July 17, 1956 A. W. KAMMERER, JR 2,755,070

HYDRAULICALLY EXPANSIBLE ROTARY DRILL BITS

Filed Aug. 25, 1954 2 Sheets-Sheet 1

Fig. 1.

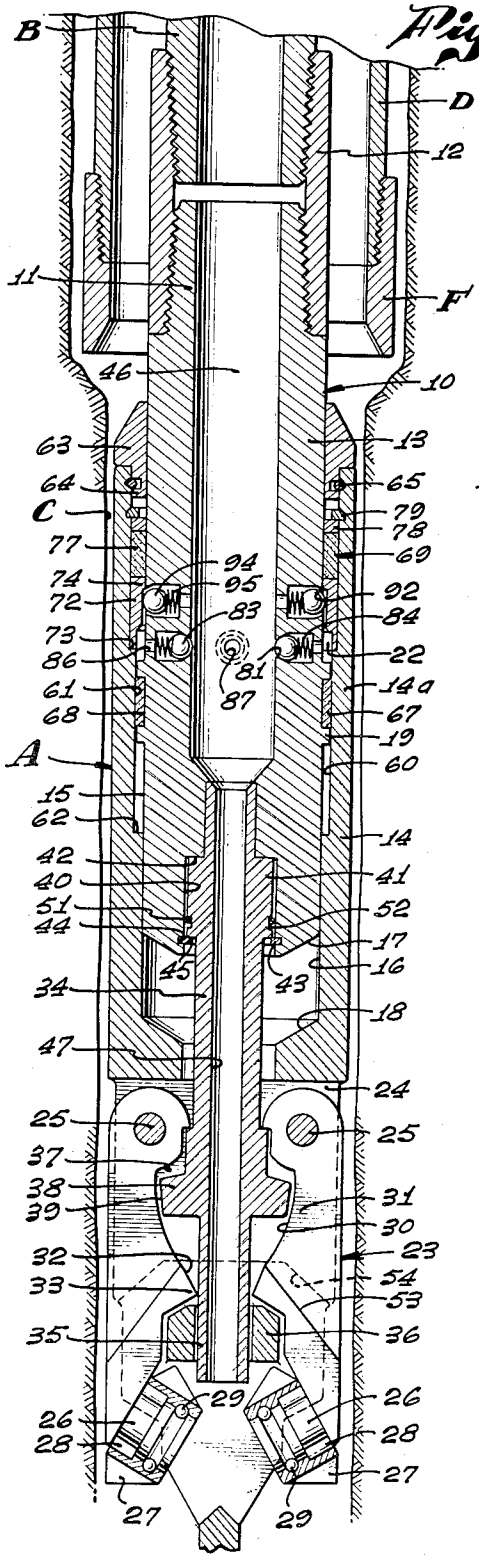
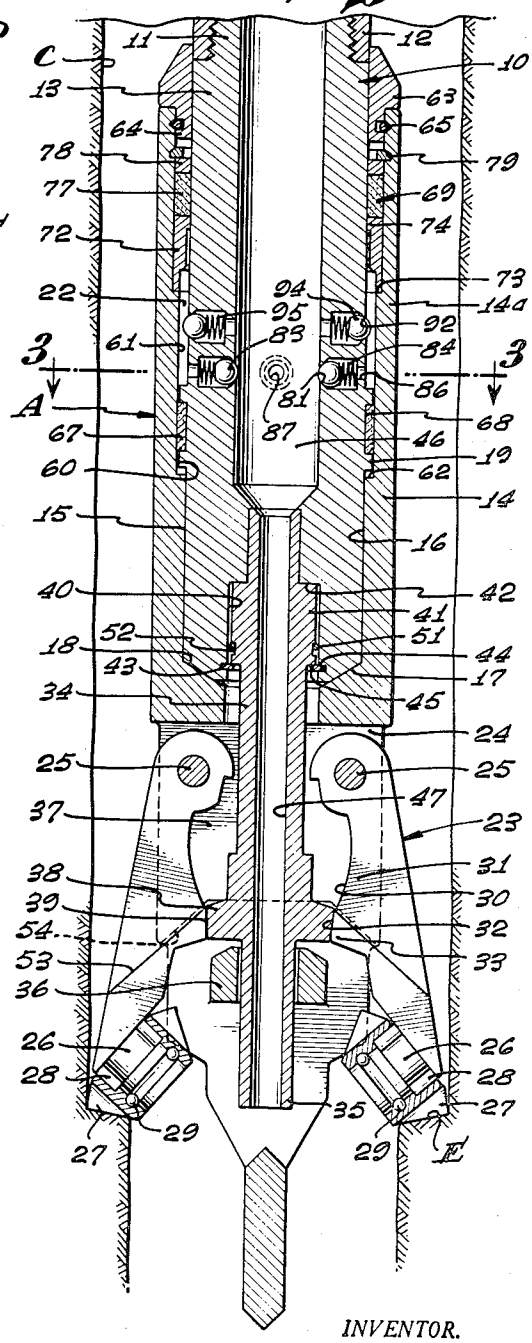


Fig. 2.



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Fig. 4.

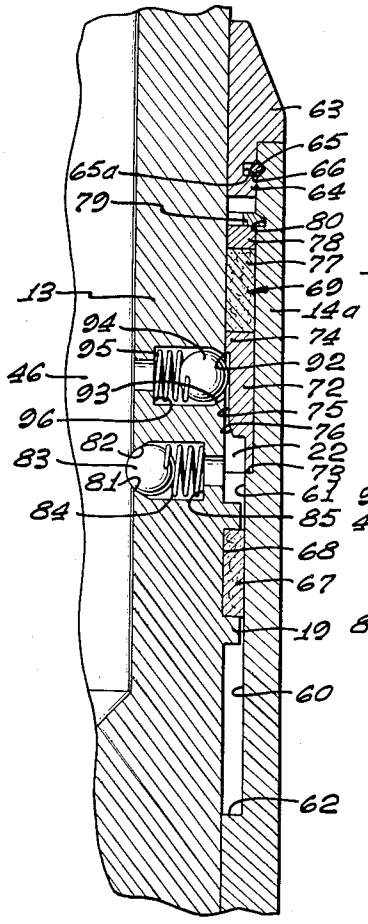


Fig. 5.

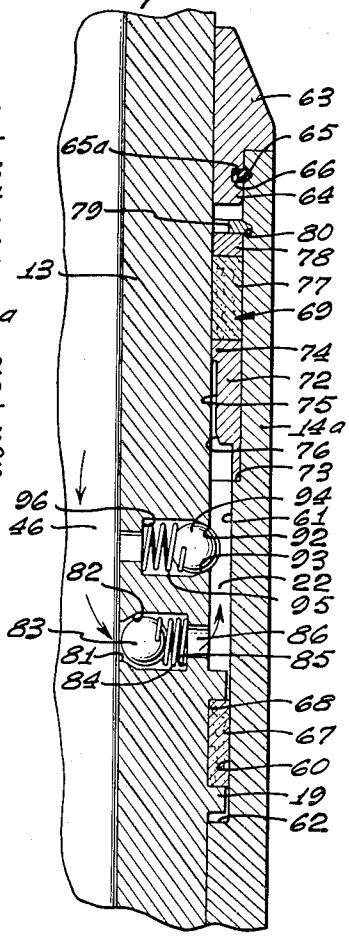


Fig. 6.

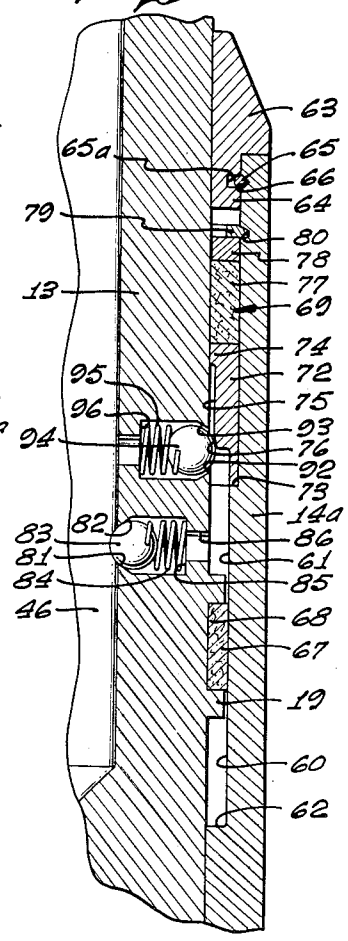
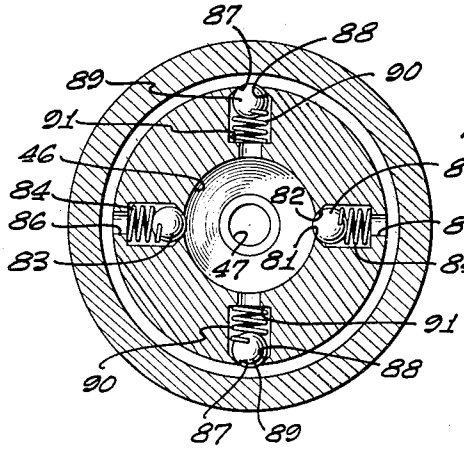


Fig. 3.



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HYDRAULICALLY EXPANSIBLE ROTARY DRILL BITS

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Application August 25, 1954, Serial No. 452,184

19 Claims. (Cl. 255—76)

The present invention relates to rotary drill bits of the expansible type, capable of being lowered through well casing and of drilling or enlarging a bore hole below the casing to a greater diameter than the inside diameter of the casing.

An object of the present invention is to provide an expansible rotary drill bit having cutters that are expanded laterally outward by hydraulic pressure applied through the fluid in the drill string to which the bit is attached, and in which the cutters are held in their expanded position by hydraulic pressure despite the relieving of the pressure in the fluid in the drill string itself.

Another object of the invention is to provide an expansible rotary drill bit having cutters which are held hydraulically in their expanded position despite the relieving of the pressure in the drill string, in which the hydraulic force holding the cutters expanded can be effectively removed, when the cutters are to be retracted.

A further object of the invention is to provide an expansible rotary drill bit embodying a cylinder and piston device for expanding the cutters laterally outward, in which fluid under substantial pressure can be trapped in the device to insure the retention of the cutters in their expanded position, but in which the trapped fluid can be released whenever retraction of the cutters is desired.

Yet another object of the invention is to provide an expansible rotary drill bit embodying a cylinder and piston device for expanding the cutters laterally outward, in which the opportunity for sand, and other foreign substances, in the drilling fluid to plug the device and prevent retraction of the cutters is greatly minimized.

Still a further object of the invention is to provide an expansible rotary drill bit embodying a cylinder and piston device for expanding the cutters laterally outward, in which fluid under pressure can be trapped in the device to hold the cutters outwardly, and in which the bit embodies a safety mechanism for insuring retraction of the cutters in the event that the trapped fluid in the device cannot be released in the normal manner, or in the event the device becomes plugged with sand or other foreign substances.

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 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 an embodiment of the invention disposed in a well bore, with the cutters and other parts in their initial and retracted positions;

Fig. 2 is a longitudinal section similar to Fig. 1, disclosing the cutters locked in their fully expanded position;

Fig. 3 is a cross-section, on an enlarged scale, taken along the line 3—3 on Fig. 2;

Fig. 4 is a fragmentary longitudinal section, on an enlarged scale, through the hydraulic actuating mechanism of the device, with the parts occupying substantially the same position as disclosed in Fig. 1;

Fig. 5 is a view similar to Fig. 4, disclosing the hydraulic actuating mechanism in the position it occupies when the cutters are expanded to their fullest extent;

Fig. 6 is a view similar to Fig. 4, disclosing the hydraulic mechanism in a position between the locations shown in Figs. 4 and 5.

The form of invention shown in the drawings includes a rotary expansible drill bit A which can be secured to the lower end of a string of drill pipe B extending to the top of the well bore C, and by means of which the drill bit is lowered through a string of well casing D to a region below the casing shoe F where the hole enlarging operation is to commence. The general type of expansible drill bit shown in the drawings is both illustrated and described in Patent No. 2,545,036, to which attention is invited for certain structural details that are not disclosed nor described herein in detail.

The upper portion of the rotary drill bit consists of a tubular mandrel 10 having an upper pin 11 threadedly connected to a sub 12 formed on the lower end of the string of drill pipe B. This mandrel includes an upper kelly or drill stem member 13 slidably splined to the main body 14 of the drill bit. The exterior 15 of the lower portion of the kelly is non-circular or hexagonal in shape, being telescopically received in a companion non-circular or hexagonal socket 16 formed in the main bit body 14. The hexagonal kelly exterior 15 and companion socket 16 form a slidable splined connection between these parts, enabling the kelly 13 to be moved longitudinally with respect to the body 14, while being capable of transmitting rotary movement to the body.

The mandrel 10 has a limited range of longitudinal movement within the body 14, its downward movement being determined by engagement of the lower end 17 of the kelly with an inwardly directed shoulder 18, its upward movement being limited by engagement of an external shoulder or piston portion 19 of the kelly, fitting within a counterbore 60 in the body of the tool above its hexagonal socket 16, with a lower abutment member 72 that rests upon a shoulder 73 formed in the body 14 of the tool. This abutment 72 constitutes part of a packing structure carried by the body of the tool, as described hereinbelow. Actually, the abutment 72 may be considered as constituting the upper end of a confined cylinder space 22 formed between the kelly or drill stem 13 and the body 14 of the tool.

The tool body 14 has a plurality of expansible parts mounted on it. These include cutter supporting members 23 pivotally mounted in body slots 24 on hinge pins 25 suitably secured to the body. Each cutter supporting member 23 depends from a hinge pin 25, terminating in a bearing supporting pin 26 inclined inwardly and downwardly. A side roller cutter 27 is rotatably mounted on each bearing supporting pin 26, being mounted on anti-friction roller and ball bearing elements 28, 29 rollable on the bearing supporting pin. The ball bearing elements 29 lock the cutters 27 against endwise movement on the bearing supporting pin 26, as well as transmitting axial and radial thrusts between the cutter and supporting pin. The roller bearing elements 28 transmit primarily radial thrusts between these parts. The manner of mounting the ball and roller bearing elements 29, 28 between the cutters 27 and bearing supporting pins 26, and of retaining them in place, is specifically described in the above-mentioned Patent 2,545,036.

The cutter supporting members 23 and cutters 27

mounted therein tend to occupy a retracted position substantially and entirely within the confines of the main body 14 of the bit. These cutter supporting members and cutters are expandible outwardly, to enlarge the sides of the well bore C and to operate upon a formation shoulder E that the cutters produce in the latter. To accomplish the expansion, each cutter supporting member 23 has an inclined expander surface 30 on its inner portion 31 below the hinge pin 25 which tapers in a downward and inward direction. Each expander surface 30 terminates in a lock surface 32 formed on a lock portion 33 of the cutter supporting member. The outward expansion is accomplished by producing relative longitudinal movement between the mandrel 10 and the bit body 14, which will produce corresponding relative longitudinal movement between the cutter supporting members 23 and the tubular member 34 of the mandrel. This tubular member 34 includes a lower portion 35 slidable within a guide 36 secured to the body 14 and extending across the slotted region of the body below the lock portion 33.

Located initially substantially above the guide 36 and below the hinge pins 25 and in cutter supporting member recesses 37 is a mandrel lock and expander 38 having outer surfaces 39 adapted to engage the expander surfaces 30 and the lock surfaces 32. The lock and expander 38 may be formed integrally with the tubular member 34, the upper end of the latter being piloted within a socket 40 in the lower portion of the kelly 13. An enlarged boss 41 on the tubular member engages a downwardly facing shoulder 42 of the kelly, the tubular member being held in this shoulder by a suitable split retainer or lock ring 43 snapped into an internal groove 44 encompassing the Kelly socket 40 and engaging a downwardly directed shoulder 45 formed on the tubular member boss 41. Leakage between the boss 41 and the wall of the Kelly socket is prevented by a suitable side seal 51, in the form of a rubber O ring, disposed within a groove 52 in the boss and engaging the wall of the socket 40.

The kelly 13 has a central fluid passage 45 therethrough communicating with the string of drill pipe B. Fluid pumped through this passage 46 can pass into an aligned central passage 47 in the tubular member 34, whereby drilling mud, or similar drilling fluid, can be pumped down through the tool, for the purpose of removing the cuttings from the well bore C and flushing them upwardly around the drill pipe B to the top of the hole.

Assuming that the body 14 of the tool is elevated relatively along the tubular mandrel 10, the inclined expander surfaces 30 of the cutter supporting members 23 will be shifted upwardly along the lock and expander portion 38 of the tubular member. During such upward shifting, the cutter supporting members 23 and the cutters 27 carried thereby may be pivoted about the hinge pins 25 and urged in an outward direction. The movement of the body 14 with respect to the tubular mandrel 10 can continue until the cutters 27 have been shifted outwardly to their fullest extent, as determined by engagement of stop shoulders 53 on the cutter supporting members with companion shoulders 54 formed in the body on opposite sides of the body slots 24. When such engagement occurs, the lower end 17 of the Kelly portion of the tubular mandrel 10 will engage the body shoulder 18, and the lock and expander 38 on the tubular member 34 will be disposed behind and in engagement with the lock portion 33 on the cutter supporting members 23.

It is to be noted that the surfaces 32 of the lock portion on the cutter supporting members 23 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, to prevent the reactive forces of the formation on the cutters 27 from moving the latter inwardly. As a practical matter, it is preferred that the coengaging lock surfaces 32, 29 be inclined slightly in a downward direction toward the axis of the tool, to insure release of the lock and expander portion 38 from the cutter supporting members 23 when the latter and the cutters 27 are to be shifted back to their retracted positions.

The relative longitudinal movement between the tubular mandrel 10 and the body 14 of the tool for effecting outward expansion of the cutters 27 is accomplished hydraulically. The counterbore 60 receiving the piston 19 of the drill stem member 13 is formed in the upper portion 14*a* of the body, which actually constitutes a cylinder having a cylinder wall 61 extending from a lower shoulder 62, defining the bottom of the counterbore 60, to an upper head and guide 63. This latter member has a depending portion 64 inserted in the upper end of the cylinder 14*a* and releasably retained therein by a split snap ring 65 carried in a groove 65*a* in the cylinder head portion 64 and adapted to be received within a generally V-shaped internal groove 66 in the upper portion of the cylinder wall. The head 63, with the snap ring 65 mounted in its groove, need merely be forced into the cylinder 14*a* and, when located opposite the V-shaped groove 66, the snap ring will expand inherently partially into the latter to releasably lock the cylinder head 63 to the cylinder 14*a*.

The confined cylinder space 22 is formed between the piston portion 19 of the kelly 13, the periphery of the kelly above the piston, and the cylinder 14*a*. To provide this space, a suitable packing or side seal structure 67 is disposed in a suitable piston ring groove 68 formed in the piston, which is adapted to slidably seal against the cylinder wall 61 and the cylinder 14*a*. Fluid is thereby prevented from passing in a downward direction between the piston 19 and the cylinder 14*a*. Similarly, fluid is prevented from passing in an upward direction out of the annular cylinder space 22 by a cylindrical packing or sealing structure 69 secured to the cylinder 14*a* and slidably engaging the periphery of the kelly 13. This structure may take any suitable form. As shown, it consists of the lower packing supporting ring or abutment 72, that rests upon the upwardly facing body shoulder 73, and which has an upper portion 74 that can slidably engage the periphery of the kelly 13, an intermediate cam surface 75 that is spaced laterally outward from the periphery of the kelly, and a lower surface 76 inclined in a downward and outward direction. A non-metallic packing 77, of any suitable material, rests upon the lower abutment 72, its upper end engaging an upper packing ring or abutment 78 bearing against a split retainer ring 79 received within an internal groove 80 in the cylinder 14*a*. The lower abutment 72 and the upper split retainer ring 79 prevent longitudinal movement of the packing structure 69 with respect to the bit body cylinder 14*a*. The non-metallic packing portion 77 of the sealing structure 69 engages the cylinder wall 61 to prevent leakage therealong, and also slidably seals against the periphery of the drill stem portion 13 of the tubular mandrel 10.

Fluid under pressure in the string of drill pipe B and within the tubular mandrel 10 can be fed into the cylinder space 22 through one or more side ports 81 extending through the tubular mandrel 13 immediately above the piston portion 19, and establishing communication between the central passage 46 through the kelly 13 and the cylinder space 22. Such fluid under pressure can be developed by restricting the area through the passage 17 in the mandrel below the ports 81, to enable a back pressure to be built up in the Kelly portion 13 of the mandrel, which pressure will be imposed on the fluid in the cylinder space 22 and acting upon the packing structure 69, to urge the body 14 of the tool in an upward direction with respect to the tubular mandrel 10, and correspondingly elevate the cutter supporting members 23 and cutters 27 with respect to the lock and expander portion 38 of the tubular member 34, expanding the cutters 27 to their fullest extent.

As disclosed in the drawings, the restriction in the fluid flow through the tubular member 34 to build up the above-described back pressure is accomplished by providing the passage 47 through the tubular member 34 with a substantially lesser diameter and area than the diameter and area of the passage 46 through the Kelly portion 13 of the mandrel thereabove.

In the manner described above, the cutters 27 can be expanded to their fullest extent merely by the act of pumping the fluid under pressure through the drill pipe B, the Kelly passage 46, and the tubular member passage 47, a back pressure of fluid being built up, which passes through the inlet port 81 and into the confined cylinder space 22, to elevate the body 14 of the tool to its fullest extent with respect to the tubular mandrel 10. The tool can be rotated, with the cutters 27 operating upon the formation shoulder E, and the cutters will remain locked in their outwardly expanded position so long as drilling weight is being imposed upon the drill pipe B and the drill bit A. In the event the drill pipe and the drill bit are elevated in the well bore C, and in the absence of hydraulic pressure within the tool, the body 14 would tend to drop down along the mandrel 10, allowing the cutters 27 to return to their retracted position. Thereafter, it would be necessary to first apply pressure to the tool to reexpand the cutters 27 before lowering the apparatus back to the position in which the cutters engage the shoulder E.

By virtue of the present invention, the cutters 27 are prevented from retracting from their maximum outwardly expanded position in the absence of fluid pressure within the drill pipe B and the mandrel passages 46, 47, and upon elevation of the tool A to raise its cutters above the shoulder E. To accomplish this purpose, fluid under pressure is trapped within the confined cylinder space 12 between the cylinder body portion 14*a* of the tool and the Kelly portion 13 of the mandrel 10. Such trapping is effected by preventing the fluid under pressure that passes through the inlet ports 81 from returning through such inlet ports. Thus, each inlet port is surrounded by a valve seat 82 engaged by a valve element 83, which may be in the form of a ball, urged inwardly against the seat by a suitable helical compression spring 84 engaging the ball and a spring seat 85 in the kelly. The fluid under pressure in the Kelly passage 46 can unseat each valve ball element 83 against the force of the spring 84, passing around the ball and through an outer passage 86 in the kelly into the confined cylinder space 22.

Because of the check or one-way valve devices 82, 83 controlling the flow of fluid through the inlet passages 81, fluid passing through the inlet passages into the cylinder space is trapped therein and cannot return through the inlet passages or ports. Accordingly, in the event the fluid pressure in a string of drill pipe B and in the mandrel 10 were relieved, fluid under pressure would still be present within the confined cylinder space 22, to retain the cutters 27 in their outwardly expanded position.

However desirable it is to prevent inadvertent retraction of the cutters 27, the latter are to be retracted when the tool is to be removed through the well casing D to the top of the well bore. Accordingly, the fluid is allowed to escape from the confined cylinder space 22 when the cutters are to be retracted. One or a plurality of outlet ports 87 (Fig. 3) may be provided through the kelly 13, these ports establishing communication between the confined cylinder space 22 and the Kelly passage 46. Each of these outlet ports 87 is controlled by a valve device, including a valve seat 88 surrounding the outlet port, and engaged by a valve element 89, that may be in the form of a ball, urged in an outward direction into engagement with the seat by a suitable helical compression spring 90 bearing against the ball 89 and against a spring seat 91 formed in the kelly.

Fluid under proper pressure in the confined cylinder space 22 can urge each release valve element 89 inwardly from its seat 88, flowing around the valve element and inwardly through the outlet passage 87 into the central passage 46 through the kelly. However, fluid cannot escape from the confined cylinder space 22 through the outlet passages 87 unless the pressure of the fluid in the cylinder space exceeds a predetermined maximum value, which is determined by the force of each spring 90 tending to hold the valve ball 89 engaged with its seat 88. The spring 90 will insure the retention of fluid under a pressure differential in the cylinder space 22, inasmuch as it will only allow fluid to bleed past the valve member 89 and through the outlet passages 87 until the pressure differential in the cylinder space 22 is equal to the unit pressure necessary to overcome the force of the outlet or exhaust valve springs 90.

The spring force is selected so that a certain minimum pressure will be retained in the confined cylinder space 22. As an example, the springs 90 may exert a force corresponding to 200 p. s. i. differential in the cylinder space 22, which will be applied over the whole area of the annular space between the wall 61 of the cylinder 14*a* and the periphery of the mandrel 10 above the piston 19, tending to hold the cutters 27 in their fully expanded position. If this area is ten square inches, for example, then a total of 2000 lbs. hydraulic force is available to hold the body 14 in its upward position along the mandrel 10, and the cutters 27 in their outwardly expanded position.

The fluid under pressure from the cylinder will be forced out through the outlet ports 87 against the action of the check valve 89, 90 when the tool is raised in the well bore C to a position in which the cutter supporting members 23 engage a smaller diameter bore hole above the enlarged well bore portion, or the casing shoe F. When contacting the casing shoe, the body 14 of the tool cannot move upwardly to any further extent, whereupon an upward pull taken on the drill string B and the mandrel 10 will move the piston 19 upwardly within the body, imparting a greater pressure to the fluid in the cylinder space 22 and forcing it outwardly through the outlet ports 87 into the central passage 46 through the kelly. The fluid will be forced outwardly until the mandrel 10 has been elevated within the body 14 to its fullest extent, as determined by engagement of the piston 19 with the lower abutment member 72 of the packing structure 69.

The outlet ports 87 are preferably provided through the mandrel wall, usually immediately above the piston 19 so as to insure the outward forcing of sand, or other foreign materials, that might be contained in the fluid within the cylinder. If the outlet ports 87 were disposed at a higher position within the mandrel 10, then the sand might tend to settle out of the drilling fluid within the cylinder space 22 and remain upon the piston 19 below the outlet ports, thereby preventing elevation of the mandrel 10 within the body to the extent necessary to insure full retraction of the cutter supporting members 23 and the cutters 27.

In place of, or in addition to, the valve controlled outlet passages or ports 87 described above, an upper outlet port or ports 92 can be provided in the kelly 13, this port establishing communication between the central passage 46 through the kelly and the confined cylinder space 22. Each upper passage 92 is surrounded by a valve seat 93 adapted to be engaged by a valve element 94, in the form of a ball, that is forced outwardly against the seat by a helical compression spring 95 engaging the ball 94 and a spring seat 96 in the kelly. Essentially, each of these upper valve members 94 functions in the same way as the lower set of outlet or exhaust valve devices 89. An excess of pressure in the fluid in the cylinder space 22 beyond the unit pressure corresponding to the force of the springs 95 will unseat the ball valve element 94 and allow the fluid in the cylinder space 22 to pass through the outlet passages 92 back into the central passage 46 through the kelly 13. This action will

occur as a result of the relieving of the pressure in the drill pipe B and Kelly passage 46, whereupon the excess of pressure in the cylinder space 22 will unseat the check valve 94 and allow escape of some fluid back into the central passage through the kelly.

In the present instance, however, it is desired to relieve all of the pressure in the cylinder space 22, to facilitate retraction of the cutters 27 and avoid potential damage or injury in the event the tool is taken apart after it has been retrieved from the well bore. Accordingly, the upper set of valve devices 94, 95 is positively opened upon elevation of the mandrel 10 with respect to the body 14. Assuming that the apparatus has been elevated until the expanded cutter supporting members 23 engage the casing shoe F, then the taking of an upward strain on the mandrel 10 will shift it upwardly along the body 14, the fluid under pressure escaping through the various outlet passages 87, 92 back into the central passage 46 through the kelly 13. After partial movement of the mandrel 10 upwardly with respect to the body 14, the upper ball valve element 94, that extends partly into the confined cylinder space 22, will engage the tapered surface 76 of the lower abutment member 72, which will force the balls 94 inwardly against the action of their springs 95 away from their companion valve seats 93, thereby allowing the fluid under pressure in the cylinder space 22 to pass relatively freely through the upper outlet passages 92 back into the central Kelly passage 46. Continued upward movement of the mandrel 10 within the body will cause the upper ball members to slide along the inner surface 75 of the abutment 72, which will hold the valves 94 in their open position.

The upper set of relief valves 94, 95 can be used in place of the lower set 89, 90, or both sets can be used, as desired. In the event that both sets are used, then the lower set will tend to minimize the opportunity for sand, or other foreign substances, in the cylinder space 22 to be packed therein and prevent full retraction of the cutters 27 and the cutter supporting members 23. Despite the mechanical opening of the upper valve members 94, any sand in the cylinder space 22 can still be forced out through the lower outlet passages 87 to insure full elevation of the mandrel 10 within the body 14 to the extent in which the piston 19 will engage the lower end of the lower abutment 72.

A safety feature is embodied in the apparatus to enable the cutters 27 to be retracted in the event the cylinder space 22 becomes packed with sand or foreign substances that plug the passages 87, 92 and thereby prevent bleeding of the fluent material in the cylinder space back through these outlet passages into the interior 46 of the kelly 13. It is to be noted that the split ring 15 releasably securing the cylinder head 63 to the cylinder 14*a* engages the tapered walls of the inner cylinder groove 66. Accordingly, the imposition of a sufficient upward longitudinal force on the cylinder head 63 will cause the upper tapered groove surface to force the ring 65 inwardly out of the groove 66, and allow the head to move upwardly out of and away from the cylinder 14*a*. The upper side 80*a* of the groove 80 for the split retainer ring 79 is also tapered in an inward and upward direction, engaging a companion tapered surface on the outer corner of the split ring 79. When this ring 79 is subjected to a sufficient upward axial or longitudinal force, it will be shifted upwardly along the tapered upper groove surface 80*a* and inwardly out of the groove 80. When this occurs, the remainder of the packing structure 69 can move upwardly within the body 14 of the tool.

In the event the cylinder space 22 has been substantially completely sanded up after the cutters 27 have been locked in their expanded position, the apparatus can be elevated until the cutter supporting members 23 engage the casing shoe F, which will prevent further upward movement of the body 14 at this time. The taking of an upward pull on the drill pipe B and the mandrel 10 will then urge the piston 19 in an upward direction, the upward force being transmitted through the sand accumulation in the cylinder space 22 to the upper backing structure 69. When this force exceeds the force that inherently holds the upper retaining ring 79 in its groove, the ring 79 will be urged inwardly because of its action against the tapered surface 80*a* of the groove, which will release the ring 79 and cause the packing assembly 69 to move upwardly in the body with the mandrel. This combination will move upwardly until the upper retainer ring 79 engages the lower end of the cylinder head 63. The upward force is then transmitted to the cylinder head 63 to force its retainer ring 65 out of the cylinder groove 66, the head then being carried upwardly with the packing structure 69 and mandrel 10 out of the body 14 of the tool. The mandrel 10 can move upwardly in the body 14 to the extent determined by engagement of the tubular member lock portion 38 with the cutter supporting members 23, with the lock portion 38 located disposed opposite the supporting member recesses 37, allowing the cutter supporting member 23 and the cutters 27 to retract completely within the confines of the body 14, permitting the apparatus A to be moved within the well casing D and elevated to the top of the well bore.

It is, therefore, apparent that a drill bit apparatus has been provided in which the cutters 27 can be expanded hydraulically by pumping fluid through the drill bit, the fluid under pressure passing through the inlet passages 81 into the cylinder space 22 to elevate the drill bit body 14, cutter supporting members 23 and cutters 27 with respect to the mandrel 10, to expand the cutters laterally outward to their maximum position, where they are locked in such maximum outward position. The inlet passages are closed against return flow of fluid therethrough by the check valves 83, trapping fluid under a pressure differential within the cylinder space 22, that will remain therein when the fluid pressure within the drill pipe B and the mandrel 10 is relieved. The pressure differential within the cylinder space 22 is dependent upon the force of the springs 90, 95 urging the outlet valve devices 89, 94 against their respective seats 88, 93, to prevent bleeding of the fluid under pressure back into the interior of the Kelly passage 46. Thus, the cutters 27 will remain in their outwardly expanded positions until it is desired to withdraw the tool from the well bore.

When the drill pipe B is elevated, to elevate the bit A therewith, the cutters 27 will remain in their outward expanded position until a restriction in the well bore is encountered, such as the casing shoe F. The cutter supporting members 23 will engage the casing shoe, to prevent upward movement of the body 14 at this time. Continued upward movement of the mandrel 10 will then apply additional pressure to the fluid in the cylinder space 22, by means of the piston 19, the increased pressure of the fluid opening the outlet valves 89, 94, and allowing the fluid to exhaust from the confined cylinder space 22 into the Kelly passage 46, the piston 19, of course, moving upwardly in the body 14 during this time to elevate the lock portion 38 of the mandrel to its fullest extent with respect to the cutter supporting members 23, allowing the latter and the cutters to shift completely to their retracted positions. Assurance is had that the fluid pressure in the cylinder space 22 is relieved by virtue of the engagement of the upper set of exhaust valve elements 94 with the cam device 72 that will shift and hold them in their open position.

In the event that any sand accumulates in the cylinder space 22, it can be forced out through the lower outlet passages 87, or, if the cylinder space is plugged with sand or other foreign substances to the extent preventing their outward movement through the outlet passages 87, then the imposition of sufficient upward force on the piston 19 and the sand accumulation will release the rings 79, 65 and shift the entire packing assembly

69, and the sand itself, upwardly along the body 14, which will, of course, allow the piston 19 and the mandrel 10 to shift upwardly along the body 14 to the extent necessary to secure complete retraction of the cutters 27 within the confines of the bit body.

The inventor claims:

1. In a rotary well drilling bit connectible to a tubular drill string: a main body; cutter means mounted on said body for expansion laterally of said body; hydraulically operable means operatively connected to said cutter means and subject to the pressure of fluid in the drill string for expanding said cutter means laterally outward; and means for entrapping fluid under pressure in said hydraulically operable means to hold said cutter means expanded laterally outward upon relieving pressure on the fluid in the drill string.

2. In a rotary well drilling bit connectible to a tubular drill string: a main body; cutter means mounted on said body for expansion laterally of said body; hydraulically operable means operatively connected to said cutter means and subject to the pressure of fluid in the drill string for expanding said cutter means laterally outward; means for entrapping fluid under pressure in said hydraulically operable means to hold said cutter means expanded laterally outward upon relieving pressure on the fluid in the drill string; and means for releasing such entrapped fluid from said hydraulically operable means to allow retraction of said cutter means.

3. In a rotary well drilling bit connectible to a tubular drill string: a main body having a fluid passage therein adapted to communicate with the tubular drill string; cutter means mounted on said body for expansion laterally of said body; hydraulically operable means operatively connected to said cutter means; an inlet for conducting fluid under pressure from said passage to said hydraulically operable means to actuate said hydraulically operable means and expand said cutter means laterally outward; a first valve controlling said inlet to allow fluid to flow from said passage through said inlet to said hydraulically operable means and to prevent flow of fluid through said inlet in the reverse direction; an outlet for conducting fluid from said hydraulically operable means to said passage; and a second valve controlling said outlet, said second valve being opened in response to a pressure differential of fluid in said hydraulically operable means exceeding a predetermined value.

4. In a rotary well drilling bit connectible to a tubular drill string: a main body having a fluid passage therein adapted to communicate with the tubular string; cutter means mounted on said body for expansion laterally of said body; hydraulically operable means operatively connected to said cutter means; passage means for conducting fluid between said passage and hydraulically operable means; valve means in said passage means controlling flow of fluid therethrough to allow fluid under pressure to flow from said passage through said passage means to said hydraulically operable means and to prevent flow from said hydraulically operable means through said passage means to said passage; and means for actuating said valve means to allow fluid to flow from said hydraulically operable means through said passage means to said passage.

5. In a rotary well drilling bit connectible to a tubular drill string: a main body having a fluid passage therein adapted to communicate with the tubular string; cutter means mounted on said body for expansion laterally of said body; hydraulically operable means operatively connected to said cutter means; passage means for conducting fluid between said passage and hydraulically operable means; valve means in said passage means controlling flow of fluid therethrough to allow fluid under pressure to flow from said passage through said passage means to said hydraulically operable means and to prevent flow from said hydraulically operable means through said passage means to said passage; and means on said hydraulically operable means engageable with at least part of said valve means to shift said part of said valve means to open position to allow fluid to flow from said hydraulically operable means through said passage means to said passage.

6. In a rotary well drilling bit connectible to a tubular drill string: a main body having a fluid passage therein adapted to communicate with the tubular drill string; cutter means mounted on said body for expansion laterally of said body; hydraulically operable means operatively connected to said cutter means; an inlet for conducting fluid under pressure from said passage to said hydraulically operable means to actuate said hydraulically operable means and expand said cutter means laterally outward; a first valve controlling said inlet to allow fluid to flow from said passage through said inlet to said hydraulically operable means and to prevent flow of fluid through said inlet in the reverse direction; an outlet for conducting fluid from said hydraulically operable means to said passage; a second valve controlling said outlet, said second valve being opened in response to the pressure differential of fluid in said hydraulically operable means exceeding a predetermined value; and means on said hydraulically operable means engageable with said second valve to shift said second valve to open position.

7. In a rotary well drilling bit connectible to a drill string: a main body; cutter means mounted on said body for expansion laterally of said body; a mandrel connectible to the drill string and slidably splined to said body, whereby drilling torque can be transmitted from said mandrel to said body; coengageable expander means on said mandrel and cutter means; hydraulically operable means on said body subject to the pressure of fluid in the drill string for elevating said body and cutter means with respect to said mandrel to cause said expander means to expand said cutter means laterally outward; and means for entrapping fluid under pressure in said hydraulically operable means to hold said cutter means expanded laterally outward upon relieving pressure on the fluid in the drill string.

8. In a rotary well drilling bit connectible to a drill string: a main body; cutter means mounted on said body for expansion laterally of said body; a mandrel connectible to the drill string and slidably splined to said body, whereby drilling torque can be transmitted from said mandrel to said body; coengageable expander means on said mandrel and cutter means; hydraulically operable means on said body subject to the pressure of fluid in the drill string for elevating said body and cutter means with respect to said mandrel to cause said expander means to expand said cutter means laterally outward; means for entrapping fluid under pressure in said hydraulically operable means to hold said cutter means expanded laterally outward upon relieving pressure on the fluid in the drill string; and means for releasing such entrapped fluid from said hydraulically operable means to allow retraction of said cutter means.

9. In a rotary well drilling bit connectible to a tubular drill string: a main body; cutter means mounted on said body for expansion laterally of said body; a mandrel connectible to a drill string and slidably splined to said body, whereby drilling torque can be transmitted from said mandrel to said body; said mandrel having a fluid passage communicating with the drill string; coengageable expander means on said mandrel and cutter means; hydraulically operable means on said body; means for feeding fluid under pressure from said passage into said hydraulically operable means to elevate said body and cutter means with respect to said mandrel to cause said expander means to expand said cutter means laterally outward; and check valve means in said feeding means to allow fluid flow from said passage to said hydraulically operable means and to prevent flow of fluid in the reverse direction.

10. In a rotary well drilling bit connectible to a tubular drill string: a main body; cutter means mounted on

said body for expansion laterally of said body; a mandrel connectible to a drill string and slidably splined to said body; said mandrel having a fluid passage communicating with the drill string; coengageable expander means on said mandrel and cutter means; hydraulically operable means on said body; means for feeding fluid under pressure from said passage into said hydraulically operable means to elevate said body and cutter means with respect to said mandrel to cause said expander means to expand said cutter means laterally outward; check valve means in said feeding means to allow fluid flow from said passage to said hydraulically operable means and to prevent flow of fluid in the reverse direction; and means responsive to the pressure of fluid in said hydraulically operable means to allow fluid to escape from said hydraulically operable means.

11. In a rotary well drilling bit connectible to a tubular drill string: a main body; cutter means mounted on said body for expansion laterally of said body; a mandrel connectible to a drill string and slidably splined to said body, whereby drilling torque can be transmitted from said mandrel to said body; said mandrel having a fluid passage communicating with the drill string; coengageable expander means on said mandrel and cutter means; hydraulically operable means on said body; means for feeding fluid under pressure from said passage into said hydraulically operable means to elevate said body and cutter means with respect to said mandrel to cause said expander means to expand said cutter means laterally outward; check valve means in said feeding means to allow fluid flow from said passage to said hydraulically operable means and to prevent flow of fluid in the reverse direction; means for exhausting fluid from said hydraulically operable means to said passage; and valve means in said exhausting means to control flow of fluid therefrom.

12. In a rotary well drilling bit connectible to a tubular drill string; a main body; cutter means mounted on said body for expansion laterally of said body; a mandrel connectible to a drill string and slidably splined to said body; said mandrel having a fluid passage communicating with the drill string; coengageable expander means on said mandrel and cutter means; hydraulically operable means on said body; means for feeding fluid under pressure from said passage into said hydraulically operable means to elevate said body and cutter means with respect to said mandrel to cause said expander means to expand said cutter means laterally outward; check valve means in said feeding means to allow fluid flow from said passage to said hydraulically operable means and to prevent flow of fluid in the reverse direction; means for exhausting fluid from said hydraulically operable means to said passage; valve means in said exhausting means to control flow of fluid therefrom; and means on said hydraulically operable means engageable with said last-mentioned valve means to shift said last-mentioned valve means to open position.

13. In a rotary well drilling bit connectible to a tubular drill string: a main body; cutter means mounted on said body for expansion laterally of said body; hydraulically operable means operatively connected to said cutter means and subject to the pressure of fluid in the drill string for expanding said cutter means laterally outward; means for entrapping fluid under pressure in said hydraulically operable means to hold said cutter means expanded laterally outward upon relieving pressure on the fluid in the drill string; said hydraulically operable means including a head portion; means releasably securing said head portion to the remainder of said hydraulically operable means; said releasable means being released when said head portion is subjected to a predetermined force within said hydraulically operable means.

14. In a rotary well drill bit connectible to a drill string: a main body; cutter means mounted on said body for expansion laterally of said body; a mandrel connectible to the drill string and slidably splined to said body; coengageable expander means on said mandrel and cutter means; hydraulically operable means on said body subject to the pressure of fluid in the drill string for elevating said body and cutter means with respect to said mandrel to cause said expander means to expand said cutter means laterally outward; means for entrapping fluid under pressure in said hydraulically operable means to hold said cutter means expanded laterally outward upon relieving pressure on the fluid in the drill string; said hydraulically operable means including a head portion; means releasably securing said head portion to the remainder of said hydraulically operable means; said releasable means being released when said head portion is subjected to a predetermined force within said hydraulically operable means.

15. In a rotary well drilling bit connectible to a tubular drill string: a main body; cutter means mounted on said body for expansion laterally outward of said body; a mandrel connectible to the drill string and slidably splined to said body, whereby drilling torque can be transmitted from said mandrel to said body; coengageable expander means on said mandrel and cutter means; said body having a cylinder portion above said expander means slidably and sealingly engaging said mandrel; said mandrel having a fluid passage communicating with the drill string and cylinder portion to feed fluid under pressure into said cylinder portion to elevate said body and cutter means with respect to said mandrel to cause said expander means to expand said cutter means laterally outward; and means for entrapping fluid under pressure in said cylinder portion to hold said cutter means expanded laterally outward upon relieving pressure on the fluid in the drill string.

16. In a rotary well drilling bit connectible to a tubular drill string: a main body; cutter means mounted on said body for expansion laterally outward of said body; a mandrel connectible to the drill string and slidably splined to said body; coengageable expander means on said mandrel and cutter means; said body having a cylinder portion above said expander means slidably and sealingly engaging said mandrel; said mandrel having a fluid passage communicating with the drill string and cylinder portion to feed fluid under pressure into said cylinder portion to elevate said body and cutter means with respect to said mandrel to cause said expander means to expand said cutter means laterally outward; means for entrapping fluid under pressure in said cylinder portion to hold said cutter means expanded laterally outward upon relieving pressure on the fluid in the drill string; said cylinder portion including a head; means releasably securing said head to the remainder of said cylinder portion; said releasable means being released when said head is subjected to a predetermined force within said cylinder portion.

17. In a rotary well drilling bit connectible to a tubular drill string: a main body; cutter means mounted on said body for expansion laterally outward of said body; a mandrel connectible to a drill string and slidably splined to said body; coengageable expander means on said mandrel and cutter means; said body having a cylinder portion above said expander means slidably and sealingly engaging said mandrel; said mandrel having a central fluid passage communicating with the drill string and lateral inlet passage communicating with said fluid passage and opening into said cylinder portion to feed fluid under pressure into said cylinder portion to elevate said body and cutter means with respect to said mandrel to cause said expander means to expand said cutter means laterally outward; a first valve controlling said inlet passage to allow fluid to flow from said central passage through said inlet passage into said cylinder portion and to prevent flow of fluid through said inlet passage in the reverse direction; an outlet passage for conducting fluid from said cylinder portion to said central passage; and a second valve controlling said outlet passage, said second valve allowing

fluid to flow from said cylinder portion through said outlet passage to said central passage and preventing flow of fluid through said outlet passage in the reverse direction.

18. In a rotary well drilling bit connectible to a tubular drill string: a main body; cutter means mounted on said body for expansion laterally outward of said body; a mandrel connectible to a drill string and slidably splined to said body; coengageable expander means on said mandrel and cutter means; said body having a cylinder portion above said expander means slidably and sealingly engaging said mandrel; said mandrel having a central fluid passage communicating with the drill string and a lateral inlet passage communicating with said fluid passage and opening into said cylinder portion to feed fluid under pressure into said cylinder portion to elevate said body and cutter means with respect to said mandrel to cause said expander means to expand said cutter means laterally outward; a first valve controlling said inlet passage to allow fluid to flow from said central passage through said inlet passage into said cylinder portion and to prevent flow of fluid through said inlet passage in the reverse direction; an outlet passage for conducting fluid from said cylinder portion to said central passage; a second valve controlling said outlet passage, said second valve allowing fluid to flow from said cylinder portion through said outlet passage to said central passage and preventing flow of fluid through said outlet passage in the reverse direction; and means on said second cylinder portion engageable with said second valve for shifting said second valve to open position.

19. In a rotary well drilling bit connectible to a tubular drill string: a main body; cutter means mounted on said body for expansion laterally outward of said body; a mandrel connectible to a drill string and slidably splined to said body; coengageable expander means on said mandrel and cutter means; said body having a cylinder portion above said expander means slidably and sealingly engaging said mandrel; said mandrel having a central fluid passage communicating with the drill string and a lateral inlet passage communicating with said fluid passage and opening into said cylinder portion to feed fluid under pressure into said cylinder portion to elevate said body and cutter means with respect to said mandrel to cause said expander means to expand said cutter means laterally outward; a first valve controlling said inlet passage to allow fluid to flow from said central passage through said inlet passage into said cylinder portion and to prevent flow of fluid through said inlet passage in the reverse direction; an outlet passage for conducting fluid from said cylinder portion to said central passage; a second valve controlling said outlet passage, said second valve allowing fluid to flow from said cylinder portion through said outlet passage to said central passage and preventing flow of fluid through said outlet passage in the reverse direction; said cylinder portion including a head; and means releasably securing said head to the remainder of said cylinder portion; said releasable means being released when said head is subjected to a predetermined force within said cylinder portion.

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