The ammeter or watt meter 22, indicating the power input, serves as a simple and convenient torque indicator as long as the speed remains constant. The position of the arm 29 of Fig. 2, working against the tension of the spring 31, by indicating the torque reaction of the motor stator, will indicate the torque of the motor rotor and shaft. Or a suitable torque indicator can be inserted in the motor shaft, as shown in Figs. 3 and 4, or at any point in the drive mechanism between the motor and the rotary table 12. The torque indicator shown in Figs. 3 and 4 comprises two opposed bevel gears 32 and 33, the gear 32 attached to the shaft 34 of the motor 17'', and the gear 33 attached to an aligned shaft 35 which carries the pulley 36 for the belt 18. Bevel pinions 37, meshing with both gears 32 and 33, are journalled in a ring frame 38 supported for oscillation about the axis of the shafts 34 and 35 by suitable means not shown. An arm 39, carrying a pointer 40 cooperating with a scale 41, extends from the ring 38, and its rotation is resisted by any suitable means not shown. Such a device will indicate directly the torque of the motor.

It is obvious that the drill pipe motor 17, 17' or 17'', need not be an electric motor. Any machine can be used which is capable of rotating the drill pipe at constant speed, and whose power input or torque can be measured. Similarly, the drill bit motor 7 need not be a hydraulic motor, but can be any machine capable of being suspended in the well by the drill pipe, and suitable for rotating the bit. It will also be apparent that the drill bit motor 7 can be suspended by a string of rods instead of by the pipe 10, or it may be lowered and raised by a cable, in which case it must be anchored to a tubular string capable of resisting the torque of the motor. Pipe is commonly used, because it not only suspends the bit and its motor, but also conducts the drilling mud

to the bottom of the well, and when a hydraulic motor is used to rotate the bit, the same mud provides the power for driving said motor. The term drilling string, as used in the claims hereto appended, therefore, should be construed as defining any suspending member having sufficient torsional resistance to transmit the reactive torque of the bit motor to the surface.

The method and apparatus herein described can be used to control and minimize the deviation of the drilled hole away from the true vertical. In the drilling of actual deep wells with apparatus as described herein, it was found that, at some stages in the drilling, the holes deviated from the vertical, and that when the rotative speed of the drilling string was changed, the deviation disappeared or was greatly reduced.

The optimum speed of rotation of the drilling string for the purpose of controlling deviation, must be found by trial. Measurements of the exact direction of the hole are made at intervals, by any means well known in the art, and when any such measurement shows a deviation greater than permissible, the speed of rotation of the drill pipe is changed, and then held constant at the changed speed, until the next measurement is taken. This process is repeated until a speed is found at which the deviation remains within the permissible limit. The optimum speed may change from time to time in the drilling of a well, as different formations are encountered, as the length of the drill pipe increases, and as different drill bits are used.

The reason why a change in the rotative speed of the drill pipe will alter or control the deviation of the hole is not subject to precise determination in the light of present knowledge. The drill bit operates in an inaccessible position and cannot be observed, and there are many variable factors involved which may give rise to deviation. It is known, however, that rotating drilling strings are subject to vibration, periodic and otherwise, and that such vibration is greater at some speeds than at others. It is also known that vibration of the drilling string may cause deviation of the hole.

In the method of drilling described herein, with a rotary bit driven by a turbine suspended at the lower end of a slowly rotating drill pipe, vibrations may be set up in said drill pipe by the rotation of the bit, by the cutting of the bit into the formation, by the character of the formation, and by the mud pump which forces the fluid down through the drill pipe. Such vibrations of the drill pipe causes nodes and anti-nodes therein, affecting its straightness, and thereby may cause deviation of the hole from the vertical.

It may be deduced, therefore, that changes in the speed of my slowly rotating drill pipe will affect its periodic vibration, and consequently will affect the tendency of the bit to deviate from the vertical. At some speeds of rotation of the drill pipe, it will have less vibration than at other speeds, and the hole will have less deviation.

This theory is consistent with the observed fact that approximately the same effect is produced by rotating the drill pipe either in the same direction as that of the bit or in the opposite direction. The direction of rotation, either of the bit or of the drill pipe, may have some effect upon the periodic vibrations set up in the drill pipe, because if the directions are the same, power is added to the bit, whereas if the directions are opposite, power is subtracted, but such difference in effect is a matter of degree only, and is very small. If the assumption is correct that the speed of rotation of the drill pipe affects and controls its vibrations, then rotation in either direction would have approximately the same effect.

I claim:

1. Rotary well drilling apparatus comprising a drill bit, a motor suspended in the well for rotating said bit, a drilling string extending downwardly from the surface by which said motor is suspended, means for lowering said drilling string to feed the bit into the earth formation, a motor for rotating said drilling string at a constant speed, and means for indicating the torque developed by the last mentioned motor.

2. Rotary well drilling apparatus comprising a drill bit, a motor suspended in the well for rotating said bit, a drilling string extending downwardly from the surface by which said motor is suspended, means for lowering said drilling string to feed the bit into the earth formation, a motor for rotating said drilling string at a constant speed, and means for indicating the power input of the last mentioned motor.

3. Rotary well drilling apparatus comprising a drill bit, a motor suspended in the well for rotating said bit, a drilling string extending downwardly from the surface by which said motor is suspended, means for lowering said drilling string to feed the bit into the earth formation, a second motor having a frame and a rotor, said rotor being connected with said drilling string to rotate the same at a constant speed, and means connected with said frame for indicating the torque reaction developed therein by said rotation of the drilling string.

4. Rotary well drilling apparatus comprising a drill bit, a motor suspended in the well for rotating said bit, a drilling string extending downwardly from the surface by which said motor is suspended, means for lowering said drilling string to feed the bit into the earth formation, a motor for rotating said drilling string at a constant speed, means connected with the last mentioned motor responsive to the torque reaction thereof, and a connection between said torque responsive means and said lowering means whereby the rate of feed of the bit is controlled by the torque reaction of the drilling string motor.

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