May 13, 1969 C. E. HOWARD 3,443,648

EARTH FORMATION UNDERREAMER

Filed Sept. 13, 1967

Sheet 1 of 4

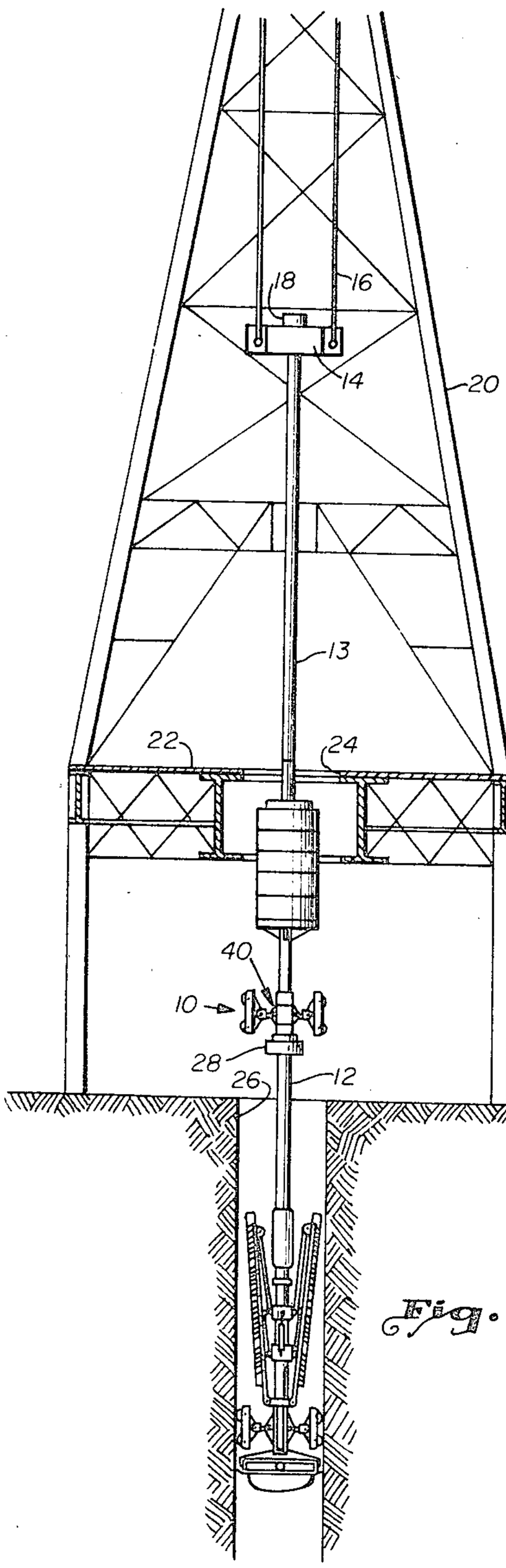

Fig. 1.

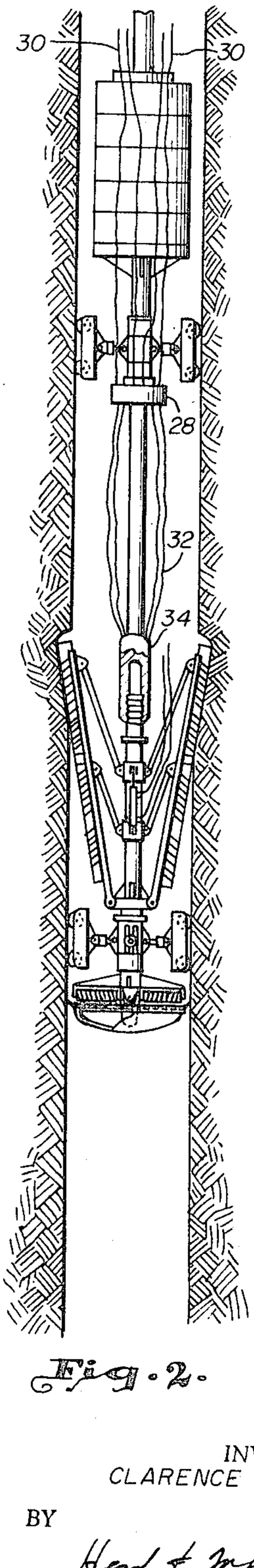

Fig. 2.

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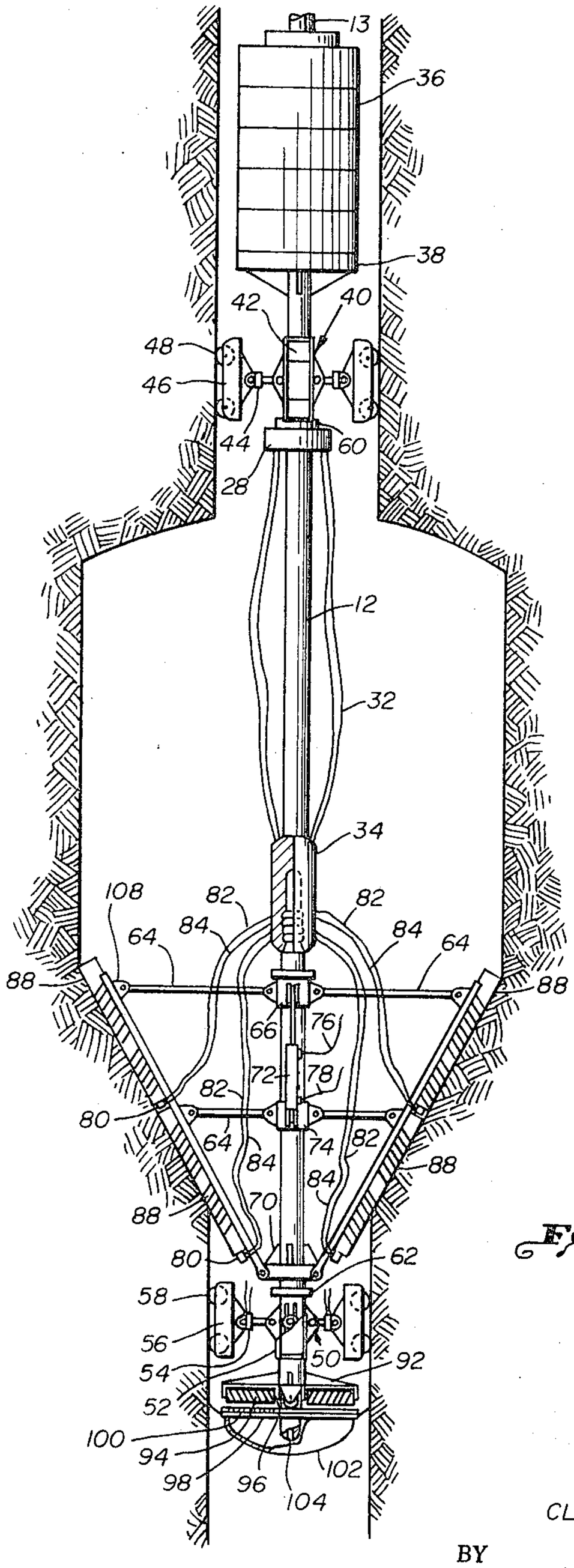

Fig. 3.

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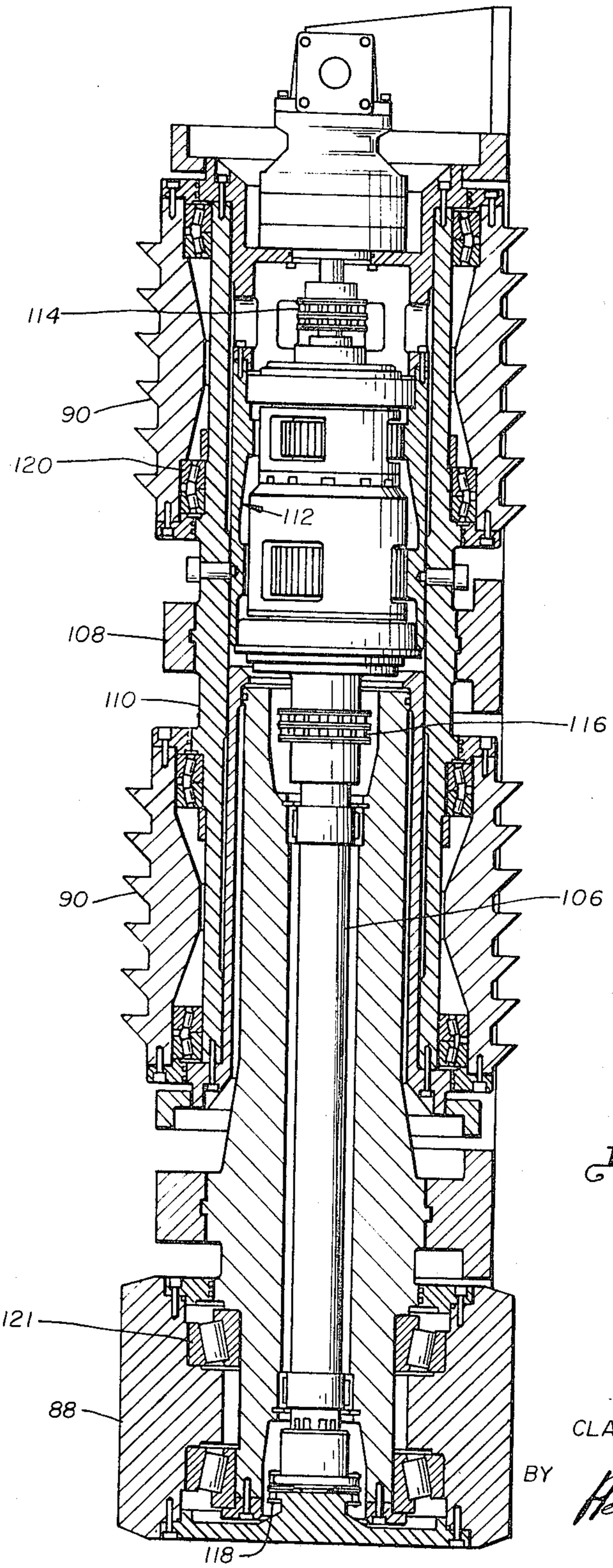

Fig. 4.

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EARTH FORMATION UNDERREAMER

Filed Sept. 13, 1967 Sheet 4 of 4

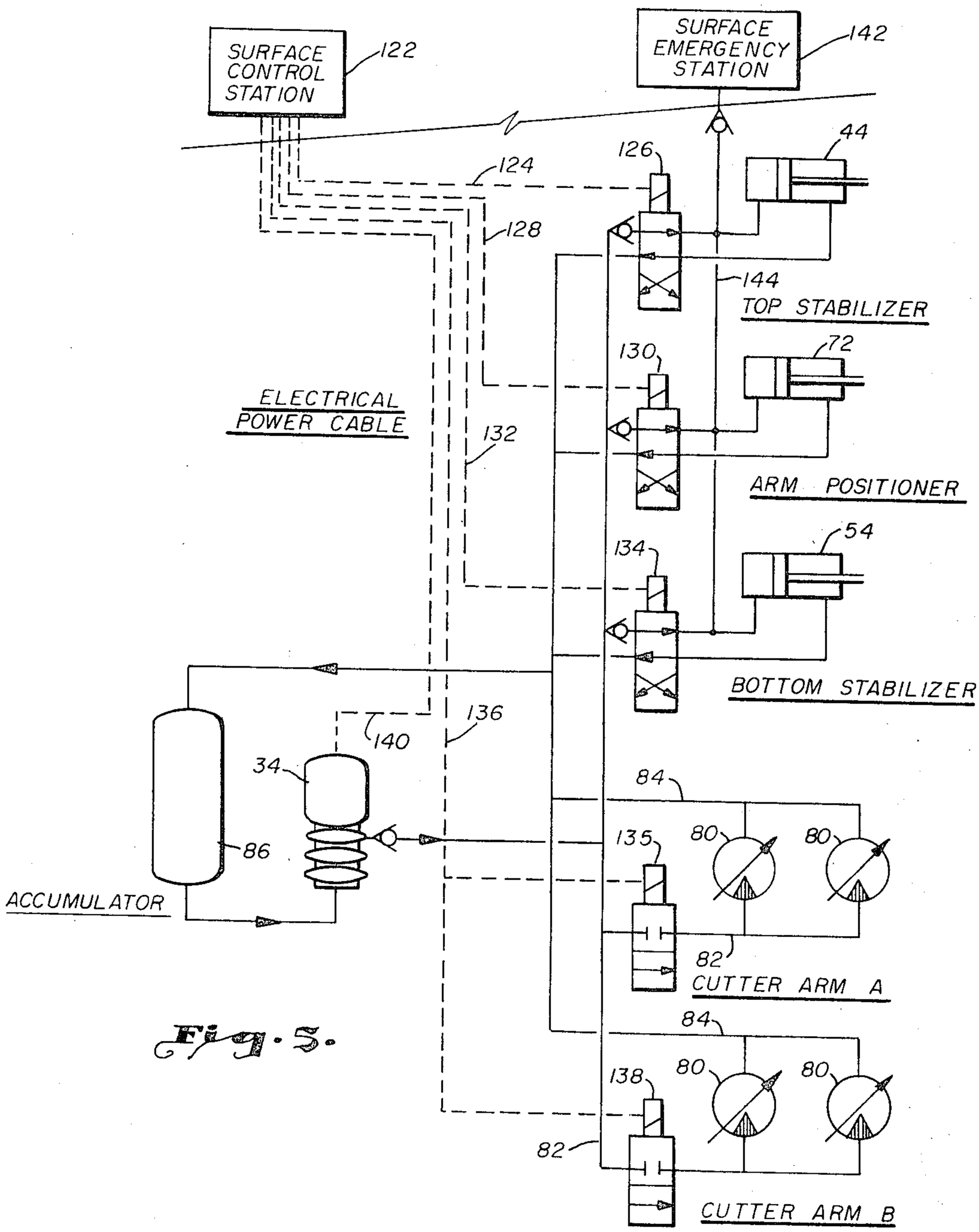

Fig. 5.

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3,443,648

EARTH FORMATION UNDERREAMER

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Int. Cl. E21b *1/06, 3/08, 5/00*
U.S. Cl. 175—103 9 Claims

ABSTRACT OF THE DISCLOSURE

An underreamer is lowered down a bore hole in an inoperative condition, and upon reaching the desired depth, the apparatus is directed by means of surface controls to begin the operation of enlarging the bore hole. The cutting components may be suspended in the bore hole on a conventional drill pipe with all operating components, except an electric control circuit, positioned at the end of the drill pipe. The cutting components include one or more extensible cutting arms which are arranged to extend angularly outward from the drill pipe and to be operated rotatably by means of a hydraulic power system. Each cutting arm includes at least one self-powered cutter which is driven by a hydraulic motor which receives power from the central hydraulic system, and each cutting arm also includes a plurality of free wheeling cutters which cut by reason of the weight of the drilling system. The drill pipe section upon which the cutting arms are mounted in held in position by stabilizers above and below the cutters. Cuttings fall to a crusher and collector positioned below the cutters and are circulated up through the drill pipe by fluid being pumped into the bore hole.

BACKGROUND OF THE INVENTION

This invention relates to earth formation drilling devices, and more particularly to drilling devices for bore holes. Still more particularly, this invention relates to drilling devices for enlarging bore holes which are known as underreamers in which the enlargement of the bore hole is accomplished by hydraulically driven cutters.

It has been known for many years that small diameter drill holes may be provided with enlarged sections, known as "bell" holes by the operation of expandable drill bits or other cutting tools suspended on the end of a drill pipe. Such expandable drill bits when rotated from the surface may provide an enlarged section of two to three feet in diameter. However, rotary underreamers operated from a rotating drill string have serious practical limitations. Some of these are enumerated below:

As the diameter of the enlarged section increases, the torque on the drill string increases. Very shortly the torque exceeds the ability of drill string to rotate the cutting member.

As the diameter of the enlarged section increases, the necessary strength of the cutting arms cannot be built into the arms or body of the tool.

Uneven cutting provides a rough operation, and the elasticity of the drill string coupled with the uneven cutting of the tool creates shock loading.

And, unless a tool is adequately stabilized, the cut section will be uneven and the desired smoothness and the diameter of the chamber wall will not be obtained. Improper stabilization leads to rough operations, shock loadings and broken tools.

Therefore, the primary object of this invention is to provide an earth formation drilling device which will easily and efficiently produce a large diameter bore hole in an earth formation.

Another object of this invention is to provide an earth formation boring device which can be removably controlled to produce a large diameter bore hole.

Still another object of this invention is to provide an earth formation boring device which can be inserted into a bore hole in a retracted condition and which can be remotely controlled from the surface to produce an enlarged bore hole section.

Still another object of this invention is to provide an earth formation boring device which is hydraulically driven to produce an enlarged bore hole section.

Another object of this invention is to provide a rotary earth formation boring device which can be suspended down a bore hole on non-rotating suspension means and positioned appropriately to enlarge a desired section of the bore hole.

Further objects and advantages of the invention will become apparent from the following description and claims, and from the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is an elevational view of the bore hole underreamer of this invention showing the device in a retracted position upon entry into a bore hole.

FIGURE 2 is a fragmentary elevational view of a bore hole underreamer according to this invention in position in a bore hole as it is when beginning operation to enlarge the bore hole.

FIGURE 3 is an elevational view of a bore hole underreamer according to this invention showing the device after it has enlarged a section of a bore hole.

FIGURE 4 is a cross-sectional view of a cutting arm of a bore hole underreamer according to this invention.

FIGURE 5 is a schematic circuit diagram of the electric control circuit of a bore hole underreamer according to this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The bore hole underreamer of this invention comprises a hydraulically driven cutter arm rotatably positioned on a supporting member such as a drill pipe retained in position by conventional drill pipe supporting devices. The underreaming device is retractable to a compact condition for easy insertion into the bore hole. At the chosen depth in the bore hole stabilizing means are actuated by a hydraulic component incorporated as a part of the underreamer. The stabilizing means is actuated to bear firmly against the side of the bore hole to hold the drill pipe or other suspending means in a non-rotative condition while the cutting arm rotates to cut into the earth formation adjacent the bore hole. Hydraulic means on the device both controls the positioning of the extensible cutting arm and drives a hydraulic motor position on the cutting arm. Operation of this hydraulic motor drives a cutter attached thereto which in turn causes rotation of the cutting arm by contact with the earth formation and also brings about additional cutting by means of contact with the earth formation of a plurality of free-wheeling cutters positioned on the cutting arm. Crusher means positioned beneath the cutting arm is also hydraulically driven and reduces in size particles chipped from the earth formation. Material passing through the crusher means is caught by collection means positioned thereunder and caused to circulate to the surface by fluid passing down the bore hole. The hydraulic means positioned down the bore hole as a part of an underreaming device is controlled from the surface by an electric circuit. Thus, all the major operating components of the underreamer are positioned at one location in the bore hole and only the electric control circuit is at the surface. A suitable device for circulating fluid down the bore hole to flush out particles removed from the earth formation is also controlled by the electric circuit means

and they consist of conventional pumps for either a gas such as air or nitrogen, or a liquid such as water or oil.

Referring now to the drawings in detail, FIGURE 1 shows a bore hole underreamer **10**, generally, which is mounted on a section of drill pipe **12** to which additional sections of drill pipe may be added, and which may be suspended in any well known form of conventional traveling block **14**, which may be supported by well known means as by cables **16** and held in position on traveling block **14** by means of a conventional bushing. The entire apparatus including the underreamer, drill pipe, and suspension cables may be mounted in the usual form of drilling rig **20** which provides that the structure for positioning the underreamer down the bore hole and removing the underreamer by the addition or removal of additional drill pipe sections as necessary. The usual drilling rig includes floor **22** having a central opening **24** therein which is aligned with bore hole **26**. Bore hole **26** has already been drilled to the prescribed depth by independent conventional drilling means preferably using the same drilling rig **20** as employed in the suspension of the underreamer of this invention. As a typical example of the use to be made of this underreamer, bore hole **26** may be an enlarged diameter bore such as 48-inch hole with the underreamer of this invention designed to enlarge this bore hole to a diameter of 28 feet. Of course, it is contemplated that smaller bore holes may be enlarged to larger diameters.

In FIGURES 1 through 3 it is seen that the underreamer of this invention is positioned on modified drill pipe section **12** which is secured bearably at its upper end to a rotary terminal block **28** which receives electric wires **30** from the surface and by rotating connections within block **28** conducts electric current from wires **30** to wires **32** which pass the motive current to an electric pump and electric motor within hydraulic component **34**. The electric motor and pump are not shown since these are simply of conventional design. Hydraulic component **34** includes an accumulator of hydraulic reservoir for the hydraulic fluid circulating through the system to hydraulic cylinders and motors hereinafter described. Thus, by this arrangement, only a single section of drill pipe is being rotated during the underreaming operation rather than the entire drill string which is the usual procedure. On drill pipe section **13** which may be a conventional section of drill pipe, a variable amount of weight may be positioned such as removable weights **36** which rest on a base plate **38**. By this means the underreaming force may be varied as desired. Also on drill pipe section **13** is bearably positioned an upper stabilizer **40** which includes a housing section **42** having therein conventional bearings abutting pipe section **13**, and an extensible hydraulic cylinder secured pivotally to housing **42** and having each side of a piston therein connected to hydraulic lines from hydraulic component **34** as described in FIGURE 5. Hydraulic cylinder **44** is in turn pivotally connected to frame **46** on which is mounted rollers **48**. Then, actuation of hydraulic cylinder **44** in one direction will force rollers **48** into firm contact with the wall of bore hole **26** to stabilize the underreamer during operation. A similar stabilizer **50** is mounted bearably near the lower end of the underreamer on a housing **52** with a hydraulic cylinder **54** pivotally attached to housing **52** and pivotally attached to frame **56**. Frame **56** also has rollers **58** therein which can be put into contact with the walls of the bore hole. Thus, actuation of hydraulic cylinders **44** and **54** can extend rollers **48** and **58** against the wall of the bore hole to a chosen degree so that the cutting components of the underreamer can be properly guided to provide a clean, true underreaming operation.

Housing **42** is made to be lockable into position on bushings **60** of rotary terminal block **28**. Bushing **60** is held non-rotatably while terminal block **28** is intended to rotate with modified drill pipe section **12** which serves as a frame for the underreamer. Hydraulic connections

between cylinder **44** and hydraulic component **34** are made through conventional hydraulic rotary seals operating between bushing **60** and terminal block **28**. Similarly, lower housing **52** is made to be lockable within bushing **62** at the lower end of drill pipe **12** in a manner to permit housing **52** to be held non-rotatively while drill pipe **12** rotates. Similar hydraulic seals are provided within bushing **62** to permit hydraulic fluid capacity component **34** to hydraulic cylinders **54**. Also, hydraulic cylinders **44** and **54** include solenoid valves as shown schematically in FIGURE 5 to control the flow of hydraulic fluid from the surface as desired for actuation of the upper and lower stabilizers.

One or more cutting arms are mounted on drill pipe section **12**, but preferably for heavy duty work and for balancing of the torque developed, at least two cutting arms should be employed. Each cutting arm includes an adjustable brace **64** pivotally mounted to a housing **66** mounted on drill pipe section **12** with the other end of housing **66** pivotally mounted to a supporting arm **68** which in turn is pivotally mounted at its lower end to a housing **70** secured to drill pipe section **12**. Positioning of the cutter arms is provided by the operation of a hydraulic cylinder **72** mounted pivotally between housing **66** and housing **74**. Hydraulic cylinder **72** includes a piston therein which has its opposite faces adaptable to be contacted by hydraulic fluid passing through lines **76** and **78** from hydraulic component **34**. A solenoid valve is included within hydraulic component **34** to control the flow of fluid to and from cylinders **72** so that the cutting arms may be positioned as desired. The construction of each cutting arm is more clearly shown in FIGURE 4. However, in FIGURE 3 is shown the hydraulic connections from hydraulic component **34** to each hydraulic motor **80** of each cutting arm. One such hydraulic line **82** supplies fluid to each motor and another line **84** serves as a return line to an accumulator within hydraulic component **34**, such as is represented by accumulator **86** shown in FIGURE 5. Motors **80** drive an internal shaft which is connected to driven cutters **88** which cause rotation of the cutter arms by their contact with their surface of the earth formation. The speed of rotation of course is controllable by the flow of hydraulic fluid into the hydraulic motor **80** which flow can be controlled from the surface. The rate of drilling is also adjustable by the addition or removal of weights **36**. Rotation of the cutting arms by operation of motors **80** cause rotation of free-wheeling cutters **90** which rotate freely and bearably around an axle housing which contains the axle driving cutters **88**. Attached to the lower end of drill pipe section **12** is a crusher frame **92** which supports a free-wheeling crusher roller **94** which rotates freely on an axle **96** mounted within frame **92**. At least two crusher rollers **94** are mounted on frame **92**. Frame **92** is held non-rotatably by being secured to housing **52**. Cuttings broken loose from the earth formation fall toward rollers **94** and are crushed between rollers **94** and a revolving crusher plate **98** which is attached to and revolves with drill pipe **12**. As cuttings are crushed between rollers **94** and plate **98** the reduced particles fall through fine openings **100** in plate **98** and are caught in a collection basin **102** secured to non-rotating crusher frame **92**. For removal of fine cuttings, water, air, or other fluid is passed downward through the bore hole **26** and the fine cuttings are washed upwardly through the open center **104** of drill pipe **12** eventually to reach the surface.

FIGURE 4 discloses a portion of one of the cutting arms of this underreamer and how the hydraulic motor **80** is connected through a transmission to a drive shaft **106** which is in turn coupled to driven cutter **88**. Each cutting arm may include more than one driven cutter with each to be driven by its own hydraulic motor. Also, each cutting arm may include a suitable number of free-wheeling cutters **90**, depending upon the length of the

cutting arm, weight of the underreamer, earth material to be encountered, and other factors. Each cutting arm is pivotally secured to brace **64** by connection of support blocks **108**. Support block **108** is secured to a cutter arm housing **110** upon which is mounted hydraulic motor **80** at one end, a transmission assembly **112** sealably mounted within housing **110**, drive shaft **106**, and driven cutter **88** at the other end of housing **110**. Hydraulic motor **80** is preferably engaged with transmission **112** by means of a flexible coupling **114** of conventional design, transmission **112** is further engaged with drive shaft **106** by a similar flexible coupling **116**, and drive shaft **106** preferably engages driven cutter **88** through another flexible coupling **118**. Free-wheeling cutters **90** are mounted on housing **110** by means of conventional bearings **120**. Also, driven cutter **88** is bearably mounted on housing **110** to bearings **121**.

FIGURE 5 describes schematically the electrical circuit controlling the operation of this underreamer and the hydraulic components which provide the actuating force for the underreamer. A surface control station **122** includes the usual switches to actuate the solenoid valves of each hydraulic component to permit the flow of hydraulic fluid into or from each component as desired to provide the motive force. Current through line **124** actuates valve **126**, line **128** actuates valve **130**, line **132** actuates valve **134**, line **136** actuates valves **138** on the cutter arms, and line **140** provides electric power to drive the electric motor in hydraulic component **34**.

In operation, the underreamer of this invention is lowered into bore hole **26** in a compacted condition as in FIGURE 1 by means of a usual drilling rig. Upon reaching the desired depth, the proper switches on the surface control station **122** are actuated to start the pump in the hydraulic component **134** and to open the hydraulic valves in top stabilizer **40** and bottom stabilizer **50** so that hydraulic fluid flows into cylinders **44** and **54** to force rollers **48** and **58** against the walls of the bore hole. Then, closing of a switch on a surface control station **122** to permit current to flow through line **128** will actuate solenoid valve **130** to permit hydraulic fluid to flow from hydraulic component **34** to arm positioner **72** which will cause the cutting arms of the underreamer to bear against the adjacent earth formation during the cutting operation. At the same time, a switch on the surface control station is closed to permit solenoid valves **138** to open so that hydraulic motors will be rotated by hydraulic fluid flowing into them, and these motors will in turn transmit their rotative energy through the transmission system and drive shaft **106** to driven cutters **88** as they bear against the earth formation. The weight imposed upon the underreamer and the rotation of driven cutters **88** cause all the free-wheeling cutters **90** to rotate and remove particles from the earth formation. Also, the traction created between drilling cutters **88** and the earth formation causes rotation of the entire underreamer from rotary block **28** downward, except for stabilizers **40** and **50** and crusher frame **92** as described above, so that the torque developed during the drilling operation is utilized by this underreamer in performing the drilling operation rather than subjecting the entire drill string to excessive torque and vibration by rotation of the drill string from the surface. Drilling may proceed with the cutting arms extended to any angle less than their full extension, or the underreamer may be maintained in position in the bore hole until the cutting arms have been extended to their full extension as shown in FIGURE 3. Thus, the diameter of the enlarged section of the bore hole may be chosen between the limits of the cutting arm extension. When the cutting arms have been extended to a desired diameter, the underreamer may be lowered in the bore hole so that the enlarged section of the bore hole may be lengthened as shown in FIGURE 3. FIGURES 1, 2, and 3 describe cutting arms which have four driven cutters on each arm and eight free-wheeling cutters on each arm. Of course, the number of driven cutters and free-wheeling cutters may be varied as described depending upon such factors as the desired diameter of the enlarged section, a depth at which the drilling proceeds, the weight imposed upon the underreamer, and the environment in which the underreamer is used. Cuttings removed from the walls of the bore hole fall to the bottom of the enlarged opening and impinge upon the crusher plate **98** which rotates simultaneously with the cutting arms. Crusher rollers **94** are held in nonrotative position in relationship to the axis of drill pipe section **12** by reason of attachment to the housing of bottom stabilizer **50**, but these crusher rollers rotate freely on crusher axle **60** which supports them in crusher frame **92**. The particles falling upon crusher plate **98** are reduced in size by the cooperation of plate **98** and roller **94**, after which the reduced particles fall through openings **100** in plate **98** to land in collection basin **102** from which they are propelled upward through drill pipe section **12** and drill pipe sections **13** by fluid pumped down the bore hole.

FIGURE 5 also describes schematically an emergency hydraulic system that, when energized from the surface, will position all components for removal of the underreamer from the bore hole. Surface emergency station **142** includes a suitable source of the electricity to operate an electric motor and hydraulic pump included in the station, which system may be automatic or manual, to pump hydraulic fluid through line **144** simultaneously to top stabilizer **44**, bottom stabilizer **54**, and arm positioner **72**, to cause arm positioner **72** to move to its retracted position and to release stabilizers **44** and **54** from their forceable contact with the wall of the bore hole so that the underreamer may be withdrawn from the bore hole in the event of any emergency such as the failure of the down hole hydraulic system.

I claim:

1. An earth formation underreamer comprising:
a rotatable supporting body,
means to suspend said supporting body in a bore hole,
hydraulic power means positionable on said supporting body,
stabilizer means positioned on said supporting body adaptable to bear against the wall of said bore hole,
a cutter arm rotatively positionable on said supporting body, said cutter arm adaptable to be driven by and positioned axially and radially on said supporting body by said hydraulic power means,
crusher means rotatively positionable on said supporting body below said cutter arm and adaptable to be driven by said hydraulic power means, said crusher means adaptable to reduce in size material dislodged from said earth formation by said cutter,
collection means cooperating with said crusher means and said supporting body to collect and circulate to the surface said material passing through said crusher means, and
electric circuit means controllable from the surface of the ground to operate said hydraulic power means.

2. An earth formation underreamer as described in claim **1**, wherein:
said stabilizer means is actuated by said hydraulic power means.

3. An earth formation underreamer as described in claim **2**, wherein:
said supporting body is a pipe section.

4. An earth formation underreamer as described in claim **3**, wherein:
said crusher means is actuated by said hydraulic power means.

5. An earth formation underreamer as described in claim **4**, wherein:
said hydraulic power means comprises an electrically driven pump, a reservoir of hydraulic fluid communicable with said pump, and fluid lines connect-

ing said pump to said stabilizer, said cutter arm, said crusher means, and said collection means.

6. An earth formation underreamer as described in claim 5, wherein:

said cutter arm includes a swivel mounting on said supporting pipe, a supporting arm swivelably attached to said supporting pipe, a stiffening arm swivelably attached to said supporting pipe and to said supporting arm, an axle housing secured to said supporting arm, a driven cutter rotatively mounted on said axle housing, a hydraulic motor mounted on said axle housing adjacent said swivel mounting, transmission assembly operatively connected to said motor, a drive axle having one end meshing with said transmission assembly and a second end driving said driven cutter, and a free wheeling cutter mounted bearably on said axle housing.

7. An earth formation underreamer as described in claim 6, wherein:

said crusher means comprises a crusher roller swivelably mounted on said supporting pipe adjacent the lower end thereof and a crusher plate mounted beneath said crusher roller and driven rotatively by said hydraulic means to cooperate with said crusher roller in reducing said material in size.

8. An earth formation underreamer as described in claim 7, wherein:

said collection means comprises a collection basin positioned adjacently beneath said crusher plate, a flexible sealing member surrounding said collection basin circumferentially and abutting said bore hole wall.

9. An earth formation underreamer as described in claim 8, wherein:

said stabilizer means includes an upper stabilizer member and a lower stabilizer member, each of said stabilizer members having a supporting frame mounted on said supporting pipe, a pair of extendable members attached to said frame, and a roller member on each of said extensible members adaptable to contact said bore hole wall, said extensible member operable by said hydraulic means.

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U.S. Cl. X.R.

175—96, 99, 267; 299—61, 71