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Delano

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[54] **CEMENTING WELL BORE CASING**

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[52] **U.S. Cl.** **166/285**, 166/78
[51] **Int. Cl.** **E21b 33/14**, E21b 19/00
[58] **Field of Search** 166/285, 286, 78; 175/195

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American Petroleum Institute, "Oil Well Cementing Practices in the United States," A.P.I., New York, N.Y., 1959, pp. 104–107 and 124.

Mills, "Rotating While Cementing Proves Economical," The Oil Weekly, Dec. 4, 1939, pp. 14 and 15.

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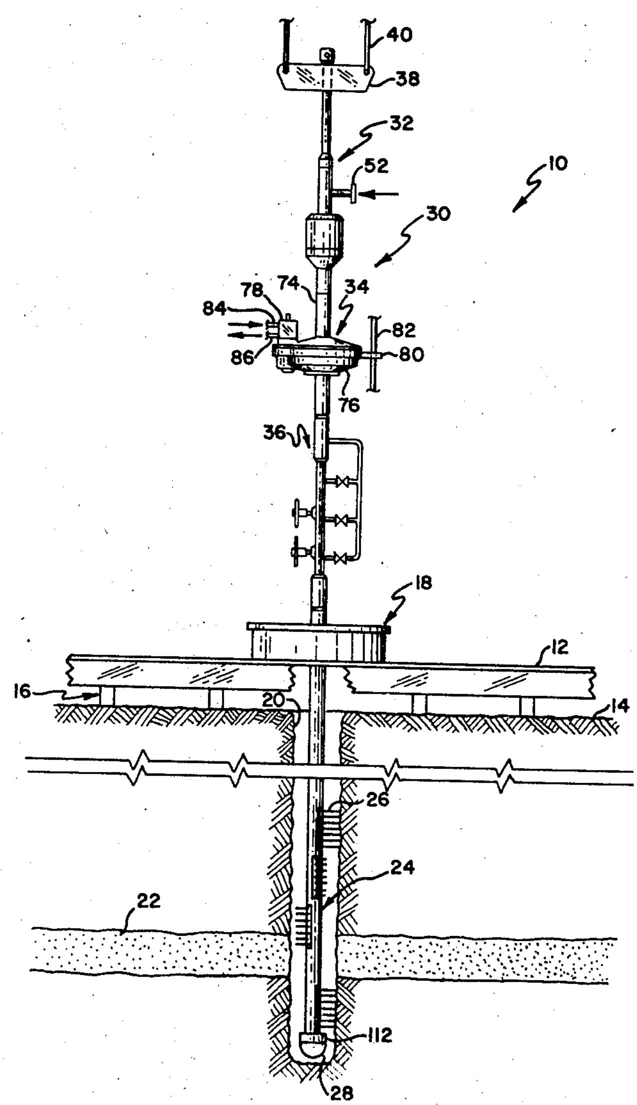
[57] **ABSTRACT**

There is disclosed a method and apparatus for cementing a tubular string in a well bore wherein the tubular string is simultaneously rotated and reciprocated while passing a cementing slurry into the well bore.

8 Claims, 4 Drawing Figures



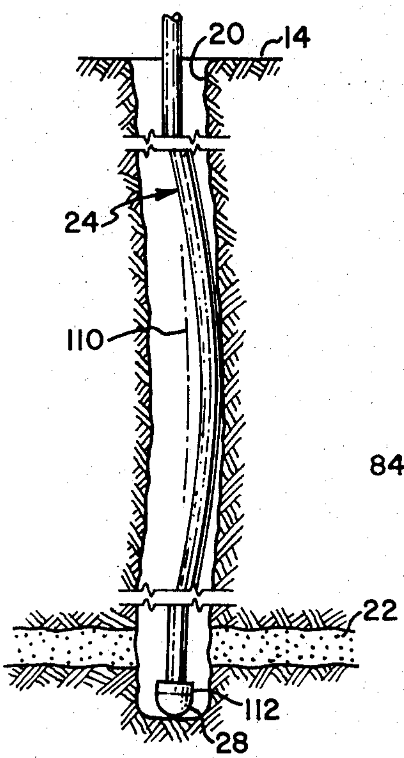
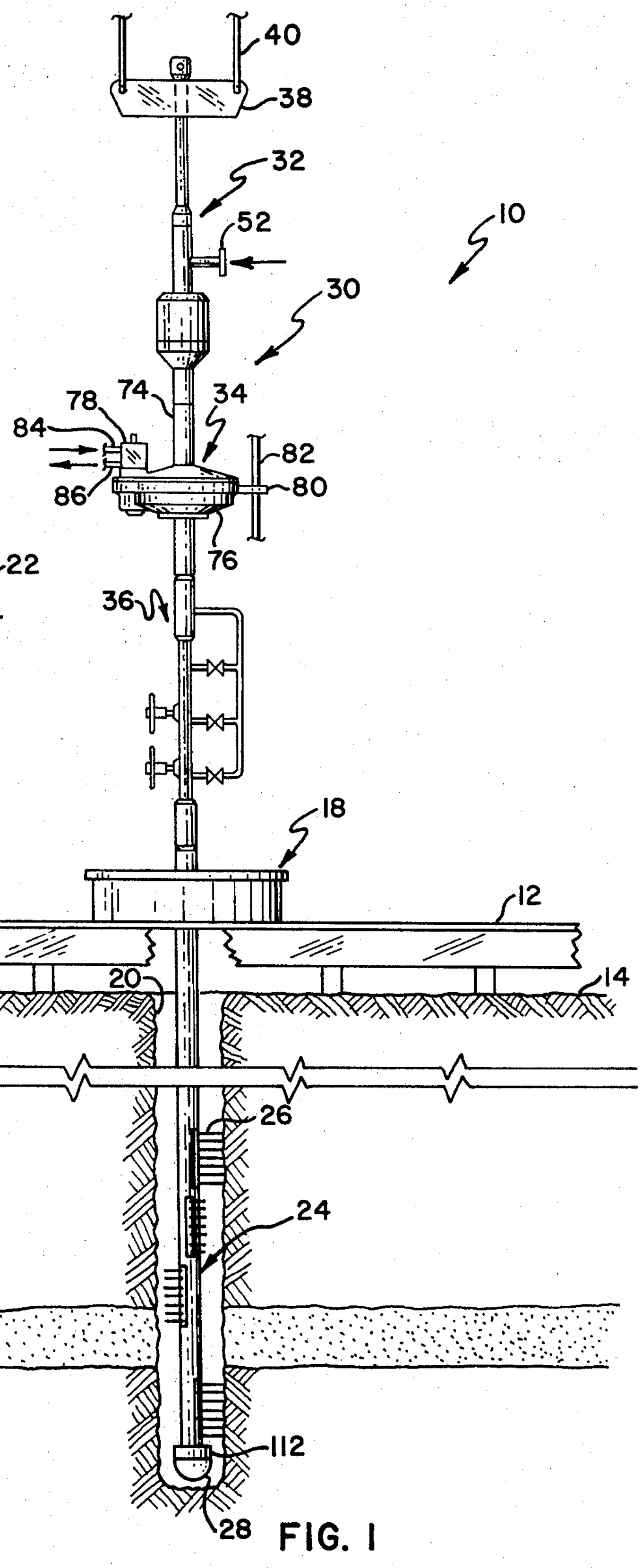

20
14
24
110
22
112
28

FIG. 4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38
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74
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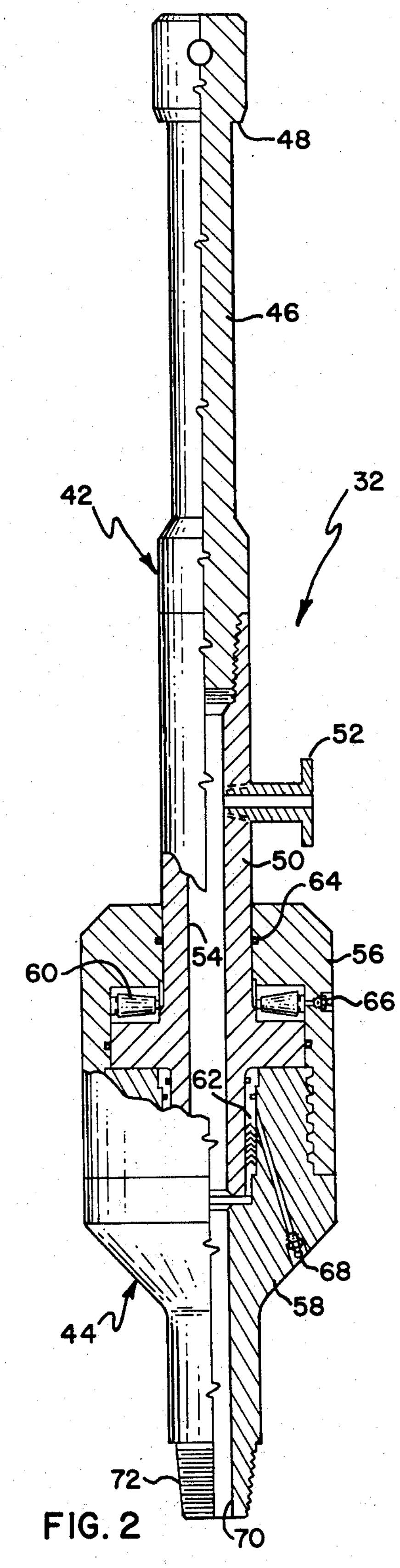
FIG. 1


48
46
42
32
52
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64
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72
70

FIG. 2

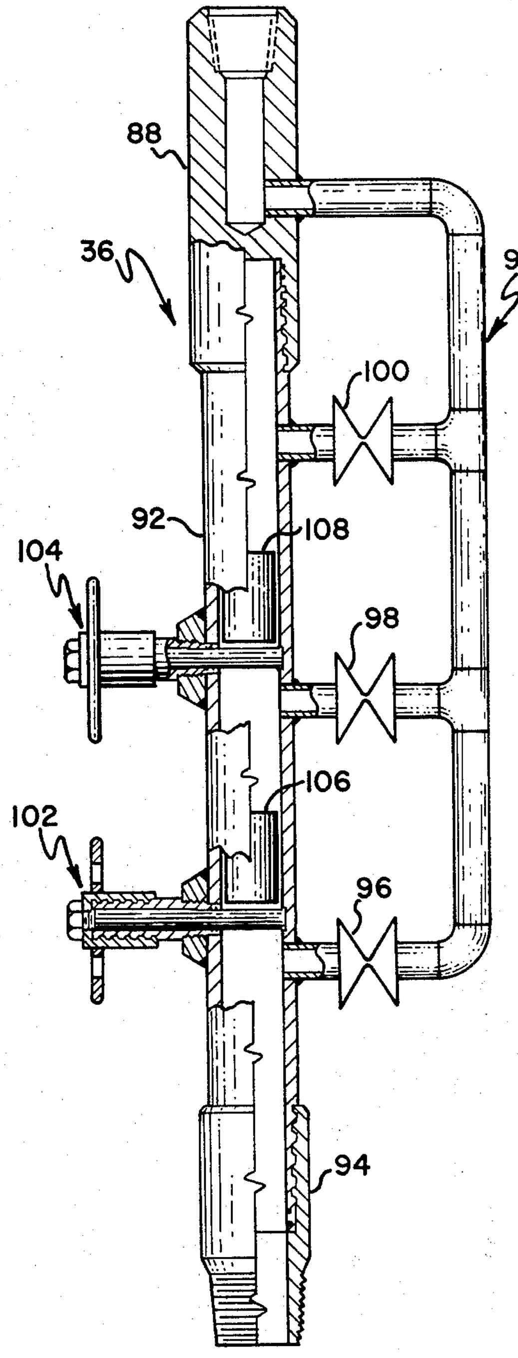
88
36
90
100
92
108
104
98
106
102
96
94

FIG. 3

CEMENTING WELL BORE CASING

BACKGROUND OF THE INVENTION

In the art of cementing tubular strings in well bores, it is well known to affix scratchers and centralizers to the tubular string in order to abrade the bore hole wall and position the string generally in the center of the bore hole. Scratchers are commercially available in various designs and are of two basic types. The first type is an elongate scratcher which is affixed longitudinally of the tubing string so that rotation of the string causes the scratching elements to abrade the bore hole wall. The other type scratcher is circular and of limited extent in the longitudinal direction of the tubular string. This type scratcher requires reciprocation of the tubular string to abrade the bore hole wall.

The general practice of cementing is to scratch the bore hole wall while circulating clean drilling mud through the hole to remove loose shale particles, excessive mud filter cake and the like from the bore hole wall. After the hole has been circulated for a desired length of time, usually on the order of about two to ten hours, cement is pumped downwardly through the tubular string. The cement exits through a cementing shoe on the bottom of the tubular string and passes upwardly into the annulus between the tubular string and the bore hole wall. Scratching of the bore hole wall generally continues during the placement of cement. Scratching the bore hole wall during placement of the cement aids chiefly in agitating the cement and assuring a generally uniform placement thereof in the annulus. It is accordingly widely practiced to rotate or reciprocate a tubular string while pumping a cement slurry into the well bore.

It has been disclosed in the prior art to "rotate and/or reciprocate" a tubular string during cementing as in U.S. Pat. No. 2,609,881 and 2,675,082. Upon analysis, the hardware illustrated in these patents allows sequential rotation and reciprocation and is incapable of simultaneous rotation and reciprocation. For example, in U.S. Pat. No. 2,609,881, the tubular string **16** passes through a conventional rotary table **18** and is presumably suspended from a conventional traveling block and elevator arrangement. The conventional traveling block is presumably operatively connected to a conventional drawworks for raising and lowering the tubular string **16**. The tubular string **16** presumably rests in a set of conventional casing slips received in the top of the rotary table **18**. Conventional casing slips are generally wedge-shaped segments of an annulus and are received in a beveled opening in the top of the rotary table. When the wedge-shaped segments are loaded against the rotary table, driving of the rotary causes the slips to rotate and consequently to rotate the casing string. It is apparent, however, that conventional casing slips do not provide a torque transmitting connection unless the weight of the casing string loads the slips against the rotary table. It is accordingly abundantly apparent that the casing string **16** of Warren cannot be rotated as the string **16** is raised since the torque transmitting connection through the rotary table is inoperative. It would appear, at first blush, that the casing slips would transmit rotation to the casing string if the casing string were moving downwardly into the well bore. In fact, this is not the case since conventional casing slips grip the exterior casing wall, as opposed to the collar. Accordingly, if the slips are loaded, the casing string is suspended from the rotary and is immobile. The apparatus disclosed in U.S. Pat. No. 2,675,082 is substantially identical and is incapable of simultaneously rotating and reciprocating the tubular string disclosed therein.

In the published prior art of which applicant is aware, there is no disclosure of an approach for simultaneously rotating and reciprocating a tubular string in a well bore while passing a cementing slurry into the well bore. There are two approaches for simultaneously rotating and reciprocating a tubular string which have been the subject of conversation. Applicant is unable to state whether these approaches have ever been published or publicly used to bring these approaches within the purview of the prior art. It will suffice for present purposes to state that applicant is not the inventor of the approaches hereinafter described.

One approach is to run the tubular string through the rotary table into the well bore, set the casing slips on the string, attach a sub to the female coupling at the top of the tubular string, attach the Kelly to the sub, remove the casing slips and rotary bushing, lower the string such that the Kelly extends through the rotary table, place the Kelly bushing in the rotary table and then simultaneously rotate and reciprocate the tubular string. This approach presents two primary disadvantages, either of which is so severe as to preclude serious consideration of this approach for use in a cementing process. The first disadvantage occurs if the casing string becomes stuck in the well bore. In this event, the Kelly must be removed from the casing string in order to attach suitable fishing tools, for example jars, wireline tools or the like. If the sub is below ground level when the tubular string sticks, it is impossible to remove the Kelly from the tubular string in order to attach suitable fishing tools thereto. In the vernacular, the operator is up a creek with no paddle. The only thing that can be done is to rotate the Kelly to the left to unscrew one of the joints, pull the freed part of the string out of the well bore, and then go in the hole with a spear or overshot. Since the joint that unscrewed bears no relation to the location where the string is stuck, the probability is that the string will have to be milled up or the well plugged. Either of these alternatives is expensive and under many circumstances is enormously so. The disastrous results of this situation are substantially duplicated if the cement sets up when the connection between the sub and the tubular string is below ground level.

Another disadvantage which is not quite so severe but still substantial occurs when the tubular string is stuck or the cement sets up and the connection between the sub and the tubular string is below the top of the blowout preventer. In this event, the blowout preventer could presumably be cut off with an acetylene torch and a makeshift table fabricated to receive casing slips and thereby suspend the casing in order to break the joint between the sub and the tubular string. It will be appreciated that this can cost many thousands of dollars and leave a very dangerous situation if the well formations are not cemented.

Since the top of the blowout preventer is normally within a few feet of the bottom of the drilling floor, the odds of the casing sticking or the cement setting up when the sub is above the top of the blowout preventer is small. In this event, the casing slips could probably be set in the top of the blowout preventer without incurring tremendous expense. Since the odds of this happening are small, it will be readily apparent that no serious consideration is given to simultaneously rotating and reciprocating a tubular string while cementing by using the Kelly.

The second approach discussed in conversation but which is not known to applicant to be within the purview of the prior art, is to rotate the casing string with a set of power casing tongs while reciprocating the casing string with the drawworks. In this situation, the casing is run into the well bore, the casing slips are set in the rotary table, the casing tongs are attached to that part of the casing string extending above the rotary table, a cementing head is attached to the tubular string, the elevators are attached to the casing string, the casing tongs are tied off against a leg of the derrick the casing slips are removed from the rotary table, and the casing string is rotated with the casing tongs while the string is reciprocated with the drawworks. This approach avoids sticking the casing or setting up the cement and not being able to attach suitable fishing tools to the casing string. One prime disadvantage of this approach is that the casing string can be reciprocated through a stroke of less than about three feet since the tie-off to the derrick leg allows only very limited reciprocating travel. Another prime disadvantage of this approach is that power casing tongs presently available are incapable of applying substantial torque to the casing string at substantial rotational speeds. In other words, this approach does not allow the tubular string to be rotated fast enough nor reciprocated through a sufficient stroke to scratch the bore hole wall to any extent. Thus, this approach is less satisfactory than either solely reciprocating the tubular string with the drawworks or solely rotating the string with the rotary table. Accordingly, no serious consideration has been given this approach for cementing a tubular string in a well bore.

SUMMARY OF THE INVENTION

It is an object of this invention to provide a cementing technique and apparatus for simultaneously rotating and reciprocating a tubular string in a well bore and passing a cementing slurry into the well bore.

Another object of this invention is to provide a cementing technique and apparatus for simultaneously rotating and reciprocating a tubular string while maintaining the rotating tool above the derrick floor and passing a cementing slurry into the well bore.

In summary, the cementing method of this invention comprises rotating a tubular string; reciprocating the string up and down for a stroke of at least 10 feet while rotating the string and maintaining the tool above the floor; and passing a cementing slurry into the well bore during rotation and reciprocation of the string.

In summary, the apparatus of this invention comprises swivel means having a stationary portion including a fluid inlet and means for attaching the swivel means to hoist means for raising and lowering the apparatus, and a rotatable portion including a fluid outlet in communication with the fluid inlet; a power sub having a conduit and means for rotating the conduit; and a cementing sub comprising a conduit and means for launching at least one cementing plug into the tubular string, the power sub conduit and the cementing sub conduit being in torque transmitting relation and in fluid transmitting relation between the swivel fluid outlet and the tubular string.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross section of a portion of a bore hole and drilling rig illustrating the apparatus of this invention;

FIG. 2 is a side elevational view, partly in section, of the swivel illustrated in FIG. 1;

FIG. 3 is a side elevational view, partly in section, illustrating the cementing sub shown in FIG. 1; and

FIG. 4 is a cross sectional view of a portion of a bore hole.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, there is illustrated a drilling rig **10** comprising a floor **12** elevated above a ground surface **14** by a structure **16**. The drilling rig **10** includes a rotary table **18**, a derrick (not shown), a drawworks (not shown) and other typical equipment. A bore hole **20** is illustrated as extending into the earth and penetrating a formation **22**. A tubular string **24** is illustrated as extending into the bore hole **20** and is comprised of a plurality of joints of pipe of any desired size. In a conventional manner, the tubular string **24** carries a plurality of scratchers **26**, a cementing shoe **28** and such other cementing equipment, for example centralizers, float equipment and the like, as may be desired during the cementing of the string **24** in the bore hole **20**.

As mentioned previously, it is highly desirable to simultaneously reciprocate and rotate the string **24** during cementing. To this end there is provided equipment **30** comprising as major components a swivel unit **32**, a rotating tool **34** and a cementing sub **36**. The swivel unit **32** is illustrated as suspended from elevators **38** which are connected by bails **40** to the traveling block (not shown) and drawworks (not shown) which are customarily part of the drilling rig **10**. In summary, the equipment **30** accomplishes simultaneous rotation and reciprocation of the string **24** by energizing the rotating tool **34** simultaneously with raising and lowering of the elevators **38**.

Referring to FIG. 2, the swivel unit **32** is illustrated in greater detail. The swivel unit may be any desired type and is illustrated as a fishing tool swivel manufactured by Texas Iron Works of Houston, Texas. The swivel unit **32** comprises a stationary portion **42** and a rotatable portion **44**. The stationary portion **42** is illustrated as comprising a solid shank **46** having a shoulder **48** thereon received in the elevators **38**. The shank **48** is conveniently threaded into the top of a sleeve **50** which also comprises part of the stationary portion **42**. The sleeve **50** includes a fluid inlet **52**, a fluid passage **54** for transmitting liquids or slurries pumped into the well bore **20** during the course of operation.

The rotatable portion **24** is conveniently made in two parts **56, 58** which are threaded together. Suitable bearings **60** mount the portion **44** for rotation about the centerline of the swivel **32**. Suitable seals **62, 64** and grease fittings **66, 68** may be provided as desired as will be recognized by those skilled in the art. The part **58** comprises a fluid outlet **70** in communication with the fluid inlet **52** and also provides a threaded connection **72** for securement to the rotating tool **34**.

The rotating tool **34** may be of any desired type so long as it has operating characteristics commensurate with its desired functions. As will be more fully apparent hereinafter, the rotating tool **34** transmits liquids or slurries pumped into the swivel unit **32** to the cementing sub **36**, allows reciprocation of the equipment **30** through a stroke of at least 10 feet and rotates the string **26** at desired torque and speed levels. The desired torque level is, of course, less than the collapse strength of the screw couplings which connect the joints of the string **24** together. In a prototype of the invention which has operated satisfactorily, the rotating tool **34** comprised a power sub manufactured by Bowen Tools, Inc., Houston, Texas. This particular device is described in an instruction manual printed December, 1965. As reported on page 23 of this manual, the maximum torque of such devices is 6,000 foot pounds.

The rotating tool **34** is illustrated as comprising a conduit **74** attached at the upper end thereof to the threaded connection **72** and at the lower end therof to the cementing sub **36**. A housing **76** encloses a gear wheel operatively connected to the conduit **74** and driven by a hydraulic motor **78**. The housing **76** includes a bracket **80** apertured to receive a stationary guide **82** therethrough. It will be seen that the rotating tool **34** is constrained for vertical movement by the guide **82** which acts to ensure that the conduit **74** is rotated rather than the housing **76**. The motor **78** is provided with suitable hydraulic lines **84, 86** for delivering and returning power fluid from the motor **78** to a suitable pump (not shown). Suitable controls and pressure gauges are provided as desired. As will be apparent to those skilled in the art, pressure readings from the lines **84, 86** may be used to determine the torque and speed delivered by the motor **78**.

The cementing sub **36** may be of any suitable type and is illustrated in FIG. **3** as comprising a coupling **88** connected to the conduit **74**, a bypass manifold **90**, a conduit **92** connected to the coupling **88** at one end thereof and to a coupling **94** at the other end thereof. Suitable valves **96, 98, 100** are provided to deliver fluid from the manifold **90** to selected locations along the conduit **92**. Cement plug gates **102, 104** are provided for delivering at least one and preferably at least two cementing plugs into the string **24**.

During the cementing process, a clean drilling mud slurry is initially circulated through the well bore by closing the valves **98, 100** and opening the valve **96**. It will be seen that the clean drilling mud passes through the cementing sub **36** without disturbing the cement plugs **106, 108** respectively positioned above the gates **102, 104**. When it is desired to commence delivery of cement into the string **24**, cement is pumped into the fluid inlet **52** while the valve **96** is closed, the valve **98** is opened and the cement plug gate **102** is open. It will be seen that cement passes through the swivel unit **32**, the bypass manifold **90**, the valve **98** and the conduit **92** to force the cement plug **106** from its resting position above the gate **102** into the tubular string **24**. When the desired column of cement has been injected into the tubular string **24**, drilling mud is again pumped into the fluid inlet **52**, the valve **98** is closed, the valve **100** is opened and the cement plug gate **104** is opened. It will be seen that drilling mud will pass through the swivel unit **32**, the bypass manifold **90**, the valve **100** and the conduit **92** to force the cementing plug **108** downwardly into the tubular string **24**. As the cementing plug **108** reaches the cement shoe **28**, the fluid passage therethrough is closed and no further liquid can be injected into the well bore **20**.

It will be apparent that the swivel unit **32** provides an attachment to the hoist means of the drilling rig **10**, provides for the injection of drilling mud and cement slurry into the well bore **20** and allows rotation of the components suspended therefrom. The rotating tool **34** causes rotation of the string **24** and does not interfere with reciprocation of the string **24** throughout a stroke of substantial length. The cementing sub **36** provides for the launching of one or more cementing plugs.

In operation, the tubular string **24** is run through the rotary table **18** into the well bore **20** in a conventional manner. After the last joint comprising the string **24** is run into the well bore **20**, the cementing sub **36** is attached thereto. The rotating tool **34** is then threaded into the top of the cementing sub **36** and the threaded connection between the swivel **32** and the rotating tool **34** is made up. The guide **82** is operatively connected to the bracket **80** and a suitable flexible hose is connected to the fluid inlet **52**. The mechanism **30** is accordingly ready to commence simultaneous rotation and reciprocation of the string **24**.

To reciprocate the string **42**, the driller manipulates the drawworks in a conventional manner to raise the elevators **38** and thereby raise the string **24**. Power hydraulic fluid is delivered through the line **84** to drive the motor **78** and thereby rotate the string **24**. Reciprocation of the string **24** for a stroke less than about **10** feet is not contemplated. Accordingly, the driller continues to raise the elevators **38** until the desired stroke is achieved. By slacking off on the drawworks brake, the weight of the string **24** causes the string **24** and the equipment **30** to fall into the well bore **20**. The rate of descent of the equipment **30** is controlled by the drawworks brake in a conventional manner. Rotating and reciprocating the string **24** in this fashion causes the scratchers **26** to abrade the wall of the bore hole **20** and thereby remove cuttings embedded in the bore hole wall, excess filter cake and the like. During initial rotation and reciprocation, clean drilling fluid is pumped into the inlet **52**, down the string **24**, through the cementing shoe **28** and upwardly through the annulus and is returned to the mudpits in a conventional manner.

After the bore hole **20** has been scratched for some time, the decision is made that the bore hole **20** has been conditioned sufficiently for cementing. Rotating and reciprocation of the string **24** is temporarily halted in order to close the valve **96**, open the valve **98** and open the cement plug gate **102**. The cementing trucks then connect to the flexible hose attached to the fluid inlet **52** and commence pumping a cementing slurry into the equipment **30**. Contemporaneously with the delivery of cementing slurry into the string **24**, rotation and reciprocation of the string **24** is commenced. When sufficient cementing slurry has been introduced into the string **24**, rotation and reciprocation of the equipment **30** is temporarily halted, the valve **98** is closed, the valve **100** is opened, the cementing plug gate **104** is opened and connections are made to pump drilling mud into the fluid inlet **92**. Rotation and reciprocation of the string **24** is again commenced and drilling mud is pumped into the inlet **52**.

When the first cementing plug **106** comes to rest in the cementing shoe **28**, larger ports are usually opened therein and cementing slurry passes into the annulus defined between the well bore **20** and the casing string

24. Pumping of drilling mud through the inlet 52 continues until the second cementing plug 108 contacts the cementing shoe 28. Flow through the cementing shoe 28 is thereupon halted and upward travel of the cementing slurry through the annulus ceases. Rotation and reciprocation of the string 24 continues and results in substantially uniform dispersion of the cementing slurry throughout the bottom part of the annulus.

Rotating and reciprocating the casing string 24 after the second cementing plug 108 is down causes kneading or working of the cement in the annulus to ensure that the cement completely fills the annulus from the bottom of the well bore 20 to a predetermined level above the formation 22. It will be appreciated that the well bore 20 may have washouts or enlargements that need to be completely filled with cement. Rotation of the string 24 aids in complete dispersion of the cement since the scratchers 26 and the centralizers (not shown) act to some extent as paddles. Simultaneous reciprocation of the string 24 acts to some extent as a plunger to propel cementing slurry laterally into washouts and the like.

It is well known in the art that a typical hole is not plumb or perpendicular to the ground surface 14 but instead meanders downwardly into the earth and often assumes a generally corkscrew shape trace. This is illustrated in exaggerated fashion in FIG. 4. The typical manner in which casing is rotated is to maintain the string 24 in tension during rotation. In this circumstance, the string 24 tends to reside along the centerline 110 of the bore hole. Since the string 24 tends to be generally centrally in the bore hole 20, particularly under the influence of conventional centralizers, rotation of the string 24 is not a particularly efficient means of churning the cement in the annulus.

In contrast to this conventional technique, the elevators 38 may be lowered so that at least a substantial part of the weight of the string 24 is borne by the cementing shoe 28 and by frictional engagement of the string 24 with the bore hole wall. This condition is illustrated in FIG. 4 where the string 24 is offset with respect to the bore hole centerline 110. Since the casing string 24 is offset, rotation thereof churns the cement in the annulus to a substantially greater extent than the conventional approach.

Since the cementing shoe 28 is carrying a load in the situation shown in FIG. 4, it is highly desirable to provide a swivel 112 above the cementing shoe 28 to allow relative rotation between the string 24 and the shoe 28. The provision of the swivel 112 substantially reduces the possibility of twisting the string 24 off at the bottom thereof.

I claim:

1. A method of cementing a tubular string, comprised of a plurality of threadably connected joints having thereon means for frictionally engaging a bore hole wall, in a well bore from the floor of a rig with a tool including a hydraulic torque applier and means for controlling the applier for varying the torque output of the tool, the method comprising the steps of rotating the tubular string with the tool;

manipulating the control means for controlling the torque output of the tool so that the torque output thereof can never exceed the strength of the joint couplings;

reciprocating the string up and down for a stroke of at least ten feet while rotating the string and maintaining the tool above the floor; and

passing a cementing slurry into the well bore during rotation and reciprocation of the string.

2. The method of claim 1 wherein the reciprocating step comprises alternately pulling upwardly on the string while rotating the same and allowing the string to move downwardly while rotating the same.

3. The method of claim 1 further comprising the steps of simultaneously rotating the reciprocating the string after delivery of cementing slurry into the well bore.

4. A method of cementing a tubular string, comprised of a plurality of threadably connected joints having thereon means for frictionally engaging a bore hole wall, in a well bore from the floor of a drilling rig spaced above an underlying surface, the method comprising the steps of

running the tubular string through a table on the rig into the well bore;

attaching onto the upper end of the string a tool including a hydraulic torque applier for rotating the string during reciprocation thereof and means for controlling the hydraulic torque applier for varying the torque output of the tool;

rotating the tubular string with the tools;

manipulating the control means for controlling the torque output of the tool so that the torque output thereof can never exceed 6,000 foot pounds;

reciprocating the tubular string up and down for a stroke sufficient to reciprocate the lower string end while rotating the string, the lowermost point of travel of the tool being above the table; and

passing a cementing slurry into the well bore.

5. A method of cementing a tubular string in a larger bore hole comprising the steps of

delivering cementing slurry into a bottom part of the annulus between the string and the well bore;

placing the string in compression; and

rotating the tubular string and maintaining the same in compression while cementing slurry is in the annulus.

6. The method of claim 5 further comprising the step of installing a swivel in the tubular string adjacent the lower end thereof and wherein the placing step comprises the steps of

suspending the string in a well bore with hoist means;

manipulating the hoist means to place the lower string end on the bottom of the well bore; and

manipulating the hoist means to insufficiently support the string therefrom thereby immobilizing the lower end of the string below the swivel and placing the string off center in the well bore.

7. A method of cementing a tubular string, comprised of a plurality of threadably connected joints having thereon means for frictionally engaging a bore hole wall, in a well bore from the floor of a rig with a tool including a torque applier and means for controlling the torque applier for varying the torque output of the tool, the method comprising the steps of

running the tubular string into the well bore;

placing a cementing slurry into the well bore;

rotating the tubular string with the tool;

manipulating the control means for controlling the torque output of the tool so that the torque output thereof can never exceed 6,000 foot pounds; and reciprocating the string up and down for a stroke of at least ten feet while rotating the string and maintaining the tool above the floor.

8. A method of cementing a tubular string in a well bore from the floor of a rig with a tool comprising the steps of

installing a swivel in the tubular string adjacent the lower end thereof;

running the tubular string into the well bore;

immobilizing the lower end of the string below the swivel;

rotating the tubular string with the tool;

passing a cementing slurry into the well bore; and

rotating the upper end of the string after the delivery of cementing slurry into the well bore.

* * * * *