April 12, 1938. J. A. ZUBLIN 2,113,820

UNDERREAMER AND OVERSIZE-HOLE DRILLING TOOL

Filed June 6, 1936 2 Sheets-Sheet 1

Fig. 1.

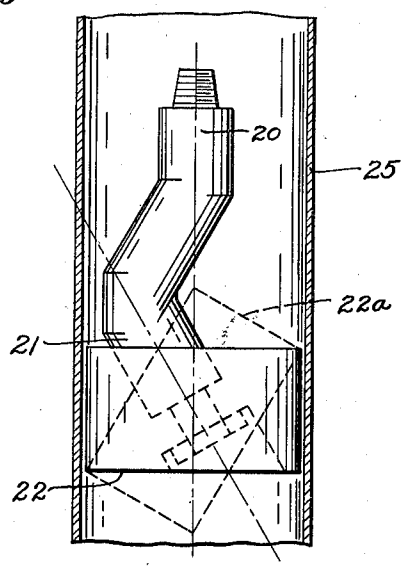


Fig. 2.

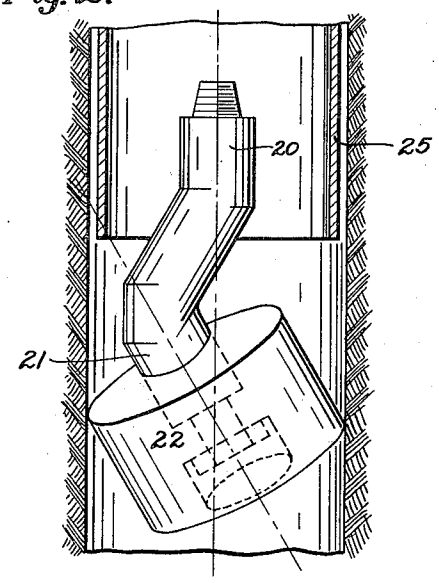


Fig. 3.

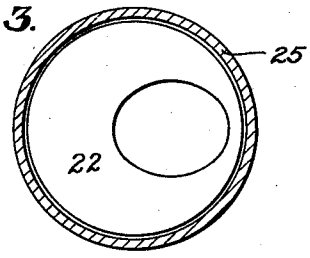


Fig. 4.

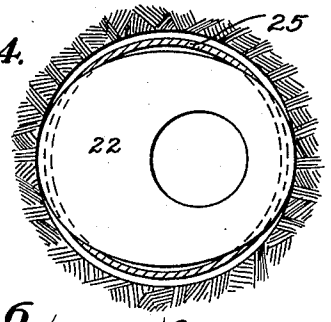


Fig. 5.

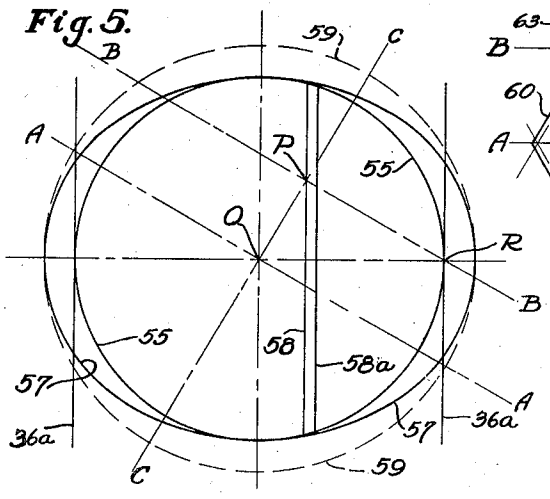
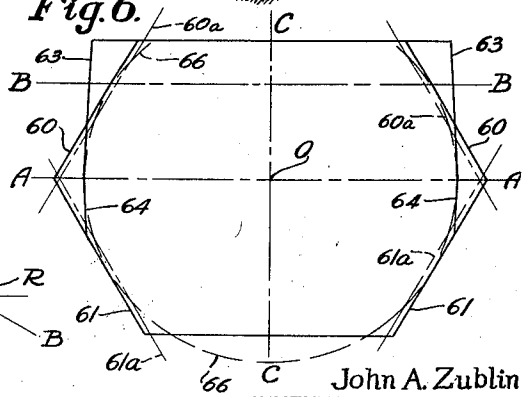


Fig. 6.



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Filed June 6, 1936 2 Sheets-Sheet 2

Fig. 9.

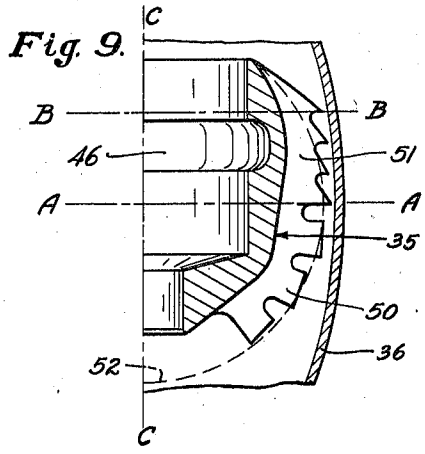


Fig. 8.

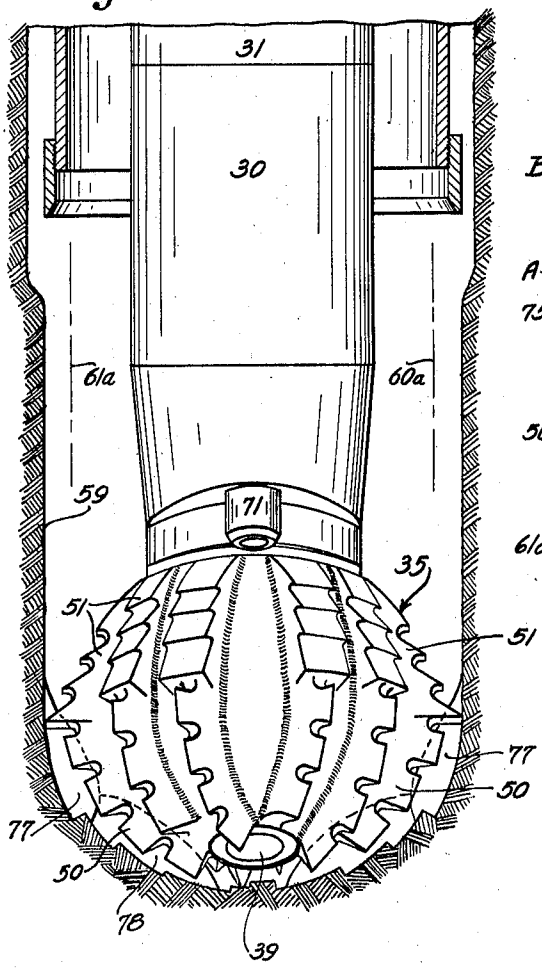
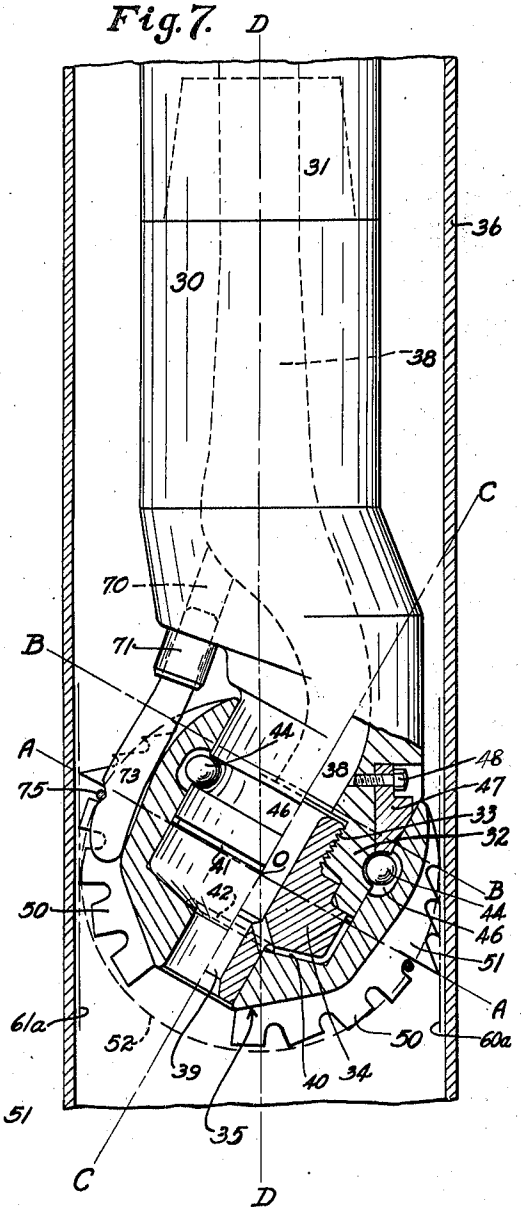


Fig. 7.



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UNITED STATES PATENT OFFICE

2,113,820

UNDERREAMER AND OVERSIZE-HOLE DRILLING TOOL

John A. Zublin, Los Angeles, Calif.

Application June 6, 1936, Serial No. 83,897

30 Claims. (Cl. 255—71)

This invention relates generally to well drilling equipment, and more especially to rotary drilling tools of the type used to drill or underream oil wells.

After a string of casing has been set in the well, the size of the bit next used is limited by the size of the casing through which the bit is lowered, and for this reason the hole drilled below the casing with a conventional bit can be no larger than the casing internal diameter, and often is smaller. Because of the considerable clearance between the formation and the casing required for cementing and to pass the pipe joints, the size of casing that can be set in a hole is considerably smaller than the hole diameter, and frequently is for this reason smaller than the largest that can be passed through casing already set. Even if the lower portion of the hole be but slightly larger than the casing diameter above it, it proves of great advantage since such enlargement will often permit the use of the next larger size of casing, perhaps the largest which will pass through the casing already in place, to obvious advantage.

It is desirable to keep the hole as large as possible, because otherwise the necessary decrease in size after each string of casing is set will soon reduce the hole to an impracticably small diameter. To enlarge the hole beneath casing, use is generally made of underreamers which in nearly every instance have moving parts that make them expansible. Construction of such a tool is complicated and expensive, requires the use of small parts unable to withstand the abuse of hard drilling, and produces a tool which is usually efficient only for underreaming and will not drill new hole to an oversize.

A tool which will both underream and drill new hole to the same size offers marked advantages in that it is more adaptable to all conditions, and reduces the number of different tools required. In addition to enlarging previously drilled hole, with such a tool a hole can be initially drilled to the full size desired then casing can be set without the necessity of underreaming and its attendant costs when performed as a separate operation.

It is therefore a general object of my invention to provide a non-expanding bit which can pass down through a casing of given size and drill a hole larger than the casing internal diameter. Since such a hole is larger than can be drilled with conventional bits of the same nominal size and is larger than the minimum bit diameter as limited by the casing, the hole is herein termed an "oversize" hole.

It is also an object of the invention to make a bit that can be used for underreaming in a previously drilled hole, as well as drilling an oversize hole in the first instance.

It is a further object to provide a bit that is simple and rugged in construction, and free from small movable parts that may become jammed or broken.

These objects are accomplished in a bit constructed according to my invention by rotatably mounting the cutter on an inclined axis and making the cutter non-circular in outline, preferably oval, relative to its axis of rotation so that in one position the vertical projection of the cutter falls within the circle determined by the casing diameter and in a second position, reached by rotation about the inclined axis, the projection of the bit lies partially outside of the casing so that cutting edges of the tool are effective at points beyond the casing and beyond the projection of the first position. Since the cutting edges are now effective beyond a circle of the casing diameter, the bit drills an oversize hole of a diameter greater than the casing interior and equal to the greatest horizontal component of the cutter dimensions. The bit has cutting edges which attack both the bottom and sides of the hole, so that it will underream a hole or drill a new one to an oversize.

Although the improvements of the present invention are applicable generally to bits having rotary cutters, for convenience of disclosure I show and describe the improvements as embodied in a bit of the type shown in my prior Patents Nos. 1,758,773, 1,758,814, and 1,758,875, all issued May 13, 1930 although I am not thereby to be limited to that type of bit.

How the above and other objects are accomplished will be better understood from the following description and annexed drawings, in which:

Fig. 1 is an elevation of a diagrammatic drill bit embodying my invention, with the cutter in position to pass downwardly through a section of casing;

Fig. 2 is a diagrammatic view similar to Fig. 1 with the cutter rotated a quarter revolution on the shank;

Figs. 3 and 4 are diagrammatic reflected bottom views of Figs. 1 and 2, respectively;

Figs. 5 and 6 are diagrams illustrating the development of theoretical maximum tooth outlines of the cutter illustrated in Figs. 7–9;

Fig. 7 is a vertical view, partially in elevation

and partially in section, showing a bit constructed in accord with my invention passing downwardly through a section of casing;

Fig. 8 is an elevation of the bit of Fig. 7 as viewed from the left of that figure but with the cutter rotated a quarter revolution relative to the shank; and

Fig. 9 is a fragmentary semi-section of the cutter alone taken on axis C—C of Fig. 7.

The first four figures illustrate diagrammatically a bit constructed to embody the general principles of my invention. The bit comprises a shank **20** having a suitably inclined bearing portion **21** upon which is rotatably mounted a cutter **22**. The cylinder **22** representing the cutter is not intended to indicate a particular type of cutter but is a representation of that solid figure which shows the limiting outline of the cutting edges or teeth upon any suitable cutter body. The cutter is here illustrated as a cylinder of a diameter but slightly less than the internal diameter of casing **25** so that when the cylinder is in the position of Fig. 1 with its side walls vertical it will pass downwardly through the casing with a small clearance (see also Fig. 3).

If, after the bit has been lowered through the casing, the shank is rotated, relative rotation between the cutter and shank will occur since the cutter will be retarded by frictional engagement with the earth so that it will not turn with the shank. During this relative rotation between the cutter and shank, the cutter revolves about the inclined axis of bearing **21**, and when rotated clockwise 90 degrees, as viewed from above, from the position of Fig. 1 the cutter assumes the position of Fig. 2. This rotation has tilted the cutter, thus raising a lower corner and depressing an upper corner, to bring diagonally opposite corners of the cutter into the same horizontal plane. When in this position, the vertical projection of the cutter taking the outline at this horizontal plane is an ellipse, as indicated in Fig. 4, the minor diameter of which is equal to the diameter of cylinder **22** and the major diameter equal to the diagonal dimension of cutter **22**; and it is therefore obvious that the maximum over all horizontal dimension of the cutter will be greater when in the tilted position of Fig. 2 than when in the position of Fig. 1.

In general, it is not necessary that the greatest dimension of the cutter become itself exactly horizontal, for its projection on a horizontal plane determines the hole diameter; and it is sufficient to drill an oversize hole that the horizontal component of the greatest cutter dimension change its effective length as a result of a change in inclination of the maximum cutter dimension.

Continued rotation of the shank will cause continued rotation of the cutter relative to the shank and to the ground. Continuing to view the shank as in Fig. 2, a quarter-turn clockwise of the cutter from the position of Fig. 2 will bring it into the dotted line position **22***a* of Fig. 1, and another quarter turn (270 degrees from Fig. 1) will again tilt the cutter as in Fig. 2, but the inclination of the cutter will be opposite to that shown. As the cutter is revolved in the hole, twice during each revolution relative to the shank it will occupy the tilted position in which it has a maximum horizontal dimension; and it is obvious that such movement of the cutter will produce a hole having a diameter at least approximately equal to the major diameter of the ellipse formed either by a vertical projection of the tilted cutter **22** (as in Fig. 4) or by passing a plane horizontally through the diagonally opposite corners which are in contact with the walls of the bore. This hole will have a diameter greater than the internal diameter of casing **25**, as shown.

As illustrated in Fig. 3, the cutter **22** has a position relative to the shank in which the cutter periphery, when vertically projected, forms a circle, all points of which are within casing **25**. The cutter also has a second position, as shown by Figs. 2 and 4, in which the vertical projection of the cutter is non-circular, it being an ellipse, or very similar to one, and points on the cutter have been extended beyond the casing so as to fall outside a circle of the internal casing diameter. Since the size of the hole produced will be determined by those parts of the cutter which extend farthest outwardly, it is clear that the cutter will drill an oversize hole, i. e., a hole of greater diameter than the nominal or minimum diameter as measured in Fig. 1, and that the cutter may be lowered through the casing into a hole of the same diameter as the casing and used to ream or enlarge this hole to an over size.

Whether reaming an old hole or drilling a new one, the enlarging action of the cutter is caused by the opposite sides of the cutter digging away the hole wall at opposite sides. If the cutter did not revolve in the hole, an elliptical hole would be produced, but as the cutter revolves in a horizontal plane the walls are cut away on all sides and a substantially round hole of oversize diameter is produced.

A section through the cutter on a plane perpendicular to the inclined axis of rotation is an ellipse, and in general may be termed non-circular, with cutting edges around the periphery. As a result of the cutter rotation about its inclined axis, the cutting edges extend varying distances from the shank axis which is shown as coincident with the center line of the casing. The combination of this non-circularity of the cutter, i. e., the location of cutting edges at varying distances from the cutter axis, together with the inclination of bearing **21**, produces a motion which moves the cutting edges through points at varying distances from the shank axis so that the cutter can at one time occupy a position in which all of its points lie within the casing or a circle of the casing internal diameter and at another time occupy a second position, reached by rotation about its own axis, in which these same points will be extended outwardly so as to fall outside of the circle represented by the casing internal diameter.

I shall now explain the application of my invention to a particular type of drill bit, as illustrated in Figs. 7–9 inclusive. This general type of bit has been made the subject matter of prior applications which have matured into my patents enumerated above, and consequently no detailed explanation of the bit and its cutting action is considered necessary here since reference may be had to said patents for this purpose. However, a brief description of the structure of the bit will now be given.

The bit generally comprises a shank **30** that is attached to a drill collar **31** and that terminates at its lower end in bearing portion **32**, which is suitably inclined, preferably at or about 30°, as indicated by axis C—C in the drawings. Bearing portion **32** is internally threaded at **33** to receive thrust bearing **34** which cooperates with shank portion **32** to provide a bearing upon which cutter **35** is rotatably mounted. The interior of shank **30** is provided with water course **38**, and thrust

bearing 34 is likewise provided with a central water course 39 through which circulation fluid passes. As an aid to lubrication, by-pass 40, leading from water course 39, is provided to communicate with the two annular passages 41 and 42 so that circulating fluid may reach the bearing faces of the cutter body and the inclined bearing.

The body of cutter 35 is generally bowl shaped and is placed on the shank by moving it axially over the thrust bearing 34, and it is then retained in position by means of a plurality of ball bearings 44 which fit within annular ball race 46 cut partly in the shank and partly in the cutter body. These balls are inserted and removed from the ball race through a notch cut in the shank, said notch being filled by lock member 47, held secured by cap screw 48, to prevent displacement of the balls through the notch.

In Fig. 7 the inclined axis C—C is the axis about which the cutter rotates relative to the shank. Axis C—C and the vertical axis D—D of the shank intersect at O, through which is passed a reference plane A—A perpendicular to axis C—C. For convenience of reference, teeth 50 below plane A—A will be referred to as digging teeth, since they contact the bottom of the hole, while the teeth 51 above plane A—A will be referred to as reaming teeth, since they contact the sides of the hole. It has heretofore been customary in bits of this type to have all teeth follow an approximately spherical outline with its center at O, as indicated by dotted line 52; and it will be realized that when such is the case the tooth outline on any section perpendicular either to axis C—C or the vertical axis D—D is circular, and that the cutter will pass downwardly through the casing without reference to any particular position of the cutter relative to the shank, since any horizontal section of the casing 36 will be circular.

An inclined section through the casing 36 will be elliptical; and consequently, as has been explained above, the cutter may have an elliptical section on an inclined plane, such as plane A—A, and still pass downwardly through the casing with a small clearance all the way around. A section on plane B—B parallel to A—A, but spaced above it as indicated to pass through the points of the top reaming teeth, will also be generally elliptical in shape, but since axis C—C does not bisect the casing outline in the plane B—B, the major axis of the ellipse will be perpendicular to the plane of the drawing instead of parallel as in plane A—A, as will be now explained.

Figs. 5 and 6 are diagrams showing the development of theoretical maximum outlines of the cutter teeth as determined by the inner casing surface, and with the aid of these diagrams I shall now explain the development of the limiting surfaces beyond which the cutter teeth will interfere with the casing. In practice, the actual tooth outlines are slightly smaller than the theoretical maximum to allow necessary clearance between teeth and casing. If parallel vertical lines 36*a* represent the inner surface of casing 36, then circle 55 with its center at O represents a plan of the casing inner surface. In plane A—A, the minor diameter of the ellipse representing the maximum tooth outline is equal to the diameter of circle 55; and the major diameter of that ellipse will be equal to the distance on line A—A between the intersections of that line with the two parallel lines 36*a*. Laying off this major diameter horizontally and the minor diameter vertically in Fig. 5, there is then developed ellipse 57 which also represents the outline of the casing inner surface where intersected by plane A—A or one parallel thereto.

The maximum tooth outline in plane B—B is derived in Fig. 5 by passing vertical line 58 through the intersection P of lines (planes) B—B and C—C, and extending the line until it intersects circle 55 at two points. The length of line 58 between the two intersections with circle 55 represents the diameter of the tooth outline perpendicular to the plane of Fig. 7. That portion of circle 55 to the right of line 58 represents a vertical projection of the right hand half of the outline, the other half of the outline being complementary and symmetrical about line 58. The slant length along plane B—B from P to R, the intersection with line 36*a*, is the semi-diameter of the ellipse in plane B—B. Next the distance P—R is laid off inwardly from the ellipse 57, along the horizontal in Fig. 5 and line 58*a* drawn at right angles through the end of the distance laid off. When 58*a* is extended to intersect ellipse 57 at two points, then that portion of ellipse 57 to the right of line 58*a* represents the right hand half of the tooth outline in plane B—B, the left hand half of this outline being complementary and symmetrical about line 58*a*. Since the diameter represented by line 58 is longer than the diameter at right angles thereto (two times P—R), it is seen that the major axis of the tooth outline in plane B—B is rotated 90 degrees from the major axis of the tooth outline in the plane A—A. Since the tooth outline in the plane B—B is only approximately an ellipse, the tooth outlines are better termed ovals, since this term includes approximately as well as theoretically elliptical figures.

Having determined the limiting outlines in planes A—A and B—B, the vertical profiles will now be determined. Returning to Fig. 7, it will be seen that during their travel, reaming teeth 51 approach the casing most closely when they are on the lower side of the cutter, that is, when they occupy the right-hand position of Fig. 7. Consequently the vertical outline of the teeth will be determined by the maximum permissible length of the teeth when in this position. In this position, the extreme right-hand points on the tooth outlines of planes A—A and B—B are in a vertical line (the inner face of casing 36) which is inclined to axis C—C from the vertical, in this case 30 degrees. Therefore, the limiting vertical outline of the reaming teeth may be determined in Fig. 6 by passing through the extremities of the outlines in planes A—A and B—B, lines 60 each at 30 degrees to the cutter axis C—C.

Likewise, the digging teeth below plane A—A most closely approach the casing when they occupy the left-hand position of Fig. 7, so that their limiting vertical outline will be determined when in this position, and will be a vertical line passing through the tip of the lowest reaming tooth, as indicated in Fig. 6 by lines 61 at 30 degrees to the cutter axis. Practically, it is not desirable that all the digging teeth have points on this line, it being desirable to place the lower tip of only the upper two digging teeth 50 on said line while the balance of teeth 50 conform more generally to spherical outline 52. Thus it is seen that, in the aspect of Fig. 7, the limiting vertical outline of the teeth may be represented by straight lines 60 and 61 inclined oppositely 30 degrees to the cutter axis. Allowing for neces-

sary clearance, the actual outline of the teeth will be limited by lines 60*a* and 61*a*, the reaming teeth intermediate planes A—A and B—B extending to but not beyond these lines.

At right angles to the plane of Fig. 7 and along the axis C—C, the vertical profile of the teeth will be limited by lines 63 and 64 of Fig. 6, the horizontal dimension in plane B—B being the length of line 58 (Fig. 5) and in plane A—A being the casing diameter. The outline of the reaming teeth will then be within lines 63 passing through the limiting points in planes A—A and B—B thus determined; and the outline of the digging teeth will be within line 64 inclined to the cutter axis an amount equal but opposite to the inclination of line 63. Since the teeth can at no point project beyond the line 61, because were they to do so they would strike the casing when in the position of the left-hand teeth of Fig. 7, the lower part of the digging tooth outline follows line 61 below the intersection of lines 61 and 64. Teeth developed according to this outline, after allowing for clearance, are illustrated in Fig. 9. It will be noticed that the upper reaming teeth are longer and that the lower reaming teeth are shorter than the same reaming teeth of Fig. 7. The top digging tooth is somewhat shorter than the corresponding tooth of Fig. 7, but the other teeth 50 follow the same outline.

By way of comparison, dotted line 66 in Fig. 6 illustrates the maximum limiting surface (without allowing for clearance) if a spherical development of the teeth is used; and the difference between a cutter constructed in accord with the present invention and one constructed according to previous practice is graphically illustrated when it is realized that the teeth are built out to fill the spaces beyond circle 66 but within the several solid lines defining the limiting outlines as explained.

The vertical outlines intermediate the two positions developed in Fig. 6 are determined from the two horizontal outlines in Fig. 5 in the general manner explained, and will be intermediate those of Fig. 6. If the clearance allowed is not equal at all points, then the vertical projection of the cutter when in the position of Fig. 7 may not be exactly circular, but will be substantially so. The outlines developed are in the nature of limiting surfaces beyond which the teeth cannot project, but within these limits the teeth may have any desired shape, number, or location.

The point O is termed the center of the cutter since it is the center of the spherical outline 52. The shank axis may intersect axis C—C at O, or may pass to one side. In my aforementioned patents, the shank axis is shown as intersecting C—C above the plane A—A, so that the cutter 35 is eccentric to the shank, and it will be plain that the present invention can be as well applied to such construction.

Leading from the main water course 38 is a branch course 70 provided with an exterior nozzle 71 through which water is forced to clean debris from the cutter teeth. As will be understood, cutter 35 will pass down the casing only in two positions, spaced 180 degrees apart, and it is desirable that it be held in one such initial position as the bit is lowered through the casing. Although any suitable means of so locking the cutter relative to the shank may be used, it has been found convenient to insert plug 73 in water nozzle 71, the body of the plug then lying between two adjacent rows of teeth, (see Fig. 8) so as to hold the cutter against rotation. Plug 73 is conveniently held in place by rubber band 75, or other suitable element, which passes around in the notch below the reaming teeth and seats in a properly positioned groove in plug 73. Plug 73 is of wood or the like, and is not strong enough to hold the cutter against rotation after it contacts the formation. Circulation pressure will clear nozzle 71 of the broken plug.

As may be seen from Fig. 8, the cutter herein illustrated is provided with 10 rows of teeth, but the invention is not limited to any particular number of rows and more or less than the number illustrated may be used. When plug 73 is inserted between two rows of teeth and the cutter is in the position of Fig. 7, the major axis of ellipse A—A bisects the space between two teeth and consequently no teeth extend out to the possible maximum length, although if other means of holding the cutter against rotation are used then the cutter may be so formed that a row of teeth lies along the major axis and is of maximum length. Thus, the teeth illustrated in Fig. 7 lie back of the median cutting plane, but for purposes of disclosure have been brought into the plane of the drawing. It will be understood that the size and shape of the teeth may be changed, and for examples of other tooth shapes suitable for cutters on these bits, reference may be had to my Patents Nos. 2,025,258, 2,025,259, and 2,025,260, as well as my previously mentioned patents.

Fig. 8 illustrates the cutter rotated approximately a quarter turn relative to the shank from the position of Fig. 7. When so rotated, two of the diametrically opposite rows of long reaming teeth are brought into the plane of the drawing. The outline of the hole actually produced is circular as illustrated by dotted line 59 in Fig. 5 and, of course, will have as its diameter the major axis of the tooth outline along plane A—A which reaches its maximum effective horizontal value (the actual dimension) when the cutter is rotated to the position of Fig. 8.

When reaming, the cutter is first held against rotation since the hole is smaller than the cutter. Consequently, the cutter rocks in a vertical plane and first forms an elliptical hole like ellipses 57, as the teeth cut away formation at opposite sides of the hole. The cutter continually tends to rotate in a horizontal plane and cut another such elliptical hole. As the cutter gradually rotates in a horizontal plane, the removal of formation at diametrically opposite points continues; and after the cutter has rotated 180° relative to the formation, there is formed a substantially round hole, as shown by line 59, which is larger than the original hole.

When a cutter is drilling new hole, frictional engagement of its teeth with the earth partially retards its motion so as to cause relative rotation between the cutter and shank at the same time the cutter rolls over the formation. Such rotation of the cutter is assured by the peculiar cutting action of this type of bit, an action which is explained in the patents above referred to. In brief, it may be said that the reaming teeth form inclined grooves along the sides of the wall separated by ridges 77, and the digging teeth likewise form on the bottom of the hole cavities separated by ridges 78. These grooves and cavities, in effect, gear the cutter to the formation and make

positive its rotation relative thereto and also relative to the rotating shank. As a result, the most extended points on the cutter are positively forced around in a complete circle and the hole produced is substantially circular. Regardless of whether the bit is used to drill an oversize hole or to underream a pre-formed hole, the cutter is forced to rotate relative to the earth and cut a circular hole.

The increase in hole diameter effected by using this oval construction, depends on the inclination of the cutter axis. Using a 30 degree inclination, the major axis dimension in plane A—A is about 16% larger than the minor axis, so that the resulting hole has an increase in diameter of 16% over one drilled with a spherical bit. This increase in size is shown graphically in Fig. 8 where lines 61*a* and 60*a* have been projected down below the casing and show the maximum diameter that could be made with the conventional spherical bit, the amount of "oversize" being the distance between the wall 59 and these projected lines.

When withdrawing the bit up the casing, it is necessary to rotate the cutter relative to the bit to return it to one of the two positions in which the cutter will pass through the casing. This is done by trial, rotating the shank little by little until the shank and bit return to the proper relative position.

It will be understood that the application of the present invention to the formation of oval or non-circular cutters is not necessarily limited to the type of bit thus far shown and described, but may in general be applied to any bit in which a cutter is rotatably mounted upon an inclined axis in such manner that a cutter formed in accordance with the invention may occupy one rotational position in which all points of the cutter fall within the circle represented by the casing internal diameter; and in another rotational position will have cutting edges which extend outside that circle to drill a hole larger than the casing internal diameter.

Having described my invention and some of the applications thereof, it will be understood that the foregoing disclosure is intended to be illustrative of rather than restrictive upon the broader claims appended hereto, and various changes may be made in arrangement, construction, and proportions of parts without departing from the scope of my invention.

I claim as my invention:

1. A drilling tool adapted to drill a hole larger than a casing bore comprising supporting means, a cutter carried by said supporting means for rotation about an inclined axis, said cutter being so shaped that all points thereon lie within the perimeter of the casing when in one rotational position, and having another rotational position in which at least one point on the cutter lies without the perimeter of the casing.

2. A drilling tool adapted to drill a hole larger than a casing bore comprising supporting means, a cutter carried by said supporting means for rotation about an inclined axis, said cutter having cutting edges so shaped that all points thereon lie within the perimeter of the casing when in one rotational position, and having another rotational position in which at least one cutting edge lies without the perimeter of the casing.

3. A drilling tool adapted to pass down through a circular casing and drill a hole larger than the casing internal diameter, comprising a shank, an inclined bearing on the shank, and a cutter rotatably mounted on said bearing to revolve about the bearing axis, said cutter having cutting edges at varying distances from its axis of rotation that upon rotation of the cutter extend outwardly beyond the casing internal diameter.

4. A drilling tool adapted to pass down through a circular casing and drill a hole larger than the casing internal diameter, comprising a shank having a vertical axis, an inclined bearing on the shank, and a cutter mounted on said bearing to rotate about an axis inclined to the bit axis, said cutter having cutting edges at varying distances from its own axis and adapted on rotation to extend to points at varying distances from the shank axis, some of which cutting edges are adapted to cut outwardly of the internal diameter of the casing.

5. A drilling tool adapted to pass down through a circular casing and drill a hole larger than the casing internal diameter, comprising a shank, an inclined bearing on the shank, and a cutter rotatably mounted on said bearing to revolve about the bearing axis; said cutter being oval in outline perpendicular to said axis and having a rotational position in which all points on the cutter lie within a circle of the casing internal diameter and a second rotational position in which points on the cutter lie outside said circle.

6. A drilling tool as in claim 1, including means preventing relative rotation between said supporting means and cutter as the tool is moved through the casing.

7. A drilling tool comprising supporting means, a cutter carried by said supporting means for rotation about an inclined axis, said cutter being shaped so that its projected outline lies on a circle in one rotational position and lies on an oval in another rotational position.

8. A drilling tool as in claim 7, wherein the major axis of the oval is greater than the diameter of said circle.

9. A drilling tool as in claim 7, wherein the major axis of the oval is greater than the diameter of said circle, and the minor axis is equal to the diameter of the circle.

10. A drilling tool adapted to drill a hole larger than a casing bore comprising supporting means, a non-expansible cutter carried by said supporting means for rotation about an inclined axis, said cutter being so shaped that in one position of the cutter on its supporting means its greatest dimension will be capable of passing through the casing bore, and in another position that dimension will be incapable of passing through the casing bore.

11. A drilling tool adapted to pass down through a circular casing and drill a hole larger than the casing internal diameter, comprising a shank, an inclined bearing on the shank, and a non-expansible cutter rotatably mounted on said bearing to revolve about the bearing axis, said cutter being of oval cross-sectional outline perpendicular to its axis of rotation, and having a position in which the vertical projection of said outline is within the casing to pass down through said casing and a second position in which said outline extends in part outwardly beyond the casing inner face when the cutter is below the casing.

12. A drilling tool adapted to pass down through a circular casing and drill a hole larger than the casing internal diameter, comprising a shank, an inclined bearing on the shank, and a non-expansible cutter rotatably mounted on said bearing to revolve about the bearing axis, said cutter being of non-circular cross-sectional outline per-

pendicular to its axis of rotation, and having two rotational positions spaced 180 degrees apart in which the vertical projection of said outline is substantially circular to pass down through said casing and positions, intermediate said two positions, in which said outline extends to points outside of the casing inner face when the cutter is below the casing.

13. A cutter for a drilling tool having an inclined bearing, comprising a bowl shaped body adapted to rotate about an inclined axis, and cutting teeth extending beyond the body, the tooth outline being oval in a plane perpendicular to the bowl axis and passing through the bowl center.

14. A cutter for a drilling tool having an inclined bearing, comprising a bowl shaped body adapted to rotate about an inclined axis, and cutting teeth extending beyond the body, the tooth outline being oval in a plane perpendicular to the bowl axis and passing through the bowl center and the tooth outline in a plane parallel to the first plane but above it; also being oval but with the longer axis of the oval at 90 degrees to the longer axis of the first oval.

15. The method of enlarging a hole that includes moving an elliptical shaped cutter in the hole to form a hole elongated in one direction, and simultaneously rotating the cutter in a transverse plane to change the direction of elongation until the enlarged hole is substantially circular with a diameter equal to the major diameter of the hole when first elongated.

16. A rotary method of enlarging a hole that includes first forming an elongated hole by forcing cutting elements into opposite points of the hole walls by rotation of the drillpipe, and subsequently forming a series of elongated holes substantially in the same transverse plane by additional rotation of the drill pipe, all the elongated holes combining to form an enlarged, substantially circular hole with a diameter equal to the maximum diameter of each elongated hole.

17. A rotary method of enlarging a hole that includes first forming an elliptical hole by forcing cutting elements into opposite points of the hole walls by a single rotation of the drillpipe, and subsequently forming additional elliptical holes substantially in the same transverse plane by additional rotations of the drillpipe, all the elliptical holes combining to form an enlarged, substantially circular hole with a diameter equal to the maximum diameter of the elliptical hole.

18. The rotary method of enlarging a hole with cutting elements rotatably mounted on a shank that includes removing formation at two opposite sides of the hole to form an elliptical shaped hole with the first revolution of the shank, and then by additional revolutions of the shank shifting the cutting elements around the hole so that continued removal of formation in elliptical shapes ultimately forms a substantially circular hole with a diameter equal to the major axis of the ellipse.

19. The rotary method of enlarging a hole that includes first forming a pair of indentations in the hole wall by forcing cutting elements into different points of the hole wall by rotation of the drill pipe, and subsequently forming additional indentations substantially all in the same transverse plane by additional rotation of the drill pipe, all the indentations ultimately combining to form an enlarged hole with a bore increased by the combined depths of opposite indentations.

20. A drilling tool adapted to drill a hole larger than a casing bore comprising supported means, a cutter carried by said supporting means for rotation about an inclined axis, said cutter having a dimension larger than the casing transverse bore which in an inclined position will pass through the casing and which, upon rotation of the cutter about its axis, will move toward a transverse position and extend to points beyond the casing bore.

21. A drilling tool comprising a supporting member, a cutter carried by said member to rotate about an inclined axis, said cutter including cutting portions whose outer margins lie on a perimeter of non-circular outline.

22. A drilling tool comprising a supporting member, a cutter carried by said member to rotate about an inclined axis, said cutter including cutting portions relieved on at least one side of said cutter.

23. A drilling tool comprising a supporting member, a cutter carried by said member to rotate about an inclined axis, a part of said cutter lying in a plane substantially at right angles to said axis including cutting portions relieved on at least one side of said cutter.

24. A drilling tool comprising a supporting member, a cutter carried by said member to rotate about an inclined axis, parts of said cutter lying in a plane substantially at right angles to said axis including cutting portions relieved at substantially diametrically opposite sides of said cutter.

25. A drilling tool comprising a supporting member, a cutter carried by said member to rotate about an inclined axis, portions of said cutter lying in a plane substantially at right angles to said axis being relieved at substantially diametrically opposite sides, and other portions of said cutter lying in a plane substantially parallel to said other plane being relieved at substantially diametrically opposite sides displaced 90° to said other relief.

26. A cutter for a drilling tool comprising a bowl shaped body, portions of said body lying in a plane substantially at right angles to the body axis being relieved at substantially diametrically opposite sides, and other portions of said body lying in a plane substantially parallel to said other plane being relieved at substantially diametrically opposite sides displaced 90° to said other relief.

27. A cutter for a drilling tool comprising a bowl shaped body adapted for rotation on the tool structure, said body including cutting portions whose outer margins in a plane substantially perpendicular to the axis of the body lie on a perimeter of non-circular outline.

28. A cutter for a drilling tool comprising a bowl shaped body adapted for rotation on the tool structure, said body including cutting portions relieved on at least one side of said body.

29. A cutter for a drilling tool comprising a bowl shaped body adapted for rotation on the tool structure, a part of said body lying in a plane substantially at right angles to the body axis including cutting elements relieved on at least one side of said body.

30. A cutter for a drilling tool comprising a bowl shaped body adapted for rotation on the tool structure, parts of said body lying in a plane substantially at right angles to the body axis including cutting portions relieved at substantially diametrically opposite sides of said cutter.

JOHN A. ZUBLIN.

CERTIFICATE OF CORRECTION.

Patent No. 2,113,820. April 12, 1938.

JOHN A. ZUBLIN.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 6, second column, line 1, claim 20, for "supported" read supporting; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 14th day of June, A. D. 1938.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.