Oct. 6, 1953 A. W. KAMMERER 2,654,575

TANDEM EXPANSIBLE ROTARY DRILL BIT

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Fig. 1.

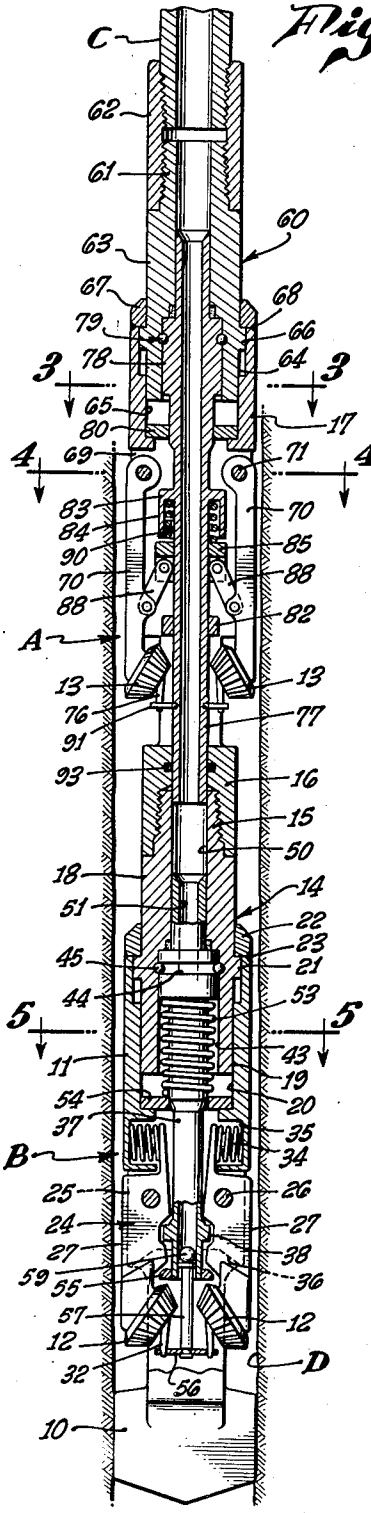


Fig. 2.

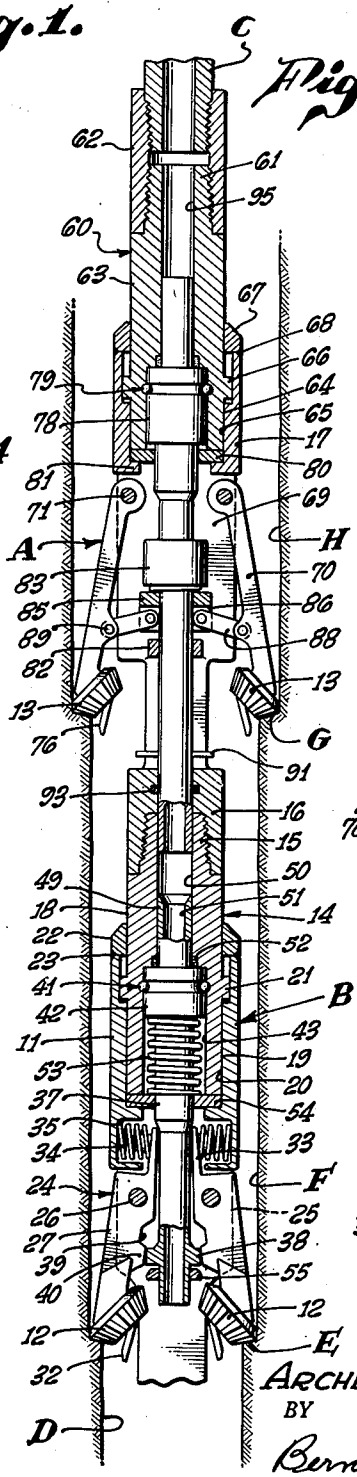


Fig. 3.

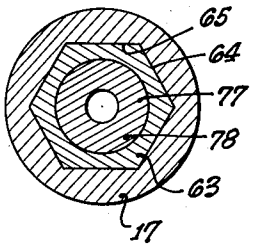


Fig. 4.

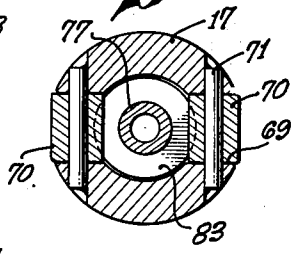
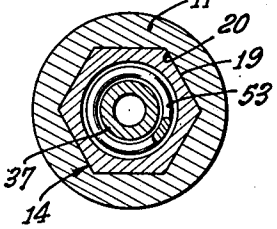


Fig. 5.



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Fig. 6.

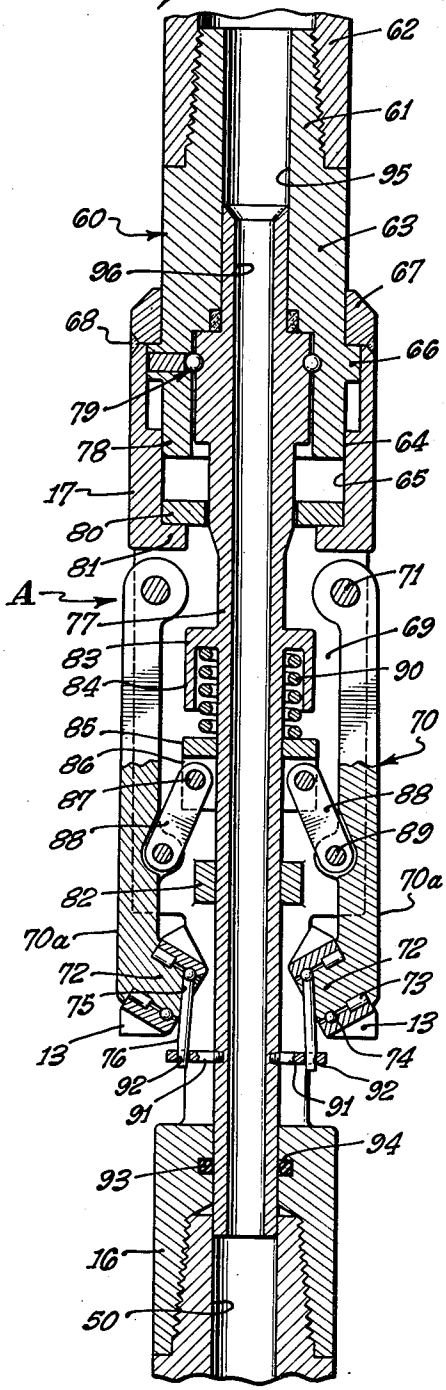
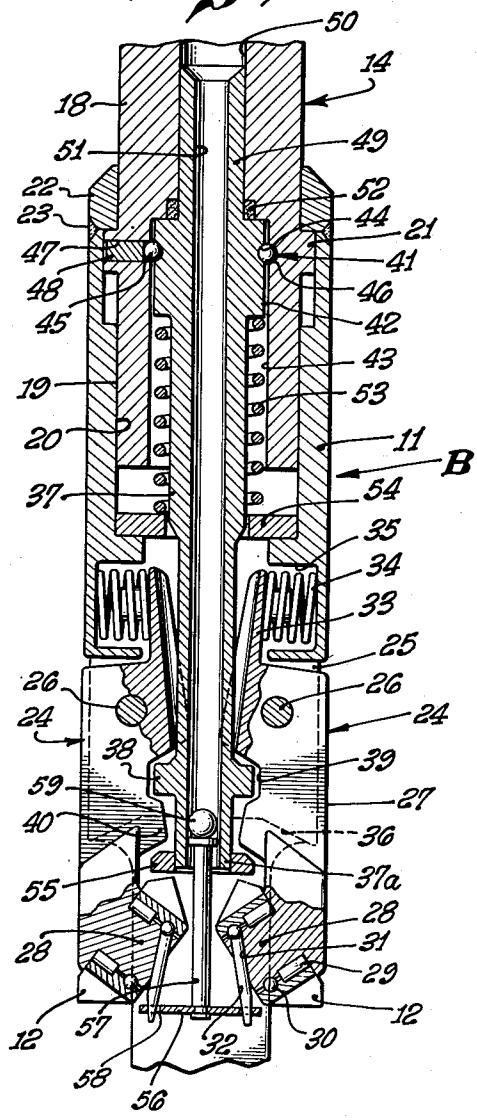


Fig. 7.



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Fig. 8.

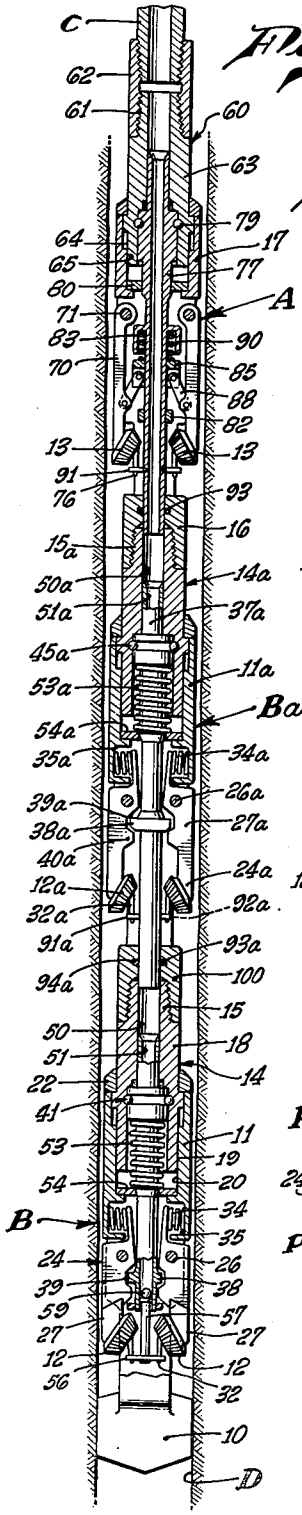


Fig. 9.

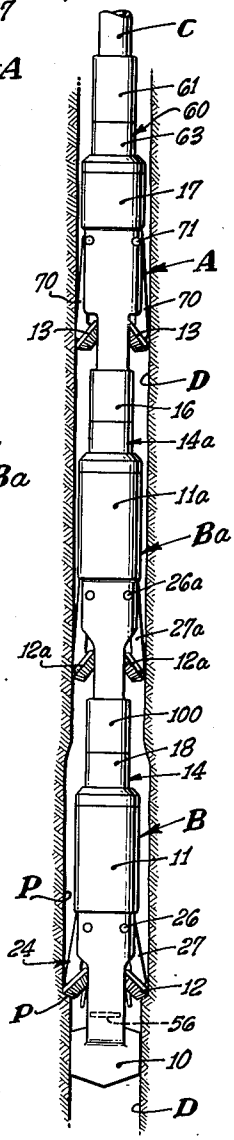


Fig. 10.

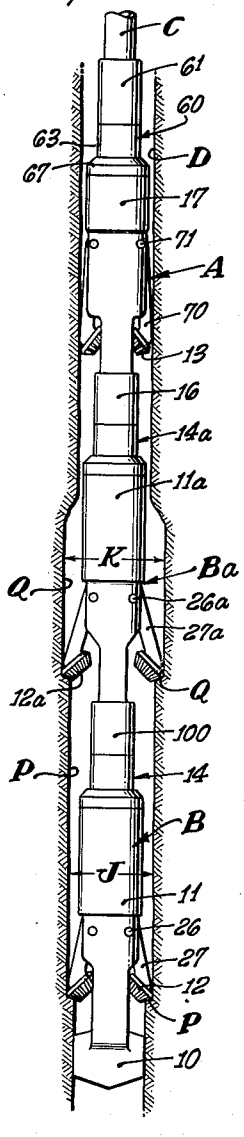
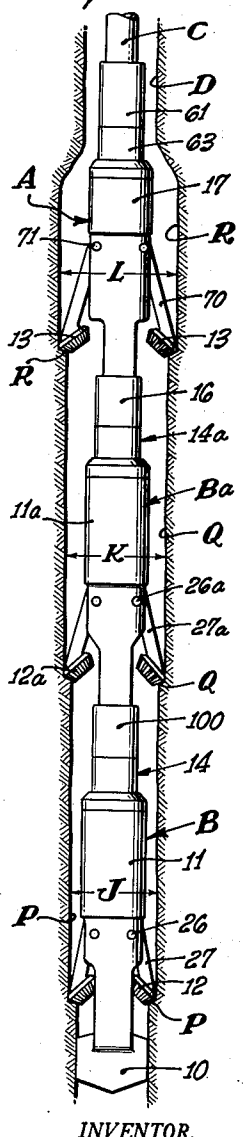


Fig. 11.



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Patented Oct. 6, 1953

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UNITED STATES PATENT OFFICE

2,654,575

TANDEM EXPANSIBLE ROTARY DRILL BIT

Archer W. Kammerer, Fullerton, Calif.

Application January 9, 1950, Serial No. 137,536

8 Claims. (Cl. 255—76)

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The present invention relates to earth boring tools, and is more particularly directed to expansible rotary drill bits which are capable of drilling or enlarging a bore hole below a casing string to a larger diameter than that of the inside diameter of the casing string.

It has been difficult, and sometimes impossible, to increase the size of certain bore holes below well casing to a substantially larger diameter than the inside diameter of the well casing. In holes drilled through comparatively hard formations, extensive increase in their diameters below well casing has been accomplished only at high cost and the expenditure of considerable time.

Accordingly, an object of the present invention is to provide an arrangement of drill bits which can drill or increase the diameters of bore holes to a considerably greater extent than the inside diameter of a well casing through which the bits are capable of passing, with their respective cutters in retracted positions.

Another object of the invention is to provide a drill bit arrangement capable of enlarging a bore hole below a casing string to a substantially greater diameter than the inside diameter of the casing string, at less time and at a substantial saving in cost. Fewer round trips are required in and out of the well bore in effecting the desired ultimate increase in the diameter of the hole.

A further object of the invention is to provide a tandem arrangement of expansible drill bits, in which assurance is had that the respective cutters of the bits are expanded outwardly to their full reaming diameters. In addition, the respective cutters of the bits are held positively in their maximum expanded positions so as to preclude the drilling of undergauged holes.

Still another object of the invention is to provide a tandem arrangement of expansible drill bits, in which a higher bit enlarges the hole to a greater diameter than a lower bit, and in which the tandem bit assembly is capable of commencing the hole enlarging operation off bottom and at any desired point along the length of the existing hole.

Yet a further object of the invention is to rely upon the formation shoulder produced by the expanded cutters of a lower bit to enable the cutters of an upper bit to be expanded outwardly. In this connection, the lower bit cutters may be expanded outwardly to their fullest extent before the upper cutters can be expanded outwardly to a still greater extent, thus insuring the progressive enlargement of the bore hole, with each bit performing its proper share of the work.

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Another object of the invention is to provide a tandem assemblage of drill bits, the bits being easily secured to and detachable from one another in any reasonable number, to obtain progressive increase in the hole diameter produced by an upper bit over the hole size produced by the adjacent lower bit.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of several forms in which it may be embodied. Such forms are shown in the drawings accompanying and forming part of the present specification. These forms will now be described in detail, 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, with parts in elevation, through a tandem arrangement of expansible drill bit apparatus, with the parts in retracted position for lowering through the well bore;

Fig. 2 is a view similar to Fig. 1, with the parts of the drill bits expanded outwardly to their full reaming diameters;

Fig. 3 is an enlarged cross-section taken along the line 3—3 on Fig. 1;

Fig. 4 is an enlarged cross-section taken along the line 4—4 on Fig. 1;

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

Fig. 6 is a longitudinal section, on an enlarged scale, of the upper expansible drill bit illustrated in Fig. 1;

Fig. 7 is an enlarged longitudinal section through the lower drill bit disclosed in Fig. 1;

Fig. 8 is a longitudinal section through a triple tandem drill bit apparatus, with the parts in retracted position;

Fig. 9 is a side elevational view of the apparatus shown in Fig. 8, with the lower cutter enlarging the hole;

Fig. 10 is a view similar to Fig. 9, with the lower and intermediate cutters enlarging the hole;

Fig. 11 is a view similar to Fig. 9, with the lower, intermediate and upper cutters enlarging the hole.

A tandem arrangement of upper and lower drill bits A, B is disclosed in the drawings, which is adapted to be lowered through a string of well casing (not shown) into a bore hole below the lower end of the casing, for the purpose of en-

larging the diameter of the bore hole to a considerable extent. The lower bit B will enlarge the bore hole diameter to an intermediate size, whereas the upper bit A is capable of increasing the size of the bore hole to a greater diameter than that produced by the lower bit. Additional bits can be mounted in tandem fashion above the upper bit, and their cutters expanded outwardly to progressively greater extents for the purpose of greatly enlarging the bore hole diameter in step-by-step fashion.

The drill bit assemblage A, B disclosed in Fig. 1 is lowered in the well bore on the lower end of a string of drill pipe C, preferably with the respective cutters of the drill bits in retracted positions. The assemblage may commence both drilling and enlarging a hole D below the well casing shoe (not shown) or it may merely enlarge an existing bore hole, as desired. As disclosed in the drawings, a pilot bit 10 is secured to the main body 11 of the lower expansible drill bit B, for the purpose of cutting a new hole or assist in centering the bit assembly in an existing hole. The cutters 12 of the lower expansible bit are adapted to form a shoulder E in the formation, and then operate upon such shoulder in a downward direction to form a bore hole F of increased diameter. The cutters 13 of the upper expansible bit A are adapted to form an annular shoulder G in the formation around the larger hole F produced by the lower expansible bit cutters 12, and operate upon such formation shoulder to form a well bore H of still further increased diameter.

The lower drill bit B is illustrated and described in my United States Patent No. 2,466,991, and in my application for "Expansible Drill Bit," Serial No. 43,789, filed August 12, 1948. The upper drill bit A is described and claimed per se in my application for "Expansible Rotary Drill Bits," Serial No. 137,535, filed January 9, 1950.

The upper end of the lower expansible bit B consists of a driving mandrel 14 whose upper pin 15 is threaded into a box 16 formed at the lower end of the main body 17 of the upper expansible drill bit A. This lower mandrel 14 includes an upper kelly or drill stem member 18 slidably splined to or telescoped within the main body 11 of the bit. As specifically disclosed in the drawings, the exterior 19 of the kelly is hexagonal in shape, being telescoped within a companion hexagonal socket 20 within the body. The mandrel 14 has a limited range of longitudinal movement within the body 11, by virtue of engagement of an external shoulder 21 on the kelly 18 with a retainer ring 22 on the upper end of the body, which is suitably secured to the latter, as by the use of welding material 23.

The lower body 11 (see Fig. 7, particularly) has a plurality of expansible parts mounted on it, comprising cutter supporting members 24 pivotally mounted in body slots 25 on pivot or hinge pins 26 suitably secured to the body. Each cutter supporting member 24 consists of a depending leg 27 having a bearing supporting pin 28 inclined inwardly and downwardly, and on which a roller side cutter 12 is rotatably mounted. Anti-friction roller and ball bearing elements 29, 30 are placed between each cutter 12 and bearing pin 28, in order to transmit the radial and axial thrusts imposed upon the cutter. The ball bearings 30 also retain each cutter 12 on the pin 28, being inserted in place through a pasage 31 in the bearing pin, which is then closed by a plug 32 welded to the pin. The plug or pin 32 depends from the passage 31 and is used to hold the cutters 12 in retracted position, as described below.

Each cutter supporting member 24 also includes an upwardly extending arm 33 against which an elastic or compressed coil spring expander 34 bears. This expander is received within a retainer pocket 35 in the body 11, and exerts its force against the arm 33, tending to swing it inwardly and thereby urge the cutters 12, on the other side of the fulcrum pin 26, in an outward direction. The extent of this outward movement is limited by engagement of the cutter supporting member with shoulders 36 of the body on opposite sides of the slots 25, which shoulders function as stop members.

After the cutters 12 have been expanded outwardly by the expander springs 34 to the maximum extent, they can be locked in this position by a tubular member 37 of the mandrel 14, which member is piloted in the kelly 18. This member 37 is provided with a lock portion 38 movable from an upper position in transverse alignment with recesses 39 formed in the supporting members 24, permitting retraction of the cutters 12, to a lower position opposite lugs 40 formed on and projecting inwardly from the supporting member legs 27, preventing retraction of the cutters 12.

The tubular member 37 may be connected in swivel fashion to the kelly 18 to permit relative arcuate rotary movement therebetween, which can occur to a slight extent. However, the kelly 18 and tubular member 37 are coupled together for movement in both directions. This is accomplished by providing an anti-friction thrust bearing 41 between a boss or shoulder 42 on the tubular member 37 and the kelly 18. The shoulder 42 is received within a socket 43 in the kelly, and has a toroidal raceway 44 on its exterior around which a plurality of bearing balls 45 can be disposed. These balls are also received in an opposed toroidal raceway 46 in the kelly 18.

The balls 45 are insertable into and between the raceways 44, 46 through a hole 47 extending through the external kelly shoulder 21 and communicating with the internal race 46. After the balls have been thus disposed in position, the hole is closed by a suitable plug 48 which is prevented from moving outwardly of the kelly by the inner wall of the surrounding body 11.

The tubular member 37 has an upper portion 49 extending into the central bore 50 of the kelly. Fluid pumped down the drill string C can flow through the upper drill bit A, and through the kelly pin 15 into the central passage 51 in the tubular member 37. Such fluid may be prevented from flowing around the exterior of the tubular member by suitable packing 52 disposed between its boss 42 and the kelly 18.

Because of the swivel connection 41, the kelly 18 and tubular member 3 are caused to move jointly in both directions, but they are free to partake of relative movement with respect to each other.

The mandrel 14 may normally be held in its upper position with respect to the main body 11 and the supporting members 24 by a helical retractor spring 53 encircling the tubular member 37, with its upper end engaging the mandrel shoulder 42 and its lower end engaging a spring seat 54 at the lower end of the hexagonal body socket 20. This spring seat 54 also serves as an upper bearing guide for the tubular member 37, whose lower end is slidable within a lower bearing guide 55 below the lugs 40, which guide is integral with or secured to the main body of the bit.

The lower drill bit B may also be provided with

a latch device for retaining the cutters 12 initially in retracted positions against the expansible forces of the springs 34. This device includes a holding plate 56 secured to the lower end of a central rod 57 projecting upwardly into the tubular member passage 51. The holding plate or member 56 has spaced holes 58 in its outer portion for receiving the lower ends of the ball bearing plugs 32.

When the holding device is disposed over the plugs 32, the cutter supporting members 24 are prevented from expanding under the influence of the compressed springs 34, thereby holding the cutters 12 in retracted position. Release of the holding device can occur hydraulically through aid of a ball 59, which may be dropped down the drill string C into engagement with the rod 57, or which may be placed in the lower drill bit passage 51 prior to its disposition in the well bore. During lowering of the apparatus through the well bore, the ball 59 may be lifted into the larger passage 50 through the kelly pin, for the purpose of allowing upward flow of fluid through the bits B, A and drill pipe C.

As explained below, when the point in the well bore has been reached at which the reaming operation is to begin, the latch device 56 is ejected hydraulically from the cutter mechanism, allowing the springs 34 to expand and urge the cutters 12 in an outward direction to enlarge the well bore.

The lower expansible drill bit B will enlarge the well bore to a certain intermediate diameter. The upper expansible drill bit A can enlarge the well bore to a still greater diameter. As shown most clearly in Fig. 6, the main body 17 of this upper bit is secured to the mandrel 14 of the lower bit B by threading the upper body box 16 onto the mandrel pin 15. An upper tubular mandrel 60 is piloted within the upper body and has its upper end formed as a threaded pin 61 which can be screwed into a sub 62 that constitutes the lowermost portion of the string of drill pipe C. The upper mandrel 60 includes an upper kelly or drill stem member 63 slidably splined to the main body of the bit, as by forming the exterior 64 of the kelly of hexagonal shape and providing a corresponding hexagonal socket 65 in the body. The mandrel 60 has a predetermined range of longitudinal movement within the body, its upward movement being limited by engagement of an external shoulder 66 on the kelly with the retainer ring 67 at the upper end of the body 17, the ring being suitably secured to the latter, as by use of welding material 68.

The upper body 17 is provided with a longitudinal transverse slot 69 extending through it, in which a pair of opposed cutter supporting members 70 are disposed. These cutter supporting members have their upper ends mounted on pivot or hinge pins 71 extending across the body slot and suitably secured to the body. The cutter supporting members or legs 70 depend from these hinge pins to a substantial extent, each having a lower bearing supporting pin 72 on which a side cutter 13 is rotatably mounted. Anti-friction roller and ball bearing elements 73, 74 are disposed between each bearing supporting pin 72 and cutter 13, to transmit the radial and axial bearing loads therebetween, the ball bearing elements 74 also serving to retain the cutter 13 on the supporting pin 72.

As in the lower bit B, the ball bearing elements 74 may be inserted between each cutter and its associated pin through a passage 75 in the latter, which is closed by a suitable plug 76 welded, or otherwise suitably attached, to the pin. The plugs 76 depending from the bearing pins 72 can be availed of for holding the supporting legs 70 and cutters 13 in retracted position, as described below.

The oppositely disposed bearing supporting members and their cutters may occupy retracted positions substantially entirely within the confines of the upper body 17. They may be expanded outwardly of the body to a larger effective diameter than the maximum reaming diameter of the cutters 12 of the lower bit B. In expanding the upper cutters 13, their supporting legs 70 are swung outwardly about the hinge pins 71 to a predetermined extent. The device for expanding the upper cutters includes a lower tubular member 77, forming part of the upper mandrel 60, and piloted within a lower socket 78 in the kelly 63. The kelly 63 and lower tubular member 77 are assembled together for joint longitudinal movement through a swivel connection 79 that is substantially the same as the swivel connection 41 between the lower kelly 18 and lower tubular member 37. This swivel connection 79 enables the upper kelly 63 and tubular member 77 to shift angularly with respect to one another, but couples them together for conjoint longitudinal movement in both directions.

The tubular member 77 extends downwardly through a guide washer and stop element 80, resting upon a shoulder 81 formed on the body. This washer initially is disposed below the lower end of the kelly 63, so as to allow the kelly and tubular member 77 to be moved downwardly, for the purpose of holding the upper cutters 13 and their supporting members 70 in an outward position. In addition, the kelly 63 and tubular member 77 resist inward movement of the cutters 13 from their outward position, and, under some conditions of usage of the equipment, can actually shift the cutters 13 to their outwardly expanded position. The tubular member 77 is also slidable in a lower guide 82 integral with the body, and forming a support for the tubular member 77, to resist its lateral movement. The lower end of the tubular member is also slidable in the body box 16, communicating with the passage 50 in the lower mandrel 18.

The tubular member 77 of the mandrel 60 also has a cup-shaped thrust head 83 intermediate the upper and lower guides 80, 82, provided with a depending skirt 84 terminating above a thrust block 85 slidable along the exterior of the tubular member 77 below its skirt 84. The block 85 has longitudinal slots 86 on opposite sides of the mandrel in alignment with the cutter supporting legs 70, to carry a pin 87 on each side of the mandrel on which the upper ends of inclined thrust links 88 are pivoted. The lower end of each link is attached to the cutter supporting member 70 by means of a lower pin 89, at a point which is intermediate the hinge pin 71 and cutter 13.

The upper cutters 13 may be expanded outwardly upon downward movement of the mandrel 60 with respect to the body 17, which causes the lower end of the skirt 84 to engage the block 85, shifting the latter downwardly and swinging the legs 70 outwardly about their hinge pins 71, through the agency of the thrust links 88. If desired, outward expansion of the upper cutters 13 and their supporting legs 70 may be accomplished by a helical compression spring 90, disposed within the skirt 84 and bearing at its upper end upon

the head 83 and at its lower end upon the thrust block 85. It is evident that this spring 90 tends to urge the thrust block 85 downwardly and the legs 70 in an outward direction.

The upper cutters 13 may be releasably locked in retracted position by a holding device, to insure the downward passage of the bit assemblage A through the casing, and the well bore below the casing, to the desired point at which the hole enlarging operation is to commence. This holding device may include a rod or eye element 91 for each cutter threaded into the tubular member 77, and having a hole 92 receiving the lower end of the ball retaining plug 76. These elements 91 will prevent outward expansion of the cutters 13 until the elements are moved downwardly from the plugs 76, as by moving the tubular mandrel 60 downwardly with respect to the body 17. The lower end of the mandrel skirt 94 is disposed a sufficient distance above the thrust block 85, when the cutters 13 are in their initial retracted position, to insure the downward removal of the lock or latch elements 91 from the plugs 76 before the skirt 84 can engage the thrust block 85. Without such relative positioning of the parts, it may be difficult, if not imposssible, to unlatch the cutters 13, since prior engagement of the skirt with the thrust block would preclude further downward movement of the mandrel 60 within the upper body 17.

As noted above, the upper mandrel 60 is slidable in the threaded box 16 at the lower end of the bit body 17, leakage around the exterior of the mandrel being prevented by a suitable side seal 93 in a box groove 94 slidably engageable with the exterior of the tubular mandrel. Accordingly, the fluid pumped down the drill pipe C can pass through the upper kelly passage 95 and the tubular mandrel passage 96, for discharge into the lower kelly passage 50 and into the lower tubular member 37, for the purpose of releasing the lower latch member 56, and thereafter discharging into the well bore to flush the cuttings to the top of the well bore.

The depending leg portions 27 of the lower cutter supporting members 24 are of such length as to enable the cutters 12 to be expanded laterally to a predetermined maximum diameter, in order to enlarge the well bore to an intermediate size F. The upper cutter supporting members or legs 70 are substantially longer than the lower legs 27, to enable the cutter elements 13 to be swung outwardly or expanded to a greater effective diameter than the lower cutters 12, in order to obtain a still further enlargement H of the bore hole diameter. The extent of expansions of the respective upper and lower cutters 13, 12 is properly selected to insure the effective operation of the drill bit apparatus in ultimately increasing the diameter of the bore hole to the required amount.

The drill bit apparatus is assembled with the upper and lower cutters 13, 12 in retracted positions, in the manner illustrated in Fig. 1, and with the upper mandrel pin 61 threaded onto the lower end of the drill pipe C. The upper and lower latches 91, 56 are in place, in order to lock the cutters in their respective retracted positions.

The apparatus is lowered through the well casing (not shown) until it reaches the location in the well bore at which the hole enlarging operation is to take place, which may be above the bottom of a previously drilled hole below the casing shoe (not shown). When this point is reached, the tandem drill bits A, B are rotated at the proper speed without imposing any downward weight upon them. The pumps at the top of the well bore are started, to impose pressure on the drilling fluid or mud in the drill pipe C and the bits A, B. The pressure acts on the ball 59 in the lower bit B (which may have been previously inserted in the bit), this ball functioning as a piston and causing the stem 57 and locking plate 56 to be shifted downwardly and ejected from the lower bit. Removal of the locking plate 56 frees the lower cutters 12 and their supporting members 24 from restraint and allows the compressed springs 34 to expand, shifting the arms 33 inwardly and the legs 27 and cutters 12 in an outward direction. With the removal of the latching device, circulating fluid can pass outwardly through the lower nozzle portion 37a of the lower mandrel 37, in order to wash the cuttings from the well bore and circulate them around the drill pipe C to the top of the hole.

Rotation of the bit assembly continues, without imposing drilling weight on the apparatus, until the lower cutters 12 form a shoulder E in the well bore, the cutters being expanded to their maximum extent. After this occurs, the drill string C may be shifted downwardly, which will shift the upper mandrel 60 and its tubular member 77 downwardly within the upper bit body 17, the latch elements 91 being moved downwardly from the upper plugs 76, releasing the upper cutters 13 for outward expansion. However, the outer surfaces 70a of the legs 70 will merely move outwardly into engagement with the wall of the hole D, since such surfaces initially project slightly beyond the cutters 13. Inasmuch as the cutters 13 cannot be expanded any further, at this time, because of the confining action of the small diameter bore hole E, continued downward movement of the drill string will then shift the entire upper bit A in a downward direction, sliding the legs 70 along the wall of the hole. As such downward movement occurs, the lower mandrel 14, which is rigidly secured to the upper body 17, is moved downwardly within the lower body 11 to a position limited by engagement of the lower end of the kelly 18 with the lower guide washer 54. Such downward movement of the lower mandrel positions the lower lock element 38 within and opposite the lower lugs 40, forming a positive stop or abutment precluding inward movement of the lower cutters 12 from their outwardly expanded position.

Rotation of the drill pipe C and cutters continues, the cutters 12 enlarging the hole to a greater diameter F by operating upon the formation shoulder E. As drilling proceeds, the upper legs 70 and cutters 13 will reach the enlarged hole portion F, whereupon they can expand outwardly, the cutters 13 engaging the enlarged hole wall, and then extending outwardly beyond the leg surfaces 70a.

Rotation of the drill pipe C and the tool assemblage A, B may then continue, the upper spring 90 urging the thrust member 85 downwardly along the mandrel 77, and, through the links 88, urging the upper cutter supporting legs 70 and cutters 13 in an outward direction, allowing the upper cutters to form an upper shoulder G in the well bore having an outside diameter H substantially greater than the outside diameter F of the lower shoulder E. The

spring 90 can shift the cutters 13 outwardly to the extent determined by engagement of the thrust block 85 with the lower guide 82 in the upper body. Thereafter, the imposition of down weight on the drill pipe C and upper mandrel 60 will shift the latter downwardly within the upper body 18, until the lower end of the kelly 63 engages the upper guide and stop washer 80. When such engagement occurs, the lower end of the mandrel skirt 84 is preferably positioned immediately above and closely adjacent the thrust block 85, to preclude any substantial inward shifting of the cutters 13 from their maximum expanded position.

With the lower mandrel 14 fully telescoped downwardly within the lower body 11, and with the upper mandrel 60 fully telescoped downwardly with the upper body 17, the drilling weight is transmitted from the respective mandrels directly to their corresponding bodies, and from such bodies to the cutter supporting members 24, 70 and the cutters 12, 13. The tubular members 77, 37 themselves are relieved of any of the drilling weight. Rotation of the drill bit assemblage takes place, with the proper drilling weight imposed upon the sets of cutters, the lower cutters 12 enlarging the well bore to an intermediate diameter F and the upper cutters 13 to the desired final diameter H, that is substantially greater than the intermediate diameter. During the drilling operation, circulation fluid is pumped downwardly through the bits A, B, in order to flush the cuttings to the top of the hole.

After the hole enlarging operation has been completed, or the drill bits have become worn, it is merely necessary to elevate the drill pipe C, which will raise the upper mandrel 60 within the upper body 17 and allow the upper cutters 13 to be retracted. The upper mandrel flange 66 engages the upper retainer ring 67, to transmit the upper pulling effort to the upper body 17. Continued upward movement then elevates the lower mandrel 14 within the lower body 11, and raises the lock member 38 above the supporting member lugs 40, which will allow the lower cutters 12 and their supporting members 24 to be retracted. Such latter relative elevating movement may be assisted by the retractor spring 53, although this spring need not be embodied in the bit at all, if desired.

When the drill bit assemblage A, B passes upwardly within the casing shoe, the latter engages the upper cutter supporting members 70 and forces them inwardly to a retracted position. Similarly, the shoe engages the lower cutter supporting members 24, and forces them inwardly to retracted position, the entire mechanism being elevated in the well casing, with the cutter supporting members 70, 24 riding the wall of the well casing, until the top of the hole is reached.

The upper spring 90 may be omitted, with the tubular member head 83 originally disposed adjacent the thrust member 85, when the cutters 13 and their supporting members 70 are in retracted position. After the lower cutters 12 have been expanded outwardly, the imposition of a downward thrust on the drill string C and upper mandrel 60 will shift the head 83 into engagement with the thrust member 85 and urge the upper supports 70 outwardly, the legs 70 sliding along the formation wall as all of the upper bit parts move as a unit in a downward direction, to shift the lower mandrel 14 within its body 11 downwardly, and to a position in which the lock element 38 is disposed within and in alignment with the lower lugs 40. Expansion of the upper cutters 13 can then proceed, after the enlarged bore F is reached, by moving the upper mandrel 60 downwardly within the upper body 17 to the extent limited by engagement of the lower end of the kelly 63 with the upper guide washer 80.

In Figs. 1 and 2, a tandem arrangement of drill bits is disclosed, in which a previously drilled hole D can be enlarged in two stages. If desired, hole enlargement can take place in three or more stages by incorporating one or more expansible drill bits in the assemblage. As illustrated in Fig. 8, the upper pin 15 of a lower drill bit B is threaded into the lower body box 100 of an intermediate drill bit B*a*, which may be of the same general design as the lower drill bit B. The intermediate mandrel 14*a* is threaded into the lower box 16 of an upper drill bit A, which may be of the same design as the upper drill bit shown in Figs. 1 and 2. The upper mandrel pin 61 of the upper bit is then threadedly secured to the lower end of the drill pipe C.

The intermediate bit mandrel 14*a* extends slidably into the lower box 100 of its associated body 11*a*, leakage around the mandrel being prevented by a suitable side seal 93*a* disposed in a box groove 94*a*. This intermediate mandrel 14*a* is also provided with locking elements 91*a* threaded into it and having holes 92*a* receiving the ball retaining plugs 32*a* depending from the intermediate bearing supporting members 24*a*.

The cutters 12 of the lower bit B are arranged to expand outwardly to a predetermined maximum diameter J, in order to accomplish the first stage of hole enlargement. The cutters 12*a* of the intermediate bit B*a* may be mounted on longer supporting legs 71*a* than the lower bit, so that their springs 34*a* may shift such cutters outwardly to a greater extent than the lower cutters 12, to produce a hole of a larger diameter K than that of the lower cutters. The supporting legs 70 of the upper bit A may be of such length as to enable them to be swung outwardly to a greater extent than the intermediate cutters 12*a*, and form a correspondingly larger diameter hole L.

The multiple tandem arrangement of drill bits illustrated in Fig. 8 may be run in the well bore with all of the cutters 12, 12*a*, 13 locked in retracted position. As in the two stage bit assemblage, the pumps can be started when the location has been reached at which the hole enlarging operation is to occur, to release the lower latch 56 from its associated cutter supporting members 24, allowing the lower springs 34 to urge the cutters 12 outwardly, while the bits are being rotated, to form the lower formation shoulder P. This shoulder prevents the lower body 11 from moving downwardly to any further extent, for the time being. The drill pipe C is then moved downwardly, shifting the upper mandrel 60 downwardly and releasing its lock elements 91 from the associated plugs 76, releasing the upper cutters 13 for outward expansion. Continued downward movement then slides the upper bit A as a unit along the formation hole D and shifts the intermediate mandrel 14*a*, connected to the upper bit A, downwardly, to release its latch elements 91*a* from the associated cutter supporting members 24*a*, allowing the inter-

mediate springs 34 to urge the intermediate cutters 12a outwardly.

Continued downward movement then slides the upper bit A and intermediate bit Ba downwardly along the formation wall D, to shift the lower mandrel 14 downwardly within the lower body 11 to a position in which the mandrel lock 36 is disposed within the cutter supporting lugs 40, as determined by abutting of the lower end of the lower kelly 18 with the guide washer 54. As the rotation of the drill pipe C and bit apparatus proceeds, the proper drilling weight is imposed, to cause the lower cutters 12 to drill away the hole by operating upon its associated formation shoulder and produce the larger hole diameter P. While such drilling proceeds, the intermediate and upper cutter supporting members 24a, 70 slide along the wall of the smallest diameter hole D, the upper and intermediate cutters 13, 12a being disposed inwardly of the outermost portions of their associated cutter supports 70, 24a. The upper and intermediate drill bits A, Ba merely move downwardly as a unit, their cutters being incapable of expanding outwardly to any appreciable extent by the confining wall of the hole D.

As drilling by the lower cutters 12 proceeds, the intermediate cutters 12a eventually reach the enlarged well bore P produced by the lower cutters, whereupon the intermediate expansion springs 34a can operate and urge these cutters 12a outwardly and into engagement with the wall of the larger hole P. The drill pipe C and tool assemblage can then be rotated, the intermediate cutters 12a, which now project outwardly beyond the outermost portions of their supporting member 24a, digging into the wall of the enlarged hole P and forming a shoulder therein of a certain predetermined diameter Q, as limited by engagement of the cutter supporting members 24a with the body shoulder 36a on the body 11a. With this shoulder formed, the drill pipe C and upper drill bit A can be moved downwardly as a unit, the upper supporting legs 70 merely sliding along the wall of the smallest hole D. This downward movement carries the intermediate mandrel 14a downwardly with it to shift its lock member 38a within the lock lugs 40a, thereby precluding retraction of the intermediate cutters 12a from their outwardly expanded position.

Drilling weight may be imposed on the bit assemblage, the lower cutters 12 producing the larger hole P, and the intermediate cutters 12a the hole Q of still greater diameter.

As drilling proceeds, the upper cutter supporting legs 70 will move out of the small diameter hole D, allowing the spring 90, or the head 83, if a spring is not used, to engage the thrust block 85 and shift it downwardly, forcing the legs 70 and upper cutters 13 outwardly against the wall of the enlarged hole Q and forming an annular shoulder beyond the diameter of the enlarged hole Q. When the upper cutters 13 have been expanded outwardly to their maximum extent, the upper mandrel 60 is shifted downwardly within the upper body 17, until the lower end of the kelly 63 engages the guide element 80, whereupon drilling weight can be imposed on the cutters 13 to urge them downwardly against the formation shoulder to produce the desired maximum diameter hole R.

When all three sets of cutters have been expanded outwardly, the bit may be rotated at the desired speed, with the proper drilling weight imposed on the cutters, the hole being enlarged in step fashion from its diameter D, through the diameters P and Q, to the final diameter R. That is, the lower cutters 12 perform the first stage of hole enlarging, the intermediate cutters 12 the second stage, and the upper cutters 13 the third stage, as the sets of cutters operate upon their respective formation shoulders and cut such shoulders progressively away in a downward direction. When the drill bit assemblage has performed its operation of enlarging the hole, it need merely be elevated through the well bore and casing, the cutters being retracted by the casing as their respective supporting members enter the casing shoe.

Additional expansible bits could be connected in tandem, if desired, within practical limits, to accomplish the desired hole enlargement in stages.

It is apparent that a tandem arrangement of drill bits has been provided, that is capable of enlarging a hole to a considerably greater diameter. The use of toothed types of roller cutters enables hole enlargement to a substantial extent to be accomplished in hard formations. With such tandem arrangement of drill bits, a single round trip into the well bore will suffice for greatly enlarging the hole and along an extended length of the hole, thereby saving considerable rig time and expense, by avoiding the necessity for making individual trips into the hole with individual expansible bits to accomplish a step-by-step increase in the well bore diameter.

With the telescopic arrangement of bits, assurance is had that each set of bit cutters is expanded and locked outwardly to its full reaming diameter, in order that each bit will perform its proper share of the drilling operation. It is simply necessary to attach the drill bits to one another, and in the desired number, each drill bit being a full and complete mechanism in and of itself. The outward expansion of the cutters of an upper bit is dependent upon the prior outward expansion of the cutters of a lower bit. The cutters are expanded outwardly in an upward sequence, and are locked outwardly, to prevent their inward retraction, by the telescopic movement of the tubular mandrels within their respective bodies.

The hole enlarging operation can commence off bottom in a previously drilled hole, or the tandem assemblage can be used in conjunction with a central bit 10 for the purpose of drilling a new hole and enlarging it in stages at one and the same time.

The inventor claims:

1. In rotary drill bit apparatus: a lower drill bit body; a lower mandrel slidably splined to said body; a lower supporting member mounted on said body for lateral outward movement with respect to said body; a lower cutter on said member; means for expanding said member and cutter outwardly of said body; an upper bit body secured to the upper end of said lower mandrel; an upper mandrel slidably splined to said upper body; an upper supporting member mounted on said upper body for lateral outward movement with respect to said upper body; an upper cutter on said upper supporting member; means for expanding said upper member and upper cutter outwardly of said upper body to a greater extent than said lower cutter; said upper cutter being disposed entirely inwardly of the outermost surface of said upper supporting member until said upper supporting member has been expanded partially outwardly, whereby said upper cutter is

prevented from penetrating the formation until it has been lowered into the enlarged bore produced by the lower cutter.

2. In rotary drill bit apparatus: a lower bit having a lower body; a lower supporting member mounted on said body for lateral outward movement with respect to said body; a lower cutter on said member; means for expanding said member and cutter outwardly of said body; an upper bit secured to the upper end of said lower bit, said upper bit having a body; an upper supporting member mounted on said upper bit body for lateral outward movement with respect to said upper body; an upper cutter on said upper member; means for expanding said upper member and upper cutter outwardly of said upper body to a greater extent than said lower cutter; said upper cutter being disposed entirely inwardly of the outermost surface of said upper supporting member until said upper supporting member has been expanded partially outwardly, whereby said upper cutter is prevented from penetrating the formation until it has been lowered into the enlarged bore produced by the lower cutter.

3. In rotary drill bit apparatus: a lower drill bit body; a lower mandrel slidably splined to said body; a lower supporting member mounted on said body for lateral outward movement with respect to said body; a lower cutter on said supporting member; means for expanding said supporting member and cutter outwardly of said body; means on said mandrel for preventing substantial inward movement of said supporting member and cutter from their outward expanded position upon downward telescopic movement of said mandrel in said body; an upper bit body secured to the upper end of said lower mandrel; an upper mandrel slidably splined to said upper body; an upper supporting member mounted on said upper body for lateral outward movement with respect to said upper body; an upper cutter on said upper supporting member; means for expanding said upper supporting member and upper cutter outwardly of said upper body to a greater extent than said lower supporting member and cutter; means on said upper mandrel for preventing substantial inward movement of said upper supporting member and upper cutter from their outward expanded position upon downward telescopic movement of said upper mandrel in said upper body; said upper cutter being disposed entirely inwardly of the outermost surface of said upper supporting member until said upper supporting member has been expanded partially outwardly, whereby said upper cutter is prevented from penetrating the formation until it has been lowered into the enlarged bore produced by the lower cutter.

4. In rotary drill bit apparatus: a lower drill bit body; a lower mandrel slidably splined to said body; a lower supporting member mounted on said body for lateral outward movement with respect to said body; a lower cutter on said supporting member; means for expanding said supporting member and cutter outwardly of said body; means on said mandrel for preventing substantial inward movement of said supporting member and cutter from their outward expanded position upon downward telescopic movement of said mandrel in said body; an upper bit body secured to the upper end of said lower mandrel; an upper mandrel slidably splinded to said upper body; an upper supporting member mounted on said upper body for lateral outward movement with respect to said upper body; an upper cutter

on said upper supporting member; means for expanding said upper supporting member and upper cutter outwardly of said upper body to a greater extent than said lower supporting member and cutter; means on said upper mandrel for preventing substantial inward movement of said upper supporting member and upper cutter from their outward expanded position upon downward telescopic movement of said upper mandrel in said upper body; said upper cutter being disposed entirely inwardly of the outermost surface of said upper supporting member until said upper supporting member has been expanded partially outwardly, whereby said upper cutter is prevented from penetrating the formation until it has been lowered into the enlarged bore produced by the lower cutter; and lock means releasable by said upper mandrel upon its downward telescopic movement in said upper body for holding said upper supporting member and upper cutter initially in retracted position.

5. In rotary drill bit apparatus: a lower drill bit body; a lower mandrel slidably splined to said body; a lower supporting member mounted on said body for lateral outward movement with respect to said body; a lower cutter on said suporting member; means for expanding said supporting member and cutter outwardly of said body; means on said mandrel for preventing substantial inward movement of said supporting member and cutter from their outward expanded position upon downward telescopic movement of said mandrel in said body; an upper bit body secured to the upper end of said lower mandrel; an upper mandrel slidably splined to said upper body; an upper supporting member mounted on said upper body for lateral outward movement with respect to said upper body; an upper cutter on said upper supporting member; means for expanding said upper supporting member and upper cutter outwardly of said upper body to a greater extent than said lower supporting member and cutter; means on said upper mandrel for preventing substantial inward movement of said upper supporting member and upper cutter from their outward expanded position upon downward telescopic movement of said upper mandrel in said upper body; upper lock means releasable by said upper mandrel upon its downward telescopic movement in said upper body for holding said upper supporting member and upper cutter initially in retracted position; and lower lock means for releasably holding said lower cutter supporting member and lower cutter initially in retracted position, whereby said lower lock means is first released to enable said lower supporting member and lower cutter to be expanded outwardly to provide a shoulder in a bore hole for stopping downward movement of said lower bit body to permit downward telescoping movement of said upper mandrel in said upper body to release said upper lock means.

6. In rotary drill bit apparatus: a lower drill bit body; a lower mandrel slidably splined to said body; a lower supporting member mounted on said body for lateral outward movement with respect to said body; a lower cutter on said supporting member; means for expanding said supporting member and cutter outwardly of said body; means on said mandrel for preventing substantial inward movement of said supporting member and cutter from their outward expanded position upon downward telescopic movement of said mandrel in said body; an upper bit body secured to the upper end of said lower mandrel;

an upper mandrel slidably splined to said upper body; an upper supporting member mounted on said upper body for lateral outward movement with respect to said upper body; an upper cutter on said upper supporting member; means for expanding said upper supporting member and upper cutter outwardly of said upper body to a greater extent than said lower supporting member and cutter; means on said upper mandrel for preventing substantial inward movement of said upper supporting member and upper cutter from their outward expanded position upon downward telescopic movement of said upper mandrel in said upper body; lock means releasable by said upper mandrel upon its downward telescopic movement in said upper body for holding said upper supporting member and upper cutter initially in retracted position; and lock means for releasably holding said lower cutter supporting member and lower cutter initially in retracted position; said upper cutter being disposed inwardly of the outermost surface of said upper supporting member, until said upper supporting member has been expanded partially outwardly, whereby said upper cutter is prevented from penetrating the formation until it has been lowered into the enlarged bore produced by the lower cutter.

7. In rotary drill bit apparatus: a lower drill bit body; a lower mandrel slidably splined to said body; a lower supporting member mounted on said body for lateral outward movement with respect to said body; a lower cutter on said supporting member; means for expanding said supporting member and cutter outwardly of said body; means on said mandrel for preventing substantial inward movement of said supporting member and cutter from their outward expanded position upon downward telescopic movement of said mandrel in said body; an upper bit body secured to the upper end of said lower mandrel; an upper mandrel slidably splined to said upper bit body; an upper supporting member mounted on said upper body for lateral outward movement with respect to said upper body; an upper cutter on said upper supporting member; means for expanding said upper supporting member and upper cutter outwardly of said upper body to a greater extent than said lower supporting member and lower cutter; means on said upper mandrel for preventing substantial inward movement of said upper supporting member and upper cutter from their outward expanded position upon downward telescopic movement of said upper mandrel in said upper body; upper lock means releasable by said upper mandrel upon its downward telescopic movement in said upper body for holding said upper supporting member and upper cutter initially in retracted position; said upper and lower drill bit bodies and mandrels having intercommunicating fluid passages therein; and lower lock means releasable by fluid pumped through said passages for holding said lower cutter supporting member and lower cutter initially in retracted position, whereby said lower lock means is first released by fluid pumped through said passages to enable said lower cutter supporting member and lower cutter to be expanded outwardly to provide a shoulder in a bore hole for stopping downward movement of said lower bit body to permit downward telescoping movement of said upper mandrel in said upper body to release said upper lock means.

8. In rotary drill bit apparatus: a lower bit having a lower body; a lower supporting member mounted on said body for lateral outward movement with respect to said body; a cutter on said member; means for expanding said member and cutter outwardly of said body; means for limiting the maximum outward expansion of said member and cutter; an intermediate bit secured to the upper end of said lower bit, said intermediate bit having a body; an intermediate supporting member mounted on said intermediate bit body for lateral outward movement with respect to said intermediate body; an intermediate cutter on said intermediate member; means for expanding said intermediate member and intermediate cutter outwardly of said intermediate body to a greater extent than said lower cutter; means for limiting the expansion of said intermediate member and intermediate cutter to a maximum extent in which the cutting path of said intermediate cutter extends outwardly a greater radial distance than the cutting path of the lower cutter but in which said paths overlap; an upper bit secured to the upper end of said intermediate bit, said upper bit having a body; an upper supporting member mounted on said upper bit body for lateral outward movement with respect to said upper body; an upper cutter on said upper member; means for expanding said upper member and upper cutter outwardly of said upper body to a greater extent than said intermediate cutter, in which the cutting path of said upper cutter is greater than that of said intermediate cutter but overlaps the path of said intermediate cutter; said intermediate and upper cutters being disposed entirely inwardly of the outermost surfaces of their respective supporting members until said respective supporting members have been expanded partially outwardly, whereby said intermediate and lower cutters are prevented from penetrating the formation until they have been lowered into the enlarged bore produced by the lower cutter.

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