This invention pertains to drill bits, and more particularly to rotary bits of the expandable type for drilling or reaming holes below well casings greater in diameter than the inside diameter of the casing through which the bit is capable of passing.

This invention is a continuation-in-part of my applications for "Rotary Drill Bits," Serial No. 597,744, filed June 6, 1945, now Patent No. 2,466,591, and "Expansible Rotary Drill Bits," Serial No. 696,506, filed July 29, 1946.

In certain types of expandible drill bits, or under-reamers, for drilling a hole of a greater diameter than the inside diameter of the casing through which the bit is moved, the cutter elements remain in their expanded positions during elevation of the string of drill pipe to which the tool is secured. Elevation of the drill string is required in adding another section of drill pipe to it to enable the bit to continue drilling ahead to greater depths. Generally, a Kelly or grief stem is gradually lowered through the rotary table at the top of the well bore to substantially elevate its fullest extent in drilling the hole, after which it is necessary to elevate the drill string and unscrew the Kelly for the purpose of attaching another section of drill pipe to the drill string, whereupon the drill string is again lowered in the well bore and the Kelly secured to the top of the added drill pipe section.

In the drilling or enlarging of a bore hole, ribs or small restrictions normally project from the wall of the formation. The extent of inward projection of such restrictive elements is not very great and is usually insufficient to require reaming of the hole, since the desired size of liner or casing to be placed in the enlarged hole can readily pass the minor restrictions without catching or hanging up. However, such small restrictions are still slightly less than the effective diameter of the expanded cutters on the bit, and during the lowering of the drill string to the lowest point to which the hole has been reamed or enlarged, following the addition of the aforementioned drill pipe section, the cutters might catch or hang up on such restrictions and prevent the tool from being lowered to its desired extent prior to attachment of the Kelly to the upper end of the added drill pipe section. As a result, it is necessary to again elevate the drill string, remove the added drill pipe section, reattach the Kelly and re-ream the hole, to remove the minor ribs or restrictions, all of which is a time consuming and costly operation, to be avoided if at all possible.

Accordingly, it is an object of the present invention to provide a drill bit whose expanded cutters can be moved past ribs or small restrictions in the well bore without catching or hanging up, allowing the drill string to be readily lowered, with the added drill pipe section thereon, to the lowermost reaming point in the well bore.

Still another object of the invention is to prevent the expandable cutter means from expanding to their fullest extent under certain operative conditions encountered in a well bore.

Another object of the invention is to provide an expandable rotary drill bit, whose cutters are normally expanded outwardly to their fullest extent, but whose degree of expansion can be limited in order to hold the cutters to an effective reaming diameter which is slightly less than the normal well bore diameter which such cutters produce during the drilling or reaming operation.

A further object of the invention is to provide an expandable well drilling bit, in which the effective drilling or reaming diameter of the cutters is controlled by the drilling weight imposed upon the drill string attached to the bit.

The invention has other objects which will become apparent from a consideration of the embodiment shown in the drawings accompanying and constituting part of the present specification.

This form will now be described in detail to illustrate the general principles of the invention, but it is to be understood that such detailed description is not to be taken in a limited sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

Fig. 1 is a side elevation of one form of drill bit embodying the invention.

Fig. 2 is a longitudinal section through the drill bit on an enlarged scale, with parts shown in retracted position for lowering through the well bore.

Fig. 3 is a view similar to Fig. 2, with the parts shown in their fully expanded position as the result of imposing downward drilling weight on the bit.

Fig. 4 is a view similar to Figs. 2 and 3, illustrating the parts in a partially expanded position, as a result of removing drilling weight from the bit.

Fig. 5 is a cross-section taken along the line 5—5 of Fig. 2.

Fig. 6 is a partial longitudinal section taken along the line 6—6 on Fig. 3.
Fig. 7 is a cross-section taken along line 7-7 on Fig. 2.

As shown in the drawings, the rotary drill bit A is attached to a string of drill pipes B, by means of which it is lowered through the Kelly and shoulder C in a well bore to a point below the casing shoe D at which enlargement of the bore hole is to commence. The drill bit preferably has a pilot bit 10 at its lower end for centering the bit in hole that already may have been drilled, or for drilling the central portion of new hole in the absence of pre-existing hole. The main portion of the bit is capable of enlarging the bore hole by producing and operating on a formation shoulder E, as hereinafter described.

The upper end of the bit consists of a driving mandrel 11 whose upper pin 12 is threadedly connected to a sub 13 forming the lower end of the drill pipe string B. This mandrel includes an upper Kelly or drill stem member 14, slidably splined to the main body 15 of the bit. As disclosed in the drawings, the exterior 14a of the Kelly is hexagonal in shape and is telescopically received in a companion hexagonal socket 15a within the body. The mandrel has a limited range of longitudinal movement within the body, its upward movement being determined by engagement of an external shoulder 16 on the Kelly with a retainer ring 17 at the upper end of the body, suitably secured thereto, as by use of welding material 18.

The body 15 has a plurality of expansible parts mounted on it, comprising opposed cutter supporting members 19, 19 disposed within a transverse slot 19b through the body and pivotally carried between bifurcated body arms 20, 20, defining the slot, on pivot or hinge pins 21, 21 suitably secured to the arms, as by use of welding material 22. Each cutter supporting member consists of a depending leg 23 having a bearing supporting pin 24 inclined inwardly and downwardly, and on which a side cutter 25 is rotatably mounted. Anti-friction roller and ball bearing elements 26, 27 are provided between each cutter 25 and bearing pin 24, the roller bearing 26 transmitting radial thrusts, and the ball bearings 27 both radial and axial thrusts.

Each cutter supporting member 19 also includes an upwardly extending arm 30 against which an elastic expander 31 bears. This expander, in the form of a compressed coil spring, is received within a retainer pocket 32 in the body 15 and exerts its force against the arm 30, tending to swing it inwardly and thus urge the cutter 25, on the other side of the fulcrum pin 21, in an outward direction. The extent of this outward movement is limited by engagement of stop shoulders 33, 33 on opposite sides of the cutter supporting members 19 with cooperative body stop shoulders 34, 34.

After the cutters 25 have been expanded outwardly by the expanded springs 31 to the maximum extent, they can be locked in this position by a tubular member 35 of the mandrel 11, which is piloted in the Kelly 14, and is provided with a locknut 36 removable from an upper position in transverse alignment with inner supporting member recesses 36, permitting retraction of the cutters, to a lower position opposite lugs 37 formed on and projecting inwardly from the supporting member legs 23, preventing retraction of the cutters.

The tubular member 35 is connected in swivel fashion to the Kelly 14 to permit relative rotary movement therebetween. However, the Kelly and tubular member are secured together for longitudinal movement in both directions. This is accomplished by providing a shoulder 39 on the tubular member received within the lower socket 40b of the Kelly and a companion shoulder 40c in the Kelly at the upper end of the socket. The tubular member 35 has an upper portion 35a extending from the shoulder 39 freely through the central bore 14d of the Kelly, with the upper terminus of the upper member 35a received within an end recess 41c in the Kelly or mandrel pin 12, where a nut 35b is threaded on the terminal portion and bears against the base 14f of the upper pin recess 14c.

The arrangement between the tubular member 35 and Kelly 14 is such that downward movement is transmitted from the Kelly to the tubular member through the abutting shoulders 41c, 35b while upward movement is transmitted to the tubular member through engagement of the recess shoulder 41f with the nut 35b. However, the nut 35b does not serve to clamp the tubular member 35 to the Kelly 14, but allows relative rotary movement.

The mandrel 11 is normally held in its upper position with respect to the main body 15 of the bit and the supporting members 19 by a helical retractor spring 38 encircling the tubular member 35, with its upper end engaging the mandrel shoulder 39 and its lower end engaging a spring seat 40 at the lower end of the hexagonal body socket 15a, the spring seat serving as an upper bearing guide for the tubular mandrel member 35 and the sides 47c of the lock portion 41 of the mandrel slidably engaging the walls 15c of the body slot 15b to further guide the mandrel and provide relative to the body, confining it to an extent determined by working clearance provided between the lock portion 47 of the mandrel and the walls 15c of the slot.

Circulating fluid may pass downwardly through the string of drill pipe-D and through the tubular mandrel 11 for ejection from its lower discharge nozzle 45c on the cutters 25, to cleanse them of cuttings and flush the latter from the drilling area to the top of the well bore. As explained hereinafter, this circulating fluid is also available to unlash the cutter supporting members 19 in the event it is desired to hold them positively in retracted position.

The positive lock may be provided by securing a hook 42 to the inner portion of each cutter supporting member 19 and inserting the ends 43 of these hooks in holes 44 in a strip 45 extending across the nozzle 45c. The cutting tool A, after being lowered in retracted position to the point at which the reaming operation is to begin, may be released for operation by starting the pumps at the surface of the well bore, which will force fluid down through the drill string B and mandrel 11, impinging upon the latch strip 45 and blowing or forcing it off the hook ends 43, permitting the springs 31 to shift the supporting arms 30 inwardly and the cutters 25 outwardly against the formation.

In the operation of the device, the tool A is mounted on the lower end of the drill string B, with its parts held in retracted position by the latch strip 45, as shown in Fig. 2. In this position of operation, the compressed retractor spring 38 holds the mandrel 11 and its Kelly 14 in an upward position with respect to the body 15, as determined by engagement of the Kelly shoulder 16 with the body retainer ring 17. When the mandrel is so positioned, its lock por-
tion 47 is elevated above the lugs 37 on the cutter supporting members 19, being received within the inner recesses 36 in the supporting members, which permit the latter to be held inwardly against the action of the expander springs 31. The tool is lowered through the well casing C, and upon reaching the position of the well bore below the casing shoe D at which the drilling operation is to begin, the pumps are started at the surface of the well bore and fluid impinged on the supporting members 9, causing the ends 43 of hooks 42 and releasing the cutter supporting members 19 for outward expansion under the influence of the spring 31.

The drill string B is then rotated to rotate the main bit body 15 through the splined Kelly and body connection 14a, 15a, the expander springs 31 forcing the arms 30 inwardly and the cutters 25 outwardly against the formation. Rotation is continued without moving the drill string longitudinally until the side cutters 25 enlarge the diameter of the hole to the maximum extent, as determined by the eventual abutting of the supporting member stop shoulders 33 with the companion stop body shoulders 34. Thereafter, the drill string is lowered, causing the formation shoulder E, produced in the well bore by the cutters 25 under the action of the expander springs 31 and rotation of the drill bit, to support the cutter members 25, 19 and body 15 and prevent their downward movement.

Since the body 15 cannot move downwardly, drilling weight imposed on the drilling string B shifts its connected mandrel 11 downwardly within the body 15 against the action of the retract spring 36, until the lower end 48 of the Kelly 14 engages the spring seat and guide 40. This downward movement also shifts the tubular member 35 downwardly, because of the abutting between the Kelly and tubular member shoulders 14c, 39, to position the mandrel or tubular member lock portion 47 opposite and in alignment with the lugs 37 on the inner portions of the cutting supporting members 19, providing a positive lock by preventing inward movement of the cutters. So long as down weight is imposed on the drill string B and the cutters 25 rotate on the formation shoulder E, the cutters are prevented from moving inwardly by engagement of their lugs 37 with the mandrel lock portion 47. It is also to be noted that further outward movement of the cutters beyond the predetermined maximum reaming diameter is prevented by contact between the supporting member shoulders 33 and the body shoulders 34, through which the drilling weight is transmitted to the roller cutters 25, thus relieving the hinge pins 21 of this load.

Drilling is continued by rotating the drill bit and imposing the proper drilling weight on the cutters, to cause removal of the formation material and reaming of the hole in a downward direction to the desired extent of length. When the drill bit is to be retracted and removed to the top of the well bore, all that need be done is elevate the drill string B, which moves the side cutters 25 above the formation shoulder E and permits the retract springs 38 to move the cutters outwardly on the body 15 and move it, together with the cutter supporting members 19 downwardly with respect to mandrel 11. This action repositions the mandrel lock portion 47 opposite the supporting member recesses 36 and above their lugs 37, because of the engagement between the pin recess shoulder 14f and tubular member nut 35d, permitting inward swinging of the cutters and their supporting members 19 when the tool passes back into the casing C upon elevation of the drill string. Cutters 25 and their supporting members 19 will ride the wall of the casing C during elevation of the string until the tool is removed from the top of the well bore.

Pads in the form of longitudinal drag reaming blades 46 can be formed at the lower outer surfaces of the cutter supporting members 19, or portions of the casing C, which will ride the inner walls of the casing and prevent the cutter teeth from hanging up in the casing coupling spaces while the tool is being lowered therein. These pads 46 can be provided in addition to the hooks 42 and latch strip 45, or in place of the latter. When the latching device is used, the tool can be lowered through the open hole below the casing shoe D to as far a distance as desired before the reaming operation commences. If the latch is not provided, downward movement of the drill string B is stopped when the bit passes out of the shoe D, and the drill pipe B and bit A rotated to allow the cutters 25 to produce the formation shoulder E under the influence of the compressed expanded springs 31. Drilling in a downward direction can then proceed as aforementioned, with the drill string B and mandrel 11 lowered against the action of the retractor spring 38 to position the lock portion 47 opposite the lugs 37 and prevent inward movement of the cutters until the drilling weight is removed from the drilling tool.

As indicated above, elevation of the drilling tool A to move its cutters 25 above the formation shoulder E relieves the cutters of the drilling weight normally imposed by the drill string B and allows the retractor spring 38 to shift the body 15 downwardly with respect to the mandrel 11 and move the lock portion 47 of the latter into the cutter recesses 36, allowing the cutters 25 to be moved inwardly against the action of the expander springs 31. However, the expander springs 31 normally tend to move the cutters outwardly to their fullest extent. It is desired to limit the extent of such outward expansion under certain conditions of operation of the tool, for certain reasons, including those mentioned above in connection with the addition of additional pipe to the string B as the drilling proceeds.

It is evident that the springs 31 tend to shift the cutter supporting members 19 outwardly to their fullest extent, as determined by abutting of the cooperable shoulders 33, 34. Consequently, upon elevation of the drill string B and attached drill bit A, for the purpose of removing the Kelly at the top of the well bore and adding another section of pipe, the springs 31 tend to maintain the cutters 25 in their fully outward expanded position. Upon relowering of the tool, after the added drill pipe section has been appropriately assembled on the drill string, and the grief stem (not shown) attached thereto, the cutters would tend to engage ribs or other projections or restrictions in the well bore, and would prevent the tool from being lowered into re-engagement with the formation shoulder E previously produced by the tool. It would be necessary to re-elevate the drill string, remove the added drill pipe section and reconnect the Kelly at the top of the well bore, in order to re-ream the well bore and remove the protections and restrictions, no matter how slightly they might extend into the hole.

If such restrictions or projections are relative-
by minor in extent; their removal is not essential, as a practical consideration. Accordingly, the present invention proposes to avoid the necessity for re-reaming, the tool being so arranged as to pass downwardly through the well bore and re-engage the cutters 25 with the formation shoulder E.  

In furtherance of the above objection, the tubular mandrel 35 is provided with cam projections 60 on its inner surface disposed on a companion inwardly directed projections 61 at the upper ends of the cutter supporting arms 30, in order that the projections can re-engage and limit the extent of outward expansion of the cutters 25 under the influence of the compressed springs 31. The mandrel projections 60 are so arranged as to occupy a position in substantial alignment with the arm projections 61 when the mandrel 11 and itsKelly 14 are in their uppermost position with respect to the body 15 of the tool, wherein the lock portion 47 of the mandrel is disposed above the lugs 37 on the cutter supporting members 19 and with the recesses 36 in the latter, which allows retraction of the cutter supporting members 19 from their fully extended positions.

However, upon downward movement of the tool mandrel 11 to position its lock portion 47 opposite the outer supporting member lugs 37, in order to hold the cutter members 25 outwardly to their fullest extent, the mandrel cam projections 60 are disposed below the corresponding projections 61 on the cutter supporting arms, as indicated in Fig. 3, to allow the springs 31 to shift the arms 30 inwardly to their fullest extent, and the cutters 25 outwardly in their full reaming diameter, as determined by abutting between the cutter supporting member and body shoulders 32, 33.

The purposes and functions of the cam projections 60, 61 will be understood from the description of the operation of the perspective parts. As indicated above, the tool A is run in the well bore with the parts in the position illustrated in Fig. 2, with the lock portion 47 disposed above the cutter supporting member lugs 37. In this position, the mandrel cam projections 60 are opposite the cutter arm projections 61. Following removal of the latch strip 45 in the manner above indicated, or if no latch strip is provided, passage of the tool from the casing shoe D, the springs 31 urge the supporting arms 30 inwardly and the cutters 25 outwardly, the drill bit being rotated to produce a formation shoulder whose maximum diameter, at that time, is limited by engagement of the arm projections 61 with the mandrel cam projections 60. The various cam projections 60, 61 are of such an extent as to allow the cutters to expand outwardly to almost their full extent. Following the formation of the shoulder E, downward weight may be imposed on the drilling string B, which will shift the lock portion 47 of the mandrel 11 between the lugs 37 on the cutter supporting members 19 and also move the mandrel cam projections 60 below the arm projections 61. Rotation may now proceed, with the spring 31 capable of moving the cutter arms 30 inwardly to a greater extent, because the arm projections 61 can no longer engage the mandrel cam projections 60, the cutters being moved outwardly to their maximum extent, as determined by abutting of the shoulders 33, 34. Drilling or reaming can continue with down weight imposed on the drilling string B and the mandrel 11 attached thereto, to hold the lock portion 47 of the mandrel in its locking position with respect to the cutter supporting members 19.

Upon elevation of the drill string B to remove the tool for re-reaming and another drill pipe section thereto, the drilling weight is removed from the cutters 25, and they are elevated above the formation shoulder E by several feet. Usually, the extent of elevation is approximately the same as the length of the Kelly 14 or drill surface disposed on the retractor spines 38 to shift the body 15 of the tool downwardly with respect to the mandrel 11 and moves the lock portion 47 of the tool above the lugs 37 on the cutter supporting members 19. At the same time, the cam projections 60 on the mandrel re-engage the arm projections 61 and shift the arms 30 outwardly against the action of the expandable springs 31, moving the cutters 25 inwardly to a slight extent. As an example, if the desired hole diameter is to be 7½", the engagement of the cutter arm projections 61 with the mandrel projections 60 moves the cutters 25 outwardly to a slight extent. The parts remain in this position, with the cam projections 60, 61 in substantial alignment with one another and also engaged with one another, as illustrated in Fig. 4, until the tool 25 is re-engaged to the formation shoulder E. Full outward expansion of the cutters can then occur, since engagement of the cutters with the shoulder E allows downwardly imposed weight on the drill string B and mandrel 11 to relocate the lock portion 47 of the mandrel in alignment with the cutter supporting lugs 37 and the cam projections 60 on the mandrel below the corresponding arm projections 61, permitting the springs 31 to shift the arms 30 inwardly and the cutters 25 outwardly to their full reaming diameter.

As has been noted above, the projections 60, 61 are in alignment with each other and the cutters 25 are moved slightly outwardly from engagement with the wall of the well bore upon elevation of the drill string B and tool A, as for the purpose of adding another drill pipe section to the upper end of the drill string 26. During the downward movement of the drill string prior to securing the Kelly thereto, ribs or projections extending slightly into the reamed well bore will not cause the tool to hang up in the well bore, since the effective diameter of the tool is then slightly less than the actual reaming diameter (see Fig. 1). As a result, the entire drilling string need merely be lowered, the Kelly attached to the uppermost portion of the added drill pipe section, and drilling continues upon re-engagement of the cutters 25 with the formation shoulder E.

If, however, the ribs or projections extend inwardly to a material extent, the partially retracted cutters will note this fact during the downward passage of the bit A by hanging upon the inward protuberances, thus advising the operator at the top of the well bore that there are restrictions in the well bore reducing its diameter below a prescribed minimum, and that liners or other casing strings to be subsequently lowered in the well bore would be incapable of passing
therethrough. The operator then would re-ream the well bore, in order to remove the ribs or other inward projections.

It is, accordingly, apparent that a drill bit has been provided which permits the tool to be moved downwardly into engagement with the formation shoulder, without the necessity for removing minor restrictions in the well bore, but which still operates to prevent such downward movement in the event of major restrictions being present in the well bore. In this sense, the drill bit operates as a gage by indicating whether the well bore has been enlarged beyond the diameter determined by the intermediate expanded position of the cutters 25, determined by engagement between the arm and the mandrel projection 61, 60. If the tool hangs up in the well bore during its lowering toward the formation shoulder 1, the operator is advised of the necessity of re-reaming the hole for the purpose of removing the restrictions projecting thereinto. Thus, costly rig time is not consumed in reaming the hole to remove minor restrictions or projections, which cannot adversely affect or prevent subsequent operations in the well bore, passage of the tool into engagement with the formation shoulder 1 being accomplished readily without the necessity for their removal. However, major restrictions must still be removed, and should be removed, since they would otherwise prevent lowering of the liner or casing string, or the performance of subsequent operations in the well bore.

Certain aspects of the disclosure herein are described and claimed in my applications for "Expansible Rotary Drill Bit and Method of Assembling and Disassembling the Same," Serial No. 779,992, filed October 13, 1947; and "Well Drilling Apparatus," Serial No. 779,991, filed October 13, 1947.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. A rotary well drilling bit, including a main body, cutter means pivotally mounted on said body and having an upwardly extending arm and a depending leg, spring means bearing against said body and arm for moving said arm inwardly and said leg outwardly, a lock device movable downwardly within said body into engagement with said leg for preventing inward movement of said leg from its outward position, and cam means on said lock device engageable with said arm when said lock device is disposed in an upward position within said body for preventing outward movement of said leg by said spring means to its fullest extent.

2. A rotary well drilling bit, including a main body, cutter means pivotally mounted on said body and having an upwardly extending arm and a depending leg, spring means bearing against said body and arm for moving said arm inwardly and said leg outwardly, a mandrel adapted to be connected directly to a tubular drill string, said mandrel being slidably splined to said body and movable downwardly within said body into engagement with said leg for preventing inward movement of said leg from its outward position, and cam means on said mandrel engageable with said arm when said mandrel is disposed in an upward position within said body for preventing outward movement of said leg by said spring means to its fullest extent.

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