June 29, 1965 F. I. ALEXANDER 3,191,683

CONTROL OF WELL PIPE ROTATION AND ADVANCEMENT

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FIG. 1.

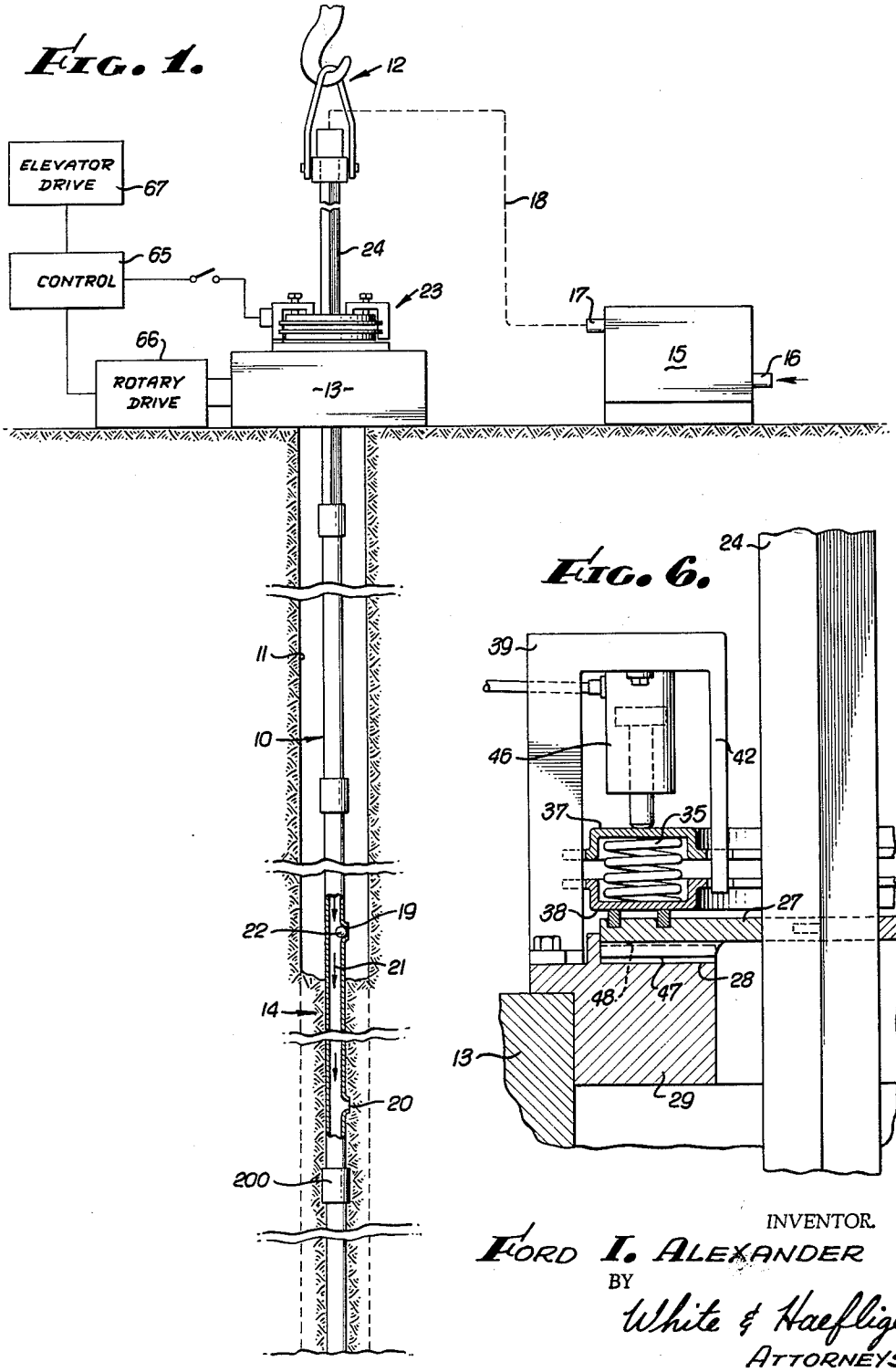


FIG. 6.

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FIG. 2.

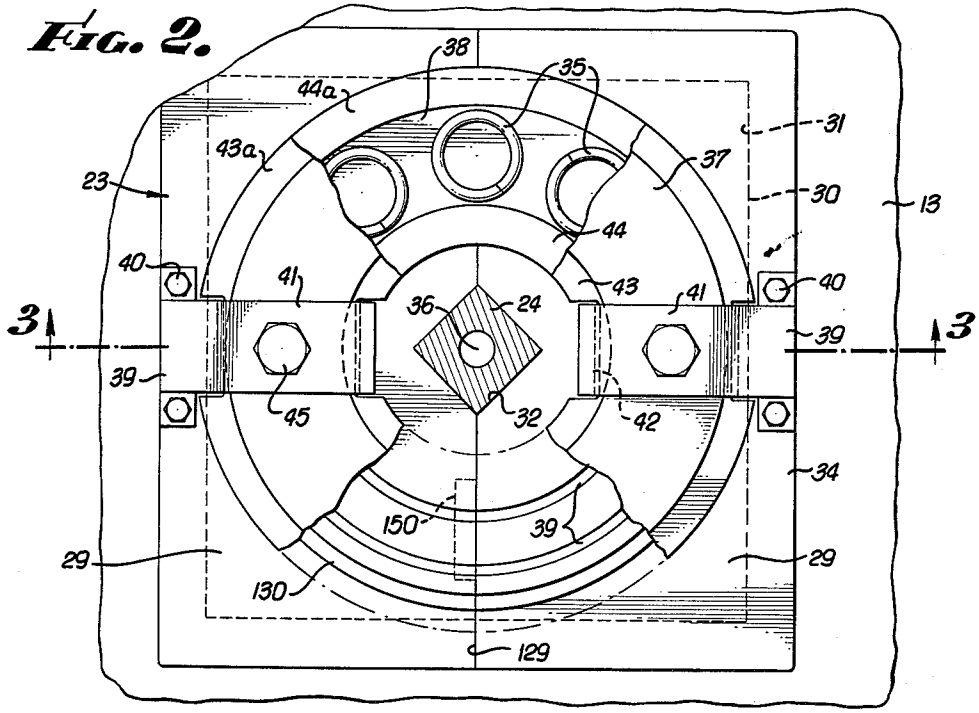
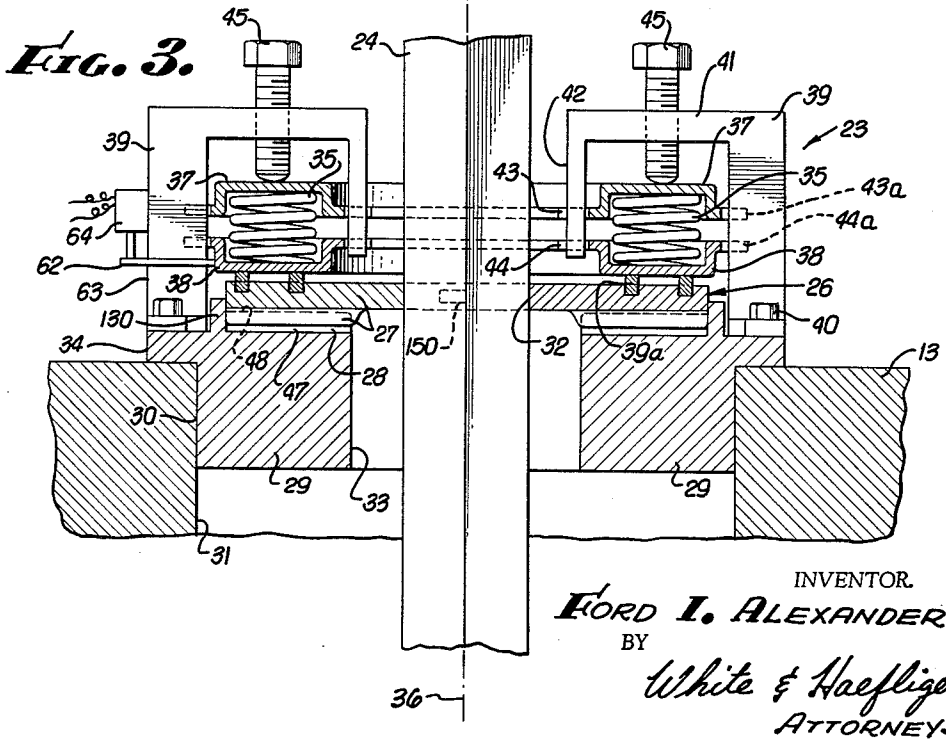


FIG. 3.



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FIG. 4.

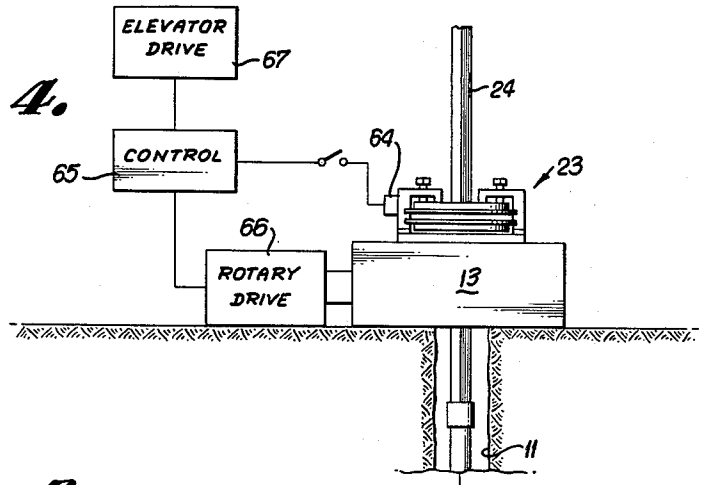
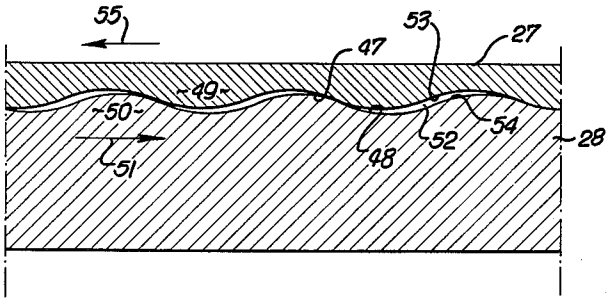


FIG. 5.



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CONTROL OF WELL PIPE ROTATION AND ADVANCEMENT

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8 Claims. (Cl. 166—178)

This invention relates generally to manipulation of well pipe to produce pipe displacement in the well. More particularly the invention concerns the control of torque and weight application to a rotating pipe string to cause the pipe in the well to move in a preferred manner, as in freeing of pipe struck in a well, restoring circulation that has been lost, and in drilling control particularly as to direction and as a warning of cave-ins.

In well drilling, it frequently happens that the drill string may become stuck at locations that may range from depths near the bit to intermediate depths many pipe stand lengths above the bit, depending upon conditions encountered in a particular well being drilled and the particular reason for the pipe becoming lodged. To illustrate, the pipe may become stuck as a result of a cave-in well, or by key seating of pipe in crooked holes. Also, well casing may become stuck in the hole.

In keeping with presently prevailing practices in the determination of the stuck point location, the pipe is manipulated at the well head as by slowly rotating, lifting and lowering of the kelly. These practices produce rather slow pipe displacement in the well, which is a disadvantage when detection of pipe movement in the well is dependent upon acceleration undergone by the pipe deep in the hole. The present invention has for one of its major objects the provision of apparatus and method for rapidly and automatically displacing the pipe at different depths in the well to produce more rapidly detectable pipe acceleration.

Referring first to freeing pipe stuck in a well, the method broadly contemplates the steps that include applying torque for rotating and twisting the string above the stuck point, displacing the string vertically at the well head to exert variable loading on the string proximate the stuck point, and suddenly releasing the torque application to allow the string to rapidly untwist and oscillate, these operations being repeatable. Also, well fluid may be circulated downwardly in the string and to the formation proximate the stuck point, particularly at successively different elevations, as will be brought out.

By carrying out these steps at the well head, it is ensured that the string will be placed in torsion and will accelerate and become displaced as for example by whipping in the hole above the stuck point no matter where the latter exists in the well. Also, the energy stored in the pipe during torsional twisting will, upon sudden release, tend to cause transmission of shock torsional loading and oscillation to the pipe at the stuck point for freeing the stuck pipe. Such movement will facilitate crushing of the formation about the pipe. In the case where drilling mud has caked due to operating conditions and has caused the pipe to become stuck, the re-dissolving of the cake will be aided by facilitating access of fluid mud to the cake through the loosened formation.

It should be noted that by rotating, twisting, oscillating and pulling of the pipe up and down, the well fluid

above the stuck formation will be better able to flow down along the pipe, lubricating and softening the formation of the mud cake, so as to allow the pipe to be removed. In this regard, pipe may be rotated far below the point from which it may be removed. Also, the pipe in a well may be considered as subject to being wound up or twisted as a rope, and then released for unwinding and reaction winding in the opposite direction due to its rotary inertia.

The apparatus which I provide for carrying out this method includes means by which and through which rotation is transmissible for forwardly rotating the pipe at the well head to twist the string placing it in trosion within the well without restricting vertical movement thereof, said means including a coupling releasable to allow counter rotation of the pipe at the well head substantially faster than forward rotation whereby the pipe string may be caused to untwist rapidly at differetn depths in the well. Also, the said means includes actuator apparatus free of the string for exerting controllable loading opposing release of the coupling. The actuator apparatus, as will be seen, includes a force adjusting device for varying the loading to be applied for opposing said coupling release.

In the method of drilling a well wherein directional control of bit downward movement is dependent upon rotary speed of the bit and string weight loading application, the invention contemplates the steps that include transmitting such loading through a rotary slip coupling and transmitting torque through the coupling to effect string rotation while the coupling and string loading are controlled to govern bit advancement direction. In this regard, the coupling may be controlled as well as string loading application and within a selectable driving torque range above which the coupling is subject to slippage.

As the pipe advances downwardly through the coupling driving, drilling, the resistance encountered by the bit or string in the hole may become altered, as for example, as may result from a change in the resistance of the formation being cut or the start of a cave-in. The invention contemplates that such a change in resistance will affect the degree of slippage of a slip coupling at the well head and further that apparatus is provided to be responsive to such slippage for controlling application of force to the string by at least one of the string elevator mechanism or the rotary drive for the string, or both of these all in a desired manner to achieve desired manipulation of the string in the well as will be seen.

These and other objects and advantages of the present invention, as well as the details of an illustrative embodiment, will be more fully understood from the following detailed description of the drawings, in which:

FIG. 1 is a general view showing the pipe string stuck in the well and in the manipulataion thereof to free the string;

FIG. 2 is an enlarged plan view of the string rotating apparatus;

FIG. 3 is a vertical section taken on line 3—3 of FIG. 2;

FIG. 4 is a view like FIG. 1, but showing the string during a directional drilling operation;

FIG. 5 is a linear extension showing the rotary parts as they are engaged during rotation of the kelly by the rotary table; and

FIG. 6 is a schematic showing of a system for controlling weight and rotary drive application to a string.

Referring first to FIG. 1, the drill string is shown generally at **10** suspended in a well open hole **11** by elevator mechanism **12**. The surface equipment also includes a rotary table **13** which is used in rotating and torsionally winding or twisting the drill string as and for the purposes later described. Typically, a cave-in such as is shown at **14** causes the pipe to become stuck in the well, the pipe extent above the stuck point being subject to varying degrees of movement as by manipulation at the well head, but the pipe extent below the stuck point is not movable until the pipe is freed, so that the location of the stuck point may be determined by traveling an acceleration detector vertically within the pipe while the latter is accelerated. As will be brought out, the pipe is twisted forwardly and then allowed to untwist rapidly, these steps being repeated, and the string is subjected to lifting and lowering for the purpose of transmitting such displacement to the stuck portion of the pipe. Also, well fluid is pumped downwardly through the pipe and into and below the top of the cave-in formation **14** to soften the latter. A mud pump is shown at **15** as having an inlet **16** and an outlet **17** for flowing drilling mud at **18** to the pipe and downwardly therethrough.

Preliminarily, the pipe may be perforated at several vertical locations, two of which are shown at **19** and **20** at the general location of the cave-in. Well fluid pumped downwardly as shown by the arrows **21** first flows outwardly through the upper perforation **19** to soften the upper portion of the cave-in formation and thereby re-establish circulation of drilling fluid. Thereafter, a ball or other plug **22** may be dropped in the pipe to plug the upper perforation **19**, and continued well fluid flow passes to and through the lower perforation **20** for loosening a lower portion of the cave-in formation to re-establish circulation. Alternatively, the pipe string may be unscrewed at joint **200** in the cave-in formation **14** to an extent permitting release of downwardly pumped well fluid into the formation to re-establish circulation, and thereafter the joint may be made up and a lower joint unscrewed for establishing circulation at a lower level. This step by step procedure, in combination with rotary twisting and rapid untwisting and oscillation of the pipe extent at the cave-in, and vertical lifting and lowering of the pipe, may be considered very effective for loosening the stuck pipe.

Coming now to a description of the apparatus by means of which the pipe string may be rapidly displaced or automatically untwisted, reference to FIGS. 2 and 3 will show that means to be indicated generally at **23** for rotating the kelly **24** by operation of the rotary table **13** to twist the string and place it in torsion within the well, without restricting vertical movement of the string. The said means includes a slip coupling **26** having interengaged upper and lower rotary parts **27** and **28**. Referring first to the part **28**, it typically comprises a split master bushing, the respective halves **29** of which are sized at their periphery **30** for fitted reception within the square opening **31** in the rotary table. As a result, the lower part **28** is connected in driven relation with the table.

The upper part **27** of the coupling typically comprizes a plate having a central square opening **32** sized for fitted reception on the kelly **24** for driving the latter while allowing relative vertical movement of the kelly through the plate. The lower part **29** has an enlarged opening **33** to pass the kelly, and which also includes a flange **34** which seats on the top surface of the table for limiting downward displacement of said part relative to the table.

Downwardly loading is exerted on the upper part **27** by an actuator apparatus which is free of the string, said loading typically being controllable to oppose slip-release of the coupling. Typically, and in the form of the invention shown, the actuator includes a series of compression springs **35** circularly spaced about the axis **36** of the

kelly, and retained between upper and lower plate members **37** and **38**, the latter having a thrust bearing relation to the coupling upper part **27** as through the rings **39***a*. The latter allow relative rotary displacement as between the part **27** and the plate member **38**, while transmitting vertical thrust to the part **27**. Both of the members **37** and **38** are rotated with the lower coupling part **28**, as by means of a series of circularly spaced arms **39** which are fastened to the flange **34** as shown at **40**. The arms project upwardly to a level above the upper member **37**, then laterally inwardly at **41** and then downwardly at **42** into notches formed in the inner flanges **43** and **44** of the members **37** and **38** for driving the latter. Members **37** and **38** may also have notched outer flanges **43***a* and **44***a* to loosely fit the arms **39**. Force adjustment means, as for example, the screws **45** projecting downwardly through the arm portions **41** to bear against the upper plate member **37**, may be adjusted to control the loading imposed on the coupling **26** to oppose release of the coupling. Alternatively, liquid or gas actuated devices may be used as shown in FIG. 6 at **46** to variably control the force exerted against the upper member or coupling part **27** to oppose release of the coupling. The pressure in device **46** may be changed when rotation of table **13** is interrupted, or during such rotation as from a source of pressure which rotates with the table.

The rotary parts **27** and **28** have formed thereon cam shoulders **47** and **48** which are respectively downwardly and upwardly presented for frictional engagement. These shoulders are formed on undulating lugs or teeth **49** and **50** which are respectively downwardly and upwardly presented on the parts **27** and **28** and are also circularly arranged around the axis of the kelly, which is common to the axes of parts **27** and **28**.

Referring to FIG. 5, as part **28** is driven in the direction of arrow **51** it tends to drive part **27** in the direction of arrow **51** for rotating the kelly with the rotary table. However, such rotation twists the drill string in the well and places it in torsion acting through part **27** to resist rotation by part **28**. As a result, during such rotation by the rotary table the torsion forces build up and tend to cause slippage at the interengaged cam shoulders **47** and **48**, FIG. 5 showing that some slippage has occurred, by virtue of the gaps **52** between the reverse shoulders **53** and **54** on lugs **49** and **50**. Such slippage is resisted by friction forces exerted at the interengaging shoulders **47** and **48** and arising from imposed loading action downwardly through plates **37** and **38**, springs **35** and rotary part **27**, the degree of imposed loading being of course under the control of the adjustable screws **45**.

Assuming that the imposed loading remains constant, the torsion forces in the drill string will build up during rotation of the kelly until they overcome the loading acting at the interengaged shoulders **47** and **48**, at which time the rotary part **27** will have lifted relative to part **28** to the extent that the parts will release and slippage will occur, part **27** counter-rotating in the direction of arrow **55** as shown in FIG. 5. This counter-rotation will occur at a rate substantially faster than rotation by the rotary table in the direction of arrow **51** and will, accordingly, rapidly untwist the pipe string in the hole imparting a sharp or high degree of torsional acceleration to the pipe.

Furthermore, the automatic counter-rotation of the rotary part **27** will be suddenly and automatically interrupted, depending upon the amount of loading imposed downwardly on the part **27** as controlled by the screws **45**. Thus, when the counter-rotation of part **27** has carried that part sufficiently in reverse that the torsion loading of the string is diminished below the point at which imposed loading causes frictional interlocking of parts **27** and **28** and shoulders **47** and **48**, counter-rotation of part **27** will cease. At this time, shoulders **47** and **48** will engage vertically and vertical shock loading on the pipe will produce a wave traveling vertically along the pipe and de-

tachable as pipe acceleration above the stuck point. The amount of counter-rotation in the direction of arrow **55** may be controlled by increasing or decreasing the activator imposed loading. After frictional engagement at shoulders **47** and **48** is re-established the rotary table effects rotation of the kelly to build up increased string torsion, with resultant repetition of counter-rotation of the kelly and the string followed by sudden interruption of such counter-rotation as previously described. Moreover, this torsional and vertical shock loading may be caused to occur as rapidly and repeatedly as is desirable so as to vibrate the pipe accelerating in the hole above the stuck point, both in torsion and longitudinally.

While such torsional and vertical shock loading is transmitted to the pipe extent at the stuck point as a result of operation of the slip coupling **26** as described the elevator **12** may be lifted and lowered as desired to superimpose additional displacement of the pipe transmitted to the extent thereof at the stuck point. Also, as previously described, fluid may be pumped into the pipe and into the formation to soften it at vertically successive elevations, all for the purpose of co-acting to free the pipe.

Reference to FIG. 2 will show that the arms **39** are carried on separate halves of the coupling part **28** integral with the bushing halves **29**, the split therebetween being indicated at **129**. Also, the coupling upper part **27**, bearing rings **39***a* and the plates **37** and **38** may each be formed as halves divided at the line of the split **129**, and assembled during assembly of the apparatus **23** about a kelly **24**. The halves of the upper part **27** may be interfitted about the kelly and with tongue and groove connection at **150**, and then dropped in position and retained by an annular flange **130** upstanding from the part **28**. Thereafter, the split bearing rings **39***a* may be dropped in position and the arms **39** bolted at **40**, with split plates **37** and **38** retained over the rings **39** by the arms **39***a* and **42**.

Referring again to FIG. 5, the lugs **49** and **50** may be so formed or staggered as to permit complete engagement at only one relative position about the vertical axis of rotation, or at a lesser number of rotary positions than the number of lugs would seem to indicate. This will allow slippage in corresponding angular increments, while in any engagement position all the lugs will afford bearing surface.

Reference to FIG. 4 will show the use of the coupling as previously described in the method of drilling a well wherein directional control of drill bit downward advancement is dependent upon rotary speed of the bit and string weight loading application. The bit is indicated at **60** with its axis **61** extending at a substantial angle to the vertical and having a lateral component desirably directionally oriented. Since the coupling freely passes the kelly **24**, string weight loading is controllable independently of operation of the coupling. Also, torque is transmitted through the coupling to effect string rotation while the coupling and string loading are controlled to govern bit advancement direction, either vertical or non-vertical and typically within a selectable torque range above which the coupling is subject to slippage. Thus, adjustment of the members **45** in FIG. 3 establishes a torque level above which the coupling will slip. In accordance with the invention, it may be desired to maintain the rotary speed of the bit at a particular level correspondent to desired directional control of bit advancement. Should the bit, for any reason, encounter greater resistance, as for example, may be due to a change in the formation, the loading to be overcome by the rotary drive increases and this would tend to slow down the drive. Such increased resistance to drilling may be noted by the operator as reflected in relative vertical displacement of the coupling parts **27** and **28**, a suitable indicator **62** in FIG. 3 projecting laterally from the part **38** to indicate such relative movement. The indicator is movable vertically with the part **38** and relative to the arm vertical extent **63**. Upon noting such movement, the operator may adjust the vertical loading exerted on the bit by the string, as through relative vertical movement of the elevator **12**, thereby to re-establish the desired rotary drilling speed for directional control of bit advancement.

FIG. 3 also shows a sensor **64** carried by the arm extent **63** and operable to provide a slippage signal usable to control either the rotary drive of the table **25**, or the vertical drive of the elevator. FIGS. 1 and 4 show the sensor **64** as being switch connectible with a control **65** which is in turn connected with the rotary drive **66** and the elevator drive **67**, and it will be understood that the control may be such as to establish or maintain a relationship between the rotary drive and the elevator position such as to effect desired directional control of the bit advancement. In this regard, the control may be such as to govern the rotary drive or the elevator in response to changes in the relative slip or positions of the parts **27** and **28**, as affected by torque transmission thereto. Thus, the rotary drive speed or r.p.m. may be fixed, and the control signal used to govern the elevator drive independently and automatically. Also, the slip coupling allows for release in the event of jamming of the bit in the formation.

The switches seen in FIGS. 1 and 4 and by which sensor **64** is connectible with control **65** may be such as to allow relative rotation of switch components, inasmuch as the sensor **64** rotates with table **13**.

I claim:

1. For use in the method of rapidly accelerating a pipe string stuck in a well, means by and through which rotation is transmissible for forwardly rotating the pipe at the well head to twist and place the string in torsion within the well without restricting vertical movement of the string, said means including a coupling releasable to allow counter rotation of the pipe at the well head substantially faster than forward rotation whereby the pipe string may be caused to untwist rapidly at different depths in the well, and actuator apparatus free of the string for exerting loading yieldably opposing said releasing of the coupling, said actuator apparatus including a force adjusting device for varying said loading to be applied for opposing said coupling release, said coupling comprising split sections sized for assembly about the pipe at the well head and in torque transmitting relation therewith.

2. The invention as defined in claim **1** including a rotary table for rotating the tube string, and a fastener for integrally attaching said means to said table.

3. The invention as defined in claim **1** in which said actuator apparatus includes a spring variably tensioned by said device.

4. The invention as defined in claim **1** in which said device includes a fluid pressure responsive element operable to exert said controllable loading.

5. The invention as defined in claim **1** in which said means includes interengaged rotary parts releasable in response to build-up of string torsion acting through the coupling in opposition to said actuator applied loading to allow counter-rotation of the string, the actuator includes springs acting to urge the interengagement of said parts and said means includes spring retainer and drive structure extending at the outside and inside of said springs and forming a central opening to pass the string.

6. The invention as defined in claim **5** in which said actuator device includes adjustable elements for controlling the tension of said springs.

7. The invention as defined in claim **1** including a signal producing means responsive to relative displacement of interengaged coupling parts for indicating varying of torque transmission through said coupling.

8. The combination of claim **1** including other apparatus for controlling the string weight applied downwardly in the well and for transmitting rotary drive to said means, and other means to control said other apparatus in response to relative displacement of coupling parts.

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