United States Patent [19]

Furse

[11] **3,817,339**

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[54] **UNDERREAMER**

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[73] Assignee: **The Servco Company,** Long Beach, Calif.

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[52] **U.S. Cl.** **175/271,** 175/286

[51] **Int. Cl.** **E21b 43/16**

[58] **Field of Search** 175/271, 286, 290

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Primary Examiner—James A. Leppink

Attorney, Agent, or Firm—Christie, Parker & Hale

[57] **ABSTRACT**

A hole drilling tool, useful in mining operations for enlarging the lower portion of a hole for explosives, is described. This underreamer has arms movable between a retracted position and an extended position for underreaming in response to weight of the drill string above the tool. The two cutter arms are urged outwardly into their extended position by a cam connected to the upper end of the drill string. In effect the cutter arms are connected to the lower end of the drill string which can telescope relative to the upper end. The pivot pin for the cutter arms is hollow for bypassing a portion of compressed air to the cutters for cooling while another portion of the air passes in parallel to the lower portion of a drill string.

A latching selector sub is connected serially with the underreamer for latching the cutter arms in their retracted position in response to fluid pressure within the drill string. The selector sub permits collapse of the telescoping underreamer when telescoping force is applied prior to fluid pressure. Conversely telescoping is prevented and the cutter arms are retained in their retracted position when fluid pressure is applied prior to the application of telescoping force.

29 Claims, 10 Drawing Figures

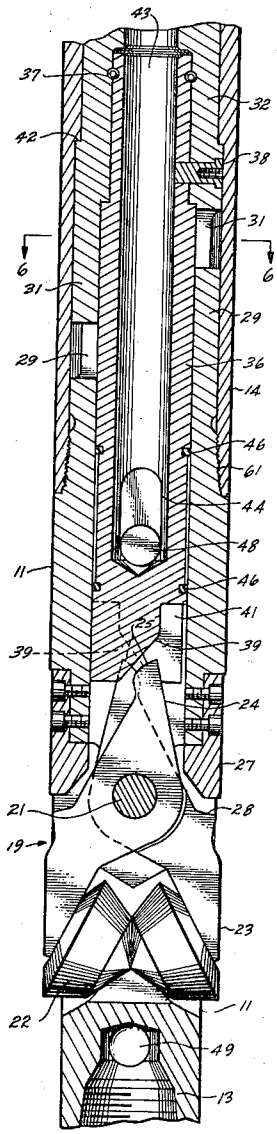


Fig. 1

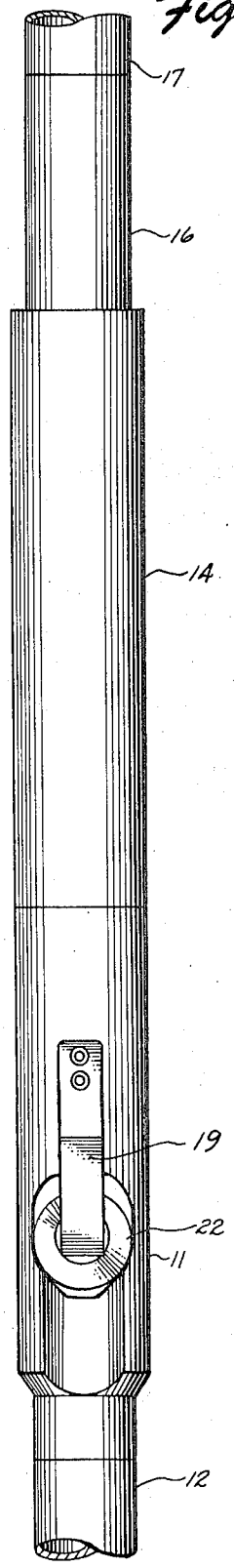


Fig. 4

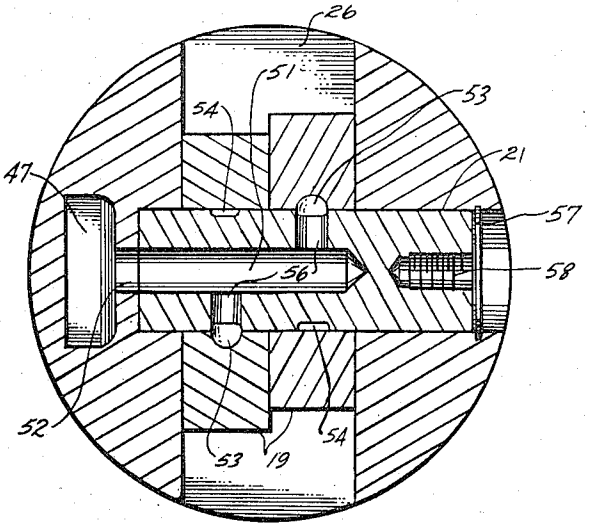


Fig. 5

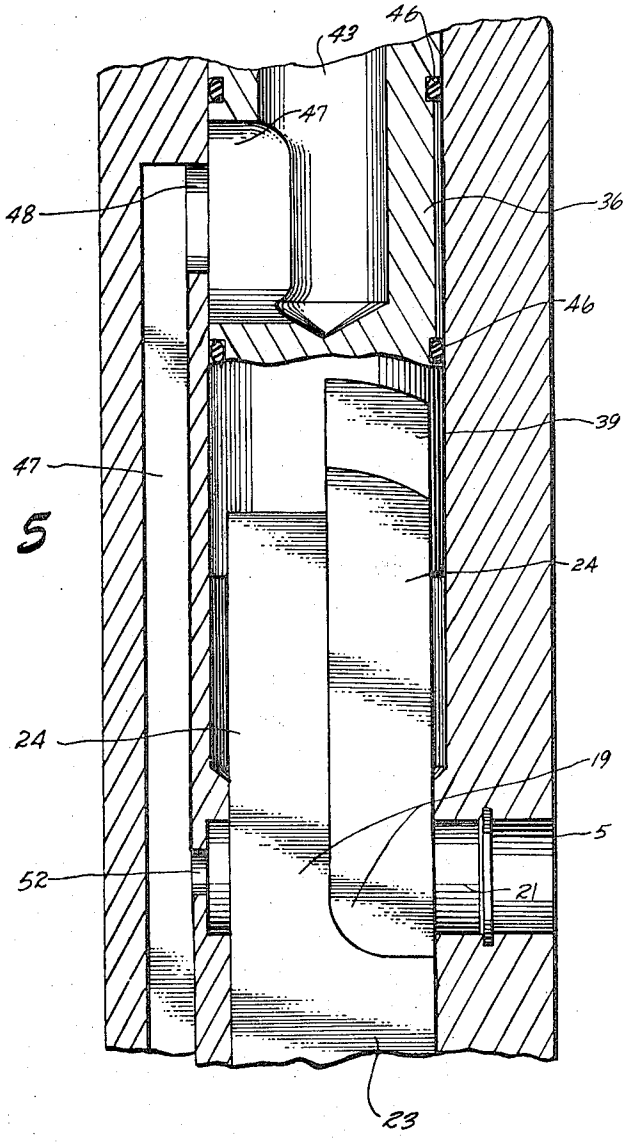


Fig. 2

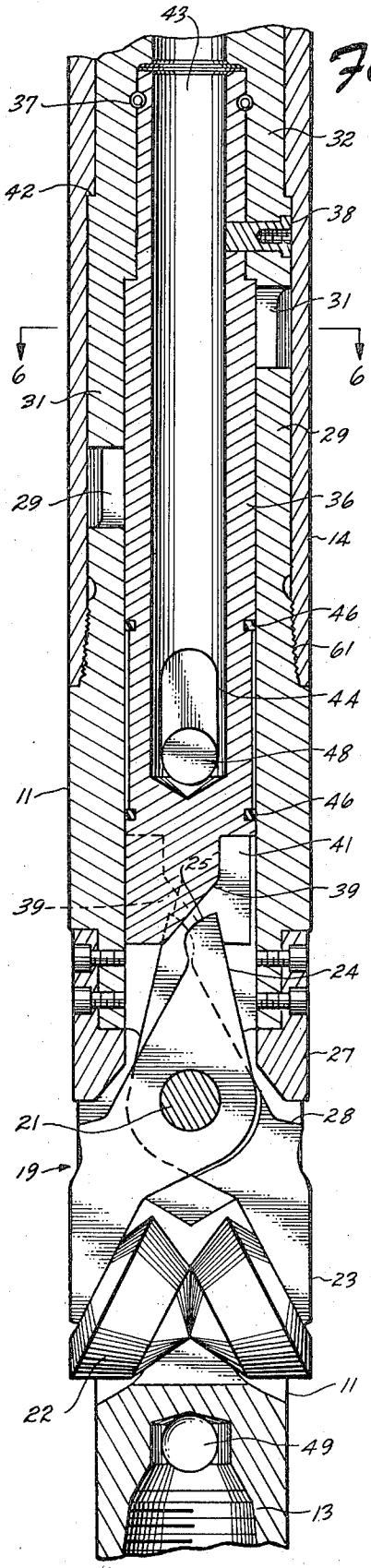

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Fig. 3

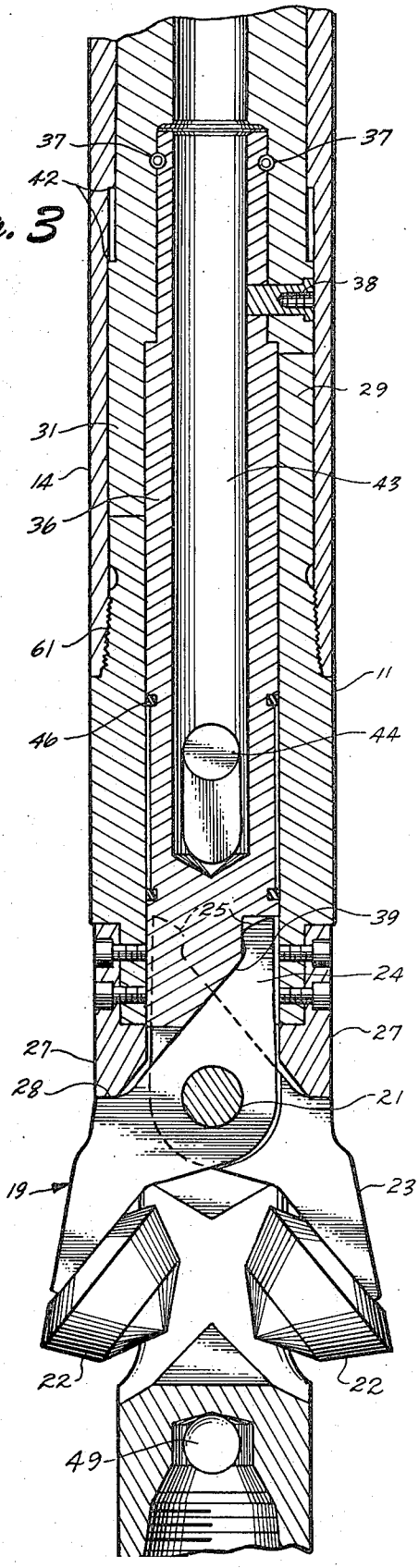

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Fig. 6

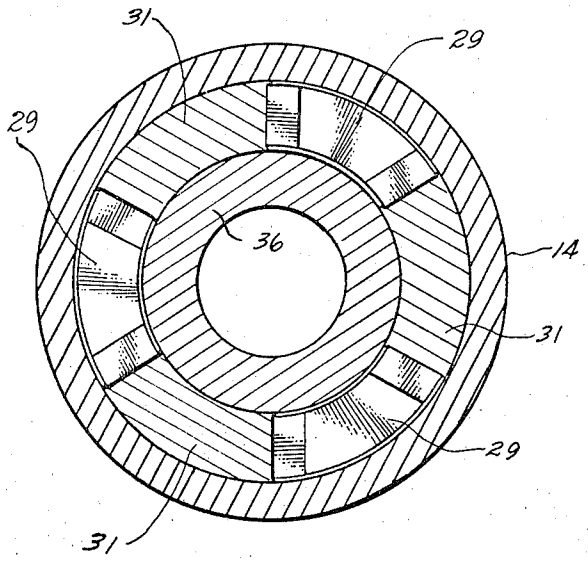


Fig. 9

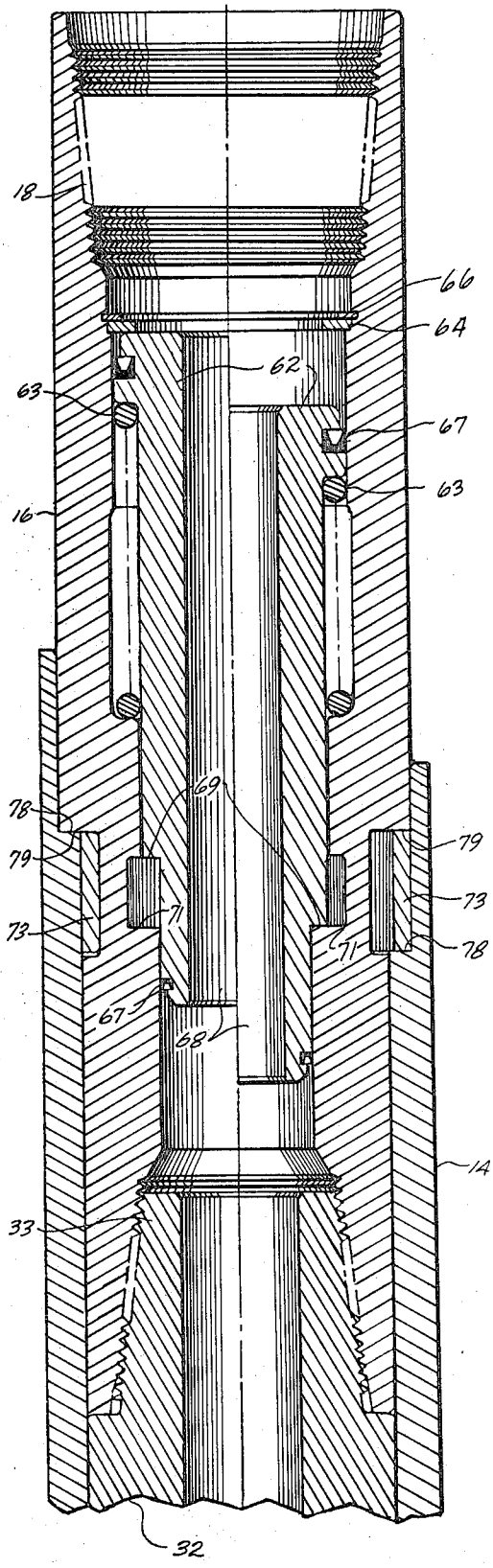


Fig. 10

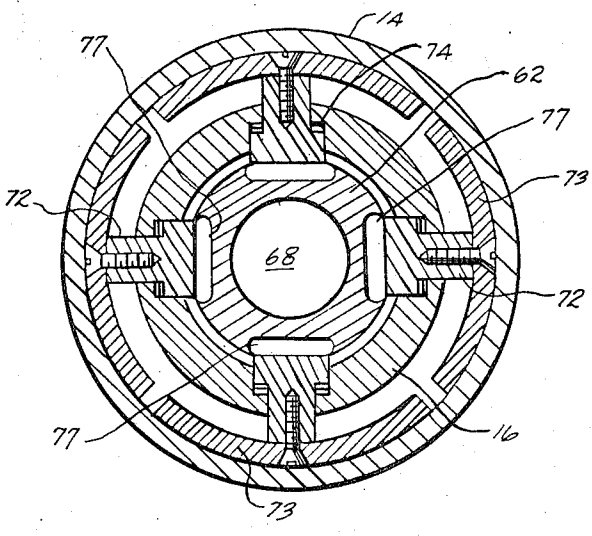


Fig. 7

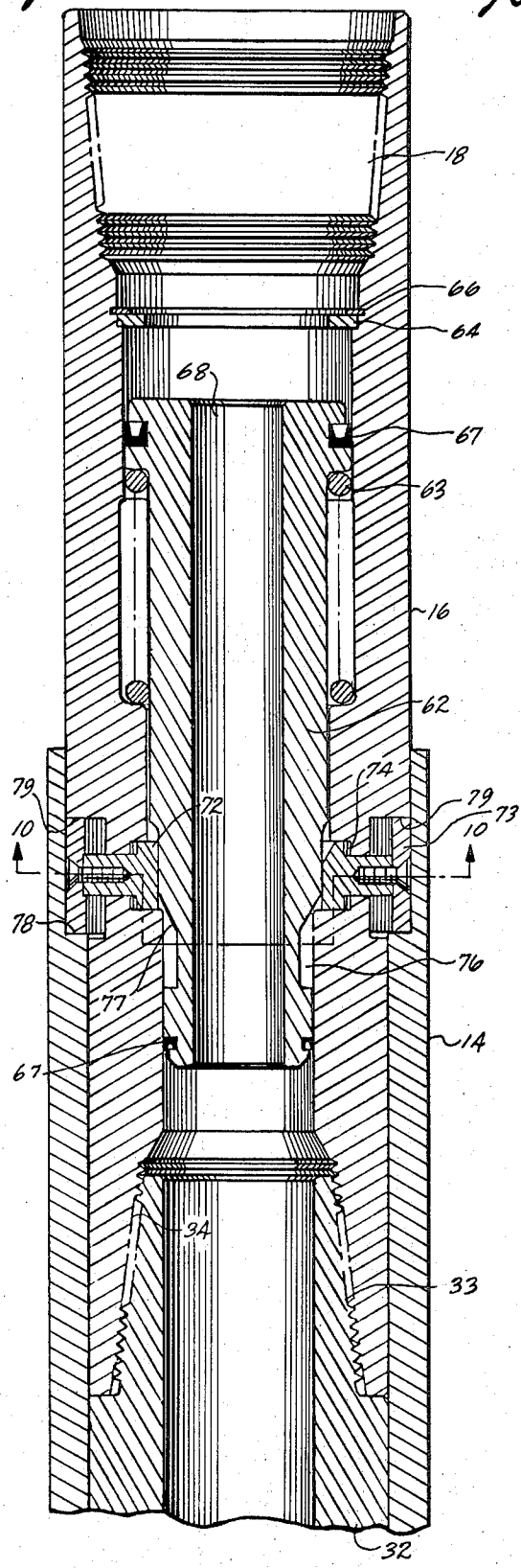
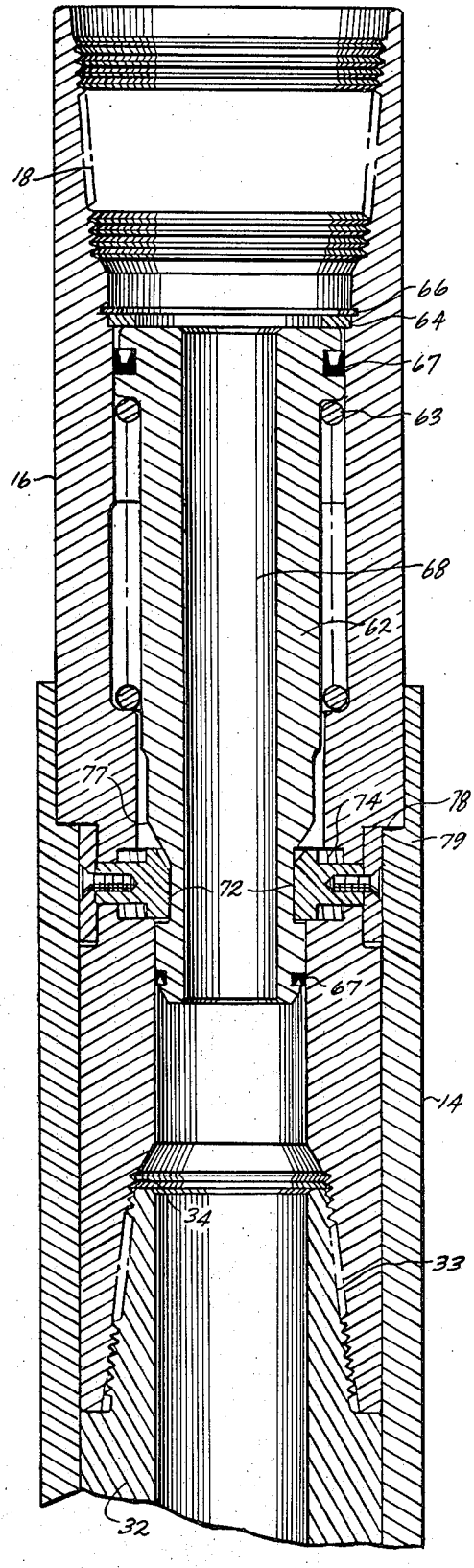

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Fig. 8


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UNDERREAMER

BACKGROUND

Rotary drills are commonly used for earth boring operations. Such drills are employed in oil and gas wells where the drill string proceeds to great depths. In such operations a drilling "mud" is typically pumped down the drill string for cooling the drilling cutters. When drilling oil and gas wells it is sometimes desirable to "underream" the hole, that is to enlarge the diameter of the hole being drilled at some point a substantial distance below the surface. To effect this, a variety of underreamers, hole openers or the like have been devised. In such operations the fluid pressure due to the drilling mud can be employed for actuating the underreaming tool. In deep well drilling operations it is typical to withdraw the drill string from the hole and install a suitable underreamer either alone or in series with a conventional pilot drill. When the drill string has been tripped back into the hole, pressure of drilling fluid is applied and through any of a variety of prior mechanisms the cutter arms on the underreamer are urged outwardly for enlarging the selected portion of the hole. After drilling, the cutter arms are retracted and the underreamer withdrawn from the hole. Typically such underreamers are extended whenever drilling fluid pressure is applied, which is at all times when drilling is being conducted.

In mining operations it is typical to use somewhat shorter drill strings which do not extend so deeply into the ground and the drilling fluid is often compressed air instead of a slurry of mud and water. Generally speaking the air pressure is not sufficient for actuating the heavy cutter arms of an underreamer. Underreaming is desirable in many mining operations for enlarging the lower portion of a drill hole so that an adequate quantity of explosives can be inserted for breaking the earth formations and permitting mucking of the fragmented earth.

Since the drill strings are shorter, tool wear does not require round tripping of the drill string during the course of most drilling operations. It is therefore desirable to have a means for underreaming a blast hole without first withdrawing the drill string and installing an underreamer. It is also desirable to have an underreamer that can be actuated by means other than the fluid pressure of drilling fluid. Since the underreamer should be in the drill string during drilling of the pilot hole it is desirable to have means for latching the underreamer so that its cutting arms are in a retracted position during at least a portion of the drilling operations.

BRIEF SUMMARY OF THE INVENTION

There is therefore provided in practice of this invention according to a presently preferred embodiment, an underreamer having a lower body connectable to the lower portion of a drill string and an upper body connectable to the upper portion of a drill string. The upper and lower bodies are connected together by means for transmitting torque therebetween and also permitting limited telescoping of the upper and lower bodies between a relatively longer length and a relatively shorter length. A plurality of cutter arms are pivotally mounted on one body and the other body interacts therewith for urging the cutter arms outwardly to an underreaming position when the bodies are telescoped to their shorter length and permitting the cutter arms to retract inwardly to a clearance position when the bodies are in their relatively longer condition. Further, means are provided for latching the arms in their retracted position by inhibiting telescoping of the upper and lower bodies. Drilling fluid pressure may be used for selectively unlatching the upper and lower bodies and hence the cutter arms. Means are provided for conveying compressed air through the pivot pin for the cutter arms for cooling the cutter assemblies while another portion of compressed air is conveyed to the lower portion of a drill string.

DRAWINGS

These and other features and advantages of the present invention will be appreciated as the same becomes better understood by reference to the following detailed description of a presently preferred embodiment when considered in connection with the accompanying drawings wherein:

FIG. **1** illustrates in side view a combined underreamer and latching selector sub constructed according to principles of this invention;

FIG. **2** illustrates in longitudinal cross-section the lower underreamer portion of the combination of FIG. **1** with cutter arms in a retracted position;

FIG. **3** is a longitudinal cross-section similar to FIG. **2** with the cutter arms extended;

FIG. **4** is a transverse cross-section of the underreamer at the pivot for the cutter arms;

FIG. **5** is a fragmentary longitudinal cross-section transverse to the cross-sections of FIGS. **2** and **3**;

FIG. **6** is a transverse cross-section at torque transmitting splines within the underreamer;

FIG. **7** is a longitudinal cross-section of the latching selector sub portion of the combination in its latched position;

FIG. **8** is a longitudinal cross-section similar to FIG. **7** with the selector sub in its unlatched position;

FIG. **9** is a composite longitudinal cross-section transverse to the cross-sections of FIGS. **7** and **8** illustrating the selector sub in its latched position (on the right side) and in its unlatched position (on the left side); and

FIG. **10** is a transverse cross-section through the selector sub in the latched position as illustrated in FIG. **7**.

DESCRIPTION

FIG. **1** illustrates in side view a combined underreamer and latching selector sub constructed according to principles of this invention. As illustrated in this presently preferred embodiment the underreamer has a lower body portion **11** which is connected to a lower portion of a drill string **12** by a conventional threaded joint **13** (FIG. **2**). The lower portion **12** of the drill string typically includes a conventional drill (not shown) for forming a hole in the earth as the drill string is rotated. Such drills are conventional and, forming no part of this invention, are not further described herein. The drill is usually coupled directly to the underreamer.

A sleeve **14** is connected to the lower body **11** and extends upwardly to surround a portion of a latching selector sub **16**. The upper end of the latching selector

sub is connected to the upper portion 17 of a drill string by a conventional threaded joint 18 (FIG. 7). The upper drill string is a series of pipes connected to a rotary drilling rig.

A pair of cutter arms 19, better seen in FIGS. 2 to 5, are mounted on the lower body 11 by a pivot pin 21. Rock crushing cutters 22 of the conventional sort, and illustrated schematically, are mounted for rotation on the lower ends of the two cutter arms 19 respectively. Each cutter arm has a lower portion 23 on which the cutter 22 is mounted and an upper follower portion 24 on the opposite side of the pivot pin 21. The upper portions 24 are each half the width of the lower portion 23 so that the two arms are mounted on the pivot pin in a scissors fashion. A curved follower 25 is formed at the upper end of the upper portion 24 of each cutter arm. As best seen in FIG. 4, the arms are mounted in a slot 26 extending across the lower body 11. In the lower portion the arms are the full width of the slot so that the cutters are radially outwardly from the center line of the underreamer. The half width portions of the cutter arms are on opposite sides of the center line of the underreamer and can swing past each other so that the two arms swing in opposite directions.

A stop lug 27 is bolted onto the lower body 11 to partially close the sides of the slot. The stop lugs are inactive when the cutter arms are in their retracted position as seen in FIG. 2. When the cutter arms are extended as illustrated in FIG. 3, a shoulder 28 on each cutter arm engages the respective stop lug 27 and limits the outward extent of the cutters. Engagement of the shoulders with the stop lugs determines the size of the underreamed portion of the hole.

The lower body 11 extends upwardly from the location of the cutter arms and terminates in three fingers or splines 29 at its upper end. The ends of these three splines each of which is 60° wide is seen in FIG. 6. The three splines 29 on the lower body are interspersed between three similar splines or fingers 31 on an upper body 32. The upper body 32 has a male thread 33 at its upper end which is connected to a corresponding female thread 34 in the lower end of the latching selector sub 16 (FIGS. 7 and 8).

A camming plunger 36 is secured to the upper body 32 by a pair of roll pins 37 and a transversely extending shear pin 38. These maintain the camming plunger 36 in fixed rotational and longitudinal position relative to the upper body. At the lower end of the camming plunger there are a pair of cam faces 39. The two cam faces 39 face in opposite directions at an angle of about 45° to the axis of the underreamer. Each of the cam faces 39 is opposite the respective curved following surface 25 on the upper end 24 of one of the cutter arms 19. A pocket 41 is provided above each of the camming surfaces 39.

The lower body 11 and upper body 32 are free to telescope relative to each other to a limited extent. Thus, for example, as illustrated in FIG. 2 when the underreamer is hanging free suspended from above by the drill string without an upward force on the lower end thereof, the lower body drops relative to the upper body. When the underreamer is in this relatively longer position the cutter arms 19 are free to pivot so that the cutters 22 are retracted to a position within the external contour of the underreamer. A gap opens up between the extreme ends of the splines 29 and 31 and the roots of the corresponding splines 31 and 29 respectively. The extent of drop of the lower body relative to the upper body is limited by a pair of interengaging shoulders 42 on the upper body 32 and sleeve 14 respectively.

When the underreamer is in this relatively longer position as illustrated in FIG. 2 torque is transmitted via the drill string to the upper body 32 and through the interengaging splines 31 and 29 to the lower body 11. This in turn transmits the torque to lower portions 12 of the drill string such as, for example, a pilot drill (not shown).

When the lower end of the drill string engages the bottom of a hole the weight of the drill string on the upper body applies a compression force to the underreamer, tending to collapse the telescoping upper and lower bodies, thereby closing the gap at the splines and opening a gap between the shoulders 42 as illustrated in FIG. 3. As the upper body telescopes relative to the lower body towards this shorter position the camming faces 39 on the plunger 36 engage the followers 25 on the upper ends of the cutter arms 19. These camming surfaces spread the upper ends 24 of the cutter arms apart and since they are mounted in scissors fashion on the pivot pin 21, the lower ends 23 of the cutter arms are also pivoted outwardly. This causes the cutters 22 to be extended towards their underreaming position. As the followers reach the ends of the camming faces 39 they are accommodated within the pockets 41 in the plunger. The outward extent of the cutters is limited by engagement of the shoulder 28 on each cutter arm with the respective stop lug 27.

Thus as the drill string is lowered in a hole the weight of the lower end thereof keeps the underreamer in its relatively longer position and permits the cutter arms 19 to remain in their retracted position as shown in FIG. 2. When the bottom of the drill string engages the bottom of the hole the upper and lower bodies of the underreamer telescope towards each other and the camming plunger urges the cutter arms relatively outwardly in a scissors fashion for enlarging the diameter of the hole.

Another feature of the preferred underreamer is the air cooling available. The camming plunger 36 has an axial bore 43 extending from its upper end and terminating short of the camming surfaces 39. This transverse bore receives compressed air through the upper portion of the drill string. An elongated opening 44 extends through the side of the camming plunger near the lower end of the bore 43. Seals 46 above and below the transverse opening 44 limit air leakage.

A passage 47 is provided along one side of the lower body 11 as best seen in FIGS. 4 and 5. A transverse hole 48 provides fluid communication between the passage 47 and the region between the seals 46 on the camming plunger. Another opening 49 (FIGS. 2 and 3) at the lower end of the passage 47 admits compressed air to the region above the threaded joint 13 leading to the lower end of the drill string. With such an arrangement compressed air comes down the drill string through the bore 43 and the opening 44 into the region between the seals 46 between the camming plunger and the lower body. Air then flows through the opening 48 and passage 47 to exit from the lower opening 49 into the lower portion of the drill string.

Compressed air is used during drilling of blast holes and the like for removing the pulverized formation and cooling the cutters. It is therefore desirable that the

cooling air be delivered as near as possible to the cutters. As seen in FIG. 4 the pivot pin 21 is provided with an axially extending bore 51 which is in fluid communication with the longitudinally extending passage 47 through the lower body by way of a transverse hole 52. Each of the cutter arms 19 is provided with an internal air passage 53 which leads from the pivot pin through the arm to the cutter and discharges adjacent the cutter in a conventional manner. A recessed portion 54 is provided around the pivot pin to provide fluid communication between a pair of transverse orifices 56 from the bore 51 in the pivot pin to the passage 53 in the respective cutter arm. In this manner a portion of the air passing through the passage 47 is diverted through the pivot pin to discharge adjacent the two cutters of the underreamer. This provides parallel air flow to the cutters of the underreamer and to a pilot drill (not shown) lower down on the drill string, thereby assuring that all cutting bearings are adequately cooled and kept clear of chips.

It will also be noted in FIGS. 4 and 5 that the pivot pin 21 is held in place by a snap ring 57 and a tapped hole 58 is provided in the end of the pin as an aid in assembling and disassembling the underreamer.

As described to this point, application of the weight of the drill string to the lower end when it bottoms in the hole invariably causes the cutter arms to be extended to their underreaming position. With such an arrangement it would be necessary to drill a pilot hole approximately to the depth where underreaming was desired and withdraw the drill string from the hole and install the underreamer. When this was again lowered into the hole and bottomed, the underreamer arms would be cammed outwardly and underreaming could commence. It is, however, desirable to perform such underreaming without round tripping the drill out of the hole and installing additional tools. A latching selector sub 16 is therefore used in combination with the underreamer in many situations.

The sleeve 14 is connected to the lower body 11 by a threaded joint 61 (FIGS. 2 and 3). The sleeve also extends up past the threaded joint 33, 34, between the upper body 32 and latching selector sub 16 as seen in FIGS. 7 to 9. FIG. 7 is a longitudinal cross-section through the selector sub with the sleeve in a position corresponding to FIG. 2, that is, with the underreamer in its relatively longer position and the cutters retracted. FIG. 8 corresponds to FIG. 3 and the sleeve is in a position corresponding to the relatively shorter length of the underreamer with the cutters extended. FIG. 9 is a composite longitudinal cross-section transverse to the cross-sections of FIGS. 7 and 8 and illustrates the selector sub in both position, the right hand side corresponding to FIG. 7 and the left side corresponding to FIG. 8.

A lightweight aluminum piston 62 is axially movable within the latching selector sub 16. A spring 63 biases the piston towards an upper position and the upward stroke is limited by engagement with a ring 64 held in place by a snap ring 66. Seals 67 at the upper and lower ends of the piston assure that air passing down through the drill string passes through an axial passage 68 through the piston. The diameters of the piston and passage are selected so that the force of compressed air is sufficient for overcoming the bias of the spring 53 and forcing the piston downwardly. The piston 62 is seen in its upper position without applied air in FIG. 8 and is seen after air pressure has been applied in FIG. 7. The downward travel of the piston in response to air pressure is limited by a shoulder 69 (FIG. 9) which engages a corresponding shoulder 71 in the surrounding body of the latching selector sub.

As seen in FIGS. 7, 8 and 10, four camming shoes 72 are mounted in the body of the latching selector sub. A 90° segment 73 of a split ring is bolted to the outer end of each of the shoes 72. The shoes and hence the segments 73 are biased relatively inwardly by springs 74.

When the piston is in its upper position the four shoes 72 move inwardly into a respective one of four pockets 76 cut into the side of the piston. When the shoes are in this retracted position the segments 73 of the split ring are also retracted.

When air pressure is applied to the drill string the piston is urged downwardly and camming faces or ramps 77 adjacent each pocket 76 engage the respective shoes and urge them relatively outwardly. The shoes and associated segments 73 move outwardly and are effectively locked in this extended position by the enlarged portion of the piston as illustrated in FIG. 7. It will be noted that the shoes and segments are in their outwardly cammed position in FIG. 10, and in the right side of FIG. 9.

When the segments 73 are retracted the sleeve 14 is free to slide relatively upwardly until a shoulder 78 thereon engages an opposing shoulder 79 on the body of the latching selector sub. Such upper position of the sleeve is seen in FIG. 8 and the left side of FIG. 9. It will be recalled that this upper position of the sleeve 14 corresponds to the relatively shorter position of the underreamer (FIG. 3) as the upper and lower bodies telescope towards each other. When the sleeve is in this upper position the cutter arms are extended into their underreaming position.

When as illustrated in FIG. 7 the piston is in its lower position and the shoes are cammed relatively outwardly the segments 73 are interposed between the shoulder 78 on the sleeve and shoulder 79 on the latching selector sub. This prevents the sleeve from sliding upwardly relative to the selector sub and thereby prevents telescoping of the upper and lower bodies so that the underreamer remains in its relatively longer position with the cutter arms retracted.

If it is desired to drill a pilot hole with the underreamer and selector sub in position, the drill string is lowered into a hole and the air pressure applied before the drill string reaches the bottom of the hole and causes telescoping of the underreamer. The air pressure cases the piston 62 to move downwardly and cam the segments 73 outwardly to latch the sleeve in its lower position and prevent telescoping of the upper and lower bodies. This retains the cutter arms in their retracted position and permits drilling with the pilot drill.

At such time as a depth is reached where it is desired to underream the hole, the drill string is raised a sufficient amount to remove the weight from the bottom of the hole. A few inches is enough. When the air pressure in the drill string is relieved the piston moves upwardly as biased by the spring 63 and the shoes 72 and segments 73 retract. Thereafter when the drill string is lowered so that the weight thereof is on the bottom and hence applied to the lower body, the underreamer telescopes and the cutter arms are urged outwardly. Typically only a few rotations of the drill string are required to assure that the cutter arms have substantially completely extended. Thereafter air pressure can be ap-

plied for cooling the cutters and removing chips from the hole. The piston **62** is inhibited from moving downwardly since the sleeve now obstructs the outward travel of the segments **73** and underreaming may continue for any desired depth.

In summary, if one wishes to simply drill, air pressure is applied to the combined latching selector sub and underreamer prior to reaching the bottom of the hole and then drilling can proceed in the customary manner. If it is desired to underream a portion of the hole air pressure can be turned off and the consequent upward motion of the piston permits telescoping of the upper and lower bodies and extension of the cutter arms. It is preferable to lift the drill string slightly from the bottom of the hole before applying or relieving air pressure. After underreaming for some desired distance the drill string can be lifted a few inches for extending the underreamer to its relatively longer position. Application of air pressure moves the piston down and latches the sleeve in its lower position as illustrated in FIG. **7.** Continued drilling can then be conducted without removing the drill string from the hole. Thus, if desired, one can produce a hole having a number of alternating relatively larger and relatively smaller diameters. These enlarged portions of the hole can then be filled with explosives for mining operations.

When the underreamer is latched in its relatively longer position with the cutters retracted the thrust applied by the upper drill string to a drill (not shown) below the underreamer is transmitted to the latching selector sub and thence to the segments **73** of the split ring by way of the shoulder **79.** The thrust is then carried into the sleeve at the shoulder **78** and is transmitted to the lower body **11** at the threaded joint **61.** The lower body is connected to the pilot drill at the joint **13.**

When the underreamer is in its relatively shorter position with the cutter arms extended for underreaming the thrust is transferred from the latching selector sub to the upper body **32** and thence to the lower body between the ends and roots of the splines **29** and **31** therebetween. Thrust is transferred to the cutter arms through the stop lugs **27** engaging the shoulders **28** and also through the pivot pin **21.**

Torque is transmitted to the lower body in both instances through the interengaging splines.

Although limited embodiments of weight actuated underreamer and means for preventing actuation in response to fluid pressure have been described and illustrated herein, many modifications and variations will be apparent to one skilled in the art. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A weight actuated underreamer comprising:
- a lower body portion connectable to a lower portion of a drill string;
- an upper body portion connectable to an upper drill string;
- means interconnecting the upper and lower bodies for transmitting torque therebetween and permitting telescoping of the lower and upper bodies between a relatively longer position and a relatively shorter position;
- a plurality of cutter arms;
- means for pivotally mounting the cutter arms on the lower body portion;
- means on the upper body portion for urging the cutter arms relatively outwardly towards an extended underreaming position when the upper and lower bodies are telescoped towards the relatively shorter position and for permitting the cutter arms to retract relatively inwardly to a clearance position when the upper and lower bodies are telescoped towards the relatively longer position;
- latch means movable between a latching position and a release position, said latching position for latching the upper and lower bodies in the relatively longer position with the cutter arms in their retracted clearance position and the release position for permitting relative telescoping of the upper and lower bodies;
- means for urging the latch means towards the latching position in response to application of increased fluid pressure; and
- means for urging the latch means towards the release position in response to release of fluid pressure.

2. A weight actuated underreamer comprising:
- a lower body portion connectable to a lower portion of a drill string;
- an upper body portion connectable to an upper drill string;
- means interconnecting the upper and lower bodies for transmitting torque therebetween and permitting telescoping of the lower and upper bodies between a relatively longer position and a relatively shorter position;
- a plurality of cutter arms;
- means for pivotally mounting the cutter arms on the lower body portion;
- means on the upper body portion for urging the cutter arms relatively outwardly towards an extended underreaming position when the upper and lower bodies are telescoped towards the relatively shorter position and for permitting the cutter arms to retract relatively inwardly to a clearance position when the upper and lower bodies are telescoped towards the relatively longer position; and
- means for selectively latching the cutter arms in their retracted clearance position in response to increased pressure of drilling fluid and selectively releasing the cutter amrs for extension in response to decreased pressure of drilling fluid.

3. An underreamer as defined in claim **2** wherein the means for latching comprises means for preventing telescoping of the upper and lower body portions towards their relatively shorter position in response to drilling fluid pressure.

4. An underreamer as defined in claim **3** wherein the means for preventing telescoping comprises:
- a sleeve on the lower body portion extending upwardly around the upper body portion; and
- means for preventing translation of the sleeve relative to the upper body portion.

5. A weight actuated underreamer comprising:
- a lower body portion connectable to a lower portion of a drill string;
- an upper body portion connectable to an upper drill string;
- means interconnecting the upper and lower bodies for transmitting torque therebetween and permitting telescoping of the lower and upper bodies be-

tween a relatively longer position and a relatively shorter position;
a plurality of cutter arms;
means for pivotally mounting the cutter arms on the lower body portion; and
means on the upper body portion for urging the cutter arms relatively outwardly towards an extended underreaming position when the upper and lower bodies are telescoped towards the relatively shorter position and for permitting the cutter arms to retract relatively inwardly to a clearance position when the upper and lower bodies are telescoped towards the relatively longer position; and
means for preventing telescoping of the upper and lower body portions towards their relatively shorter position in response to drilling fluid pressure for latching the cutter arms in their retracted clearance position, said means for preventing telescoping comprising:
a sleeve on the lower body portion extending upwardly around the upper body portion; and
means for preventing translation of the sleeve relative to the upper body portion, said means for preventing translation comprising:
a shoulder inside the sleeve;
a plurality of segments of a split ring engageable with the shoulder when the segments are in a radially extended position;
means for biasing the segments relatively inwardly; and
means for urging the segments radially outwardly in response to drilling fluid pressure.

6. An underreamer as defined in claim **5** wherein the means for urging the segments radially outwardly comprises:
an axially slidable piston co-axial with the underreamer;
a plurality of downwardly facing ramps on the piston;
a plurality of shoes, each of the shoes being connected to a respective segment and engageable with a respective ramp on the piston;
means for biasing the piston upwardly relative to the underreamer; and
means for applying drilling fluid pressure to the upper end of the piston.

7. A weight actuated underreamer comprising:
a lower body portion connectable to a lower portion of a drill string;
an upper body portion connectable to an upper drill string;
means interconnecting the upper and lower bodies for transmitting torque therebetween and permitting telescoping of the lower and upper bodies between a relatively longer position and a relatively shorter position;
a pair of opposed cutter arms;
means for pivotally mounting the two cutter arms in scissors fashion on the lower body portion with cutter assemblies at a lower end thereof and cam followers at the upper end thereof; and means on the upper body portion for urging the cutter arms relatively outwardly towards an extended underreaming position when the upper and lower bodies are telescoped towards the relatively shorter position and for permitting the cutter arms to retract relatively inwardly to a clearance position when the upper and lower bodies are telescoped towards the relatively longer position comprising a pair of camming surfaces on the upper body portion for camming the cam followers on the cutter arms relatively outwardly whereby the cutter assemblies are urged outwardly.

8. An underreamer as defined in claim **7** wherein the upper body portion comprises a plunger co-axial with the lower body portion and at least partly within the lower body portion and wherein the camming surfaces each comprise an angulated surface at the lower end of the plunger, each of said surfaces facing in the opposite direction from the other and being on opposite sides of the center line of the underreamer.

9. A weight actuated underreamer comprising:
a lower body portion connectable to a lower portion of a drill string;
an upper body portion connectable to an upper drill string;
means interconnecting the upper and lower bodies for transmitting torque therebetween and permitting telescoping of the lower and upper bodies between a relatively longer position and a relatively shorter position comprising a plurality of upwardly extending fingers at the upper end of the lower body portion and a plurality of downardly extending fingers on the upper body portion interlaced with the fingers on the lower body portion;
a pair of opposed cutter arms;
means for pivotally mounting the two cutter arms on the lower body portion in scissors fashion with cutter assemblies at a lower end thereof and cam followers at the upper end thereof;
means for urging the cutter arms relatively outwardly towards an extended underreaming position when the upper and lower bodies are telescoped towards the relatively shorter position and for permitting the cutter arms to retract relatively inwardly to a clearance position when the upper and lower bodies are telescoped towards the relatively longer position comprising a pair of camming surfaces on the upper body portion for camming the cam followers on the cutter arms relatively outwardly; and wherein
the upper body portion comprises a plunger coaxial with the lower body portion and at least partly within the lower body portion and wherein the camming surfaces each comprise an angulated surface at the lower end of the plunger, each of said surfaces facing in the opposite direction from the other and being on opposite sides of the center line of the underreamer.

10. A weight actuated underreamer comprising:
a lower body portion connectable to a lower portion of a drill string;
an upper body portion connectable to an upper drill string;
means interconnecting the upper and lower bodies for transmitting torque therebetween and permitting telescoping of the lower and upper bodies between a relatively longer position and a relatively shorter position;
a pair of opposed cutter arms;
a pivot pin for pivotally mounting the two cutter arms in scissors fashion on the lower body portion with cutter assemblies at a lower end thereof and cam followers at the upper end thereof;

means on the upper body portion for urging the cutter arms relatively outwardly towards an extended underreaming position when the upper and lower bodies are telescoped towards the relatively shorter position and for permitting the cutter arms to retract relatively inwardly to a clearance position when the upper and lower bodies are telescoped towards the relatively longer position including a pair of camming surfaces on the upper body portion for camming the cam followers on the cutter arms relatively outwardly;

means for conveying compressed air from the upper portion of a drill string to the lower portion of a drill string; and

means for bypassing a portion of the air through the pivot pin to the cutter arms for cooling the cutter assemblies.

11. An earth boring underreamer comprising:

an underreamer body;

a plurality of cutter arms each having a cutter assembly mounted on the underreamer body for motion between a relatively retracted clearance position within the profile of the underreamer body and an extended underreaming position radially outwardly from the underreamer body;

means for extending the cutter arms radially outwardly in response to compression force applied to both ends of the underreamer body; and

means for selectively latching the cutter arms in the retracted position in response to application of fluid pressure irrespective of subsequent application of compression force to the ends of the underreamer body and for selectively releasing the latching in response to relief of drilling fluid pressure.

12. An earth boring underreamer as defined in claim **11** wherein the underreamer body comprises:

an upper body portion and a lower body portion capable of axially telescoping relative to each other in response to compression force; and wherein

the means for extending the cutter arms comprises means for urging the cutter arms radially outwardly in response to telescoping of the upper and lower body portions.

13. An earth boring underreamer as defined in claim **12** wherein the means for latching the cutter arms comprises means for preventing telescoping of the upper and lower body portions.

14. An underreamer for use in combination with a pilot drill comprising:

an upper body portion;

means for connecting the upper body portion to a drill string;

a lower body portion;

means for connecting the lower body portion to a pilot drill;

means for connecting the upper and lower body portions together for transmitting torque therebetween and permitting limited relative axial movement between the upper and lower body portions;

a plurality of cutter assemblies mounted on the underreamer for movement between a retracted position within the profile of the upper and lower body portions and an extended position outside the profile of the upper and lower body portions; and

means for urging the cutter assemblies towards their extended position in response to relative shortening of the axial length of the underreamer in response to axial compression externally applied to the underreamer.

15. An underreamer as defined in claim **14** further comprising means for inhibiting relative axial shortening of the underreamer in response to increased drilling fluid pressure.

16. An underreamer as defined in claim **14** wherein the cutter assemblies mounted on the underreamer comprise:

a pair of cutter arms;

a cutter mounted on the lower end of each of the arms; and

a pivot pin extending transverse to the axis of the underreamer, said cutter arms both being mounted on said pivot pin in scissors fashion; and wherein

the means for urging comprises means for camming the upper portions of the respective cutter arms away from each other.

17. An underreamer comprising:

an elongated hollow lower body having a spline at its upper end;

a pivot pin extending transverse to the tool body;

a pair of cutter arms mounted on the pivot pin for pivoting in scissors fashion between a retracted position with an outer profile within the profile of the lower body and an extended position beyond the profile of the body, each of said cutter arms including a cutter assembly at its lower end below the pivot pin and a cam follower portion at its upper end above the pivot pin;

an elongated upper body co-axial with the lower body and having a spline at its lower end mated with the spline on the upper end of the lower body for transmitting torque therebetween, and means at its upper end for connecting the upper body to a drill string, said lower body being axially translatable relative to the upper body between a lower "closed" position and an upper "open" position;

cam means connected to the upper body and extending into the hollow lower body, said cam means having a pair of oppositely facing cam surfaces for engaging the cam follower portions of the respective cutter arms and camming them relatively outwardly upon upward translation of the lower body relative to the upper body; and

means for limiting downward translation of the lower body relative to the upper body.

18. An underreamer as defined in claim **17** further comprising means for latching the lower body in its lower "closed" position in response to fluid pressure in the drill string.

19. An underreamer as defined in claim **18** wherein the means for latching comprises:

a sleeve on the lower body extending upwardly around the lower body; and

means for preventing translation of the sleeve relative to the upper body.

20. An underreamer as defined in claim **19** wherein the means for preventing translation comprises:

a shoulder inside the sleeve;

a plurality of segments of a split ring engageable with the shoulder when the segments are in a radially extended position;

means for biasing the segments radially inwardly;

a plurality of shoes, each of the shoes being connected to a respective segment;

an axially slidable piston co-axial with the underreamer;
a plurality of downwardly facing ramps on the piston, each of said ramps being engageable with a respective one of the shoes;
means for biasing the piston relatively upwardly; and

means for applying drilling fluid pressure to the upper end of the piston for urging it downwardly.

21. An underreamer as defined in claim **17** further comprising:
means for conveying compressed air from the upper body through the lower body; and
means for bypassing a portion of the air through the pivot pin to the cutter arms for cooling the cutter assemblies.

22. A latching selector sub comprising:
an elongated housing;
a piston axially slidable in the housing from an upper position towards a lower position in response to fluid pressure;
means for biasing the piston towards its upper position;
a sleeve around at least a portion of the housing and axially slidable relative thereto between a lower position and an upper position;
stop means mounted in the housing for preventing sliding of the sleeve towards its upper position; and

means for moving the stop means radially relative to the housing in response to moving of the piston.

23. A latching selector sub as defined in claim **22** wherein downward movement of the piston in response to fluid pressure cams the stop means radially outwardly for preventing sliding of the sleeve.

24. An underreamer as defined in claim **23** wherein the stop means comprises:
a plurality of segments of a split ring engageable with the sleeve when the segments are in a radially extended position; and
means for biasing the segments relatively inwardly.

25. A weight actuated underreamer comprising:
a lower body portion connectable to a lower portion of a drill string;
an upper body portion connectable to an upper drill string;
means interconnecting the upper and lower bodies for transmitting torque therebetween and permitting telescoping of the lower and upper bodies between a relatively longer position and a relatively shorter position;
a plurality of cutter arms;
means for pivotally mounting the cutter arms on the lower body portion;
means on the upper body portion for urging the cutter arms relatively outwardly towards an extended underreaming position when the upper and lower bodies are telescoped towards the relatively shorter position and for permitting the cutter arms to retract relatively inwardly to a clearance position when the upper and lower bodies are telescoped towards the relatively longer position;
sleeve means on the lower body portion extending upwardly around the upper body portion;
an upwardly facing shoulder on the sleeve means;
a downwardly facing shoulder on the upper body portion opposed to the upwardly facing shoulder;
a plurality of members movable between an extended position in between the shoulders and a retracted position removed from between the shoulders;
means for resiliently biasing the members towards the retracted position; and
means for urging the members towards the extended position in response to drilling fluid pressure.

26. An underreamer comprising:
a tool body including means at its lower end for connection to a lower portion of a drill string and means at its upper end for connection to an upper drill string;
a pivot pin in the tool body transverse to the length thereof;
an axial bore in the pivot pin;
a cutter arm mounted on the pin for pivoting between an extended underreaming position and a retracted clearance position;
a cutter assembly on the cutter arm;
a passage through the cutter arm to the vicinity of the cutter assembly and in fluid communication with the axial bore in the pin; and
means for delivering drilling fluid to the axial bore.

27. An underreamer as defined in claim **26** further comprising a bypass fluid passage between the upper and lower connection means past the axial bore so that a portion of drilling fluid can flow through the bypass passage and a portion can flow through the axial bore.

28. An underreamer as defined in claim **26** further comprising:
a second cutter arm mounted on the pivot pin for pivoting between an extended underreaming position and a retracted clearance position;
a cutter assembly on the cutter arm; and
a fluid passage through the second cutter arm to the vicinity of the cutter assembly and in fluid communication with the axial bore in the pin;
each of said cutter arms including a camming portion on the opposite side of the pivot pin from the respective cutter assembly; said underreamer further comprising:
cam means in the tool body for camming the cutter arms towards the extended underreaming position.

29. An underreamer as defined in claim **10** wherein the means for bypassing comprises an axial bore in the pivot pin and a fluid passage through each of the cutter arms to the vicinity of the respective cutter assembly and in fluid communication with the axial bore in the pivot pin.

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