June 5, 1956 T. N. HUDSON 2,749,090

CABLE TOOL DRILL

Filed Oct. 16, 1951 4 Sheets-Sheet 1

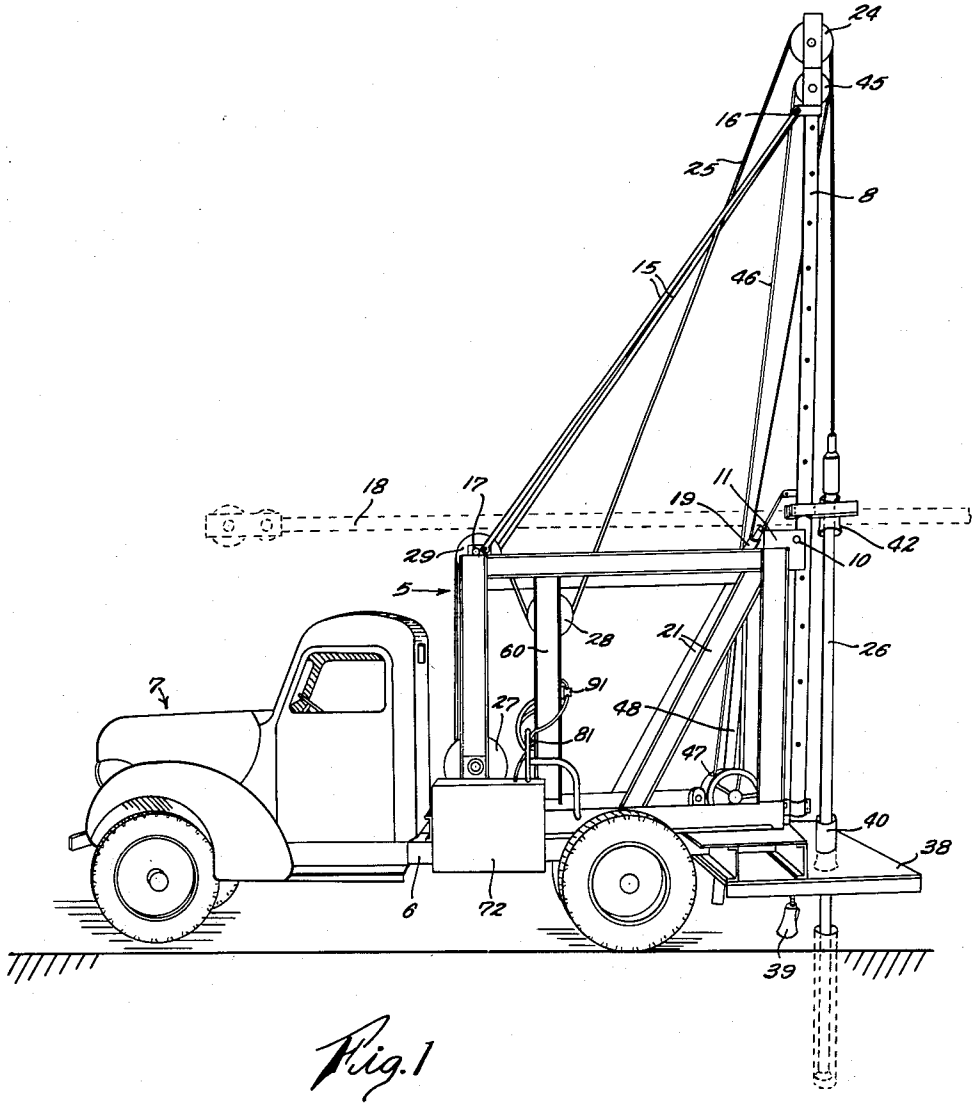

Fig. 1

INVENTOR.
Tom N. Hudson

BY

Murray, Jackhoff & Murray
ATT'YS

June 5, 1956 T. N. HUDSON 2,749,090

CABLE TOOL DRILL

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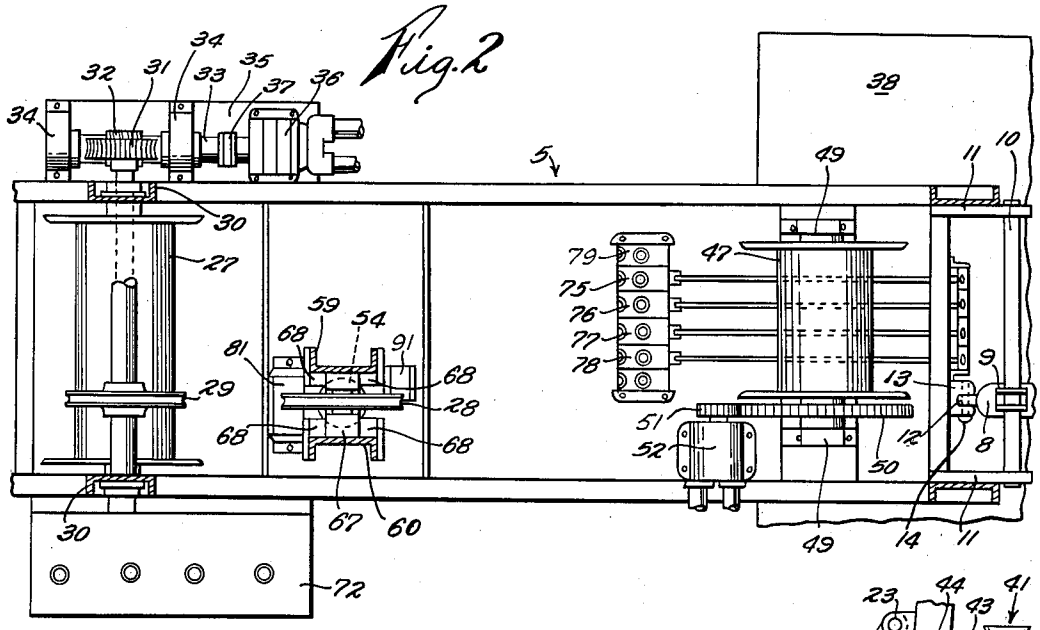
Fig. 2



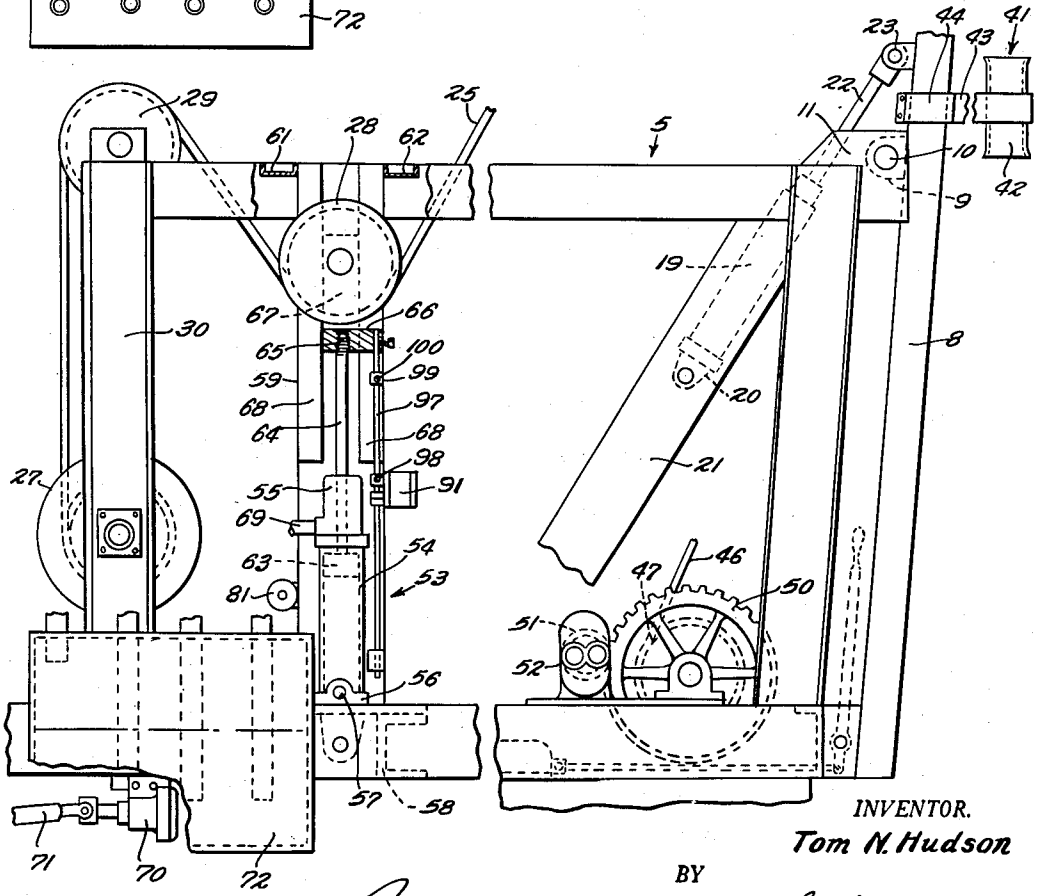


Fig. 3

INVENTOR.
Tom N. Hudson
BY
Murray, Seabloff & Murray
ATT'YS

June 5, 1956 T. N. HUDSON 2,749,090

CABLE TOOL DRILL

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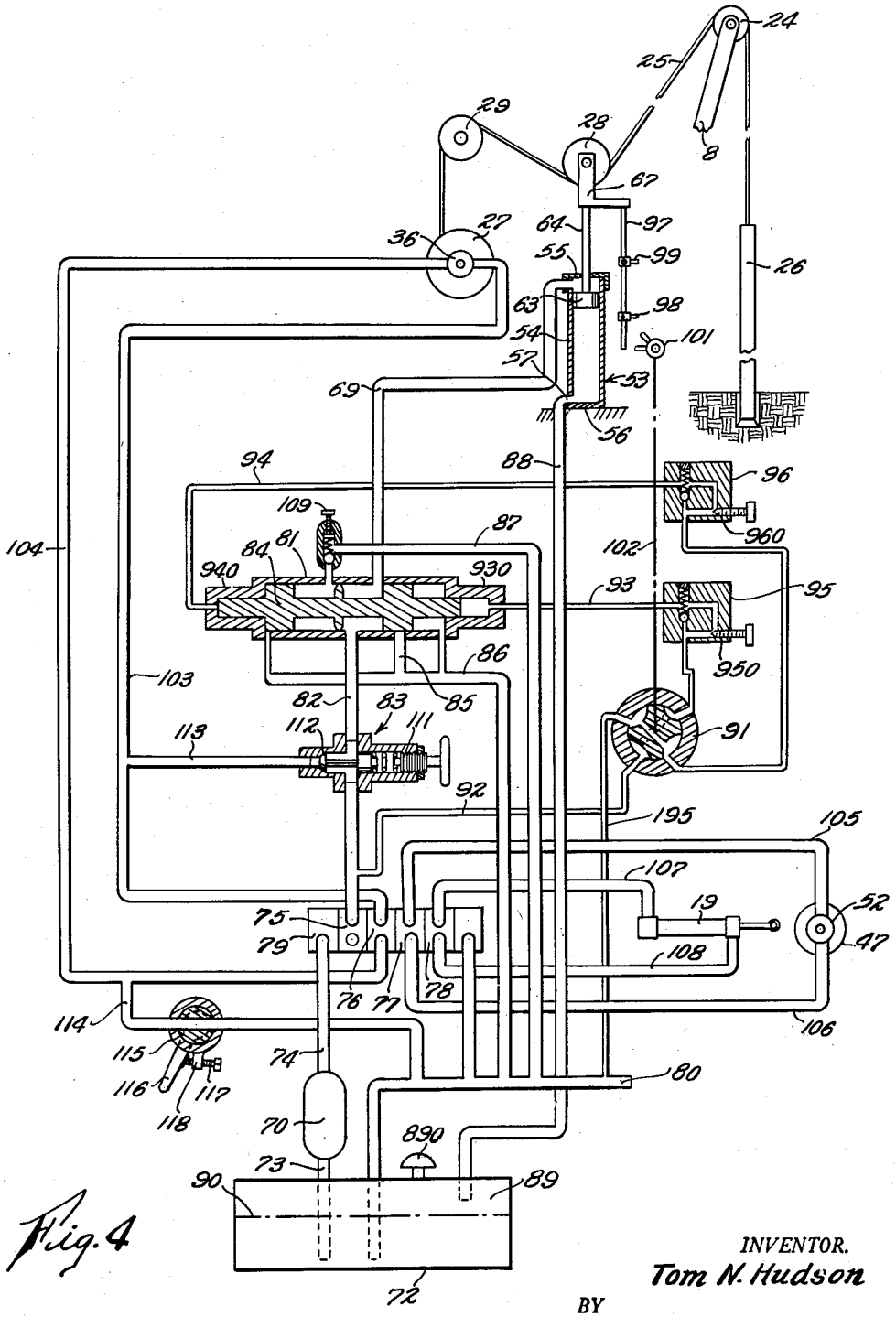

Fig. 4

INVENTOR.
Tom N. Hudson

BY
Murray, Sackhoff & Murray
ATT'YS

June 5, 1956 T. N. HUDSON 2,749,090

CABLE TOOL DRILL

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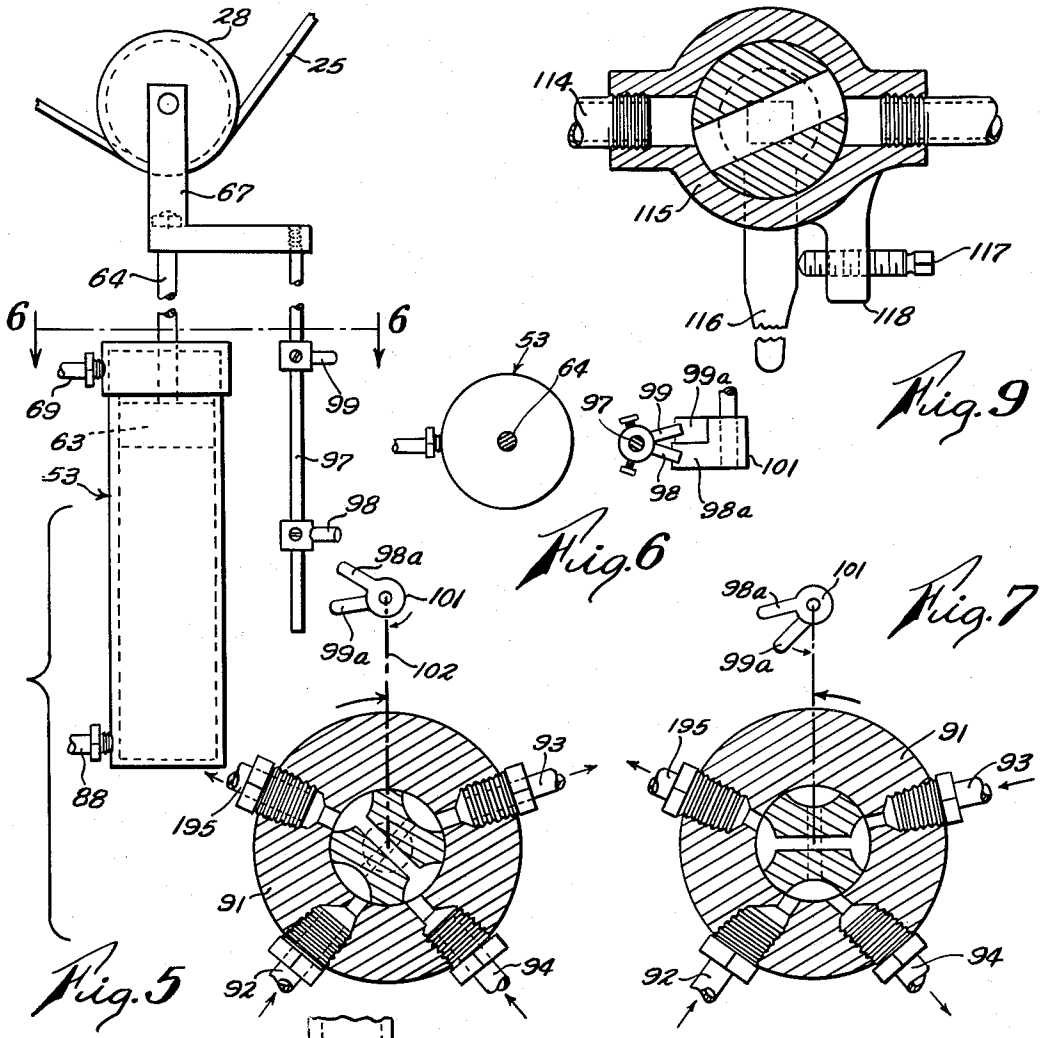

Fig. 5

Fig. 9

Fig. 6

Fig. 7

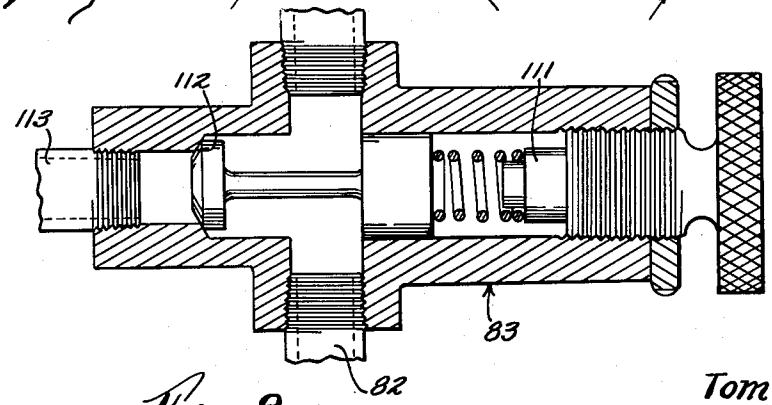

Fig. 8

INVENTOR.
Tom N. Hudson
BY
Murray, Sachhoff & Murray
ATT'YS

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CABLE TOOL DRILL

Tom N. Hudson, Lynchburg, Ohio

Application October 16, 1951, Serial No. 251,499

18 Claims. (Cl. 255—10)

The present invention relates to improvements in cable-tool drills and is particularly directed to novel spudding apparatus for imparting vertical reciprocating movement to the cable suspended tools of well and blast hole drills, and the like.

This application is a continuation-in-part of my co-pending application Serial No. 180,241, filed August 18, 1950, now abandoned.

It is essential to the most efficient operation of a cable-tool drill that, in spite of the widely variant conditions which may be encountered from cycle to cycle, the spudding mechanism must never lag at all behind, nor materially overrun, the normal gravity drop of the tools. Lagging behind will counteract the gravitational acceleration of the tools, thus reducing their velocity, and hence their momentum, and hence their impact upon the bottom of the hole. Material overrunning will have several bad effects, namely: (1) slack in the line, which if pronounced may cause fouling; (2) premature initiation of the return stroke, which premature return (if pronounced) will counteract the gravitational acceleration of the tools, thus reducing their impact (as already spelled out for the case of lag); and (3) a combined effect from slack line and premature return (even though not pronounced), namely a severe jerk on the cable, with resulting shock to the machinery and cable.

No known means exists for adjusting the mechanical spudding devices of the prior art so as to avoid this lag, and this overrunning, which frequently alternate on one and the same machine on one and the same job. The same is true of prior art steam, pneumatic, and hydraulic machines which employ cylinder-piston assemblies to effect spudding.

Accordingly the principal objective of this present invention is to eliminate this lag and this overrunning, or, in other words to provide an automatically self-synchronized drilling operation.

A further objective is thereby to speed up the cable-tool drilling cycle, without any deleterious results.

The character of the cable-tool stroke is of paramount importance. Anything but a true straight fall of the tools reduces the penetrating effect to a surprising degree. Accordingly it is one of my objectives to provide a smooth operation which will give stability to the tools as they fall.

A still further objective is to utilize the same mechanism which solves the above objectives, so as to pay out automatically a quantity of cable that is sufficient for the drill tool to follow the progress of the hole being drilled, whenever, due to the deepening of the hole, the bit fails to strike the bottom of the hole with sufficient impact for effective drilling.

Another object of the invention is to provide in the automatic cable feed set forth in the next preceding object, an adjustable means for regulating the maximum amount of cable payed out for each drill-bit stroke to thereby control the effective drill phase of the bit impact

stroke to obviate overrun of the bit in relatively soft earth strata which would oherwise cause the bit to stick in he hole or preclude a proper churning of the sludge in the hole for free bit movement therein.

Other objects will be apparent from the following specification taken in conjunction with the accompanying drawings which illustrate a preferred embodiment of my invention, it being understood that I am not limited to the particular structure shown except in so far as is set forth in the appended claims.

In the drawings, wherein like reference numerals indicate similar parts throughout the several views:

Fig. 1 is a perspective view of a drilling rig embodying the features of my invention.

Fig. 2 is a fragmental plan view of the well drilling rig shown in Fig. 1, parts thereof being shown in section.

Fig. 3 is a fragmental side elevational view of the rig, the spudder device being shown in section.

Fig. 4 is a diagrammatical view of the hydraulic system for operating the drilling apparatus of the invention.

Fig. 5 is an enlarged detail view of the directional controls for the piston-cylinder assembly for my cable tool drill showing the parts in the position indicated in Fig. 4 to raise the tool.

Fig. 6 is a section taken on line **6—6** of Fig. 5.

Fig. 7 is a view of the pilot valve similar to Fig. 5 showing said valve in position to permit the tool to descend by gravity into the hole being drilled.

Fig. 8 is an enlarged detail view of the cable feed valve shown in Fig. 4.

Fig. 9 is an enlarged detail view of the regulator cock shown in Fig. 4, depicted in open position but with the stop bolt set for a reduced flow of fluid therethrough.

The preferred embodiment of my invention comprises a frame **5** suitably mounted upon the chassis **6** of a motor vehicle **7**. This frame is made from a number of metal structural members bolted or welded together to form an open and rigid box-like structure which carries all the parts of the rig. The rear end of the frame supports a mast **8** which is pivotally mounted intermediate its ends to the upper rear portion of the frame. To this end a U-shaped bracket **9** (Figs. 2 and 3) is welded to the mast, the ears therefor having aligned eyes through which a cross shaft **10** extends, said cross shaft being anchored in side plates **11—11** secured to the frame. The lower end of the mast has a downwardly extending lug **12** which is received in a boss **13** fixed to the frame, a removable pin **14** being provided for connecting said parts to hold the mast in an upright position for normal operation of the rig. The mast is braced by two rods **15—15** pivotally mounted at **16** to the upper portion of the mast and secured at their lower ends to the front upper corners of the frame by detachable ball and socket joints **17**. The mast may be lowered to a horizontal position upon the frame, indicated by dotted lines **18** in Fig. 1, by means of a fluid motor **19** which has its cylinder clevis **20** mounted between inclined frame members **21—21** and its piston rod **22** pivotally connected to the mast by a bracket **23** situated above the cross shaft **10**.

In the operative position of the rig, illustrated in Fig. 1, the upper end of the mast **8** carries a crown pulley **24** over which a cable **25** passes for suspending a percussion drill-bit **26** for vertical reciprocating motion. As most clearly shown in Figs. 1 and 3 the end of the cable opposed to its drill tool connection is wound around a winch **27**, whilst the intermediate portion of the cable between the winch and crown pulley engages a reciprocated spudding means, such as shav **28**, and preferably passes over a suitable idler pulley **29** located between the spudder means and the winch. As best shown in Fig. 2 the winch 27 is mounted between two forward,

upright posts 30—30 of the frame in suitable journal bearings, the winch shaft extending through one post and having a pinion 31 fixed thereto for meshing engagement with a worm 32 fixed to shaft 33. The shaft 33 is journaled in spaced blocks 34—34 that are secured to a platform 35 extending from the side of the frame 5. The worm shaft is driven by a fluid motor 36 also mounted upon the platform and which has a flexible drive connection 37 with said motor.

An operator's platform 38 is mounted beneath, and extends from, the rear portion of the frame, and, as illustrated in Fig. 1, suitable jacks 39 or other removable means are interposed between the ground and the platform to provide a firm support for the rig during the drilling operation. The platform carries a large bell shaped sleeve 40 which acts as a lower guide for the drill-bit. As best shown in Fig. 3 an upper guide 41 for the tool is carried by the mast 8 and comprises a sleeve 42 having a flared mouth at each end, said sleeve being secured to an arm 43, that is swingably mounted to the mast at 44. The upper end of the mast has also mounted thereon a pulley 45 over which a cable 46 passes, said cable being wound around a bailing reel 47 and having its free end secured to the usual well bailer 48 which stands beside the rig while the drilling operation is in progress and is let down into the well by the reel 47 and cable 46 after removal of the bit therefrom to clear the well of chips and the like. With reference to Figs. 2 and 3 numerals 49—49 show bearing blocks mounted on the frame for journalling the shaft for the reel 47, said reel having fixed thereto a large gear 50 which meshes with a gear 51 driven by a fluid motor 52.

The means for vertically reciprocating the drill-bit through its cable connection with the spudding means 28 consists of a fluid-pressure actuated, single acting cylinder-piston assembly illustrated in the drawings as an hydraulic, reciprocating motor 53 having an actuating connection with said spudding means. As best shown in Figs. 2 and 3 this motor has a vertical cylinder 54 with a closed end 55 and an opposite end 56 which has a breather port 57 formed therein. The open end of the cylinder is mounted by bolts, or the like, to a cross member 58 of the frame and is situated between opposed channels 59 and 60 welded at their lower ends to said cross member and secured at their upper ends to two spaced transverse channels 61 and 62 extending between the upper longitudinal members of the frame.

A piston 63 is slidable in the cylinder toward and away from the closed end 55 and has secured thereto a piston rod 64 which preferably passes through said closed end and is threaded at its upper end in a threaded bore 65 formed in the cross piece 66 of a U-shaped block 67 carrying the spudding sheave 28. The block is guided between the channels 59 and 60 for reciprocating movement by four corner members 68 (Fig. 2) which are each secured to a side of the inner face of said channels to form two opposed vertical guide-ways in which the spudding block slides.

As most clearly illustrated in Fig. 4 the bit raising work strokes of the motor are effected by a fluid pressure system preferably using an hydraulic operating medium. The system introduces pressure fluid into a pressure conduit 69 connected to the pressure cylinder intermediate the closed end 55 and the piston 63, said means also having means to alternately constitute the conduit a fluid drain line for exhaust of the pressure fluid from the cylinder to permit the piston return stroke to be effected by the gravity actuated work stroke of the drill-bit.

The pressure supply means for the spudder comprises a constant displacement pump 70 mounted on the frame and preferably driven by a power take off shaft 71 connected to the transmission of the engine of motor vehicle 7. The driven pump takes fluid from a sump tank 72 mounted on the side of the frame by a line 73 immersed at its lower end in fluid which only partially fills the tank. The pump delivers fluid under pressure through pressure supply line 74 to a bank of conventional master control valves 75, 76, 77 and 78 each controlled by a manual lever mounted adjacent the operator's station and connected to its valve by an individual link (Figs. 2 and 3). This bank of master control valves functions to introduce pressure fluid to, and exhaust fluid from, one or a number of the motors for the rig when the particular "off-on" control lever or levers therefor are operated, and, in the event pressure in the fluid systems served by any of the master control valves exceeds a predetermined maximum, excess fluid pressure from the pump is returned to sump through a conventional master relief valve 79 that is connected to a drain line 80 by an internal passageway (not shown) extending through the bank.

With respect to the pressure conduit 69 for the spudding means it will be noted that it is connected to a reversing valve 91 preferably located on the spudder supports 59—69, and that said valve in turn is connected to the pressure fluid delivery port of the master control valve 75 by means of a pressure line 82 which has an adjustable cable feed valve 83 interposed therein. This valve 83 might equally well be in, or leading off of, line 69 or line 74 or the upper end of cylinder 53, the only requirement being that it lie somewhere in, or lead off of some part of, the pressure circuit between pump 70 and the pressure face of piston 63.

It will therefore be noted that fluid under pressure will be delivered to the closed end 55 of the cylinder 54 to effect a bit raising work stroke when a spool 84 of the reversing valve 81 is in the position depicted in Fig. 4 of the drawing. In said spool position pressure fluid will be delivered by the pump 70 through line 74, master valve 75, line 82, reversing valve 81 and the pressure conduit 69. Upon reversal of the spool position from the left to the right side of the valve 81 the pressure conduit 69 is connected to the drain line 80 through branch line 85, which has a connection to said drain through a line 86. Said spool position also directs the full volume of pressure fluid in line 82 to sump 72 through a drain line 87 and the drain line 80. Adjustable constriction 109, which preferably should take the form of a valve which can be adjustably set to open only at a predetermined pressure, is interposed in drain-line 87, for the purpose of maintaining a predetermined minimum pressure in the pilot means for the reversing valve 81 sufficient to operate said reversing valve even when pressure fluid is being by-passed from pump to sump. A further object of this back pressure, set up by valve 109, is to maintain a minimum pump engine load at all times, so as to prevent too wide changes in the engine load with the resulting lag in pump output behind demand, which lag would slow up the drilling cycle. In this reversing valve position the conduit 69 becomes a drain line and the weight of the bit raised to a potential working position is substantially free to fall to deliver from said position a blow to the bottom of the hole being drilled, the fall of the bit being impeded only by a counter force sufficient to drive fluid from the closed end of the cylinder through the conduit 69 back to sump.

As has been specified heretofore the cylinder end 56 has a breather port 57 therein. This port is preferably connected by a pipe 88 to the closed space 89 in the sump tank 72 above the level of the pressure fluid which is indicated by the reference numeral 90 in Fig. 4. This closed space communicates with the atmosphere by a suitable filter and air breather 890. The line 88 also serves as a drain for pressure fluid that may leak past the piston from the cylinder pressure side during the piston work stroke.

The actuation of the reversing valve 81 is accomplished by a pilot means comprising a valve 91 located on the spudder support 59. The pilot valve is connected to the fluid pressure line 82 by a pipe 92, and upon oscillation

through 45°, alternately constitutes lines **93** and **94**, connected to opposite ends of the reversing valve **81**, one a pressure line and the other simultaneously a drain line, or one a drain line and the other simultaneously a pressure line for shifting the spool **84** to the left-hand or right-hand end respectively of the said valve. As illustrated in Fig. 4 pressure fluid from either lines **93** and **94** enters the respective ends of the valve **81** which are preferably provided with auxiliary cylinder-piston assemblies **930** and **940** respectively. The lines **93** and **94** each have a back check ball valve **95** and **96** respectively interposed therein which permit free flow of pressure fluid toward the reversing valve through their respective lines, each of said valves having a by-pass conduit with an adjustable choke valve **950** and **960** respectively therein, to meter fluid expelled from the respective ends of the reversing valve at a predetermined rate to thereby control the rate of spool reversal of said valve. Drain fluid from the pilot valve is directed through line **195** to the drain line **80**. If the operation of the balls in valves **95** and **96** were reversed, these valves, and the by-pass conduits and adjustable choke valves **950** and **960**, would perform identically the same functions as now, except that each valve would meter the input of pressure fluid from the pilot valve to the reversing valve, instead of the exhaust from the reversing valve to the pilot valve, and accordingly each would control the opposite direction of motion of the spool **84** from that which characterizes the illustrated form of the choke valves.

The pilot valve is operated by a means responsive to the movement of the spudding means **28** which automatically reverses the means between predetermined limits prescribing the working cycle of the drill-bit. Said responsive means comprises a control rod **97** fixed to and bodily movable with the sheave block **67** and carrying an upper bit reversing pin **99** and a lower bit reversing pin **98**, each adapted for axial adjustment along the rod. The position of the pin **98** determines the position of the piston in the cylinder at which reversal takes place to raise the bit. The position of the pin **99** determines the position of the piston in the cylinder at which reversal takes place to cause the bit to fall. Therefore the distance between the two pins determines the length of the stroke. But, inasmuch as neither the depth of the hole nor the length of the cable are fixed distances, the position of neither pin determines at what position of the bit with respect to the bottom of the hole, either reversal takes place. The position with respect to the bottom of the hole at which each reversal (and more particularly the lower) takes place is controlled by paying out the cable or taking it in. These pins are fixed to the rod in adjusted positions by means of set screws **100** threaded therein and bearing, when tightened, upon the rod. The pins **98** and **99** alternately engage an individual arm **98***a* and **99***a*, respectively, each an integral projection on a reversing dog **101** which is fixed on the moving part of the pilot valve **91** as indicated by the dot and dash line **102** in Fig. 4.

With particular reference to Figs. 5, 6 and 7 it will be understood that the pin **98** reciprocates in the plane of the arms **98***a* and the pin **99** reciprocates in the plane of the arm **99***a*, the latter plane being parallel to and spaced from the plane of reciprocation of the pin **98**. In Figs. 4 and 5 there is illustrated the clockwise position of the pilot valve **91** just as the piston rod has completed its ascent and after the pin **98** has engaged the arm **98***a* and tripped it to the position depicted in the said figures. In said clockwise position pressure fluid from pipe **92** will flow through the dotted line passageway in the spool of the pilot valve **91** and from thence to end **930** of the reversing valve **81** by way of pipe **93**, and valve **95**, while fluid is exhausted from the opposite end **940** of the reversing valve through pipe **94**, valve **96**, the full line passageway in the spool of the pilot valve **91** and exhaust pipe **195**. In the position of the reversing valve spool shown in the drawing, pressure fluid from pipe **82** will be admitted to the piston-cylinder assembly through pipe **69** to raise the drill bit **26** until it approaches its upper limit of motion when the pin **99**, in the course of its descending motion engages the arm **99***a* which trips the pilot valve **91** and moves its spool to the counterclockwise position shown in Fig. 6 of the drawings. In the counterclockwise position of the pilot valve pressure fluid from pipe **92** will be directed to the end **940** of the reversing valve **81** via pipe **94** and valve **96**, thus shifting the spool **84** to the right which spool motion (Fig. 4) exhaust fluid from the end **930** of the reversing valve through line **93**, the pilot valve spool and thence to sump through exhaust pipe **195**. When the spool **84** of the reversing valve is shifted to the right the pipe **69** is connected to the sump connected exhaust pipe **85** thus permitting the tool to freely fall by gravity into the hole being dug; whilst the pressure pipe **82** is connected to the return line **87** that has the pressure relief valve **109** therein.

The cable winch motor **36** has alternate pressure and drain lines **103** and **104** which are connected to the master valve **76**, whilst the bailing reel motor **52** for the rig is provided with similar lines **105** and **106** that are connected to the master valve **77**. Master valve **78** is connected to the mast raising and lowering motor **19** by alternate pressure and drain lines **107** and **108**, it being understood that drain fluid returned to the master valve bank is returned to sump through a branch line within the valve that is connected to all the drain lines and to the drain pipe **80**.

By moving the manual lever for the master valves **76**, **77** and **78** inclusive their respective motors **36**, **52** and **19** may be operated and their speeds and directions of drive regulated in the usual manner. With respect to the cable winch motor **36**, for example, one position of the valve **76** and its lever is adapted to constitute line **103** a pressure conduit and line **104** an exhaust conduit to actuate the said motor in a direction to pay out the cable **25** whilst an opposed position of the valve and lever is adapted to introduce fluid pressure into line **104** thereby constitutng line **103** an exhaust conduit thus reversing the drive direction of the motor. The valve may also have intermediate positions on each side of a central "off" position for regulating the rate of delivery of pressure fluid into either of the lines **103** and **104** to change the speed and/or the power of the motor **36**, as will be readily understood by those skilled in the art.

Referring now to the automatic actuating means for the cable winch **27** which is adapted to feed or pay out sufficient cable to the drill-bit so that the latter closely follows the progress of the hole being drilled, it will be noted that the cable feed valve **83** (Figs. 4 and 8) has a manually adjustable setting stem **111** which regulates the spring load on a pressure responsive element which takes the form of a valve head normally seated in a port **112** communicating with a through-passageway for the pressure conduit **82** in the valve body. The cable feed valve has a setting less than the master relief valve **79** and is therefore adapted to open at a predetermined pressure in line **82** and when opened directs pressure fluid from said line into the line **103** for the winch motor **36** via line **113**, provided that regulator cock **115** (Figs. 4 and 9) is open, so that line **104** and by-pass line **114** can serve as a return line from said winch motor to sump **72**. The cable feed valve **83** therefore controls the predetermined maximum pressure to be maintained in the system for a given operation, said valve being set to open at a pressure slightly greater than the pressure required for lifting the drill-bit during the normal operation of the cable-tool motor **53** after the bit has struck a free falling blow on the bottom of the hole being drilled. When digging in rock, the bit after striking the bottom of the hole normally bounces before the piston **63** reverses, and hence the piston has merely to continue the thus initiated upward movement of the bit. When drilling in softer

materials, although the piston has to initiate the uplift, it normally does not have to start to do this until after the drop of the bit has been stopped by impact with the bottom of the hole, and so normally the piston does not have to overcome any downward momentum of the bit. But, as the drilled hole is deepened with a given length of cable, the rebound of the bit from the bottom of the hole becomes less (in the case of rock drilling) or the bit is still falling when the piston starts its upstroke (in the case of drilling in softer materials), and the resulting additional work-load on the piston sets up an abnormal back-pressure in line **69**. This abnormal back-pressure instantly trips cable feed valve **83** (which has been adjusted to respond to the appropriate back-pressure characteristic of the material being drilled), and the valve thereupon discharges a slug of pressure fluid into line **103** which slug of pressure fluid actuates the winch motor **36** to unwind or pay out enough cable to restore normal impact of the bit against the bottom of the hole for immediately succeeding bit strokes. The cable feed valve continues to monitor the cable-tool during the entire drilling operation to the end that the bit stroke is constantly adjusted for maximum drilling efficiency.

The movable element for the adjustable stop and volume regulating cock **115** is connected to a suitable hand lever **116**. The open position of the movable valve element is determined by an adjustable stop bolt **117** threaded in a lug **118** extending from the valve body. Adjustment of the stop will control the effective size of the discharge orifice in the cock and therefore regulate the volume of fluid to be exhausted from line **104** when the cable feed valve **83** is operative to discharge a slug of pressure fluid into line **103**. By this control of fluid discharged from line **104** the maximum rate of flow of fluid in the winch motor system during automatic feeding is predetermined, and consequently the maximum amount of cable that can be paid out by the winch for each actuation of the cable feed valve will also be determined by the setting of cock **115**. When the cock **115** is in an open position shown in Fig. 4 of the drawing the cable-tool drill is said to be on "automatic setting."

When the machine is operated on "manual control"; i. e. the cock **115** is closed and the cable winch motor operated by actuation of the master valve **76**; the cable feed valve does not operate, and the cable-bit motor system is then protected by the master relief valve **79** which will prevent abnormal pressures from building up in the system. This valve **79** will operate if the drill-bit should stick or the operator fail to lower the bit properly by actuating valve **76** to pay out the cable on the winch **27** as the drilling progresses and the well is deepened. The relief valve **79** will also permit the machine to be operated at full speed even though the bit is not striking the bottom of the hole. Should the bit stick in the hole said relief valve will maintain sufficient pressure in the cable-tool motor system to lift the tool without damage to the machine, while the usual methods are applied to free the bit. If there is not sufficient force to raise the bit, the spudder may be disengaged and the bit raised with the winch **47**.

In the operation of my rig the cable feed valve **83** is adjusted to the mass of the particular drill-bit **26** to be reciprocated. As drill bits vary considerably in weight and are interchangeable on drilling apparatus it is of prime importance that the cable feed valve adjustment be made with a newly installed tool. To this end the cable feed valve **83** is closed to an adjustment which will direct all the pressure fluid delivered to it into line **69**. The pump **70** is then put in operation and the tool reciprocated. The cable feed valve is then opened until pressure fluid is introduced into the line **113** to cause the bit to strike the bottom of the hole with the proper impact. The cable feed valve is then set in adjusted condition and remains thereat as long as that particular bit is used with the rig for normal drilling operations. It may be necessary when drilling extremely deep wells to readjust the cable feed valve to compensate for the additional weight of extremely long cable lengths that suspend the drill-bit.

I have shown and described my automatic feed as applied to a reversible hydraulic winch, which winch is primarily directed to paying out and hauling in the cable which suspends the drill-bit. In the foregoing description, my automatic feed utilizes the normal alternative feed and exhaust lines **103** and **104**. However, my automatic feed is equally applicable to a winch, so geared that the normal reeling and unreeling is accomplished by some other power source (as, for example, the gearing shown and described in the co-pending application of Johann H. Meier, Serial No. 618,843, filed September 27, 1945, now Patent 2,587,638 for improvements in automatic feed for cable-tool drill), in which event lines **103** and **104** will perform no other function than as conduits for my automatic feed. In fact line **104** could be omitted in connection with an appropriate type of unspooling drive (as, for example, the cylinder piston actuated ratchet shown and described in the copending application of Trevor O. Davidson, Serial No. 219,481, filed April 5, 1951, for improvements in automatic feed for cable-tool drill).

As illustrated in Fig. 4 the hydraulic system is in condition to initiate a drill-bit raising stroke. Introduction of fluid pressure to the closed end of the cylinder **54** will cause the drill-bit to be raised to its upper, potential working position. As the spudder sheave **28** descends, during the cylinder working stroke, pin **99** trips the dog **101** on the pilot valve to reverse the spool position of the reversing valve **81**, the speed of reversal being determined by the adjustment of the back check valve **95** which meters the fluid trapped in its valve side through the choke valve **950** whilst returning it to drain through line **195**. A relatively slow reversal is desirable at the top of the drill-bit stroke to uniformly decelerate the bit and reverse its uppermost limit of motion thereby keeping sufficient tension in the cable to prevent undesirable whipping motions therein. The choke valve **950** may therefore be adjusted towards closed position.

In reversed position the drill-bit descends with a substantially free falling motion upon the bottom of the hole being drilled in stone, or the like, thereby delivering a maximum blow on relatively hard obstructions in the well bottom. After impact, the bit will normally rebound, and it is at this point in the drill-bit cycle that my spudding means reverses itself and picks up the bit during the initial rebound motion and raises it to its potential working position with a continuous motion and at a rate closely approximating the said initial rebound motion, subject only to uniform deceleration at the upper portion of the bit stroke preparatory to bit reversal. To this end the choke valve **960** is relatively open so that quick reversal of the piston movement is effected when the stop **98** actuates the dog **101** to initiate the raising stroke of the bit. The adjustment of the choke valve **960** is made whilst the rig is in operation on a particular earth stratum, said adjustment being made by observation of the cable at the point of bit rebound until a minimum vibratory motion is noticeable in the cable.

Having now described and illustrated one form of my invention, I wish it to be understood that my invention is not to be limited to the specific form or arrangement of parts herein described and shown.

What is claimed is:

1. In a cable-tool drill having a cable engaging spudding means adapted to impart vertical reciprocating motion to a percussion drill-bit suspended by a cable, the combination of: a fluid pressure actuated single-acting cylinder piston assembly; a sump; a pressure source for the fluid; a conduit connecting the pressure source to the sump, whereby the pressure source can draw hydraulic fluid from the sump; means connecting the cylin-

der piston assembly to the cable engaging means to raise the drill-bit; a pressure conduit leading from the pressure source; at least one exhaust conduit leading to the sump; a conduit leading to the actuating side of the cylinder piston assembly; a reversing valve connecting the pressure, exhaust, and cylinder-piston conduits, and having two positions, namely (1) connecting the pressure conduit to the cylinder piston conduit, and (2) connecting the pressure conduit and the cylinder piston conduit each to an exhaust conduit; pilot means; operating connection means between the pilot means and the reversing valve, to set the reversing valve responsive to the setting of the pilot means; actuating connection means between the cylinder piston assembly and the pilot means, whereby the cylinder piston assembly near the end of the fall of the drill-bit sets the pilot means to set the reversing valve in its first-mentioned position, and whereby the cylinder piston assembly near the end of the rise of the drill-bit sets the pilot means to set the reversing valve in its second-mentioned position, and delayed-action means interposed in said operating connection means to control the rate of response of the reversing valve to at least one of the settings of said pilot means.

2. A cable-tool drill according to claim 1, characterized by the fact that the reversing valve is fluid pressure actuated; that the pilot means is a two-position pilot valve; and that the operating connection means between the pilot valve and the reversing valve comprises two fluid conduits.

3. A cable-tool drill according to claim 1, further characterized by the fact that there are two exhaust conduits leading from the reversing valve; that the second setting of the reversing valve connects the pressure conduit to one of these exhaust conduits, and connects the cylinder piston conduit to the other of these exhaust conduits; and that there is in the first of these two exhaust conduits an adjustable constriction, whereby, when the reversing valve is set as above, to maintain in the system a predetermined constant pressure.

4. A cable-tool drill according to claim 3, further characterized by the fact that the adjustable constriction is a valve which can be adjustably set to open only at a predetermined minimum pressure.

5. A cable-tool drill according to claim 1, further characterized by the fact that there are two exhaust conduits leading from the reversing valve; that the second setting of the reversing valve connects the pressure conduit to one of these exhaust conduits, and connects the cylinder piston conduit to the other of these exhaust conduits; and that there is in the first of these two exhaust conduits a constriction, whereby, when the reversing valve is set as above, to maintain in the system a predetermined constant pressure.

6. A cable-tool drill according to claim 5, further characterized by the fact that the constriction is a valve set to open only at a predetermined minimum pressure in the pilot means.

7. A cable-tool drill according to claim 1, characterized by the fact that the reversing valve is fluid pressure actuated; that the pilot means is a two-position pilot valve; that the operating connection means between the pilot valve and the reversing valve comprises two fluid conduits; and by having in at least one of these two conduits an adjustable constriction to delay the response of the reversing valve to a change in setting of the pilot valve; a by-pass around said constriction; and a check valve in said by-pass to permit flow only in one direction through said by-pass, said direction being such that the rate of shift of the reversing valve into its first-mentioned position is unrestricted by said adjustable constriction.

8. A cable-tool drill according to claim 7, characterized by having: a similar constriction in the second conduit; a by-pass around each constriction; and a check valve in each by-pass, both check valves being oriented so as to permit flow only in the same direction between the pilot valve and the reversing valve.

9. In a cable-tool drill having a cable engaging spudding means adapted to impart vertical reciprocating motion to a percussion drill-bit suspended by a cable, the combination of: a fluid pressure actuated cylinder piston assembly; a pressure source for the fluid; means for connecting the cylinder piston assembly to the cable engaging means to raise the drill-bit; a pressure conduit leading from the pressure source; at least one exhaust conduit; a conduit leading to the bit raising side of the cylinder piston assembly; a reversing valve connecting these conduits, and having two positions, one of which connects the pressure conduit to the drill-bit raising cylinder piston conduit; a winch for the cable of the drill, a fluid pressure motor to actuate the winch to unwind the cable; a pressure conduit leading to this motor; a pressure responsive cable feed valve connected to the pressure circuit for the cylinder piston assembly, said valve being set to discharge pressure fluid from said pressure circuit into the pressure conduit leading to the motor whenever the pressure in said circuit exceeds the normal operating drill-bit raising pressure, whereby the liquid thus admitted to the motor by virtue of the excess pressure in the pressure circuit will operate the motor to actuate the winch to unwind the cable.

10. A cable-tool drill according to claim 9, characterized by the fact that the winch motor is reversible; that this motor has two conduits; that there is a reversing valve to selectively connect one of the two conduits of this motor to the pressure source, and the other to exhaust; that there is a conduit which connects to exhaust, bypassing this reversing valve, the one of the two winch motor conduits which serves as the exhaust conduit when the winch motor is unwinding the winch; and that there is in this by-pass conduit a stop cock to selectively open or close this conduit at will, thereby selectively bringing automatic control of unspooling into play, or permitting only manually controlled spooling and unspooling.

11. A cable-tool drill according to claim 10, characterized by the fact that the effective orifice of the stop cock is adjustable to regulate the volume of fluid discharged from the exhaust conduit into the by-pass conduit.

12. In a cable-tool drill having a cable engaging spudding means adapted to impart vertical reciprocating motion to a percussion drill bit suspended by a cable, the combination of: a fluid pressure actuated means connected to the spudding means for raising the drill bit, a cable winch, power actuated means operatively connected to the winch to rotate the winch to unspool the cable therefrom, and means responsive to abnormally high back-pressure conditions in the fluid pressure actuated means to admit power to the power actuated unspooling means due to the drill bit continuing to fall after the motor is reversed to raise the drill bit.

13. In a cable-tool drill having a cable engaging spudding means adapted to impart vertical reciprocating motion to a percussion drill bit suspended by a cable, the combination of: a fluid pressure actuated motor having a reciprocated element controlled to move in a fixed cycle and connected to the spudding means, a pressure source for the fluid, a pressure circuit connecting the pressure source to the motor for raising the drill bit, a cable winch, a power actuated drive means for operating the winch to unspool the cable therefrom, and a pressure responsive means connected in the pressure circuit and actuable by abnormally high back-pressure conditions in the said circuit due to the drill bit continuing to fall after the motor is reversed to raise the drill bit to admit power to the power actuated drive means to unspool the cable.

14. In a cable-tool drill having a cable engaging spudding means adapted to impart vertical reciprocating motion to a percussion drill bit suspended by a cable, the

combination of: a fluid pressure actuated motor having a reciprocated element controlled to move in a fixed cycle and connected to the spudding means, a pressure source for the fluid, a pressure circuit connecting the pressure source to the motor for raising the drill bit, a cable winch, a fluid pressure drive means for operating the winch to unspool the cable therefrom, and a normally closed pressure responsive valve connected in the pressure circuit and openable by abnormally high back-pressure conditions in the said circuit due to the drill bit continuing to fall after the motor is reversed to raise the drill bit to admit fluid pressure to the drive means to unspool the winch.

15. A cable-tool drill according to claim 14 characterized by the fact that the pressure responsive valve admits pressure fluid from the said circuit to the drive means to unspool the winch.

16. In a drilling apparatus, the combination of: a reciprocated spudder sheave adapted to impart vertical reciprocating motion to a drill tool; an hydraulically actuated reciprocating motor connected to the sheave and including a single acting pressure cylinder having a closed end and a breather port formed in its opposite end to permit free fall of the drill tool; a piston movable in the cylinder toward and away from the closed end; a sump; an hydraulic pump; a fluid conduit connecting the pump to the sump whereby the pump can draw hydraulic fluid from the sump; a second fluid conduit operatively connected to the cylinder intermediate the piston and the closed end; a fluid pressure actuated reversing valve connected to the second fluid conduit; a pressure fluid conduit connecting the reversing valve to the pump; an exhaust conduit connecting the reversing valve to the sump; said fluid pressure actuated reversing valve being adapted to shift to alternatively connect the second conduit to the pump to actuate the motor and to the sump to exhaust the motor cylinder; a pilot valve; hydraulic lines connecting the pilot valve to the reversing valve to actuate the latter; means responsive to the movement of the sheave to shift the pilot valve; a choke valve associated with the reversing valve to vary the rate of shift of the reversing valve; a by-pass around said choke valve; and a check valve in said by-pass to permit flow only in one direction through said by-pass, said direction being such that the rate of shift of the reversing valve to connect the second conduit to the pump to actuate the motor is unrestricted by said choke valve.

17. In a cable-tool drill having a cable-engaging spudding means adapted to impart vertical reciprocating motion to a percussion drill bit suspended by a cable, the combination of: fluid pressure actuated means connected to the spudding means for raising the drill bit, a first fluid pressure circuit operatively connected to said fluid pressure actuated means to actuate the same, a cable winch, a cable unspooling device operatively connected to the winch, a second fluid pressure circuit operatively connected to said cable unspooling device to actuate the same, valve means having a normally unactuated position and an actuated cable unspooling position, said valve means being interposed in said second fluid pressure circuit, means normally biasing said valve means to assume its unactuated position, and means connecting said valve means to said first fluid-pressure circuit to introduce fluid pressure in opposition to said biasing means so that said valve means will be actuated to assume its cable-unspooling position responsive to abnormally high back pressure in said first fluid pressure circuit due to the drill bit continuing to fall after the fluid pressure actuated means is reversed to raise the drill bit.

18. In a cable-tool drill having a cable engaging spudding means adapted to impart vertical reciprocating motion to a percussion drill bit suspended by a cable, the combination of: a fluid pressure actuated motor having a reciprocated element connected to the spudding means, a pressure source for the fluid, a fluid pressure circuit connecting the pressure source to the motor for raising the drill bit, a cable winch, power-actuated cable unspooling means operatively connected to the winch, a fluid pressure responsive control means to control unspooling of said cable winch, means operatively connecting said control means and said cable unspooling means, and means connecting said control means to said motor to transmit to said control means a response to back pressure in said motor, said control means including a control element actuable to assume a cable unspooling position in response to abnormally high back pressure conditions in said motor due to the drill bit continuing to fall after the motor is reversed to raise the bit.

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