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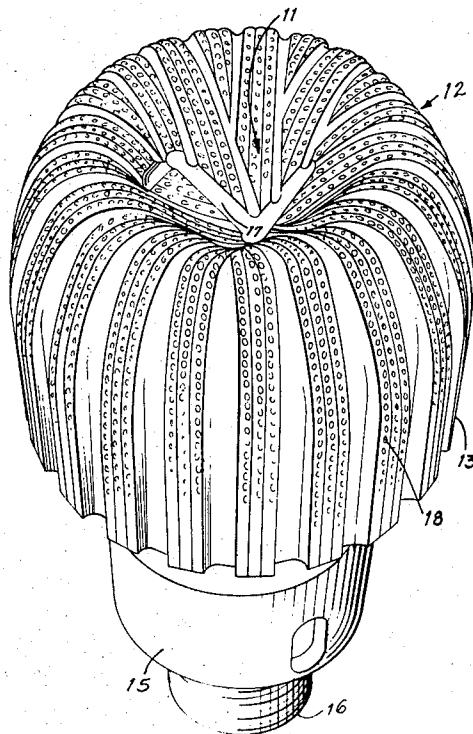
[54] **ROTARY DRILL BIT**
16 Claims, 4 Drawing Figs.

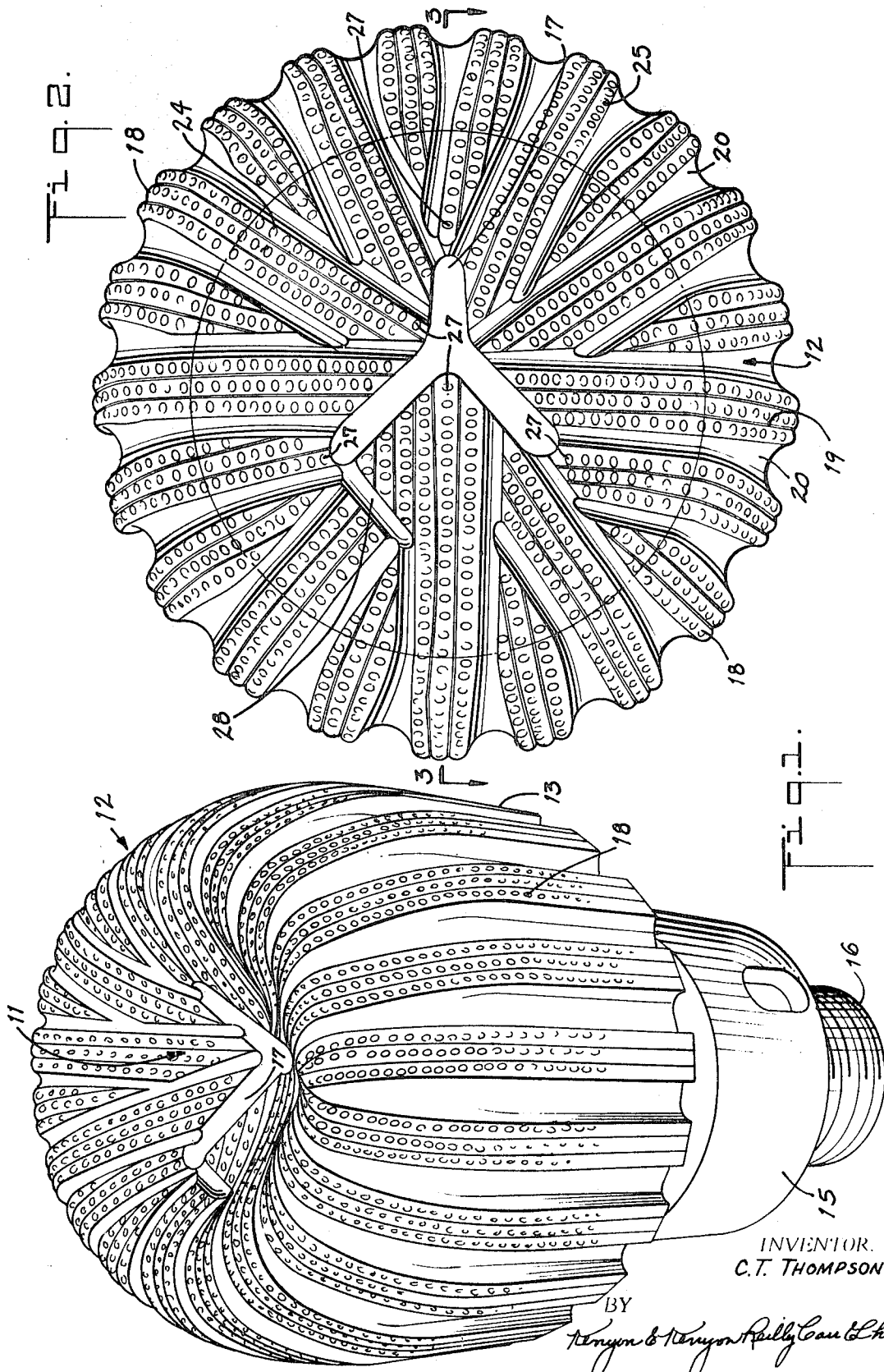
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 [50] Field of Search **175/329,**
327, 330, 398, 400

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ABSTRACT: A rotary bit for drilling earth formations of the type having an elongated cylindrical body and an enlarged head having wear-resistant abrasive particles embedded therein to form a cutting surface. An improved cutting surface comprises a concave face, a convex annular tapered crown faired into the face at its inner limit and a cylindrical skirt extending a substantial axial distance from the outer limit of the crown. Wear-resistant abrasive particles are embedded in substantially parallel rows upon the surfaces of an odd number of cutting lands substantially equally spaced about the skirt and crown and terminating asymmetrically in the face region. Drilling fluid is conveyed by an inner passageway through the body of the bit to a Y-shaped outlet on the face and thence uniformly to the cutting surfaces through primary waterways between the lands and secondary waterways between the rows of wear-resistant particles.





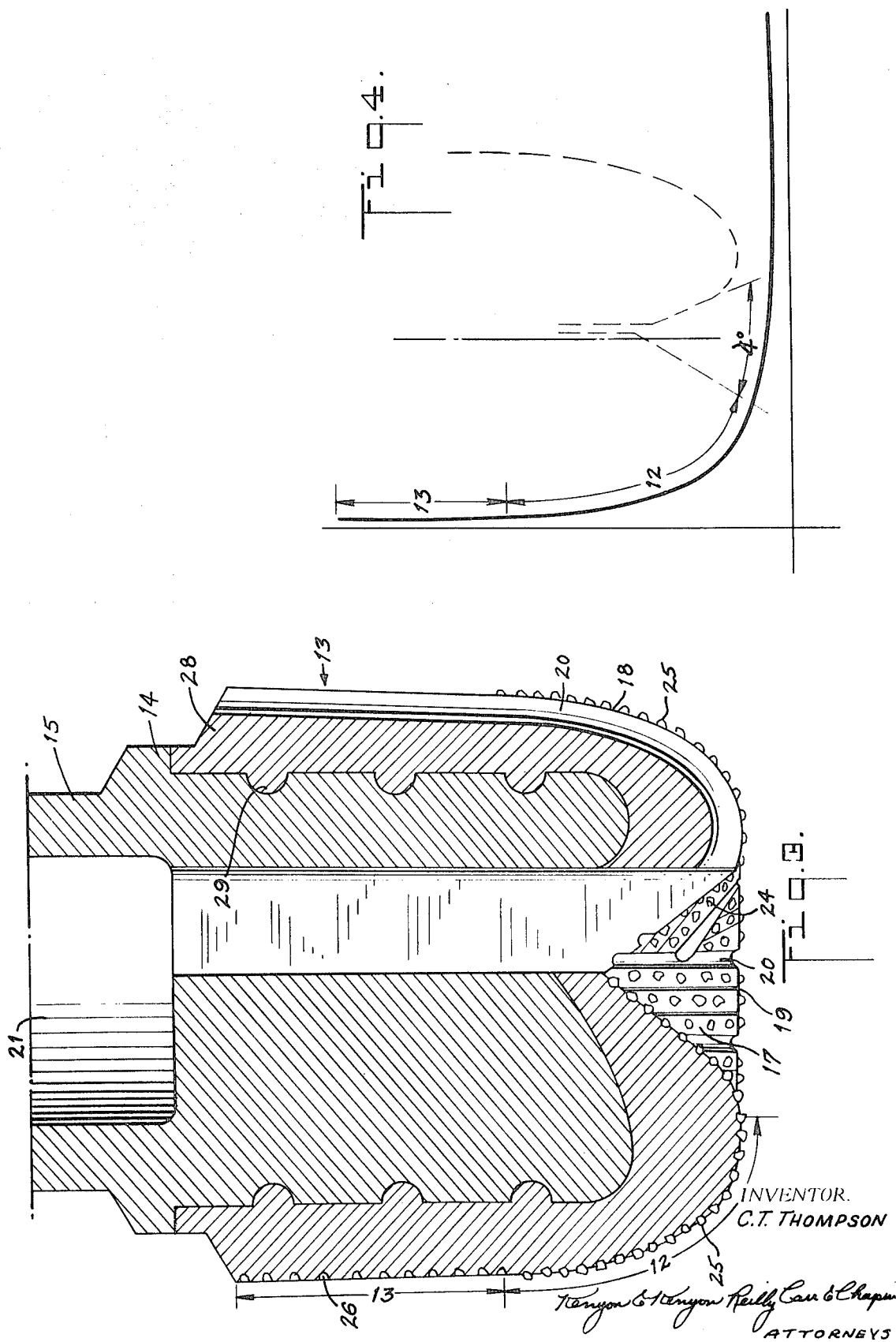
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SHEET 2 OF 2



ROTARY DRILL BIT

BACKGROUND OF THE INVENTION

This invention relates to rotary bits for drilling earth formations and, more particularly, to rotary drill bits having abrasive particles imbedded in the cutting face to permit faster drilling and to prolong the life of the bit.

A problem affecting successful operation of bits of this type, particularly diamond drill bits, is proper lubrication, both for keeping the drill bit cool and for flushing away cuttings to prevent clogging. At the drill pressures and rotational speeds encountered in drilling deep bore holes, such as for oil and gas wells, local overheating can easily occur if drilling fluid is not continuously fed to all parts of the cutting surface.

The ordinary diamond bit is very sensitive to clogging or "balling" by an accumulation of fine cuttings and mud solids in the spaces between exposed diamonds and between the diamond-bearing matrix and the surface of the bore hole.

Balling leads to overheating of bit parts, low drilling rates and premature wear. Even if there is not sufficient solids accumulation to cause balling, nonuniform flushing action by the drilling fluid may have other adverse effects. Friction between the formation and solids trapped between the diamonds leads to the generation of heat which must be dissipated to avoid excessive temperatures and resultant damage to the diamonds and their surrounding matrix.

Diamonds may also be lost when a clogged and overheated portion of the bit is subjected to sudden cooling and thermal shock when the drilling fluid is able to flush away the clogging material. Efforts to avoid these and similar difficulties by varying the size and location of the discharge ports and drilling fluid grooves on diamond drilling bits have not in the past been completely successful.

Another problem encountered with bits of this type is the tendency to drill polygonal rather than round holes. This problem has often been aggravated by the steps taken to provide adequate flow of drilling fluid to and about the cutting surfaces.

For example, a large passageway flow area is needed to carry the drilling fluid and entrained cuttings upward between the head of the bit and the walls of the bore hole without causing a piston or swabbing action by the drill bit. To provide this flow area, these bits generally have three or four large deep grooves or slab sides covering substantial angular segments of the sides of the bit. The three or four major cutting surfaces separated by these grooves form, in effect, a lobed cutting tool.

As is well known, lobed cutting tools tend to cut polygonal holes having one more side than the number of lobes of the tool. Thus, three-lobed tools tend to drill square holes; four-lobed tools tend to drill pentagonal holes; and so on.

Still another problem is lack of directional stability and control. It is very important in drilling deep wells that the drill proceed in the desired direction, either straight or offset as the case may be, without deviating or wandering.

Conventional drills usually have wedge-shaped lands forming the cutting face which extend substantially radially outward from the axis of the drill body. Such lands create cutting surfaces extending across a full diameter of the drill bit. If such a "true diameter" cutting surface encounters a ridge of harder material in the formation being drilled, forces are set up which tend to deflect the drill from the desired direction.

Accordingly, it is an object of the present invention to provide an improved diamond drill bit which will permit better cooling and lubrication of the diamonds than have generally been obtained with bits available in the past.

Another object is to provide a drill bit which will bore substantially round holes of exact size.

Another object is to provide a diamond drill bit having strong self-piloting action for good directional hole control.

Still another object of the invention is to provide a drill bit with asymmetrical cutting blades so that ridges of harder

material encountered in drilling will not set up extensive reaction forces tending to deflect the drill from the desired direction.

Yet another object of the invention is to provide a diamond drill bit having a high concentration of diamonds for cutting the outer portion of the bore hole.

Another object is to provide a diamond drill bit which makes optimum use of cheaper grade diamonds without sacrificing bit life.

Another object is to provide a diamond drill bit which minimizes wear of the drill head skirt to maintain a constant bore hole gauge size.

These and other objects of the invention will become apparent from the following summary and detailed description of the invention and its preferred embodiment.

SUMMARY OF THE INVENTION

In accordance with the present invention, the drill bit has the conventional cylindrical body with a threaded shank portion on one end for mating with and coupling to the usual string of drilling pipe. The shank can be either internally or externally threaded, depending upon the corresponding threaded portion of the drilling string.

The other end of the body of the bit is an enlarged cutting head in which abrasive elements such as diamonds, are embedded to form a cutting surface. A central passageway having an inlet at the shank end and discharge outlet near the center of the cutting surface conveys drilling fluid downward and outward over the face and sides of the cutting head to flush away cuttings and entrained solids.

The surface of the cutting head comprises three portions or zones; a central concave portion is denominated the face; surrounding the face is an annular convex crown which tapers in a ridged surface to join a cylindrical fluted skirt concentric with the body.

The discharge outlet is adjacent to but slightly offset from the axis of the cylindrical body member. A multiplicity of cutting lands extend asymmetrically across the face of the bit adjacent the discharge outlet outward to the crown of the cutting head and then extend in generally parallel relation from the crown to the end of the skirt.

Adjacent cutting lands define drilling fluid passageways sized to provide, as nearly as possible, uniform fluid flow to all parts of the cutting surface.

An important feature of the invention is the tapered crown. This crown extends from a circle concentric with the axis of the drill body and marking the outer limit of the concave face section to the cylindrical skirt section in a path of varying curvature substantially in the form of a portion of a conical section, such as a parabola, hyperbola or ellipse, but not including a circle. The greatest curvature of the crown occurs at its circular junction with the face section; the least curvature is where it fairs into the cylindrical skirt section. The axial length of the crown is approximately equal to the axial length of the skirt.

It has been found that a tapered crown section of this shape greatly improves directional control of the drill bit and, when combined with a cylindrical skirt of substantial length, eliminates the need for a pilot collar at the shank end of the bit.

Another important feature of the invention is that the concave cutting face defines a cone having its apex substantially at the axis of the drill body and with an apex angle of approximately 80°. It has been found that an included angle of substantially less than 80° will generate a central conical core which tends to break up into relatively large chunks rather than pulverize into finer cuttings which can be flushed through the fluid passageways. On the other hand, an included angle substantially greater than 80° will reduce the surface area of the cutting face relative to its projected area; thus less surface is available for mounting diamonds, and greater wear results.

Still another important feature of the invention is that the conical cutting face occupies approximately half of the projected area of the cutting surface, and the tapered crown occupies the other half of the projected area. Thus the junction of the face portion and the crown occurs on a circle concentric with the axis of the drill body and in the vicinity of approximately 70 percent of the radial distance from the axis to the gauge circumference. Since the forces exerted against the drill bit during the drilling operation have a radial outward component in the face region and a radial inward component in the crown region, equalizing the projected areas of these two regions appears to optimize the direction stability of the drill bit.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of the drill bit of the invention; FIG. 2 is a view of the crown and face portions of the drill bit of the invention;

FIG. 3 is a vertical view taken along the line 3-3 in FIG. 2 and showing the internal fluid passages of the drill bit; and

FIG. 4 is a graphical presentation of the curve which corresponds to the profile of the crown and skirt portions of the drill bit.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in FIG. 1, drill bit 10 of the invention comprises face 11, crown 12, and skirt 13. The face, crown, and skirt portions of the drill bit are mounted upon cylindrical body portion 14 (FIG. 3) which extends from collar 15. As shown in FIG. 1, the collar is provided with threaded coupling 16 for attachment of the bit to the drill string.

The concave face of the bit extends outwardly from outlet 17 (FIG. 2) which is substantially in the form of the letter Y. The face portion extends to crown 12 as shown in FIGS. 2 and 3. Extending across the face of the bit are a plurality of lands 18, each of which has its surface divided by two parallel extending grooves or secondary waterways 19. Between lands 18 extend grooves or primary waterways 20. Drilling or cooling fluid such as drilling mud can be pumped through the drill string into passage 21 (FIG. 3) having a substantially circular cross section and then into passage 22 having a substantially Y-shaped cross section and leading to outlet 17. As shown in FIG. 2, the cooling fluid enters the majority of primary waterways 20 directly from outlet 17, but in certain regions of the face of the drill bit, fluid passes first through an auxiliary waterway 23 before entering one of the primary waterways 20. It can also be seen in FIG. 2 that the cooling or cutting fluid can enter the majority of the secondary waterways 19 either directly from outlet 17 or by way of primary waterways 20. The result is that the flow of cooling or cutting fluid is equally distributed to all parts of the face, crown, and skirt of the drill bit and, thereby, areas of excessive or insufficient flow are eliminated.

It can be seen in FIG. 2 that lands 18 are substantially equally spaced from one another along crown 12 and skirt 13. It also can be seen that from the crown outwardly the lands have approximately constant width and extend in a substantially radial direction. The result is that the outside diameter of the drill bit adjacent to the skirt is of a substantially circular cross section having an odd number of equally spaced lands separated by primary waterways 20.

The provision of an odd number of lands 18 insures that lands at the opposite sides of the drill bit are not located along a common diameter. Thus, no two lands extending across the face and crown of the bit are disposed on a common diameter. An advantage of this construction is that in the presence of a formation extending across a diameter of the working face of the bore hole, no two lands will simultaneously meet with such a formation. This provision is one of the factors that enable the drill bit to be self-stabilizing in straight hole drilling and to be maintained in a predetermined direction in the drilling of a deviated or offset hole.

As shown in FIGS. 3 and 4, crown 12 is substantially in the form of a body of revolution generated by a portion of a conic section such as a parabola, a hyperbola, or an ellipse, but not including a circle. Crown 12, as shown by the arrows in FIG. 3, is substantially equal in axial extent to the length of skirt 13. The crown terminates in a circle which is coaxial with and spaced apart from the axis of the body. The portion of the crown adjacent the circle is the extremity of the crown facing away from the body of the drill.

As shown in FIG. 2, the preferred radius of this circle which marks the extremity of the crown is approximately 70 percent of the gauge radius of the drill bit. For example, if the radius of the drill bit is $3\frac{1}{2}$ inches, the preferred radius of this circle is approximately $2\frac{1}{2}$ inches. Consequently, the projected area of the concave conical face section is approximately equal to the projected area of the tapered crown section. This relation between projected areas has been found to produce directional stability with minimum wear rate.

Crown 12 serves to cut the adjacent face of the bore hole along with face 11 of the bit and at the same time, due to the tapered form of the crown, serves to pilot the drill bit along a predetermined line as the drill bit advances in the bore hole. Skirt 13, which is substantially elongated, engages a length of the inner core of the bore hole and assists the crown in piloting the drill to advance along a straight line. For this reason the skirt is provided with a long length which is at least as long as the surface length of the crown.

As shown in FIGS. 1, 3 and 4, face 11 of the drill bit is in the form of an approximation of a cone extending inwardly from crown 12 toward outlet 17 adjacent to the center of the face of the bit. The included angle of the cone to which the face corresponds is selected to enable the face to cut the surface of the bore hole in an optimum manner. A narrow included angle, such as a 30° angle, could generate a central conical core in the bore hole. Such a core tends to break free of the bore hole during drilling into one or a few large chunks and interfere with the drilling operation instead of being pulverized into finer cuttings which can be flushed through the waterways 20. On the other hand, an excessively large included cone angle could reduce the surface area of the cutting face available for mounting diamonds below a minimum desirable area, which also would interfere with a proper cutting operation. The proper cone angle, as shown in FIGS. 3 and 4, represents a compromise between the undesirable formation of a core by too narrow a cone angle and insufficient cutting area at the face by an excessively flat cone angle. By way of example, the included cone angle of face 11 may be in the range of angles extending in the vicinity of approximately 80° .

As shown in FIGS. 2 and 3, lands 18 on face 11 are provided with cutting diamonds 24 disposed in rows which are parallel to the waterways. Cutting diamonds 25 are disposed in parallel rows extending along lands 18 in crown 12 of the drill bit. By way of example, West African cutting diamonds can be used as cutting diamonds 24 and 25 in view of their superior wear resistance and cutting capabilities. Diamonds 26 in skirt 13 of the bit do not serve to cut, but instead prevent wear of the lands in rubbing contact with the inner core of the bore hole. For this reason, diamonds 26 can be, by way of example, Congo diamonds.

At the locations identified by reference numeral 27, diamonds of superior hardness and strength can be used, since, at these locations, the presence of outlet 17 prevents the use of a sufficient number of diamonds 24. By way of example, diamonds 27 can be Carbonado diamonds which are the toughest form of industrial diamonds.

As shown in FIG. 2, cutting diamonds 24 and 25 are positioned along lands 18 in positions which enable each diamond, upon rotation of the bit, to travel along a somewhat different circle. In this way, the diamonds are presented to all positions of the surface at the face of the bore hole during the cutting operation.

The diamonds 24, 25 and 26 are disposed in the lands and retained therein as the result of a casting operation. As shown

in FIG. 3, lands 18 and the waterways are formed in matrix 18 which is cast about hub 14 of the drill bit. Grooves 29 in the outside diameter of hub 14 mechanically interlock the matrix to the hub. The matrix bonds the diamonds in place along its surface and, in addition, can bond a structure of cement material adjacent to the surface of the matrix to prevent wear of the matrix. By way of example, the matrix may be formed from a nonferrous material which bonds particles of tungsten-carbide adjacent to the surface as well as bonding diamonds 24—26. Here it should be noted that cutting diamonds 24, 25 and 27 are exposed at the surface of the matrix while diamonds 26 are mounted flush with the surface of the skirt 13.

In FIG. 2, it can be seen that there are 21 lands 18 extending across the crown and into the skirt of the bit. This construction has the advantage of distributing the cutting diamonds in an odd number of areas, each separated by a primary waterway. As a result, the waterways in the region of the crown and the skirt provide a plurality of passages through which fluid can pass when the drill bit descends into a bore hole containing fluid. Thus, any tendency of establishing a "piston-effect" is eliminated. An additional advantage of this construction is that the periphery of the cutting surface provided by the crown of the drill bit is divided into an appreciable number of equally spaced cutting areas. It is known that in operation, the long drill string tends to "walk" the drill bit within the bore hole. It is also known that where a drilling tool has a given number of cutting faces along its periphery, the tool upon "walking" tends to generate a hole having a polygonal form comprising a number of sides greater by one than the number of cutting surfaces on the tool. Thus, a three-sided cutting tool, upon "walking," tends to generate a four-sided hole. By providing an appreciable number of lands bearing the cutting diamonds in the region of the face and crown of the drill bit, the bit tends to generate a circular hole regardless of the presence of some tendency for the drill string to cause the drilling bit to "walk" within the bore hole.

In conjunction with the large number of lands, the provision of the long crown and the long skirt aid in stabilizing the bit and insure that it cuts along a predetermined line. Experience has shown that due to the form of the crown in the shape of a portion of conic section, such as a parabolic, a hyperbolic or elliptical section, and the long skirt, the drill bit of the invention can be operated successfully without the need of compensating devices such as a "near-bit stabilizer."

What I claim is:

1. A rotary bit for drilling earth formations, the bit being of the type having an elongated body portion with a threaded shank at one end thereof for coupling to a drill string, an enlarged drilling head on the other end of the body portion, the drilling head having cutting particles imbedded in its outer surface for cutting the earth formations, and an interior passageway extending through the body from an inlet at the shank end to an outlet at the cutting surface of the drilling head for supplying drilling liquid to cool the cutting particles and flush away the cut formations, wherein the improvement in the drilling head comprises:

a. a multiplicity of lands for supporting the cutting particles adjacent the surface thereof, the multiplicity of lands forming grooves therebetween and being spaced about the body portion, the lands extending from a location intermediate the ends of the body portion to form successively,

- i. an outer cylindrical fluted skirt section coaxial with and of larger diameter than the body portion,
- ii. an intermediate convex crown section which tapers smoothly inwardly from the skirt section and away from the one end of the body portion in the form of a body of revolution generated by a curve which is a portion of a substantially conic section, the crown section terminating along a circle coaxial with and at a distance from the axis of the body portion, the portion of the crown section adjacent the termination thereof forming the extreme free end portion of the drilling head, and

iii. an inner concave face section concentric about the axis of the body portion and fairing smoothly into the crown section along the termination thereof;

each of said lands having substantially constant width through the skirt and tapered crown sections, the grooves between adjacent lands forming primary waterways which extend substantially parallel in the skirt section and gradually narrow in width in the tapered crown section, the lands terminating in tapered asymmetrical relation within the concave face section and the grooves therebetween extending the primary waterways to connect each of the grooves of the skirt and tapered crown sections to the outlet for drilling liquid.

2. A rotary bit in accordance with claim 1 in which the cutting particles are disposed in substantially parallel rows extending along the length of the lands, the radial positioning of the cutting particles being staggered in the radial direction with respect to one another to enable all portions of the bore hole be subjected to the cutting action of the cutting particles.

3. A rotary bit in accordance with claim 1 in which the lands of the cylindrical skirt section are provided with wear-resistant particles mounted substantially flush with the surface thereof for preventing wear of the lands of the skirt section.

4. A rotary bit in accordance with claim 1 in which the cross section of the outer cylindrical fluted skirt section extending transverse with respect to the axis of the body portion comprises the surface of each of the multiplicity of lands being disposed upon and spaced apart along a common circle and the relieved surface of each of the grooves forming the primary waterways extending inwardly from the common circle between each of the adjacent lands, whereby the disposing of the lands along the common circle improves the stability of the drill and the grooves along the common circle provide a flow passage with respect to the wall of the bore hole whenever the bit is moved toward or away from the bottom of the bore hole.

5. A rotary bit in accordance with claim 1 wherein the cylindrical skirt section has an axial length approximately equal to the length of the intermediate convex crown section, whereby the tapered crown and cylindrical skirt serve to respectively pilot and stabilize the bit in the desired drilling direction.

6. A rotary bit in accordance with claim 1 wherein the inner concave face section is substantial in the form of an inverted cone having an included angle in the vicinity of approximately 80°.

7. A rotary bit in accordance with claim 1 in which the portion of each of the multiplicity of lands forming the inner concave face section extend in an approximately radial direction with respect to the central axis of the inner concave face section.

8. A rotary bit in accordance with claim 1 in which the improvement further comprises cutting particles of diamond material mounted in the surface of the multiplicity of the lands in the inner concave face section and the intermediate convex crown section.

9. A rotary bit in accordance with claim 8 wherein the circular termination of the crown section has a radius in the vicinity of about 70 percent of the outer radius of the skirt section of the bit.

10. A rotary bit in accordance with claim 1 in which each of said lands contain additional grooves forming secondary waterways extending along the surface thereof substantially parallel to the grooves adjacent to the land and forming the primary waterways.

11. A rotary bit in accordance with claim 10 in which the cutting particles are disposed in rows extending adjacent to and substantially parallel to the additional grooves forming the secondary waterways.

12. A rotary bit in accordance with claim 1 in which the number of the multiplicity of lands is an odd number to prevent lands at opposite sides of the intermediate convex crown section from being disposed along a common diametral line.

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13. A rotary bit in accordance with claim 12 in which the odd number of the multiplicity of lands is in the vicinity of the odd number of approximately 21.

14. A rotary bit in accordance with claim 1 in which the outlet of the interior passageway for supplying drilling liquid extends across a portion of the lands forming the inner concave face section and a portion of the grooves adjacent thereto, whereby drilling fluid is distributed to the cutting particles supported on the lands.

15. A rotary bit in accordance to claim 14 in which the outlet of the interior passageway for supplying a drilling liquid is

offset with respect to axis of the body portion, whereby the portion of the inner concave face section adjacent the axis of the body portion is avoidable to applying cutting particles to the bore hole.

16. A rotary bit in accordance with claim 15 in which the outlet of the interior passageway is substantially in the form of a letter Y with the portion of the outlet corresponding to the notch of the letter Y being disposed offset from but adjacent to the axis of the body portion.

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