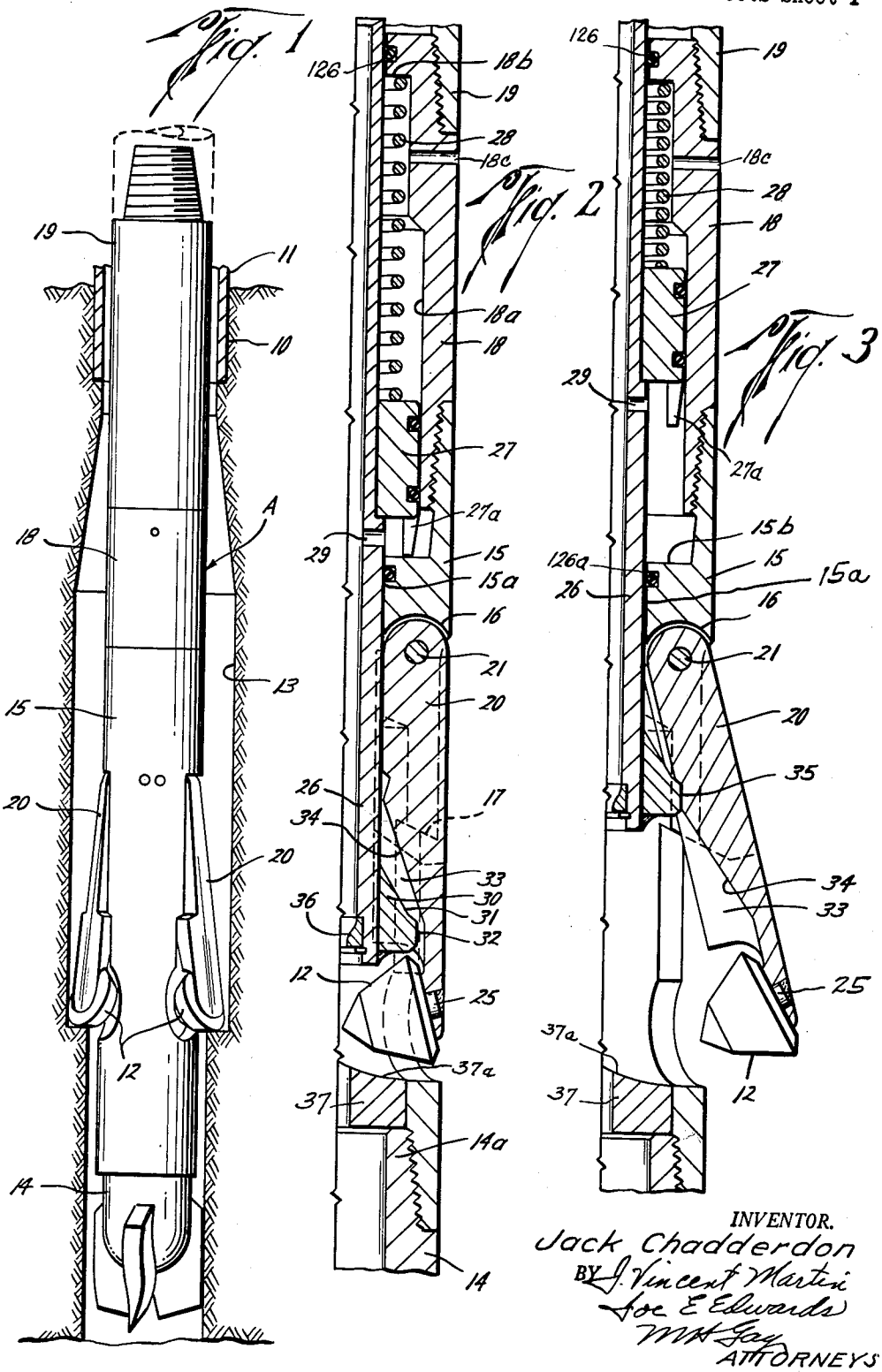
March 24, 1964 J. CHADDERDON 3,126,065

WELL TOOL HAVING HYDRAULICALLY EXPANSIBLE CUTTER ELEMENTS

Filed Feb. 5, 1960

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

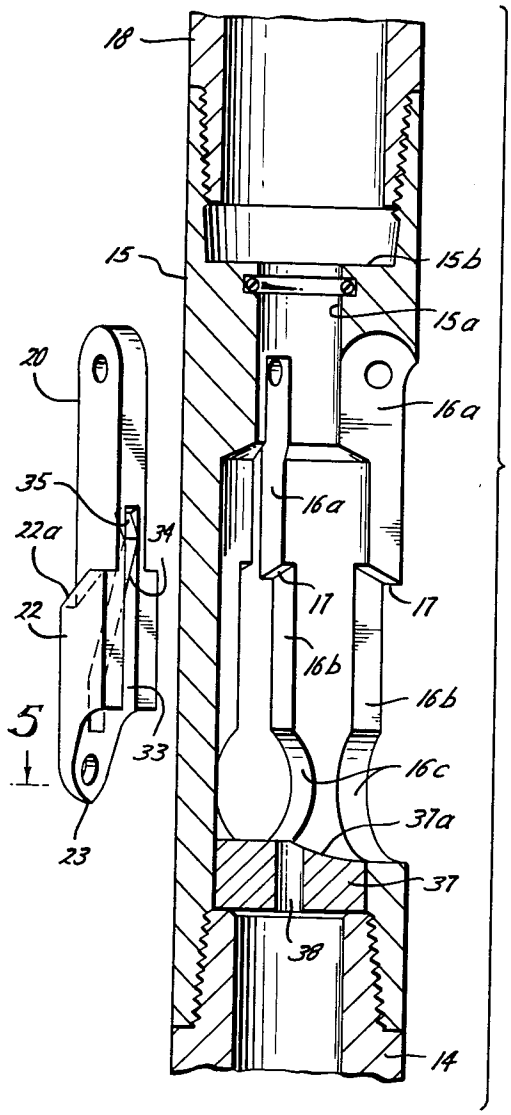

Fig. 4

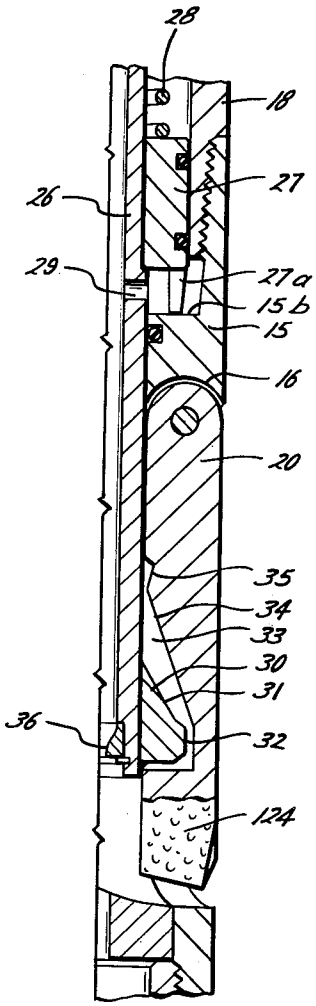

Fig. 6

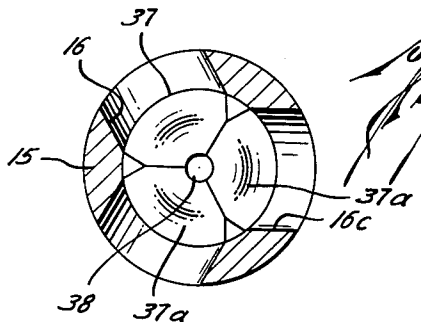

Fig. 5

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Fig. 7

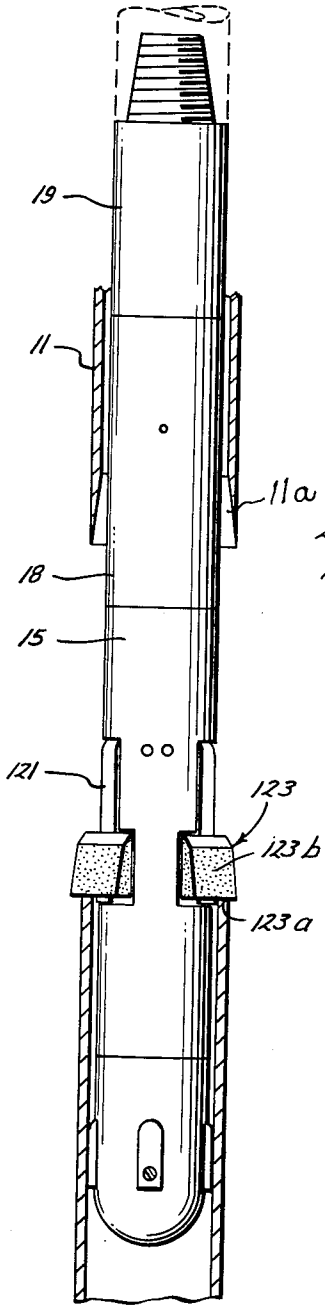


Fig. 8

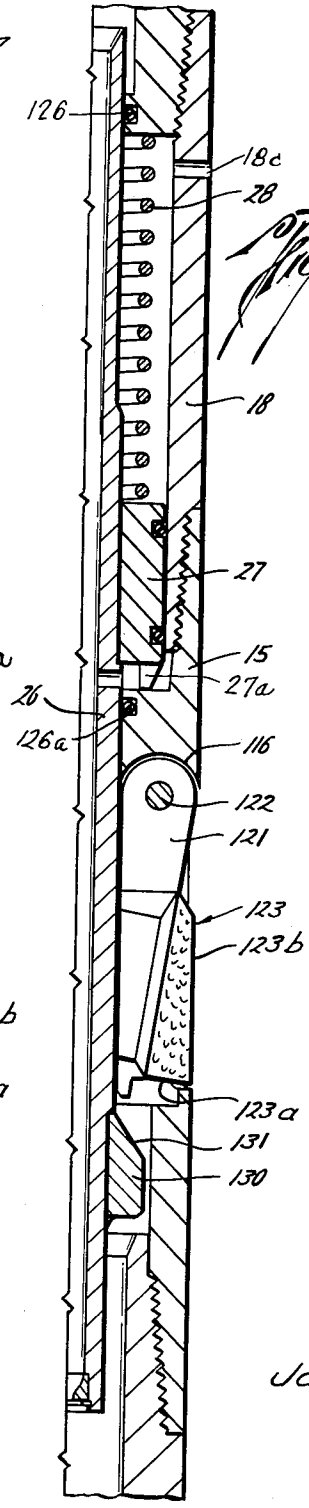
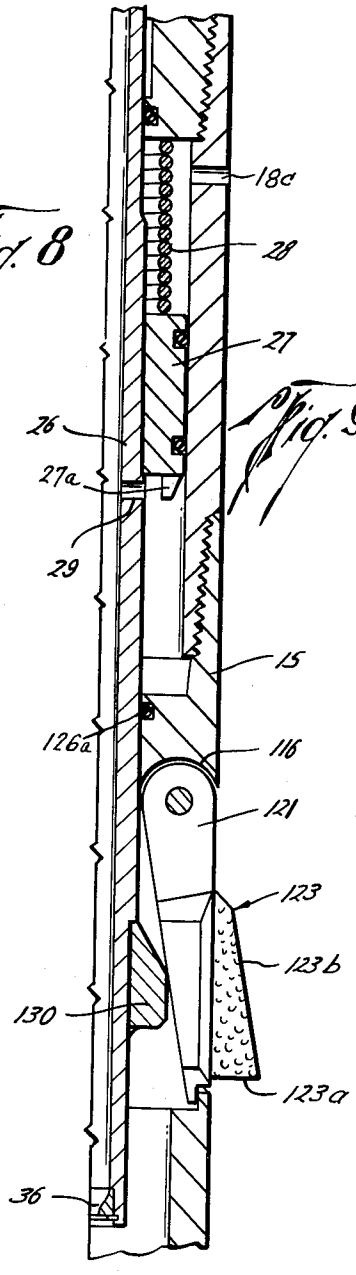


Fig. 9



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United States Patent Office 3,126,065 Patented Mar. 24, 1964

3,126,065

WELL TOOLS HAVING HYDRAULICALLY EXPANSIBLE CUTTER ELEMENTS

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Filed Feb. 5, 1960, Ser. No. 7,041
1 Claim. (Cl. 175—269)

This invention relates to new and useful improvements in well tools having expansible cutter elements.

One object of the invention is to provide an improved expansible underreamer device for reaming holes below the usual well casing or other well conduit, greater in diameter than the inside diameter of the casing through which the device may be lowered.

An important object is to provide an underreamer device having expansible cutter elements of the rock bit type wherein said cutter elements may be fully retracted into the body of the device to facilitate lowering of the assembly through the well pipe or casing; said cutter elements being expansible by the application of a predetermined fluid pressure to an actuating piston means within said device, whereby movement of said cutter elements to expanded or cutting position is controlled from the surface.

Another object is to provide an improved actuating assembly for expanding the cutter elements of a well tool, which includes a floating sleeve or tube located axially of the tool to form a flow passage and which also includes an annular piston secured to the sleeve and movable by the application of fluid pressure thereto, whereby movement is imparted to said sleeve; said sleeve having expander means thereon coacting with the cutter elements to expand the latter. The assembly being relatively simple in construction, compact in design and positive in operation to provide an economical and efficient cutting tool.

A further object is to provide a hydraulically-actuated expansible type cutting tool in which the hydraulically-actuated means is of such design that it takes up a minimum space within the body of the tool and makes it possible to employ the rock bit or roller cutters as the cutting elements, while still permitting the cutter elements to be fully retracted substantially completely within the body when not in cutting position.

Still another object is to provide an improved cutting tool of the character described, which is primarily adapted for use of an underreamer but which, by varying the type of cutter element, has been found satisfactory as a section milling tool for cutting out a complete section of well pipe or casing.

The construction designed to carry out the invention will be hereinafter described, together with other features thereof.

The invention will be more readily understood from a reading of the following specification and by reference to the accompanying drawings forming a part thereof, wherein an example of the invention is shown, and wherein:

FIGURE 1 is a view illustrating a well cutting tool, constructed in accordance with the invention, performing an underreaming operation within a well bore;

FIGURE 2 is a quarter-sectional view illustrating one of the cutter elements in its retracted position and showing the hydraulically-actuated means which is associated with said cutter element;

FIGURE 3 is a similar view illustrating the actuator moved to a position which expands the cutter to its outward position;

FIGURE 4 is a vertical sectional view of the main body of the tool and illustrating one of the cutter elements which is adapted to mount within said main body disposed at one side thereof, the rotatable cutter being removed from the cutter element for the sake of clarity;

FIGURE 5 is a horizontal cross-sectional view taken on the line 5—5 of FIGURE 4;

FIGURE 6 is a partial vertical sectional view illustrating a modified form of cutter element;

FIGURE 7 is a view similar to FIGURE 6 and showing the well tool having cutter elements which permit the tool to operate as a section mill, the tool being illustrated in position cutting a section from the well pipe;

FIGURE 8 is a quarter-sectional view of the form shown in FIGURE 7 and illustrating the cutter element in its retracted position; and

FIGURE 9 is a view similar to FIGURE 8 with the cutter element expanded.

In the drawings, the numeral 10 designates a well bore having the usual well casing 11 therein, the lower portion of said casing being illustrated. The improved well tool of this invention is generally designated by the letter A and includes expansible cutters 12 which are adapted to be expanded outwardly so that an underreaming operation may be performed. When in expanded position, the cutters 12 will underream or enlarge the bore of the well as indicated at 13, such underreaming being at a point below the lower end of the well casing 11. As will be explained, the tool A is arranged to be lowered downwardly through the well casing 11 with the cutters 12 in their retracted position so that the tool may freely pass therethrough. After the cutters are located at a point below the well casing, the tool may be actuated to expand said cutters and thereafter perform the underreaming operation. If desired, the tool A may have a pilot bit 14 secured to its lower end.

As is clearly shown in FIGURES 2 to 4, the tool A includes a main body section 15 which is formed with a plurality of slots 16 in its wall. Preferably three slots are provided and each slot extends radially through the wall of the body 15 and is of considerable longitudinal extent. Each slot has an upper relatively narrow portion 16*a* (FIGURE 4) below which the slot is enlarged as shown at 16*b*. Below the widened portion of the slot, each slot is cut out in a generally circular form as indicated at 16*c*. Between the upper narrow portion 16*a* of each slot and its widened portion 16*b*, inclined shoulders 17 are provided; as will be explained, these shoulders co-act with the cutter supporting elements and function as a stop or outward limit means which restricts outward swinging of the cutter supporting elements.

A cylinder 18 is threaded into the upper end of the main body 15 and extends upwardly therefrom. The upper end of this cylinder is attached to the lower end of the well pipe 19 by which the tool is lowered into the well bore. The lower end of the body 15 may have threaded connection with the upstanding pin 14*a* of the pilot bit 14.

Pivotally mounted within each slot 16 of the main body 15 is a cutter supporting element or arm 20. Each arm has its upper end portion confined within the narrow part 16*a* of each slot and such upper end is supported upon a pivot pin 21. The arm is of considerable longitudinal extent and normally hangs vertically from the pivot pin 21 in the manner illustrated in FIGURE 2. The lower portion of each supporting element 20 is enlarged as shown at 22 (FIGURE 4) and this enlarged portion fits within the widened part 16*b* of each slot. An extension 23 is formed at the lower end of each supporting element 20 and has a rotatable rock bit type of cutter 12 mounted therein by means of a suitable shaft 25. When the supporting element 20 is in retracted position (FIGURE 2) the cutter 12 has moved inwardly through the circular portion 16*c* of the slot and at this time the outer edge of each element 20 is in substantial alignment with the outer periphery of the main body 15. The

weight of the supporting element 20, together with the weight of its cutter 12, is sufficient to maintain the cutter supporting element in its retracted or substantially vertical position, which position it occupies during lowering of the tool within the well casing.

As has been noted, the number of slots 16 and, therefore, the number of cutter supporting elements 20, is subject to some variation although it has been found that the use of three cutter elements, which are equally spaced about the periphery of the body, are satisfactory. For moving the cutters 12 to an expanded position, a tubular actuator 26 in the form of an elongate sleeve is provided. The sleeve or tube 26 is slideable within the bore 15*a* of the main body 15 and its upper portion extends entirely through the cylinder 18. An annular piston 27 is secured to the actuator sleeve 26 and said piston is slideable within the bore 18*a* of the cylinder 28. A coil spring 28, which is confined between the upper end of the piston 27 and an internal shoulder 18*b* formed in the upper end of the cylinder 18, constantly exerts its pressure in a direction to urge the piston 27 downwardly within the cylinder and against an internal shoulder 15*b* formed in the body 15. A suitable extension 27*a* may depend from the piston 27 to limit downward movement of the piston; the provision of the extension assures that the lower end of said piston will be spaced from the shoulder 15*b* when the piston is in its fully lowered position. Adjacent the lower end of the piston, the actuator sleeve is provided with a radial port 29 whereby pressure fluid from the bore of the actuator sleeve 26 may be directed into the lower end of the cylinder below the piston. When this pressure is sufficient to overcome the force of the spring 28, the piston 27, together with the actuator sleeve 26 which is secured thereto, are moved upwardly with respect to the main body.

Upward movement of the piston 27 is permitted by reason of a vent opening 18*c* which extends radially through the upper end of the piston 18; the opening is vented to the area exteriorly of the cylinder and permits a displacement of fluid within the upper end of the cylinder as the piston moves upwardly. In order to properly seal the ends of the cylinder, an upper seal ring 126 seals between the exterior of the actuator sleeve or tube 26 and the bore of the cylinder at the upper end of said cylinder. The lower end of the cylinder is sealed by a seal ring 126*a* which seals between the exterior of the actuator sleeve and the bore of the main body 15 just below shoulder 15*b*.

For effecting an outward swinging of each cutter supporting element 20 upon upward movement of the actuator sleeve relative to the body, the sleeve has a plurality of expander elements 30 secured thereto; one expander element is provided for each cutter supporting element 20. Each expander 30 is in the form of a radial projection secured to the lower portion of the actuator sleeve 26 and each projection has an inclined upper edge 31. The inclined edge 31 has its lower end terminating in a lug portion 32. Each projection 30 is confined within a groove 33 formed in the rear face of its associated cutter supporting element, and as clearly shown in FIGURES 2 and 3, each groove has its base formed with an inclined wall 34, said wall being arranged to co-act with the projection 30 when the actuator sleeve is moved up relative to the main body and to the cutter supporting element carried thereby.

It will be evident that when the actuator sleeve 26 and its expander projection 30 move upwardly from the position of FIGURE 2 relative to the cutter element, the projection co-acts with the inclined wall 34 of the cutter supporting element and swings said element to an outward position. Outward swinging of each element 20 is limited by inclined shoulders 22*a* (FIGURE 4) formed on each element 20 engaging the inclined stop shoulders 17 of the slot 16. Upon the cutter reaching the outward limit of its swinging movement, as shown in FIGURE 3, the lug 32 formed at the lower extremity of the projection 30 engages and co-acts with the angular recess 35 formed in the rear surface of each cutter element. Therefore, so long as the sleeve is maintained in its uppermost position, the cutter supporting elements 20 are held in their outward position to locate the rotatable cutters 12 carried thereby in a position to perform the reaming operation.

For imparting an upward movement to the actuator sleeve and its expander projections, the bore of the sleeve has its extreme lower end restricted by a collar 36, the bore of which is smaller than the bore of the sleeve. With this arrangement, fluid circulated downwardly through the lowering pine 19 and downwardly through the actuator sleeve will build up a back pressure within the bore of said sleeve. This pressure is directed from the bore of the sleeve into the cylinder below the piston 27 and when the pressure in this area builds up sufficiently to overcome the force of the spring 28, the piston 27 is moved upwardly within its cylinder 18. Since the piston is secured to the actuator sleeve, this results in upward movement of the actuator sleeve relative to the main body and to the cutter supporting elements 20 carried thereby. The upward movement of the actuator sleeve moves its radial expander projections 30 upwardly with respect to the cutter supporting elements 20, thereby resulting in outward swinging movement of the elements to expand the cutters 12 carried by said elements. The parts move to the position of FIGURE 3 and so long as pressure is maintained within the bore of the sleeve, the cutters 12 remain in expanded position.

After the cutters 12 have been expanded, rotation of the pipe 19 imparts rotation to the main body of the tool and since the cutter supporting elements are confined within their respective slots, rotation is transmitted to the cutters 12 which perform the reaming operation illustrated in FIGURE 1. Some of the circulating fluid is directed outwardly from the lower end of the actuator sleeve 26 and in order to cause this fluid to flow outwardly into contact with the cutters 12, a diverter member 37 is located in the lower portion of the main body 15. This diverter (FIGURES 4 and 5) has its upper surface contoured to provide sloping portions 37*a*, one of which is directed toward each cutter 12; a central opening 38 may be provided in the diverter member. When the underreaming operation is being performed, pressure fluid is flowing downwardly through the actuator sleeve and the fluid escaping from the lower end of the sleeve is directed by means of the diverter into contact with the cutters 12 to lubricate and wash said cutters.

After the underreaming operation is complete, it is only necessary to discontinue the circulation of fluid downwardly through the actuator sleeve 26. When this occurs, the pressure acting within the lower portion of the cylinder 18 below the piston 27 is reduced and the coil spring 28 may return the piston to its lowermost position. Downward movement of the piston results in lowering of the actuator sleeve 26 from the position of FIGURE 3 to the position of FIGURE 2 and the cutter supporting elements 20 may swing to their inner or retracted positions. The tool may then be withdrawn from the well bore.

It is noted that the actuator sleeve has its lower end terminating above the roller or rotatable cutters 12 when the sleeve is in its lowered position (FIGURE 2). With this construction, sufficient room is provided for the cutters 12 to move completely within the confines of the main body when the cutter supporting elements 20 are swung inwardly. The size of the restriction through the restricting collar 36 at the lower end of the sleeve 26 is subject to variation. Of course, the smaller the opening through this restriction is made, the faster a buildup of pressures sufficient to actuate the piston will occur.

The particular rotatable or rock bit type of cutters 12 shown in FIGURES 1 to 3 have been found particularly satisfactory for underreaming harder formations.

However, it is apparent that it would be possible to change the particular type of cutter which is employed and in FIGURE 6 a cutter means 124 is illustrated as attached to the lower end of each cutter supporting element 20. This type of cutter means would be adaptable for underreaming the softer formations. It is within the scope of the invention to provide any type of cutting blade on the cutter supporting elements in accordance with the particular earth formation which is being drilled.

Although the invention finds particular application in underreaming operations, experience has shown that the tool may be employed as a section mill. A section mill is a tool which is adapted to mill out and cut away a complete section of a well pipe such as a casing. The present tool may be converted to a section mill by merely substituting a different type of cutting means. Where the tool is employed as a section mill, a simpler type of expander mechanism may be employed and in FIGURES 7 to 9 a modification of the invention is shown.

In the particular modification, the main body 15, the actuator sleeve 26, piston 27 and cylinder 18 are employed in the manner hereinbefore described. However, in place of the individual expander elements or projections 30, a single annular expander 130 is provided. This expander is in the form of a collar which is secured to the external surface of the actuator sleeve and said expander has an upper inclined surface 131.

In place of the cutter supporting elements 20 and rotatable cutters 12, cutter supporting elements 121 are pivotally mounted at 122 wtihin the slots 116 formed in the main body 15. Each cutter element has a cutter 123 attached to its lower portion and the shape of said cutter is illustrated in FIGURE 7. This type of cutter is arranged to perform a cutting action by means of its lower end 123*a*; the outer longitudinal edge 123*b* of the cutter also functions as a cutting surface.

In the operation of the form of the invention shown in FIGURES 7 to 9, the tool is lowered within a well casing 11, a section of which is to be removed. Upon reaching the point at which the tool is to operate, pressure is applied within the actuator sleeve to effect an upward movement of said sleeve. Such upward movement causes the annular expander 130 to move behind each of the cutter supporting elements 121 to urge the cutters 123 outwardly. The tool is then rotated to cause the outer face 123*b* of each cutter element to cut away the casing as indicated at 11*a* in FIGURE 7. After the casing has been cut through, the lower edge 123*a* of each cutter engages the casing as illustrated in FIGURE 7. Continued rotation of the tool, together with applied downward force on the tool, will result in the cutters 123 cutting out or removing a complete section of the casing 11. After the operation is complete, it is only necessary to stop fluid circulation through the actuator sleeve 26 to allow the spring 28 to move the piston and sleeve to its downward position. This lowers the expander collar 130 below the cutter supporting elements 121 and allows said elements to swing inwardly to their retracted position. The tool may then be removed from the well pipe.

In all forms of the invention a very simple type of hydraulically-actuated means is employed for effecting an expansion of the cutter elements. It is only necessary to circulate downwardly through the actuator sleeve 26 and because of the restriction at its lower end, the back pressure built up within the bore of the sleeve is directed against the piston which moves upwardly to move the sleeve upwardly; as explained, upward motion of the actuator sleeve causes the expanders to expand the cutters into cutting position and said cutters are maintained in such position so long as the fluid circulation is continued. Retraction of the cutters is automatically effected at any time that the fluid circulation is halted.

The foregoing disclosure and description of the invention is illustrative and explanatory thereof and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made within the scope of the appended claim without departing from the spirit of the invention.

What I claim is:

An underreamer cutting tool including, a main tubular body, a cutter supporting element having its upper end pivotally mounted on the body and having a rotatable cutter carried by its lower end, said cutter being located within the confines of the body when the supporting element is in retracted position, a tubular actuator slideable within the body and initially in a lower position in the body with its lower end above the cutter of the supporting element, an expander means on the exterior of the actuator adapted to co-act with the cutter supporting element when the actuator moves upwardly relative to said element to swing the element radially outwardly of the body and thereby move the cutter to expanded position, a cylinder formed in the upper portion of the main body and having an upwardly facing internal shoulder at its lower end, a seal between the actuator and the bore of the main body below said shoulder, a second seal between said actuator and body at the upper end of the cylinder, an annular piston surrounding and secured to said tubular actuator and slideable within the cylinder, downward movement of said piston being limited by said upwardly facing internal shoulder, said actuator having a port in its wall establishing communication between the bore of the actuator and that area of the cylinder below the annular piston whereby fluid pressure from the bore of the actuator may be directed into the cylinder below said piston, means restricting the bore of the tubular actuator below said communication port whereby pumping of pressure fluid at a predetermined rate downwardly through the actuator builds up a sufficient back pressure in the lower end of the cylinder to move the piston and actuator upwardly to thereby swing the cutter supporting element outwardly and expand said cutter, and fluid diverting means in the form of an annular element having a curved upper surface within the main body below the actuator and contiguous to the cutter for directing fluid flowing from the lower end of said actuator outwardly against said cutter.

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