Feb. 4, 1958 A. W. KAMMERER, JR 2,822,149

ROTARY EXPANSIBLE DRILL BITS

Filed Aug. 25, 1954 2 Sheets-Sheet 1

Fig. 1.

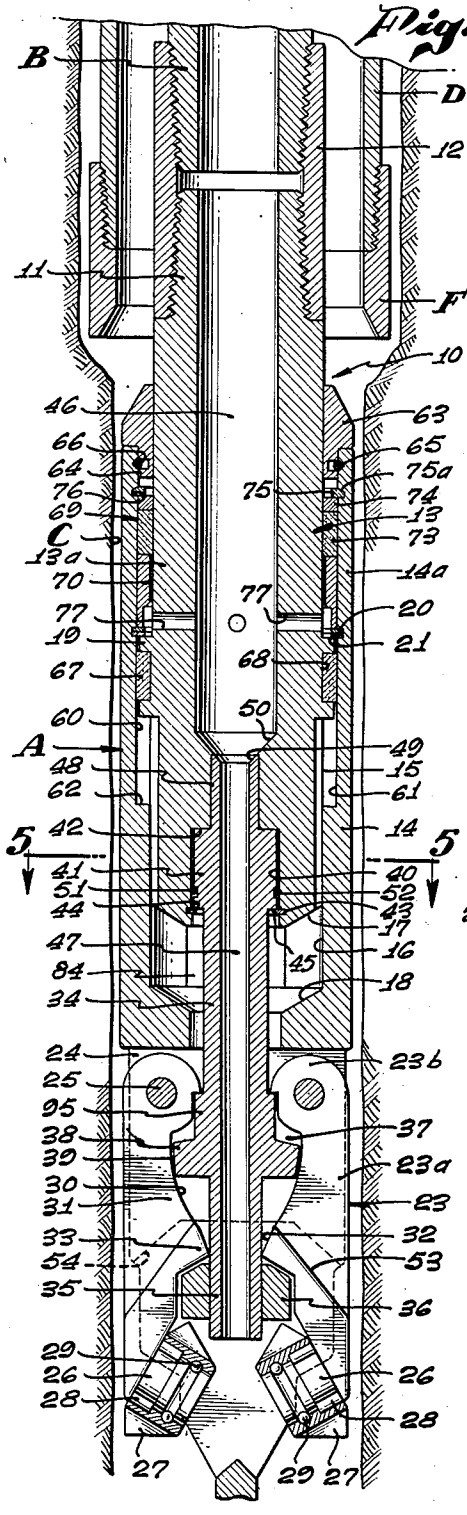
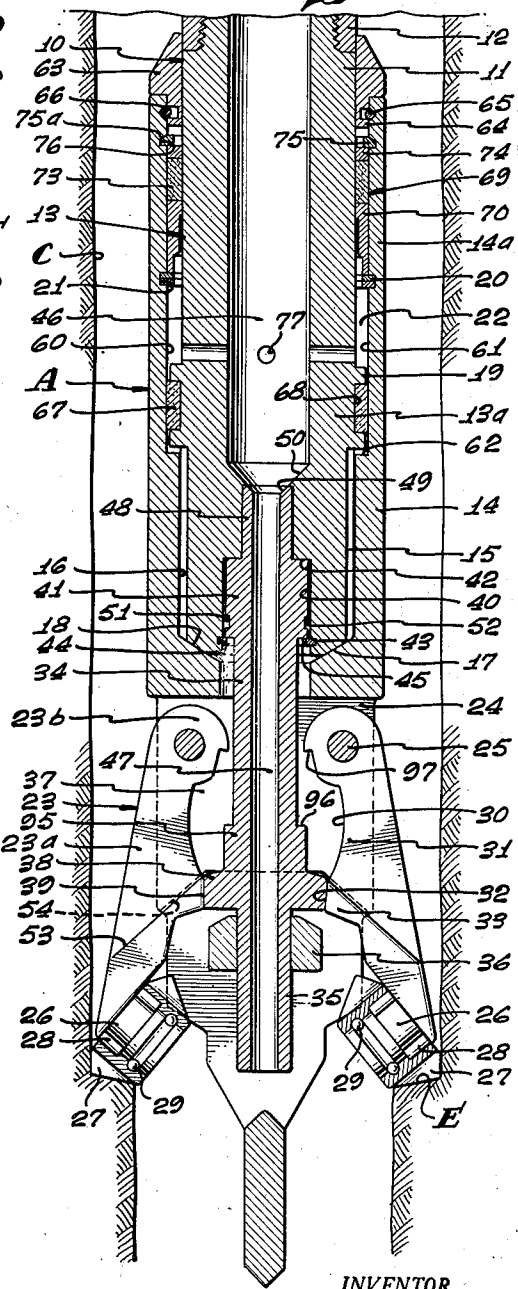


Fig. 2.



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Filed Aug. 25, 1954 2 Sheets-Sheet 2

Fig. 3.

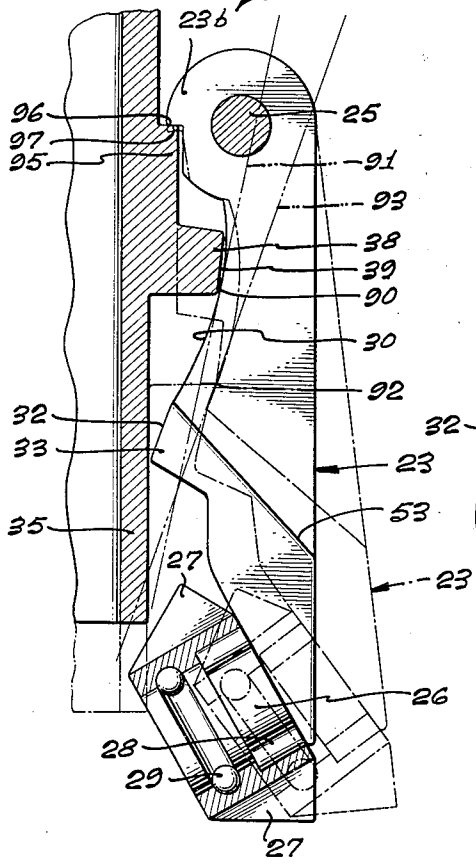


Fig. 4.

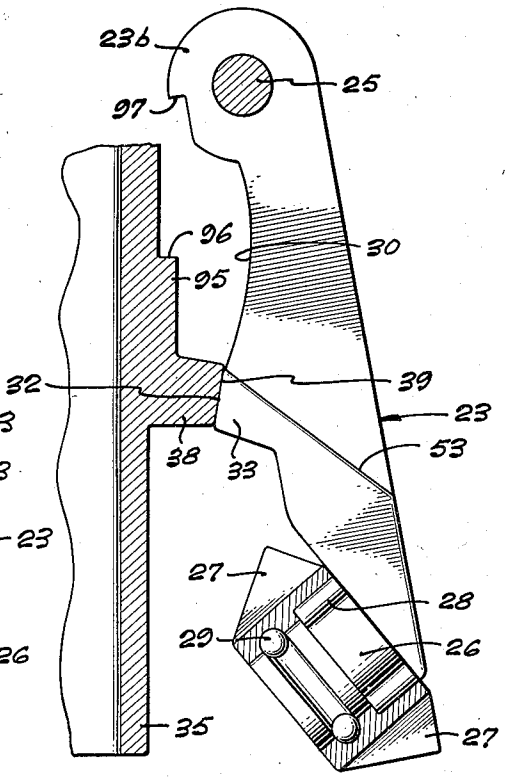
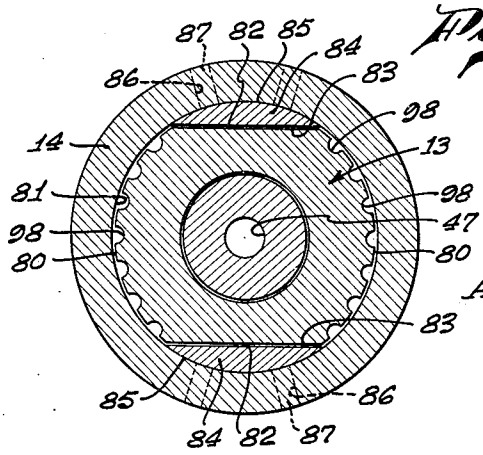


Fig. 5.



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ROTARY EXPANSIBLE DRILL BITS

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Application August 25, 1954, Serial No. 452,183

11 Claims. (Cl. 255—76)

The present invention relates to rotary drill bits, and more particularly to drill bits of the expansible type capable of drilling or enlarging bore holes below a string of well casing to a greater diameter than the inside diameter of the casing string through which the bits are moved.

Some forms of rotary drill bits of the expansible type embody a mandrel which is slidably splined to the main body of the tool and movable with respect to the body to a position holding the cutters in their outwardly expanded position. Proper operation of the bit and long life of the mandrel and body is dependent to a great extent upon the provision of a proper splined connection between them. Heretofore, such connection has been comparatively costly to manufacture and had to be made to relatively close tolerances, to insure the appropriate coaxial position of the mandrel in the body of the expansible bit. The coaxial relation should be maintained after the cutters have been expanded fully and drilling weight is being imposed on them, for the purpose of insuring smooth operation of the bit and to minimize wear on the parts.

Accordingly, an object of the present invention is to provide an improved spline connection between the mandrel and the body of an expansible rotary drill bit, which is comparatively simple and economical to manufacture, possesses the desired tolerances or clearances between the companion parts, and insures the maintenance of a coaxial relation between the mandrel and the body.

Another object of the invention is to provide an expansible rotary drill bit embodying a mandrel slidably splined to the bit body, in which the mandrel is automatically centered and retained in a coaxial position with respect to the body during the hole enlarging operation, thereby insuring smooth functioning of the apparatus and increasing its useful life.

A further object of the invention is to insure the coaxial relation, at their slidable spline interconnection, between the mandrel and body of a rotary expansible drill bit having cutters expanded outwardly by hydraulic pressure, to minimize wear at the hydraulically actuated portion of the drill bit, and to increase the life of the sealing devices embodied in the hydraulically actuated portion.

Yet another object of the invention is to insure freedom of sliding movement between the mandrel of a rotary expansible drill bit and the main body of the bit to which it is slidably splined, by allowing comparatively free passage of fluids, sand, and the like, between the mandrel and body at their splined interconnection.

Still another object of the invention is to provide a rotary expansible drill bit having a mandrel telescopically related to the main body of the bit, in which the mandrel can forcibly retract the cutters from their outwardly expanded position, if such action becomes necessary or desirable. The mandrel can also be effective to hold the cutters retracted during elevation of the drill bit in the well bore.

Certain rotary expansible drill bits have cutter supporting members pivotally carried by the bit body, the supporting members and the cutters mounted thereon being shifted outwardly by an expander engaging the supporting members. The expander may slide relatively along tapered expander surfaces on the supporting members in effecting outward shifting of the latter and the cutters.

Ordinarily, when the cutter supporting members are in retracted position, the expander engages them close to their fulcrums or pivotal supports on the body. Accordingly, the lever arm of the outward force applied against each cutter supporting member is comparatively small, the force urging the cutters against the wall of the formation also being relatively small. As the cutters shift outwardly, the expander moves relatively along the supporting members away from the fulcrums, the lever arm increasing and the outward force against the cutters also increasing. When the cutters are fully expanded, the lever arm and the outwardly directed force are at a maximum.

It is not necessary for the outward cutter expansion force to increase as the cutters move outwardly. In fact, it is desirable for such force not to increase. It is important to have adequate expansion force when the cutters are in their retracted position and dig initially into the wall of the hole, particularly when operating in hard formations. To provide such initial force, the point of initial engagement between the expander and each cutter supporting member has heretofore been disposed an adequate distance from the supporting member fulcrum. Such disposition required an increase in the length of the cutter supporting members to secure their proper outward expansion, increasing the over-all length of the drill bit and its cost. The outward force still increased as outward expansion of the cutters occurred, due to increase in the lever arm of the force applied to each cutter supporting member and an increase in the wedge angle between the expander and supporting member as the latter pivots outwardly on its fulcrum.

It is another object of the invention to relate the expander and cutter supporting members to each other in such manner that ample initial outward expansion force can be applied against the cutter supporting members and at a point relatively close to their fulcrums, thereby enabling the length of the supporting members and the length of the body to be held to a minimum.

A further object of the invention is to shape the coengaging portions of the expander and cutter supporting members in such manner that the outward expansion force applied against each cutter supporting member decreases as the point of contact between the expander and cutter supporting members move further away from the fulcrum of the cutter supporting members, thereby compensating for the increased lever arm of the force applied to the cutter supporting members and preventing the application of an undesirably large force of the cutters against the wall of the hole. If desired, the outward force of the cutters against the wall of the hole can be kept substantially constant as expansion of the cutters proceeds to the maximum extent. Again, instead of the force against each cutter supporting member decreasing as the point of contact between the expander and the cutter supporting member moves away from the fulcrum of the cutter supporting member, the forces applied may be held constant or be prevented from increasing to any substantial extent.

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 retracted positions;

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

Fig. 3 is an enlarged fragmentary section disclosing the cutter and expander portions of the device, with the cutter in retracted position;

Fig. 4 is a view similar to Fig. 3, with the cutter locked in its fully expanded position;

Fig. 5 is a cross-section, on an enlarged scale, taken along the line 5—5 on Fig. 1.

As shown in the drawings, a rotary expansible drill bit A is 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 therebelow where the hole enlarging operation is to commence. The general type of expansible drill bit disclosed in the drawings is shown and described in Patent No. 2,545,036, to which attention is invited for certain structural details.

The upper portion of the rotary drill bit consists of a mandrel 10 having an upper pin 11 threadedly connected to a sub 12 forming the lower end of the string of drill pipe B. This mandrel includes an upper kelly or drill stem 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 in shape, being telescopically received in a companion non-circular socket 16 provided in the main bit body, the kelly 13 being capable of moving longitudinally with respect to the body 14 and also being capable of transmitting rotary movement thereto.

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 body shoulder 18, and its upward movement being limited by engagement of an external shoulder or piston portion 19 of the kelly with one or more stop rings 20 that may be split to enable them to be inserted within an internal groove 21 in the main body of the bit, the stop rings extending into a cylinder space 22 formed between the kelly or drill stem 13 and the body 14 of the tool. It is to be noted that the coengageable surface of the lower end 17 of the kelly and the inwardly directed body shoulder 18 are frustoconical in shape, tapering in a downward and inward direction, in order that the engagement of the lower end of the kelly with the shoulder will tend to center, and insure the retention of the kelly 13 in a central and coaxial position, within the body 14 of the tool.

The 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 to prevent their loss therefrom. Each cutter supporting member 23 has a leg portion 23*a* depending from the hinge pin 25 and 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 upon antifriction roller and ball bearing elements 28, 29 rollable on the bearing supporting pins. The ball bearing elements 29 serve to lock the cutter 27 against endwise movement on the bearing supporting pin 26, as well as to transmit axial and radial thrusts, the roller bearing elements 28 transmitting primarily radial thrusts. The manner of mounting the ball and roller bearing elements 29, 28 between the cutter 27 and bearing supporting member 26 is specifically described in the above-mentioned Patent No. 2,545,036, to which attention is invited.

Each cutter supporting member 23 and cutter 27 tend to occupy a retracted position substantially entirely within the confines of the main body 14 of the bit. These cutter supporting members and their cutters are expanded outwardly to enlarge the sides of the well bore C and to operate upon a formation shoulder E that the cutters form 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 merges smoothly into and 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 the relative longitudinal movement between the cutter supporting members 23 and a 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 body slots 24. This guide is disposed below the lock portions 33 of the cutter supporting members 23.

Located initially substantially above the guide 36 and below the hinge pin 25 and in cutter 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 32. The lock and expander 38 may be formed integral with the tubular member 34, the upper end of the latter being piloted within a socket 40 formed 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 against 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.

To facilitate passage of drilling or other fluid down through the central passage 46 of the kelly or drill stem 13 and into the central passage 47 extending completely through the tubular member 34, the latter has a portion 48 extending upwardly from its boss 41 and provided with an upwardly flaring end 49 merging smoothly into the lower tapered surface 50 of the kelly passage 46. Leakage of fluid around the exterior of the tubular member 34 is prevented by a suitable side seal ring 51, such as a rubber O ring, located in a peripheral groove 52 in the boss 41, which engages the wall of the kelly socket 40.

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 portions 38 of the tubular member. During such upward shifting, the cutter supporting members 23 and the cutters 27 carried thereby will be pivoted about the hinge pins 25 and urged in an outward direction. The upward movement of the body 14 with respect to the tubular mandrel 10 can continue until the cutters 27 have 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 portions of the cutter supporting members 23 and the companion surfaces 39 on the lock and expander portions 38 of the tubular member are substantially parallel to the axis of the drill bit, when the cutters are fully expanded, 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, 39 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 to a retracted position.

In the specific form of the invention disclosed in the drawings, the relative longitudinal movement between the tubular mandrel 10 and body 14 of the tool is accomplished hydraulically. Thus, the piston or enlarged portion 19 on the drill stem 13 is received within a counterbore 60 formed on the upper portion 14*a* of the body 14 of the tool. This upper portion 14*a* actually constitutes a cylinder having a cylindrical wall 61 extending from a lower shoulder 62, defining the bottom of the counterbore, to an upper head and guide 63, which has a depending portion 64 inserted in the upper end of the cylinder and releasably retained therein by a split snap ring 65 carried in a groove in the cylinder portion 64 and adapted to be received within a generally V-shaped internal groove 66 in the upper portion of the cylinder wall 61. The head 63, with the snap ring 65 therein, 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*. A suitable packing or side seal structure 67 may be disposed in a suitable piston ring groove 68 formed on the piston 19, which is adapted to slidably seal against the cylindrical wall 61 of 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 cylinder 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 disclosed, it consists of a lower packing supporting ring 70 resting upon the split retainer ring 20 received within the internal groove 21 in the cylinder 14*a*. A non-metallic packing 73, which may be made of any suitable material, rests upon the ring 70, with its upper end engaging an upper backing ring 74 bearing against a split retainer ring 75 received within an internal groove 76 in the cylinder 14*a*. The outer upper portion 75*a* of the retainer ring 75 and the adjacent upper wall of the internal groove 76 are preferably inclined in an upward and inward direction, in order that the split retainer ring 75 will be forced inwardly out of the groove 76 when it is subjected to a sufficient upwardly directed longitudinal force. It is evident that the upper and lower split retainer rings 75, 20 prevent longitudinal movement of the packing structure 59 with respect to the bit body cylinder 14*a*, the non-metallic packing portion 73 of the sealing structure 69 engaging the cylinder wall 61 to prevent leakage therealong, and also slidably engaging the periphery of the drill stem portion 13 of the tubular mandrel 10.

Fluid under pressure in the string of drill pipe B and in the tubular mandrel 10 can be fed into the cylinder space 22 through one or more side ports 77 establishing communication between the central passage 46 through the kelly 13 and the cylinder space. Such fluid under pressure is developed in the form of invention disclosed in the drawings by virtue of the fact that the passage 47 through the tubular member 34 of the mandrel is of a restricted diameter as compared to the passage 46 through the kelly portion 13 of the mandrel. As a result, the pumping of drilling mud, or other fluid, at an adequate rate through the passage will build up a back pressure of fluid in the passage 46, which pressure will be imposed on the fluid in the cylinder space 22 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, to secure the outward expansion of the cutter supporting members 23 and cutters 27 to their fullest extent.

For the purpose of securing the proper cooperation between the tubular mandrel 10 and the body 14 of the tool, the slidable spline connection 15, 16 therebetween must be made accurately. By virtue of the specific structure disclosed in the drawings, a slidable spline connection is provided which insures the coaxial relation between the tubular mandrel and the body of the tool, while insuring the transmission of large torques between them during the performance of the hole enlarging operation. As described above, the lower portion 15 of the kelly 13 is non-circular in cross-section, and this is also true of the companion socket 16 formed in the body 14 of the tool above its lower tapered shoulder 18. Actually, the non-circular configurations described above lie partially on sections of circles, to enable the desired coaxial relationship to be obtained between the parts (Fig. 5). Thus, the exterior 15 of the lower part of the kelly is first formed with a cylindrical shape 80, the cylinder having the required external diameter. Similarly, the socket 16 in the body, which lies between the counterbore shoulder 62 and the lower stop shoulder 18 on the body, is also bored out to provide a cylindrical wall 81 having the requisite diameter, which is only greater than the external diameter of the kelly surface 80 sufficient to provide the necessary working clearance between these parts. Opposite portions of the lower kelly region are then flattened, as by milling away the material, to provide the opposed flat sides 82. Companion flat surfaces 83 are provided in the body socket. Specifically, such flat surfaces are formed on opposed wear members or shoes 84 of segmental shape having arcuate outer surfaces 85 of a curvature conforming to the inner wall 81 of the socket 16. These wear members 84 are integrated to the body 14 of the tool by providing lateral holes 86 through the wall of the body through which welding material 87 can be deposited, to firmly secure the wear members to the body of the tool. The wear members 84, of course, extend from the lower end of the counterbore 60 substantially to the lower shoulder 18 of the body 14.

By virtue of the splined connection described, the mandrel 10 can shift longitudinally with respect to the body 14, and will be held in a coaxial position relative thereto by virtue of the coengagement between the opposed arcuate surfaces 80 on the exterior of the mandrel with the circular wall 81 of the body. When the mandrel is rotated, the turning effort is transmitted to the body of the tool through the coengaging flat surfaces 82, 83 on the mandrel and the wear members or shoes 84.

Accordingly, as the mandrel 10 moves downwardly relative to the body 14 in accomplishing the outward expansion of the cutter supporting members 23 and of the cutters 27, proper coengagement between the expander 38 on the tubular member 34 with the expander surfaces 30 on the cutter supporting members is assured, since the mandrel is held in the coaxial position with respect to the body. Moreover, following full expansion of the cutters, the tapered lower end 17 of the kelly 13 engages the companion tapered shoulder 18 on the body, which will tend to center and retain the mandrel 10 centered with respect to the body of the tool.

A comparatively simple splined arrangement has been provided that insures against the tilting of the mandrel 10 within the body 14, or any material play therebetween. Substantially all of the lateral forces between the mandrel and the body are transmitted through the splined connection, the sealing portions 67, 69 on the piston 19 and the cylinder 14*a* being relieved of such lateral forces or play, which insures the proper sliding of the seals against their companion surfaces, holding the wear on the sealing parts of the hydraulic portion of the apparatus to a minimum.

As the body 14 of the tool is shifted relatively in an

upward direction, to expand the cutter supporting members 23 and the cutters 27 outwardly, the expander 38 engages the expander surfaces 30 at steadily greater distances from the fulcrum pins 25, thereby increasing the lever arm at which the outwardly directed expansion forces are applied. Inasmuch as the supporting members 23 swing outwardly, the tapered expander surfaces 30 will be inclined at a progressively greater angle to the horizontal or at a lesser angle to the vertical. If the tapered surfaces 30 were straight, then the laterally outward directed component of the longitudinal force of the expander 38 upon these surfaces would increase as the points of contact of the expander against each expander surface moved further away from the hinge pin fulcrum 25. Accordingly, the outward force of such cutter 27 against the wall of the formation, in producing the formation shoulder E, would be increased substantially over the initial outward force when the cutters occupy substantially their fully retracted position. The increase in force would be due to an increase of the tangent angle to the horizontal (or a plane normal to the axis of the tool) at the point of contact of the expander 38 with the expander surface 30, as such point of contact moves further away from the fulcrum pin 25, and it is also due to the increase of the lever arm of the force at the point of engagement as the latter moves further away from the hinge pin. Accordingly, the initial expansion force applied would be at a minimum when the cutters 27 are in substantially their fully retracted positions, and steadily increases to a maximum as the cutters are expanded outwardly. In the present instance, it is proposed to increase the amount of force that the cutters exert against the wall of the formation when the cutters are in substantially their fully retracted position, and not to increase such force substantially, or, for that matter, to actually hold such force constant and even decrease it as the cutters move laterally outward of their maximum expanded position.

The expander surface 30 on the inner portion of each cutter supporting member 23 may be formed as a concave curve. This curve is shaped in such manner that, when a cutter supporting member 23 is in its fully retracted position, the expander 38 will engage the expander surface 30 on the cutter supporting member at a point 90 at which a tangent 91 (Fig. 3) drawn to this point of contact will be relatively steeply pitched, or make a compartively large angle with the horizontal (assuming the tool to be disposed with its axis in a vertical position). The lateral outward or horizontal force on the cutter supporting member 23 under these conditions is dependent upon the tangent of the angle that the tangent line 91 makes to the horizontal. Thus, the value of the natural tangent of this angle will provide a mechanical advantage that the outwardly directed force will have with respect to the longitudinal force exerted between the expander 38 and the expander surface 30, and, in view of the provision of a relatively large tangent angle, the mechanical advantage will be relatively great. Accordingly, with a steeply pitched tangent 91 to the point of contact 90, when each cutter supporting member 23 is in its substantially fully retracted position, a large outwardly directed force can be imposed on the cutter supporting member, despite the fact that the point of contact 90 is then comparatively close to the fulcrum or hinge pin 25.

As the expander 38 moves relatively in a downward direction along the expander surface 30, the point of contact 92 against the latter moves away from the hinge pin 25, increasing the lever arm and the force that the cutter 27 could apply against the wall of the formation. However, in the present instance, such increase in lever arm is compensated by the fact that the expander surface is curved in such a manner that as the point of contact moves away from the hinge pin, a line 93 drawn to such point of contact makes a lesser angle to the horizontal, and such angle will progressively decrease as the point of contact moves further away from the hinge pin 25. Inasmuch as the natural tangent of such angle will decrease, so will the mechanical advantage of the force applied by the expander 38 against the cutter supporting member 23. Accordingly, despite an increase in the lever arm as the point of contact moves further away from the fulcrum 25, the mechanical advantage is decreased, resulting in the maintenance of the force of each cutter 27 against the wall of the formation substantially constant, or, at least, such force will not increase to as great an extent as before. As a matter of fact, depending upon the shape of the expander curve 30, the force can actually be decreased.

The decrease in the angle of the tangent that the point of contact makes with the horizontal, or plane normal to the axis of the tool, occurs despite the fact that the cutter supporting member 23 is swinging in an outward direction and tends to cause the tangent to the point of contact to assume a more steeply pitched angle. This is clear from Fig. 3, in which the line 91 tangent to the point of contact 90, when the cutter supporting member is in its retracted position, will make a greater angle to a plane normal to the axis of the tool than the line 93 drawn to the point of contact 92, designated in broken lines in the drawings, following partial expansion of the cutter supporting member and the cutter in an outward direction.

As aforestated, the lower portion of the curved expander surface 30 preferably merges smoothly into the holding or lock surface 32 provided on the lock portion 33 of each cutter supporting member 23, insuring a smooth transfer of the expander and retainer member 38 from the expander surface 30 of each cutter supporting member into full engagement with the lock surface 32 of each cutter supporting member.

When the rotary expansible drill bit A is run in the well casing D, with the cutter supporting members 23 and the cutter 27 in their initial retracted positions, the wall of the well casing D will prevent the outward expansion of the cutters 27, the supporting members 23 merely sliding along the casing wall during descent of the apparatus. When the apparatus has been lowered below the casing shoe F, the pumps at the top of the well bore are started, to pump fluid at a sufficient rate through the drill pipe B and the tubular mandrel passages 46, 47. Pumping of the fluid builds up a back pressure in the kelly passage 46 and in the fluid in the ports 77 and cylinder space 22, which pressure will act upon the cylinder packing structure 69, to urge the body 14, the cutter supporting members 23 and cutters 27 in an upward direction with respect to the mandrel 10.

During such upward movement, the upper ends of the expander surfaces 30 on the cutter supporting members 23 are brought to bear against the lock and expander portion 38 of the mandrel, the cutters 27 being urged in an outward direction against the wall of the well bore C. As stated above, a line 91 drawn to the point of contact 90 and tangent thereto will make a relatively steeply pitched angle with respect to a plane normal to the axis of the tool, insuring a maximum mechanical advantage of the force being applied between the lock and expander portion 38 of the mandrel and each cutter supporting member. The drill pipe B and the rotary drill A are rotated at the proper speed, while fluid is being pumped through the apparatus, the cutters 27 enlarging the well bore without the drill pipe being moved vertically. As the cutters enlarge the well bore, the hydraulic force acting upon the body 14 raises the latter, the cutter supporting members 23, and the cutters 27 to a further extent, to further expand the cutters outwardly. During such elevational movement, the point of contact 92 between the expander portion 38 of the mandrel and the expander surfaces 30 moves further away from the fulcrum pins 25, to increase the lever arm of the force being imposed by the expander portion 38 on the cutter

supporting members. However, due to the shape of each expander surface 30, a line 93 drawn to the point of contact between the expander portion 38 and this surface, and tangent to such point of contact, will make a lesser angle to a plane normal to the axis of the tool, thereby decreasing the mechanical advantage of the force being applied between the expander portion 38 of the mandrel and the cutter supporting member 23. The net result is the imposition of the proper force of each cutter 27 against the wall of the well bore.

As the cutters continue to enlarge the well bore, the body 14 is raised relatively along the mandrel 10 to a greater extent, to elevate the cutter supporting members 23 along the lock and expander portion 38 of the mandrel. The lever arm of the force transmitted from the expander portion 38 to the cutter supporting members 23 continues to increase. However, the mechanical advantage of the force transmitted between the two members continues to decrease, in view of the fact that the tangent to the point of contact between the parts continues to make a steadily lesser angle with the plane normal to the axis of the tool. Eventually, the cutter supporting members and cutters will be shifted outwardly to their maximum extent as determined by engagement of the supporting member stop shoulders 53 with the companion body stop shoulders 54, and the engagement of the body shoulder 18 with the lower end 17 of the kelly portion 13 of the tubular mandrel 10. As explained above, with the parts in this position, the lock portion 33 of the cutter supporting members 23 will bear against the lock and expander portion 38 of the tubular member 34, to preclude inadvertent partial retraction of the cutters 27 to their fully expanded position.

Downweight of the proper amount can now be imposed on the string of drill pipe B, this downweight being transmitted through the kelly 13 to the body shoulder 18 and from the body through the stop shoulder 54 directly to the cutter supporting members 23 and the cutters 27, urging the teeth of the latter into the transverse formation shoulder E previously produced, in order to drill away the formation shoulder and enlarge the well bore to the required diameter and along a desired length of hole. During the imposition of such downweight on the apparatus, the tapered surface engagement between the lower end 17 of the kelly 13 and the body shoulder 18 will insure the coaxial position of the mandrel 10 with respect to the body 14 of the tool.

In the event it is desired to retrieve the apparatus A from the well bore after the hole enlarging operation has been completed, or as a result of the cutters 27 becoming worn, it is only necessary to discontinue the pumping of the drilling fluid through the drill pipe B in the apparatus, to relieve the pressure in the cylinder 13*a*, and to elevate the drill pipe. Such elevating movement will elevate the tubular mandrel 10 with respect to the body 14 and the cutter supporting member 23, to raise the lock and expander portion 38 above the expander surfaces 30, whereupon the cutters 27 can drop back to their retracted position. In the event the cutters are reluctant to move to their retracted position, the outer surfaces of the cutter supporting members 23 will engage the casing shoe F, which will then force them inwardly, whereupon the apparatus can be withdrawn through the well casing D to the top of the hole.

For the purpose of forcibly retracting the cutter supporting members 23 and cutters 27 without the necessity for their engaging the casing shoe F, and to hold the cutter supporting members and cutters in such retracted position, the tubular member 34 of the mandrel is provided with an enlarged portion 95 above its expander 38 having an upwardly facing shoulder 96 adapted to engage downwardly facing surfaces 97 on relatively short arms 23*b* on the cutter supporting members 23 extending laterally inward from the fulcrum pins 25. Following the relieving of the hydraulic pressure within the apparatus, and the elevation of the mandrel 10 with respect to the body 14, the expander and retainer 38 is moved upwardly along the cutter supporting members 23, to allow the latter to drop back to their retracted position under the action of gravity. In the event the cutter supporting members do not retract by themselves to the fullest extent, then the upwardly facing shoulder 96 on the tubular member will engage the arms 23*b* on the cutter supporting members, to swing them in an upward direction and thereby swing the depending leg portions 23*a* and the cutters 27 inwardly of the apparatus. During the elevation of the apparatus in the well bore, the shoulder 96 on the mandrel will be engaging the cutter supporting member arms 23*b* steadily, exerting a continuing upward force therein tending to hold the leg portions 23*a* of the cutter supporting members 23 and the cutters 27 in their full inward positions.

In the event the cylinder space 22 becomes packed with sand, which will not allow the mandrel 10 to move upwardly within the body 14 freely, the apparatus will be elevated until the cutter supporting members 23 engage the casing shoe F, whereupon the taking of a sufficient upward strain on the mandrel will cause the sand to engage the packing structure 69 and force the split snap ring 75 inwardly out of its groove 76, carrying it upwardly into engagement with the cylinder head 63, whose retainer ring 65 will also be urged out of its groove 66, allowing the mandrel 10 to shift upwardly within the body 14 and enabling the cutter supporting members 23 to retract to their fullest position. Such retraction will be assisted, if need be, by the engagement of the tubular mandrel shoulder 96 with the cutter supporting member arms 23*b*. In this connection, if the snap rings 20 were not present in the cylinder for engagement by the piston 19, the release of the packing structure 69 and of the cylinder head 63 in the manner described would allow the mandrel 10 to continue moving upwardly within the body 14 of the tool. However, such upward movement is definitely limited by engagement of the mandrel shoulder 96 with the cutter supporting arms 23*b* and by the fact that the cutter supporting members can move inwardly only to the extent determined by their engagement with the tubular member portion 34 of the mandrel or the lower guide 36. Accordingly, the apparatus will then be removed as a unit and withdrawn to the top of the hole.

Any drilling fluid and other material that might be disposed in the counterbore 60 below the piston 19 of the mandrel may have a tendency to remain packed therein. Foreign substances, such as sand in the drilling mud, may also tend to pack and bind in this region of the apparatus. Accordingly, the outer circular portions 80 of the kelly below the piston 19 are preferably provided with circumferentially spaced flutes or grooves 98 extending from the piston down to the lower end 17 of the kelly. Such flutes or grooves 98 facilitate the passage of fluid, and other substances, between the kelly 13 and the body 14 of the tool below the counterbore 60, and preclude binding of such foreign materials therebetween. Despite the presence of the flutes or grooves 98, the periphery 80 of the kelly will still make a comparatively close fit with the circular wall portions 81 of the body 14 of the tool, to maintain the mandrel 10 concentrically disposed with respect to the body of the tool.

The inventor claims:

1. In a rotary well drilling bit: a main body; cutter means pivotally mounted on said body for expansion laterally outward of said body; means for expanding and holding said cutter means laterally outward, said expanding and holding means comprising a mandrel connectible to a drill string and telescoped within said body for longitudinal movement with respect thereto and engageable with said cutter means on one side of its pivot axis to hold said cutter means laterally outward; and coengage-

able means on said mandrel and cutter means to exert a force on said cutter means in a direction on the opposite side of its pivot axis for retracting said cutter means from its expanded position upon upward movement of said mandrel within said body.

2. In a rotary well drilling bit: a main body; a cutter supporting member pivotally mounted on said body for expansion laterally outward of said body; a cutter on said supporting member; means for expanding and holding said supporting member and cutter laterally outward, said expanding and holding means comprising a mandrel connectible to a drill string and telescoped within said body for longitudinal movement with respect thereto; said mandrel engaging said supporting member on one side of its pivot axis to hold said cutter laterally outward; and means on said mandrel engageable with means on said supporting member to exert a force on said supporting member in a direction on the opposite side of its pivot axis for shifting said supporting member and cutter to retracted position upon upward movement of said mandrel within said body.

3. In a rotary well drilling bit: a main body; a cutter supporting member pivotally mounted on said body for expansion laterally outward of said body; a cutter on said supporting member; means for expanding and holding said supporting member and cutter laterally outward, said expanding and holding means comprising a mandrel connectible to a drill string and slidably splined within said body, said mandrel being movable downwardly within said body to a position engageable with said supporting member on one side of its pivot axis to hold said supporting member and cutter in their outwardly expanded position; and means on said mandrel engageable with means on said supporting member to exert a force on said supporting member in a direction on the opposite side of its pivot axis to shift said supporting member and cutter to retracted position upon upward movement of said mandrel within said body.

4. In a rotary well drilling bit: a main body; a cutter supporting member pivotally mounted on said body for expansion laterally outward of said body; a cutter on said supporting member; an operating member movable longitudinally relative to said body and engageable with said cutter supporting member to expand said cutter supporting member and cutter laterally outward; one of said members engaging an expander surface on the other of said members to effect such expansion; said expander surface being of such shape that a tangent to the point of contact between said surface and said one of said members makes a decreasing angle to a plane normal to the axis of the body as said cutter supporting member and cutter are shifted laterally outward.

5. In a rotary well drilling bit: a main body; a cutter supporting member pivotally mounted on said body for expansion laterally outward of said body; a cutter on said supporting member; an operating member movable longitudinally relative to said body and engageable with said cutter supporting member to expand said cutter supporting member and cutter laterally outward; one of said members engaging an expander surface on the other of said members to effect such expansion; said expander surface being of such shape that a tangent to the point of contact between said surface and said one of said members, as said cutter supporting member and cutter move laterally outward, makes an angle to a plane normal to the axis of the body no greater than the angle that the tangent to the point of contact between said surface and said one of said members makes when said cutter supporting member and cutter are in substantially their fully retracted position with respect to said body.

6. In a rotary well drilling bit: a main body; a cutter supporting member pivotally mounted on said body for expansion laterally outward of said body; a cutter on said supporting member; an operating member movable longitudinally relative to said body and engageable with said cutter supporting member to expand said cutter supporting member and cutter laterally outward; said cutter supporting member having an expander surface thereon engaged by said operating member to effect such expansion; said expander surface being of such shape that a tangent to the point of contact between said surface and said operating member makes a decreasing angle to a plane normal to the axis of the body as said cutter supporting member and cutter are shifted laterally outward.

7. In a rotary well drilling bit: a main body; a cutter supporting member pivotally mounted on said body for expansion laterally outward of said body; a cutter on said supporting member; an operating member movable longitudinally relative to said body and engageable with said cutter supporting member to expand said cutter supporting member and cutter laterally outward; said cutter supporting member having an expander surface thereon engaged by said operating member to effect such expansion; said expander surface being of such shape that a tangent to the point of contact between said surface and said operating member, as said cutter supporting member and cutter move laterally outward, makes an angle to a plane normal to the axis of the body no greater than the angle that the tangent to the point of contact between said surface and said operating member makes when said cutter supporting member and cutter are in substantially their fully retracted position with respect to said body.

8. In a rotary well drilling bit: a main body; a cutter supporting member pivotally mounted on said body for expansion laterally outward of said body; a cutter on said supporting member; an operating member movable longitudinally relative to said body and engageable with said cutter supporting member at a progressively greater distance from the pivot of said cutter supporting member to expand said cutter supporting member and cutter laterally outward; one of said members engaging an expander surface on the other of said members to effect such expansion; said expander surface being of such shape that a tangent to the point of contact between said surface and said one of said members makes a decreasing angle to a plane normal to the axis of the body as said point of contact moves further away from the pivot of said cutter supporting member.

9. In a rotary well drilling bit: a main body; a cutter supporting member pivotally mounted on said body for expansion laterally outward of said body; a cutter on said supporting member; an operating member movable longitudinally relative to said body and engageable with said cutter supporting member at a progressively greater distance from the pivot of said cutter supporting member to expand said cutter supporting member and cutter laterally outward; one of said members engaging an expander surface on the other of said members to effect such expansion; said expander surface being of such shape that a tangent to the point of contact between said surface and said one of said members, as said contact point moves away from the pivot of said cutter supporting member, makes an angle to a plane normal to the axis of the body no greater than the angle that the tangent to the point of contact between said surface and said one of said members makes when said cutter supporting member and cutter are in substantially their fully retracted position with respect to said body.

10. In a rotary well drilling bit: a main body; a cutter supporting member pivotally mounted on said body for expansion laterally outward of said body, said cutter supporting member depending from its pivot; a cutter on the lower portion of said cutter supporting member; an operating member movable downward relative to said body and engageable with said cutter supporting member at a progressively greater distance from the pivot of said cutter supporting member to expand said cutter supporting member and cutter laterally outward; said

cutter supporting member having an expander surface thereon engaged by said operating member to effect such expansion, said surface being inclined inwardly and downwardly when said cutter supporting member and cutter are in their retracted position with respect to said body; said expander surface being so shaped that a tangent to the point of contact between said operating member and surface makes a decreasing angle to a plane normal to the axis of the body as said operating member moves downward relative to said body and said point of contact moves downward further away from the pivot of said cutter supporting member.

11. In a rotary well drilling bit: a main body; a cutter supporting member pivotally mounted on said body for expansion laterally outward of said body, said cutter supporting member depending from its pivot; a cutter on the lower portion of said cutter supporting member; an operating member movable downward relative to said body and engageable with said cutter supporting member at a progressively greater distance from the pivot of said cutter supporting member to expand said cutter supporting member and cutter laterally outward; said cutter supporting member having an expander surface thereon engaged by said operating member to effect such expansion, said surface being inclined inwardly and downwardly when said cutter supporting member and cutter are in their retracted position with respect to said body; said expander surface being so shaped that a tangent to the point of contact between said operating member and surface, as said operating member moves downward relative to said body and said point of contact moves downward further from the pivot of said cutter supporting member, makes an angle with a plane normal to the axis of the body no greater than the angle that the tangent to the point of contact between said operating member and surface makes when said cutter supporting member and cutter are in substantially their fully retracted position with respect to said body.

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