Oct. 4, 1955 A. W. KAMMERER 2,719,700

APPARATUS FOR ENLARGING WELL BORES

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Fig. 3.

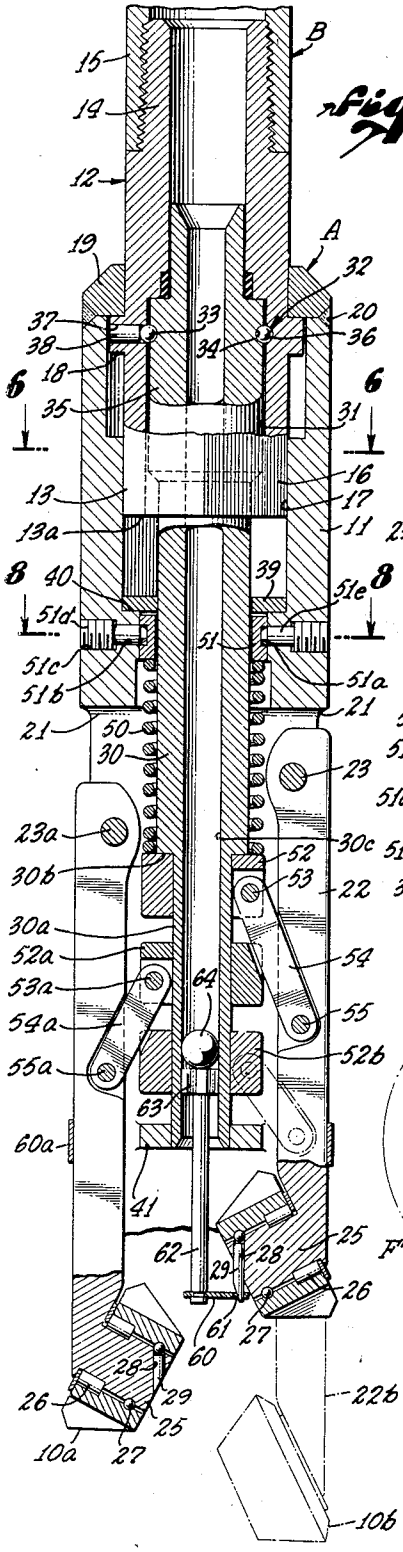


Fig. 1.

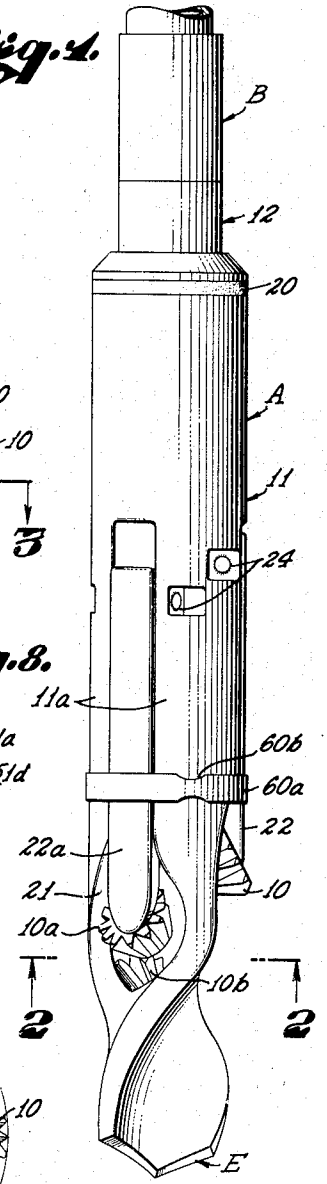


Fig. 2.

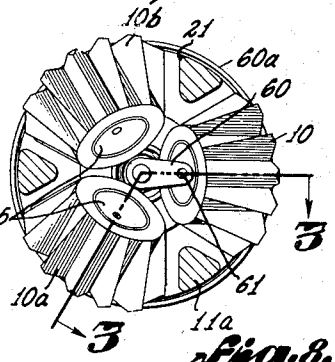


Fig. 8.

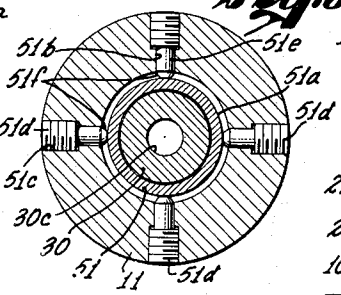
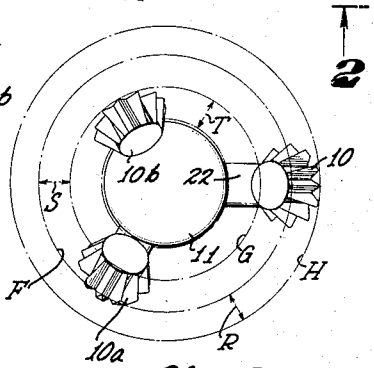


Fig. 7.



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Fig. 4.

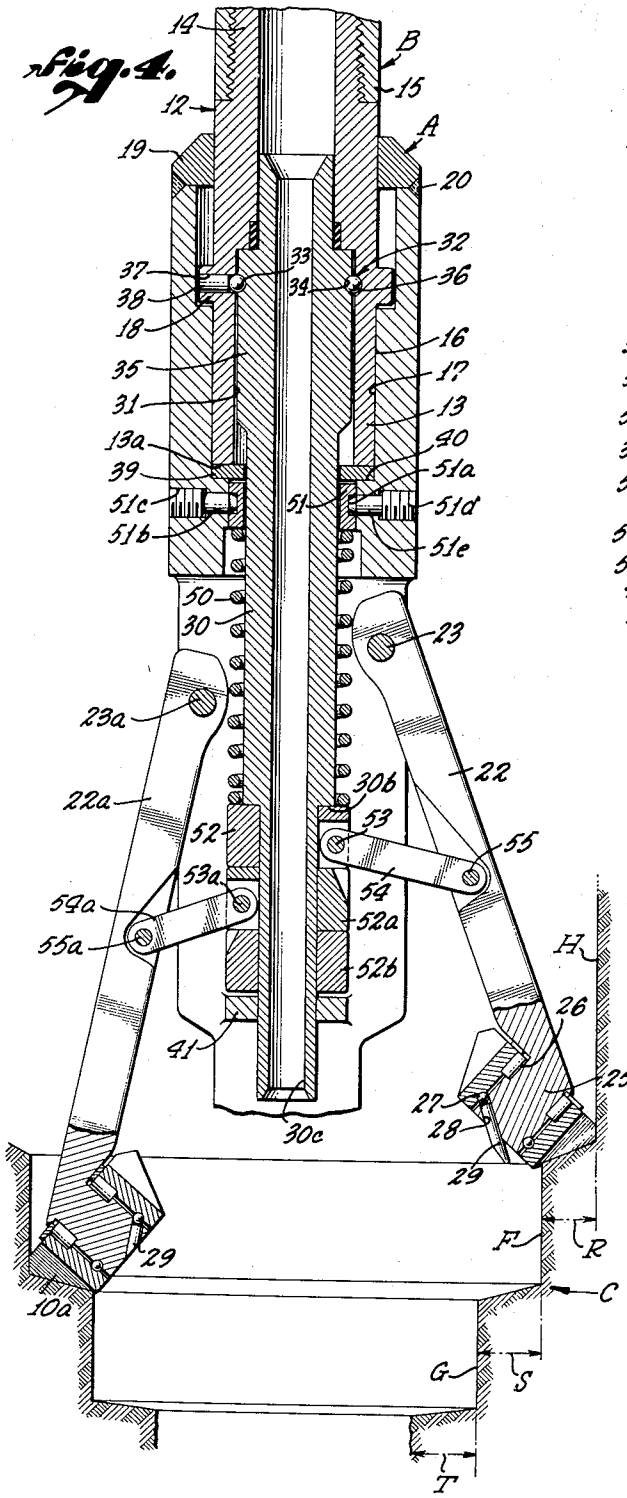


Fig. 5.

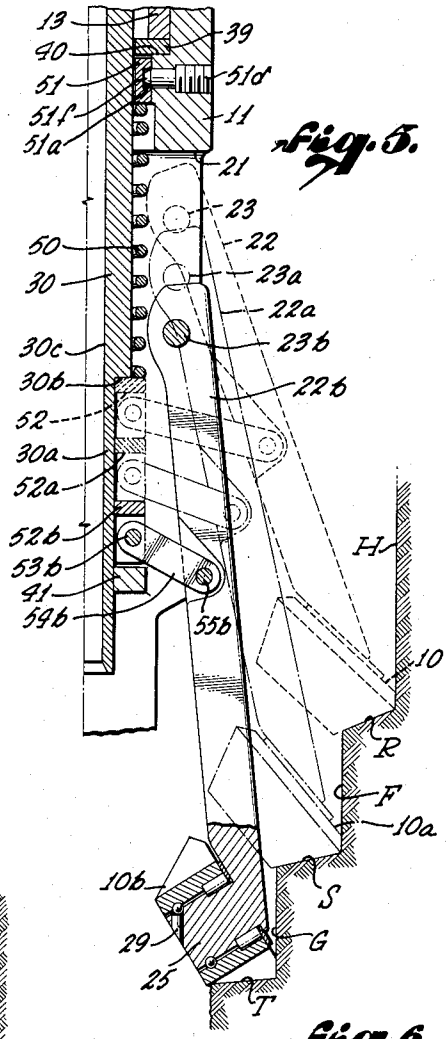
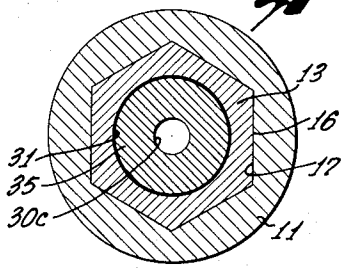


Fig. 6.



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United States Patent Office 2,719,700 Patented Oct. 4, 1955

2,719,700

APPARATUS FOR ENLARGING WELL BORES

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Application May 7, 1951, Serial No. 225,005

16 Claims. (Cl. 255—76)

The present invention relates to rotary drill bits, and more particularly to drill bits of the type having expandible cutters for drilling a hole below well casing larger in diameter than the inside diameter of the casing through which the bits must pass.

In my application for "Multiple Expansion Rotary Drill Bits," filed August 18, 1950, Serial No. 180,167, now Patent No. 2,650,072, an expansible type of rotary drill bit is illustrated for greatly enlarging the diameter of well bores through use of a plurality of cutters, which individually operate upon different portions of a formation shoulder in the well bore.

An object of the present invention is to provide an expansible drill bit having cutters that are expandible to different lateral extents from their retracted positions, for the purpose of operating simultaneously upon different portions of the bore hole formation, and in which the drill bit is more stable and has a greater tendency to drill a concentric hole.

Another object of the invention is to provide a drill bit of the expandible type having cutters individually operating upon different portions of a formation shoulder, in which the formation itself is caused to act upon the cutters; so as to stabilize them during their revolution in the hole, causing the cutters to mutually support one another and to trace paths on the formation shoulder concentric of the hole axis.

A further object of the invention is to provide a rotary drill bit of the expandible type having cutters that collectively form a stepped shoulder in the well bore, which shoulder coacts with the cutters to stabilize the drill bit and minimize the shock loads to which it would otherwise be subjected.

Yet another object of the invention is to provide a rotary drill bit having expandible cutters that are so disposed with respect to each other as to permit the use of larger cutters which may yet be fully retracted within the body of the drill bit.

Still a further object of the invention is to provide an improved spring seat arrangement in an expansible drill bit which facilitates assembly of the bit parts.

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 side elevation of an expansible rotary drill bit embodying the present invention;

Fig. 2 is a cross-section, on an enlarged scale, taken generally along the line 2—2 on Fig. 1;

Fig. 3 is a longitudinal section through the drill bit,

taken along the line 3—3 on Fig. 2, with the cutters in retracted position;

Fig. 4 is a view similar to Fig. 3, illustrating several of the cutters in their outwardly expanded positions;

Fig. 5 is a somewhat diagrammatic view illustrating the different extents of expansion of the cutters, and their manner of forming and operating upon a stepped formation shoulder, which they produce in the well bore;

Fig. 6 is a cross-section taken along the line 6—6 on Fig. 3;

Fig. 7 is a somewhat diagrammatic view looking upwardly from beneath the drill bit, disclosing the different paths traced on the formation shoulder by the cutters when in expanded positions;

Fig. 8 is a cross-section taken along the line 8—8 on Fig. 3.

The drill bit A disclosed in the drawings may be attached to the lower end of a string of drill pipe B, by means of which the bit can be lowered through a well casing (not shown), for the purpose of greatly enlarging the well bore below the casing shoe (not shown). The drill bit cutters **10**, **10***a*, **10***b* are expanded outwardly to different extents, for the purpose of producing a stepped annular formation shoulder C in the well bore, the cutters operating upon different annular portions R, S, T of this shoulder, for the purpose of collectively enlarging the diameter of the well bore to the desired extent.

The drill bit A includes an elongate main body **11**, in which a tubular member **12** is piloted. The upper portion of this member is constituted by a kelly **13** having an upper threaded pin **14** screwed into a sub **15**, which may form the lowermost portion of the drill pipe B. The drill stem member **13** itself is slidably splined in the upper portion of the body, as by forming the exterior **16** of the kelly of hexagonal shape (Fig. 6), fitting within a corresponding hexagonal socket **17** in the body. The drill stem member is provided with an external flange **18** fitting within the body, and serving the purpose of holding the drill stem member within the body. After the drill stem member **13** has been placed into the upper end of the body **11**, a retainer ring **19** may be disposed over the member above its flange **18** and secured to the upper end of the body, as by use of welding material **20**, in order to prevent upward withdrawal of the kelly **13** from the body **11**.

The body has a plurality of depending leg portions **11***a* defining longitudinal transverse body slots **21**, in which cutter supporting members **22**, **22***a*, **22***b* are disposed. These cutter supporting members are preferably equiangularly spaced around the bit axis and have their upper ends mounted on pivot or hinge pins **23** extending across the body slots **21** and suitably secured to the body, as by the use of welding material **24**. The cutter supporting legs **22**, **22***a*, **22***b* depend from their hinge pins **23**, **23***a*, **23***b* to a substantial extent. They each have a bearing supporting pin **25** at the lower end, on which a roller side cutter **10**, **10***a* or **10***b* is rotatably mounted. Anti-friction roller and ball bearing elements **26**, **27** are disposed between each bearing supporting pin **25** and cutter **10**, **10***a* or **10***b*, to reduce the friction therebetween. The ball bearing elements **27** also serve to retain the cutter on the bearing supporting pin.

The balls **27** may be inserted between each cutter **10**, **10***a*, or **10***b* and its associated pin **25** through a passage **28** in the latter, which is closed by a suitable plug **29** welded, or otherwise suitably secured, to the pin.

The bearing supporting members **22**, **22***a*, **22***b*, and their cutters **10**, **10***a*, **10***b*, may occupy retracted positions substantially entirely within the confines of the main bit body **11**, or they may be expanded outwardly of the body to a larger effective diameter than the inside diameter of a casing string (not shown) through

which the bit is moved, for the purpose of enlarging the well bore below the casing shoe (not shown). In expanding the cutters 10, 10*a*, 10*b*, their supporting legs 22, 22*a*, 22*b* are swung outwardly about the hinge pins 23, 23*a*, 23*b* to a predetermined extent.

The device for holding the cutters expanded includes a lower tubular member 30, which actually forms part of the mandrel 12, and which is piloted within a lower socket 31 in the kelly 13. The kelly 13 and lower tubular member 30 are assembled together for joint longitudinal movement by a swivel connection 32, which enables the lower tubular member to move angularly with respect to the upper kelly. Such swivel connection may include ball bearing elements 33 mounted in a raceway 34 formed on an enlarged portion 35 of the lower member 30, the ball bearing elements also being rollable in an internal raceway 36 formed in the kelly itself. The balls may be inserted in place through a passage 37 extending through the kelly flange 18. After the required number of balls have been mounted in the raceways 34, 36, they are held in assembled position by a plug 38 in the passageway 37, which is prevented from inadvertent outward movement from the passageway by engaging the main bit body 11.

The lower tubular member 30 depends from its boss portion 35 through a guide and thrust member 39, which rests upon a shoulder 40 formed on the body. This thrust member initially is disposed below the lower end of the kelly 13; so as to allow the kelly 13 and tubular member 30 to be moved downwardly, for the purpose of holding the cutters 10, 10*a*, 10*b* and their supporting members 22, 22*a*, 22*b* in an outward position, resisting inward movement of the cutters from their outward position, and, under some conditions, actually shifting the cutters to their outwardly expanded position. The lower end of the mandrel member 30 is slidable in a lower guide 41 integral with the body 11, and forming a support for the mandrel to resist its lateral movement.

The cutter supporting members or legs 22, 22*a*, 22*b* and the cutters carried thereby may be expanded outwardly by a compressed helical expander spring 50 encompassing the tubular member 30 and bearing upon an upper spring seat 51 attached to the body 11 immediately below the guide member 39. The lower end of the spring bears upon an upper thrust block 52 that has a pin 53 carrying the upper end of a link or connecting rod 54, whose lower end is pivotally mounted on a pin 55 suitably secured to the cutter supporting leg 22.

The upper spring seat 51 is in the form of an annular member having an external circumferential groove 51*a* that may be disposed opposite a plurality of holes 51*b* extending through the body. The outer ends 51*c* of these holes are counterbored and threaded to receive the threaded portions of set screws 51*d*, whose inner shank portions 51*e* extend through the holes and into the seat groove 51*a*.

In assembling the spring 50 in appropriate position between its upper seat 51 and the upper thrust block 52, the tubular mandrel 12 is telescoped into the body until the lower end 13*a* of the kelly engages the guide member 39, which bears upon the upper spring seat 51. The tubular member is forced inwardly of the body 11 to force the guide member 39 and spring seat 51 downwardly to compress the spring 50, as limited by engagement of the guide member 39 with the body portion at the lower end of the hexagonal socket 17. When the guide member 39 engages the body, the circumferential groove 51*a* of the spring seat is disposed opposite the lateral holes 51*b*, whereupon the set screws 51*c* may be threaded in the holes, their inner tapered ends 51*f* engaging the lower side of the circumferential groove 51*a* to force the spring seat 51 slightly downwardly away from the thrust member 39. The ends 51*f* of the set screws remain in the groove 51*a*, to hold the spring seat 51 in appropriate position within the body.

Slidable on the mandrel 30 below the upper thrust block 52 is an intermediate thrust block 52*a* having a pin 53*a* on which the upper end of a thrust link or connecting rod 54*a* is pivoted, the lower end of this link being pivoted on a pin 55*a* secured to another one of the cutter supporting members or legs 22*a*. Yet another or lower thrust block 52*b* is slidable on the mandrel below the intermediate thrust block 52*a* and carries the pin 53*b* on which the upper end of a lowermost link 54*b* is pivotally mounted, the lower end of this link being pivoted on a pin 55*b* secured to still a third cutter supporting member or leg 22*b*.

As illustrated, the upper, intermediate and lower thrust blocks 52, 52*a*, 52*b* are slidable on a reduced diameter lower portion 30*a* of the tubular member 30, the upper thrust block 52 being initially disposed adjacent a mandrel shoulder 30*b*, which may engage the upper portion of the upper thrust block.

One manner of expanding the cutters outwardly is to allow the compressed spring 50 to expand, which will shift the upper thrust block 52 downwardly on the mandrel 30, and, through the agency of the link 54, urge the cutter supporting leg 22 and the cutter 10 outwardly. The upper thrust block 52 will move downwardly under the influence of the spring 50 until it engages the intermediate thrust block 52*a*, the spring then moving both the upper and intermediate blocks 52, 52*a* downwardly as a unit to urge the cutter supporting legs 22 and 22*a* outwardly. Thereafter, as the spring 50 continues to expand, the intermediate thrust block 52*a* engages the lower thrust block 52*b*, the three blocks 52, 52*a*, 52*b* moving downwardly as a unit to urge all three of the cutter supporting legs 22, 22*a*, 22*b* and their associated cutters 10, 10*a*, 10*b* outwardly, through the agency of the intermediate connecting rods 54, 54*a*, 54*b*. The extent of expansion is limited by engagement of the lower thrust block 52*b* with the lower body guide 41.

The spring 50 can be effective to urge the cutters outwardly in the event it is desired to begin enlarging the well bore below the well casing at a point above the bottom of the hole. If desired, the tubular mandrel 30 can be employed, in the absence of the expander spring 50, or to supplement the expander spring, in urging the cutters 10, 10*a*, 10*b* outwardly, particularly if downward movement of the body 11 can be prevented or resisted by the bottom of the well bore, as upon resting of a pilot bit E on the bottom. It is to be noted that the driving mandrel 12 originally occupied an upper position with respect to the body 11. Downward movement of the mandrel by urging the drill pipe string B downwardly will force the mandrel shoulder 30*b* against the upper thrust block 52 and first urge the cutter supporting leg 22 and its cutter 10 outwardly. As downward movement of the mandrel 12 within the body 11 continues, the upper thrust block engages the intermediate block 52*a*, to urge the second cutter supporting leg 22*a* and cutter 10*a* outwardly. Continued downward movement will then cause the intermediate block to engage the lowermost block 52*b*, for the purpose of urging the third cutter supporting leg 22*b* and cutter 10b outwardly. The extent of such urging will be determined by engagement of the lower end 13*a* of the kelly 13 with the upper thrust and guide washer 39.

The cutters 10, 10*a*, 10*b* may be locked in retracted position initially by a holding arrangement, with the expander spring 50 fully compressed, and with the driving mandrel 12 occupying an upward position within the body 11; so as to insure downward passage of the bit through the well casing, and to enable the bit to be moved to any desired point in the well bore below the casing shoe before the hole enlarging operation is commenced.

This holding device may include a holding plate or arm 60 having a hole 61 receiving the lower end of the ball retaining plug 29 for the cutter 10 and supporting arm 22. The plate 60 will prevent outward expansion of the cutter 10 until the former member is removed, hold-

ing the expander spring **50** in its highly compressed condition and preventing its expansion, for the purpose of urging the supporting member **22** and the cutter **10** outwardly. The spring **50** is initially tending to urge only the cutter supporting member **22** and its cutter **10** outwardly, in view of the force exerted by the spring upon the upper thrust block **52** and the link **54** interconnecting the latter to the supporting member **22**. The other cutters **10***a*, **10***b*, and their respective supporting members **22***a*, **22***b*, do not have any force exerted upon them; so long as the holding arm **60** is in place. However, it is preferred to hold them positively in a retracted position during lowering of the apparatus through the well bore to the point at which the hole enlarging operation is to commence. Thus, the cutters **10***a*, **10***b* are held initially in retracted position by a metallic strap **60***a*, such as relatively thin box strapping, embracing their supporting members **22***a*, **22***b* and the body, as well as the supporting member **22**.

Removal of the holding plate **60** may be effective hydraulically. A central rod **62** is secured to the plate and projects upwardly into the central passage **30***c* formed through the lower tubular member **30**. A fluted head **63** at the upper end of the rod is freely slidable within the passage **30***c*, to enable fluid to flow upwardly through the tubular member passage and the kelly passage **13***b* and into the drill pipe string B. A ball **64** may also be disposed in the passage **30***c*, or may be dropped down the drill pipe B when the cutters are to be expanded, this ball having a diameter substantially equal to the diameter of the passage **30***c*; so as to function as a piston and enable the fluid under pressure within the drill pipe B and drill bit to force the central rod **62** downwardly and remove the holding plate **60** from the plug element **29** of the supporting member **22**. Such removal allows the spring **50** to expand, to bear upon the strap and break it; releasing the other supporting members **22***a*, **22***b* and their cutters **10***a*, **10***b* for lateral outward shifting. All of the cutters and their supporting members can now be expanded either by the expander spring **50**, the driving mandrel **12**, or both. If the spring **50** is incapable of breaking the strap **60***a*, rotation of the bit and rubbing of the strap upon the wall of the formation will produce its disruption. In this connection, disruption may be facilitated by providing a weakened section **60***b* in the strap.

It is desired to have each of the cutter members operate upon a particular annular portion of the formation shoulder. Thus, the cutter member **10** is to operate around the annular portion R of the shoulder (see Fig. 5); the cutter member **10***a* is to operate upon the annular portion S of the shoulder; and the cutter member **10***b* is to operate upon the annular portion T of the shoulder. Inasmuch as these annular portions are disposed different lateral distances from the axis of the well bore, the cutters are to be expanded outwardly different amounts to locate each cutter at its proper position upon the formation shoulder C.

Since the cutter supporting leg **22** and its cutter **10** are to be swung outwardly from their fully retracted position to the greatest extent, the pin connection **55** between the connecting rod **54** and the cutter supporting leg **22** is disposed a lesser distance from the hinge pin **23** of the cutter supporting leg **22**, than the distance from its hinge pin **23***a* of the pin connection **55***a* between the second cutter supporting leg **22***a* and its connecting rod **54***a*. Similarly, the distance from the hinge pin **23***b* for the cutter supporting leg **22***b* and its pin connection **55***b* with its connecting rod **54***b* is greater than the distance between the hinge pin of the second leg **22***a* and its pin connection **55***a* to its link or connecting rod **54***a*. Accordingly, for the same longitudinal movement, the upper thrust block **52** will swing its cutter supporting leg **22** a greater arcuate extent than the intermediate thrust block **52***a* will swing its cutter supporting leg **22***a*, and this latter thrust block will, in turn, swing the cutter supporting leg **22***a* a greater arcuate distance than the lower thrust block **52***b* swings the cutter supporting leg **22***b*.

Despite the fact that the lever arm distance of the pins **55**, **55***a*, **55***b* connecting the rods **54**, **54***a*, **54***b* to the cutter supporting members is different, it is desired to have the first cutter supporting leg **22** swing outwardly to a certain arcuate extent before the intermediate supporting leg **22***a* commences moving outwardly from its retracted position. Also, this intermediate leg **22***a* is to swing outwardly from its fully retracted position to a certain extent before the remaining leg **22***b* and its cutter **10***b* commences moving outwardly. To accomplish this purpose, the intermediate thrust block **52***a* is initially spaced downwardly from the upper thrust block by a certain distance; so that the upper thrust block **52** must move downwardly through this distance and swing its cutter supporting leg **22** and cutter **10** outwardly before the upper thrust block **52** engages the intermediate thrust block **52***a*, to commence outward swinging of the intermediate leg **22***a* and cutter **10***a*. Similarly, a longitudinal space exists initially between the intermediate and lower thrust blocks **52***a*, **52***b*, to require the intermediate thrust block **52***a* to swing the intermediate cutter **10***a* outwardly to a certain arcuate extent before it engages the lower thrust block **52***b* and shifts the latter downwardly, to effect outward swinging of the cutter supporting leg **22***b* and cutter **10***b*.

Thus, the upper thrust block **52** will move downwardly to shift the cutter **10** outwardly, and while the drill string and bit is rotating, cause the cutter to start producing the formation shoulder C. After an inner portion of this formation shoulder, corresponding to the distance T in Fig. 5, is formed by the outward expansion of the cutter **10**, the upper thrust block **52** will then engage the intermediate thrust block **52***a* and commence shifting the intermediate cutter **10***a* outwardly. The first cutter **10** has been expanded outwardly to a greater extent than the second cutter **10***a* and will remain in this advanced position during rotation of the drill bit, whereby the first cutter **10** enlarges the formation shoulder C to a still greater lateral extent, as by commencing to operate upon a formation shoulder portion corresponding to the distance S in Fig. 5. The second cutter **10***a*, during further outward swinging of the first cutter **10**, will be disposed over the inner distance T of the formation shoulder. As the two thrust blocks **52**, **52***a* move downwardly as a unit along the mandrel **30**, to expand their cutters **10**, **10***a* outwardly, the intermediate block engages the lower thrust block **52***b* and commences urging the remaining cutter supporting leg **22***b* and its cutter **10***b* outwardly. Inasmuch as all three thrust blocks are contacting one another, they will swing outwardly simultaneously, the first supporting member **22** and its cutter **10** leading the second supporting member **22***a* and its cutter **10***a* in lateral extent, and the second cutter supporting member and its cutter, in turn, leading the remaining supporting member **22***b* and its cutter **10***b* in lateral extent. The blocks all continue moving downwardly to their maximum extent, the first cutter **10** swinging across the entire formation shoulder distance C, and finally being capable of rolling around the outermost annular portion R of the shoulder. The second cutter **10***a* is capable of rolling around the intermediate annular portion S of the shoulder, and the third cutter **10***b* is capable of rolling around the inner annular portion T of the shoulder.

In the event that the thrust blocks have been shifted downwardly by the spring **50**, the production of the full shoulder C will enable the operator to lower the drill pipe B slightly, to telescope the mandrel **12** within the body **11** until the lower end **13***a* of the kelly **13** engages the thrust washer **13***a*. The drilling weight can then be imposed directly through the kelly **13** onto the body **11**, and through the hinge pins **23**, **23***a*, **23***b* and supporting members **22**, **22***a*, **22***b* to the cutters **10**, **10***a*, **10***b*. At the same time, the mandrel shoulder **30***b* is disposed immediately

adjacent the upper thrust block **52**, in order to hold all of the thrust blocks in their downward position and preclude the reactive forces of the formation on the cutters from urging the latter inwardly to a position in which they would drill an undersized hole. In effect, the mandrel shoulder **30***b* locks or retains the cutters outwardly to their maximum expanded positions.

In order to stabilize the drill bit in the hole, decrease shocks that would otherwise be imposed thereon, and introduce a greater tendency to drill a concentric enlarged well bore, the cutters are longitudinally spaced with respect to each other; so as to have respective longitudinal wall portions of the well bore against which they can bear. A longitudinal spacing can be obtained by making the cutter supporting leg **22***a* for the cutter **10***a* longer than the length of the supporting leg **22** for the cutter **10**, and by making the cutter supporting leg **22***b* for the cutter **10***b* longer than the leg **22***a*.

Another mode of longitudinally spacing the cutters with respect to each other is to dispose the hinge pin **23***a* for the cutter **10***a* lower than the hinge pin **23** for the cutter **10**, and by disposing the hinge pin **23***b* for the cutter **10***b* lower than the hinge pin **23***a*. Although either of the above arrangements can be used to obtain longitudinal spacing of the cutters, both arrangements can also be employed, which is done in the present case. Thus, the lower disposition of the hinge pin **23***a* and the greater length of its associated supporting arm **22***a* places the cutter **10***a* lower than the cutter **10**; whereas, the still lower disposition of the hinge pin **23***b* and the greater length of the supporting leg **22***b* places the cutter **10***b* lower than the cutter **10***a*, as clearly illustrated in Fig. 5.

The cutter **10** operates upon the outermost formation shoulder R, its back tooth portions bearing upon the outermost wall H of the enlarged well bore. The cutter **10***a* operates upon a lower and intermediate formation shoulder portion S, with the back faces of its cutter teeth engaging the longitudinally extending intermediate wall F of the well bore. Again, the cutter **10***b* is disposed in a still lower position, operating upon the inner formation shoulder portion T and with the back faces of its cutter teeth engaging the inner enlarged longitudinal formation wall G.

In view of the stepped arrangement of the cutters and their engagement with their associated formation walls, the drill bit has greater stability during its hole enlarging operation, in view of the resistance provided by the formation walls H, F, G against the back faces of the cutters. There is less tendency for the drill bit to wobble in the well bore, which results in a greater tendency for the bit to drill an enlarged hole which is concentric to the axis of the well bore previously produced. In addition, the greater stability of the operation of the drill bit decreases any shock loads that might otherwise be imposed upon it.

The longitudinal spacing of the cutters from each other has yet a further important advantage. Such spacing enables each cutter to be made of a much larger diameter and still be fully retractable within the confines of the body **11**. If the cutters all were located in substantially the same cross-sectional plane, their diameter, or diameters, would be limited by the factor of interference with each other when in retracted position. With longitudinally spaced cutters, however, such interference is greatly minimized, if not eliminated entirely, each cutter being capable of spanning a greater chordal distance across the body when in retracted position, and, if desired, it can also be made of greater axial length so as to have greater tooth lengths. It is apparent from the drawings, and especially from Fig. 3, that the cutters do not interfere with each other, because of their relative longitudinal spacing along the body **11**.

The tool A is assembled with the parts occupying the positions illustrated in Fig. 3, the holding plate **60** and band **60***a* securing the cutters **10**, **10***a*, **10***b* in retracted position, with the spring **50** (when a spring is used) under maximum compression. The tubular mandrel **12** is disposed upwardly with respect to the body **11**, as limited by engagement of the kelly flange **18** with the retainer ring **19**. The bit is attached to the drill pipe B and lowered in the well bore.

When the location in the bore hole below the casing shoe has been reached at which the underreaming or hole enlarging operation is to commence, the pumps at the top of the well bore are started and the fluid in the drill pipe B subjected to pressure. This pressure acts upon the ball **64** and forces both the ball and the central rod **62** out of the passage **30***c*, which removes the holding plate **60** from the plug element **29** and allows the entire holding device to be ejected from the bit, leaving the passage **30***c* free and allowing the circulating fluid to exit from the lower end of the passage into the well bore, for the purpose of cleaning the cutters and washing the cuttings upwardly to the top of the well bore.

After the holding device has been removed, the spring **50** can expand to exert its force upon the band **60***a* to break it and release all of the legs **22**, **22***a*, **22***b* and their associated cutters. This expanding action first urges the upper block **52** downwardly, and, through the thrust link **54**, swings the first cutter **10** outwardly, forcing the cutter **10** against the wall of the formation. The drill pipe and the rotary drill bit are then rotated at the proper speed, without imposing drilling weight on the pipe and bit, the single cutter **10** digging into the wall of the formation and commencing the enlargement of the inner distance T of the stepped shoulder C therein under the influence of the spring **50**. As the spring expands, as a result of outward movement of the first cutter **10**, the upper block **52** moves down until it engages the intermediate thrust block **52***a*, which then urges the second cutter supporting member **22***a* and cutter **10***a* outwardly. The spring **50** continues its expansion, simultaneously shifting the first and second cutter supporting members **22**, **22***a* and their associated cutters **10**, **10***a* outwardly, the first cutter **10** leading the second cutter **10***a* and continuing to enlarge the lateral extent of the stepped formation shoulder, commencing the production of the intermediate distance S of the shoulder during rotation of the drill bit.

As the two cutters continue their outward movement, as a result of expansion of the spring and downward movement of the upper and intermediate thrust blocks, the intermediate block **52***a* finally engages the lower thrust block **52***b*, which is urged downwardly to swing the third cutter supporting member **22***b* and cutter **10***b* outwardly. Rotation of the drill bit is continued, the spring **50** shifting all three blocks downwardly together and urging the cutters outwardly, the first cutter producing the outermost portion R of the shoulder. When the lower block **52***b* engages the lower body guide **41**, the cutters **10**, **10***a*, **10***b* are precluded from swinging outwardly to any further extent, but they are then located with the outermost cutter **10** disposed upon the outermost portion R of the shoulder, the intermediate cutter **10***a* on the lower, intermediate portion S of the shoulder, and the innermost cutter **10***b* upon the still lower, innermost portion T of the shoulder. The annular paths R, S, T traced by the cutters upon the formation shoulder C during rotation of the bit preferably overlap one another to a slight extent; to insure that the cutter teeth will operate upon all portions of the stepped formation shoulder.

After the stepped formation shoulder C has been produced, down weight or drilling weight may be imposed on the drilling string B, which will telescope the mandrel **12** in the body **11** and shift the lower end **13***a* of the kelly **13** into engagement with the thrust washer **39**, the drilling weight then being transmitted directly through the body **11** to the cutter supporting members **22**, **22***a*, **22***b* and the cutters **10**, **10***a*, **10***b*. During the imposition of the drilling weight, the bit is rotated at the proper speed, the cutters operating upon their individual

and longitudinally spaced annular portions of the shoulder to remove the formation material in a downward direction, effecting the hole enlarging to the desired greatly increased diameter. As mentioned above, the downward telescoping of the driving mandrel **12** in the body **11** also locates the mandrel shoulder **30***b* immediately adjacent the upper thrust block **52**, to prevent any substantial retraction of the cutters from their maximum expanded positions.

When the well bore has been enlarged to the desired length, or upon the cutters becoming dull, the entire tool may be removed from the well bore merely by elevating the drill string B. Such elevating movement will lift the driving mandrel **12** within the main bit body **11** and will raise the mandrel shoulder **30***b* above the upper thrust block **52**. As the tool passes into an upper lesser diameter portion of the well bore, or into the well casing, the walls of the casing or well bore will engage the cutter supporting legs **22**, **22***a*, **22***b*, and force them inwardly against the action of the expander spring **50**. The cutter supporting members will ride the wall of the casing during removal of the bit to the top of the well bore.

As indicated above, if the pilot bit E is resting upon the bottom of the well bore, the spring **50** need not be used, expansion occurring as a result of shifting the driving mandrel **12** downwardly within the body **11**, to positively force the thrust blocks **52**, **52***a*, **52***b* downwardly and the cutter supporting legs and cutters outwardly in the above-noted sequence, in order to produce the stepped formation shoulder C. The extent of downward movement of the mandrel **12**, and of outward expansion of the cutters, is limited by engagement of the lower end **13***a* of the kelly **13** with the thrust and guide washer **39**.

It is, accordingly, apparent that an expansible drill bit has been provided which is capable of increasing the well bore diameter considerably. A stepped formation shoulder of substantially great lateral extent is first formed, and each cutter is caused to operate upon its individual portion of this shoulder; so that each cutter, in effect, constitutes an individual bit capable of enlarging the well bore from one diameter to another diameter. Thus, the innermost cutter **10***b* will enlarge the hole by the radius T, the next, or intermediate, cutter **10***a* will increase the size of the enlarged hole by the additional radius S, and the outer cutter **10** will further increase the size of the hole by the additional radius R. The cutters, collectively, progressively increase the bore hole diameter, and achieve the same purpose as if individual bits were run in the hole, one bit increasing the well bore size by the radius T, another bit then being run in the hole to further increase the hole size by the radius S, and still another bit being thereafter run in the hole to further increase the size of the bore by the radius R. By virtue of the present invention, a single bit achieves the same result as the plurality of bits, with a single run of the equipment in the bore hole. In addition, the ability to use roller cutters allows the bit to operate effectively in comparatively hard formations, and to increase the bore hole size in such formations considerably. Each cutter engages its own formation wall, and, because of the circumferential spacing of the cutters from each other, tend to maintain each other in their proper paths on the stepped formation shoulder concentrically of the well bore axis.

The inventor claims:

1. In an expansible drill bit: a body; a plurality of individual cutter means mounted on said body for lateral movement with respect to said body and each cutter means initially occupying a retracted position on said body; one of said cutter means extending along said body substantially lower than another of said cutter means; and means for shifting said individual cutter means laterally outward, said shifting means including instrumentalities movable with respect to said body and engageable with all of said individual cutter means for shifting said lower cutter means laterally from its initially retracted position to a lesser maximum extent than said another of said cutter means to place said lower cutter means a lesser maximum distance from the axis of said body than said another of said individual cutter means to cause said lower cutter means to form and operate upon a transverse formation shoulder disposed within and lower than the transverse formation shoulder formed and operated upon by said another of said individual cutter means.

2. In an expansible drill bit: a body; a plurality of individual cutter means mounted on said body for lateral movement with respect to said body and each cutter means initially occupying a retracted position on said body; said individual cutter means being circumferentially disposed around said body with one of said cutter means located substantially lower along said body than another of said cutter means; means engageable with said individual cutter means and movable with respect to said body for shifting said lower individual cutter means laterally outward from its initially retracted position to a lesser maximum extent than another individual cutter means located in a higher position along said body to place said lower cutter means a lesser maximum distance from the axis of said body than said higher cutter means to cause said lower cutter means to form and operate upon a transverse formation shoulder disposed within and lower than the transverse formation shoulder formed and operated upon by said higher cutter means; and stop means for limiting the extent of outward expansion of all of said individual cutter means.

3. In an expansible drill bit: a body; a plurality of supporting members disposed circumferentially around said body; a cutter mounted on each of said supporting members; means mounting said supporting members on said body for lateral movement with respect to said body; one of said supporting members being substantially longer than another of said supporting members so as to dispose the cutter on said one of said supporting members substantially lower along said body than the cutter on said another of said supporting members; and means engageable with said supporting members and movable with respect to said body for shifting said supporting members laterally of said body to shift said longer supporting member a lesser maximum lateral distance from the axis of said body than said another of said supporting members to place said lower cutter a lesser maximum distance from the axis of said body than said cutter on said another of said supporting members, to cause said lower cutter to form and operate upon a transverse formation shoulder disposed within and lower than the transverse formation shoulder formed and operated upon by said cutter on said another of said supporting members.

4. In an expansible drill bit: a body; a plurality of supporting members disposed circumferentially around said body; a cutter mounted on each of said supporting members; means mounting said supporting members on said body for lateral movement with respect to said body, said mounting means including instrumentalities mounting one of said supporting members at a substantially lower position on said body than another of said supporting members to dispose the cutter on said one of said supporting members at a substantially lower position along said body than the cutter on said another of said supporting members; and means engageable with said supporting members and movable with respect to said body for shifting said supporting members laterally of said body to shift said lower cutter a lesser maximum lateral distance from the axis of said body than another cutter to place said lower cutter a lesser maximum distance from the axis of said body than said another cutter to cause said lower cutter to form and operate upon a transverse formation shoulder disposed within and lower than the transverse formation shoulder formed and operated upon by said another cutter.

5. In an expansible drill bit: a body; a plurality of sup-

porting members disposed circumferentially around said body; a cutter mounted on each of said supporting members; means mounting said supporting members on said body for lateral movement with respect to said body, said mounting means including instrumentalities mounting one of said supporting members at a substantially lower position on said body than another of said supporting members to dispose the cutter on said one of said supporting members at a substantally lower position along said body than the cutter on said another of said supporting members; said one of said supporting members being longer than said another of said supporting members; and means engageable with said supporting members and movable with respect to said body for shifting said supporting members laterally of said body to shift the cutter on said one of said supporting members a lesser maximum lateral distance from the axis of said body than the cutter on said another of said supporting members to place said lower cutter a lesser maximum distance from the axis of said body than said cutter on said another of said supporting members, to cause said lower cutter to form and operate upon a transverse formation shoulder disposed within and lower than the transverse formation shoulder formed and operated upon by said cutter on said another of said supporting members.

6. In an expansible drill bit: a body; a plurality of supporting members disposed circumferentially around said body; a cutter mounted on each of said supporting members; means pivotally mounting said supporting members on said body for lateral movement with respect to said body; the pivotal axis of one of said supporting members being disposed substantially lower on said body than the pivotal axis of another of said supporting members to dispose the cutter on said one of said supporting members substantially lower along said body than the cutter on said another of said supporting members; and means engageable with said supporting members and movable with respect to said body for shifting said supporting members laterally of said body to shift said cutter on said one of said supporting members a lesser maximum lateral distance from the axis of said body than the cutter on said another of said supporting members to place said lower cutter a lesser maximum distance from the axis of said body than said cutter on said another of said supporting members, to cause said lower cutter to form and operate upon a transverse formation shoulder disposed within and lower than the transverse formation shoulder formed and operated upon by said cutter on said another of said supporting members.

7. In an expansible drill bit: a body; a plurality of supporting members disposed circumferentially around said body; a cutter mounted on each of said supporting members; means pivotally mounting said supporting members on said body for lateral movement with respect to said body; one of said supporting members being substantially longer than another of said supporting members to dispose the cutter on said one of said supporting members substantially lower along said body than the cutter on another of said supporting members; and means engageable with said supporting members and movable with respect to said body for shifting said supporting members laterally of said body to shift said lower cutter a lesser maximum lateral distance from the axis of said body than another cutter to place said lower cutter a lesser maximum distance from the axis of said body than said another cutter to cause said lower cutter to form and operate upon a transverse formation shoulder disposed within and lower than the transverse formation shoulder formed and operated upon by said another cutter.

8. In an expansible drill bit: a body; a plurality of supporting members disposed circumferentially around said body; a cutter mounted on each of said supporting members; means pivotally mounting said supporting members on said body for lateral movement with respect to said body; one of said supporting members being substantially longer than another of said supporting members, said one of said supporting members having its pivotal axis substantially lower than the pivotal axis of said another of said supporting members, to dispose the cutter on said one of said supporting members substantially lower than the cutter on said another of said supporting members; and means engageable with said supporting members and movable with respect to said body for shifting said supporting members laterally of said body to shift said lower cutter a lesser maximum lateral distance from the axis of said body than another cutter to place said lower cutter a lesser maximum distance from the axis of said body than said another cutter to cause said lower cutter to form and operate upon a transverse formation shoulder disposed within and lower than the transverse formation shoulder formed and operated upon by said another cutter.

9. In an expansible drill bit: a body; a plurality of supporting members disposed circumferentially around said body; one of said supporting members being disposed higher along said body than another of said supporting members; a cutter mounted on each of said supporting members; means mounting said supporting members on said body for lateral movement with respect to said body; means engageable with said supporting members and movable with respect to said body for shifting said supporting members laterally of said body to shift one of said cutters a greater maximum lateral distance from the axis of said body than another cutter; latch means secured to said higher supporting member only for holding said higher supporting member in retracted position; and a readily breakable member surrounding said supporting members to hold said another of said supporting members in retracted position.

10. In an expansible drill bit: a body; a plurality of supporting members disposed circumferentially around said body; one of said supporting members being disposed higher along said body than another of said supporting members; a cutter mounted on each of said supporting members; means mounting said supporting members on said body for lateral movement with respect to said body; spring means engageable with said supporting members and movable with respect to said body for shifting said supporting members laterally of said body to shift one of said cutters a greater lateral maximum distance from the axis of said body than another cutter; latch means secured to said higher supporting member only to prevent expansion of said spring means and to hold said higher supporting member in retracted position; and means encompassing all of said supporting members to hold said another of said supporting members in retracted position.

11. In an expansible drill bit: a body; a plurality of individual cutter means mounted on said body for lateral movement with respect to said body; means for shifting said individual cutter means laterally outward, including a stressed spring; a spring seat disposed above said spring and against which said spring bears, said spring seat having a peripheral groove therein; and pins extending generally radially through said body and into said groove to secure said spring seat to said body.

12. In an expansible drill bit: a body; a plurality of individual cutter means mounted on said body for lateral movement with respect to said body; means for shifting said individual cutter means laterally outward, including a stressed spring; a spring seat disposed above said spring and against which said spring bears, said spring seat having a peripheral groove therein; and elements threaded generally radially into said body and having tapered ends adapted to be guided into and disposed within said groove to secure said spring seat to said body.

13. In an expansible drill bit: a body; a plurality of supporting members disposed circumferentially around said body; a cutter mounted on each of said supporting members; means mounting said supporting members on said body for lateral movement with respect to said body; means including a spring for shifting said supporting

members laterally of said body; means connectible to a drill string and slidably splined to said body for holding said supporting members outwardly of said body; a movable guide element engageable by said connectible means to limit longitudinal movement of said connectible means with respect to said body in one direction; a spring seat engageable with said spring and guide element and movable longitudinally of said body by said connectible means and guide element to compress said spring; and means extending laterally through said body and engaging said spring seat to secure said spring seat to said body.

14. In an expansible drill bit: a body; a plurality of supporting members disposed circumferentially around said body; a cutter mounted on each of said supporting members; means mounting said supporting members on said body for lateral movement with respect to said body; means including a spring for shifting said supporting members laterally of said body; means connectible to a drill string and slidably splined to said body for holding said supporting members outwardly of said body; a movable guide element engageable by said connectible means to limit longitudinal movement of said connectible means with respect to said body in one direction; a spring seat engageable with said spring and guide element and movable longitudinally of said body by said connectible means and guide element to compress said spring, said spring seat having a circumferential groove; and elements threaded into said body and disposed in said groove to retain said spring seat in said body.

15. In an expansible drill bit: a body; a plurality of supporting members disposed circumferentially around said body; a conical cutter mounted on each of said supporting members for rotation on said supporting member about an axis inclined inwardly and downwardly and to form a transverse shoulder in the formation of a bore hole in which the drill bit is disposed; means mounting said supporting members on said body for lateral movement with respect to said body; one of said supporting members being substantially longer than another of said supporting members so as to dispose the cutter on said one of said supporting members substantially lower along

said body than the cutter on said another of said supporting members; and means engageable with said supporting members and movable with respect to said body for shifting said longer supporting member laterally a lesser distance than said another supporting member to cause said cutter on said longer supporting member to form and operate upon a transverse formation shoulder disposed within and lower than the transverse formation shoulder formed and operated upon by said cutter on said another supporting member.

16. In an expansible drill bit: a body; a plurality of supporting members disposed circumferentially around said body; a conical cutter mounted on each of said supporting members for rotation on said supporting member about an axis inclined inwardly and downwardly and to form a transverse shoulder in the formation of a bore hole in which the drill bit is disposed; means mounting said supporting members on said body for lateral movement with respect to said body; one of said supporting members and the cutter mounted thereon being disposed along said body substantially lower than another of said supporting members and the cutter mounted thereon; and means engageable with said supporting members and movable with respect to said body for shifting said lower supporting member and its cutter laterally a lesser distance than said other of said supporting members and its cutter to cause said cutter on said lower supporting member to form and operate upon a transverse formation shoulder disposed within and lower than the transverse formation shoulder formed and operated upon by said cutter on said other supporting member.

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