

Feb. 18, 1958

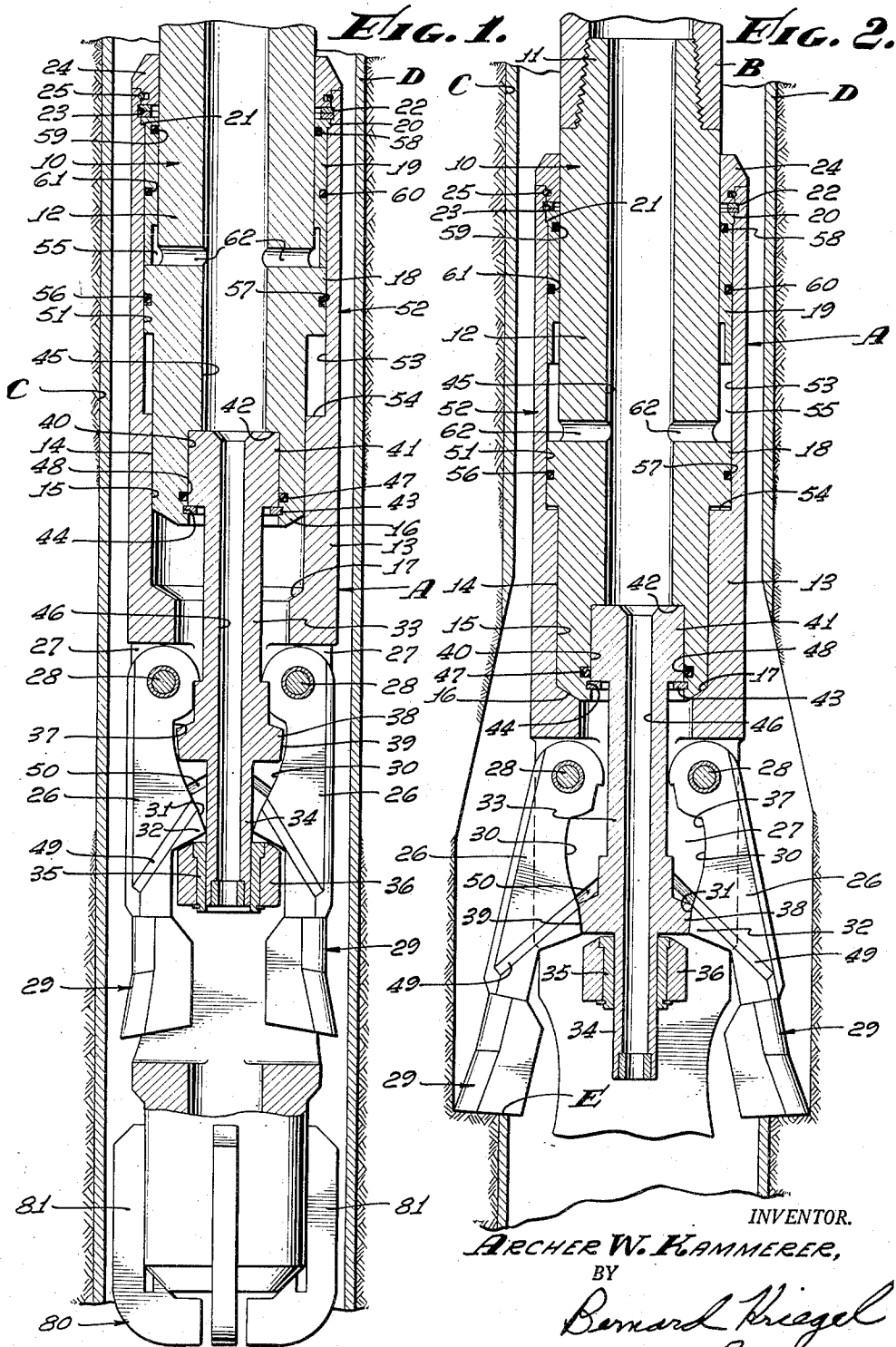
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2,823,901

EXPANSIBLE ROTARY DRILLING TOOLS

Filed Nov. 7, 1955

2 Sheets-Sheet 1



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Fig. 3.

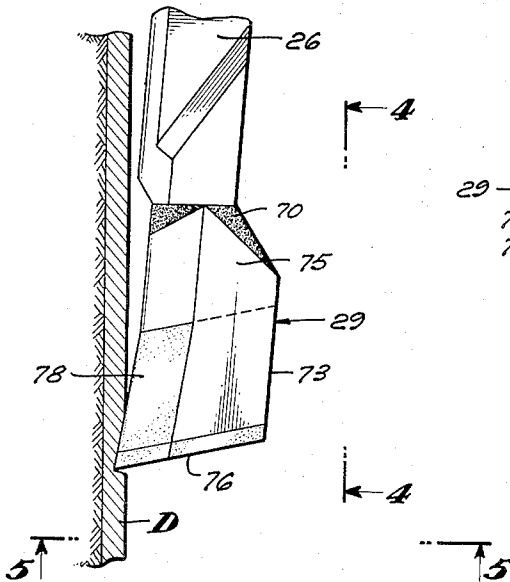


Fig. 4.

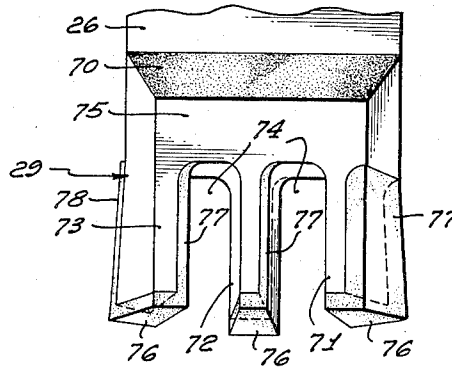


Fig. 5.

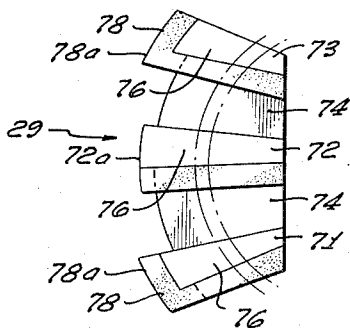


Fig. 7.

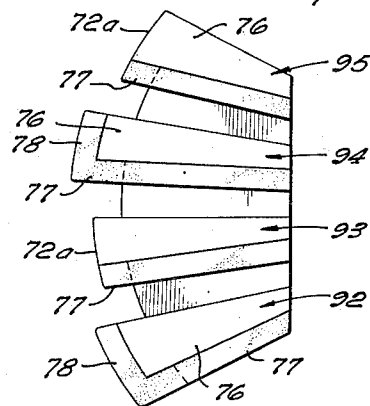
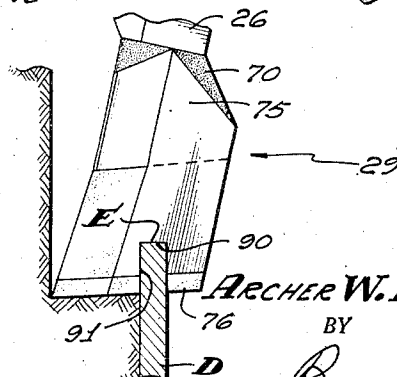


Fig. 6.



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EXPANSIBLE ROTARY DRILLING TOOLS

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9 Claims. (Cl. 255—76)

The present invention relates to drilling tools, and more particularly to tools usable in a well bore to perform diverse operations therein, such as enlarging the diameter of the well bore or milling out a portion of the casing in the well bore.

Rotary drill bits of the expansible type are used to enlarge the diameter of the well bore and to sever and mill away a desired extent or length of casing therein. Such bits include cutters disposed initially in retracted position, where are expanded outwardly to initially enlarge the well bore at a particular location, or to sever the casing at a predetermined point, after which the expanded cutters are effective to drill ahead as the bit is rotated and gradually lowered in the well bore.

After the cutters have been expanded, any desirable drilling weight can be imposed thereon through the agency of the drill string to which the tool is secured. However, the force available for expanding the cutters from their initially retracted position to enlarge the well bore or to sever the casing is limited. Such limited force might be insufficient to secure proper penetration of the cutters in the material being operated upon and could require considerable time for the cutters to make a severing cut in casing, or to be expanded to their maximum extent in very hard formations. This is particularly true of the use of cutters having large tooth areas for engagement with the formation or severed end of the casing after the cutters have been expanded to their maximum extent. For example, it is desirable to have a large tooth surface in contact with the severed end of a casing, since greater drilling weights can be imposed on the cutters to mill the casing away more rapidly, while the cutters still possess a long useful life. Such large tooth surfaces would also engage the casing wall when making a severing cut in the casing, and since the cutter expanding force is limited, such force, spread over a large surface, would result in slow progress being made in severing the casing.

Accordingly, it is an object of the present invention to provide an expandible rotary drill bit having a relatively large total tooth surface available for enlarging the well bore or milling away casing in a well bore after the cutters have been expanded, in which the effectiveness of a limited cutter expansion force in penetrating the cutters into the wall of a formation or of a casing is greatly enhanced.

Another object of the invention is to provide an expandible rotary drill bit embodying cutters capable of effective operation upon casing and very hard formations, the cutters possessing great strength and long life, and capable of easy maintenance, free from cuttings and in a cool state by the drilling fluid circulated through the bit, thereby preventing balling up of the cutters and the retarding of their cutting action.

A further object of the invention is to provide an expandible rotary drill bit capable of severing casing in a well bore and of milling away a desired length or extent

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of casing, the bit cutters coacting with the casing to center the bit in the latter and insure its stable operation.

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. These forms are shown in the drawings accompanying and forming part of the present specification. They will now be described in detail, for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

Figure 1 is a longitudinal section through an embodiment of the invention disposed in a well casing, with the cutters and other parts occupying their initial retracted positions;

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

Fig. 3 is an enlarged fragmentary view of a cutter in performing its severing action on casing;

Fig. 4 is an inside elevational view of one of the cutter structures, as seen along the line 4—4 on Fig. 3;

Fig. 5 is a bottom plan view of one of the cutter structures, as seen along the line 5—5 on Fig. 3;

Fig. 6 is a view of a cutter structure in fully expanded position and operating upon a severed end of the casing;

Fig. 7 is a bottom plan view of a modified form of cutter structure.

As shown in the drawings, a rotary expansible drill bit or milling tool A is secured to the lower end of a string of drill pipe B that extends to the top of the well bore C, and by means of which the drill bit is lowered through a string of well casing D to a region therein where a casing milling operation is to commence. Although described herein in connection with a casing milling operation, it is to be understood that the apparatus is capable of performing other operations in the well bore, such as enlarging its diameter.

The upper portion of the rotary drill bit consists of a mandrel 10 having an upper pin 11 threadedly connected to the lower end of the string of drill pipe B. This mandrel includes an upper kelly or drill stem member 12 slidably splined to the main body 13 of the drill bit. The exterior of the lower portion 14 of the kelly is non-circular in shape, being telescopically received in a companion non-circular socket 15 formed in the main bit body 13. Specifically, the Kelly exterior and the socket 15 may be of hexagonal shape, to enable the kelly 12 to be moved longitudinally with respect to the body 13, while still being capable of transmitting rotary motion to the body.

The mandrel 10 has a limited range of longitudinal movement within the body, its downward movement being determined by engagement of the lower end 16 of the kelly with an inwardly directed body shoulder 17, and its upward movement being limited by engagement of an external shoulder or piston portion 18 of the kelly with a cylinder head 19 secured to the body. The upper end of the head has a flange 20 engaging a body shoulder 21, the flange being prevented from moving upwardly of the body by split snap retainer rings 22 fitting in a body groove 23 and overlying the flange 20. An annular guide 24 is releasably secured to the body 13 by a split snap ring 25 above the retainer rings.

The body 13 has a plurality of expansible parts mounted on it. These include cutter supporting members 26 pivotally mounted in body slots 27 on hinge pins 28 and suitably secured to the body, to prevent their loss therefrom. Each cutter supporting member 26 depends from the hinge pin 28 and carries a drag or milling cutter struc-

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ture 29 at its lower end, which structure is specifically described hereinbelow.

The cutter supporting members 26 and the cutter structures 29 themselves tend to occupy a retracted position substantially entirely within the confines of the main body 13 of the bit. These cutter supporting members and the cutter structures are expandible outwardly, to sever the casing and mill it away by operating upon the upper end E of the casing therebelow. To accomplish the expansion, each cutter supporting member 26 has an inclined expander surface 30 on its inner portion below the hinge pin 28 which tapers in a downward and inward direction. Each expander surface terminates in a lock surface 31 formed on a lock portion 32 of the cutter supporting member. The outward expansion is accomplished by producing relative longitudinal movement between the mandrel 10 and the bit body 13, which will produce relative longitudinal movement between the cutter supporting members 26 and the tubular member 33 of the mandrel 10. This tubular member includes a lower portion 34 slidable within a guide bushing 35 mounted in a bridge 36 secured to the body and extending across the body slots 27. This guide bushing 35 is disposed below the lock portions 32 of the cutter supporting members 26.

Located initially substantially above the guide bushing 35 and below the hinge pins 28, and in cutter member recesses 37, is a mandrel lock and expander 38 which has outer surfaces 39 adapted to engage the expander surfaces 30 and the lock surfaces 31. The lock and expander 38 may be formed integral with the tubular member 33, the upper end of the latter being piloted within a socket 40 formed in the lower portion 14 of the kelly 12. An enlarged boss 41 on the tubular member 33 engages a downwardly facing shoulder 42 of the kelly, the tubular member being held against this shoulder by a suitable split retainer or lock ring 43 snapped into an internal groove 44 encompassing the Kelly socket and engaging the lower end of the tubular member boss 41.

Drilling mud or other fluid can pass down through the central passage 45 in the kelly or drill stem 12 and into the central passage 46 extending completely through the tubular member 33. Leakage of fluid around the exterior of the tubular member 33 is prevented by a suitable side seal ring 47, such as a rubber O ring, in a peripheral groove 48 in the kelly, which engages the interior of the boss 41.

Assuming that the body 13 of the tool is elevated relatively along the tubular mandrel 10, the inclined expander surfaces 30 of the cutter supporting members 26 will be shifted upwardly along the lock and expander portion 38 of the tubular member 33. During such upward shifting, the cutter supporting members 26, and the cutter structures 29 carried thereby, will be pivoted about the hinge pins 28 and urged in an outward direction. The upward movement of the body 13 with respect to the tubular mandrel 10 can continue until the cutter structures 29 have been shifted outwardly to their fullest extent, as determined by engagement of stop shoulders 49 on the cutter supporting members 26 with companion shoulders 50 formed in the body on opposite sides of the body slots 27. When such engagement occurs, the lower end 16 of the kelly portion 12 of the tubular mandrel will engage the body shoulder 17, and the lock and expander 38 on the tubular member 33 will be disposed behind and in engagement with the lock portions 32 on the cutter supporting members 26.

It is to be noted that the surfaces 31 of the lock portions 32 of the cutter supporting members 26 and the companion surfaces 39 on the lock and expander portion 38 of the tubular member are substantially parallel to the axis of the drill bit, to prevent the reactive forces on the cutter structures 29 from moving the latter inwardly. As a practical matter, it is preferred that the

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coengaging lock surfaces 39, 31 be inclined slightly in a downward direction toward the axis of the tool, to insure release of the lock and the expander portion 38 from the cutter supporting members 26 when the latter and the cutter structures 29 are to be shifted to retracted position.

The relative longitudinal movement between the tubular mandrel 10 and the body 13 of the tool is accomplished hydraulically in the specific form of apparatus disclosed in the drawings. Thus, the piston or enlarged portion 18 on the drill stem 12 is received within a counterbore 51 formed on the upper portion of the body of the tool. This upper portion actually constitutes a cylinder 52 having a cylindrical wall 53 extending from a lower shoulder 54, defining the bottom of the counterbore 51, to the cylinder head 19.

A confined cylinder space 55 is formed between the piston portion 18 of the kelly, the periphery of the kelly above the piston, and the cylinder 52. A suitable packing or side seal ring 56 may be disposed in a suitable piston ring groove 57 formed in the piston 18, which is adapted to slidably seal against the cylindrical wall 53 of the cylinder 52. Fluid is thereby prevented from passing in a downward direction between the piston and the cylinder. Similarly, fluid is prevented from passing in an upward direction out of the annular cylinder space 55 by an inner side seal ring 58 carried in an internal groove 59 in the cylinder head 19 and slidably and sealingly engaging the periphery of the kelly 12 above the piston 18, and also by an outer side seal ring 60 disposed in an external groove 61 in the head 19 and sealingly engaging the cylinder wall 53.

Fluid under pressure in the string of drill pipe B and in the tubular mandrel passage 45 can be fed into the cylinder space 55 through one or more side ports 62 establishing communication between the central passage 45 through the kelly and the cylinder space. Such fluid under pressure is developed, in the form of invention disclosed in the drawings, by virtue of the fact that the passage 46 through the tubular member 33 of the mandrel 10 is of a restricted diameter as compared to the passage 45 through the kelly portion of the mandrel. As a result, the pumping of drilling mud, or other fluid, at an adequate rate through the apparatus will build up a back pressure of fluid in the passage 45, which pressure will be imposed on the fluid in the cylinder space 55, acting upon the cylinder head 19 to urge the body 13 of the tool in an upward direction with respect to the tubular mandrel 10, to secure the outward expansion of the cutter supporting member 26 and cutter structures 29 to their fullest extent, as above described.

As apparently disclosed in the drawings, a set of diametrically opposed supporting members 26 and cutter structures 29 are employed, displaced substantially 180 degrees apart from each other. Actually, it is preferred to employ three sets of supporting members and supporting structures displaced substantially 120 degrees from each other, to secure a smoothly running rotary expandible bit. The two sets of supporting member structures are shown in the interests of simplicity of the drawings. Each cutter structure 29 is secured to the lower portion of a cutter supporting member 26 by use of welding material 70, which functionally integrates the cutter structure to the depending supporting member or leg 26. The lower portion of the cutter structure has a plurality of depending legs 71, 72, 73 separated from one another by substantial spaces 74, the depending legs, in effect, constituting cutter teeth, which depend to substantially the same extent from the upper body portion 75 of the cutter structure. The lower ends of the teeth 71, 72, 73 are preferably provided with hardfacing material 76, whereas the leading faces of the depending teeth are also provided with hardfacing material 77. Such hardfacing material may be of any suitable type. However, it is found that the brazing of sintered tungsten

carbide particles on the leading faces of the teeth, as well as on their bottom faces or surfaces, is very effective in milling away casing sections and in acting upon very hard formations.

As specifically disclosed in Figs. 4 and 5, each cutter structure 29 has three depending legs or teeth 71, 72, 73. It is preferred to use a plurality of teeth, in order to have a large cutting surface in contact with the casing section or formation, after the cutter supporting members 26 and cutter structures 29 have been expanded outwardly to their maximum extent. The necessary drilling weight can be imposed on the string of drill pipe B and on the rotary drill bit A itself, to secure a proper cutting away of the casing material or of the formation. However desirable the plurality of teeth may be, they offer a disadvantage in securing the initial severing cut in the casing D in view of the large surface that will contact the inner wall of the casing and the relatively limited expanding force available for urging the cutters 29 from their retracted to their fully expanded positions.

The present invention overcomes the aforementioned disadvantage by causing a lesser number of teeth to engage the casing D and make the severing cut than are available to engage the casing at E after it has been severed, and when drilling weight can be imposed in a downward direction on the cutters 29. Thus, it will be noted that each cutter tooth 71, 72, 73 extends radially outward beyond the upper body portion 75 of the cutter structure 29, but that only some of the cutter teeth, such as the end teeth 71, 73, are capable of engaging the casing in effecting its severing. As specifically disclosed, the end teeth 71, 73 are each provided with a layer of hardfacing material 78 running lengthwise therealong from the lower end of the tooth to the region where the tooth emerges into the body portion 75 of the cutter structure, and that such hardfacing material 78 extends radially outward of the cutter structure to a much greater extent than the intermediate tooth 72. As a matter of fact, since the intermediate tooth 72 is not caused to perform any severing action on the casing D, it is not even supplied with hardfacing material on its outer surface 72a. Its outer surface is disposed inwardly of the outer surfaces 78a of the end teeth 71, 73 to a substantial extent, so that the outer face of the intermediate tooth cannot even engage the casing until the end teeth 71, 73 have completed the severing action on the casing.

The lower ends of the teeth will all lie substantially in the same plane when the cutter supporting members 26 and cutter structures 29 have been expanded outwardly to their maximum extent, whereas the outer surfaces 78a of the end teeth 71, 73 lie on an arc of a circle that has a substantially greater radius than the arc of the circle on which the outer surface 72a of the intermediate tooth lies.

In the operation of the apparatus A, it is run in the well casing with the cutter supporting members 26 and the cutter structures 29 in their initial retracted position, such as shown in Fig. 1. The lower portion of the body 13 of the apparatus may have a pilot structure 80 secured thereto, such pilot structure being constituted by circumferentially spaced, longitudinally extending blades 81 which are capable of riding along the wall of the casing D, to center the apparatus therewithin. When the apparatus has been lowered to the desired point in the well casing D at which the latter is to be severed, the pumps at the top of the well bore are started to pump fluid at a sufficient rate through the drill pipe B and into the mandrel passages 45, 46 building up a back pressure in the Kelly passage 45 and in the fluid in the ports 62 and cylinder space 55, which pressure will act upon the cylinder head 19 to urge the body 13, the cutter supporting members 26, and the cutter structures 29 in an upward direction with respect to the mandrel 10.

During such upward movement, the expander surfaces 75

30 on the cutter supporting members 29 are brought to bear against the lock and expander portion 38 of the mandrel, the cutter structures being urged in an outward direction against the wall of the well casing. The drill pipe B and the rotary drill bit A are rotated at proper speeds while fluid is being pumped through the apparatus, the outer casing severing or reaming edges 78 of the cutter teeth 71, 73 acting upon the wall of the casing and gradually milling it away. During this operation, the apparatus is retained in the same longitudinal position in the well casing. As the casing is cut away, the hydraulic force acting upon the body 13 raises it and the cutter supporting members 26 and cutter structures 29 to a further extent, until the reamer edges 78 of the cutter teeth 71, 73 have completely severed the casing. Such severing action will occur before the outer face 72a of the intermediate cutter tooth 72 can engage the inner wall of the casing D. Thereafter, rotation of the drill pipe B and the rotary drill bit A continues, so that the reamer edges 78 continue to cut away the casing and dig into the formation, until the cutters 29 have been fully expanded outwardly to the maximum extent, as determined by engagement of the stop shoulders 50, and the lower end 16 of the Kelly portion of the mandrel with the body shoulder 17. With the parts in this position, the lock portion 32 of the cutter supporting member 26 will bear against the lock and expander portion 38 of the tubular member 33 to preclude inadvertent partial retraction of the cutter structures 29 from their fully expanded position.

Downweight of the proper amount is now imposed on the string of drill pipe B, this downweight being transmitted through the Kelly 12 to the body shoulder 17, and from the body through the stop shoulders 50, 45 directly to the supporting members 26 and the cutter structures 29, urging the three blades 71, 72, 73 of each cutter 29 against the upwardly facing severed end E of the well casing D. It is evident that a greater number of teeth and surfaces are not available for a milling action upon the upper end E of the casing than was used in severing the casing. Assuming that three sets of supporting members 26 and cutter structures 29 are used, each cutter structure 29 having the configuration disclosed in Figs. 4 and 5, a total of nine cutter teeth will be available for action upon the severed end E of the casing. With such large number of cutter teeth, and in view of the extent of their bottom faces 76, a relatively large drilling weight can be imposed upon the cutter teeth to cause a relative rapid milling away of the casing D. The drilling weight can be varied within wide ranges. However, since the expanding force in making the severing cut on the casing is limited to the hydraulic pressure that can be made available in the cylinder space 55, and since the total force, as a practical matter, can only be of a certain maximum value, the distribution of the outward expanding force over a lesser number of teeth 71, 73 than are used in milling away the casing after it has been severed, means that a greater unit penetrating pressure is being supplied on the reamer edges 78 of the teeth 71, 73 than would be present if the intermediate tooth 72 were also made effective in performing the casing severing action. With such latter tooth 72 active, inadequate penetration into the casing wall might result.

It is to be noted that there are relatively wide spaces 74 between the depending teeth 71, 72, 73. Accordingly, the cuttings that the teeth produce can readily be flushed from between them by the drilling fluid circulated down through the drill pipe B and through the tool, discharging from the lower end of the mandrel passage 46. Each tooth will have fluid circulating therearound, which will not only insure that the tooth faces 76, 77 are maintained free from cuttings, but will insure that the circulating fluid will maintain the teeth in a cool condition, to enhance their life.

As the bottom ends 76 of the teeth operate upon the

casing section, the latter will be gradually milled away in a downward direction. During the milling action, the casing itself may wear grooves 90 in the casing teeth (Fig. 6), the grooves extending upwardly from their lower ends 76 with the side walls 91 of the grooves of the teeth closely sliding along the inner and outer surfaces of the casing D. Such grooves are of advantage in connection with the stability in the operation of the apparatus, since it assists the pilot portion 80 in centering the bit in the well casing, to insure its smooth operation. The multiple cutter teeth 71, 72, 73 of each cutter structure extend along a substantial arc of casing, as is evident from an inspection of Fig. 5, the grooves 90 formed in the teeth being arcuately spaced from one another, so as to insure the stable positioning of each cutter structure 29 on top of the casing. In addition, the fact that it is preferred to use three sets of cutter structures spaced 120 degrees apart means that there are nine cutter tooth grooves 90 receiving the upper end of the casing after the tool has been operated to some extent, which cause the teeth to embrace the casing at a large number of points around the latter. The use of a plurality of arcuately spaced cutter teeth in each cutter structure, and of a plurality of structures, all assist in the stability in the operation of the apparatus in milling away casing sections in a well bore, and increases the efficiency of the tool. In actual practice, the apparatus disclosed has been capable of milling away hard casings in a well bore in a comparatively rapid manner.

The plurality of arcuately separated cutter teeth 71, 72, 73 in each cutter structure also provides a much greater cutting surface capable of simultaneous operation upon the well casing. As the cutter teeth wear away, there is effective hardfacing material on the leading face 77 of each tooth capable of a cutting operation on the upwardly facing casing end E. Such hardfacing material is available and is effective until the casing has formed grooves 90 in the cutter teeth to their uppermost ends, where they are joined to the main steel body 75 of the cutter structure 29.

The cutter structure disclosed in Fig. 7 possesses more cutter teeth than that disclosed in Figs. 4 and 5. Actually, the cutter structures disclosed in Fig. 7 have four cutter teeth 92, 93, 94, 95 arcuately separated from each other, with their leading faces 77 and bottom faces 76 provided with hardfacing material. However, only alternate cutter teeth 92, 94 have their casing severing or reaming edges 78 provided with hardfacing material, these edges extending outwardly to a substantially greater extent than the outer edges 72a of the other cutter teeth 93, 95. As was described in connection with the cutter structure shown in Fig. 5, the hardfaced reamer edges 78 extend outwardly beyond the other outer tooth edges 72a to an extent insuring severing of the casing before the unhardfaced outer edges 72a could engage the casing wall.

Accordingly, in Fig. 7, the unit force acting on the reamer edges 78 to sever the casing is much higher than would be available if all four outer edges 78, 72a of the teeth 92 to 95 were permitted to engage the well casing in making the severing cut. Despite the fact that there are only two cutter teeth 92, 94 available to accomplish the severing action, four spaced cutter teeth 92 to 95 are available for action upon the severed end E of the casing, which will permit a greater total drilling weight to be supplied on the tool, effective over a large number of cutting teeth, to cause the casing to be milled away at a comparatively rapid rate.

When it is desired to retrieve the apparatus A from the well bore after the hole enlarging operation has been completed, or as a result of the cutter teeth becoming worn, it is only necessary to discontinue the pumping of the drilling fluid through the drill pipe B and the apparatus A, to relieve the pressure on the cylinder 52, and elevate the drill pipe B. Such elevating movement will elevate the tubular mandrel 10 with respect to the body

13 and the cutter supporting members 26 to raise the lock and expander portion 38 above the expander surfaces 30, whereupon the cutter structures 29 can drop back to their retracted position, such as disclosed in Fig. 1. In the event the cutters 29 are reluctant to move to such position, the outer surfaces 26 of the cutter supporting members will engage the casing above and adjacent the location where the severing cut was made, when the apparatus is elevated in the well bore, which will force the cutter supporting members 26 and cutters 29 inwardly, enabling the apparatus to be withdrawn through the well casing D to the top of the well bore.

It is, accordingly, apparent that an expansible rotary drill bit has been provided in which a large tooth surface is available for action upon the severed end of a well casing, or for action upon hard formation, when drilling weight can be imposed thereon. However, during the initial expansion of its cutters, as in making a severing cut of the casing, only a portion of the cutter teeth are utilized to enhance the penetration of the cutter teeth into the casing, and effect its severing in a more expeditious manner. The cutter teeth are widely separated from each other, to insure their being maintained free from cuttings by the fluid being circulated down through the drill pipe B and apparatus A, as well as in a cool state. The use of a plurality of cutter teeth on each cutter structure, arcuately separated from each other, causes the severed end E of the casing to form grooves 90 along arcuately spaced portions of the teeth of the cutter structure, which insures the centering of the apparatus in the well casing and stability in its operation therewithin.

The inventor claims:

1. In a rotary drill bit to be lowered in a well bore: a main body; cutter means mounted on said body for expansion laterally outward of said body; means for expanding said cutter means laterally outward of said body; said cutter means including a drag cutter structure having a plurality of depending teeth arcuately spaced from each other and having lower cutting faces lying in the same plane so that all teeth and lower faces are adapted for simultaneous operation upon a shoulder formed in the well bore which opposes the advance of said teeth; at least one of said teeth having an outer reaming surface extending radially outward to a substantially greater extent than the corresponding outer surface of another of said teeth.

2. In a rotary drill bit to be lowered in a well bore: a main body; cutter means mounted on said body for expansion laterally outward of said body; means for expanding said cutter means laterally outward of said body; said cutter means including a drag cutter structure having a plurality of depending teeth arcuately spaced from each other and adapted for simultaneous operation upon a shoulder formed in the well bore which opposes the advance of said teeth; at least one of said teeth having an outer reaming surface extending radially outward to a substantially greater extent than the corresponding outer surface of another of said teeth; the lower and leading faces of all teeth being hardfaced, said reaming surface being hardfaced and said corresponding outer surface of said another of said teeth being devoid of hardfacing.

3. In a rotary drill bit to be lowered in a well bore: a main body; a supporting member pivotally mounted on said body; a drag cutter structure secured to the lower portion of said member; means for expanding said member and cutter structure laterally outward of said body; said drag cutter structure having a plurality of depending teeth arcuately spaced from each other and having their lower cutter faces lying in the same plane so that all teeth and lower faces are adapted for simultaneous operation upon a shoulder formed in the well bore which opposes the advance of said teeth; at least one of said teeth having an outer longitudinal reaming surface extending radially outward to a substantially greater extent than the corresponding outer surface of another of said teeth.

4. In a rotary drill bit as defined in claim 3; wherein said reaming surface is hardfaced and said corresponding outer surface of said another of said teeth is devoid of hardfacing material.

5. In a rotary drill bit to be lowered in a well bore: a main body; a supporting member pivotally mounted on said body; a drag cutter structure secured to the lower portion of said member; means for expanding said member and cutter structure laterally outward of said body; said drag cutter structure having a plurality of depending teeth arcuately spaced from each other and having their lower faces adapted for simultaneous operation upon a shoulder formed in the well bore which opposes the advance of said teeth; at least one of said teeth having an outer longitudinal reaming surface extending radially outward to a substantially greater extent than the corresponding outer surface of another of said teeth; the lower and leading faces of all teeth being hardfaced, said reaming surface being hardfaced and said corresponding outer surface of said another of said teeth being devoid of hardfacing.

6. In a rotary drill bit to be lowered in a well bore: a main body; supporting members pivotally mounted on said body in equiangular circumferentially spaced relation; a drag cutter structure secured to the lower portion of each of said members; means for expanding said members and cutter structures laterally outward of said body; each of said drag cutter structures having a plurality of depending teeth arcuately spaced from each other and having their lower faces adapted for simultaneous operation upon a shoulder formed in the well bore which opposes the advance of said teeth; at least one of said teeth of each cutter structure having an outer longitudinal reaming surface extending radially outward to a substantially greater extent than the corresponding outer surface of another of said teeth; the lower and leading faces of all teeth of all cutter structures being hardfaced, said reaming surface of all cutter structures being hardfaced and said corresponding outer surface of said another of said teeth of each cutter structure being devoid of hardfacing.

7. In a rotary drill bit to be lowered in a well bore: a main body; cutter means mounted on said body for expansion laterally outward of said body; means for expanding said cutter means laterally outward of said body; said cutter means including a drag cutter structure having a plurality of depending teeth arcuately spaced from each

other and having lower cutting faces lying in the same plane so that all teeth and lower faces are adapted for simultaneous operation upon a shoulder formed in the well bore which opposes the advance of said teeth; the outer reaming surfaces of alternate teeth extending radially outward to a substantially greater extent than the corresponding outer surface of each intervening tooth.

8. In a rotary drill bit to be lowered in a well bore: a main body; cutter means mounted on said body for expansion laterally outward of said body; means for expanding said cutter means laterally outward of said body; said cutter means including a drag cutter structure having a plurality of depending teeth arcuately spaced from each other and adapted for simultaneous operation upon a shoulder formed in the well bore which opposes the advance of said teeth; the outer reaming surfaces of alternate teeth extending radially outward to a substantially greater extent than the corresponding outer surface of each intervening tooth; the lower and leading faces of all teeth being hardfaced, said reaming surfaces being hardfaced, and said corresponding outer surface being devoid of hardfacing.

9. In a rotary drill bit to be lowered in a well bore: a main body; supporting members pivotally mounted on said body in equiangular circumferentially spaced relation; a drag cutter structure secured to the lower portion of each of said members; means for expanding said members and cutter structures laterally outward of said body; each of said drag cutter structures having a plurality of depending teeth arcuately spaced from each other and having their lower faces adapted for simultaneous operation upon a shoulder formed in the well bore which opposes the advance of said teeth; the outer reaming surfaces of alternate teeth of each cutter structure extending radially outward to a substantially greater extent than the corresponding outer surface of each intervening tooth; the lower and leading faces of all teeth of each cutter structure being hardfaced, said reaming surfaces of each cutter structure being hardfaced, and said corresponding outer surface of each cutter structure being devoid of hardfacing.

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