

Oct. 4, 1955

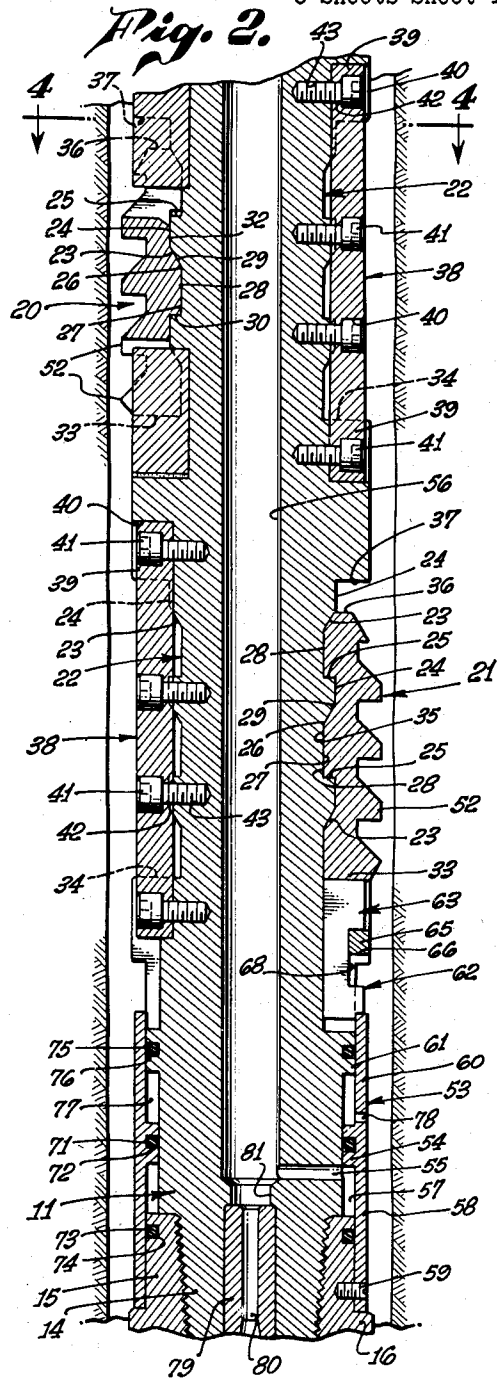
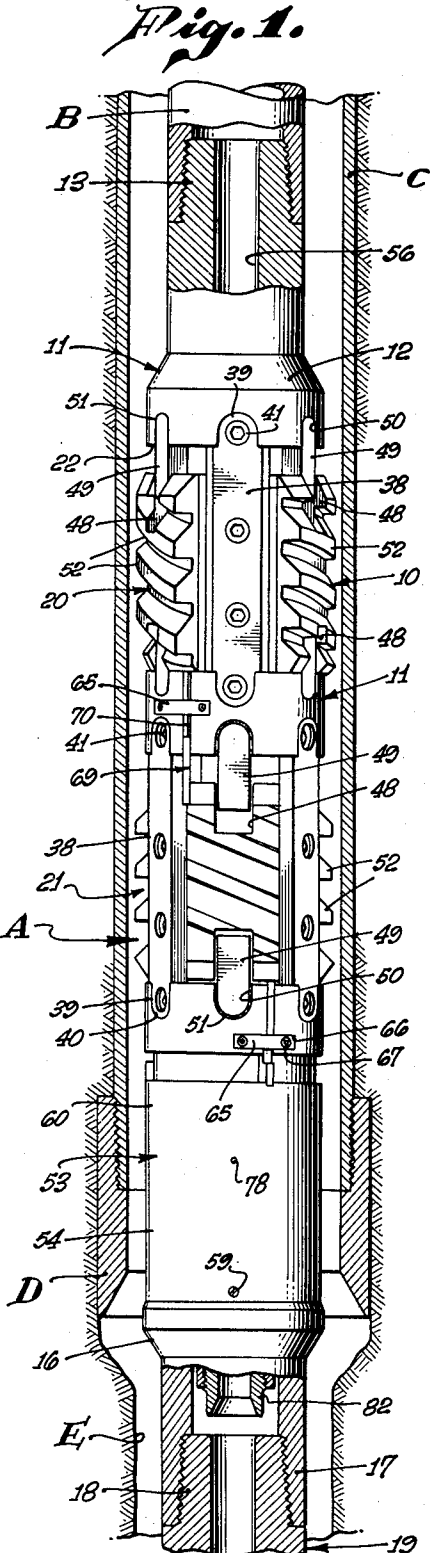
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2,719,699

EXPANSIBLE DRILL BITS

Filed July 3, 1951

5 Sheets-Sheet 1



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Fig. 3.

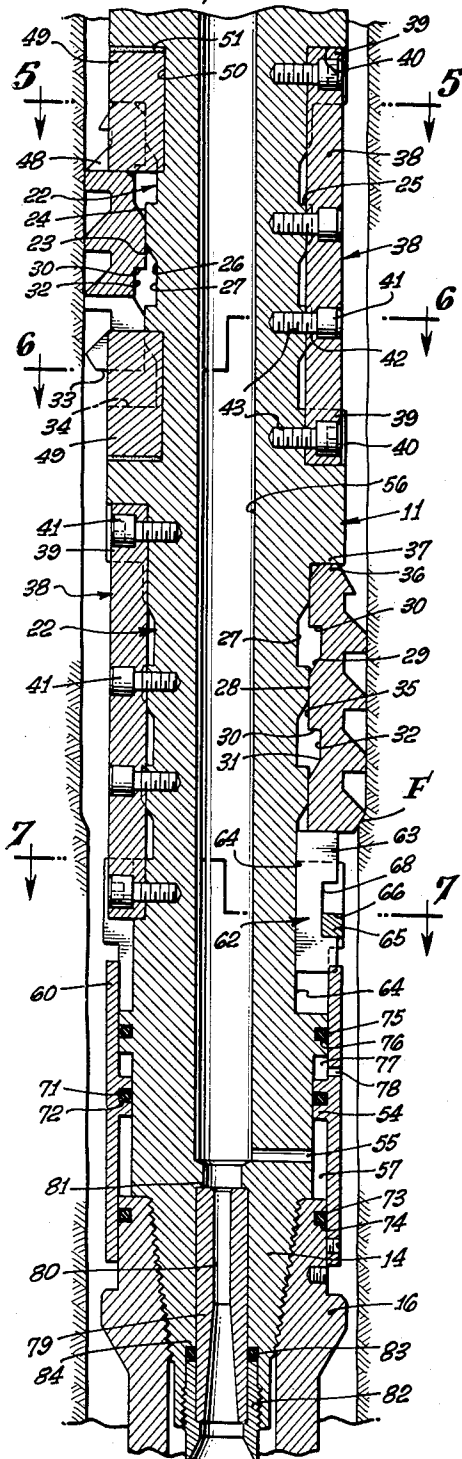


Fig. 4.

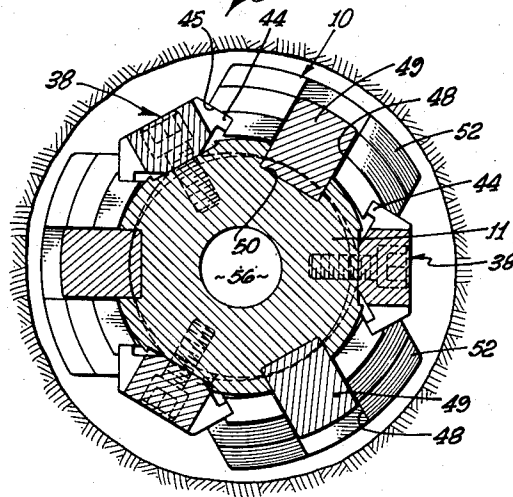
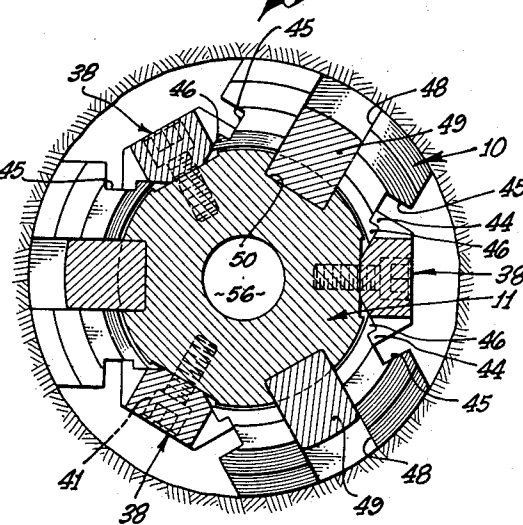


Fig. 5.



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Fig. 6.

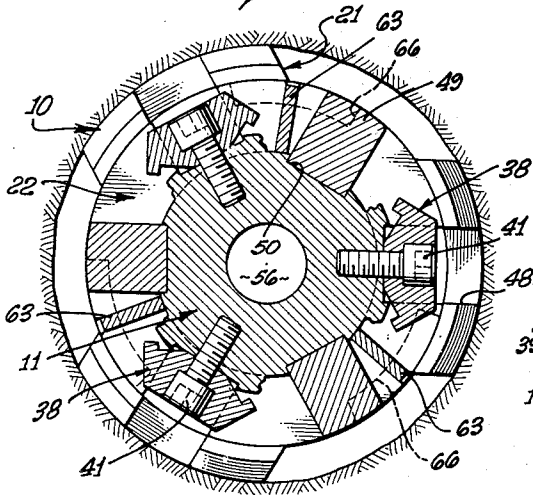


Fig. 7.

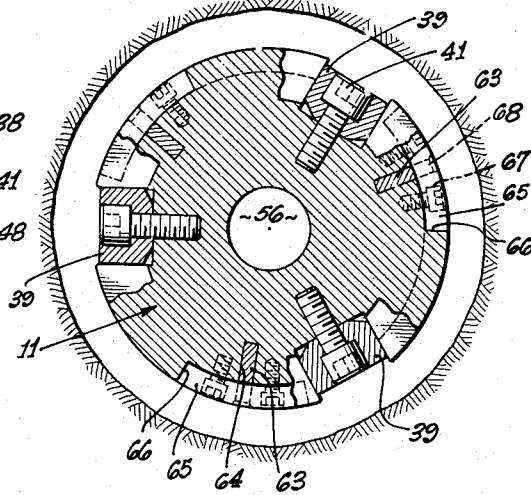


Fig. 8.

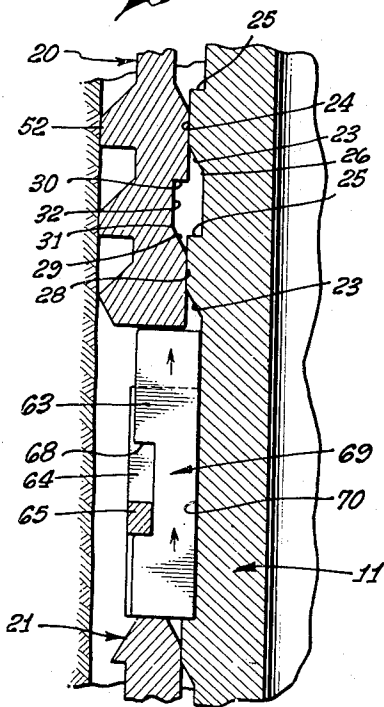
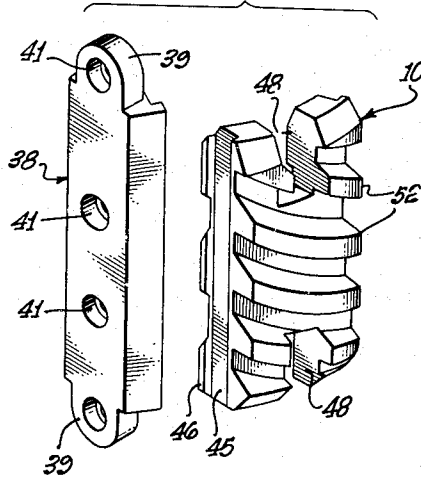


Fig. 9.



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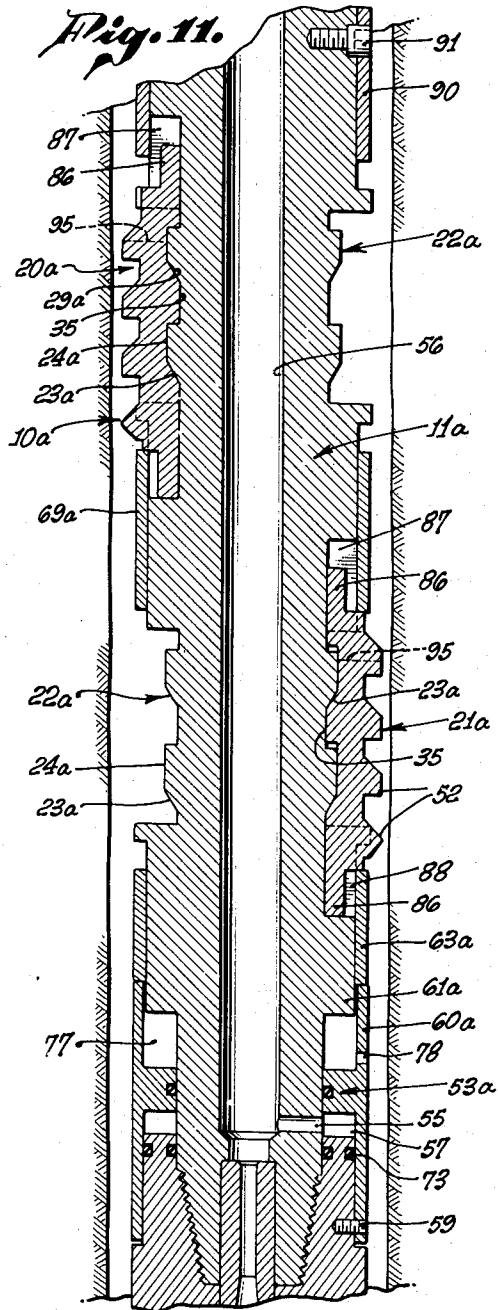
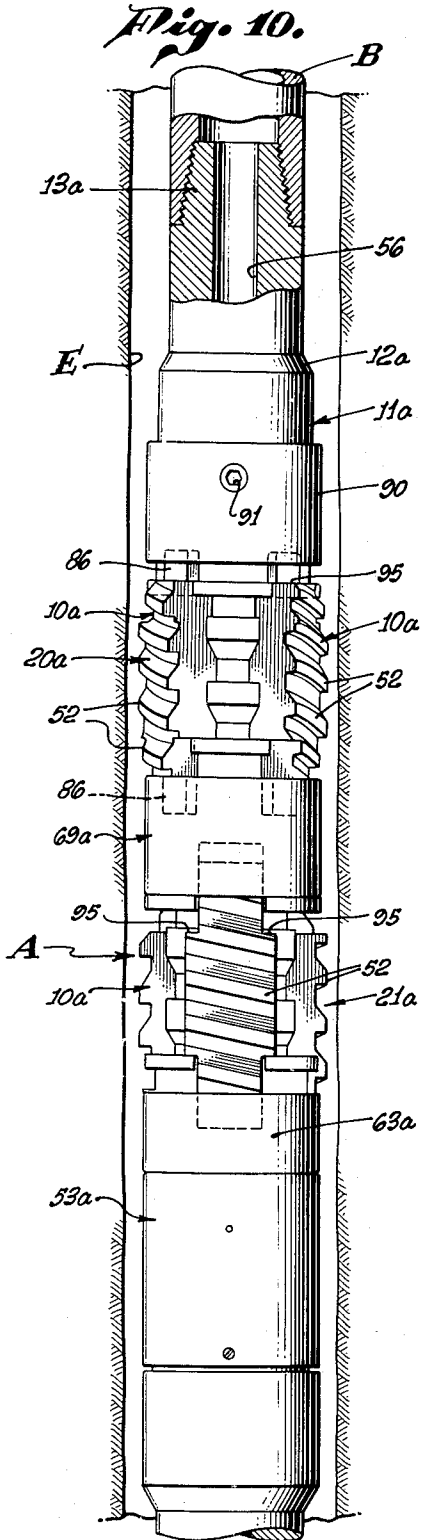
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EXPANSIBLE DRILL BITS

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Fig. 12.

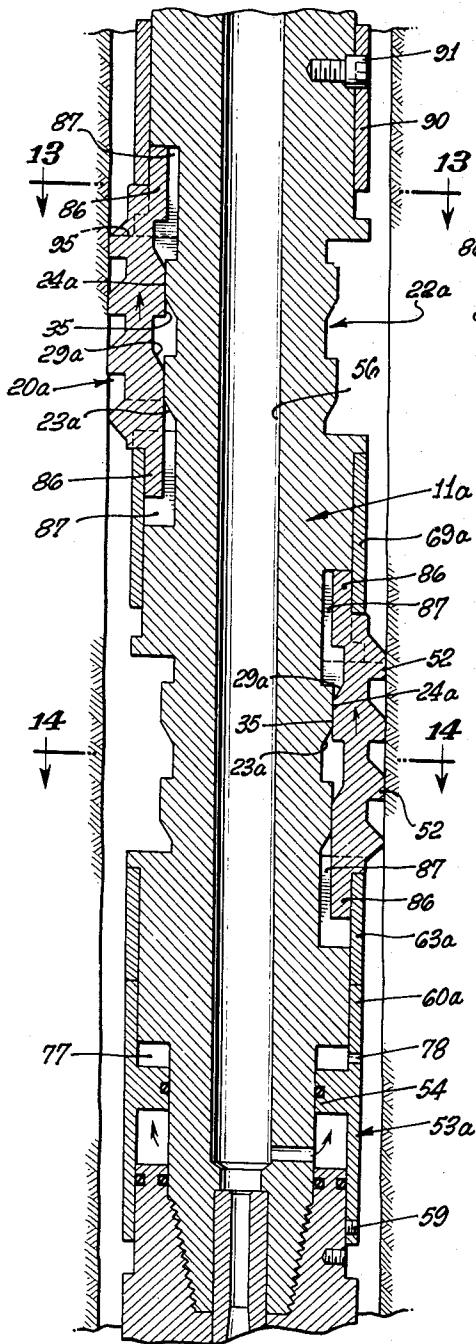


Fig. 13.

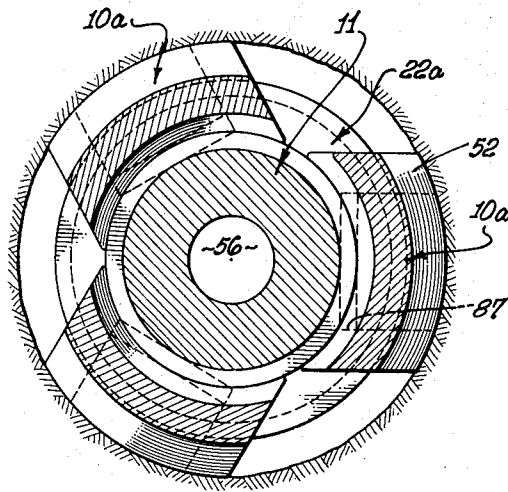
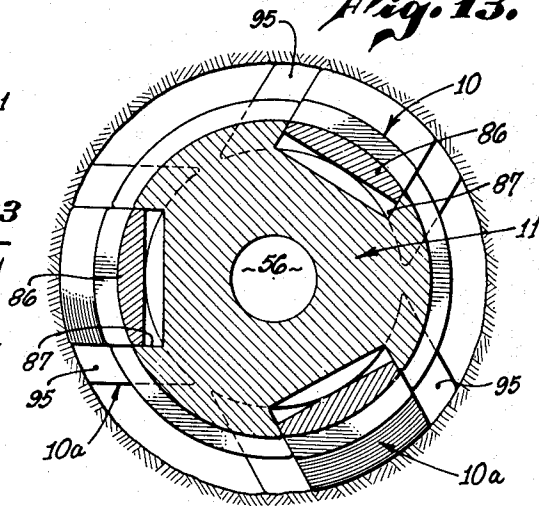


Fig. 14.

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2,719,699

EXPANSIBLE DRILL BITS

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Application July 3, 1951, Serial No. 235,071

21 Claims. (Cl. 255—75)

The present invention relates to drill bits, and more particularly to drill bits having expandible cutters for enlarging a well bore below a string of casing to a greater diameter than the inside diameter of the casing string itself.

An object of the present invention is to provide improved expansible drill bits capable of enlarging the diameters of previously drilled well bores.

Another object of the invention is to provide drill bits that can enlarge the diameters of well bores as a result of rotating the drill bits or of longitudinally moving the drill bits, assurance being had in both cases that the full circumference of the well bores will be covered by the drill bit cutters to produce enlarged well bores of the desired circular cross-sections.

A further object of the invention is to expand the cutters of a drill bit outwardly hydraulically and to positively hold the cutters in their full outwardly expanded position, thereby precluding inadvertent inward shifting of the cutters and the drilling of an undergauged hole.

Yet another object of the invention is to provide a hole enlarging drill bit having an exceedingly large cutter tooth surface for operating on the formation material, thus enabling a large footage of hole to be drilled before the cutters become dull, necessitating withdrawal of the bit to the top of the well bore.

Still a further object of the invention is to provide a strong and sturdy expansible drill bit, capable of manufacture in an economical manner.

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 side elevation of an expansible drill bit disposed in a well casing, with the bit cutters in retracted position;

Fig. 2 is a longitudinal section, on an enlarged scale, through the major portion of the drill bit disclosed in Fig. 1, and with the cutters in retracted position;

Fig. 3 is a view similar to Fig. 2, illustrating the cutters in their full outwardly expanded position;

Fig. 4 is a cross-section taken along the line 4—4 on Fig. 2;

Fig. 5 is a cross-section taken along the line 5—5 on Fig. 3;

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

Fig. 7 is a cross-section taken along the line 7—7 on Fig. 3;

Fig. 8 is an enlarged fragmentary longitudinal section through a portion of the device illustrated in Fig. 3;

Fig. 9 is an exploded isometric projection of a cutter and a retainer and stop member therefor;

Fig. 10 is a side elevation, partly in section, of another

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embodiment of the invention disposed within a well bore and with the cutters in retracted position;

Fig. 11 is an enlarged longitudinal section through the major portion of the bit disclosed in Fig. 10, with the cutters in retracted position;

Fig. 12 is a view similar to Fig. 11, illustrating the cutters in expanded position;

Fig. 13 is a cross-section taken along the line 13—13 on Fig. 12;

Fig. 14 is a cross-section taken along the line 14—14 on Fig. 12.

The drill bits A disclosed in the drawings are adapted to be secured to the lower end of a string of drill pipe B, or other tubular device, for lowering through well casing C disposed in the well bore to a point below the casing shoe D at which the cutters 10 of the bit are expanded outwardly, for the purpose of enlarging the well bore E below the shoe. Expansion of the cutters 10 can take place at any desired point below the casing shoe D simply through the expedient of pumping drilling fluid down through the drill pipe B and the expansible drill bit A, the cutters producing a shoulder F in the wall of the formation on which they will operate. When the cutters 10 are expanded outwardly to their full extent, they are precluded from inadvertent inward movement; so long as drilling weight is being imposed on the apparatus. Because of this fact, drilling of an undergauged hole is prevented.

The cutters 10 are arranged to enlarge the hole E as a result of rotating the drill bit A, or as a result of moving the bit longitudinally in the well bore. The cutting surfaces of the cutters collectively cover at least 360 degrees around the drill bit. The cutters are, therefore, capable of operating upon the entire circumference of the well bore upon moving the expansible drill bit A longitudinally through the well bore. The circumferential extent of the cutters not only insures the production of a circular hole, but also stabilizes the apparatus and tends to maintain it centered in the well bore.

As disclosed in the drawings, the expansible drill bit A includes an elongate main body 11 consisting of an upper portion 12 having a pin 13 threaded into the lower end of the string of drill pipe B. The lower end of the upper body portion 12 is provided with a threaded pin 14 screwed within the threaded box 15 of a lower body portion 16 which has a terminal box portion 17 that may be threaded onto the upper pin end 18 of another drill bit 19, if another drill bit is used. The lower drill bit 19 may be omitted entirely, if desired.

A plurality of sets 20, 21 of expandible cutters 10 are provided on the main bit body 11. These sets are circumferentially offset with respect to each other; so as to collectively cover at least the entire circumference of the bit body 11 and of the wall of the formation on which they operate. Inasmuch as the sets 20, 21 of cutters are substantial duplicates of one another, a description of one set, such as the upper set 20, will suffice for both sets.

The upper set 20 of cutters 10 is disposed in a circumferential elongate groove 22 formed in the bit body. The base of this groove is provided with a plurality of longitudinally spaced, upwardly diverging frusto-conical cam expander portions 23, the upper ends of which merge into generally cylindrical holding surfaces 24, which are substantially parallel to the axis of the bit body. The cylindrical portions 24 terminate in shoulders 25 disposed substantially perpendicular to the axis of the bit. The lower ends 26 of the cam surfaces 23 are spaced longitudinally from the next lower shoulder 25 and form a circumferential recess 27 therebetween in which inner portions 28 of the cutters 10 are receivable, when the cutters are in retracted position on the bit body 11. Thus, each cutter 10 is provided with longitu-

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dinally spaced cam surfaces 29 companion to the body cam surfaces 23, and they also have downwardly facing shoulders 30 spaced from the upper ends 31 of the cam surfaces 29, providing recesses 32 in which the cam and holding rib portions 23 of the body are receivable when the cutters are in retracted position.

The spaced cam and rib portions 23 can be formed on the bit body in a lathe, which is also true of the companion cam and rib portions 29 formed on the interior of the cutters.

The cutters 10 are disposed in the circumferential groove 22, and have a length that is less than the length of the groove. These cutters initially occupy a retracted position downwardly of the body 11, with their lower ends 33 in engagement with the lower side 34 of the circumferential groove 22. The cutters 10 are shiftable upwardly along the body cam surfaces 23, to expand them outwardly to a position in which the inner cylindrical surfaces 35 of the cutters are in full bearing engagement with the holding surfaces 24 on the body, the extent of such upward shifting being limited by engagement of the upper ends 36 of the cutters with the upper side 37 of the circumferential body groove 22. The coengagement between the inner cylindrical surfaces 35 of the cutters with the body cylindrical surfaces 24 precludes inadvertent inward movement of the cutters. Their outward movement to any further extent is prevented by engagement of the cutters 10 with retainer and stop members 38 secured to the bit body.

As disclosed in the drawings, the cutters of the upper set 20 are spaced equi-angularly from one another around the circumference of the bit body 11. The retainer and stop members 38 are also spaced equi-angularly around the bit body, and are disposed between the cutters. Each retainer and stop member 38 is disposed radial of the axis of the bit body, and extends lengthwise the full length of the circumferential groove 22. At its upper and lower ends it is provided with ears 39 received within recesses or notches 40 milled in the bit body. Each stop member 38 is attached to the body by use of screws 41 extending through holes 42 in its ear and intermediate portions and received within threaded holes 43 in the body at its recess and cam expander portions 40, 23.

Extending laterally from the main body of each segment 38 are longitudinal wings 44 received within longitudinal side grooves 45 in cutters 10 on opposite sides of the stop member 38, which grooves 45 are substantially wider than the width of the wings 44; so as to allow lateral movement of the cutters 10 to a predetermined extent without interference from the wings 44. When the cutters are in their retracted positions, the wings 44 are disposed in the outer portions of the side grooves 45 spaced outwardly from the inner longitudinal shoulders 46 of the cutters (Fig. 4). However, when the cutters 10 are moved longitudinally along their companion body expander portions 23 and radially outwardly, the extent of such outward movement is determined by engagement of the side shoulders 46 on the cutters with the stop member wings 44 (Fig. 5).

When the cutters 10 have been shifted outwardly to a position in which their inner cylindrical surfaces 35 engage the external holding surfaces 24 on the base of the body groove 22, the outer surfaces of the cutter shoulders 46 are just on the verge of engaging the longitudinal retainer wings 44. Accordingly, it is apparent that the holding surfaces 24 on the body will then preclude inward movement of the cutters 10 from their fully expanded position, and that the side wings 44 of the retainer segments will preclude further outward movement of the cutters.

When the cutters 10 have been expanded outwardly to their fullest extent, their upper ends 36 engage the upper side 37 of the circumferential groove 22. Accordingly, drilling weight imposed on the main body 11 of the bit will be transmitted directly to the cutters 10, passing from

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the upper side 37 of the circumferential groove to the upper ends 36 of the cutters. During rotation of the drill bit, the torque can be transmitted from the body 11, through the retainer members 38 to the side margins of the blades 10. However, it is preferred to transmit the drilling torque between the body 11 and cutters 10 through another arrangement, that will now be described.

The upper and lower ends of each cutter 10 are provided with notches or grooves 48 preferably disposed centrally of each cutter. Driving blocks or elements 49 are disposed in recesses 50 formed in the body at each end of the circumferential groove 22, these driving blocks being suitably secured to the body, as by use of welding material 51. The drive blocks 49 extend longitudinally into the cutter recesses 48 and snugly engage the side walls of such recesses, to provide a slidable driving connection between the body 11 and the cutters 10. The lower drive blocks 49 extend upwardly into the recesses 48, preferably to the upper end of the latter, when the cutters 10 are in their lower retracted position on the drill bit body 11. The upper drive blocks 49 extend downwardly into the cutter recesses 48, but their lower ends are initially spaced above the lower ends of the upper notches 48; so as not to interfere with the upward movement of the cutters 10 along the drill bit body 11 to their outwardly expanded positions.

During the rotation of the drill bit A, the driving effort, rather than being transmitted through the intermediate retainer and stop members 38, is transmitted through the drive blocks 49 directly to the cutters 10.

As was stated above, the lower set 21 of cutters and cooperating elements are a substantial duplicate of the upper set 20. However, the two sets 20, 21 are displaced from one another; so that the cutters will collectively encompass the entire circumference of the bit body 11 and the wall of the well bore E. As illustrated in the drawings, three cutters are embodied in each set, the cutters being displaced about 120 degrees from each other. Each cutter 10 subtends an arc of about 70 degrees; so that the cutters of each set collectively cover about 210 degrees of arc. Since the sets of cutters are displaced about 60 degrees with respect to each other, it is apparent that both sets 20, 21 of cutters collectively cover about 420 degrees around the circumference of the bit body 11.

Each cutter 10 is provided with longitudinally spaced helical teeth 52. Because of the helical disposition of the teeth, they are effective to remove the formation material upon rotation of the drill bit A, and they are also effective to remove the formation material upon longitudinal movement of the drill bit A in a downward direction, and without its rotation. As noted above, the teeth 52 collectively cover at least the full circumference of the well bore E, which enables the cutters to ream the entire circumference of the hole, as a result of longitudinal movement or reciprocation of the drill bit within the well bore.

The cutters 10 are shifted from their retracted to their outwardly expanded positions by hydraulic instrumentalities. As disclosed in the drawings, a hydraulic annular cylinder 53 is mounted on the bit body 11 below the lower set 21 of cutters. This cylinder includes an inwardly directed cylinder head 54 slidable along the exterior of the body 11 above one or more side ports 55 extending through the body between its central fluid passage 56 and a cylinder space 57 between the body and the cylinder. Depending from the cylinder head 54 is a cylinder sleeve 58 slidable along the body 11, and initially secured to the lower body portion 15 by one or more shear screws 59. Extending upwardly from the cylinder head 54 is a skirt 60 slidable along a body flange 61, the upper end of this skirt 60 engaging the lower ends of a lower set 62 of longitudinally arranged transfer or thrust plates 63 slidable in longitudinal grooves 64 in the body. The upper ends of these plates 63 engage

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the lower ends 33 of the lower set 21 of cutters 10. The thrust plates 63 are prevented from moving laterally outward of the body by arcuate retainer elements 65 secured in arcuate grooves 66 in the body by screws 67, and extending across outer notches or recesses 68 formed in the plates 63.

An upper set 69 of intermediate or upper transfer and thrust plates 63 is disposed in longitudinal grooves 70 in the body between the upper and lower sets 20, 21 of cutters 10 and merging into the upper and lower circumferential grooves 22. The lower end of each intermediate plate 63 engages a lower cutter 10 and its upper end engages the lower end 33 of an upper cutter 10; so that the upward movement of the lower cutters is transferred to the upper cutters through the plates. These intermediate plates 63 are also prevented from lateral outward movement by arcuate retainer elements 65 extending across the longitudinal grooves 70 and secured in arcuate recesses 66 in the body by screws 67. These upper elements 65 also extend within recesses or notches 68 formed in the upper plates 63.

Leakage of fluid from the cylinder space 57 in an upward direction is prevented by providing a suitable side seal ring 71 in an inner groove 72 in the cylinder head 54, which seal ring is slidable along the periphery of the bit body 11.

Leakage of fluid in a downward direction from the cylinder space 57 is prevented by a side seal ring 73 disposed in an internal body groove 74, and slidably engaging the inner wall of the cylinder sleeve 58. A wiper ring 75 may also be provided in a groove 76 in the body flange 61, slidably engaging the inner wall of the cylinder skirt 60. Fluid is allowed to bleed from the annular space 77 between the flange 61 and head 54 through a suitable bleeder hole 78 provided through the skirt 60 adjacent the head 54.

In order to move the cylinder 53 hydraulically upwardly along the body 11, for the purpose of expanding the cutters 10 outwardly, pressure must be built up within the bit body and also within the cylinder space 57. Such pressure is increased in the present case by providing an orifice 79 in the lower portion of the bit body 11, having a restricted passage 80 therethrough. This orifice 79 may be clamped between an inner shoulder 81 formed in the body and a nut 82 threaded into the lower end of the body, leakage around the orifice member 79 being prevented by a suitable seal ring or gasket 83 compressed between the end of the nut 82 and a body shoulder 84.

The drill bit apparatus A is threaded into the lower end of a string of drill pipe B, and is lowered through the well casing C to a point in the open hole E below the casing shoe D at which the hole enlarging operation is to commence. At this time, the cutters 10 all occupy their lower retracted positions with respect to the bit body 11, illustrated in Figs. 1, 2 and 4. When the cutters 10 are to be expanded outwardly, drilling fluid is pumped down the drill pipe B, and through the central passage 56 through the body 11, the flow of fluid from this passage being restricted by the orifice 79, which causes a back pressure to be built up in the body passage 56 which is imparted to the fluid in the body ports 55 and cylinder space 57, exerting an upward force on the cylinder head 54. When this back pressure exceeds the shear strength of the screw or screws 59 initially holding the cylinder 53 to the body 11, the screws 59 are disrupted and the cylinder 53 is urged in an upward direction along the body 11. The upward movement of the cylinder is transferred through the lower set 62 of plates to the lower set 21 of cutters 10, urging the later longitudinally upwardly of the body 11 and along the expander cam surfaces 23 in a radially outward direction. At the same time, the longitudinal upward movement of the lower set 21 of cutters is transferred to the upper set 20 of cutters through the intermediate set 69 of thrust

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plates 63, this upper set 20 of cutters also moving along their companion cam surfaces 23 and in a radial outward direction.

The drill bit body 11 may be rotated while fluid is being pumped through it to rotate the cutters 10 and cause the cutter teeth 52 to enlarge the wall of the well bore. As the diameter of the hole increases, the cutters 10 can move along the cam surfaces 23 outwardly to a further extent, until they are moved upwardly off the cam surfaces 23 and onto the holding portions 24 of the circumferential ribs formed in the base portions of the body grooves 22. At this time, the shoulders 46 on the cutters engage the side wings 44 of the retainer members 38, which preclude further outward movement of the cutters 10, the cylindrical body surfaces 24 preventing inward movement of the cutters (Figs. 3 and 5).

Rotation of the drill bit A can then continue, the lower portions of the cutter teeth 52 operating upon the lower shoulder F produced in the formation wall, to ream and enlarge the hole E in a downward direction. The drilling weight is being transmitted directly from the body 11 to the upper ends 36 of the cutters, while the drilling torque is being transmitted through the drive blocks 49 directly to the cutters 10. The cutter teeth 52, in view of their helical or inclined arrangement, are effective to shear or slice across the formation material, to insure the production of an enlarged well bore of circular cross-section throughout its length. In view of the large number of cutter teeth present, the drill bit is effective to enlarge the well bore to a substantial longitudinal extent before the cutter teeth become dull. When this happens, the pumping of drilling fluid through the drill pipe B and the drill bit A is discontinued, the drill pipe being elevated to elevate the drill bit with it. When the cutters 10 engage the lower end of the casing shoe D, they will be forced downwardly off the cylindrical holding surfaces 24 and downwardly along the tapered cam surfaces 23 and inwardly to their initial retracted positions, allowing the drill bit to be moved upwardly through the well casing C to the top of the well bore.

The cutters 10 may be dismantled from the drill bit and a set of sharp cutters mounted in their place in retracted position. The drill bit with the sharp cutters is again run in the well bore, and, upon reaching the upper end of the enlarged section of the well bore E, fluid can again be pumped through the drill pipe and body to again expand the cutters 10 outwardly to their fullest extent. Lowering of the drill bit A through the previously enlarged length of the well bore E can then continue without rotating the drill bit. Any projections or restrictions encountered in the well bore will be removed by the cutters 10 themselves, simply as a result of moving them longitudinally through the well bore, inasmuch as the cutter teeth 52 collectively cover the entire circumference of the well bore. If resistance is encountered, the drill bit A can be reciprocated, to remove the restricting portion of the wall of the well bore. If substantial resistance to removal is encountered, the drill bit can be rotated, to enlarge the restricting portion of the well bore to its proper final diameter. When the drill bit reaches the shoulder F previously formed in the enlarged well bore, it can commence enlarging the well bore in a downward direction from that point.

In the form of invention illustrated in Figs. 10 to 14, inclusive, longitudinally spaced, elongate circumferential grooves 22a are provided, in which sets 20a, 21a of cutters 10a are disposed in angularly offset relation with respect to each other; so as to collectively cover the entire circumference of the bit body 11a and the formation wall on which the cutters are operative. The base of each groove 22a and the cutters have substantially the same cam expander and holding surfaces 23a, 24a, 29a, 35 as in the other form of invention. However, the cutters 10a have longitudinally extending upper and lower end lugs or portions 86 slidably fitting within up-

per and lower longitudinal grooves or recesses 87 merging into the circumferential groove 22a. The sides of each cutter 10a slidably fit the sides of the end grooves 87; so that the rotational effort imparted to the body 11a is transmitted directly to the cutters 10a.

The cutters 10a are movable upwardly along the body 11a to expand them outwardly by means of the hydraulic cylinder 53a in essentially the same manner as in the other form of the invention. The skirt 60a of this cylinder is slidable along the body flange or head 61a, the upper end of the skirt engaging the lower end of a thrust and stop sleeve 63a slidable on the periphery of the body. This thrust or stop sleeve engages the lower end portions of the lower set 21a of cutters, there being a substantial radial gap 88 between the outer surfaces of the lower cutter lugs 86 and the inner wall of the sleeve 63a, which gap is slightly greater than the rise of the cam surfaces 23a on the body 11a. As the cylinder 53a moves upwardly, the upward movement is transmitted through the thrust sleeve 63a to the lower set 21a of cutters 10a, which are shifted upwardly along their companion cam surfaces 23 and radially outward toward the wall of the formation. The upper portions of the lower set 21a of cutters engage the lower end of an intermediate thrust and stop sleeve 69a slidable on the periphery of the body, and the upper end of this latter sleeve 69a engages the lower end portions of the upper set 20a of cutters. Here again, the inner wall surface of the intermediate sleeve 69a is initially spaced outwardly from the upper lugs 86 of the lower cutters and the lower lugs of the upper cutters by a distance that is slightly greater than the rise of the cams 23a.

As the lower set 21a of cutters moves upwardly, the intermediate thrust sleeve 69a is also moved upwardly, which, in turn, shifts the upper set 20a of cutters upwardly. In this fashion, both sets 20a, 21a of cutters are shifted simultaneously upwardly along their respective body cam surfaces 23a and radially outward into engagement with the well bore wall. When the cutters move off their inclined cam surfaces 23a and onto the holding surfaces 24a of the body, their lugs 86 are just contacting the thrust sleeves 63a, 69a, which function as stop members to prevent further outward movement of the cutters 10a with respect to the body. In this connection, an upper stop sleeve 90 is disposed on the body above the upper set 20a of cutters, being secured to the body by means of a screw 91, the lower end of this sleeve overlapping the upper longitudinal body grooves 87 and the upper lugs 86 of the upper set 20a of cutters. When the upper cutters 20a are expanded outwardly to the fullest extent, the upper lugs 86 will engage the upper sleeve 90, which will preclude further outward expansion of the upper set of cutters.

The drill bit is lowered through the well casing C with the cutter parts in retracted position. When the position below the casing shoe D is reached at which the under-reaming operation is to commence, fluid is pumped down the drill pipe B and through the orifice 79 below the body ports 55, the back pressure being exerted upon the cylinder 53a to shift it upwardly. This upward movement is transmitted through the lower sleeve 63a to the lower set 21a of cutters, and from the latter through the intermediate sleeve 69a to the upper set 20a of cutters, all of the cutters being shifted longitudinally along the body cam or expander surfaces 23a and radially outward against the wall of the formation. The drill bit A is then rotated, to cause the inclined cutter teeth 52 to enlarge the well bore. As the hole size increases, the cutters move further up along their cam surfaces 23a until their inner cylindrical surfaces 35a are shifted upon the holding surfaces 24a on the body 11a, at which time the cutter lugs 86 engage the several stop sleeves 63a, 69a, 90. Upward shifting of the cutters is limited by engagement of their upper portions 95 with the upper walls of the circumferential grooves 22a. Drilling weight can now be imposed on

the drill bit, to enlarge the hole in a downward direction to the desired extent, the drilling weight being transmitted directly from the body 11a to the cutters 10a. The drilling torque is also transmitted directly from the side walls of the longitudinal body grooves 87 to the sides of the cutters 10a. The holding surfaces 24a, 35a prevent inadvertent inward movement of the cutters 10a from their fully expanded positions, whereas the various stop sleeves 63a, 69a, 90 prevent further outward movement of the cutters. When the drill bit is to be removed from the well bore, the pumps at the top of the hole are stopped and the drill pipe B moved upwardly to elevate the drill bit A with it. When the cutters 10a engage the lower end of the casing shoe D, they will be shifted downwardly and radially inward to their initial retracted position, which allows the entire drill bit to be withdrawn through the casing to the top of the well bore.

The inventor claims:

1. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body; cutters movable longitudinally of said body; coengageable cam means on said cutters and body for expanding said cutters laterally outwardly of said body upon longitudinal movement of said cutters along said body; means for shifting said cutters longitudinally of said body; and means having stop portions initially spaced laterally outward from companion portions of said cutters, said stop portions being engageable with said companion portions to limit the extent of movement of said cutters laterally outwardly of said body, said last-mentioned means being disposed between said cutters and engageable with said cutters to guide said cutters in their movement laterally outwardly of said body.

2. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body having an external groove around its entire circumference defined by upper and lower end walls in said body and a base between said end walls, the base of said groove being circular in cross-section and having a cam portion thereon; cutters in said groove movable longitudinally of said body and having cam means engageable with said cam portion, in order that longitudinal movement of said cutters along said body shifts said cutters laterally outwardly of said body; means on said body for shifting said cutters longitudinally of said body; means on said body for retaining said cutters in said groove; and means providing a slidable connection between said body and each cutter to transmit the rotation of said body to said cutters and to guide said cutters in their movement laterally outwardly of said body.

3. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body having an external groove around its entire circumference, the base of said groove being circular in cross-section and having a cam portion thereon; cutters in said groove movable longitudinally of said body and having cam means engageable with said cam portion, in order that longitudinal movement of said cutters along said body shifts said cutters laterally outwardly of said body; means on said body for shifting said cutters longitudinally of said body; means providing a slidable connection between said body and each cutter to transmit the rotation of said body to said cutters and to guide said cutters in their movement outwardly of said body; and means initially spaced laterally outward from portions of said cutters and engageable with said cutter portions to limit the extent of movement of said cutters laterally outwardly of said body.

4. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body; cutters movable longitudinally of said body; coengageable cam means on said cutters and body for expanding said cutters laterally outwardly of said body upon longitudinal movement of said cutters along said body; and means for shifting said cutters longitudinally of said body, said shifting means having stop portions initially spaced laterally outward

from companion portions of said cutters, said stop portions being engageable with said companion portions to limit the extent of movement of said cutters laterally outwardly of said body.

5. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body having an external groove around its entire circumference, the base of said groove having a cam portion thereon; cutters in said groove movable longitudinally of said body and having cam means engageable with said cam portion, in order that longitudinal movement of said cutters along said body shifts said cutters laterally outwardly of said body; means on said body for shifting said cutters longitudinally of said body, said shifting means having stop portions initially spaced laterally outward from companion portions of said cutters, said stop portions being engageable with said companion portions to limit the extent of movement of said cutters laterally outwardly of said body; and means providing a slidable connection between said body and each cutter to transmit the rotation of said body to said cutters and to guide said cutters in their movement outwardly of said body.

6. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body having an external groove around its entire circumference defined by upper and lower end walls in said body and a base between said end walls, the base of said groove being circular in cross-section and having a tapered surface inclined in an upward and outward direction; cutters in said groove movable longitudinally of said body and having tapered surfaces companion to and engageable with said other tapered surface, in order that upward movement of said cutters along said body shifts said cutters laterally outwardly of said body; means on said body for shifting said cutters upwardly of said body; means on said body for retaining said cutters in said groove; and means providing a slidable connection between said body and each cutter to transmit the rotation of said body to said cutters and to guide said cutters in their movement laterally outwardly of said body.

7. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body having an external groove around its entire circumference, the base of said groove being circular in cross-section and having longitudinally spaced tapered surfaces inclined in an upward and outward direction; cutters in said groove movable longitudinally of said body, each of said cutters having longitudinally spaced tapered surfaces companion to and engageable with said other tapered surfaces; means on said body for shifting said cutters upwardly along said body to cause said tapered surfaces on the base of said groove and on said cutters to expand the cutters outwardly of said body; and means providing a slidable connection between said body and each cutter to transmit the rotation of said body to said cutters and to guide said cutters in their movement outwardly of said body.

8. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body; cutters movable longitudinally of said body; coengageable cam means on said cutters and body for expanding said cutters laterally outwardly of said body upon longitudinal movement of said cutters along said body; means for shifting said cutters longitudinally of said body; means providing a radially slidable connection between said body and each cutter to transmit rotary motion of said body to said cutters, said last-mentioned means having stop portions initially spaced laterally outward from companion portions of said cutters and engageable with said companion portions to limit the extent of movement of said cutters laterally outwardly of said body.

9. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body having an external groove around its entire circumference, the base of said groove having a cam portion thereon; cutters in said groove movable longitudinally of said body and having

cam means engageable with said cam portion, in order that longitudinal movement of said cutters along said body shifts said cutters outwardly of said body; means on said body for shifting said cutters longitudinally of said body; and means providing a radially slidable connection between said body at opposite ends of said groove and the end portions of each cutter to transmit rotary motion of said body to said cutters.

10. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body having an external groove around its entire circumference, the base of said groove having a cam portion thereon; cutters in said groove movable longitudinally of said body and having cam means engageable with said cam portion, in order that longitudinal movement of said cutters along said body shifts said cutters outwardly of said body; means on said body for shifting said cutters longitudinally of said body, each of said cutters having end grooves therein; and drive lugs secured to said body and extending into said end grooves in slidable relation to said cutters.

11. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body having an external groove around its entire circumference, the base of said groove having a cam portion thereon; cutters in said groove movable longitudinally of said body and having cam means engageable with said cam portion, in order that longitudinal movement of said cutters along said body shifts said cutters laterally outwardly of said body; means on said body for shifting said cutters longitudinally of said body; means for retaining said cutters in said groove; said body having end grooves on opposite sides of said external groove; and means on said cutters extending into said end grooves in slidable relation to said body.

12. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body having longitudinally spaced grooves therein separated by an intervening body portion; longitudinally spaced separate sets of cutters disposed in said grooves and movable longitudinally of said body; coengageable cam means on said cutters and body for expanding said cutters outwardly of said body upon longitudinal movement of said cutters along said body; means for shifting one set of cutters longitudinally of said body; and means slidable along said intervening body portion for transmitting the longitudinal movement of said one set of cutters to another set of cutters.

13. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body having longitudinally spaced grooves therein separated by an intervening body portion; longitudinally spaced separate sets of cutters disposed in said grooves and movable longitudinally of said body; coengageable cam means on said cutters and body for expanding said cutters outwardly of said body upon longitudinal movement of said cutters along said body; means for shifting one set of cutters longitudinally of said body; means slidable along said intervening body portion for transmitting the longitudinal movement of said one set of cutters to another set of cutters; and means engageable with all of said cutters to limit the extent of their movement outwardly of said body.

14. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body; longitudinally spaced sets of cutters movable longitudinally of said body; coengageable cam means on said cutters and body for expanding said cutters laterally outwardly of said body upon longitudinal movement of said cutters along said body; means for shifting one set of cutters longitudinally of said body; and means for transmitting the longitudinal movement of said one set of cutters to another set of cutters; said shifting means and transmitting means having stop portions initially spaced laterally outward from companion portions of said cutters, said stop portions being engageable with said companion portions to limit

the extent of movement of said cutters laterally outwardly of said body.

15. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body; longitudinally spaced separately movable sets of cutters movable longitudinally of said body; the outer portions of said cutters collectively encompassing substantially the entire circumference of said body; coengageable cam means on said cutters and body for expanding said cutters outwardly of said body upon longitudinal movement of said cutters along said body; means for shifting one set of cutters longitudinally of said body; and means for transmitting the longitudinal movement of said one set of cutters to another set of cutters.

16. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body having longitudinally spaced external grooves around its entire circumference, the base of each groove having a tapered surface inclined in an upward and outward direction; longitudinally spaced sets of cutters in said grooves movable longitudinally of said body, the cutters in each set having tapered surfaces companion to and engageable with the tapered surface of the groove in which it is disposed, in order that upward movement of said cutters along said body shifts said cutters outwardly of said body; means providing a slidable connection between said body and each cutter to transmit the rotation of said body to said cutters and to guide said cutters in their movement outwardly of said body; means for shifting one set of cutters upwardly of said body; and means for transmitting the upward movement of said one set of cutters to another set of cutters.

17. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body having longitudinally spaced external grooves around its entire circumference separated by an intervening body portion, the base of each groove having a tapered surface inclined in an upward and outward direction; longitudinally spaced sets of cutters in said grooves movable longitudinally of said body, the cutters in each set having tapered surfaces companion to and engageable with the tapered surface of the groove in which it is disposed, in order that upward movement of said cutters along said body shifts said cutters outwardly of said body; means including a sleeve encompassing said body and engageable with a lower set of cutters for shifting said lower set of cutters upwardly of said body; a thrust sleeve slidable along said intervening body portion engageable with said upper and lower sets of cutters for transmitting the upward movement of said lower set of cutters to said upper set of cutters; and means providing a slidable connection between said body and each cutter to transmit the rotation of said body to said cutters and to guide said cutters in their movement outwardly of said body.

18. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body having longitudinally spaced external grooves around its entire circumference, the base of each groove having a tapered surface inclined in an upward and outward direction; longitudinally spaced sets of cutters in said grooves movable longitudinally of said body, the cutters in each set having tapered surfaces companion to and engageable with the tapered surface of the groove in which it is disposed, in order that upward movement of said cutters along said body shifts said cutters outwardly of said body; means including a sleeve encompassing said body and engageable with a lower set of cutters for shifting said lower set of cutters upwardly of said body; a thrust sleeve engageable with said upper and lower sets of cutters for transmitting the upward movement of said lower set of cutters to said upper set of cutters, said cutters engaging said sleeves to limit the extent of movement of said cutters outwardly of said body; and means providing a slidable connection between said body and each cutter to transmit the rotation of said body to said cutters and to guide

said cutters in their movement outwardly of said body.

19. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body having longitudinally spaced external grooves around its entire circumference, the base of each groove having a tapered surface inclined in an upward and outward direction; longitudinally spaced sets of cutters in said grooves movable longitudinally of said body, the cutters in each set having tapered surfaces companion to and engageable with the tapered surface of the groove in which it is disposed, in order that upward movement of said cutters along said body shifts said cutters outwardly of said body; means for shifting a lower set of cutters upwardly of said body; said body having longitudinally extending grooves between said external grooves; longitudinally movable plates in said longitudinal grooves engageable with the lower set of cutters and upper set of cutters for transmitting the upward movement of the lower set of cutters to the upper set of cutters; and means providing a slidable connection between said body and each cutter to transmit the rotation of said body to said cutters and to guide said cutters in their movement outwardly of said body.

20. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body having longitudinally spaced external grooves around its entire circumference separated by an intervening body portion, the base of each groove having a tapered surface inclined in an upward and outward direction; longitudinally spaced sets of cutters in said groove movable longitudinally of said body, the cutters in each set having tapered surfaces companion to and engageable with the tapered surface of the groove in which it is disposed, in order that upward movement of said cutters along said body shifts said cutters outwardly of said body; means for shifting a lower set of cutters upwardly of said body, comprising an annular cylinder slidable on said body, means for feeding fluid under pressure into said cylinder to move said cylinder upwardly of said body; and means slidable longitudinally along said intervening body portion for transmitting the upward movement of said lower set of cutters to an upper set of cutters.

21. In an expansible drill bit to be lowered in a well bore on a running-in string: a bit body; cutters movable longitudinally of said body; coengageable cam means on said cutters and body for expanding said cutters laterally outwardly of said body upon longitudinal movement of said cutters along said body; coengageable holding surfaces on said cutters and body substantially parallel to the axis of said body for preventing inward movement of said cutters from their outward expanded position; means for shifting said cutters longitudinally of said body to cause said cam means to expand said cutters outwardly of said body and to then engage said coengageable holding surfaces with each other; and means initially spaced from portions of said cutters and engageable with said cutter portions when said coengageable holding surfaces are in engagement with each other to limit the extent of movement of said cutters laterally outwardly of said body; said last-mentioned means being disposed between said cutters and engageable with said cutters to guide said cutters in their movement laterally outwardly of said body.

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