

July 27, 1965

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3,196,960

FLUID PRESSURE EXPANSIBLE DRILL BITS

Filed March 19, 1963

2 Sheets-Sheet 1

FIG. 1.

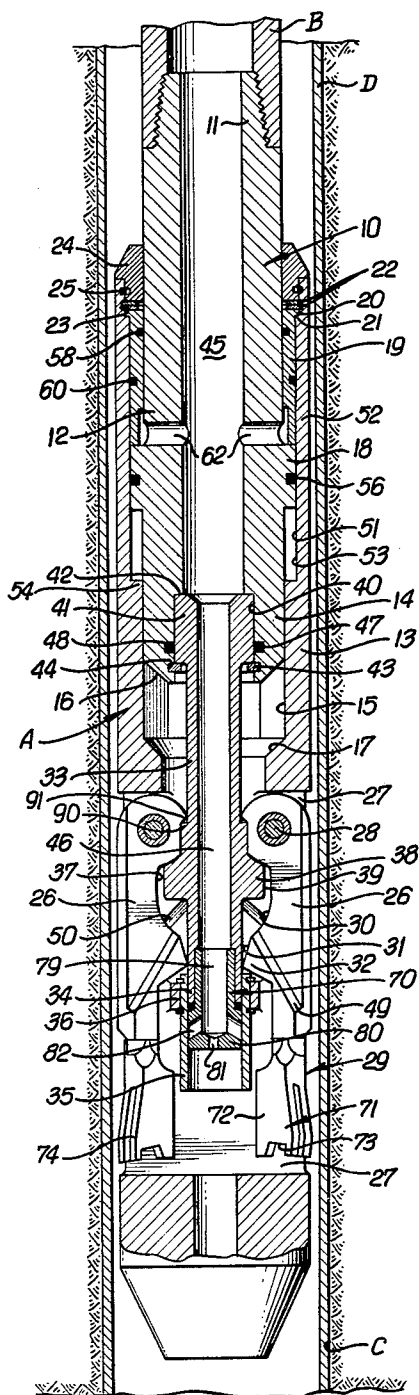
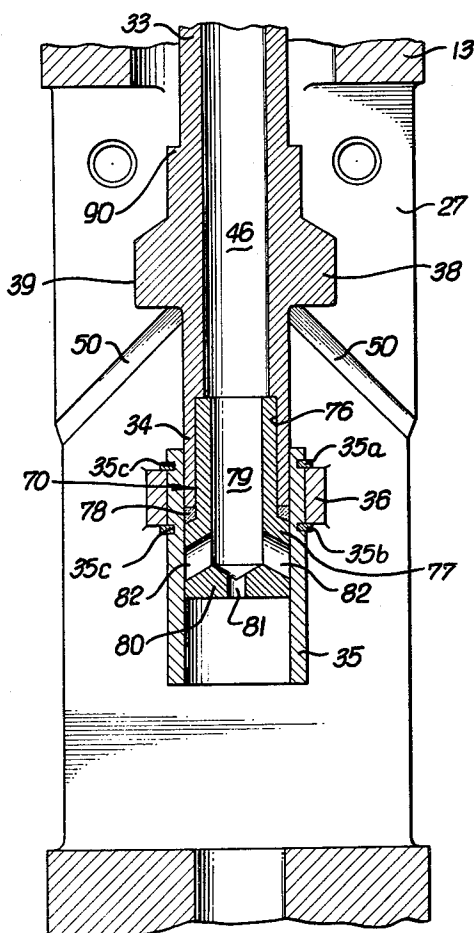


FIG. 2.



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FIG. 3.

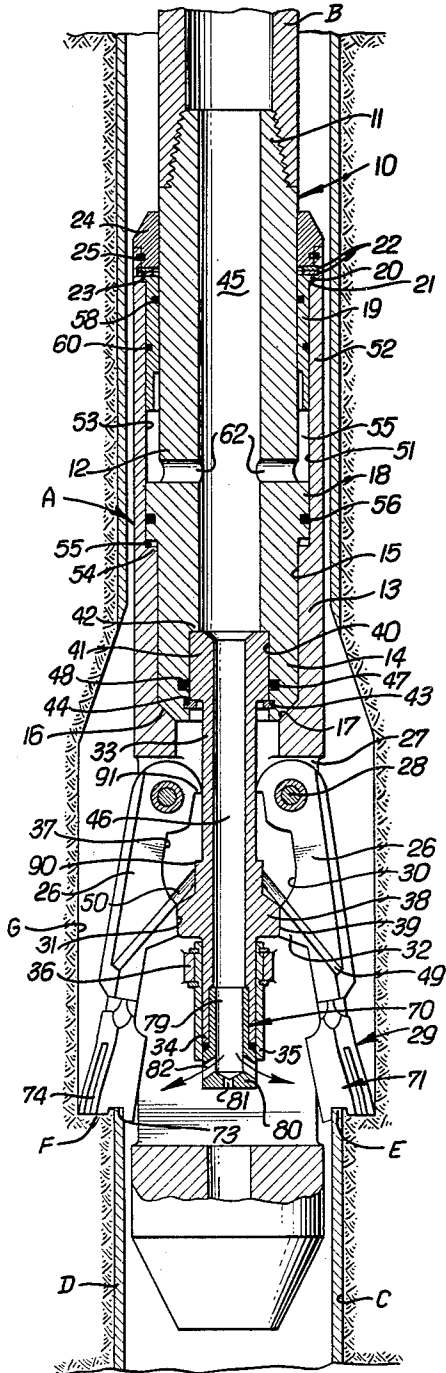
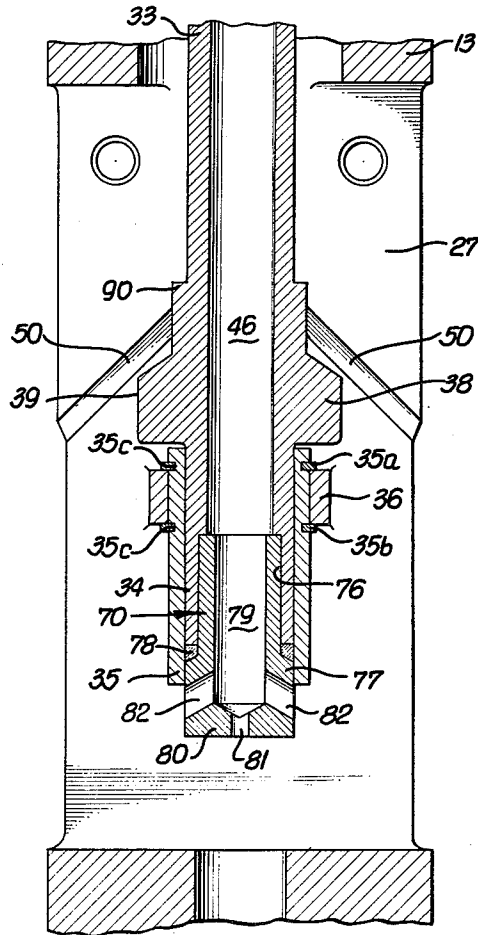


FIG. 4.



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FLUID PRESSURE EXPANSIBLE DRILL BITS
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6 Claims. (Cl. 175-267)

The present invention relates to rotary drill bits, and more particularly to drill bits of the expansible type capable of enlarging the diameter of the well bore, or milling out a portion of casing, or similar conduit, in the well bore, or both.

The retracted cutters of a rotary expansible drill bit have been expanded outwardly under the action of fluid pressure, resulting from pumping fluid down through the rotary drill string, to which the bit is attached, and into or through the bit. The fluid discharges from the bit to clean and cool its cutter members and flush the cuttings to the top of the hole. The quantity of fluid necessary for proper removal of cuttings from the well bore requires the use of fluid discharge passages or areas of such size as to prevent the development of high pressures in the bit for effecting cutter expansion, unless comparatively large volume and pressure pumps or compressors are used. In enlarging the diameter of a well bore in a very hard formation, or in milling through the wall of a casing in the well bore, the absence of high cutter expansion fluid pressures renders it difficult to secure full cutter expansion, or makes the securing of full cutter expansion a comparatively long and tedious process. Moreover, the operator at the top of the well bore may not be able to determine with certainty when full cutter expansion has been secured, in order that he might then proceed with the imposition of drilling weight on the bit to enlarge the well bore, or mill away casing, to the desired longitudinal extent.

Accordingly, it is an object of the present invention to provide an improved rotary drill bit of the fluid pressure expansible type for operation in a well bore, in which greater fluid pressure can be developed in the bit for expanding its cutters outwardly, and in which the bit permits a large flow of circulating fluid through it for the purpose of cleaning the bit and flushing the cuttings from the well bore.

Another object of the invention is to provide an improved rotary drill bit of the fluid pressure expansible type for operation in a well bore, in which the area of fluid flow through the bit during outward expansion of the cutters is restricted to enable an increased back pressure to be developed in the bit for expanding the cutters, and in which the area of fluid flow is greatly increased after full cutter expansion has been achieved to allow a greatly increased flow of fluid through the bit. The greater facility for fluid flow through the bit is accompanied by a substantial drop of the pressure of the fluid pumped into the well bore, thereby giving the operator at the top of the well bore a definite indication that the cutters have been expanded to their maximum extent.

A further object of the invention is to provide an expansible rotary drill bit embodying an improved mechanism for signalling to the operator at the top of the well bore of the fact of full cutter expansion.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of a form in which it may be embodied. This form is shown in the drawings accompanying and forming part of the present specification. It will now be described in detail, for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed description is

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not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

FIGURE 1 is a longitudinal section through a rotary expansible drill bit, such as a milling tool, disposed within a well casing, with the cutter and other parts occupying an initial retracted position;

FIG. 2 is an enlarged longitudinal section through a lower portion of the bit disclosed in FIG. 1 with the cutter members removed;

FIG. 3 is a longitudinal section similar to FIG. 1 disclosing the cutters in their fully expanded position;

FIG. 4 is an enlarged longitudinal section of the lower portion of the bit disclosed in FIG. 3 with the cutter members removed.

As shown in the drawings, a rotary expansible drill bit or milling tool A is secured to the lower end of a string of drill pipe B extending to the top of a well bore C, and by means of which the drill bit is lowered through a string of well casing D to a location therein where a casing milling operation is to commence. In lieu of milling a casing, the drill bit could be used for enlarging the diameter of the well bore C itself.

The upper portion of the rotary drill bit consists of a mandrel 10 having an upper pin 11 threadedly connected to the lower end of the string of drill pipe B. This mandrel includes an upper kelly or drill stem member 12 slidably splined to the main body 13 of the drill bit. The exterior of the lower portion 14 of the kelly is non-circular in shape, being telescopically received in a companion non-circular socket 15 formed in the main bit body 13. Specifically, the kelly exterior and the socket 15 may be of hexagonal shape to enable the kelly 12 to be moved longitudinally with respect to the body 13, while still being capable of transmitting rotary motion to the body.

The mandrel 10 has a limited range of longitudinal movement within the body, its downward movement being determined by engagement of the lower end 16 of the kelly with an inwardly directed body shoulder 17, and its upper movement being limited by engagement of an external shoulder or piston portion 18 of the kelly with a cylinder head 19 secured to the body. The upper end of the head has a flange 20 engaging a body shoulder 21, the head being prevented from moving upwardly of the body by split snap retainer rings 22 fitting in a body groove 23 and overlying the flange 20. An annular guide 24 is releasably secured to the body 13 by a split snap ring 25 above the retainer rings.

The body 13 has a plurality of expansible parts mounted on it. These include cutter supporting members 26 pivotally mounted in one or more body slots 27 on hinge pins 28 which are suitably secured to the body to prevent their loss therefrom. Each cutter supporting member 26 depends from the hinge pin 28 and carries a drag or milling cutter structure 29 on its lower end.

The cutter supporting members 26 and the cutter structures 29 themselves tend to occupy a retracted position substantially entirely within the confines of the main body 13 of the bit. These cutter supporting members and the cutter structures are expansible outwardly to sever the casing and mill it away by operating upon the upper end E of the casing therebelow (FIG. 3), or to enlarge the diameter of an existing well bore. To accomplish the expansion, each cutter supporting member 26 has an inclined expander surface 30 on its inner portion below the hinge pin 28 which tapers in a downward and inward direction. Each expander surface terminates in a lock surface 31 formed on a lock portion 32 of the cutter supporting member. The outward expansion is accomplished by producing relative longitudinal movement between the mandrel 10 and the body 13, which will produce relative longitudinal movement between the cutter supporting members 26

and the tubular member 33 of the mandrel. The tubular member includes a lower portion 34 slidable within an elongate guide bushing 35 mounted in a bridge 36 secured in the body and extending across the body slot or slots 27. The guide bushing 35 is disposed below the lock portions 32 of the cutter supporting members 26 and is secured in place by upper and lower contractible split retainer rings 35a, 35b disposed in grooves 35c in the bushing and engaging the upper and lower ends of the bridge 36.

Located initially substantially above the guide bushing 35 and below the hinge pins 28 and in cutter supporting member recesses 37 is a mandrel lock and expander 38 which has outer surfaces 39 adapted to engage the expander surfaces 30 and the lock surfaces 31. The lock and expander 38 may be formed integral with the tubular member 33, the upper end of the latter being piloted within a socket 40 formed in the lower portion 14 of the kelly 12. An enlarged boss 41 on the tubular member 33 engages a downwardly facing shoulder 42 of the kelly, the tubular member being held against this shoulder by a suitable split retainer or lock ring 43 snapped into an internal groove 44 encompassing the kelly socket and engaging the lower end of the tubular member boss 41.

A gaseous fluid medium, drilling mud, or other suitable fluid can pass down through the central passage 45 in the kelly or drill stem 12 and into the central passage 46 extending completely through the tubular member 33. Leakage of fluid around the exterior of the tubular member 33 is prevented by a suitable side seal ring 47, such as a rubber or rubber-like O ring, in a peripheral groove 48 in the kelly, which engages the interior of the boss 41.

Assuming the body of the tool to be elevated relatively along the tubular mandrel 10, the inclined expander surfaces 30 of the cutter supporting members 26 will shift upwardly along the lock and expander portion 38 of the tubular member 33. During such upward shifting, the cutter supporting members 26 and the cutter structures 29 carried thereby will pivot about the hinge pins 28 and be urged in an outward direction. The upward movement of the body 13 with respect to the mandrel 10 can continue until the cutter structures 29 have been shifted outwardly to their fullest extent, as determined by engagement of stop shoulders 49 on the cutter supporting members 26 with companion shoulders 50 formed in the body on opposite sides of the body slot or slots 27. When such engagement occurs, the lower end 16 of the kelly portion 12 of the tubular mandrel will engage the body shoulder 17 and the lock and expander 38 on the tubular member 33 will be disposed behind and in engagement with the lock portions 32 of the cutter supporting members 26.

It is to be noted that the surfaces 31 of the lock portions 32 of the cutter supporting members 26 and the companion surfaces 39 on the lock and expander portion 38 of the tubular member are substantially parallel to the axis of the drill bit, when the cutters 29 are fully expanded, to prevent their reactive forces on the cutter structures 29 from moving the latter inwardly. As a practical matter, it is preferred that the coengaging lock surfaces 39, 31 be inclined slightly in a downward direction toward the axis of the tool to insure release of the lock and the expander portion 38 from the cutter supporting members 26, when the latter and the cutter structures 29 are to be shifted to retracted position.

The relative longitudinal movement between the tubular mandrel 10 and the body 13 of the tool is accomplished by the action of fluid pressure. Thus, the piston or enlarged portion 18 on the drill stem 12 is received within a counterbore 51 formed on the upper portion of the body of the tool. This upper portion actually constitutes a cylinder 52 having a cylindrical wall 53 extending from a lower shoulder 54 defining the bottom of the counterbore to the cylinder head 19.

A confined cylinder space 55 is formed between the piston portion 18 of the kelly, the periphery of the kelly above the piston, and the cylinder 52. A suitable pack-

ing or side seal ring 56 may be provided on the piston 18, which is adapted to slidably seal against the cylindrical wall 53 of the cylinder 52. Fluid is thereby prevented from passing in a downward direction between the piston and the cylinder. Similarly, fluid is prevented from passing in an upward direction out of the annular cylinder space 55 by an inner side seal ring 58 on the cylinder head 19 slidably and sealingly engaging the periphery of the kelly above the piston 18, and also by an outer side seal ring 60 disposed in the head 19 and sealingly engaging the cylinder wall 53.

Fluid under pressure in the string of drill pipe B and in the tubular mandrel passage 45 can be fed into the cylinder space 55 through one or more side ports 62 establishing communication between the central passage 45 through the kelly and the cylinder space. Such fluid under pressure is developed by restricting the flow of fluid through the kelly 12 and its companion tubular member 33 by means of a flow control member 70 mounted in the lower portion of the mandrel. As a result of such restriction of flow, the pumping of compressed gas or drilling mud at an adequate rate through the apparatus will build up a back pressure of fluid in the passage 45, which pressure will be imposed on the fluid in the cylinder space 55, acting upon the cylinder head 19 to urge the body 13 of the tool in an upward direction with respect to the tubular mandrel 10 to secure outward expansion of the cutter supporting members 26 and cutter structures 29 to their fullest extent, as above described.

As apparently disclosed in the drawings, a pair of diametrically opposed supporting members 26 and cutter structures 29 is supplied, such devices being disposed substantially 180 degrees from each other. Actually, it is preferred to have a drill bit with three sets of supporting members and cutter structures, spaced substantially 120 degrees from each other, to secure a smoothly running device. The two sets of supporting member structures, and slots 27 in which they are disposed, are shown in the interest of simplicity of the drawings.

As shown, each cutter structure 29 forms the lower portion of the cutter supporting member 26 and is expressly designed in the specific device illustrated in the drawings to sever the casing D and mill it away along a desired length. Each cutter structure includes cutter teeth 71, the leading faces 72 of the tooth preferably being provided with a suitable hardfacing material, which extends from the lower ends 73 of the teeth upwardly to a substantial extent along the tooth faces. Similarly, the outer surface 74 or face of each of the teeth may be provided with hardfacing material. Such outer tooth surfaces 74 are effective in making an initial severing cut through the well casing D, or in initially enlarging the diameter of the well bore C, until the cutters 29 have been expanded outwardly to their fullest extent, after which it is the lower ends 73 of the cutter teeth that are operable upon the upwardly facing end E of the severed well casing or upon the formation shoulder F provided in an enlarged well bore G, to mill away the casing D, or to enlarge the diameter of the well bore C, or both, in a downward direction.

To insure an adequate fluid pressure within the drill bit to obtain outward expansion of the cutters 29 to their fullest extent, the flow of fluid through the drill bit is greatly restricted. After full cutter expansion has occurred, a greater quantity of fluid is permitted to flow through the bit. As shown, the flow control member 70, which may be made of a suitable hard material, such as tungsten carbide, is piloted upwardly within a downwardly facing counterbore 76 in the lower end 34 of the tubular member 33 of the mandrel. Below the end of the tubular member 33, the flow control device 70 is enlarged in diameter to provide a head 77 conforming to the internal diameter of the guide bushing 35 and capable of sliding therealong. The flow control member 70 is secured to the tubular member 33, as by use of welding material 78.

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The flow control member has a central passage 79 of a comparatively large diameter opening upwardly into the passage 46 through the tubular member of the mandrel. This central passage terminates in a lower end wall 80 of the control member having a choke orifice 81 extending therethrough communicating with the central passage 79 and opening downwardly through the end wall into the body slots 27. Above the central orifice 81, the head of the flow control member has side ports or nozzles 82 communicating with the central passage 79 and opening through the periphery of the head 80, these side ports having areas that are substantially greater than the area through the central orifice 81. The side ports 82 are circumferentially spaced from one another to the same extent as the cutter supporting members 26 and are aligned with the slots 27, so that when the ports 82 of the flow control member are disposed below the guide bushing 35, the ports or nozzles can discharge fluid through the slots 27 toward the expanded cutter members 29, to cool them and flush the cuttings upwardly around the drill bit A and the drill pipe B to the top of the well bore.

When the cutters 29 are in their retracted position, such as disclosed in FIG. 1, the mandrel 10 and its tubular member 33 are in an upper position with respect to the body 13 of the tool and the guide bushing 35 secured thereto, to close the side ports or nozzles 82 of the control member (FIGS. 1, 2). As a result, all of the fluid pumped down through the drill string B and the mandrel passage 45, 46 must pass out through the choke orifice 81 of relatively small diameter, causing a comparatively large back pressure to be built up in the fluid within the kelly 12, which pressure is transmitted to the fluid in the ports 62 and the cylinder space 55 for upward action on the cylinder head 19, to elevate the body 13 and cutters 26, 29 with respect to the mandrel 10, the cutter structures 26, 29 moving upwardly along the expander member 38 and shifting outwardly, as described hereinabove. During their outward shifting, the outer portions 74 of the cutter teeth engage the casing wall and effect a cutting thereon as the drill string B and drill bit A are rotated, the rotary motion being transmitted from the mandrel 10 to the body 13, and from the body to the cutter supporting members 26 and cutters 29. As the casing is milled away, the cutters 29 expand outwardly to an additional extent under the upward force exerted by the fluid on the cylinder head 19 to further elevate the body 13 with respect to the mandrel 10. As the body moves upwardly, the guide bushing 35 moves upwardly with it, until full cutter expansion has occurred. When such expansion occurs, the casing D will have been completely severed and the cutters 26, 29 will be located in their outward position, such as disclosed in FIG. 3.

Immediately after full cutter expansion has occurred, the body 13 and cutters 26, 29 can move upwardly suddenly along the mandrel 10 to bring the lock portions 32 of the cutter supporting members 26 along and in full engagement with the lock portion 38 of the tubular member, this sudden upward shifting of the body and cutter members also effecting an upward shifting of the guide bushing 35 along the flow control member 70 and bringing the lower end of the guide bushing above the side ports or nozzles 82 of the flow control member, as disclosed in FIGS. 3 and 4. The fluid being pumped down through the string of drill pipe B, or other tubular string, and through the mandrel passages 45, 46 can now discharge through the central orifice 81 and also through the nozzles 82, the area of fluid discharge from the mandrel being much greater than when all of the fluid was required to pass downwardly through the orifice alone during outward expansion of the cutters. A much larger volume of fluid can now be pumped down through the apparatus, jetting from the nozzles or ports 82 toward the cutters 29 to effect their cleaning and to flush the cuttings from the well bore itself. The sudden increase in

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the effective area through which fluid can flow through the control member 70 is accompanied by a pronounced drop in fluid pressure readily detectable at the top of the well bore, which advises the operator that the cutters 29 have been expanded outwardly to their fullest extent.

When it has been definitely determined that the cutters 29 have been expanded outwardly to their fullest extent, drilling weight can be imposed through the string of drill pipe B on the mandrel 10 of the tool, such weight passing downwardly through the body shoulder 17 to the body 13 and through the shoulders 50 to the cutter supporting members 26, and the cutters 29 themselves, the lower ends 73 of the cutters being forced against the upwardly facing severed end E of the casing and also against the formation shoulder F. Disintegration of the casing D and of the formation can now occur as the result of rotation of the drill pipe B and drill bit A, and the circulation of fluid down through the drill pipe and the bit, the fluid discharging from the control member 70 into the well bore.

After a desired length of casing D has been milled away, or the desired length of hole has been enlarged in diameter, or the cutters 29 have been completely worn, the apparatus is removed from the well bore. All that need be done is to discontinue the pumping of the drilling fluid through the drill pipe B and the apparatus A, to relieve the pressure in the cylinder 52, and then elevate the drill pipe. Such elevating movement will elevate the tubular mandrel 10 with respect to the body 13 and the cutter supporting members 26, raising the lock and expander portion 38 above the expander surfaces 30, whereupon the cutter supporting structures 26, 29 will drop back to their retracted positions, such as disclosed in FIG. 1. In the event the cutters 29 do not move readily to such position, an upwardly facing shoulder 90 on the tubular mandrel member 33 will engage inward projections 91 at the upper portions of the cutter supporting members 26, effecting an upward swinging of such projections 91 about the hinge pins 28 and an inward shifting of the cutter supporting members 26 and cutters 29 within the confines of the body 13. If such action still fails to shift the cutter supporting members 26 inwardly to their fullest extent, they will engage the casing D above and adjacent to the location of the initial severing cut, upon elevation of the apparatus in the well bore, which engagement will effectively force the cutter supporting members 26 inwardly, enabling the apparatus A to be withdrawn through the well casing D to the top of the well bore.

I claim:

1. In a rotary drill bit to be lowered in a well bore on a rotary drill string: a body having a slot; cutter means in said slot carried by said body for expansion from a retracted position laterally outwardly of said body; means for expanding said cutter means laterally outwardly of said body, including a tubular member movable relatively longitudinally in said body; said tubular member having a fluid passage adapted to receive fluid from the drill string and also having first passage means and second passage means communicating with said passage and through which fluid is adapted to discharge from the tubular member; means on said body closing said second passage means when said tubular member occupies one position in said body with said cutter means retracted and with said first passage means open, relative longitudinal movement of said tubular member in said body from said one position upon expansion of said cutter means shifting said second passage means to open condition in alignment with said slot; said second passage means directing fluid through said slot toward said cutter means when in open condition.

2. In a rotary drill bit to be lowered in a well bore on a rotary drill string: a body having a slot; cutter means in said slot carried by said body for expansion from a

retracted position laterally outwardly of said body; fluid actuated means responsive to the pressure of fluid pumped down the tubular string for expanding said cutter means laterally outwardly of said body, including a tubular member movable relatively longitudinally in said body; said tubular member having a fluid passage adapted to receive fluid from the drill string and also having an orifice communicating with said passage and through which fluid from the tubular member is adapted to discharge to provide a back pressure for action on said fluid actuated means to effect expansion of said cutter means; said tubular member also having passage means communicating with said passage through which fluid from the tubular member is adapted to discharge; means on said body closing said passage means when said tubular member occupies one position in said body with said cutter means retracted and with said orifice open, relative longitudinal movement of said tubular member in said body from said one position upon expansion of said cutter means shifting said passage means to open condition in alignment with said slot; said passage means directing fluid through said slot toward said cutter means when in open condition.

3. In a rotary drill bit to be lowered in a well bore on a rotary drill string; a body having a slot; cutter means in said slot carried by said body for expansion from a retracted position laterally outwardly of said body, means for expanding said cutter means laterally outwardly of said body, including a tubular member movable relatively longitudinally in said body and coengageable expander means on said tubular member and cutter member; guide means on said body slidably receiving said tubular member; said expander means being disposed on one side of said guide means; said tubular member having a fluid passage adapted to receive fluid from the drill string and also having first passage means communicating with said passage and through which fluid from said tubular member is adapted to discharge; said tubular member having second passage means communicating with said passage through which fluid from the tubular member is adapted to discharge; said second passage means being located within and closed by said guide means when said tubular member occupies one position in said body with said cutter means retracted and with said first passage means open, relative longitudinal movement of said tubular member in said body from said one position upon expansion of said cutter means shifting said second passage means from said guide means to open condition at the opposite side of said guide means and in alignment with said slot; said second passage means directing fluid through said slot toward said cutter means when in open condition.

4. In a rotary drill bit to be lowered in a well bore on a rotary drill string; a body having a slot; cutter means in said slot carried by said body for expansion from a retracted position laterally outwardly of said body; fluid actuated means responsive to the pressure of fluid pumped down the drill string for expanding said cutter means laterally outwardly of said body, including a tubular member movable relatively downwardly in said body and coengageable expander means on said tubular member and cutter means; guide means on said body slidably receiving said tubular member; said expander means being disposed below said guide means; said tubular member having a fluid passage adapted to receive fluid from the drill string and also having an orifice communicating with said passage and through which fluid from the tubular member is adapted to discharge to provide a back pressure for action on said fluid actuated means to effect expansion of said cutter means; said tubular member also having passage means communicat-

ing with said passage through which fluid from the tubular member is adapted to be discharged; said passage means being located within and closed by said guide means when said tubular member occupies a relative upper position in said body with said cutter means retracted and with said orifice open, relative downward movement of said tubular member in said body from said upper position upon expansion of said cutter means shifting said passage means from said guide means to open condition below said guide means and in alignment with said slot; said passage means directing fluid through said slot toward said cutter means when in open condition.

5. In a rotary drill bit to be lowered in a well bore: a body having a slot; cutter means mounted on said body in said slot for expansion laterally of said body; means for expanding and holding said cutter means laterally outwardly of said body, including a mandrel connectible to a drill string and slidably splined to said body, said mandrel having a fluid passage adapted to receive fluid from the drill string; said mandrel having first passage means and second passage means communicating with said passage and through which fluid from the mandrel is adapted to be discharged; means on said body closing said second passage means when said mandrel occupies an upper position in said body with said cutter means retracted and with said first passage means open, relative downward movement of said mandrel in said body from said upper position upon expansion of said cutter means shifting said second passage means to open condition in alignment with said slot; said second passage means directing fluid through said slot toward said cutter means when in open condition.

6. In a rotary drill bit to be lowered in a well bore: a body having a slot; cutter means mounted on said body in said slot for expansion laterally of said body; means for expanding and holding said cutter means laterally outwardly of said body, including a mandrel connectible to a drill string and slidably splined to said body and coengageable expander means on said mandrel and cutter means, said mandrel having a fluid passage adapted to receive fluid from the drill string; said mandrel having first passage means and second passage means communicating with said passage and through which fluid from the mandrel is adapted to be discharged; guide means on said body below said expander means slidably receiving said mandrel; said second passage means being located within and closed by said guide means when said mandrel occupies an upper position in said body with said cutter means retracted and with said first passage means open, relative downward movement of said mandrel in said body from said upper position upon expansion of said cutter means shifting said second passage means below said guide means to open condition in alignment with said slot; said second passage means directing fluid through said slot toward said cutter means when in open condition.

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