ABSTRACT OF THE DISCLOSURE

A rotary rig for drilling shallow holes, exemplified in a truck mounted hydraulic power auger used in drilling holes for electrical transmission and distribution pole lines, pilings, foundation footings, etc. The invention lies in the direct coupling of a rotary power motor to the drill stem or kelly having a drill bit (auger) mounted on its lower end for supplying torque to rotate the kelly and auger. The kelly is non-circular in cross section, and received in common rotary relationship in a congruent axial opening in the shaft of the motor, preferably hydraulic, using a sliding fit to permit axial movement of the kelly. A direct coupling is also used for thrust, the kelly extending above the drive motor into the bore of a hydraulic crowd cylinder and terminating in a direct connection to the piston of this cylinder, so that as hydraulic pressure is applied on the upper face of the piston this pressure is transmitted directly through the kelly to the auger.

Another feature of the invention lies in the combination of two or more hydraulic power units, particularly the rotary motor and crowd cylinder, with a simplified hydraulic control system. Such system may be used either with or without the direct power application mentioned above. Preferably two valves are used, one for a fast movement of the crowd cylinder and the other for operating the rotary motor. The flow lines of these two valves are connected so that operation of fluid flows to the motor or its valve when the fast crowd valve is actuated to circulate operating fluid through the crowd cylinder, and when the fast crowd valve is in its neutral position such circulation through the crowd cylinder is blocked and all the fluid flows to the valve controlling the motor. This makes it possible to leave the rotary valve open most of the time, so that in running the bit in and then rotating it to disintegrate the earth only the fast crowd valve need be manipulated. When an auger is used, the same valves make it possible to raise the auger and spin off the cuttings by manipulating only the same fast crowd valve.

An optional hydraulic circuit improvement is also disclosed, utilizing a pilot operated relief valve between the flow lines connecting the crowd cylinder and a slow crowd valve used to apply thrust to the auger when the auger is on bottom and drilling. This relief valve senses the fluid pressure in the pressurized end of the crowd cylinder, and when such pressure reaches a predetermined operating value or level the relief valve is actuated to dump the inflowing fluid into the tank line. A check valve in the input line locks the pressurized fluid in the cylinder, and this valve may be equipped for pilot operated reverse opening to drain such fluid when the slow crowd valve is actuated for reverse flow to lift the auger.

The present invention lies in the field of rotary drilling rigs, and is described herein primarily as applied to heavy weight, easily transportable rotary drilling rigs peculiarly suited for drilling relatively shallow holes, e.g., to a maximum depth below the earth's surface of about 50 feet. Such holes may be quite variable in diameter, from three or four inches for exploration work to six feet or larger for the auger type bits with which the invention is exemplified below. Drilling rigs of this type penetrate earth formations by rotating an auger or other type bit fixed on the lower end of a drill stem or kelly while applying an axial load through the kelly to the bit, either intermittently or steadily.

Herefore various means have been utilized to supply load and torque to such drill stems. While hydraulic devices have been used increasingly as the sources of axial load and rotary power, almost invariably they are coupled to the drill stem by mechanical components such as rotary tables, shafts, gears, chains, pulleys, cables and the like. Such mechanical couplings have several disadvantages, not the least of which is the initial cost of such couplings and their supporting structure and auxiliary equipment such as derricks, housings, winch motors and the like. They are attended by vibration, frictional losses and resulting wear, which require lubrication, inspection, extra maintenance and the inevitable and expensive replacement of parts.

It is therefore the main object of the present invention to provide a drilling rig in which a drill bit is mounted on the lower end of a drill stem, such rig including power means to rotate the drill stem and another power means to forcibly feed the drill stem and bit into an earthen formation, and to couple both such power means directly to the drill stem, avoiding as much as possible the mechanical couplings of the prior art.

A kindred object is to improve on prior art rotary drilling rigs which include a drill stem adapted to receive a drilling bit on its lower end and a power means to rotate the drill stem and bit by coupling such power means to the drill stem without using any intervening mechanical members.

Another object is to provide a rotary drilling rig which includes a drill stem, means to rotate such drill stem and means to supply axial thrust to such drill stem, each of the rotary means and thrust means being coupled to the drill stem with a minimum of mechanical coupling members.

Another disadvantage of prior art devices is the difficulty and complexity of operating and controlling them. Where mechanical couplings are used, the controls frequently include stiff manual clutches and shift levers. When hydraulic power units have been introduced, a separate valve is usually provided for each power unit and typically each such valve must be moved back and forth between open and closed positions several times during a complete cycle (e.g., starting with the drill bit on bottom, raising it, spinning off any collected cuttings, running it back to bottom, and simultaneously applying torque and crowding until it is time to raise the bit again). The overall control system is typically a collection of many mechanical devices and hydraulic valves which are so numerous and require so many manipulations that the operator's attention is diverted from his main task of observing the tool and its progress in the hole. Such multiplied controls also have the disadvantages of extra capital investment, higher maintenance costs, and the greater likelihood of manipulating the wrong controls, particularly if the operator is relatively inexperienced.

It is therefore an additional object of the present invention to provide a simplified hydraulic control system for a rotary drilling rig of the type described, and such simplified control system may be advantageously applied either with the direct rotary and crowd system of the present invention or to other systems using mechanical couplings but powered with hydraulic components.

A kindred object is to provide hydraulic power sources for two or more functions of a rotary drilling rig together
with a control system for such power sources in which no operating hydraulic fluid will be supplied to one such power source during the time the second such power source is operating, and the manipulation of a single control will transfer the flow of all available operating fluid from the second power source to the first.

A related object is to provide an automatic valve means in the hydraulic crowd circuit to further simplify such circuit and minimize the number of manipulations required of an operator, such valve means functioning to limit the pressure available in the crowd cylinder during the drilling operation.

These objects are achieved by mounting in coaxial relationship a Kelly or drill stem, a motor to rotate the drill stem and a hydraulic cylinder to supply thrust directly on the upper end of the drill stem. The central shaft of the motor is hollow, the opening having a polygonal or other non-circular cross section adapted to receive in sliding relationship a portion of the drill stem having a cross section of the same shape and virtually the same dimensions, differing from the shaft opening dimensions by only sufficient clearance to provide a close sliding fit. The drill stem extends through this opening in the shaft and above the motor into the hydraulic cylinder, terminating at its upper end in a fixed connection to the axially slidable piston of the crowd cylinder. This connection may be either one in which the drill stem and piston rotate together, which makes for a more difficult sealing problem between the periphery of the piston and the inside of the cylinder barrel, or, preferably, one in which only the drill stem rotates—which requires a swivel or bearing and hence does not completely eliminate all mechanical coupling members.

With such an arrangement, the drill stem and bit are rotated at high efficiency and with no investment in mechanical components such as a rotary table and gear connections between the motor and the rotary table. The only auxiliary equipment, assuming a hydraulic drive, is the pump and its associated prime mover, and the hydraulic lines and auxiliary equipment such as valves, gages and the like, but of course these are required for the hydraulic system whether mechanical couplings are used or not. Similarly, the direct connection between the top of the drill stem and the piston of the crowd cylinder avoids mechanical connections such as chains and sheaves, pulleys, etc.

In the hydraulic system, the simplified control for fast crowd and motor rotation is achieved by running the supply flow line for the motor through a type of valve for the fast crowd (by which is meant rapid lowering and raising of the Kelly and auger between a position at the top of a hole, out of contact with the earth, and a drilling position at the bottom of the hole) which has three positions: (1) neutral, (2) downward operating and (3) upward operating, or reverse. In the neutral position the flow lines connecting the fast crowd valve with the crowd cylinder are blocked to prevent any circulation, but the supply flow line to the rotary motor is open to allow flow through the valve also having three positions and primarily controlling the rotary motor.

In both of its operating positions the fast crowd valve is connected to the crowd cylinder and the flow line to the rotary motor is blocked. One such operating position, of course, is furnished to run the auger rapidly down to the bottom of the hole being dug while the other is to raise it rapidly out of the hole, usually with a load of cuttings collected on the flights of the auger. During repeated cycles of lowering, digging, raising and spinning off the cuttings the rotary motor valve may be left in its operating position for clockwise rotation of the auger while only the fast crowd valve is manipulated.

The optional automatic valve means in the slow crowd circuit (the slow crowd valve being used when the auger is on bottom and digging, and the fast crowd valve being in neutral at such times) forms the heart of a relief valve connected through a pilot line to measure or sense the pressure of the fluid above the piston of the crowd cylinder, together with a check valve in the flow line supplying such flow. When the crowd cylinder pressure reaches the level for which the relief valve is set, it is actuated from its normally closed or blocking position to an open position in which it directly connects the inflow and tank lines leading to the crowd cylinder, thus shorting out the cylinder and preventing further build-up of pressure. At the same time, the check valve prevents any backflow of fluid out of the pressurized end of the cylinder, trapping such fluid to maintain a steady thrust on the piston, Kelly and auger until these interconnected members move downward and cause the pressure to drop. As this dropping pressure reaches a second predetermined level, it is sensed by the relief valve and such valve is actuated back to its blocking position to allow more fluid to flow into the crowd cylinder.

The check valve may also be actuated by the pressure sensed through a pilot line. In this instance the pilot line is connected between the check valve and the opposite of the pair of flow lines to the crowd cylinder, so that the slow crowd control valve may be used for lifting the auger from the bottom by means of reverse operating position. In such position the check valve senses through its pilot line the pressure above the crowd cylinder piston, and moves to its reverse open condition to permit the pressurized fluid above the piston to drain through the tank return line.

The invention may perhaps be better understood by referring to the attached drawing, which exemplifies the invention as applied to a portable auger digger mounted on a truck for digging holes for electrical pole lines. In the drawing:

FIG. 1 is an overall perspective showing the drilling rig raised to its operating position at the rear end of a truck bed which carries the hydraulic pumps, gasoline engine prime mover, tanks for hydraulic fluid and gasoline, and all other auxiliary equipment, the Kelly and auger being shown raised so that the auger just clears the surface of the earth.

FIGS. 2 and 3 together are a longitudinal section through the mast assembly of the rig as disposed for vertically vertical digging, although it may be disposed for off-vertical drilling by the use of one or both of its associated raise cylinder and side level cylinder. FIG. 2 showing the bottom part of the mast and FIG. 3 the upper part.

FIG. 4 is a schematic of the hydraulic circuit and all of the devices controlled by it.

FIG. 4A is an enlarged schematic showing only one of the control valves of FIG. 4, and

FIG. 5 is a schematic of the aforementioned automatic control system for the slow crowd hydraulic circuit.

The overall apparatus and carrier illustrated in FIG. 1 comprise the mast assembly 10, truck 11, gasoline engine prime mover 12, pump assembly or triple pump 13, hydraulic fluid tank 14, and the pair of jacks 16R and 16L, raised to elevate the truck bed 17 and thus stabilize the digger, its auxiliary equipment and the driving load, rather than letting this weight rest on the springs of truck 11. Also visible in this figure is the hydraulic cylinder 18 and its piston rod 19 used to move the mast 10 between operating and transport positions, the rest or "headache rack" 21 used to support the mast in its transport position, the bifurcated trunnion 22 used to pivotally support derrick 10, the side leveling hydraulic cylinder 23 used to tilt the derrick and trunnion for off-vertical digging, and the operator O and his seat and station S.

The principal components of the mast assembly 10 are also visible in FIG. 1, specifically hydraulic motor 50, the drill stem or Kelly 60, the auger 70 fixed to the lower end of the Kelly, and the crowd cylinder 80. Seen at the rear of the carrier are a pair of long final drive slide rails 20 supported by a bearing 15 built into the truck bed 17 and a carriage 29 which is movable longi-
tudinally on such rails between a forward transport position and the rearward operating position illustrated. The bearing 15 functions as a positioning table rotate through an arc of 240 degrees centered on the longitudinal axis of the truck bed, and is operated by a pair of hydraulically cylinders 24L and 24R (not visible except in the FIG. 4 schematic) disposed parallel to the longitudinal axis of the truck and supported within the truck bed, being coupled to a sprocket 56 (see FIG. 4) fixed to the underside of the bearing 15 by a length of chains 57 secured at its ends to the rails 58 of the track extending from such cylinders. The sprocket 56 and chain 57 are indicated schematically in the hydraulic circuit of FIG. 4. The sliding platform or carriage 29 supports the trunnion 22 and through it supports all components of the mast assembly 10, and also supports all auxiliary equipment such as prime mover 12, triple pump 13 and hydraulic tank 14. The carriage 29 is slid back and forth by the action of a single hydraulic cylinder 25 (FIG. 4) supported on positioning table 15 and disposed between rails 20.

Turning to the mast assembly illustrated in FIGS. 2 and 5, it will be seen that the lowest extending member is the drill stem or Kelly 60, a non-circular cross section member which is in square in the illustrated embodiment but can have any feasible shape permitting a fit into the hollow shaft 51 of motor motor 50 to insure common rotation therewith while permitting the Kelly to slide within the motor shaft. Actually only the portion of the Kelly which slides through the motor motor motor need be non-circular. The lowermost portion 61 shown in FIGS. 1 and 2, having the transverse opening 62 to receive a cross pin 63 that also fits aligned openings in the hollow shank 71 of auger 70, may be of the conventional circular cross section. A non-circular cross section is preferred for better torque transmission to the digging tool. Of course, the Kelly is true of the uppermost part of the Kelly, which moves up and down in crowd cylinder 80 but never passes through motor 50. The auger shank 71 has an internal pocket (not shown) receiving the lower end of Kelly bar 52 so that when the Kelly is loaded the crowd force is transmitted through the Kelly rather than through pin 63.

Reading from bottom to top in FIGS. 1-3, Kelly 60 first passes through a shock-absorbing spring 26 floating on the Kelly below the motor, and then through a seal and packing assembly 27 designed to prevent leakage lengthwise of the Kelly, this assembly being secured to the lower extension 52 of the motor motor motor being secured to the shaft and Kelly but being fixed to the shaft to prevent it from moving longitudinally with the Kelly. The Kelly then passes longitudinally through the complete length of shaft 51, including its upper extension 53 passing through the fixed coupling or mast base 30, and into the crowd cylinder 80 through its open lower end 81. Kelly bar 60 then passes upwardly through crowd cylinder 80 and terminates at its top with a rounded end portion 66 which is screwed threaded into a pair of lock nuts 84 disposed within piston 83. Just below threaded end 66 is a portion 67 of the Kelly of Intermediate diameter 60. It will be seen that being of circular cross sections and fitting within the inner periphery of the inner race member of the tapered roller bearing 85. The outer race member of bearing 85 is press fitted within the bore of the inverted annular U-shaped body 86 of the piston, and the assembly of Kelly, bearing and lock nuts 84 is prevented from moving downward by the trunnion bearing ring 87 partially underlying the outer race member of bearing 85 and partially received in the indicated groove in inner surface of the body 86 of the piston. To prevent relative axial motion in the upward direction, a cup member 88 received within the hollow portion 56 of the Kelly 60 and secured by pins 89 passing through the body 86 of the piston contacting the upper surface of the outer race member of the bearing 85, while the base 92 of cup 88 lies between the upper 66 end of the Kelly and the base 91 of piston body 86. A pair of interlocking set screws 92 and 93 are threaded into the indicated tapped opening in base 91 so that the lowermost screw 92 bears against base 90 of the cup 88 and thus forces rim 89 of the cup against bearing 85 to clamp such bearing 85 on cup 88 and retaining ring 87. Appropriate seals and wear rings are provided between the outer diameter of the piston 83 and the inner surface of cylinder tube 82, as illustrated.

Crown cylinder 80 is provided with the open lower end 81 because it is somewhat difficult to provide a sealable entrance for the rotating Kelly 60 of polygonal cross section, and for the same reason the lower portion of the cylinder barrel 82 is threaded on its outer periphery and engages interior threads in the upper end of the longitudinal passage 51 through mast base 30. By this means, the upper extension 53 of hollow motor shaft 50, and the packing 32 provided around shaft extension 53 and within the longitudinal passage 51 of the mast base, the Kelly extends between the motor motor motor and the crowd cylinder with a minimum of leakage of hydraulic fluid between these two main power units. Of course, the mast base 30 also provides a firm support for crowd cylinder 80. If such support were otherwise furnished, the lower end 81 of the cylinder could be provided with a member such as shaft extension 53 to rotate with Kelly 60 but remaining fixed to the end 81 to permit sliding of the Kelly bar, together with the packings necessary to prevent leakage between the circular outer surface of such special member and the end 81 of the cylinder.

The crown cylinder 80 is provided with a sealed and threaded upper cap 95 which serves as the additional function of providing a threaded coupling 96 for a hydraulic conduit C and a connecting passage 97 for the passage of hydraulic fluid to and from the upper end of the crowd cylinder, above piston 83. A similar coupling 36 and connecting passage 37 are provided in derrick base 30 for the flow of hydraulic fluid to and from the lower end of crowd cylinder 80 below piston 83.

As previously noted, the top of Kelly bar 52 may alternatively be fixed to piston 83 so that these two members rotate together as well as moving axially as a unit. This modification makes it possible to eliminate the mechanism coupling provided by bearing 85, as could be done, for instance, by eliminating all parts of the piston except body 86, making body 86 a solid block except for a longitudinal passage to accommodate the upper end of the Kelly bar, and rotating Kelly 60 and piston 83 together by a threaded engagement or suitable fasteners. The problem of providing against leakage between the piston and the cylinder wall would be aggravated, but this can be minimized by the use of an adequate number of the proper type and size of suitably disposed rotary seals.

In addition to support from mast base 30, the crowd cylinder 80 is further braced and supported by support subassembly 38, this member comprising an out-turned base flange 41 and an annular L-shaped packing retainer top member 42 connected by circumferentially spaced stiffening fins or grooves 46. Such top 42 is external 60 threaded to receive the cap 43 which aids in pressing down on the packing ring 44 and annular packings 45 disposed in the annulus between top member 42 and barrel 82 to compress the packings axially and thus expand them radially to make them grip the confining steel surfaces of the barrel and top member. This packing is not designed to prevent leakage of hydraulic fluid, but is intended primarily to stabilize the cylinder in such a way as to avoid distortion of the cylinder at the point of engagement with the top of the support subassembly 38.

Such support subassembly 38 is welded at 39 at its base 41 to the upper member 36 of the mast and the base 90 is in turn welded at 40 to trunnion bearings 28. These trunnion bearings 28 are supported by trunnion 22, which thus supports the entire mast assembly 10. A series of cir-
cumferentially spaced capscrews 33 extending through flange 34 of the mast base 30 secure the motor 50 in position, with its shaft 51 coaxially aligned with crowd cylinder 80 and disposed below the same.

The hydraulic motor 50 (which can be replaced by an electric motor, air motor, etc., see below) is not shown in detail because the present invention does not include the motor considered by itself, and also because each manufacturer guards the details of his own motor as proprietary information at the present time. It is sufficient to observe here that for drilling purposes such motor should develop high torque under load over a range of rotary speeds from about 150 revolutions per minute (r.p.m.) down to 5 r.p.m., or virtually to stalling. It must also be provided with a shaft of sufficient cross section to be made with an opening therethrough to receive in axially sliding interfit a Kelly or drill stem of non-circular cross section, as this is necessary to make the present invention operable. A particular hydraulic motor that is commercially available and has been successfully used in an actual reduction to practice of the present invention is a Mod. F17-250 Vane Motor made by Vickers Incorporated, a division of Sperry Rand Corporation. This motor has the following characteristics:

| Torque: | 4500 lb-ft. at 2000 p.s.i. pressure drop over motor, from 5 r.p.m. to 150 r.p.m. |
| Efficiency: | 88-92% at 1500-2000 p.s.i. |
| Displacement: | 180 cubic inches per revolution |
| Flow required: | 125 gallons per minute maximum at 150 revolutions per minute |
| Weight without shaft: | 440 pounds |
| Overall dimensions: | 15% inches diameter x 11% inches axial length (housing) |

**OPERATION AND CONTROL**

The operation and control of the invention will be discussed in connection with the hydraulic circuit schematic of FIGS. 4 and 4A. As shown therein, the principal components of the hydraulic system include the usual fluid reservoir or tank 14, pumps 13a, 13b and 13c which are actually sections of the single shaft triple pump 13, valve bank assembly 102 and its associated supply tank 103 and tank return line 104, valve bank assembly 106 and its supply line 107, this tank also being connected to return line 104, and return line 109. The bank 102 includes the valves 111, 112 and 113, for controlling the high flow rate devices of the system, respectively crowdf cylinder 80 (for fast operation) rotary motor 50 and winch motor 75. Tank 106, on the other hand, includes the valves 121 through 129 for controlling the devices requiring a lower rate of flow, respectively from bottom to top side leveling cylinder 23, positioning cylinders 24L and 24R, raise cylinder 18, crowd cylinder 80 (slow crowd) slide cylinder 25, left and right jack cylinders 16L and 16R, pole extender cylinder 76 and pole grabber cylinder 77. It should be noted that crowd cylinder 80 is connected for flow control through both the fast crowd cylinder 111 and slow crowd cylinder 124, the fast crowd being used to run the bit 60 auger into the hole and pull it out while the slow crowd is used to apply thrust to the auger during the digging operation. Normally only one of the valves 111 and 112 is actuated at any one time but they are not interlocked to prevent simultaneous closing because no particular damage can result from such an occurrence. The slow crow cylinder is normally operated intermittently, being actuated to its downward digging position (crossed arrows) for a few seconds and then returned to its illustrated neutral position to apply a steady thrust until the auger digs downward and reduces the pressure above the piston.

The other valves and circuitry associated with slow flow bank 106 are otherwise mostly conventional and straightforward. A special tank line 108 is provided for positioning table cylinders 24L and 24R, to keep them filled with oil. The operation of these two cylinders is somewhat unusual, as suggested by the symbolic sprocket 56 and the chain 57 passing around the sprocket and secured at its two ends to the piston rods 58 of cylinders 24L and 24R. When the piston of 24L moves to the right, for instance, to rotate the sprocket 56 and thus rotate positioning table 15 in the counterclockwise direction, the piston of the other cylinder 24R necessarily must move to the left. In fluid flow terms, when the rod end of cylinder 24L is being supplied with fluid through line 144 the rod end of cylinder 24R must be permitted to drain through line 146, and thus the two rod ends are appropriately connected through an ordinary hydraulic valve 122. These two lines 144 and 146 pass through the double counterbalance valve 131, which act to prevent fluid from draining from one cylinder until the other is pressurized and thus keep tension in what otherwise would be the slack side of the chain 57. The adjustable flow control valves 132 meter the oil flowing to and from the rod ends of cylinders 24L and 24R to regulate the operating speed of these cylinders and thus keep the positioning table speed within reasonable limits.

Of course, while the pistons of cylinders 24L and 24R are moving to rotate the positioning table 15 counterclockwise, as discussed above, hydraulic fluid must also flow out of the piston end of cylinder 24L and into the piston end of cylinder 24R. For the most part the same fluid is simply passed back and forth through linking line 59 between the piston ends of cylinders during successive movements in opposite directions, but the direct connection of this link to tank 14 through valve 109 insures that any losses will be replaced and the pistons ends of cylinders will be kept filled with fluid at all times. It might also be noted that the slow crowd valve 124 is the only valve in tank 106 which is more or less continuously operated. For any one hole being dug the jacks 16L and 16R are operated only at the beginning and conclusion of the digging, and the same is true of raise cylinder 18, slide cylinder 25, turntable cylinders 24L and 24R, and if it is used at all, side level cylinder 23. The pole extender and pole grabber cylinders 76 and 77 are only operated sporadically.

With respect to various elements in the flow lines, check valves 133, pressure smudgers (orifice type gauge protectors) 134, pressure gages 136, pressure relief valves 137 and filters 138 are conventional, the filters being largely to protect operating components such as motor 50. Motor 50 is provided with a special drain line 139 connected between its casing or housing and tank 14 to drain off the hydraulic fluid which leaks past the vanes of the motor and thus protect the seals against pressure build-up. Low opening pressure (5 p.s.i.) check valve 141 is provided to insure that the motor case remains filled with fluid for proper lubrication.

With respect to the supply lines and the pumps, it should be noted that all three pump sections draw fluid through a common line 142 and filter 138 (200 mesh) in tank 14, such filter being connected through branch lines 142a to pump section 13c, branch 142b to pump section 13b and the branch line 142a to pump section 13a. The tank 14 is also equipped with an externally visible fluid level and temperature gage 143.

Pump section 13c, having a 58 gallons per minute (g.p.m.) capacity, is connected directly through branch supply line 103a to the pipe line 103, whereas pump section 13b, having a 65 g.p.m. capacity, is connected first to foot pedal operated valve 109. The valve 010 is normally used only in pulling the loaded auger 70 out of a hole and during the throw or cuttings disposal step, when the extra speed obtained in using the two pump sections in parallel results in high centrifugal forces on the cuttings carried on the auger flights and permits them to be thrown clear of the hole, and in returning the empty auger to the bottom of the hole.
The second feature of the invention discussed in the introduction lies in the interconnection of fast crowd valve 114 and its connections to both the crowd cylinder 80 and the control of its supply line 103 leading to valve 112 for rotary motor 50. As depicted in the drawing figures each of these valves is in its neutral position and, assuming the pump to be operating, all fluid is circulated through supply line 103 and back to tank 14 through return line 104, since which valve 113 is also in neutral position. Because which 72 is used only in special situations, it will not be further discussed. When the valve spool 114 of valve 111 (see FIG. 4A) is moved to the right within the body 115 of valve 111 to its forward (downward) operating position, hydraulic fluid will pass through the branch 16 of supply line 103, through valve 111, upwardly as indicated by the upwardly pointing arrow and through line 117 to the top or right hand end (piston end) of crowd cylinder 80. At the same time, a return flow circuit is established from the bottom of crowd cylinder 80 (left end in figure) through line 118 and downwardly through valve 111 to return line 104 (as symbolized by the downwardly pointed arrow). Also, at the same time, forward movement of the spool 114 causes main flow line 103 to be blocked, as symbolized by the broken line or gap 119 between the arrows. This prevents any flow of hydraulic fluid upwardly to the rotary motor 50 through its valve 112, and ensures that all fluid flow available will be utilized for a quick movement of the Kelly 60 and auger 70 which are link directly to the piston of crowd cylinder 80.

Assuming the auger to be fully retracted to a position above the predetermined location of a hole to be dug, both valves 111 and 112 may be actuated to their forward positions (right in the figure) simultaneously. Since valve 112 has a detent 120 to keep it in the forward position, it will stay put and the operator can usually ignore the valve 112 until the hole is completed. The movement of fluid through valve 111 and crowd cylinder 80 will rapidly lower the auger to the bottom of the hole, at which time all that the operator need do is release the handle 130 linked to spool 114 of the fast crowd valve 111. Since this spool is spring biased to the neutral position at both ends, as symbolized by the spring symbols 135 depicted in the figure at each end of spool 114, it will return to the neutral position as soon as released. All fluid and through valve 111 and crowd cylinder 80 will immediately stop, and all flow will be immediately diverted to valve 112 and through to motor 50—merely on the operator’s releasing a single valve control.

Since the forward position of the spool 114 of valve 112 is that appropriate for screwing the auger into the earth formation, it will automatically carry on this operation, and the operator will call forth the necessary slow crowd by manipulating the spool of slow crowd valve 124 between the forward and neutral positions, this being the only control he need lay a hand on during the entire augering operation.

Reference is now directed to FIG. 5, illustrating an optional improvement consisting of a pilot operated relief valve 147 and a check valve 148 connected in the portion of the hydraulic circuit which includes the flow lines 117 and 118 interconnecting crowd cylinder 80 and its fast crowd and slow crowd valves 111 and 124 (the latter differing from valve 124 of FIG. 4 only in that valve 124 includes a detent 140 for retaining the valve in the forward position, whereas line 117 is connected to supply line 107 and line 118 is connected to tank line 104). These valves 147 and 148 make for simplicity of control in that during the augering step the slow crowd valve 124 may be actuated to its forward or first position (fast crowd valve 111 being in its neutral position shown in the drawing) and left there for the balance of the augering operation. Without these valves 147 and 148 the operator will apply crowd to the auger by intermittent-
the crowd cylinder is the end that is under high pressure during the earth penetrating operation, whereas with the illustrated auger the piston end of the cylinder is pressurized during the beginning. After case the auger is rapidly pressed in the circuit of FIG. 5 for use with an underwater or raise drill it is to switch the connection of flow lines 117 and 118 between the ends of crowd cylinder 80, specifically by replacing lateral line 105 and line 105' and line 110 with line 110'. To indicate this adaptability of the circuit in the appended claims, the end of the cylinder which is connected to the input flow line during the earth penetrating operation is referred to as the "pressurized digging end" while the end connected to the tank return is referred to simply as the "other end."

When the auger is loaded to capacity, the operator releases the handle of slow crowd valve 124 (or 124') and it returns to the neutral position by spring action (124' must be actuated by hand to move it from the downward operating position to neutral). He also throws the fast crowd valve 111 to the rearward or reverse position (left in drawing, as symbolized by the crossed arrows) and holds it there to connect lines 118 and 166 and supply line 163 to the bottom of crowd cylinder 80, and connecting the top of the cylinder to lines 117 and return line 104. Since the piston 83 at this time is near the bottom of cylinder 80 (left in drawing), the reverse flow will cause it to move upwardly to raise the auger out of the hole. Foot pedal valve 109 is also normally manipulated to the forward position at this same time, to provide extra flow by coupling pump section 13b in tandem with 13c and thereby increase the speed at which the auger is raised. It should be noted that nothing has been done to valve 112 since starting the cycle, and it has remained detented in its initial forward position. The movement of the ag 114 of valve 111 to the rearward position blocks the flow of all fluid to the motor 50 and thus halts rotation of the auger by inserting a block 119 in supply line 103, just as in the forward position of valve 111.

When the auger has been fully raised out of the hole, all that the operator is required to do is release the handle of valve 111, again permitting the spring action on spoil 114 to return the spoil to the neutral position. All fluid flow is immediately diverted from valve 111 and crowd cylinder 80 to flow through valve 112, still in its forward position, and through rotary motor 50. The foot valve 109 is still in its forward position to obtain extra speed from the pump 13b, and the motor consequently accelerates rapidly, and with it Kelly 60 and auger 70. The cuttings collected on the auger flights 72 are rapidly thrown clear of the hole, and the operator prepares for another cycle by again manipulating the fast crowd valve 111 to its forward position. Foot pedal valve 109 is held in position to keep pump section 13b connected to the supply line 103 until the auger again reaches the bottom of the hole.

It should be noted especially that during the complete cycle and for many further cycles, usually until the hole is completed, the valve 112 controlling rotary motor 50 may be left in its forward position. The same direction of rotation used for augering into the earth is normally used for throwing the cuttings clear of the auger and hole. The reverse direction is used only in the event the auger becomes stuck and has to be backed out, or when clearing the auger of collected cuttings having a sticking nature. In the latter case, the auger is rapidly reversed over the hole to shake these cuttings loose. It may also be noted that the cross link 151 of valve 112, which ties together lines 154 and 155 running between the valve and the motor, is present only when the valve 112 is in the neutral position illustrated. When this valve is manipulated in the rearward or forward position, such link 151 is removed and lines 154 and 155 are connected to supply and return lines 103 and 104 as indicated by the arrows for the particular position, as in any valve lacking such a link 151. The purpose of the link is to assure a closed circulating loop for the fluid already moving through motor 50, for if the lines 154 and 155 were abruptly blocked when the motor is rotating, circulation would stop and sudden change in momentum is likely to cause considerable damage.

The specific embodiment of the invention illustrated in the drawing has been reduced to practice with the hydraulic motor previously described and also having the following characteristics:

Auger diameter—48 inches maximum
Hole Depth
8 feet—12 feet usual
25 feet maximum
Minimum truck size—84 inches cab to axle dimension Wheelbase—156 inches
Weight, with truck—(gross vehicle weight)—20,000 pounds
Weight, digger and accessories—12,500 pounds
Road height:
12 foot model, 10 feet
25 foot model, 11 feet 9 inches
Height, derrick up—12 foot model, 25 feet
Kerry bar size—2½ inches square, solid
Engine BHP at 2200 r.p.m.
Torque available at Kelly—4500 ft./lb. at 2000 p.s.i.
Rotary speeds:
Dig—65 r.p.m.
Throw—140 r.p.m.
Crowd rate:
Fast—115 ft./min.
Slow—18 ft./min.
Crowd capacity—12,500 pounds
Hoist rate—170 ft./min.

While the invention illustrated and described has been confined to an all hydraulic system it is believed to be apparent that the direct coupling feature of the invention is not so limited. Any type motor may be mounted with its axis in a vertical (or off-vertical) position in coaxial alignment with a Kelly and crowd cylinder, so long as it provides high torque at low speeds and its shaft may be provided with a non-circular longitudinal passage to receive and rotate a similarly cross-sectioned Kelly bar and permit the Kelly to move axially through such opening. Any suitable electrical motor which satisfies these requirements may be substituted, and also suitable motors powered by other circulating fluids such as air. Similarly, the crowd cylinder may be powered by other available fluids and means, just so the piston of the cylinder can be attached to the top of the Kelly and exert a steady force on it, variable on demand. It is also within the invention to use any suitable crowd means when a directly coupled rotary motor is employed.

Similarly, the combination of hydraulic controls and operating units is not limited to the direct coupling feature of the invention, although it finds its greatest utility therein. Prior art systems utilizing a hydraulic power unit to rotate a drill stem or Kelly and another hydraulic power unit to exert an axial thrust on the Kelly may be advantageously combined with the interlocking valve controls of the present invention, even though such driving units are mechanically coupled to the driven devices.

It may also be mentioned that the present invention is not necessarily limited to the described auger types of drill bit. Rolling cutter bits and drag bits may also be used, providing a suitable circulation system to flush the cuttings out of the hole is added. Such bits have the advantage of requiring no throwoff operation, as with an auger, but they are not as fast as augers in penetrating soft earth and find their greatest utility in cutting through rock formations.

The valve means used to control the flows to the crowd cylinder and rotary motor may take other forms than the two valves 111 and 112 shown in FIG. 4. For the purposes of the invention, valve 112 could be eliminated en-
tirely, as its chief purposes are to provide for reverse rotation and an independent neutral position to completely stop the motor when the fast crowd valve 112 is in neutral position. The latter function can be accomplished by shutting down the pumps, and reverse rotation can also be sacrificed. A single valve to replace both valves 111 and 112 and yet accomplish all the functions of both may also be substituted, provided it is either equipped with more position so auxiliary valves and pilot lines are added which operate automatically in response to pressure changes. Specific circuits are not illustrated because many such circuits will now occur to those skilled in the art.

With respect to operating fluids, while customarily known and used hydraulic fluids such as MS grade number 10 engine oil ("MS" meaning motor usage, severe service) are preferred, it is within the contemplation of the invention to use any suitable fluid which is compatible with the materials of the power units and other elements of the system, whether liquid, gaseous or combinations. As used herein and in the appended claims, it is to be understood that the term "hydraulic fluid" has this meaning and the adjective "hydraulic" modifies a word implying a unit or element compatible with or capable of utilizing a fluid as thus broadly described.

We claim:

1. A rotary drilling rig comprising
   (1) an elongated drill stem having a non-circular cross section along at least a portion of its length, an upper end, and a lower end adapted to have a rotary digging tool secured thereon,
   (2) a hydraulic rotary motor adapted to be secured above ground with its axis of rotation making an angle with the surface of the ground, said motor having a hollow shaft with a lengthwise opening therethrough of approximately the same non-circular cross section and receiving said portion of the drill stem in common rotary relationship and with a snug sliding fit to permit axial motion of the drill stem within the motor shaft, said drill stem as thus received, including a part of said non-circular cross section, extending above said motor in pre-drilling position,
   (3) a hydraulic crowd cylinder disposed above said motor in coaxial relationship therewith, said crowd cylinder receiving the part of said Kelly extending above the motor and having a piston coupled to the upper end of the drill stem for at least common axial movement therewith between the ends of the cylinder to raise and lower the drill stem, and
   (4) a hydraulic supply and control system for operating said drilling rig, said hydraulic system including valve means for simplified control of the rotation of said hydraulic motor and the up and down movement of the piston of the hydraulic crowd cylinder, said valve means including a manually controlled valve movable to at least a first position in which hydraulic fluid is circulated through the crowd cylinder in the piston-raising direction and all flow through the rotary motor is blocked, and a second position in which hydraulic fluid is circulated through the rotary motor and not through the crowd cylinder, whereby when the valve is in its first position the drill stem and digging tool will be lowered without rotation until the digging tool contacts an earth formation, and, by manipulating said valve from its first to its second position the drill stem and digging tool will be rotated without supplying hydraulic fluid to the crowd cylinder through said valve.

2. The rotary drilling means of claim 1 in which said manually controlled valve also includes a third position in which hydraulic fluid is circulated to said crowd cylinder in the piston-raising direction and none is circulated to said rotary motor, whereby said digging tool may be raised from engagement with an earth formation without rotating it by manipulating said valve from its second position to said third position.

3. The rotary drilling rig of claim 2 in which said digging tool is an auger-like tool which accumulates cuttings on portions of the tool stem and said cuttings are raised to the surface of the ground when said valve is manipulated to the third position, and whereby said cuttings are deposited on the ground surface adjacent the hole formed by the auger by manipulating said valve from said third to said second position, that in which said rotary motor rotates the said stem and auger but said cuttings pass through the valve to operate said crowd cylinder.

4. The rotary drilling rig of claim 1 in which said valve means consists of two separate valves, the first being a manually controlled valve having said first and second positions and the second being a valve having at least a first position providing a path for the flow of fluid from said first valve to said rotary motor to cause it to rotate the digging tool in its normal rotary direction, whereby when said first valve is in its first position and said second valve is in its first position said digging tool may be lowered without rotation from a raised position above the earth to an earth-contacting position, and said auger may then be rotated in contact with the earth solely by manipulating said first valve from its first to its second position to divert said fluid from the crowd cylinder to the rotary motor.

5. The rotary drilling rig of claim 1 in which said valve also has a third position, in which it blocks the flow of fluid to the second valve and the rotary motor and permits it to flow through the crowd cylinder in the piston-raising direction, whereby the drilling operation of the digging tool may be stopped and the tool raised without rotation from the bottom of a hole solely by manipulating said first valve from its second position to its third position.

6. The rotary drilling rig of claim 5 in which said digging tool is one that accumulates cuttings on a part of itself and said cuttings are raised to the surface without rotation during said raising operation, said valves being adaptable to throw said cuttings clear of the hole onto the surface of the ground solely by manipulating said first valve from its third position to its second position, whereby all fluid is diverted through said second valve and through the rotary motor.

7. The drilling rig of claim 1 in which said hydraulic and control system further includes a second valve means actuated by an operator to control the circulation of fluid through said crowd cylinder and an automatic valve means to control and limit the pressure in the pressurized-digging end of said cylinder, said automatic valve means comprising both a normally blocking pilot operated relief valve connected between the flow lines linking said second valve means and the crowd cylinder and a check valve connected in the one of said flow lines connected to the pressurized-digging end of the cylinder to permit flow in said flow line only in the direction toward said end of the cylinder, the relief valve being connected through a pilot line to a point in the circuit sensing the pressure of the fluid in the pressurized-digging end of the cylinder and being actuable to an open position when the pressure in said end reaches a predetermined level for which the relief valve is set.

8. The drilling rig of claim 7 in which said second means is actuable to a position reversing the direction of flow through said crowd cylinder and said check valve is also pilot operated and is actuable to reverse flow therethrough by a predetermined pressure sensed through said pilot line connecting the check valve to the other of the pair of flow lines.

9. In combination with a drilling rig which includes an elongated drill stem adapted to support a drill bit on its lower end, a first hydraulic power means coupled to said drill stem to rotate the drill stem while permitting it to move longitudinally, and a second hydraulic power
means coupled to the drill stem to move it longitudinally, the improvement comprising a hydraulic circulation and control system which includes a valve means furnishing a simplified control of said first and second hydraulic power means, said valve means including a manually controlled valve having at least a first position in which hydraulic fluid is circulated through said second power means in the direction to lower said drill stem and bit, and the flow of fluid through said first power means is blocked, and a second position in which hydraulic fluid is circulated through the first power means but not through the second.

10. In combination with a drilling rig which includes a drill stem having a portion of its length of non-circular cross section adapted to support a drill bit pendent from its lower end, a rotary member adapted to be supported above the earth with its axis of rotation oriented at an angle to the earth's surface and having a similarly oriented opening therethrough centered on said axis, said opening having a cross section of similar non-circular shape receiving said portion of the drill stem with a close sliding fit for common rotation therewith, hydraulic thrust means connected to said drill stem to move it axially with respect to said rotary member, and hydraulic power means connected to said rotary member to rotate it and the drill stem and bit when said bit is in contact with an earth formation to be drilled: the improvement comprising a hydraulic circulation and control system which includes a hydraulic valve means furnishing a simplified control of the operation of said hydraulic thrust means and said hydraulic power means, said valve means including a manually controlled valve having at least a first position in which hydraulic fluid is circulated through said first power means in the direction to lower said drill stem and bit, and the flow of fluid through said hydraulic power means is blocked, and a second position in which hydraulic fluid is circulated through the power means but not through the thrust means, whereby when the drill stem and drill bit are moved upward said valve may be set in its first position to lower the drill bit without rotating it into contact with the ground, and said bit may then be caused to rotate solely by manipulating said valve from its first to its second position.

11. The improvement drilling rig of claim 10 further improved by the addition of a second hydraulic valve means, such additional valve means being actuable to increase the rate of flow of the hydraulic fluid circulated by the first valve to said hydraulic thrust means and hydraulic power means to thereby increase the speed with which said drill stem is rotated and moved axially.

12. In a drilling rig of the type set forth in claim 10, the improvement therein which said manually controlled valve includes a third position wherein hydraulic fluid is circulated through said hydraulic thrust means in the direction to raise said drill stem and bit and none is circulated through the hydraulic power means coupled to said rotary member, whereby said drilling operation of rotating the drill stem and bit may be stopped and these members may be raised from the hole being dug solely by manipulating said valve means from its second position to its third position.

13. The improvement drilling rig of claim 12 further improved by the addition of a second hydraulic valve means, such additional valve means being actuable to increase the rate of flow of the hydraulic fluid circulated by the first valve to said hydraulic thrust means and hydraulic power means to thereby increase the speed with which said drill stem is rotated and moved axially.

14. An earth penetrating rotary drilling rig comprising a drill stem adapted to be disposed to intersect the surface of the earth with a drill bit fixed to its lower end and mounted for rotary movement and movement along its own longitudinal axis, a hydraulic motor coupled to said drill stem to rotate it, and a hydraulic crowd cylinder also coupled to the drill stem to lower and raise such drill stem and drill bit into and from contact with earth formations to be drilled, and further comprising a hydraulic control system to control the sequential operation of said motor and crowd cylinder connected in the hydraulic lines which supply said motor and crowd cylinder with operating fluid,

(a) the first of said valves being a manually controlled valve having a first position permitting the flow of operating fluid to the crowd cylinder and blocking the flow of such fluid to the second valve, and also having a second position blocking the flow of operating fluid to said crowd cylinder and permitting such flow to the second valve,

(b) the second of said valves having at least a first position permitting such fluid to flow through the hydraulic motor, whereby, when said drill stem and bit start from a raised position in which the bit is spaced above the bottom of a hole being drilled, a cycle of lowering the bit to contact said bottom and then rotating it is completed by preliminarily permitting the first valve in its first position and the second valve in its first position to lower the drill bit into contact with the bottom of the hole and then shifting the first valve to its second position.

15. The drilling rig of claim 14 which includes a third valve connected in separate hydraulic lines to said crowd cylinder to supply operating fluid thereto independently of said first and second valves, said third valve having at least a first position blocking all flow to the crowd cylinder through the separate hydraulic lines and a second position permitting such flow.

16. A drilling rig which includes a drill stem adapted to be mounted at an angle to the earth's surface with a drilling bit secured on its lower end, rotary means coupled to the drill stem for common rotation but permitting axial movement of the drill stem toward and away from the earth, and a hydraulic crowd cylinder coupled to said drill stem and bit but not movable with the ends of said cylinder being connected to a pair of hydraulic flow lines for supplying fluid to one said end and returning it to a reservoir from the other, the improvement comprising automatic valve means to limit the thrust applied through said drill stem and bit, said automatic valve means including

(1) a pilot operated relief valve between said pair of flow lines and connected by a pilot line to sense the pressure in the pressurized-digging end of the cylinder, said valve having a normally closed position in which it blocks all flow between said pair of flow lines and an open position to which it is actuated by the pressure of the fluid in said pilot line when such pressure reaches a first predetermined level, said relief valve in such open position permitting the flow of fluid only in the direction from the one of said pair of flow lines connected to the pressurized-digging end of the crowd cylinder to the other flow line, said relief valve being adapted to be returned to its closed position when the pressure of the fluid in said pilot line reaches a second and smaller predetermined level, and

(2) a check valve in the one of said pair of flow lines connected to the pressurized-digging end of the cylinder, said check valve being oriented to permit the flow of fluid into said pressurized-digging end and block the reverse flow, whereby (a) during a digging operation the relief valve will be actuated from its closed to its open position when the pressure in the pressurized-digging end of the crowd cylinder reaches said first predetermined value to dump...
the fluid from the supply line into the tank line, effectively short circuiting the pressurized-digging end of the cylinder and preventing further build-up of pressure therein, (b) the check valve functioning to prevent the flow of fluid out of the pressurized-digging end of the cylinder, thus enabling the fluid trapped in such end to cause a steady force to be exerted on the drilling bit until it makes a further advance, and (c) upon such advance of the bit the pressure of such trapped fluid is reduced until it reaches a second predetermined value sensed by the pilot line and transmitted to the relief valve to actuate the same back to its closed position to remove the short circuit and allow further flow of fluid into the pressurized-digging end of the cylinder.

17. The improved drilling rig of claim 16 in which the check valve is also adapted to permit flow out of the pressurized-digging end of the crowd cylinder and is connected by a pilot line to sense the pressure in the other end of the cylinder, said check valve having a characteristic operating pressure at which it is actuated through the fluid in said pilot line, whereby said automatic valve means is adapted for reverse operation of said crowd cylinder to withdraw the drilling bit from digging contact with the earth when said flow lines are reversed so that the pressurized-digging end of the cylinder is connected to the tank return line and the other end is connected to the supply line, said check valve being actuated when the fluid in its pilot line senses a pressure in said other end of the cylinder equal to the characteristic operating pressure of the check valve to permit the fluid in the pressurized-digging end to pass through the tank return line.

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