EXPANSIBLE DRILLING TOOL
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ABSTRACT OF THE DISCLOSURE
A tandem hole opener or drilling tool for underground holes is described. The lower portion of the tool is conventional. The upper portion of the tandem drilling tool has cutters mounted on a pair of cutter arms that are pivotedly mounted on a pair of dovetail members fitting into a dovetail groove in the tool body. Pipe plugs between the dovetail members wedge them into frictional engagement with the slot. An axially slidable piston has a camming end for riding along a camming ramp on each cutter arm for camming them into an extended cutting position. A bearing surface on the piston engages a bearing surface on each arm for holding them in the extended position. The piston has an axial passage with an orifice of selected diameter through which drilling fluid can flow to the cutters. A parallel passage through the tool body permits drilling fluid to be apportioned between the upper cutters and cutters on the lower portion of the tandem drilling tool. Drilling fluid pressure also strokes the piston downwardly for camming the arms into cutting position. If the piston should fail to retract when drilling fluid pressure is relieved, drawing the tool upwardly against an object of lesser diameter than the extended arms presses downwardly on the arms thereby sliding the dovetail members in the dovetail slot and disengaging the bearing surfaces between the arms and piston so that the arms cam the piston into a retracted position.

BACKGROUND
In the course of drilling subterranean wells for oil, gas, or the like, it is often desirable to enlarge the diameter of a hole beneath the casing in the well. This requires that a drilling tool be lowered through a relatively smaller diameter casing and then expanded or enlarged when it reaches the portion of the hole to be opened so that it can cut into the earth formations. After the hole is open, the drilling tool must be contracted to its original size so that it can be withdrawn through the casing.

In the course of drilling such wells, the time required for withdrawing the drill string from the hole, replacing the tool, and lowering the drill string back into the hole is lost time which involves substantial expense. In order to minimize such expense, it is desirable to enlarge the diameter of the hole as much as possible in a single operation so that it is not necessary to pass a plurality of drilling tools into the hole in order to obtain the full desired diameter. It is also desirable to drill as great a length of hole as possible in the shortest possible time for similar reasons of economy. It is also desirable to employ a large number of cutters on a tool for minimizing wear on each and permitting a maximum length of hole to be drilled before it is necessary to withdraw the tool.

Arrangements have been provided for drilling tools having a plurality of drilling cutters arranged at varying distances from the center of the drilling tool. By increasing the number of cutters, the work can be distributed for faster drilling, and also there is greater opportunity for drilling a larger diameter hole in a single drilling operation. The prior arrangements for tandem drilling tools have had a variety of problems due to rather complicated mechanisms for actuating the several drilling cutters so as to extend them to drilling positions and also to retract them so that the tool can be extracted from the hole after drilling is completed. There has also been a problem in providing adequate drilling fluid properly distributed to the several drilling cutters.

BRIEF SUMMARY OF THE INVENTION
Therefore, in practice of this invention according to a preferred embodiment there is provided an expandable drilling tool having a lower cutter assembly for drilling at a relatively smaller diameter, an upper cutter assembly for drilling at a relatively larger diameter, parallel conduits for delivering drilling fluid under pressure to each of the cutter assemblies and means for apportioning flow between the parallel conduits. Means are also provided for mounting cutters on pivotable arms cammed from a retracted position to a cutting position in response to fluid pressure. Means are also provided for preventing upward axial movement of the arms and permitting downward axial movement thereof in response to a predetermined downward force on the arms for reversing the outward camming operation.

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 is a side view of a drilling tool constructed according to principles of this invention;
FIG. 2 is a longitudinal cross section of the upper portion of the tool of FIG. 1 with cutters retracted;
FIG. 3 is a transverse cross section through the tool;
FIG. 4 is another transverse cross section through the tool;
FIG. 5 is another transverse cross section through the tool; and
FIG. 6 is a composite longitudinal cross section showing in the right half the cutters extended and in the left half the cutters retracted after drilling is completed and the cutters have been retracted by forcing against a formation.

Throughout the drawings like numerals refer to like parts.

DESCRIPTION
FIG. 1 is a side view of a tandem expandable drilling tool constructed according to principles of this invention. As illustrated in this presently preferred embodiment, the tool has an upper substantially cylindrical tool body 10 and a lower tool body 11 screwed into engagement therewith. The lower tool 11 is a substantially conventional hole opening tool having three or more pivotally mounted arms 12. A conventional conical rock cutter 13 is mounted on the lower end of each of the arms 12. The upper tool 10, sometimes known as a sub, has a pair of pivotal arms 14 described in greater detail hereinafter. On each of the two arms 14 is a conventional cutter 16. All of the arms 12 and 14 are movable between a retracted position wherein the arms and cutters are substantially within the cylindrical profile of the tool body, and an extended position, as shown, for cutting into subterranean formations.

Typically, such a tool would be used in a drilled hole for enlarging the diameter thereof and a conventional bull nose 17 is provided on the lower end of the tool.
After lowering into a hole, the arms 12 on the lower tool body 11 are extended sufficiently to enlarge the hole to an intermediate diameter, and the arms 14 on the upper tool body are extended a sufficient amount to enlarge the intermediate diameter hole to a relatively larger diameter. Thus, in one typical embodiment, a 7½ inch diameter hole may be expanded to about 11 to 13 inches by the lower cutters and further expanded to about 15 inches by the upper cutters.

FIG. 2 illustrates in longitudinal cross section the upper tool body 10. The lower tool body is not shown in cross section since it may be either substantially identical to the upper portion or it may be a conventional hole enlarging tool. FIGS. 3, 4, and 5 are transverse cross sections through the tool body of FIG. 2 taken in the locations indicated in FIG. 2 to show the mode of mounting the cutter arms 14.

The upper end of the tool body has a female threaded portion 18 which is fitted in operation to a conventional drill string for operation in the bottom of an oil well or the like. An axial chamber 19 is provided below the threaded portion 18 for receiving drilling fluid from the drill string. At the opposite or bottom end of the tool body is a conventional male threaded portion 21. This bottom portion also has an axial chamber 22 for passing drilling fluid to the lower tool body 11 (FIG. 1). A pair of approximately rectangular fluid passages 23 pass along most of the length of the tool body to provide fluid communication between the upper chamber 19 and lower chamber 22. The two passages 23 have a sufficiently large cross section that hydraulic losses due to drilling fluid flow are not substantial.

A piston 24 is mounted for axially slidable motion within an axial bore through a portion of the tool body 10. At its upper end the piston has a piston head 26 which is a retracted position between the tool body. A coil spring 28 biases the piston upwardly in the tool body towards a retracted position as illustrated in FIG. 2.

The piston has an axial passage 29 along its length for permitting drilling fluid to flow therethrough. At the lower end of the passage 29 there is a streamlined mounting ring 31 in which is inserted a streamlined orifice 32. The orifice 32 is made of tungsten carbide or similar hard material to resist the abrasive action of drilling fluid flowing therethrough at relatively high velocity. The orifice has a controlled diameter so that there is a known pressure drop across the orifice when a known volume of drilling fluid is passed to the tool.

Thus, when drilling fluid at a sufficient flow volume is provided to the top of the tool, pressure is applied to the upper end of the piston to overcome the bias of the spring 28 and stroke the piston downwardly in the tool body to an extended position, as illustrated in the right-hand side of FIG. 6. A piston stop sleeve 33 limits the extent of travel of the piston. It will be noted that FIG. 6 is a split longitudinal cross section, the right-hand half of which shows the piston in its fully extended position, and the left-hand side of which shows the cutter arms and portion of the tool body, described in greater detail hereinafter. The two half views are sufficient since the actions in both halves of the tool are identical.

The two arms 14, each mounting a conventional drilling cutter 16 (shown only schematically), are substantially identical and the same elements are present in each of the two opposed cutter members. The cutters are mounted opposed to each other so that the forces in the tool are substantially balanced. Each of the cutter arms 14 is mounted on a pivot pin 34 extending transverse to the axis of the tool body and offset therefrom. The pivot pin is not connected directly to the tool body but instead is mounted in a pair of arm mounting members 36. The two opposed arm mounting members 36 are in general an L shape with a transverse hole through the base portion of the L in which the pivot pin 34 is mounted.

The top of the base of the L-shaped mounting member abuts against a downwardly facing shoulder 37 on a tool body.

When the drilling tool is in use, such as, for example, when the arms are deployed to a cutting position as illustrated in the right-hand side of FIG. 6, there is a substantial upward force developed from the drilling cutter through the cutter mounting arm 14 and transmitted through the pivot arm 34 and arm mounting members 36 to the shoulder 37. The cutter mounting arms are thus constrained from moving upwardly relative to the tool body.

As seen in FIG. 3, the leg portion of each L-shaped arm mounting member 36 is substantially in the form of a trapezoid with the two legs portions cooperating to define a dovetail member that fits into a longitudinally extending dovetail slot 38 in the tool body 16. Each of the arm mounting members has one half of each of a pair of tapped holes 39 extending transverse to the tool body. Preferably the pair of arm mounting members 36 on one side of the tool body are made by forming a single dovetail member and tapping the holes 39 therein for a standard tapered pipe thread. After the tapping operation is complete, the dovetail member is slt longitudinally to form the two alocchiral arm mounting members. This assures that the portions of the tapped holes 39 in the two members are in proper alignment.

When installed in the tool body, a standard socket head pipe plug (not shown) is threaded into each of the tapped holes 39 and tightened so as to wedge the arm mounting members into tight engagement with the dovetail slot 38. A standard pipe thread is used since it has a taper for providing the wedging action. The dovetail slot with the arm mounting members wedged into frictional engagement with the sides prevents the arm mounting members from moving laterally relative to the tool body, and also prevents downward movement of the cutter arms 14 under their weight alone.

Each of the cutter arms 14 has a pair of legs 41 straddling the arm mounting members for connection to the pivot pin 34. Between the legs 41 is a camming ramp 42 having its upper end relatively near the periphery of the tool body and its lower end relatively nearer the center of the tool body. At the lower end of the camming ramp 42 is a bearing surface 43.

The axial piston 24 is circularly symmetrical along the principal portion of its length. At its lower end there are a pair of opposed radially extending lugs 44 narrow enough to fit between the legs 41 so that the piston has a somewhat mallet shape. (Note FIG. 5.) The laterally extending lugs 44 have a lower outside corner 46 that engages the camming ramp 42 on the cutter mounting arm 14 when the piston is in the retracted position, as illustrated in FIG. 2. In this retracted position the cutter arms 14 and cutter 16 are substantially within the external periphery of the tool body, and the piston is retracted under the influence of the biasing spring 28. This enables the entire tool to be lowered through a casing or other hole having a diameter approximately that of the tool body.

When the tool reaches the formation where it is desired to enlarge the hole, drilling fluid is applied under pressure through the drill string (not shown) into the chamber 19 at the upper end of the tool. A portion of the drilling fluid flows through the orifice 32 and another portion flows through the passages 23 in parallel with the passage through the piston. The hydraulic pressure of the drilling fluid acts on the piston 24 to overcome the bias of the spring 28 and move the piston downwardly in the tool body. This downward stroking of the piston moves the outer corner 46 of the legs 44 on the piston against the camming ramp 42 on each cutter mounting arm 14. This cams the cutter arms outwardly relative to the tool body as the piston strokes downwardly. When the legs 44 pass the end of the camming ramp 42, the outside surface of the lug is in engagement with the bearing surface 43 on
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the cutter mounting arm so that inwardly directed loads on
the two opposed cutters are substantially balanced. The cutter
mounting arms move outwardly to a maximum dis-
tance determined by a conventional stop (not shown) be-
tween the tool body and the cutter arm. The stroke of the
piston is limited by the sleeve 33 so that the lugs 44
remain in engagement with the bearing surfaces 43 on the
cutter arms throughout the drilling operation.

During the drilling speed of cutting is enhanced and tool
life is prolonged by providing a conventional drilling fluid to
the cutters 16. Previously it had been observed that, during drilling
operations, the entire flow of drilling fluid has been to the
lowermost cutters through an axial passage in the tool
body, and flow to the upper cutters has been restricted to
that drilling fluid passing upwardly through the hole. This
has tended to limit the effectiveness of the cutting fluid
at the upper drilling cutters since it may not adequately
reach the cutting surfaces.

In the illustrated arrangement, a portion of the drilling
fluid passes through the passages 23 in parallel with the
orifice 32 in the piston, and thence to the lower set of
cutting cutters 13 (FIG. 1). A flow limiting orifice (not
shown in the tool) similar to the orifice 32 illus-
trated in FIG. 2, apportions the flow of drilling fluid be-
tween the upper cutters and the lower cutters. The parallel
flow through the two flow limiting orifices permits control
of the quantity of cutting fluid reaching each set of cutters
so as to obtain maximum drilling and minimum wear of the
cutters. At the upper cutters when the piston is ex-
tended for drilling operations, as illustrated in the right-
hand side of FIG. 6, the drilling fluid flows through the
orifice 32 into a sort of hourglass-shaped cutout portion
47, the ends of which are curved for directing the drilling
fluid outwardly to the upper cutters 16. This assures a flow
of fresh drilling fluid to the upper cutters while the prin-
cipal flow of used drilling fluid from the lower cutters passes
upwardly around the tool body in the portion not occupied by
the upper cutters.

The parallel flow passages through the piston to the upper
cutters and through the flow passages 23 to the lower
cutters permits greater flow capacity without exceed-
ing flow velocities that would cause undue wear in critical
regions than if all flow were to the lower cutters only.
This results in significantly longer tool life. The hydraulic
losses due to drilling fluid flow through the tool are also
kept low due to the relatively large fluid flow passages.
The hydraulic head due to drilling fluid flow actuates the
piston 24 and also a similar piston in the lower drilling
body 11. This use of parallel passages using a common
hydraulic pressure drop for actuation also assists in keep-
ing hydraulic head losses to a minimum.

When a desired length of hole has been enlarged, the
expansible drilling cutter is withdrawn from the hole back
through the casing to the surface. This, of course, requires
that the arms 14 return to a retracted position so that they
are within the perimeter of the tool body, and can pass
upwardly through the smaller diameter casing. Typically,
this is accomplished by stopping the flow of drilling fluid,
thereby relieving hydraulic pressure on the piston 24,
which retracts to a position as shown in FIG. 2, thereby
permitting the arms 14 to retract in a normal manner.

The piston 24 can, however, become jammed and not
retract properly so that unless other measures are taken,
the arms would remain extended and the tool could not be
withdrawn from the hole. The arrangement provided in
practice of this invention permits retraction of the cutters
even though the piston may not completely retract initially.

In order to retract the cutter arms 14, the flow of
drilling fluid is ceased and the tool is raised in the hole.
If the arms remain extended, they encounter the forma-
tion drilled or the lower end of the casing and are pushed
downwardly and inwardly by such encounter. If the
piston retracts fully the arms pivot inwardly in a normal
manner. If the piston remains extended, such as illus-
trated in the right-hand side of FIG. 6, inward motion of
the arms is inhibited. Downward motion of the cutter
arms is, however, permitted because of frictional engage-
ment of the arm mounting members 36 in the dovetail
slot 38. These arm mounting members may slide down-
wardly in the slot under this downwardly directed force,
thereby shifting the entire arm mounting assembly down-
wardly relative to the tool body and the piston. This
downward shifting continues until the bearing surface 43
on the inside of the cutter arms 14 passes off of the lugs
44 so that the corner 46 on the lug is in engagement with
the camming ramp 42. The inwardly directed force
on the cutter arm then prevails and the piston is cammed
upwardly relatively to the tool body, thereby permitting
the cutter arms to pivot inwardly relative to the tool
body so as to finally come to rest within the perimeter
of the tool body in a position as illustrated in the left-
hand side of FIG. 6. This permits the tool to be with-
drawn through casing.

Although but one embodiment of tandem drilling tool
constructed according to principles of this invention has
been described and illustrated herein, many modifications
and variations will be apparent to one skilled in the
art. Two such upper portions may be used in combination
with a third lower tool for obtaining still larger hole
openings than the dual tool illustrated. Other specific
structures employing the principles described can be de-
vised. 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. An expansible drilling tool comprising:
a tool body including an axially extending dovetail
slot;
means at the upper end of the tool body for connect-
ing the body to a drill string and a source of drilling
fluid under pressure;
an arm;
a cutter mounted on the arm;
means for pivotally mounting the arm for motion
between a retracted position substantially within
the perimeter of the tool body and a cutting position
extended from the tool body;
means in the tool for camming the arm from the
retracted position to the cutting position in response
to fluid pressure; and
means connecting the means for pivotally mounting
to the tool body for preventing upward movement of
the means for pivotally mounting, and permitting
downward axial movement of the means for pivotally
mounting in response to a predetermined downward
force on the arm comprising:
first and second dovetail members collectively
substantially complementary to the dovetail
slot and
means for wedging the dovetail members into
frictional engagement with the dovetail slot.
2. An expansible drilling tool as defined in claim 1
wherein:
the first and second dovetail members comprise an
allochiral pair of members each in the form of a
general L shape having a dovetail portion on the leg
of the L in the dovetail slot;
the means for pivotally mounting comprising a pivot
pin extending through the base of the L-shaped
dovetail members and through a portion of the arm;
the tool body comprises a downwardly facing shoulder
for engagement with the upper portion of the base
of the L-shaped dovetail members; and
wherein
the means for wedging comprises a portion of a female
pipe thread on each dovetail member and a pipe plug
threaded into the threaded portions.
3. An expansible drilling tool comprising:
a tool body;
a cutter mounted on the tool movable between a retracted position substantially within the perimeter of the tool body and a cutting position extending outwardly from the perimeter of the tool body for forming the retracted cutters.

2. a piston in the tool body axially slidable from a retracted position to an extended position in response to fluid pressure;

means on the piston for camming the cutter from the retracted position to the cutting position when the piston moves from the retracted position to the extended position; and

an open fluid flow passage including a restrictive orifice through the piston for permitting limited fluid flow therethrough, one side of the orifice being in fluid communication with the interior of the tool body and the other side being in fluid communication with the exterior of the tool body adjacent the cutter; and

a second fluid passage through the tool body in parallel flow arrangement with the orifice whereby drilling fluid flow is apportioned between the orifice and the second passage.

4. An expandable drilling tool as defined in claim 3 further comprising:

a fluid chamber at the upper portion of the tool body in fluid communication with the fluid flow orifice through the piston and with the second fluid passage through the tool body;

a chamber in the lower portion of the tool body in fluid communication with the second fluid passage; and

wherein the second fluid passage comprises a pair of fluid flow conduits extending longitudinally of the tool body and spaced laterally from the axis thereof in a portion remote from the cutter.

5. An expandable drilling tool as defined in claim 3 wherein the piston includes a head portion having a diameter substantially larger than the diameter of the orifice for piston actuation by fluid pressure.

6. An expandable drilling tool as defined in claim 5 further comprising a curved flow-directing portion between the orifice and the cutter when the piston is in an extended position for directing fluid flow therewith.

7. An expandable drilling tool comprising:

a lower cutter assembly for drilling at a relatively smaller diameter;

an upper cutter assembly expandable from a retracted position to an extended position for drilling at a relatively larger diameter and connected serially with the lower cutter assembly;

for expanding the upper cutter assembly in response to fluid pressure;

a first conduit through the means for expanding for delivering drilling fluid under pressure to the upper cutter assembly;

a second conduit parallel to the first conduit for delivering drilling fluid under pressure to the lower cutter assembly; and

restrictive orifice means in the first conduit for apportioning flow between the first and second conduits.

8. An expandable drilling tool as defined in claim 7 further comprising a piston in the upper cutter assembly for expanding the upper cutter assembly from the retracted position to the extended position; and wherein.

the restrictive orifice is mounted in the piston for permitting fluid flow therethrough and for inducing a pressure differential across the piston.

9. An expandable drilling tool as defined in claim 7 wherein the upper cutter assembly comprises:

a pair of opposed cutters movable between a retracted position and an extended position for forming a retracted position to an extended position;

a piston slidably from a retracted position to the cutting position; and

means on the piston for camming the cutters from the retracted position to the cutting position when the piston moves from the retracted position to the extended position; and wherein

the second conduit comprises a pair of passages extending parallel to the piston and displaced from the upper opposed cutters.

10. An expandable drilling tool as defined in claim 7 wherein the resistence to flow through the first conduit is greater than resistance to flow through the second conduit.

11. An expandable drilling tool comprising:

a substantially cylindrical tool body;

means at the upper end of the tool body for connecting the tool body to a drill string and a source of drilling fluid under pressure;

means at the lower end of the tool body for connecting a drilling tool or the like thereto, including means for transmitting fluid under pressure thereto;

a pair of opposed cutter assemblies mounted on the tool body, each of the cutter assemblies comprising:

an axially extending dovetail slot in the tool body; a downwardly facing shoulder on the tool body at the lower end of the dovetail slot; and

allobiartial arm mounting members, each in the form of a general L-shape having the upper portion of the base of the L in engagement with the downwardly facing shoulder and a dovetail portion on the leg of the L in the dovetail slot;

means for wedging the arm mounting members into engagement with the dovetail slot;

a mounting pin transverse to the axis of the tool body extending through the base of the L-shaped arm mounting member;

a cutter mounting arm on the pivot pin, including an inwardly facing camming ramp and an inwardly facing bearing surface at the end of the camming ramp; and

a cutter mounted on the end of the cutter arm remote from the pivot pin;

a piston mounted in the tool body for axial motion between an upper retracted position and a lower extended position;

means for biasing the piston towards the upper retracted position;

a fluid passage through the piston including an orifice having a predetermined diameter;

a fluid passage from the upper end of the tool body to the lower end thereof in parallel with the fluid passage through the piston whereby drilling fluid flow is apportioned between the orifice and the fluid passage through the tool body;

camming means on the piston for engaging the camming ramp on each cutter arm for camming the cutter arms from the retracted position to the cutting position as the piston moves from the upper retracted position to the lower extended position; and

opposed bearing means on opposite sides of the piston for engaging the bearing surfaces on the opposed cutter arms for maintaining the cutter arms in the cutting position.

12. An expandable drilling tool comprising:

a tool body;

means at the upper end of the tool body for connection to a drill string and for receiving drilling fluid; and

means at the lower end of the tool body for connection to a second drilling tool and for conveying drilling fluid from the expandable drilling tool to the second drilling tool;

a non-axial drilling fluid passage through the tool body between the upper means for receiving and the lower means for conveying;

A cutter assembly intermediate between the ends of the tool body and expandable from a retracted position to an extended position at a relatively larger diameter;
an axial piston in the tool body having a drilling fluid passage therethrough, the flow resistance of the passage through the piston being greater than the passage through the tool body, the drilling fluid passage through the piston being open to the upper means for receiving at its upper end and being in fluid communication with the cutter assembly at its lower end; and
means on the piston for expanding the cutter assembly.

13. An expandable drilling tool comprising:
a tool body;
means at the upper end of the tool body for connecting the tool body to a drill string and a source of drilling fluid under pressure;
means at the lower end of the tool body for connecting a drilling tool or the like thereto, including means for transmitting fluid under pressure thereto;
an expandable cutter assembly mounted on the tool body;
a piston mounted in the tool body for axial motion between an upper retracted position and a lower extended position;
means for biasing the piston towards the upper retracted position;
a fluid passage through the piston including an orifice having a predetermined diameter;
a fluid passage from the upper end of the tool body to the lower end thereof in parallel with the fluid passage through the piston whereby drilling fluid flow is apportioned between the orifice and the fluid passage through the tool body; and
means on the piston for engaging the cutter assembly for expanding the cutter assembly from a retracted position to an expanded cutting position as the piston moves from the upper retracted position to the lower extended position.

References Cited

UNITED STATES PATENTS
2,457,628 12/1948 Baker --------------- 175—267
1,804,681 5/1931 Fitch --------------- 175—268
2,699,921 1/1955 Garrison --------------- 175—267
1,997,436 4/1935 Seay --------------- 175—269
2,654,575 10/1953 Kammerer --------------- 175—266
2,754,090 7/1956 Kammerer --------------- 175—266
3,575,245 4/1971 Cordary --------------- 175—268

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