

[54] **UNDERREAMER HAVING VARIABLE ARM EXTENSION**

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3,483,394 12/1969 Fuchs..... 175/267

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[51] Int. Cl. **E21b 9/26**

[58] Field of Search..... **175/267, 269, 287**

[56] **References Cited**

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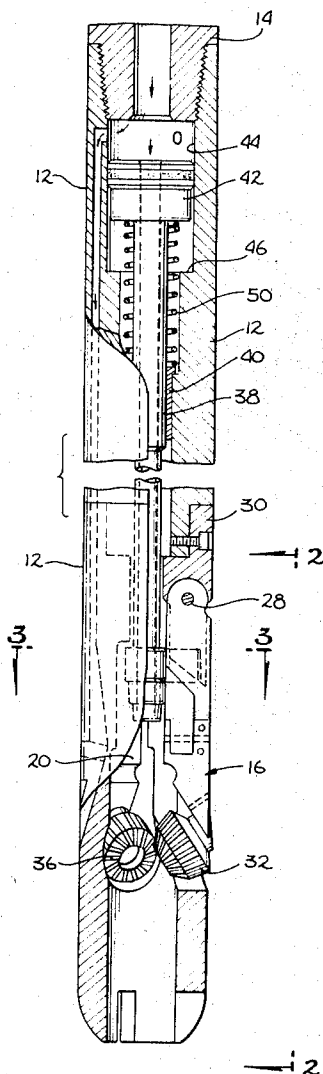
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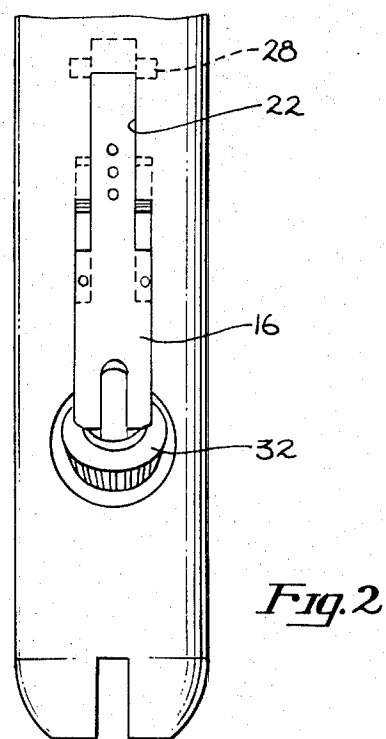
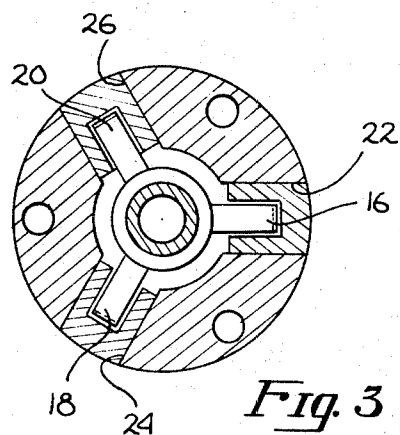
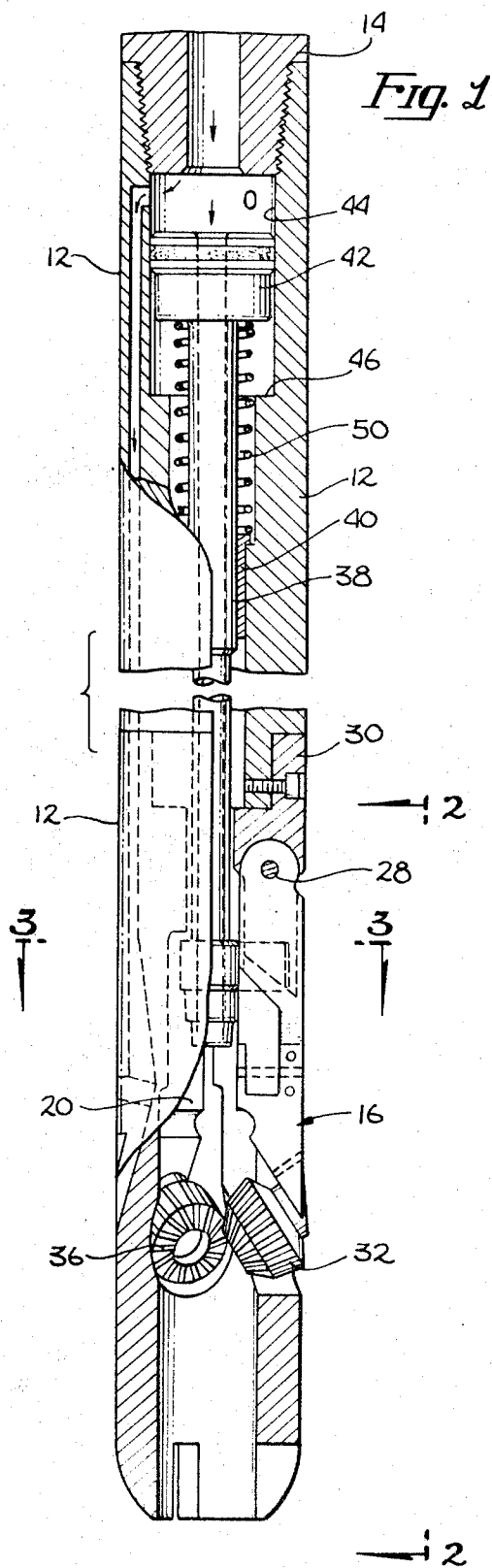
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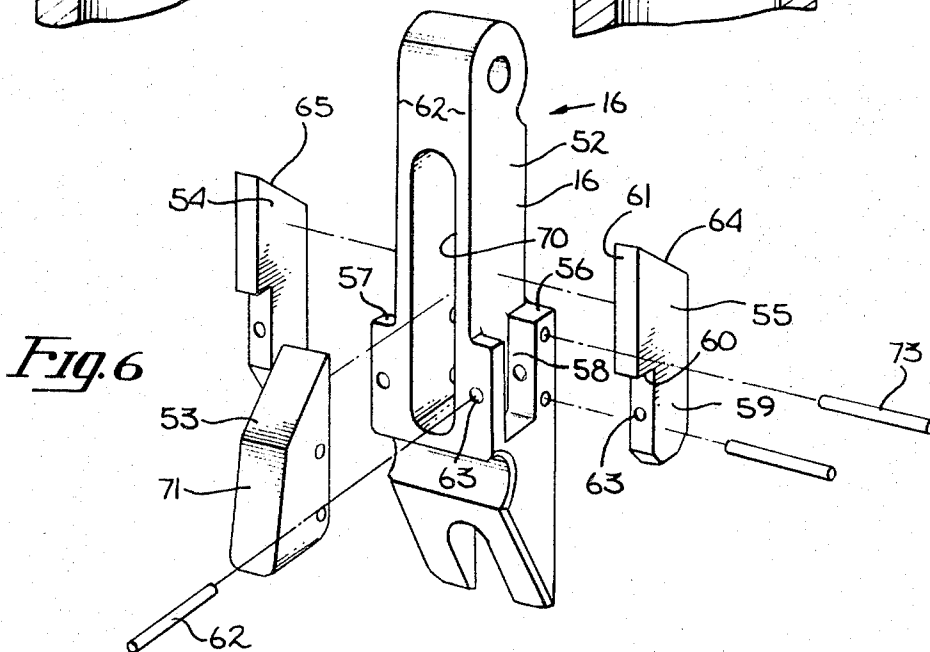
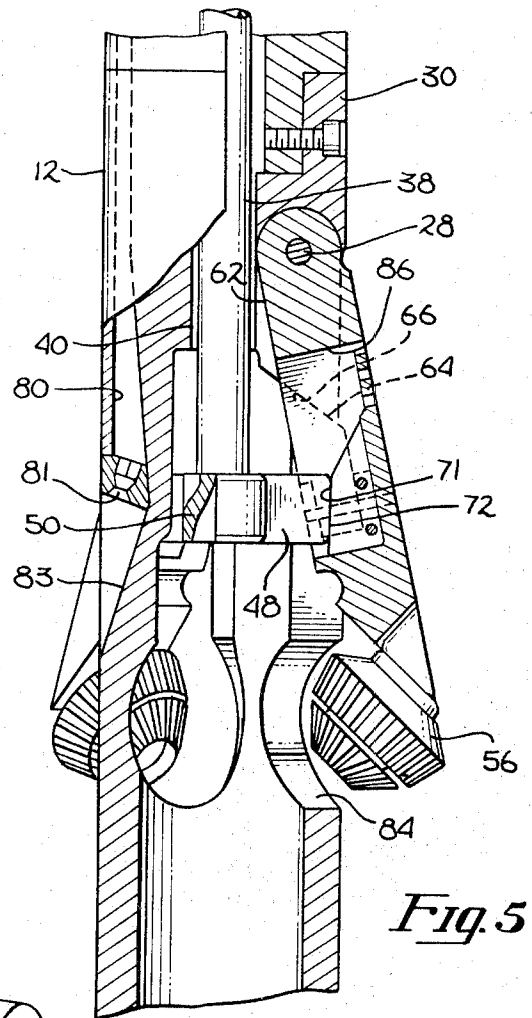
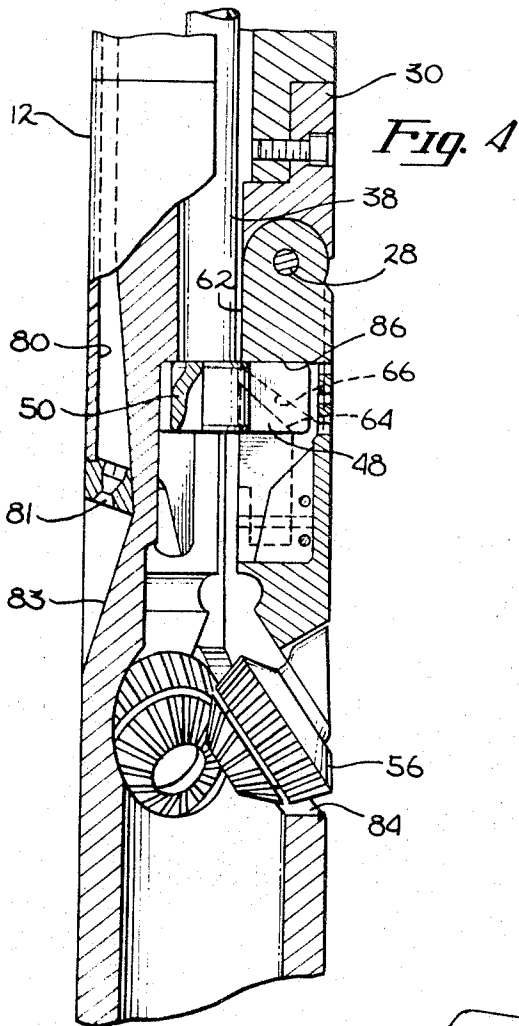
[57] **ABSTRACT**

An underreamer for enlarging a well bore wherein a plurality of cutter cones are rotatably supported on pivoted cutter arms which pivot outwardly from the body of the tool in response to fluid pressure. The amount of outward pivotal movement is adjustable without the removal and replacement of the cutter arms. This permits the same tool body and pivotable arms to be used for bore enlargements to different diameters relative to the contracted diameter of the tool.

3 Claims, 6 Drawing Figures







UNDERREAMER HAVING VARIABLE ARM EXTENSION

BACKGROUND OF THE INVENTION

Underreamers are employed extensively for enlarging portions of the well bore in oil and gas wells for various purposes, as for example, to provide clearance for running casing, to obtain adequate annular space in the hole for cementing, to enlarge zones for gravel pack completion or cementing and for other purposes.

One type of underreamer known to the prior art employs three cutter cones that are rotatably supported on respective pivoted arms which swing from an initial retracted position, wherein the arms and cutter cones are completely withdrawn into the body of the tool, outwardly to an extended or expanded position, wherein the cutter cones project radially outward from the body of the tool so as to enlarge the existing bore. In such conventional underreamers the cutter cones are all of the same length in the radial direction relative to the body of the tool. Similarly, in conventional underreamers the three pivoted arms upon which the cutter cones are rotatably supported swing outwardly to the same radial extent. The length of the cutters is limited in such conventional underreamers by the requirement that the cutters all fit completely within the diameter of the body of the tool when in the retracted position. The amount of hole enlargement that can be accomplished is in general limited to the cutter length since the cutters must generally operate upon the full annular formation area between the wall of the original bore and the wall of the enlarged bore. It can thus be seen that conventional underreamers having cutter cones of equal length and cone support arms which swing outwardly to equal extents are limited in the amount of bore enlargement which they can achieve. It is desirable with this type of tool to obtain the largest possible effective cutting diameter relative to the retracted tool diameter, i.e., it is desirable to obtain the maximum possible outward extension of the cutters consistent with efficient cutting and durability of the cutters in operation.

One prior art attempt to obtain a greater amount of cutter extension is described in U. S. Pat. No. 3,483,934 by Benjamin H. Fuchs which patent is assigned to the assignee of the present application. The underreamer of that patent utilizes pivoted arms which swing outwardly from the body of the tool by different radial amounts to thereby dispose the respective cutter cones in radially stepped relationship. By means of this arrangement the underreamer obtains a greater radial spread of cutter surface and provides greater bore enlargement relative to the contracted diameter of the tool than with conventional underreamers described above wherein the arms all swing out by the same amount.

The present invention is equally applicable to underreamers of both types, i.e., those in which the cutter cones all swing outwardly to the same radii and those described in the aforementioned patent in which the cutter cones swing out to different radii. The present invention is, however, presently utilized with an underreamer of unequal arm extension and will accordingly be described in connection with such a utilization.

SUMMARY OF THE INVENTION

In the underreamers of both types described above it

is desirable to utilize the same tool body for underreaming several sizes of holes. For example, the tool body for underreaming holes to diameters from seven to eleven inches all utilize a 5 $\frac{3}{4}$ th inch outside diameter tool body. However, in order to underream to the desired diameter it is necessary to have a specific set of arms. In order to change the diameter to which the underreamer opens the hole, a different set of arms must be inserted into the tool body. The necessity of changing cutter arms for each different bore radius results in the need for a large inventory of cutters and results in large expense. The present invention provides an underreamer apparatus which utilizes the same tool body and the same pivoted arms for underreaming holes to different predetermined diameters. The construction of the apparatus is such that easily replaceable portions of the expansion assembly are utilized to pivot the cutter arms outwardly to different desired radii.

An underreamer in accordance with the present invention comprises an elongate body with the series of circumferentially spaced cutter arms pivotally mounted thereon. A longitudinally movable wash-barrel includes a plurality of cams which engage cam follower surfaces on the respective cutter arms to force the cutter arms outwardly to the desired respective radius. The cam follower surfaces are defined by a replaceable cam follower plate mounted upon the respective cutter arm. The cam follower surface which is removable and replaceable upon the cutter arm without removal of the arm from the body determines the radius to which the arm is extended by the action of the cam. At least one radius limiter plate is replaceable affixed to the respective cutter arm to define a surface which comes into bearing engagement with a bearing shoulder on the tool body at the predetermined radius to limit the radially outward movement of the cutter arm.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view in elevation illustrating an underreamer embodying the present invention with the cutter arms disposed in the collapsed position;

FIG. 2 is a view elevation taken along line 2—2 of FIG. 1;

FIG. 3 is a sectional view taken along line 3—3 of FIG. 1;

FIG. 4 is a detailed partial view in elevation showing the cutter arms in the collapsed position;

FIG. 5 is a view comparable to FIG. 4 showing the arms in the extended operative position; and

FIG. 6 is an enlarged view in exploded perspective of the various components of the cutter arm.

DETAIL DESCRIPTION

Referring now to the drawings an expendable underreamer embodying the present invention is shown. The underreamer is illustrative of the type known as a full coverage underreamer which has two arms which are extendable to gauge size while the third arm is only partly extended from its cone pocket. It has been found that the most common problem in maximum size hole opening has been cone failure which occurs not at the gauge area but at the cone ends nearest the tool body. This is due to the fact that the amount of cone available at the end nearest the tool body is substantially less in proportion to the amount of material to be removed. By only partially extending the third arm a larger tooth

area works upon the formerly weak zone of the underreamer.

The arm with the smaller radius engages the formation at a lower plane creating a two-level saucer shaped pattern on the bottom of the shelf. By means of the present invention the same relationship of the cutter arms can be employed at different diameters in order to utilize the same apparatus to underream through a range of hole sizes without the necessity of replacing the cutter arms. The apparatus of the present invention comprises a tubular elongated body 12 which is threadably connected to a suitable tubular top sub 14.

Three cutter arms 16, 18 and 20 described in detail hereinafter are circumferentially arranged at regularly spaced intervals about the tubular body 12 in the lower portion thereof. The arms 16, 18 and 20 are pivotally supported in respective elongated slots 22, 24 and 26 in the body 12. The cutter arms 16, 18 and 20 are pivotally supported proximate their upper ends to swing generally in respective vertical planes which are radially oriented relative to the axis of the body 12 on horizontal support pins 28 which are mounted in the body 12. The cutter arms 16, 18 and 20 are provided with arcuate upper ends which are seated in complimentary recesses in arm retainers 30 which are welded or otherwise secured to the body 12 and serve as thrust bearing means for applying drill string weight to the cutters. Conventional cutter cones 32 and 34 (only two of which are visible in the views) are rotatably mounted at the lower ends of the respective cutter arms 16, 18 and 20.

A wash barrel 38 is axially mounted within the tubular body 12 and is slidably supported nears its lower end in a bushing 40. The wash barrel has a piston 42 secured to its upper end portion which piston is slidable within an enlarged cylindrical portion 44 of the tubular body 12. In the collapsed or retracted position of the underreamer the wash barrel 38 and piston 42 are in the uppermost position as shown in FIG. 1. In the expanded or fully operative position of the tool the wash barrel 38 and piston 42 are in the lowermost position as shown in FIG. 5. The lowermost position of the piston is determined by engagement of the piston with an upwardly facing shoulder 46 at the bottom of the cylinder 44. A helical spring 50 is mounted in an enlargement of intermediate diameter surrounding the wash barrel beneath the piston 42 and normally urges the piston and wash barrel toward their uppermost positions as illustrated in FIG. 1. The piston and wash barrel are moved downwardly to the extended position of the tool by the pressure of drilling fluid introduced into the drill string and through the sub 14 into the cylinder 44.

Positioned proximate the lower end of the wash-barrel 38 are three radially projecting cams 48, 49 and 50. The cams are affixed to the wash-barrel in any suitable manner such as by welding. The cams are circumferentially spaced about the wash-barrel and are in alignment with the longitudinal center line of a respective one of the cutter arms. Each of the cams extends the same radial distance from the center line of the wash-barrel which is coincident with the longitudinal center line of the tool. The thickness of the cams, i.e., in the transverse direction is such as to be matable with a pocket formed in the interior surface of the respective cutter arm as described more fully hereinafter.

Referring now particularly to FIGS. 4, 5 and 6 an illustrative cutter arm is shown in detail and is shown in exploded perspective in FIG. 6. Each of the cutter arms comprises an arm section 52, a center block 53 and two identical side blocks 54 and 55. The arm section 52 has an upper portion 52a of lesser transverse thickness than the lower portion 52b upon which a cutter cone 56 is rotatably mounted in the conventional manner. The lesser thickness of the upper arm portion and greater thickness of the lower portion form upwardly facing shoulders 56 and 57 on the side surfaces of the arm section 52. A downwardly extending recess 58 is formed in the side surface of the arm section extending downwardly from the shoulders 56 and 57. A side plate 55 has a mating section 59 matable with the recess 58 and a downwardly facing shoulder 60 which bears against the inner portion of the upwardly facing shoulder 57. When mated in the recess the side block has its inner edge 61 coincident with the inner surface 62 of the arm section 52. A fastening pin 62 extends through aligned pin openings 63 to securely retain the side plate in the recess such that it becomes an integral portion of the cutter arm. The side plate 54 is comparable in construction and the manner in which it is fastened to the opposite side of the cutter arm. Thus, the side plates when affixed to the arm section of the cutter arm assembly provide two bearing shoulders 64 and 65 on opposite sides of the cutter arm assembly. The bearing shoulders 64 and 65 are radially outwardly facing and downwardly inclined when the cutter assembly is mounted in the tool body. The shoulders 64 and 65 form bearing shoulders matable with load bearing shoulders 66 in the wall of the tool body 12 to thereby limit the amount of radial outward travel of the cutter arm assemblies. Thus, referring to FIGS. 4 and 5 it can be seen that as the cutter arm moves from its collapsed position of FIG. 4 to its fully extended position of FIG. 5, the bearing shoulders of the cutter arm assembly are moved into bearing contact with the bearing shoulders 66 of the tool body and the expansion of the cutter arm assembly is complete when the bearing engagement is made. The radius of extension of the cutter arms is thus limited through the shoulder 66 which is formed by a replaceable element 30. The slope of the bearing shoulder 66 of the tool body is constant whereas the replaceable side plates of the cutter arm assembly will determine by their slope the amount of extension allowable to the cutter arm assembly. For example, to provide a cutter arm assembly with a greater degree of extension than is shown in FIG. 5 the side plates of the cutter arm assemblies are replaced with side plates having a greater degree of inclination than those shown in the Figures. The greater degree of inclination will allow more extension before the shoulder 64 comes into bearing contact with the bearing shoulder 66. Conversely if less extension is desired side plates 54 and 55 are affixed to the cutter arm section 52 having a lesser inclination from horizontal such that they come into bearing contact with the stop shoulders when the cutter arm assembly has not been extended as far as is shown in FIG. 5.

Referring now again particularly to FIG. 6, a pocket or recess 70 is formed in the inner surface of the arm section of the cutter assembly symmetrically about the longitudinal center line of the cutter arm. The width of the pocket is substantially equal to, but greater than, the width of the cam which is matable with the respec-

tive cutter arm assembly. The downward movement of the cam 48 causes the cutter arm assembly to be extended by engagement of the camming surface 48 with the camming follower surface 71 of the cutter arm. The camming follower surface 71 of the cutter arm is provided by a center block 53 which is removably positioned within the pocket 70 and retained therein by fastening pins 73 which extend transversely through the cutter arm. The center block has a cam follower surface 71 with a radially downward and inward inclination which determines the extent to which the cutter arm is extended by the cam mounted upon the wash-barrel during the downward movement of the wash-barrel. As can be seen most clearly in FIG. 5 the cam follower surface 71 has a downward inclination which is substantially vertical at its fully extended position of the cutter arm assembly and is thus mateable with the vertical camming surface of the cam 48.

By reference particularly to FIG. 5 it can be seen that the slope of the cam follower surface 72 on the removable center block 53 and the slope of the bearing shoulders 64 and 65 at opposite sides of the cutter arm assembly are interrelated such that the cam follower surface 71 and the cam surface 72 are in bearing engagement at the same amount of radial extension at which the bearing shoulder 64 is in bearing engagement with the stop shoulder 66 of the tool body. For different amounts of radial extension it is necessary only to replace the center block 53 and the two side blocks 54 and 55 on the cutter arm assembly with center and side blocks having different but related bearing shoulders and cam follower surfaces. Accordingly, if a greater amount of extension is required, the cam follower surface is of greater radially inward slope and conversely if less extension is required the cam follower surface 71 has a slope which more nearly approaches the vertical.

In the presently preferred embodiment of the present invention the slope of cam follower surface 71 and the bearing shoulders 64 and 65 on two of the cutter assemblies is the same and is such that the two cutter arms are extended to the full gauge to be underreamed whereas the third cutter assembly arm has a lesser degree of slope to the cam followers surface and a correspondingly lesser amount of slope to the bearing shoulders such that when fully extended the third cutter arm is at a lesser radius than the two full gauge cutter arm assemblies.

Three fluid passages 80 extend longitudinally through the tool body with fluid jets 81 positioned in the passages. The jet orifices are located as close as practical above the cutter cones and each jet orifice opens into a recess in the outer space of the body that is formed by a downwardly and outwardly extending guide surface. These jet guide surfaces 83 provide a convenient means for directing the jet flow of pressurized fluid in a downwardly and outwardly diverging stream. The fluid passages and jets are circumferentially disposed in the tool body 12 intermediate the cutter arms 16, 18, and 20. Thus when the tool is rotating during a cutting operation to ream a portion of a hole out to the enlarged bore, as illustrated in FIG. 5, each of the cutting cones is lead by a jet stream which is directed generally into the region of the cutting plane and in this manner the jet stream will provide a full high velocity washing flow directly in the region of the cutting ledge where it is most effective, the flow being unim-

paired by any structure on the underreamer or by the ledge itself.

The opening for the cutter arm assembly in the tool body is such that the upper portion of the opening is mateable with the upper section of the arm and is expanded to a greater width to accommodate the increased width of the lower portion of the cutter arm assembly and finally terminates in a circular opening 84 through the wall of the tool body into which the cutter cone is retractable. Thus, in a retracted position as shown in FIGS. 1 and 4 the cutter arm assemblies are generally within the overall radius of the tool body and can be lowered into a bore hole having a diameter only slightly greater than the diameter of the drill string.

In the inoperative or retracted position of the underreamer as it is being lowered through the hole to a desired region of operation, drilling fluid is not pumped through the drill string into the cylinder 44 and the biasing force of the spring 50 will hold the piston, wash-barrel, and cams in their uppermost position as illustrated in FIGS. 1 and 4. In this inoperative or collapsed condition of the underreamer the three cutter arms are held in their retracted position by gravity and also by the spring bias engagement of the cams against shoulders 86 in the respective cutter arms.

When the tool is at the desired position in the hole, to commence reaming the tool is rotated and drilling fluid is introduced under pressure through the sub into the cylinder 44. Some of the drilling fluid will pass on downwardly through the wash-barrel 38 and thence through the hollow lower portion of the body 12 into the hole below the underreamer and the flow of this fluid back upwardly around the tool washes away the cuttings which are relatively free and which are freed by the jet streams provided from the orifices 81. Preferably there is a constriction in the wash pipe which serves to build up fluid pressure in the cylinder so as to more effectively actuate the cutters and provide high pressure and velocity to the jet streams from the orifices. The fluid pressure forces the piston 42 downwardly from the position of FIG. 1 to the position of FIG. 5. This in turn moves the wash-barrel and cams downwardly so as to swing the respective cutter arms 16, 18 and 20 outwardly to their operative position.

When it is desired to change the underreaming diameter of the tool, in accordance with the present invention it is necessary only to remove the side plates and center plate from each of the cutter arm assembly and replace them with a center plate and side plates which define a different fully extended position of the cutter arm assemblies as described hereinbefore. Accordingly, by means of the present invention the single tool body and plurality of cutter arm assemblies can be utilized to underream holes to different gauges by merely replacing the cam follower center plates and bearing shoulder side plates of the cutter arm assemblies.

What is claimed is:

1. An expandable underreamer which comprises an elongate, generally cylindrical tool body adapted to be suspended from and rotatably driven by a drill string; roller cutter cones supported on respective cutter arms;

said arms being peripherally spaced and arranged generally longitudinally of said body and being pivotally connected to the body adjacent their upper ends and supporting the respective cutter cones thereon adjacent their lower ends;

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said arms being pivotal between an inoperative position at which said cutter cones are retracted and wherein said arms are generally recessed within elongated slots in the body and an operative position at which said cutter cones are projected radially outwardly from said body wherein the arms incline downwardly and radially outwardly from their pivotal connections with the body, the pivot axes of said arms being substantially horizontally coplanar and said arms having substantially the same length, each of said arms including a cam follower plate and a radius limiting plate;
said radius limiting plate being engageable in bearing contact with a load bearing shoulder on said tool body to limit the outward extension of the cutter assembly;
said cam follower plate having a cam follower surface thereon;
said radius limiting plate and cam follower plate

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being removable and replaceable;
a vertically extending actuating member movable longitudinally downwardly within the tool body in response to fluid pressure;
a cam member affixed to said movable actuating member having a cam surface in camming engagement with the cam plate of said cutter arm assembly; and
the construction of said cam surface and cam follower surface being such as to move said cutter arm to a predetermined radius upon downward movement of said actuating member.
2. The apparatus as defined in claim 1 in which the cam follower plate is removably inserted in a longitudinal slot defined in said respective cutter arm.
3. The apparatus as defined in claim 2 in which two radius limiting plates are utilized and are positioned at opposite transverse sides of the respective cutter arm.
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