Aug. 18, 1931. J. GRANT 1,819,367

EXPANDING ROTARY REAMER

Filed Feb. 14, 1928 2 Sheets-Sheet 1

Fig. 1.

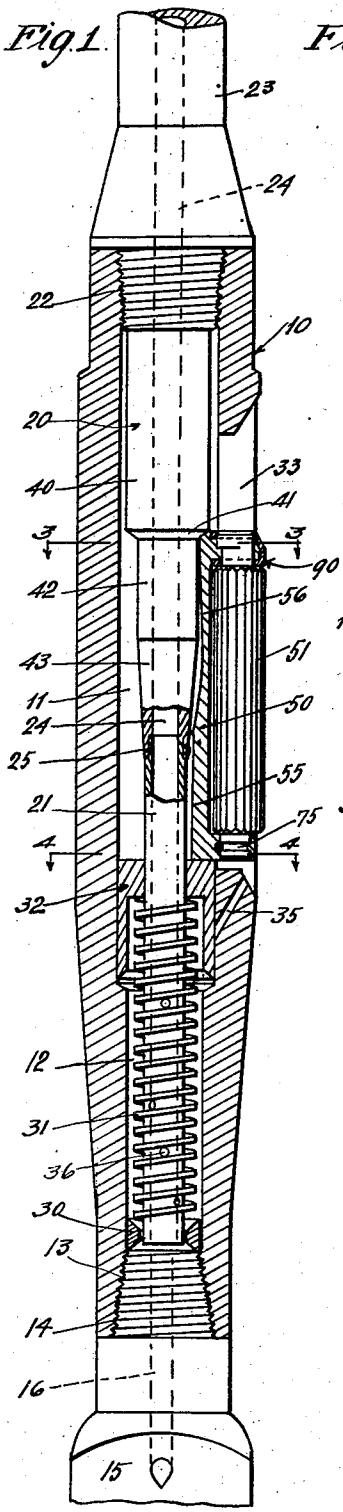


Fig. 2.

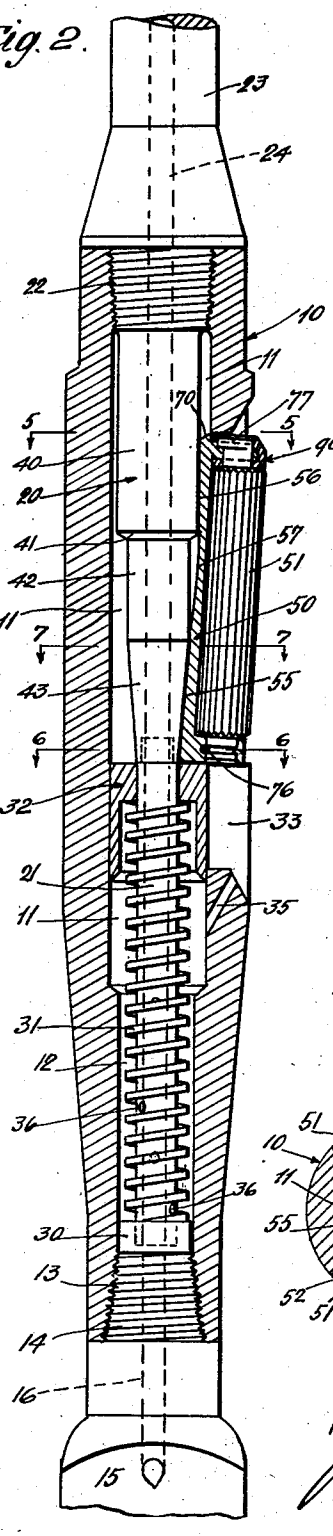


Fig. 3.

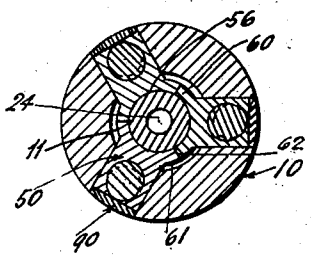


Fig. 4.

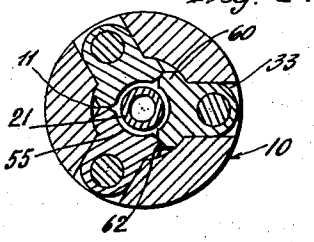


Fig. 5.

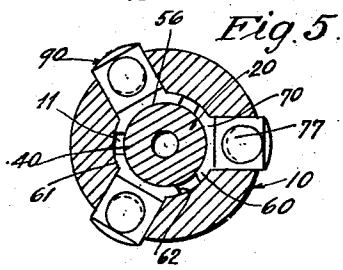


Fig. 6.

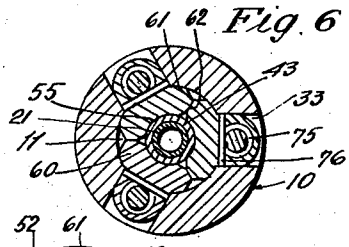
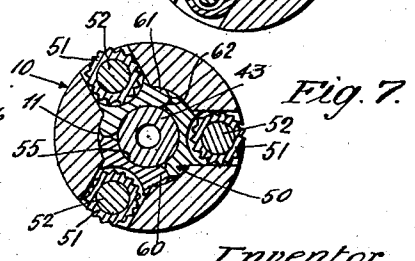


Fig. 7.



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Fig. 8.

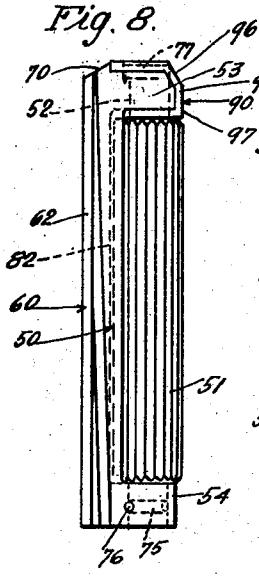


Fig. 9.

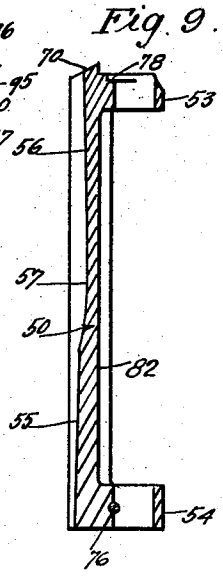


Fig 10.

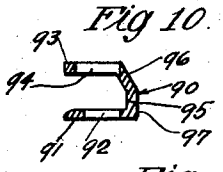


Fig. 11.

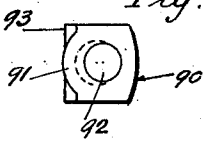


Fig. 12.

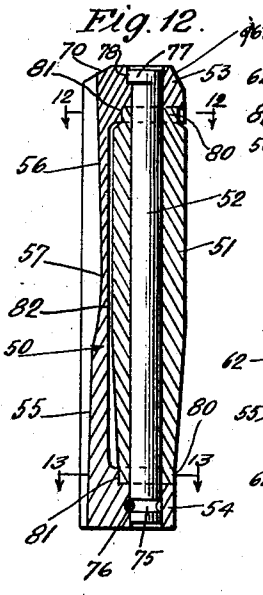


Fig. 13.

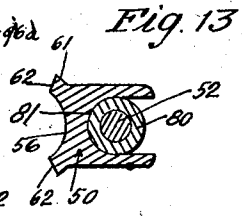


Fig 14.

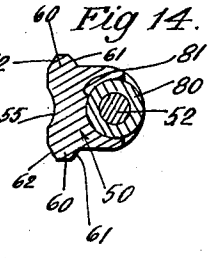
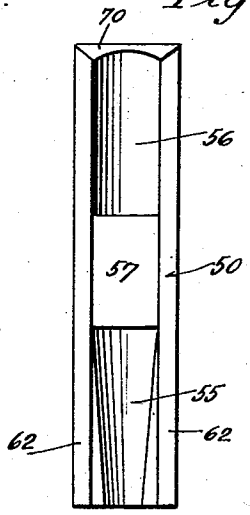


Fig 15.



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UNITED STATES PATENT OFFICE

JOHN GRANT, OF LOS ANGELES, CALIFORNIA

EXPANDING ROTARY REAMER

Application filed February 14, 1928. Serial No. 254,266.

This invention has relation to expanding reamers or underreamers, or similar expanding tools particularly adapted for well work; the invention contemplating and characteristically consisting of certain improvements in that type of reamer which is set out in the application of John T. Phipps, Serial No. 61,808 filed October 10, 1925. The reamer described in said Phipps application is characterized by a substantially tubular slotted body within which there is a longitudinally extending central mandrel. The cutters or cutter carries play in the slots and extend through the body wall and by relative longitudinal movement, with relation to the mandrel, and propelled by a spring actuated propeller, the cutters are moved outwardly or expanded; their outward movement, when moved longitudinally, being due to interengaging conformations of the mandrel and cutter carriers which cause expansion and allow contraction. In that Phipps underreamer, as in the one now about to be described, relative longitudinal movement between the mandrel and cutter-carriers is effected by longitudinal movement of the carriers in the body. And also in that Phipps construction the cutter carriers are propelled by a propeller surrounding the mandrel or an extension of it and by a spring which likewise surrounds the mandrel or its extension, and the water course is in the same mandrel.

The above described features of the Phipps underreamer are included in the underreamer of the present invention; the improvements concerned in this present invention referring to the mounting and bearings of the cutter carriers, the interengaging conformation of the carriers and the mandrel and body, and various other improvements having particularly to do with the carriers and cutters. These various improvements will be best understood from a detailed description of preferred and illustrative designs, rather than from any general preliminary description of their natures, and I accordingly proceed with a detailed description of specific illustrative embodiments of the invention and for this purpose refer to the accompanying drawings, in which

Figure 1 is a central longitudinal section of my improved reamer showing the parts in their contracted or collapsed positions.

Fig. 2 is a similar view showing the parts in their expanded positions.

Fig. 3 is a cross-section on line 3—3 of Fig. 1.

Fig. 4 is a cross section on line 4—4 of Fig. 1.

Fig. 5 is a cross section on line 5—5 of Fig. 2.

Fig. 6 is a cross section on line 6—6 of Fig. 2.

Fig. 7 is a cross section on line 7—7 of Fig. 2.

Fig. 8 is a somewhat enlarged side elevation of a carrier equipped with a roller cutter.

Fig. 9 is a central vertical section of the carrier shown in Fig. 8.

Fig. 10 is a central vertical section.

Fig. 11 is a plan of a preferred form of protective washer which is shown in the other figures.

Fig. 12 is a vertical central section showing a modified form of roller cutter mounting in a carrier.

Fig. 13 is a cross section on line 13—13 of Fig. 12.

Fig. 14 is a cross section on line 14—14 of Fig. 12, and

Fig. 15 is an inner face elevation of the carrier shown in Fig. 9.

In the drawings a substantially tubular body 10 is illustrated suitable for the design of reamer which I have chosen here to describe as illustrative of the invention. This body has a central longitudinal bore 11 which may preferably be of uniform size from the top of the body down to a point near its lower end where the bore is reduced in size as at 12.

At the lower end of the body the usual taper-threaded box 13 is provided for taking the tool joint pin 14 of the usual drilling bit 15, the drilling bit having its usual or any suitable water course or courses 16 to which water or other circulating fluid is supplied through the central mandrel 20 and its extension tube 21. This central mandrel 20 depends from the upper end of the body where it is crew-threaded into the body with a taper-threaded pin 22, the mandrel extending above the upper end of the body in the form of a sub 23 which may be adapted (but not shown in the drawings) for attachment to the usual rotary drill stem. The mandrel throughout its length is provided with a longitudinal water-course 24 which water course is extended through the tubular mandrel extension 21 to a point near the lower end of the body. The mandrel extension 21 may be made, in effect, integrally with the upper part of the mandrel. But it is convenient to make the part 21 as a separate piece and join it to the mandrel by fitting its upper end into the lower end of the upper mandrel part, as illustrated particularly at 25 in Fig. 1. This joint of the tube 21 with the upper part of the mandrel may be more or less tight, but is not necessarily so tight that the tube cannot be easily removed. It is, however, preferably fitted tightly enough that to all intents and purposes the tube forms a physically rigid extension of the mandrel; and it thus may be regarded as a part of the mandrel. The lower end of tubular extension 21 preferably lies closely above the tool joint pin 14 so that if the mandrel should break the lower end of its extension, resting upon pin 14, will support the mandrel substantially at its proper elevation in the body and keep the tool in operative condition even though the mandrel should be broken completely through at a point below the taper-threaded joint at 22. From the description that follows it will be seen that the mandrel, even if broken, is held in central position by the cutters or cutter carriers. Also to prevent any liability of mandrel breakage by vibration, the lower end of tube 21 is confined inside a spring seat collar 30 which fits in bore 12 and rests upon tool joint pin 14. The fitting of the lower end of tube 21 in collar 30 may be made more or less tight if desired, but it is preferred not to make the collar 30 fit too tightly in bore 12 or to make the tube fit too tightly in the collar as the disassembly of the reamer is thereby facilitated.

The cutter-actuating spring 31 rests at its lower end on collar 30 and at its upper end it supports a cutter propeller 32 which is here shown as cylindric in form and slidably fitting in the lower part of bore 11. This cylindric propeller 32 is of a length somewhat greater than the upward stroke of the propeller so that, when the propeller is in the position of Fig. 2, its lower end is still somewhat below the lower ends of cutter-receiving slots 33 and thus prevents the entry of mud or silt through the slots into the lower part of bore 11 in which the spring 31 is located. The spring chamber is thus substantially closed off against entry of the mud or silt which might otherwise fill the spring chamber and clog the spring action; and to continuously wash out the slight amount of silt, which would otherwise enter through clearance spaces, I provide for carrying a certain amount of the water circulation through the spring chamber. It will be noted that the open lower end of mandrel extension 21 is in communication with the circulation passage 16 of the bit. Some of the circulating water may pass from the lower end of tube 21 up into the spring chamber and thence out through discharge passages 35 under the cutters when the cutters are expanded and propeller 32 is in lifted position. But to provide for free circulation of a considerable amount of the circulating water through the spring chamber, I may provide perforations 36 in tube 21.

In the particular design here illustrated the mandrel has a cylindric upper part 40 at whose lower end there is a conical or diagonal shoulder 41. Below this diagonal shoulder 41 the mandrel has a reduced cylindric part 42, and below the cylindric part 42 the mandrel has a conical or downwardly tapering part 43, this last part being of comparatively slight taper.

The number of cutters and cutter-carriers utilized in my reamer may be as desired, the number being largely a matter of choice. I have found, however, that three cutters are very well adapted to perform efficient service and I therefore illustrate three cutters and cutter carriers here. Thus the body is provided with three longitudinally extending slots 33 and in each of these slots there is a cutter-carrier 50, the formation of which I shall now describe. Broadly speaking it is immaterial, at least as to the major characteristic features of my invention, whether the ultimate cutting element or cutter in an integral part of the cutter-carrier or is provided as a separate part. Thus the ultimate cutter may be in the form of a cutting edge formed upon the cutter-carrier itself; but for purposes of typical illustration I here prefer to show the ultimate cutters in the form of rollers 51 mounted on pins 52, which extend longitudinally of carriers 50 and are mounted at their upper and lower ends in lugs 53 and 54, which extend outwardly from the body of the carriers. The details of this mounting will be considered later, it being sufficient now to observe that the outer longitudinal edge of the roller 51, and therefore the axis of pin 52, if the roller 51 is cylindric, has such relation to the bearing surfaces of the carrier (the bearing surfaces

that bear against the mandrel and the body) that when the cutter is collapsed or retracted, as in Fig. 1, its outer cutting edge stands substantially vertically or substantially parallel to the central vertical axis of the whole tool; while it stands in a tilted position when expanded, as in Fig. 2.

The cutter-carrier 50 has an inner lower mandrel engaging face 55 which stands substantially vertically when the carrier is in the position in Fig. 1. These faces 55 of the three carriers are parts of a conic surface whose diameter at the lower ends of the carriers is substantially or exactly the same as the diameter of the extreme lower end of the tapered mandrel part 43. These slightly tapered conic bearing faces 55 are of substantially the same length as that of the tapered mandrel part 43, and their diameter at their upper ends is substantially or exactly the same as the diameter of the mandrel at the upper end of tapered part 43; so that when the carriers are in their upper positions these conic bearing surfaces 55 surround the tapered mandrel part 43 and bear inwardly against it at all points. These features will be understood best by a consideration of Figs. 2, 6 and 7.

The upper inner bearing surface of each carrier 50 is a cylindric surface 56 of the same diameter as the upper cylindric part 20 of the mandrel. When the carriers are in their upper and expanded positions, these cylindric bearing faces 56 are situated concentrically about the central vertical axis of the mandrel and stand in a vertical position, and therefore bear inwardly against part 40 of the mandrel as is shown in Figs. 2 and 5. When the carriers are in their lower and collapsed positions, these cylindric bearing faces 56, due to the fact that the carrier swings inwardly at its upper end to reach collapsed position, stand somewhat out of the vertical position, as is best illustrated in Fig. 1. The cylindric bearing faces 56 are at least as long as the vertical distance between the upper ends of slots 33 and the lower end of cylindric mandrel part 40, so as to give the carriers a full and true inward bearing on the mandrel at their upper ends. The cylindric bearing faces may, however, extend below the mandrel shoulder 41 when in the position of Fig. 2. The lower ends of cylindric faces 56 are joined up with the upper ends of conic faces 55 by curved surfaces 57 of any suitable conformation.

Each of the carriers is provided with vertically extending wings 60 at the inner edges of its sides, these wings overhanging the side edges of slots 33 to limit the outward movements of the carriers by bearing against the wall of bore 11 at the longitudinal sides of the slots. The wings have outer cylindric faces 61 which are adapted to bear throughout their lengths against the wall of bore 11, and are therefore generated at the same curvature as the wall of that bore. When the carriers are in their upper, expanded and tilted positions of Fig. 2, these cylindric bearing faces 61 are vertical and bear against the bore wall throughout their lengths. This will best be understood by reference to Figs. 5, 6 and 7. The cylindric faces 61 are therefore substantially or exactly parallel to inner cylindric bearing faces 56 of the carriers and, like those faces 56, make a slight angle with the vertical elements of conic faces 55 and with the cutter 51. This angular relationship is perhaps best shown in Fig. 8. The angle, as will readily be seen from a consideration of the drawings, is the angle of tilt of the cutters.

The wings 60 also have inner bearing faces 62 which lie in vertical planes radial to the central axis of the mandrel when the carriers are in the collapsed position in Fig. 1; and these inner radial bearing faces 62 of the several carriers bear against each other at their lower ends, and preferably throughout their entire vertical lengths when the carriers are in their collapsed positions. When in collapsed position the lower ends of the carriers thus bear or abut circumferentially against each other around the mandrel, but without touching the mandrel part 21; and also the lower ends of the outer bearing faces 61 are bearing outwardly against the wall of bore 11. This feature may be seen illustrated in Fig. 4. Consequently the upward movement of the lower end of each cutter-carrier is purely a movement of vertical translation, the lower ends of the carriers having no lateral inward or outward movement. The lower end of each carrier merely moves straight upwardly while the upper end of each carrier moves upwardly and tilts outwardly. This outward tilting of the upper end of the carrier is permitted by the fact that the outer cylindric bearing faces 61 of the wings are vertical when the carrier is in tilted position—that is, the wings 60 are narrower at their upper than at their lower ends, and the wing thickness at the upper end is just such as will fit snugly between the wall of the bore 11 and the upper large cylindric part 40 of the mandrel.

Thus, in operation, the action of spring 31 and propeller 32 is to push the carriage upwardly, pushing the upper beveled end surface 70 of each carrier up against the beveled annular mandrel shoulder 41. By this action the upper ends of the carriers are first forced upwardly and outwardly until the carriers are tilted and the upper ends of the carrier bearing faces 56 (then in vertical position) will ride over cylindric mandrel part 40. Then the further action of the spring and propeller 32 is to push the tilted carriers directly upwardly to the position of Fig. 2.

The cutting rollers 51 are mounted on their vertical bearing pins 52 which, as I have said before, are mounted at their upper and lower ends in the outwardly projecting lugs 53 and 54 of the carrier, the rollers being confined longitudinally between these lugs. In order to hold the pins 52 in place longitudinally, they may be provided at their lower ends with a circular groove 75 into which a transverse pin or dowel 76 fits; and in order to prevent rotation of the bearing pins 52 their upper ends may be provided with eccentric heads 77 which fit into eccentric bores 78 in the upper lugs 53. The rollers 51 may either be cylindric as shown in Figs. 1 and 2, or they may be conic or partly conical, as shown in Fig. 12; and they may have their exclusive rolling bearing upon the pin 52 or, as particularly illustrated in Figs. 12, 13 and 14, they may have auxiliary rotary bearing faces engaging directly with the body of the carriers. Thus, as shown in these last mentioned figures, the upper and lower ends of the rollers may be provided with cylindric smooth parts 80 which fit back against the semi-cylindric bearing faces 81 provided on the carrier body. The grooved or toothed main part of the roller itself will, of course, have no direct bearing against the carrier, but will have a small clearance in front of the cylindric front face 82 of the carrier. But the provision of the bearing faces 80, 81, acting directly between the carrier and the ends of the roller cutter, is designed to take a considerable shearing or bending strain off the bearing pin 52.

Another feature of the invention in connection with the carriers and cutters is shown in Figs. 1 to 11. When a reamer of this type is being lowered through a well pipe, the constant tendency of spring 31 is to force the cutters upwardly and outwardly against the wall of the pipe; and considerable wear on the pipe and on the cutters may result. The outward pressure of the cutters on the pipe is augmented by the upward drag of the pipe on the cutters. I have provided a simple means for obviating at least a great deal of such wear; and, applying this means to the form of reamer here illustrated, I have provided a form of wear-washer 90 which is shown in the various figures, but is perhaps best illustrated in Figs. 8 to 11. This wear-washer will either be in the form of a washer placed around the bearing pin 52 at its upper end and above the roller 51, or in the form of a clip placed upon the upper lug 53. The design shown in the drawings contains both such features, being in the form of a flat metal strip or bar bent or otherwise formed substantially to a U-shape to fit over the upper lug 53; the lower leg 91 of the U-shaped member having a hole 92 to pass the pin 52, the upper leg 93 of the U-shaped member having a hole 94 to fit over head 77 of the pin, and the outer web 95 of member 90 being shaped to bear against the outer face of lug 53. Where this member 90 is thus made to fit over the outer face of lug 53 the member 90 is provided with a diagonal upper and outer casing engaging face 96 so that engagement with the lower end of the casing will move the upper ends of the carriers both downwardly and inwardly. Where the wear-washer or member 90 is not used, this diagonal face is applied directly to the carrier itself, as shown at 96*a* in Fig. 12. The outer face 97 of the member 90 is arranged to be at least as far out as the extreme projection of the cutter 51; and it may preferably project a little beyond the outermost face or cutting edge of cutter 51. In such a position this outer face of member 90 will bear against the well casing while the tool is being lowered and raised, and will not allow the cutter to bear, or at least will not allow it to bear heavily, against the casing. The member 90 may either be made of relatively hard or relatively soft material. If made of hard material, it may last a considerable period of time before having to be replaced. It does not interfere materially with the reaming action of the cutters when in operation, because although the member 90 may project even to a diameter slightly beyond the greatest projection of the cutters, it will be understood that the drill hole at the position of members 90 has been reamed out to the full diameter of the cutters, or even to a slightly greater diameter. On the other hand, if it is found in any case that the members 90 interfere to any extent with the proper cutting action of the cutters, these members may be made of a sufficiently soft material that, although hard enough not to be badly worn by friction with the casing when the reamer is inserted in the hole, they will be quickly worn down or worn away by frictional contact with the formation when the reamer is in operation. In any case the washers may be easily renewed as often as desired.

I claim:

1. An expanding reamer, comprising a tubular body having a slotted wall, a cutter carrier movable transversely in the wall slot for expansion and contraction, a longitudinally extending mandrel in the body interior and against which the carrier bears inwardly, means for causing relative longitudinal movement between the carrier and mandrel moving the carrier upwardly relative to the mandrel, the upper part of the mandrel having a relatively large and substantially cylindric portion with a diagonally downwardly facing shoulder below said cylindric portion and a lower part of the mandrel having a downwardly tapered portion, and the carrier being adapted in its expanded position to seat inwardly simultaneously against said cylindric and tapered portions.

2. An expanding reamer, comprising a tubular body having a slotted wall, a cutter carrier movable transversely in the wall slot, a longitudinally extending mandrel in the body interior and against which the carrier bears inwardly, means for causing relative longitudinal movement between the carrier and mandrel moving the carrier upwardly relative to the mandrel, the upper part of the mandrel having a relatively large and substantially cylindric portion with a diagonally downwardly facing shoulder below said cylindric portion and a lower part of the mandrel having a tapered portion, and the carrier being adapted to seat inwardly against said cylindric and tapered portions, the carrier having near its upper end a substantially vertical cylindric bearing face and near its lower end a tapered conical bearing face.

3. In an expansive reamer, the combination of a tubular body having a slotted wall provided with a plurality of circumferentially spaced slots, cutter carriers movable transversely in said slots, a central vertical longitudinal mandrel extending through the body interior and against which the cutter carriers are adapted to bear inwardly, the upper part of said mandrel being relatively large to cause expansion of the cutter carriers when their upper ends are moved longitudinally upwardly onto said mandrel part, said cutter carriers having bearing wings overhanging the side edges of the slots and said bearing wings of the several cutter carriers circumferentially abutting each other near the lower ends of the carriers when the wings at their lower ends are in contact with the wall of the body at the slot edges.

4. An expanding reamer, comprising a tubular body provided with a plurality of circumferentially spaced slots which extend longitudinally of the body, a plurality of cutter carriers, one in each slot and movable lengthwise therein and transversely therein, said cutter carriers having side wings which overhang the side edges of the slots and are adapted to bear outwardly against the body wall along the side edges of the slots, said wings being shaped so that when the carriers are in position substantially parallel to the body axis the wings of the several carriers circumferentially abut each other substantially throughout their lengths, and being so shaped that at their lower ends said wings engage the body wall but are spaced inwardly from the body wall at their upper ends to allow the upper ends of the carriers to move outwardly, a central mandrel having a relatively large part near its upper end and onto which the upper ends of the carriers are moved by upward carrier movement, and means to move the carriers upwardly.

5. An expanding reamer, comprising a tubular body provided with a plurality of circumferentially spaced slots which extend longitudinally of the body, a plurality of cutter carriers, one in each slot and movable lengthwise therein and transversely therein, said cutter carriers having side wings which overhang the side edges of the slots and are adapted to bear outwardly against the body wall along the side edges of the slots, said wings being shaped so that when the carriers are in position substantially parallel to the body axis the wings of the several carriers circumferentially abut each other substantially throughout their lengths, and being so shaped that at their lower ends said wings engage the body wall but are spaced inwardly from the body wall at their upper ends to allow the upper ends of the carriers to move outwardly, a central mandrel having a relatively large part near its upper end and onto which the upper ends of the carriers are moved by upward carrier movement, and means to move the carriers upwardly comprising a cutter propeller mounted around and slidable longitudinally on the mandrel, and a spring surrounding the mandrel and acting upon said propeller.

6. An expanding reamer, comprising a tubular body provided with a plurality of circumferentially spaced slots which extend longitudinally of the body, a plurality of cutter carriers, one in each slot and movable lengthwise therein and transversely therein, said cutter carriers having side wings which overhang the side edges of the slots and are adapted to bear outwardly against the body wall along the side edges of the slots, said wings being shaped so that when the carriers are in position substantially parallel to the body axis the wings of the several carriers circumferentially abut each other substantially throughout their lengths, and being so shaped that at their lower ends said wings engage the body wall but are spaced inwardly from the body wall at their upper ends to allow the upper ends of the carriers to move outwardly, a central vertical longitudinal mandrel extending through the interior of the body, said mandrel having a relatively large cylindric part near its upper end onto which the upper parts of the carriers are adapted to be moved by upward movement, the upper parts of the carriers having cylindric bearing faces to bear against said cylindric part of the mandrel, the mandrel having a lower tapered part of lesser diameter than its cylindric part, and the carriers having near their lower ends tapered bearing faces adapted to bear upon the tapered part of the mandrel and means to move the carriers upwardly.

7. An expanding reamer, comprising a tubular body provided with a plurality of circumferentially spaced slots which extend longitudinally of the body, a plurality of cutter carriers tiltingly mounted in the body slots, said carriers having longitudinal side

wings which overhang the side edges of the slots, said wings being shaped so that when the carriers are in position substantially parallel to the body axis the wings of the several carriers circumferentially abut each other substantially throughout their lengths, and being so shaped that at one end the abutting wings of the several carriers bear against the body wall but at their other ends are spaced inwardly from the body wall to allow outward movement of those ends of the carriers.

8. In an expansive well reamer, a body, a plurality of tilting cutter carriers in the body, means to cause tilting of the cutter carriers to a position where one of their end parts projects further from the body than the other, cutters mounted on said carriers, and a removable wear member mounted on an outermost part of each carrier and projecting outwardly at least as far as any other point of the carrier or cutter to take frictional wear against a well casing, said wear member having a smooth casing engaging surface.

9. In an expansive well reamer, a body, a plurality of tilting cutter carriers in the body, means to cause tilting of the cutter carriers to a position where one of their end parts projects further from the body than the other, rotating roller cutters carried by the carriers, bearing pins for said roller cutters, and removable wear washers fitted upon said bearing pins at the furthest projected parts of the carriers, said wear member having a smooth casing engaging surface.

10. In an expensive reamer, a cutter carrier having bearing lugs at each end, a longitudinal bearing pin mounted in and between said lugs, a roller cutter mounted on the bearing pin between the lugs, and a removable wear member in the form of a U-shaped clip the web of which overlies a bearing lug and the legs of which lie at opposite sides of said bearing lug and surround said bearing pin.

11. An expanding reamer, comprising a tubular slotted body, a plurality of cutter carriers tiltingly mounted in the body slots, said carriers having longitudinal side wings which overhang the side edges of the slots inside the body, said wings being of such form that the wings of the several carriers abut each other and also bear outwardly against the body wall at one point in the length of the carriers, and are spaced from each other at another point in the lengths of of the carriers to allow inward movement of the carriers at said last mentioned point, and means to move and support the last mentioned points of the carriers outwardly.

12. In an expansive reamer, the combination of a tubular body having a slotted wall provided with a plurality of circumferentially spaced slots, cutter carriers movable transversely in said slots, a central vertical longitudinal mandrel extending through the body interior and against which the cutter carriers are adapted to bear inwardly, the upper part of said mandrel being relatively large to cause expansion of the cutter carriers when their upper ends are moved longitudinally upwardly onto said mandrel part, and said cutter carriers abutting each other near their lower ends and each cutter carrier bearing outwardly against the body wall.

13. In an expansive reamer, the combination of a tubular body having a slotted wall provided with a plurality of circumferentially spaced slots, cutter carriers movable transversely in said slots, a central vertical longitudinal mandrel extending through the body interior and against which the cutter carriers are adapted to bear inwardly, the upper part of said mandrel being relatively large to cause expansion of the cutter carriers when their upper ends are moved longitudinally upwardly onto said mandrel part, said cutter carriers bearing outwardly against the body wall, bearing inwardly against the upper part of said mandrel, and near their lower ends bearing inwardly against said mandrel and circumferentially abutting each other around the mandrel.

14. In an expansive reamer, the combination of a tubular body having a wall with a plurality of circumferentially spaced longitudinally extending slots, cutter carriers movable transversely in said slots, a central longitudinal abutment mandrel in the body against which mandrel the carriers are adapted to bear inwardly, the mandrel and carriers being so formed that relative longitudinal movement between them causes outward transverse movement of the carriers, and the cutter carriers abutting each other circumferentially at one point in their lengths, and having bearings outwardly against the body wall at substantially the same point.

15. In an expansive reamer, the combination of a tubular body having a wall with a plurality of circumferentially spaced longitudinally extending slots, cutter carriers movable transversely in said slots, a central longitudinal abutment mandrel in the body against which mandrel the carriers are adapted to bear inwardly, the mandrel and carriers being so formed that relative longitudinal movement between them causes outward transverse movement of the carriers, and the cutter carriers abutting each other circumferentially at one point in their lengths, and having bearings outwardly against the body wall along their lengths.

16. In an expansive reamer, the combination of a tubular body having a wall with a plurality of circumferentially spaced longitudinally extending slots, cutter carriers movable transversely in said slots, a central longitudinal abutment mandrel in the body against which mandrel the carriers are

adapted to bear inwardly, the mandrel and carriers being so formed that relative longitudinal movement between them causes outward transverse movement of the carriers, and the cutter carriers abutting each other circumferentially and having bearings outwardly against the body wall at one point in their lengths, and having bearings inwardly against the mandrel and outwardly against the body wall at another point in their lengths.

17. In an expansive reamer, the combination of a tubular body having a wall with a plurality of circumferentially spaced longitudinally extending slots, cutter carriers movable transversely in said slots, a central longitudinal abutment mandrel in the body against which mandrel the carriers are adapted to bear inwardly, the mandrel and carriers being so formed that relative longitudinal movement between them causes outward transverse movement of the carriers, and the cutter carriers abutting inwardly against said mandrel, abutting circumferentially against each other, and bearing outwardly against the body.

18. In an expansive reamer, the combination of a tubular body having a wall with a plurality of circumferentially spaced longitudinally extending slots, cutter carriers movable transversely in said slots, a central longitudinal abutment mandrel in the body against which mandrel the carriers are adapted to bear inwardly, the mandrel and carriers being so formed that relative longitudinal movement between them causes outward transverse movement of the carriers, and the cutter carriers abutting inwardly against the mandrel and outwardly against the body at one point in their lengths, and abutting inwardly against the mandrel and circumferentially against each other and outward against the body at another point in their lengths.

19. An expanding reamer, comprising an elongate body having a longitudinal cutter carrying slot, a longitudinally extending cutter abutment central of the body and back of the slot and against which the cutter bears inwardly, the abutment being fixed with relation to the body, the upper part of the abutment having a relatively large portion with a substantially longitudinal cutter abutment surface and a diagonally downwardly facing cutter expanding shoulder below that surface, the lower part of the abutment having a cutter abutment surface which makes an acute angle with the longitudinal, a cutter element movable both longitudinally and transversely in the body slot for expansion and contraction and adapted in expanded position to seat inwardly against both abutment surfaces, and means for moving the cutter element upwardly relative to the body and abutment.

20. An expanding reamer, comprising an elongate body having a longitudinal cutter carrying slot, a longitudinally extending cutter abutment central of the body and back of the slot and against which the cutter bears inwardly, the abutment being fixed with relation to the body, the upper part of the abutment having a relatively large portion with a substantially longitudinal cutter abutment surface and a diagonally downwardly facing cutter expanding shoulder below that surface, the lower part of the abutment having a cutter abutment surface which makes an acute angle with the longitudinal, a cutter element movable both longitudinally and transversely in the body slot for expansion and contraction and adapted in expanded position to seat inwardly against both abutment surfaces, the cutter element having near its upper end a substantially vertical bearing face and near its lower end a bearing face that makes an acute angle with the vertical, and means for moving the cutter element upwardly relative to the body and abutment.

21. In an expansive reamer, a vertically extending body rotatable about a vertical axis, vertically extending cutters mounted in the body for movement vertically thereof, bearing means at the lower ends of the cutters holding the lower ends of the cutters against movement outwardly from the axis during upward vertical movement of said cutters, bearing means in the body lying between and forming an internal abutment for the upper ends of the cutters and guiding the upper ends in movements upwardly and outwardly from the axis, and actuating means carried by the body and acting to move the cutters upwardly.

22. In an expansive reamer, a vertically extending body rotatable about a vertical axis, vertically extending cutters mounted in the body, bearing means at the lower ends of the cutters guiding the lower ends in vertical axial movement in the body, bearing means in the body lying between and forming an internal abutment for the upper ends of the cutters and guiding the upper ends in movements upwardly and outwardly from the axis, and actuating spring means acting on the lower ends of the cutters and tending to move them upwardly.

23. In an expansive well reamer, a body and a tilting cutter therein, the cutter including a non-rotating carrier and a rotating cutter, means to cause tilting of the cutter to a position where a part of the carrier is projected further than other parts, and a removable wear member with a smooth casing engaging face mounted on said part of the carrier.

24. In an expansive well reamer, a body and a tilting cutter therein, the cutter including a carrier and a cutting element car-

ried thereby, means to cause tilting of the cutter to a position where a part of the carrier is projected further than other parts, and a removable wear member with a smooth casing engaging face mounted on said part of the carrier.

In witness that I claim the foregoing I have hereunto subscribed my name this 4 day of February, 1928.

JOHN GRANT.