

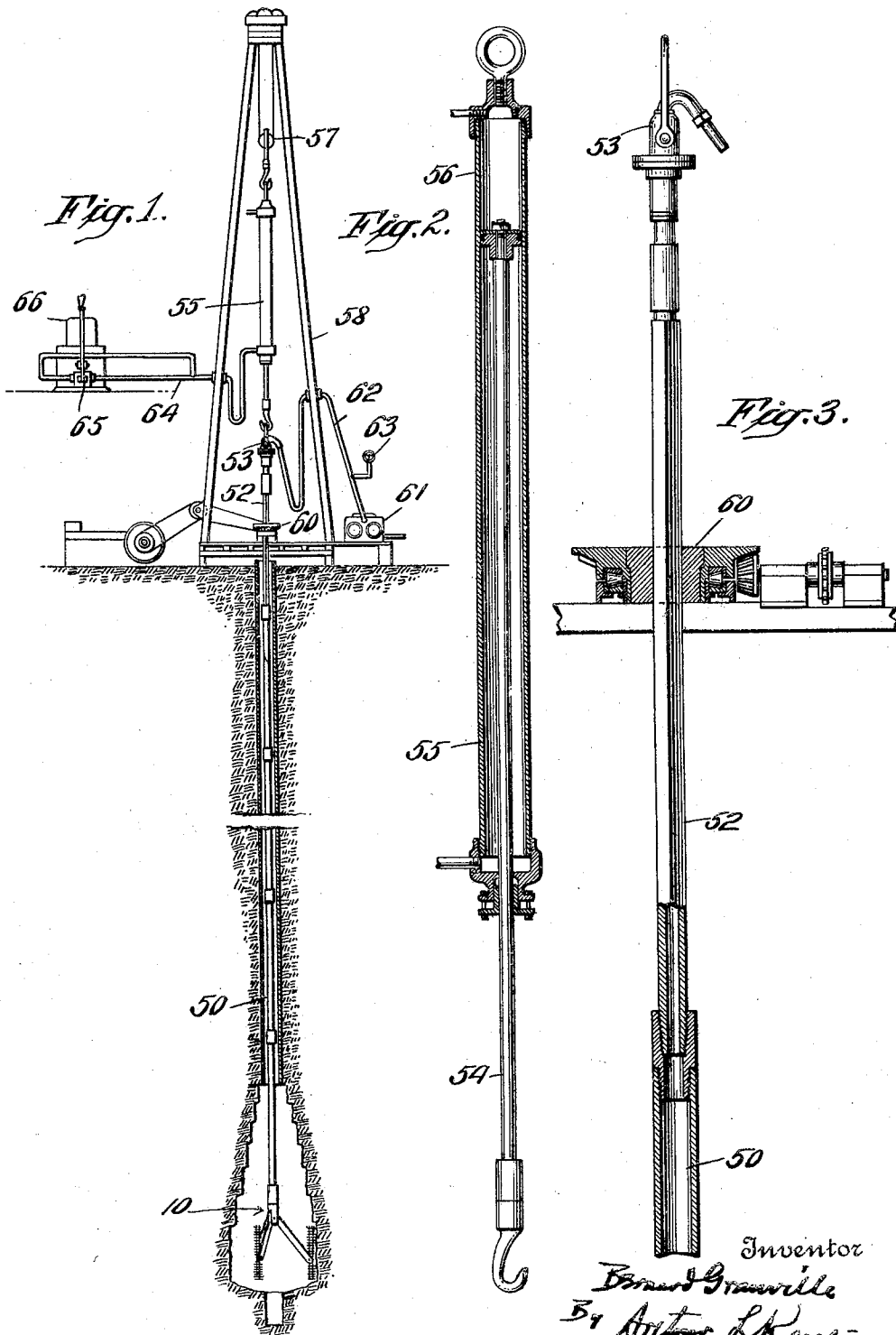
July 26, 1932.

B. GRANVILLE

1,868,702

UNDERREAMING APPARATUS

Original Filed July 21, 1923 3 Sheets-Sheet 1



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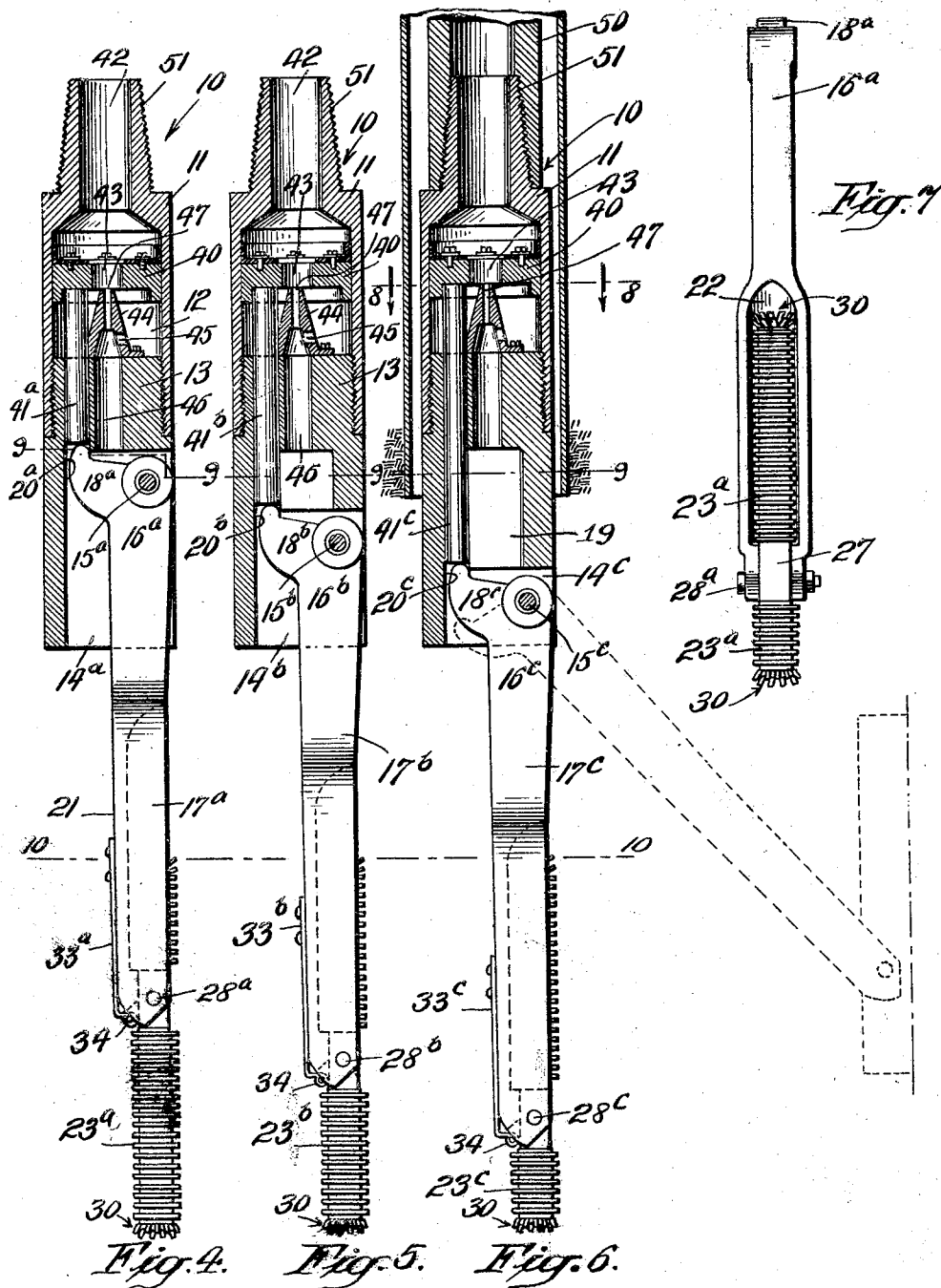
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Original Filed July 21, 1923 3 Sheets-Sheet 2



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**July 26, 1932.**

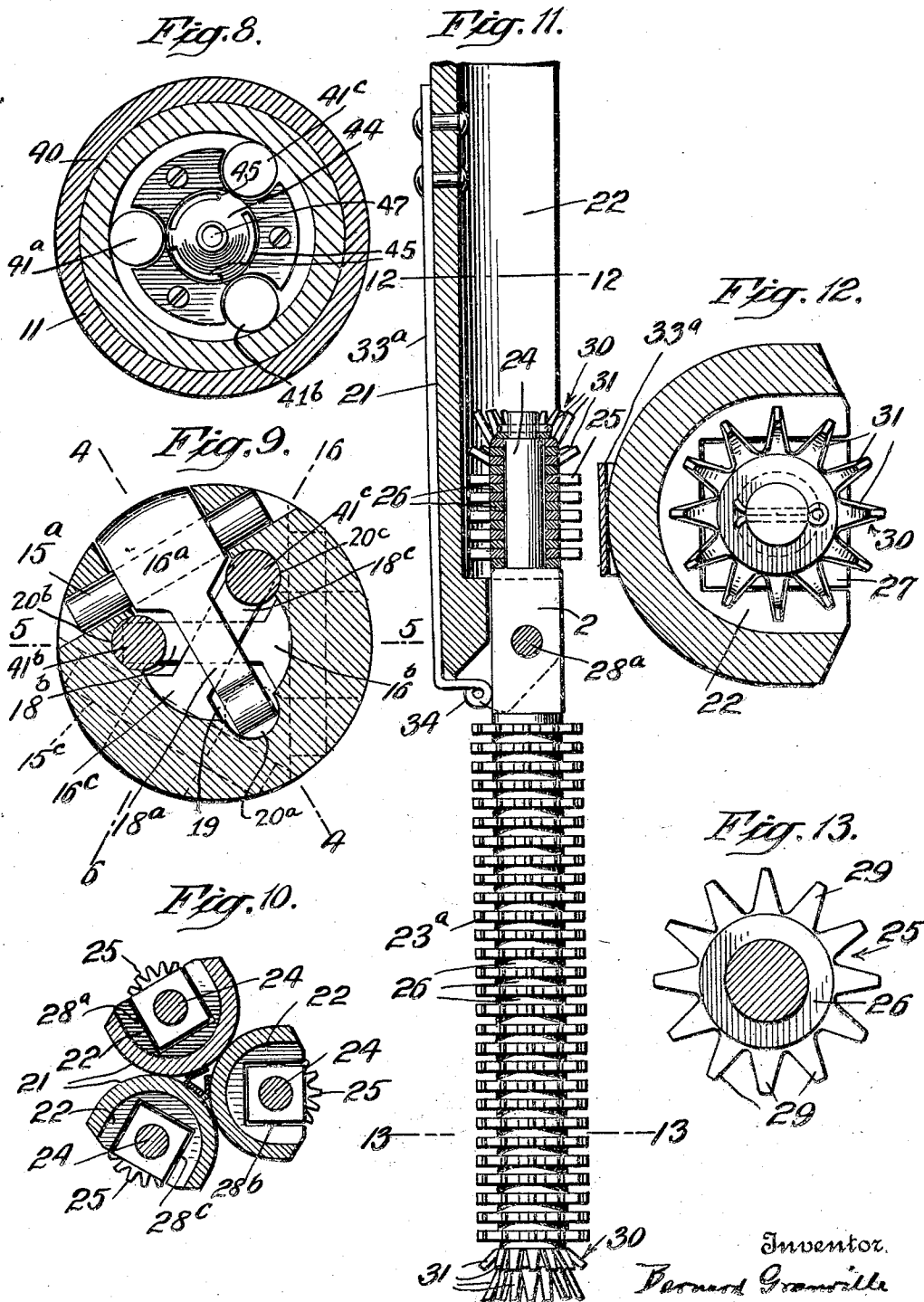
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## UNDERREAMING APPARATUS

Original Filed July 21, 1923

3 Sheets-Sheet 3



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# UNITED STATES PATENT OFFICE

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## UNDERREAMING APPARATUS

Application filed July 21, 1923, Serial No. 652,906. Renewed October 13, 1931.

This invention relates to under-reaming apparatus and aims to provide an improved means for forming an enlarged cavity at the bottom, or at any other desired point, of an oil well, or other deep vertical hole.

An object of the invention is to provide indicating means by which the width of the cavity being formed by the under-reamer may be known at the top of the well as the cavity is in process of being formed. A further object is to provide an under-reamer which is self-centering. A still further object is to provide improved means for feeding the under-reamer during the cutting. Other objects and advantages of the invention are hereinafter described.

An under-reaming apparatus of approved construction embodying the invention includes an under-reamer having a cylindrical body, three arms pivotally mounted on the body at angles of  $120^\circ$  from each other, cutters pivoted to the outer ends of the arms, and a plunger in the body adapted to force the arms outwardly when hydraulic pressure is applied to it. A hollow drill rod is provided for rotating the under-reamer and conducting water or other fluid from a force pump at the top of the well to one side of the plunger of the under-reamer. The plunger is provided with a leakage opening whose size is dependent upon the extent to which the arms are spread out. The width of the cavity formed by the under-reamer may, therefore, be determined by the rate of escape of liquid forced against the plunger. This rate may be determined by the pressure in the drill rod indicated on a pressure gage at the top of the well. The diameter of the cavity formed is thus indicated at the top of the well during the operation of the under-reamer. The under-reamer and the drill rod are suspended from a hydraulic lift which provides means for gradually feeding the under-reamer up and down during the cutting.

In order that the invention may clearly be understood, I will describe in detail the specific embodiment of it which is shown in the accompanying drawings, in which

Fig. 1 is a diagrammatic sectional eleva-

tion showing the complete under-reaming apparatus in operation in an oil well;

Fig. 2 is a sectional elevation of the hydraulic lift;

Fig. 3 is a side view of the grief stem which is suspended from the lift, showing, in axial section, the apparatus for rotating the stem;

Fig. 4 is an axial section of the under-reamer on the line 4—4 of Fig. 9, with parts omitted for the sake of clearness;

Fig. 5 is a similar section on the line 5—5 of Fig. 9;

Fig. 6 is a similar section on the line 6—6 of Fig. 9;

Fig. 7 is a front elevation of one of the cutters and the lever on which it is pivoted;

Fig. 8 is an enlarged transverse section of the under-reamer on the line 8—8 of Fig. 6;

Fig. 9 is a similar section on the line 9—9 of Figs. 4 to 6;

Fig. 10 is a transverse section of the cutters taken on the line 10—10 of Figs. 4 to 6;

Fig. 11 is an enlarged side elevation of one of the cutters partly in section;

Fig. 12 is a transverse section on the line 12—12 of Fig. 11 on a still larger scale; and

Fig. 13 is a transverse section on the line 13—13 of Fig. 11, on the same scale as Fig. 12.

The under-reamer 10, best shown in Figs. 4 to 13, has a cylindrical body 11 in the upper part of which is a cylindrical chamber 12. The central part 13 of the body provides a closure for the lower end of this chamber. In the lower part of the body 11 are three radial slots 14a, 14b, 14c spaced at  $120^\circ$  from each other. These slots are of progressively decreasing length, the slot 14a being the longest. Near the upper end of the slot 14a is a transverse pivot rod 15a on which is pivoted a bell crank lever 16a having a long depending arm 17a and a short arm 18a extending inwardly across the body of the under-reamer. In the slots 14b and 14c are similar transverse pivots 15b, 15c on which similar bell crank levers 16b, 16c are pivoted. The pivot rods 15a, 15b, 15c are at different levels so that the short arms 18a,

18*b*, 18*c* of the three bell crank levers may extend across the axis of the body without interfering with each other. Space for these arms may be provided in the lower part of the body by extending the slots 14*a*, 14*b*, 14*c* inwardly, or, as shown in the drawings, the lower part of the body may contain a central bore 19 having internal longitudinal grooves 20*a*, 20*b*, 20*c* opposite the slots 14*a*, 14*b*, 14*c* respectively, and providing space for the inner ends of the arms 18*a*, 18*b*, 18*c*.

The depending arms 17*a*, 17*b*, 17*c* of the three bell crank levers are of the same length and the lower part 21 of each of them is U-shaped in cross-section so as to provide a recess 22 in its outer side. Cutters 23*a*, 23*b*, 23*c* are pivotally secured to the lower ends of the arms 17*a*, 17*b*, 17*c* respectively. The cutter 23*a* has a central shaft 24 on which toothed cutting discs 25 separated by spacers 26 are rotatably mounted. The shaft 24 is fixed in a block 27 which is pivotally mounted on a pivot 28*a* at the lower end of the arm 17*a*. The pivot 28*a* is parallel to the pivot 15*a*. Some of the cutting discs 25 are placed on the shaft 24 above the block 27 and others are placed below the block. The arrangement is such that the pivot 28*a* is spaced from the upper end of the shaft 24 by about one-third of the length of the shaft. The cutters 23*b* and 23*c* are similar to the cutter 23*a* except that their cutting discs 25 are so divided by their blocks 27 that the upper ends and the lower ends of the three cutters 23*a*, 23*b*, 23*c* are on the same level, notwithstanding the difference in the level of the lower ends of the arms 17*a*, 17*b*, 17*c* which, in the form shown, results from the difference in the level of the pivots 15*a*, 15*b*, 15*c*.

The cutting discs 25 are provided with cutting prongs 29 which project outwardly in planes perpendicular to the axis of the cutter shaft. In addition to the cutting discs 25 each cutter is provided with two cutting discs 30. These discs are mounted, one near each end of the cutter shaft. Each of them is provided with inclined cutting prongs 31 which extend beyond the end of the cutter shaft.

Flat springs 33*a*, 33*b*, 33*c* are secured to the arms 17*a*, 17*b*, 17*c*. Each of these springs has an in-turned lower end 34 which presses against one of the blocks 27 below its pivot, and thus normally positions the cutter shaft 24 which extends through this block parallel to the arm on which it is mounted, as shown in Fig. 11.

A plunger 40 in the cylindrical chamber 12 provides means for swinging the three arms 17*a*, 17*b*, 17*c* outwardly from the axis of the under-reamer. For this purpose push rods 41*a*, 41*b*, 41*c*, extending through bores in the central portion 13 of the body, provide means for transmitting downward movement of the plunger 40 to the inner ends of

the short arms 18*a*, 18*b*, 18*c* of the three bell crank levers. To provide for the difference in the level of the pivots 15*a*, 15*b*, 15*c* the push rods are made of progressively increasing length, the rod 41*c* being the longest.

The plunger 40 may be forced down by water forced into the chamber 12 through a central opening 42 in the upper end of the body. In order to provide for indicating the extent to which the arms 17*a*, 17*b*, 17*c* have been swung out a variable leakage opening is provided. The variable leakage opening comprises the space between the walls of a central hole 43 in the plunger 40 and the outer wall of a cone 44 fixed on the closure 13. The water which passes through this variable leakage opening flows out of the lower portion of the chamber 12 through lateral passages 45 in the cone 44, and a central hole 46 in the closure 13. A small axial passage 47 through the cone 44 permits some leakage of water through the plunger 40 and the chamber 12 even when the variable leakage opening is closed. It is apparent that the cross section of the variable leakage opening between the hole 43 and the cone 44 will progressively decrease as the plunger 40 is forced downward, swinging the arms 17*a*, 17*b*, 17*c* outward.

The under-reamer is secured to the lower end of a hollow sectional drill rod 50 by screwing a threaded projection 51 at the upper end of the body 11 into the lower end of the lowest section of the drill rod. The upper end of the drill rod 50 is secured to the lower end of a grief stem 52 which is suspended through a water swivel 53 from the piston rod 54 of a hydraulic lift 55. The upper end of the cylinder 56 of the lift is secured to the traveling block 57 of the draw-out works of an ordinary oil-well derrick. The under-reamer may be rotated through the drill rod 50 by a rotary head 60 cooperating with the grief stem 52 in the ordinary manner. Water may be forced into the upper end of the under-reamer through the drill rod by a force pump 61 connected by a pipe 62 with the intake opening of the water swivel 53. A pressure gage 63 is mounted on the pump 61 or connected to the pipe 62, as shown.

The cylinder 56 of the hydraulic lift 55 is connected by a pipe 64 with a three-way valve 65 of usual construction and adapted to place the pipe 64 in communication, either with an outlet opening, or with the discharge of a force pump 66.

The use and operation of the under-reaming apparatus which has been described is as follows:—The under-reamer 10 and the sectional drill rod 50 are lowered into a well in the ordinary manner. Enough rod sections are attached to bring the under-reamer to the point in the well at which it is desired to form an enlarged cavity. The upper end of the drill rod 50 is then secured to the grief

stem 52 which is supported by the means already described. During the lowering of the under-reamer, the arms 17a, 17b, 17c hang down vertically, and the cutters 23a, 23b, 23c are held parallel to the arms, with their upper cutting discs in the recesses in the arms, by the force of the springs 33a, 33b, 33c. In consequence, no part of the under-reamer projects beyond the periphery of the cylindrical body to interfere with the lowering.

After the under-reamer has been lowered to the proper position, it is rotated by means of the rotary head 50 and water is forced into the upper part of the chamber 12 by means of the force pump 61. The pressure thus applied to the upper side of the plunger 40 urges the arms 17a, 17b, 17c outwardly, bringing the cutters 23a, 23b, 23c against the side walls of the well. Owing to the pivoting of the cutters, the outward pressure applied to them holds them approximately vertical against the walls of the well, so that as the under-reamer rotates they form an approximately cylindrical enlargement in the well. Owing to the effect of centrifugal force on the cutters, however, the cavity formed is slightly tapered, being largest at its upper end. The cutting action of the cutting discs 25 may be increased by moving the under-reamer slightly up and down during the cutting by manipulation of the three-way valve 65. As the cutting proceeds, the under-reamer is fed gradually downward by moving the three-way valve 65 so as to permit water to escape slowly from the cylinder 56 of the hydraulic lift 55. Such endwise movements of the under-reamer are greatly facilitated by the fact that the end cutting discs 30 have prongs projecting beyond the ends of the cutter shafts.

As the wall of the well is cut away, the arms 17a, 17b, 17c swing outwardly more and more and the plunger 30 moves down further. This results in a gradual closing of the variable leakage opening between the hole 43 and the cone 44. As this opening is decreased in size so that the flow of water through the chamber 12 is diminished, a rise in pressure is indicated on the gage 63. It follows that if the pump 61 is operated at a constant speed the exact diameter of the cavity may be ascertained at any moment during the under-reaming by reading the gage 63. The gage may be calibrated so as to indicate the diameter of the cavity directly, or the diameter of the cavity may be calculated from a knowledge of the proportions of the bell crank levers and the taper of the cone 44.

When a very large cavity is desired, the under-reamer may be moved downward by permitting the escape of water from the cylinder of the hydraulic lift whenever the arms 17a, 17b, 17c have swung out so far that they are likely to hit the upper edge of the cavity formed by the cutters. In this way it is pos-

sible to form a stepped cavity whose bottom is of large diameter, as shown in Fig. 1.

During the cutting, the three cutters are always at substantially the same level, while the portions of the cutters which contain no cutting discs are each at a different level so that the part of the wall not reached by the discs of one cutter is attacked by the discs of the other two.

The provision of three cutters forced outwardly at equal angles from each other gives the under-reamer what may be termed a three-point support so that all side strain on the drill rod is avoided.

As the three cutters are forced out by a single plunger, no one of them can be forced out more than the others. Consequently, the cutters will pass over a wider longitudinal fissure in the wall of the well without being caught in it than they would if they were forced out independently.

If any one of the cutters is suddenly forced inwardly by striking a hard obstruction, the plunger 40 is moved upwardly in the chamber 12 so that no part of the mechanism is broken. Such upward yielding of the plunger 40 is made possible by the continuous leakage through the plunger which is provided by means of the openings hereinbefore described.

When a cavity of the desired size has been formed the pump 61 is stopped. The water remaining in the drill rod 50 flows out through the hole 43 in the plunger and the openings 45, or through the passage 47. In this way the upper side of the plunger 40 is relieved of all hydrostatic pressure so that the plunger is moved upward by the weight of the long arms 17a, 17b, 17c of the bell crank levers. These arms, therefore, swing down into vertical position, drawing the cutters away from the wall of the cavity. The springs 33a, 33b, 33c swing the cutter shafts into vertical position so that no part of the under-reamer projects beyond the periphery of its body and the under-reamer may easily be withdrawn from the well.

For the purpose of illustration, I have described a practical under-reaming apparatus embodying my invention. I wish it clearly understood, however, that my invention is by no means limited to the particular form and arrangement of the parts of the apparatus described, except in so far as is specified in the claims which follow.

What is claimed is:

1. An under-reamer, comprising a body containing a chamber, a plunger in said chamber, said parts being formed and arranged to provide a leakage opening between the portions of the chamber at opposite sides of the plunger and to decrease the cross-section of said opening progressively in accordance with the longitudinal movement of the plunger in the chamber in one direction, a cutter,

and means actuated by such longitudinal movement of the plunger in the chamber to move the cutter outwardly from the axis of the body.

2. An under-reamer, comprising a body containing a vertical cylindrical chamber having an inlet opening at its top end and an outlet opening at its bottom end, a plunger in said chamber containing a hole, a conical member fixed in said chamber so as to obstruct said hole to a greater and greater extent as the plunger is moved downwardly in the chamber, a cutter, and means actuated by downward movement of the plunger to force the cutter out from the axis of the body.

3. An under-reamer, comprising a body containing a vertical cylindrical chamber having an inlet opening at its top end and an outlet opening at its bottom end, a plunger in said chamber containing a hole, a conical member fixed in said chamber having an axial opening registering with the opening of the plunger and an outer surface positioned to obstruct the hole in the plunger to a greater and greater extent as the plunger is moved downwardly in the chamber, a cutter, and means actuated by downward movement of the plunger to force the cutter out from the axis of the body.

4. An under-reamer, comprising a body having an upper part containing a cylindrical chamber, a middle part forming a closure for said chamber and containing a central outlet hole and a plurality of eccentric holes, and a lower part containing longitudinal slots; pivots extending across said slots and located at different levels; bell crank levers mounted on said pivots and each having a short arm extending across the axis of the body to a point under one of said eccentric holes, and a long depending arm provided with a cutter; a plunger in said cylindrical chamber; and push rods of different lengths extending through said eccentric holes and serving to force the short arms of the levers down when the plunger is moved down.

5. An under-reamer having a body, a plurality of bell crank levers pivoted to said body at different levels and each having a short arm extending inwardly across the axis of the body and a long arm depending longitudinally of the body, cutters mounted on the long arms of said levers, and means for simultaneously forcing downward the short arms of said bell crank levers so as to swing their long arms outwardly from the axis of the body.

6. An under-reamer, comprising a body, an arm pivoted to said body, means for swinging said arm outwardly at an angle to the axis of the body, and a cutter pivotally secured to the outer end of said arm so that it may remain approximately parallel to the axis of the body when the arm is swung out, and means for moving the cutter into a posi-

tion parallel to the arm when the arm is retracted.

7. An under-reamer, comprising a body, an arm pivoted to said body, means for swinging said arm outwardly at an angle to the axis of the body, a cutter pivotally secured to the outer end of said arm so that it may remain approximately parallel to the axis of the body when the arm is swung out, and a spring urging the cutter into a position parallel to the arm.

8. An under-reamer having a body, an arm pivoted to said body, means for swinging said arm outwardly from the axis of the body, a cutter shaft pivotally secured at a point between its ends to the outer end of the arm, and cutting elements mounted on said shaft above and below the point at which the shaft is pivoted, said arm having a longitudinal recess for receiving the cutting elements mounted on the cutter shaft above the pivot point when the cutter shaft is parallel to the arm.

9. An under-reamer as claimed in claim 8 provided with a spring normally holding the cutter shaft parallel to the arm.

10. An under-reamer having a body, a plurality of arms pivoted to said body, means for swinging said arms outwardly from the axis of the body, and a cutter mounted on each arm and comprising a block pivoted at the outer end of the arm and a shaft extending through said block and cutting elements mounted on said shaft above and below said block, the outer ends of the arms and the blocks pivoted thereto being located at different levels and the shaft of each cutter being so positioned in its block that the upper ends of all the cutters are approximately at the same level.

11. A cutter for an under-reamer, comprising a shaft, a plurality of cutting discs rotatably mounted on said shaft and each having cutting prongs extending outwardly perpendicular to the axis of the shaft, and a cutting disc rotatably mounted on said shaft near each of its ends and having cutting prongs inclined to the axis of the shaft and projecting beyond the end of the shaft near which the disc is mounted.

12. Under-reaming apparatus, comprising an under-reamer having a cutter as described in claim 11 and means for thrusting said cutter outwardly while maintaining its shaft approximately vertical, means for rotating the under-reamer, and means for reciprocating the under-reamer in a vertical direction during its rotation to facilitate the action of the cutter.

In testimony whereof I have hereunto set my hand.

BERNARD GRANVILLE.