United States Patent

Hampe et al.

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[54] ROTARY DIAMOND CORE BIT

[72] Inventors: **Walter R. Hampe,** Severna Park; **Albert B. Simon,** Ellicott City, both of Md.; **William H. Hampton; William E. Decker,** both of Punxsutawney, Pa.

[73] Assignees: **Westinghouse Electric Corporation,** Pittsburgh; **Hoffman Diamond Products, Inc.,** Punxsutawney, Pa. ; part interest to each

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[52] **U.S. Cl.** **175/330**

[51] **Int. Cl.** **E21b 9/36**

[58] **Field of Search** 175/330, 329

[56] **References Cited**

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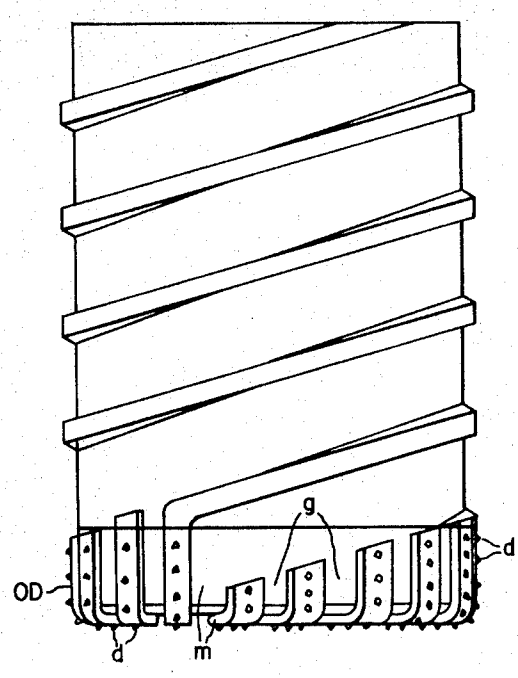
Primary Examiner—David H. Brown

Attorney—F. H. Henson, E. P. Klipfel and D. F. Stratiff

[57] ABSTRACT

Described is an improved rotary diamond core bit offering longer life in dry and in chip flush drilling. Grade AAAA dodecahedron diamonds within the range of 18 to 22 diamonds per carat size, each having a select rectangular pyramid point region free of internal flaws and with an included angle of 100° to 120°, are anchored in a bit matrix to project such select point regions outwardly a distance of 0.015 ± 0.003 inch from a semi-round angular bit face in hard-vector face-set orientation in the rotary cutting direction of the bit and with a negative rake angle of nominally 4-½°. Such bit-face diamonds are arranged in circumferentially spaced-apart rows extending radially outward and backward with respect to rotary motion of the bit. Such "snow-plow" linear arrays of bit-face diamonds are disposed on respective discrete similarly snow-plow-oriented land areas or cutting segments of the annular bit face, and chip release face grooves extend from inner to outer diameter of the annular bit face between all cutting segments. The diamonds on the annular segmented cutting face are arranged with the tips of their projecting cutting portions at equal radial intervals of 0.010 ± 0.001 inch along concentric line circles. Thirty-seven line circles cover the full annular segmented bit face region, and two diamonds are employed in all but the innermost and outermost line circles, which each have four. Axially extending chip release grooves at the inner and outer diameters of the bit register with opposite ends of the bit-face grooves, and axially extending rows of reaming diamonds continue from opposite ends of the rows of bit-face diamonds. A curvature of 0.050 ± 0.005 inch at the intersection of each cutting segment surface and the inner and outer diameter portions of the bit enable proper non-girth-exposing anchoring and the 0.015 inch projection of the diamonds in the transition region between the bit-face diamonds and the reaming diamonds at the interior and exterior surfaces of the bit. The axially extending chip release grooves in the outer diameter portion of the bit feed into auger grooves formed in a continuing shank portion of the bit for dry or wet chip removal.

4 Claims, 6 Drawing Figures



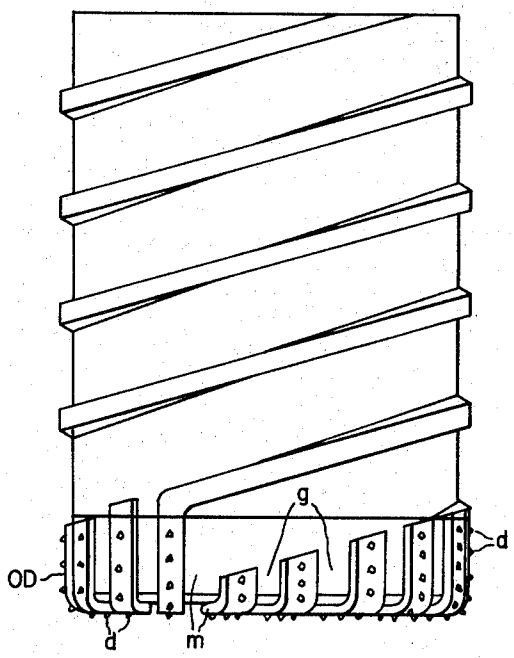


FIG. 1.

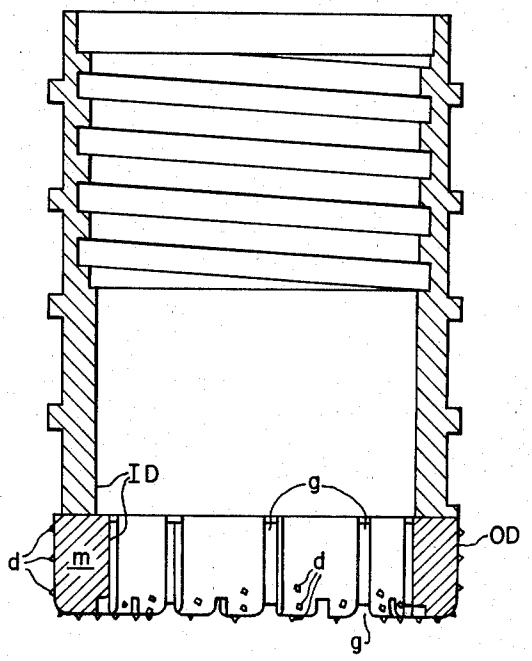


FIG. 2.

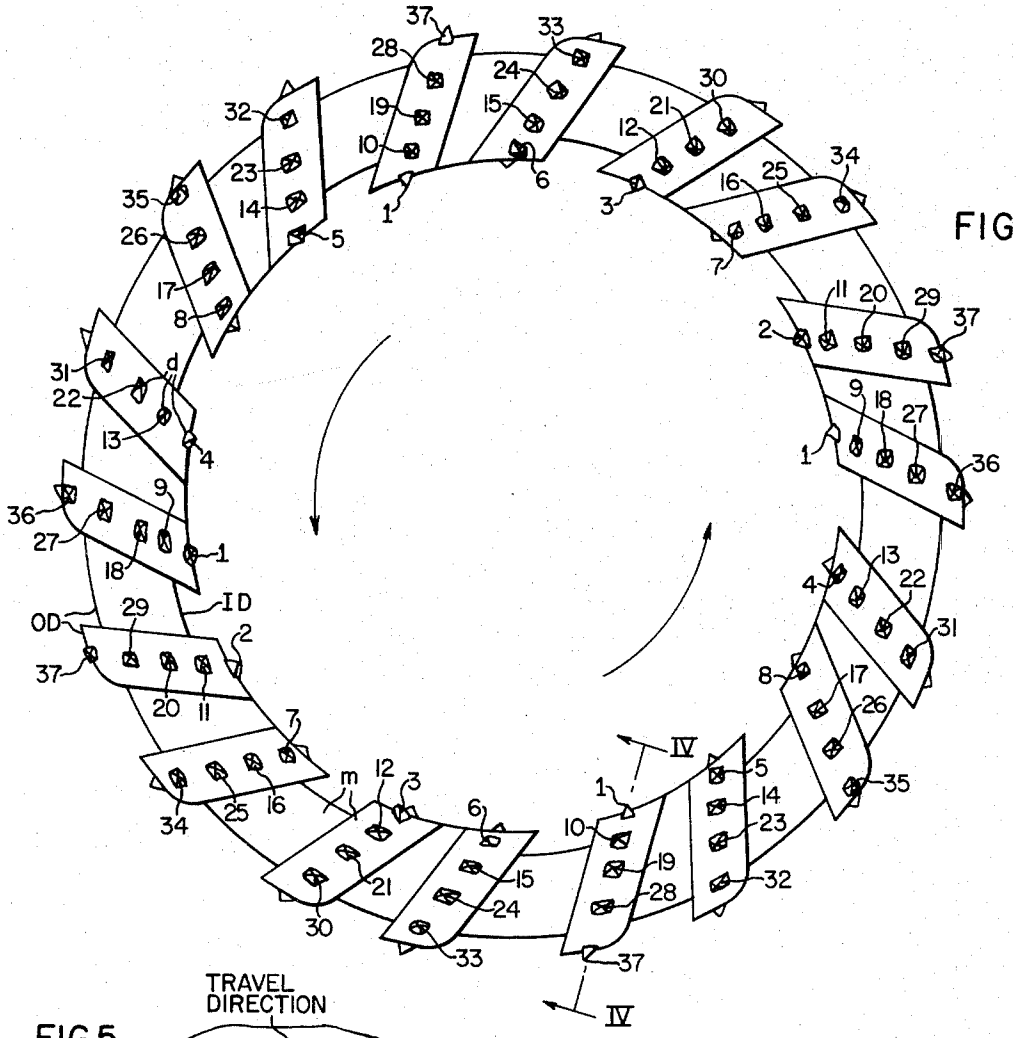


FIG.3.

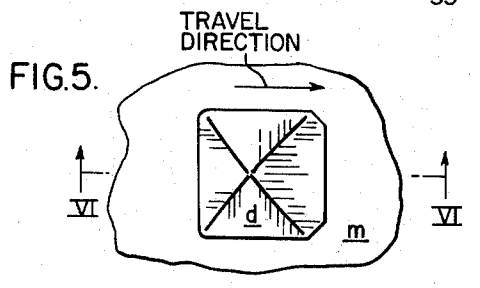


FIG.5.

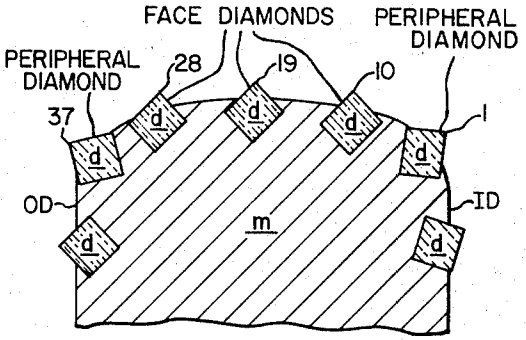


FIG.4.

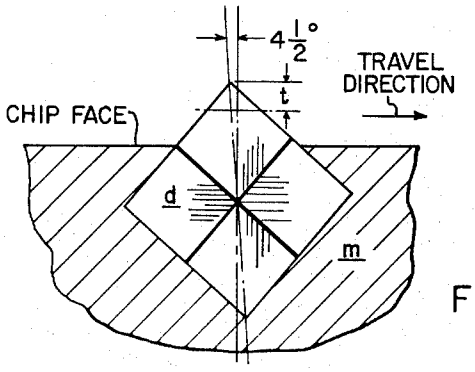


FIG.6.

ROTARY DIAMOND CORE BIT

The invention described herein was made under contract with the National Aeronautics and Space Administration, Marshall Space Flight Center.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to diamond core bits.

2. Description of the Prior Art

Diamond rotary coring bits are used in geological exploration and exploitation to provide core samples from various depths. Diamond coring bits are used also in drilling holes in other hard materials for use with explosives where man-made cutters are ineffective or uneconomical.

In a hard igneous rock such as the intrusive basalt from the quarries at Dresser, Wis. (nominal 43,000 psi compressive strength and 79 Shore hardness), a life of 30 feet/bit is considered a normal life when using a water chip flush.

The rotary diamond coring bits employed in cutting rock follow Diamond Core Drill Manufacturer's Association standard sizes, but the diamond size, diamond patterns, and orientation employed vary greatly.

Bit manufacturers market bits of their own designs and custom-make a considerable number of design variations for drilling contractors. These designs are derived from the bit manufacturers' and drilling contractors' experience, or from data somewhat unscientifically derived.

The drilling operations with these bits, in turn, are often based strictly on the judgment of the driller.

In general, the cost/foot of hole is the major guideline of the drilling industry with the common philosophy being — the cheaper the bit, the cheaper the hole. With such variables as bit design and operations based upon relatively unscientific data, the drilling of a hole can be disastrous financially if the bit and the drillers' approach doesn't match the formation being drilled.

In addition, the skilled drillers are in very short supply due to the long learning period (up to 10 years of drilling experience before becoming a recognized driller), the frequency of drilling in remote locations and in unfavorable climatic conditions, the relatively low pay, and the winter shutdown character of the geological drilling operation.

The drilling and other material working industries have been reluctant to concur that rotary diamond coring bits can be utilized without the cooling of the diamonds and the removal of the chips by means of a liquid or a gas. There are many applications where drilling with dry chip removal would be preferred. Among these applications are decorative stone quarrying where stains from liquids add to the finish costs, in masonry where the immediate surroundings cannot permit it (hospitals, manufacturing processes, hotels, etc.), and where contaminants carried in will effect the final usage of the material (ablative material, composites, etc.).

In either dry or wet modes of chip removal, there appears to be a need for an improved diamond core bit capable of longer service life.

SUMMARY OF THE INVENTION

A diamond core bit constructed in accord with the present invention has dry-drilled over one hundred twenty four feet of Dresser basalt before wearout, and offers promise of even greater service life in wet-chip flushing mode of use.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an elevation view in outline of a diamond core bit constructed in accord with the present invention;

FIG. **2** is a vertical section view of the bit of FIG. **1**;

FIG. **3** is an end view of the bit of FIG. **1**, taken in the direction of arrow III to show details of the annular cutting face of the bit;

FIG. **4** is a section view of a cutting segment of the bit taken along the line IV—IV in FIG. **3**;

FIG. **5** is a plan view in outline showing a preferred arrangement for the diamonds as embedded in the crown of the bit; and

FIG. **6** is a section view of the diamond of FIG. **5**, taken along the line VI—VI.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The diamond core bit of FIGS. **1–5** is constructed in accord with the following:

CLASS OF DIAMONDS

Exclusive or substantially exclusive use of diamonds d free of surface and subsurface defects at least in a select rectangular pyramid point region having an included angle of 110° to 120°, chosen by microscope from grade AAAA commercial stones such as South African borts and Brown Premiers (also called Creams, 4A, Quadruple A, Special, Special Rounds, Gem, Gem Grade).

CRYSTAL FORM OF DIAMONDS

Exclusive or substantially exclusive use of the rhombic dodecahedron crystal form rather than the octahedron form.

SIZE OF DIAMONDS

Exclusive or substantially exclusive use of nominal 20/carat stones, within the range of 18 to 22 per carat sizes.

EXPOSURE OF THE DIAMONDS

Protrusion of each of the select nominal 20/carat diamonds *d* an average of 0.015 inches above the matrix m provides for adequate anchoring of such diamonds at least two-thirds or more of their length in the matrix material of the bit, while affording clearanceway for hard-rock chip passage between the cutting tip portion *t* of such protrusion and such matrix, FIG. **6**.

ORIENTATION OF THE DIAMONDS

Each of the diamonds d is arranged with a face of its select rectangular pyramid cutting point region facing forwardly with respect to its travel direction, as shown in FIGS. **5** and **6**, and with a nominal negative (backward) rake of 4-½° with respect to such travel direction, as shown in FIG. **6**.

PATTERN OF THE DIAMOND

The projecting tips of the face and peripheral diamonds, FIG. 6, are arranged in a pattern based upon line circles which are imaginary lines on the bit face at a given radius from the bit center; the numerals given the diamonds *d* of FIGS. 3 and 4 indicate the line circles on which tips of such diamonds are located, in numerical order from ID to OD. The line circle spacing must be less than 0.040 inches apart since 20/carat diamonds are approximately this wide at the matrix m level. A spacing of 0.010 inches ± 0.001 inches between line circles appears optimum and permits better chip flow since the resultant kerf is smoother. For the set size of 1.955 inches OD × 1.375 inch ID, 37 line circles are employed. From one to three diamonds/line circle are acceptable with two diamonds/line circle being preferred for the face, and three or four diamonds/line circle in the peripheral line circle. The diamonds are placed in radially and negatively extending rows. The individual diamonds form spirals in combination with diamonds in other rows. These spirals are designed to promote the sweeping of chips across the chip face to the OD periphery. The cutting tip axes of the face diamonds on the semi-round annular bit face, radius 0.273 inch, (FIG. 6) lie in vertical planes parallel to the rotary axis of the bit, and those of the peripheral diamonds lie in plane perpendicular to the tangent of the 0.050 ± 0.005 inch curved regions of the bit at the intersections of such semi-flat annular bit face with the inner and outer diameter portions (ID, OD) of the bit.

CHIP RELEASE

The face chip release grooves g are canted negatively, and are approximately 0.304 inch long from OD to ID and are approximately 0.065 inch deep. These areas are carried around the OD periphery until they meet the auger flight in their respective sectors. The ID release areas are carried to the upper ID boundary of the crown and are continuations of the alternate face chip release areas.

ENTRIES FOR CHIP REMOVAL AUGER

Three primary auger entries extend from OD chip release grooves in the bit crown to three upwardly extending auger flights. Five other entries per auger flight are provided by other OD chip release grooves.

CHIP REMOVAL AUGER

Three or six auger flights work equally well, with three being preferred for ease of manufacture. A 15° auger angle at rotational speeds of 500 r.p.m. or less has more than the needed capacity to lift the chips which can be cut by the bit in harder rock formations. The chip flow grooves between auger flights are about 0.050 inch deep and 0.35 inch wide. The OD at the auger flight lands is only 0.015 inch less than the nominal OD of the bit crown for several inches, to help stabilize the bit in the hole. The auger flight OD above this point is 0.040 inches in diameter less than the OD set size.

MATRIX MATERIAL OF BIT CROWN

A matrix material of sintered tungsten carbide powder with silver based alloy, equivalent to T-4 made by Kennametal Corporation of Latrobe, Pa., has proved to be sufficiently strong and abrasive-resistant to anchor the diamond in the bit.

A bit of the 1.955 inch OD − 1.375 inch ID set size constructed in accord with the foregoing details has yielded the following performance information and operational recommendations for the listed operating parameters:

THRUST

To reduce diamond fracture and to increase bit life by utilizing a high penetration/revolution, a nominal load of 30 pounds thrust per load bearing diamond has been set. Where hard inclusions such as quartz are encounterable, the thrust is limited to approximately 16 pounds per load bearing diamond. The thrust/load bearing diamond is defined as the total thrust on the bit divided by the sum of the face stones and two-thirds of the peripheral stones. For drilling break-in and for softer formations, lower loads are used.

RPM

The rpm was found to be a tradeoff between high bit temperatures, relatively rapid diamond wear and chatter accompanying high rpm and low temperatures, longer life, little chatter but low penetration rates for low rpm.

For bits of the 1.955 inch OD and 1.375 inch ID set size, 375 rpm appears optimum in Dresser basalt.

BIT BREAK-IN

Within 1 to 8 feet of drilling hard rock, the initial high penetration rate falls off until it reaches a rate where it will drill steadily under a small range of thrust loadings for the greater part of the bit's life. It has been shown that the high cutting rate is related to the variance in the protrusion of the diamonds. To even out the protrusion variance, the bit must be run at a lower rpm than the normal rate, and at a thrust which permits no chatter until the drill rate stabilizes.

CHATTER

Chatter limits bit life through promoting diamond fracture and wear. Chatter is defined as a combination of vertical and horizontal oscillating movements inflicted upon the bit diamonds by a number of causes. Chatter can be caused by excessive rpm, low thrust, unsatisfactory chip removal, incomplete break-in and other off-center bit anomalies. Chatter is controlled by suitable break-in procedures, changing rpm and/or thrust, and by optimizing the physical clearances in bit design for the penetration rates expected, and by keeping the auger flights partly filled for lateral stabilization purposes.

PENETRATION/REVOLUTION

Penetration/revolution is the advance of the drill bit into the material/revolution and is termed "bite." Besides thrust, the other influence on "bite" is the number of diamonds/line circle and number of line circles. For the 1.955 inch OD × 1.375 inch ID bit, two diamonds/line circle and 37 line circles with 0.010 inches between the line circles have proven optimum. For two diamonds/line circle, at the optimum rate of

0.006 inch/revolution for basalt, the depth of cut per diamond is 0.003 inches per revolution.

TEST MATERIAL VARIATIONS

Material variations, including microstructure, hardness compressive strength, fractures, cavitations, and new strata may have a detrimental effect upon the bit diamonds. To reduce diamond fracture, the diamonds should be loaded to a maximum thrust of 16–30 pounds per load bearing diamond with the higher levels being applied as the bit ages. This thrust increase is based upon a maximum penetration rate set for the type of materials or combination of materials being drilled. In Dresser basalt, the maximum penetration/revolution which appears optimum is 0.006 inches per revolution.

Bit mold design and bit manufacturing techniques can facilitate obtaining the desired bit dimensional characteristics:

A smooth cutting hard carbon has been utilized for a three-piece mold (not shown), and inserts employed to make chip release areas and other crown configurations.

Each element of the mold was machined to within
+0.001 inches
−0.000 inches.

The mold was made in three pieces to make it easier to drill the diamond setting pips.

The pip marks were drilled to a specific depth and to the precise diamond orientation rake angle on a milling machine equipped with an index head capable of indexing to an angle of 5 minutes.

The burr used to drill the pip had an included angle that took into consideration the included angle of the selected diamond point and the angular tolerances expected in the selected 18–22/carat stones.

A skilled diamond setter was utilized to set the stones carefully so that each diamond presents the appropriate cutting face in the finished bit, and so that each diamond point is on the bottom of the pip.

The remaining bit manufacturing procedures were followed with unusual care to prevent disturbing the diamond setting positions.

The bit blank was machined out of FM Invar stock. Invar was used for its stable thermal characteristics. Since the OD of the augers machined into the blank must be within 0.015 inches of the bit set size to assure prompt clearing from the bit crown OD, a bit blank, which expands greatly under the drilling heat, could cause the bit to bind in the hole.

The bit was machined to a maximum runout of 0.001 inch to avoid chatter due to the eccentricities.

We claim:

1. A rotary diamond core bit, comprising,

a cylindrical crown of metallic matrix material having a plurality of snow-plow oriented circumferentially distributed land areas separated by chip release grooves formed in an annular semi-round cutting face of such crown, said crown having lesser radius rounded peripheral regions joining the inner and outer perpheries of said annular face with inner and outer cylindrical regions of such crown; and

a plurality of Grade AAAA dodecahedron diamonds within the range of 18 to 22 diamonds per carat size embedded in said matrix material with select flow-free rectangular pyramid point regions thereof projecting therefrom a distance of 0.015 ± 0.003 inch in hard-vector face-set orientation to the rotary cutting direction of the bit with a negative rake angle,

certain of said diamonds being disposed in the inner and outer cylindrical regions of said crown as reaming stones, and others of said diamonds being disposed on said annular face and on said peripheral regions as cutting stones,

such cutting stone diamonds being arranged in snow-plow oriented linear rows extending along said land areas, respectively,

said cutting stone diamonds collectively being arranged such that their projecting cutting tips lie on concentric line circles at equal radial intervals of 0.010 ± 0.001 inch;

the axes of such tips on the annular cutting face lying in vertical planes parallel to the axis of said bit, and the axes of such tips on the rounded peripheral regions lying in planes perpendicular to the tangents to such regions.

2. The rotary diamond core bit of claim 1, wherein the majority of line circles each have only two cutting stone diamond tips disposed therein.

3. The rotary diamond core bit of claim 1, wherein,

said crown also comprises axially extending chip release grooves in its inner and outer cylindrical regions which communicate with the aforesaid chip release grooves in the cutting face, and,

said bit further comprises a coaxial cylindrical auger portion attached thereto and having auger flights defining chip flow grooves which communicate at a bottom end with the axially extending chip release grooves in the outer cylindrical region of said crown.

4. The rotary diamond core bit of claim 1, wherein,

said bit is of 1.955 inch OD and 1.375 inch ID set size,

the radius of said semi-round annular face is about 0.273 inch,

the radius of each of said rounded peripheral regions is 0.050 ± 0.005,

cutting diamond tips are arranged along 37 line circles, with the innermost and outermost circles having four cutting diamond tips each, and the remainder having two cutting diamond tips each.

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