Dec. 16, 1969 B. H. FUCHS 3,483,934

UNDERREAMER HAVING UNEQUAL ARM EXTENSION RADII

Filed May 6, 1968 2 Sheets-Sheet 1

FIG. 1.

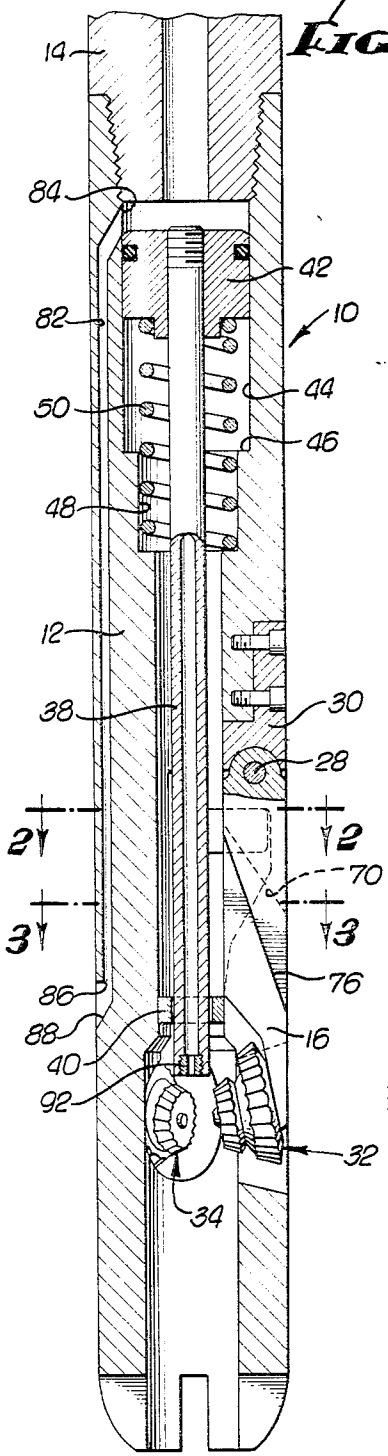


FIG. 2.

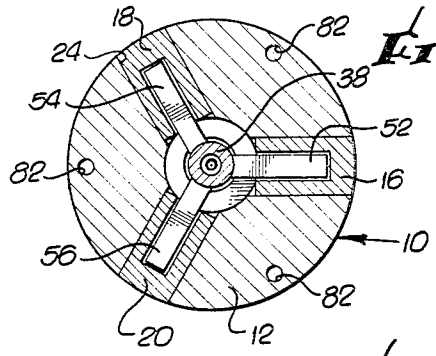


FIG. 3.

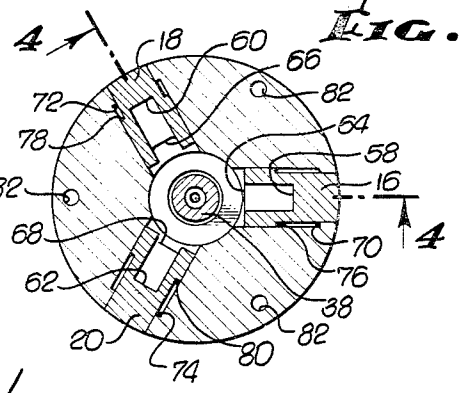
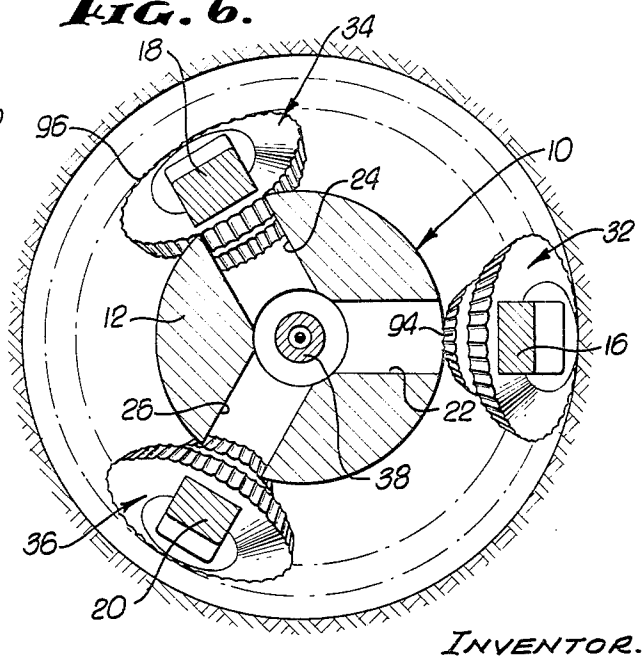


FIG. 6.



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FIG. 4.

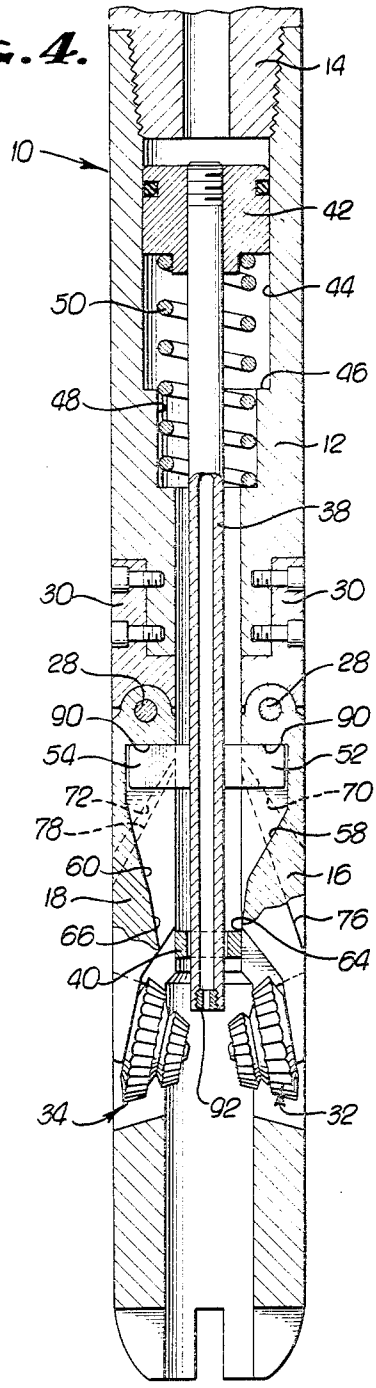
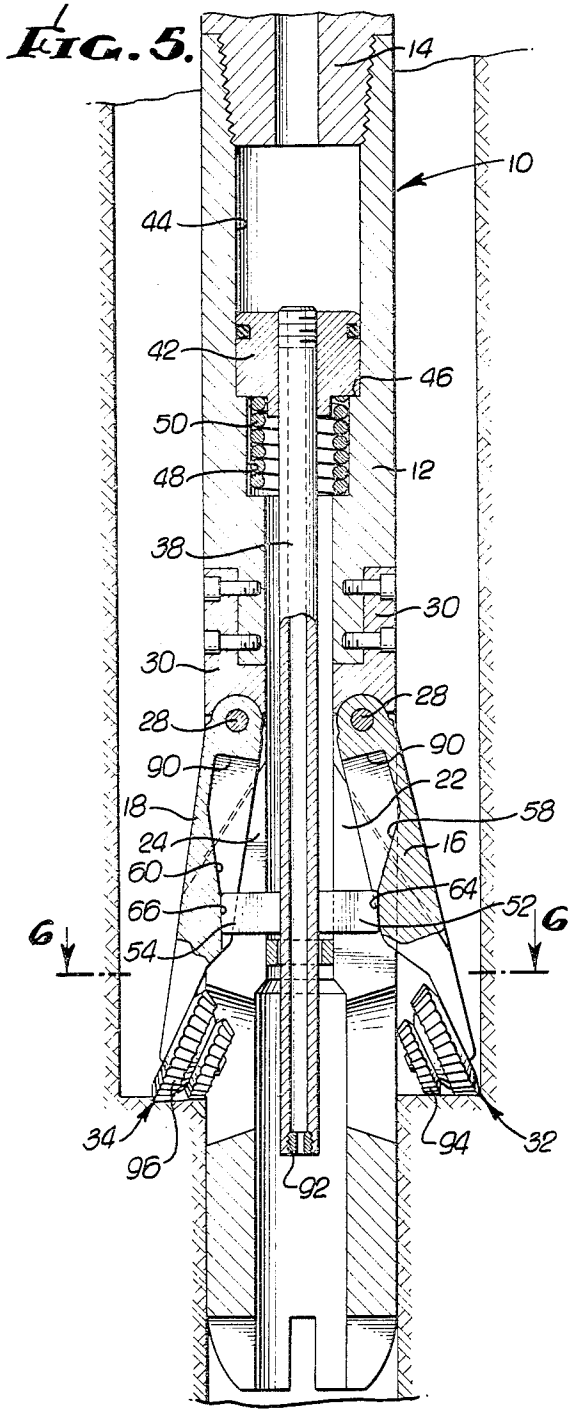


FIG. 5.



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UNDERREAMER HAVING UNEQUAL ARM EXTENSION RADII

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U.S. Cl. 175—267 7 Claims

ABSTRACT OF THE DISCLOSURE

An underreamer for enlarging a well bore wherein a plurality of cutter cones are rotatably supported on pivoted arms which swing outwardly from the body of the tool different radial amounts, thereby disposing the respective cutter cones in radially stepped relationship. This permits a greater radial spread of the cutter working surfaces, and hence greater bore enlargement relative to the contracted diameter of the tool, than the conventional practice of extending all of the cutters out to the same radial extent.

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, and for other purposes.

Conventional underreamers employ 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 outwardly 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 strictly 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, and 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 lengths and cone support arms which swing outwardly to equal extents are rather strictly limited in the amount of bore enlargement which they can achieve. Nevertheless, 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 than with conventional underreamers of the type described hereinabove involved the use of two relatively short cutter cones and one relatively long cutter cone which was substantially longer than conventional cones used for underreamers of similar body size. With this arrangement, the long cutter nested between the two short cutters in the retracted position,

yet in the extended position the long cutter permitted a greater cutting area to be covered. However, with this arrangement all three of the cutters were swung outwardly to the same radial extent, with the long cutter being the only one operating upon the full annular formation area between the wall of the original hole and the wall of the enlarged hole, the two short cutters only operating upon the outermost part of such annular formation. This resulted in the small end of the large cutter doing the entire cutting work on the inner annular portion of the formation area adjacent the original hole. This not only placed an undesirable limitation upon the cutting speed, but since the small end of a cone type of cutter is, in general, substantially weaker than the large end, it placed an undue burden upon a relatively weak portion of the device, tending to overload the small end of the large cutter, and thereby impairing the reliability and durability of the device as compared with conventional underreamers.

SUMMARY OF THE INVENTION

In view of these and other problems in the art, it is an object of the present invention to provide a novel underreamer having a plurality of cutter support arms which swing outwardly from the body of the tool differenct amounts so as to dispose the respective cutters in radially stepped relationship and thereby obtain a greater radial spread of cutter surface and provide greater bore enlargement relative to the contracted diameter of the tool than with conventional underreamers wherein the arms all swing out the same distance.

Another object of the invention is to provide an underreamer of the character described wherein the use of unequal cutter cone support arm extension radii permits conventional cutter cones of standard, equal lengths to be employed, despite the fact that the bore can be reamed out to a substantially greater extent than was heretofore possible with such conventional cutters of equal lengths.

Another object of the invention is to provide an underreamer of the character described wherein a plurality of roller cutter cones are arranged during the cutting operation at different extension radii relative to the axis of the tool, in such a way that a relatively large portion of an inner cone leads the small end portion of an outer cone in generally overlapping relationship, whereby the relatively tough larger portion of the inner cone protects the weaker small part of the outer cone by working in advance thereof.

A still further object of the invention is to provide an underreamer of the character described which embodies three cutter cones that, in operation, are disposed in three generally overlapping radial positions, whereby the cutting work will be generally equalized among the three cutters, while at the same time a considerably greater hole enlargement can be achieved than with conventional underreamers.

A still further and more general object of the invention is to provide a novel underreamer of the character described which is particularly simple in structure, is positive in operation, and is unusually efficient and durable.

Further objects and advantages of this invention will appear during the course of the following part of this specification, wherein the details of construction and mode of operation of a preferred embodiment are described with reference to the accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a vertical, axial section, with portions in elevation, illustrating an underreamer embodying the

present invention, with the cutter arms disposed in their collapsed or withdrawn positions.

FIGURE 2 is a horizontal section taken on the line 2—2 in FIGURE 1.

FIGURE 3 is a horizontal section taken on the line 3—3 in FIGURE 1.

FIGURE 4 is a vertical, longitudinal section, with portions in elevation, taken on the line 4—4 in FIGURE 3, illustrating two of the cutter arms and their respective cutter cones in their collapsed or withdrawn positions.

FIGURE 5 is a vertical, longitudinal section similar to FIGURE 4, but illustrating the underreamer of FIGURES 1 to 4 in operation enlarging a bore, with the two cutter arms illustrated in FIGURE 4 swung outwardly different amounts in their extended, operative positions, to place the respective cutter cones at different extension radii.

FIGURE 6 is a horizontal section taken on the line 6—6 in FIGURE 5, illustrating the overlapping cutting relationship of the three cutters disposed at different, stepped radial positions.

DETAILED DESCRIPTION

Referring to the drawings, an expandable underreamer embodying the present invention is generally designated **10**, and includes a tubular, elongated body **12** which is threadedly connected to a suitable tubular top sub **14**.

Three cutter arms, **16**, **18** and **20**, are longitudinally arranged at regularly spaced intervals about the tubular body **12** in the lower portion thereof, the arms **16**, **18** and **20** being 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 respective 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 complementary recesses in respective arm retainers **30** which are bolted 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**, **34** and **36**, which, if desired, may be the same length, are rotatably mounted at the lower ends of the respective cutter arms **16**, **18** and **20**.

A wash barrel **38** is axially centered within the tubular body **12**, being slidably supported near its lower end in a bushing **40**, and having a piston **42** secured to its upper end portion, the piston **42** being slidable within an enlarged cylinder **44** in the tubular body **12**. In the collapsed or retracted position of the underreamer as shown in FIGURES 1 and 4, the wash barrel **38** and piston **42** are in an uppermost position, while in the expanded or fully operative position of the tool as illustrated in FIGURES 5 and 6, the wash barrel **38** and piston **42** are in a lowermost position which is defined by engagement of the piston **42** against an upwardly facing shoulder **46** at the bottom of the enlarged cylinder **44**. An intermedate enlargement **48** in the bore of body **12** provides seating for a helical spring **50** which biases the piston and wash barrel toward their uppermost positions as illustrated in FIGURES 1 and 4. The piston **42** and wash barrel **38** are normally in the uppermost position of FIGURES 1 and 4, but may be selectively moved downwardly to the position of FIGURE 5 by the introduction of drilling fluid under pressure through the sub **14** and into the cylinder **44**.

Three cams, **52**, **54** and **56**, project radially outwardly from the wash barrel **38**, the cams **52**, **54** and **56** being integrally connected to the wash barrel **38** as by welding, and being regularly spaced about the wash barrel so that the cams **52**, **54** and **56** are in alignment with the respective cutter arms **16**, **18** and **20**. The arms **16**, **18** and **20** have generally radially inwardly facing cam follower surfaces **58**, **60** and **62** thereon, respectively, which are engaged by the respective cams **52**, **54** and **56** upon downward movement of the piston **42** and wash barrel **38**, and consequently of the cams, to move the cutter arms **16**, **18** and **20** from their fully retracted positions as illustrated in FIGURES 1 and 4 outwardly to their expanded or extended, operative positions as illustrated in FIGURES 5 and 6. The cam follower surfaces **58**, **60** and **62** terminate at their lower ends in respective cam ledges **64**, **66** and **68** against which the cams abut for holding the cutter arms in their fully extended or full swing positions as illustrated in FIGURES 5 and 6.

In the form of the invention that is illustrated in the drawings, the three cams **52**, **54** and **56** are of equal radial height, and the cutter arms **16**, **18** and **20** are caused to swing outwardly different amounts by relative differences between the three respective cam follower surfaces **58**, **60** and **62**. Thus, the cam follower surface **58** is the steepest of the three, and its respective ledge **64** is positioned radially inwardly on the arm **16** further than the others, whereby the cutter arm **16** and its respective cutter cone **32** are cammed outwardly to the greatest extension radius of the three.

Conversely, the cam follower surface **60** has the least incline of the three cam follower surfaces, and the respective ledge **66** is disposed radially outwardly in the arm **18** further than the other two ledges, whereby the arm **18** and respective cutter **34** are cammed outwardly to the smallest extension radius of the three.

The cam follower surface **62** has a slope which is intermediate the slopes of surfaces **58** and **62**, and the ledge **68** is disposed at a radial position in its respective arm **20** which is intermediate the positions of the ledges **64** and **66**. Accordingly, the cutter arm **20** and its respective cone **36** are cammed outwardly to an extension radius that is intermediate the radii of arm **16** and its cutter **32** on the one hand, and arm **18** and its cutter **34** on the other hand.

While the cutter arms are thus swung outwardly different amounts by cam members which are the same size operating against cam surfaces and ledges that are in different relative positions on the respective arms, alternatively the cam follower surfaces and ledges on all three arms may be the same, and the different radial extension of the three arms may be accomplished by employing three cams corresponding to the cams **52**, **54** and **56** which are of different heights.

Cooperating with the aforesaid cam means for positively moving the cutter arms and respective cones outwardly to different operating radii are opposed shoulders engageable between the body **12** and the respective cutter arms **16**, **18** and **20** to positively limit the amount of radial extension of the arms. This shoulder means includes pairs of generally radially inwardly directed, inclined stop shoulders **70**, **72** and **74** in the body **12** which are engageable with respective pairs of generally radially outwardly facing, inclined shoulders **76**, **78** and **80** on the respective cutter arms **16**, **18** and **20**. In the form of the invention illustrated in the drawings, the body stop shoulders **70**, **72** and **74** are all similarly positioned and oriented, while the cutter arm shoulders **76**, **78** and **80** are arranged at different angles and radial positions on each of the three cutter arms **16**, **18** and **20**, so as to cooperate with the previously described cam means to positively locate the three cutter arms, and hence the respective cutter cones, in their three different radial positions during operation. Thus, the shoulders **76** on cutter arm **16** are the innermost of the three pairs of arm shoulders, with the mildest angle of inclination, whereby the arm **16** may be cammed outwardly the greatest amount of the three arms. Conversely, the shoulders **78** on the arm **18** are the outermost of the three pairs of arm shoulders, with the steepest incline, thereby allowing the least amount of radial outward

movement of the arm **18**. The shoulders **80** on the arm **20** are intermediate the shoulders **76** and **78**, thereby allowing an intermediate amount of swinging movement of the arm **20**.

It will be apparent that if desired, the shoulders on the cutter arms may all be positioned alike, and the stop shoulders in the body may be varied in radial position and orientation to stop the three cutter arms in their respective differing radial operative positions.

Three fluid passages **82** extend longitudinally through the body **12** from respective entrances **84** located in the upper end of the enlarged cylinder **44** to respective jet orifices or outlets **86** that are located as close as is practical above the cutter cones. Each of the jet orifices **86** opens into a recess in the outer surface of body that is formed by a downwardly and outwardly curving guide surface **88**. These jet guide surfaces **88** provide a convenient means for directing the jet flow of pressurized fluid in a downwardly and outwardly diverging stream, and these jet guide surfaces may be considered as forming a part of their respective jet orifices.

Preferably, the fluid passages **82** are circumferentially disposed in the body **12** intermediate the cutter arms **16**, **18** and **20**, as best illustrated in FIGURES 2 and 3. Similarly, the jet orifices **86** are circumferentially arranged about the body **12** intermediate the cutter arms **16**, **18** and **20**, and immediately above the cutter cones **32**, **34** and **36**. Thus, when the tool is rotating during a cutting operation to ream a portion of a hole out to an enlarged portion as illustrated in FIGURE 5, each of the cutting cones is led 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 unimpaired by any structure on the underreamer or by the ledge itself. Since each of the three cutter cones **32**, **34** and **36** is operating at a different average radial position on the ledge, it is desirable for each of the jet orifices **86** to be arranged to direct its jet stream at a radius which is most effective for the average radius of the cone which follows it as the tool rotates.

In the inoperative or retracted position of the underreamer **10** as it is being lowered through the hole to a desired region of operation, drilling fluid will not be pumped through the sub **14** into the cylinder **44**, and hence the biasing force of spring **50** will hold the piston **42**, wash barrel **38** and cams in their uppermost positions as illustrated in FIGURES 1 and 4, these positions being defined by engagement of the cams **52**, **54** and **56** against shoulders **90** in the cutter arms. In this inoperative or retracted condition of the underreamer the three cutter arms are held in their collapsed or retracted positions as shown in FIGURES 1 and 4 by gravity, and also by the spring biased engagement of the cams **52**, **54** and **56** against the shoulders **90** in the respective cutter arms **16**, **18** and **20**.

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 **14** into the cylinder **44**. Some of this 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 will wash away the cuttings which are relatively free and which are freed by the jet streams provided from the orifices **86**. Preferably, there is a constriction **92** in the wash pipe which serves to build up fluid pressure in the cylinder **44** so as to more effectively actuate the cutters and provide high pressure and velocity to the jet streams from orifices **86**.

The fluid pressure in cylinder **44** will force piston **42** downwardly from the position of FIGURES 1 and 4 to the position of FIGURE 5, which will in turn move wash barrel **38** and cams **52**, **54** and **56** downwardly so as to swing the respective cutter arms **16**, **18** and **20** outwardly to their operative positions. The pressurized fluid in cylinder **44** will also cause fluid to be forced through the fluid passages **82** from entrances **84**, and thence out through the jet orifices **86** which direct the jet streams divergently downwardly and radially outwardly in the general region of the cutting plane.

It will be noted from FIGURE 5 that the small, relatively weak inner end portion **94** of cutter **32** operates during cutting at generally the same diametrical position on the ledge as the relatively sturdy large outer end portion **96** of the cutter **34**. Additionally, the somewhat more vertical positioning of the arm **18** which supports the cutter **34** causes the large outer portion **96** of cutter **34** to slightly lead the small inner portion **94** of cutter **32** as the tool advances downwardly in the hole, whereby the sturdy, large portion **96** of cutter **34** takes the brunt of the cutting ahead of the weaker portion **94** of cutter **32**.

In a similar manner, by having all three of the cutters, **32**, **34** and **36** located in different, but generally overlapping radial positions, the extra work of cutting a considerably larger diameter than that which is cut by conventional underreamers is generally evenly distributed to the three cutters. In test boring I have found that it is preferable to somewhat concentrate the cutter strength toward the outer part of the ledge. This can be accomplished by having the radial position of the intermediate cutter cone **36** somewhat closer to that of the outer cone **32** than to the inner cone **34**. In one test tool which proved to be highly efficient and durable, the operating diameters for the outer edges of each of the three cones **32**, **34** and **36** were, respectively, 15 inches, 14 inches and12¼ inches. If desired, the outer two cones may be disposed at the same diameter, and the tool will still enable a considerably larger underreaming diameter to be achieved than can be achieved with conventional equipment.

While the instant invention has been shown and described herein in what is conceived to be the most practical and preferred embodiment, it is recognized that departures may be made therefrom within the scope of the invention, which is therefore not to be limited to the details disclosed herein, but is to be accorded the full scope of the claims, so as to embrace any and all equivalent devices.

I claim:

1. An expandable underreamer which comprises an elongated, generally cylindrical body adapted to be suspended from and rotatably driven by a drill string, first and second roller cutter cones mounted on said body in peripherally spaced relationship with each cutter cone having a large outer portion and a small inner portion, both of said cutter cones being selectively movable between an inoperative position generally retracted into said body and an operative position projecting generally radially outwardly from the body, said cutter cones being supported on respective first and second arms, said arms being 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, said arms being pivotal between an inoperative position corresponding to said inoperative position of the cutter cones wherein said arms are generally recessed within elongated slots in the body and an operative position corresponding to said operative position of the cutter cones 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, said first arm swinging outwardly to a substantially greater angle relative to the axis of the body than said second arm in said operative position of the arms so as to dis-

pose said first cutter cone outwardly from the axis of the body to a substantially greater extent than said second cone defining an annular cutting area during rotation of the body that radially overlaps and axially leads the annular cutting area of said small inner portion of said first cutter cone.

2. An expandable underreamer as defined in claim 1, which includes a third arm arranged generally longitudinally of the body in peripherally spaced relationship to said first and second arms, said third arm having substantially the same length as said first and second arms and being pivoted to the body adjacent its upper end on a pivot axis substantially horizontally coplanar with the other said pivot axes, and a third roller cutter cone supported on said third arm adjacent the lower end thereof, said third arm being pivotal between an inoperative position wherein it is generally recessed within an elonggated slot in the body and said third cone is generally retracted into said body and an operative position wherein it inclines downwardly and radially outwardly from its pivotal connection with the body and said third cone projects generally radially outwardly from the body.

3. An expandable underreamer as defined in claim 2, wherein all three of said cutter cones in said operative positions of the arms are located in different but generally overlapping positions relative to the axis of the body.

4. An expandable underreamer as defined in claim 2, wherein said third cutter cone in said operative positions of the arms is disposed outwardly from the axis

of the body to a greater extent than said first cutter cone, but wherein the spacing between said first and second cones is greater than the spacing between said first and third cones relative to the axis of the body.

5. An expandable underreamer as defined in claim 2, wherein said third cutter cone in said operative positions of the arms is disposed outwardly from the axis of the body to substantially the same extent as said first cutter cone.

6. An expandable underreamer as defined in claim 1, which includes cam means in the body engageable with cam follower surface means on said arms to swing said arms outwardly from the body.

7. An expandable underreamer as defined in claim 6, which includes shoulder means in the body engageable with opposed shoulder means on said arms to positively limit the extent of outward movement of the arms.

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