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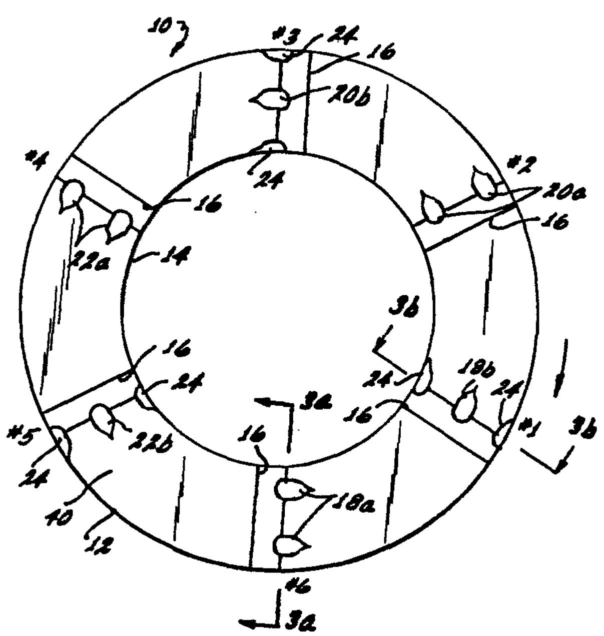
(54) **An improved kerfing drag bit.**

(57) Cutting a rock formation with a polycrystalline diamond rotating bit (10) is optimized by cutting by means of a kerfing action. The polycrystalline diamond cutters (18) are arranged and configured on the bit face to form a plurality of triads. Each triad includes two kerf cutting teeth (18a) and a clearing tooth (18b). The kerf cutting teeth (18a) each cut a kerf into the rock formation. The two radially spaced kerf cutting teeth (18a) thus define an interlying annular space of rock. A clearing tooth (18b) removes the interlying space. In a preferred embodiment, the radial width of the land is equal to or less than the effective cutting width of the clearing tooth (18b), and each of the kerf cutting teeth (18a) and the clearing tooth (18b) are azimuthally offset one from the other on the bit face with the clearing tooth (18b) azimuthally disposed between the kerf cutting teeth (18a).



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An Improved Kerfing Drag Bit

Background of the Invention

Field of the Invention

The present invention relates to the field of earth boring tools and in particular to rotating drag bits utilizing polycrystalline synthetic diamond teeth as the cutting elements.

Description of the Prior Art

One of the primary differences provided in the cutting action of a rotating drag bit and a roller cone bit is that the rotating drag bit cuts by shearing action whereas the roller cone bit cuts by crushing. The performance of rotating drag bits has been substantially increased by the introduction of synthetic polycrystalline diamond elements which can be used as the cutting elements. The Assignee of the present invention has pioneered in the design of synthetic diamond rotating bits and the means by which such diamond teeth are attached to, retained on and exposed above the face of the bit to provide useful cutting action.

Typically, diamond teeth on a rotating bit will slice into or shear grooves into the rock formation in the bottom of a hole. According to designs known in the art the teeth are collectively arranged on a bit face in an overlapping arrangement. For example, one row of diamond teeth will typically have an offset row of diamond teeth disposed behind it. In some designs the offset row is disposed on the bit face with a radial distribution which leaves the teeth in the half spaces between the teeth of the preceding row, albeit as azimuthally displaced behind the preceding row. Other designs contemplate disposition of succeeding rows of teeth in other fractional radial increments such as three rows collectively comprising a cutting unit with each row radially offset from the azimuthally preceding row by one third of the intertooth spacing.

The result is that a plurality of grooves are cut by the first row into the face of the rock formation at the bottom of the borehole. The next row of teeth is rotated through the same given radial line and cuts the next adjacent annular one-third or half space adjacent to the groove cut by the first row. This cutting sequence continues until the entire inter-tooth spacing is cut from the rock formation. Thus, the corresponding teeth in the associated rows will cut a complete annular ring from the rock face. The annular rings of adjacent sets of teeth are also adjacent, thereby resulting in the removal of an entire layer from the face of the borehole. The progression of cutting elements generally continues radially outward as adjacent, consecutive, radial increments, or may be designed to cut inwardly by successive radial increments .

Although the predominant form of current cutting practices is as described above, cutting through kerfing is also known, although little used. One example can be found in a soft rock cutter in Kandle, "Drill Cutting Head" U.S. Patent 2,960,312. In Kandle two concentric annular wheels, each carrying a plurality of teeth in a rotating drag bit, cut two circular kerfs with the interlying land between the kerfs being cut, crumbled or crushed by one of two interlying clearing cutters. Although the clearing cutters are added to the design almost as an afterthought, Kandle is an example of an instance where two spaced-apart kerfs are cut into the rock formation and the interlying rock removed by an interkerf cutter.

The removal of ridges which are created between adjacent kerfs, or are created by kerf cutting, has also been applied to some extent in rock bit or roller cone bits. In Baker, "Hybrid Rock Bit" U. S. Patent 4,343,371 Stratapax cutters are disposed on two opposing extensions of the bit body between two opposing roller cones. The kerfs cut by the plurality of teeth on the roller cones leave raised lands which are then removed by Stratapax cutters acting in part as a drag bit.

Kerf cutting has also been used to an extent within the roller cones itself as is exemplified by Youngblood, "Roller Cutter with Major and Minor Insert Rows", U.S. Patent 4,202,419.

However, none of the prior art designs efficiently maximize or exploit kerf cutting to any extent. In fact, it remains substantially unappreciated that kerf cutting is even necessarily desirable or advantageous in any sense over other types of cutting action, even when kerf cutting is used solely in rotating drag bits.

Therefore, what is needed is a design for a rotating drag bit which maximizes the cutting action of the rotating bit, particularly when the cutting elements are synthetic polycrystalline diamond elements.

Brief Summary of the Invention

The present invention is an improvement in a rotating bit having a bit face including a plurality of polycrystalline diamond teeth disposed on the bit face. The improvement comprises at least a first and second polycrystalline diamond tooth for cutting kerfs. A third polycrystalline diamond tooth, associated with the first and second polycrystalline diamond teeth and disposed therebetween, is provided for clearing material lying between the kerfs which is cut by the first and second teeth. The third tooth is azimuthally displaced with respect to at least one of the first and second teeth. By reason of this combination of elements, cutting by kerfing with the first, second and third teeth acting in combination is optimized on the bit.

More specifically, the improvement is illustrated in four embodiments. In the first embodiment the first and second teeth are disposed on the bit face at substantially the same azimuthal position. The first and second teeth are radially spaced apart and the third tooth is azimuthally disposed behind or follows the first and second bit teeth as defined by the direction of rotation of the rotating bit.

In the second embodiment the first and second teeth are both radially and azimuthally offset from each other. The third tooth is radially disposed between the first and second, and is azimuthally disposed behind or follows both the first and second teeth.

In the third embodiment the first and second teeth are azimuthally and radially disposed from each other on the bit face of the bit. The third tooth is azimuthally disposed behind the first tooth and in front of or leads the second tooth.

In the fourth embodiment the third tooth is azimuthally disposed in front of or leads both the first and second teeth.

In each of the embodiments the radial spacing between the first and second teeth of each triad decreases as the distance of the triad from the center of rotation of the bit increases.

The invention further includes a method of cutting with a rotating bit having a plurality of synthetic polycrystalline diamond elements disposed on the bit comprising the steps of cutting two radially spaced concentric kerfs into a rock formation by two kerf cutting teeth. The space between the kerf cutting teeth is cleared with a third clearing tooth. Each of the two kerf cutting teeth have a corresponding third clearing tooth. In particular the step of cutting further comprises the steps of cutting a first kerf, clearing the rock disposed between the first kerf and a second kerf to be cut by an azimuthally following third clearing tooth, and then subsequently cutting a second kerf with an azimuthally following tooth.

These and other embodiments of the invention are better understood by now turning to consider the following Figures wherein like elements are referenced by like numerals.

Description of the Drawings

Figure 1 is a plan view of a mining bit having the cutting teeth collectively arranged as kerf cutters according to the invention.

Figure 2 is a diagrammatic cross sectional depiction of the pattern of coverage of one collective group of cutters of the bit of Figure 1 as seen in a radial line as the bit rotates.

Figure 3a is a cross sectional view of a mold used to dispose the cutters of Figure 2 into a matrix infiltration bit.

Figure 3b is a cross-sectional view of a mold for the remaining tooth of the collective group depicted in Figure 2.

Figure 4 is a diagrammatic plan view of a first embodiment of the kerf cutting teeth.

Figure 5 is a diagrammatic plan view of a second embodiment of the kerf cutting teeth.

Figure 6 is a diagrammatic plan view of a third embodiment of the kerf cutting teeth.

Figure 7 is a diagrammatic plan view of a fourth embdiment of the kerf cutting teeth.

Figure 8 is a diagrammatic plan view of a petroleum bit utilizing the selective disposition of kerf cutting teeth of the invention.

Figure 9 is a diagrammatic cross sectional view taken through line 9-9 of Figure 8 showing a profile of the petroleum bit.

Figure 10 is a diagrammatic plot diagram of the teeth as disposed on the petroleum bit of Figures 8 and 9.

The invention and its various embodiments are now best understood by considering the detailed description as illustrated by the Figures described above.

Detailed Description of the Preferred Embodiments

The invention relates to a design wherein kerfing action in a synthetic polycrystalline diamond rotating bit is optimized. In the preferred embodiment the cutting teeth of the bit are associated in triads. The first two teeth of the triads are particularly adapted and arranged to cut parallel kerfs. The third tooth of the triad is particularly adapted and arranged to cut into the interlying space in the rock formation between the first two teeth or to remove the interlying land between the kerfs cut by the preceding first two teeth of the triad. The last tooth is arranged and configured to act as a hammer or chisel and to provide a broad surface of cutting contact than the corresponding first two teeth of the triad. It has been determined according to the invention that the azimuthal and radial disposition of each of the teeth, which collectively forms a triad of cutters, is of material importance to maximize cutting efficiencies through kerfing action. The invention, its operation and various embodiments may better be understood by now turning to the plan view of a mining bit shown in Figure 1.

In Figure 1 a coring mining bit, generally denoted by reference numeral 10, is characterized by an outer gage 12 and inner gage 14. Bit 10 is divided into six 60 degree segments as delineated by radial waterways 16. At least one and generally a plurality of polycrystalline diamond teeth 18 are disposed near or on the edge of each waterway 16. Teeth 18 may in fact be any cutting elements now known or later devised in the art although they are described here as synthetic polycrystalline diamond teeth such as incorporated in the various designs of bits sold under the trademark BallaSet marketed by Norton Christensen, Inc. of Salt Lake City, Utah.

Teeth 18 are collectively arranged to form groups of triads. For example, teeth 18a form a leading pair of a first collective triad of teeth of which tooth 18b is the third tooth. As depicted in the plan view of Figure 1, tooth 18b is radially disposed in the half space between teeth 18a and azimuthally displaced behind tooth 18a by a predetermined angle, in this case approximately 60 degrees. Teeth 20a serves substantially the same purpose with respect to tooth 20b. Thus, teeth 20a and 20b collectively forming a kerfing triad. Additional teeth, such as gage defining teeth 24 may also be provided on bit 10 to provide cutting assistance in a conventional fashion.

Turn now to Figure 2, which shows the pattern of coverage of a single triad of teeth in a cross-sectional view in enlarged scale as would be seen in a fixed longitudinal plane as the bit rotates. The triad, comprised of teeth 18a and b, are depicted by way of example in Figure 2. First teeth 18a will traverse any given plane cutting two parallel circular kerfs. Thereafter the next tooth encountering the fixed longitudinal plane will be tooth 18b which is disposed approximately in the half space between teeth 18a. In the embodiment of Figures 1-3, each of the teeth are shown as triangular in cross section, such as would be the case when triangular polycrystalline synthetic diamond teeth are used, such as manufactured by General Electric Co. under the trademark "GEOSET". However, as will be illustrated in the additional embodiments described below, the invention is not restricted or limited to the use of any particular profile of tooth or cutting element.

Figure 3a is a cross-sectional view of a mold corresponding to line 3a-3a of Figure 1 in which the pair of teeth of the triad, such as teeth 18a would be disposed. The triangular diamond element is disposed in a corresponding triangular indentation 26a or b machined into graphite mold 28. Mold 28 is then backfilled with a conventional tungsten carbide powder matrix and the entire composite is infiltrated by a conventional process to form an infiltrated matrix bit. In the illustrated embodiment, each tooth 18a is inclined at a selected angle within mold 28. For example, indentation 26a for one of teeth 18a is inclined at an angle of 11 degrees with respect to centerline 30.

Figure 3b illustrates a second section taken from mold 28 corresponding to the position of tooth 18b and teeth 24, corresponding to line 3b-3b of Figure 1. Teeth, such as teeth 18b, 20b and 22b of Figure 1, will be disposed within indentation 36 and gage teeth 24 are disposed within indentations 38. Tooth 18b is generally perpendicularly disposed with respect to the bit face 40 and teeth 24 extend outwardly at an angle of 27 degrees with respect to the vertical. Only a small portion of teeth 24 is exposed (0.070

inch) as compared to the exposure of teeth 18a and 18b (0.180 inch). The teeth, disposed in mold 28 and as depicted in the radial dispositions illustrated in Figures 3a and 3b, collectively combine to cut an azimuthal swath or form a pattern of coverage as diagrammatically depicted by Figure 2.

Turn now to Figure 4 where another embodiment of a mining bit, generally denoted by reference numeral 42, and which is a variation of the tooth pattern as depicted in Figures 1-3, is shown in plan view. Face 44 of bit 42 is divided into three 120 degree sectors as defined by radial waterways 46. A triad of teeth 48a and 48b are disposed within each sector, beginning at an azimuthal displacement of approximately 45 degrees behind the preceding waterway 46. The triad is comprised up a pair of teeth 48a and a following single tooth 48b. Teeth 48a include a generally triangular prismatic polycrystalline synthetic diamond elements such as manufactured by General Electric under the trademark "GEOSET" in a tooth structure such as those found in the BallaSet bits manufactured by Norton Christensen of Salt Lake City, Utah. However, it is entirely within the scope of the invention that other tooth structures now known or later devised could be substituted with equal facility. In any case, pair of teeth 48a are disposed on bit face 44 on the same azimuthal position, but are radially displaced by predetermined distance. The triangular cutters of teeth 48a are tangentially set, namely having an apical ridge generally parallel to the tangent of the radius at the situs of the tooth placement. Teeth 48a thus cut two parallel circular kerfs into the underlying rock formation.

Behind teeth 48a is a third tooth 48b which is comprised of a cylindrical axially mounted synthetic polycrystalline diamond such as is sold by the People's Republic of China. The radial distance between teeth 48a is equal to or less than the diameter of cylindrical tooth 48b. Tooth 48b is azimuthally displaced behind pair of teeth 48a and in the interlying radial gap between teeth 48a. Thus, after the pair of kerfs are cut by teeth 48a, tooth 48b follows to hammer, chisel or otherwise remove the interlying land in the rock formation left between the two kerfs.

Each sector of bit 42 may also include a plurality of gage protecting cutters 50 which generally maintain or protect the gage, but do not coact with the triad of cutters 48a and 48b to cut by kerfing. Each of the triad of cutters in each of the sectors are radially disposed on bit face 44 to provide a complete coverage across the radial sweep of the bit face as seen by any given longitudinally fixed plane in the rock formation. For example, the triad of teeth 52 sweep through a portion of bit face 44 nearest outer gage 54, while a triad of teeth 56 sweep through a middle portion, and triad of teeth 48a and 48b sweep that portion nearest inner gage 58. Each of these portions are overlapping, although no kerf line of any one tooth lies identically on the same line of any other tooth of the bit.

For example, in the illustrated embodiment of Figure 4, outermost triad 52 scribes its outermost kerf at approximately 0.12 inch (3.05 millimeters) from outer gage 54 while the center of the outermost kerf line of triad 56 is scribed at 0.15 inch (3.81 millimeters) from outer gage 54. The center of the outermost kerf of triad 48a and 48b is scribed at 0.19 inch (4.83 millimeters) from outer gage 54. The exposure above bit face 44 of the leading pair of teeth, such as teeth 48a of the triad 48a and 48b is at least 0.150 inch (3.81 millimeters) above bit face 44, while gage protecting teeth 50 and the third tooth of the triad, such as tooth 48b have a lesser exposure, for example 0.105 inch (2.67 millimeters).

In each of these triads the spacing between the kerfs cut by the teeth of the triad may vary among the teeth. For example, the outermost triad 52 may have a inter-kerf spacing of approximately 0.25 inch (6.35 millimeters), triad 56 an inter-kerf spacing of 0.31 inch (7.87 millimeters) and triad 48a and 48b in inter-kerf spacing of 0.38 inch (9.65 millimeters). Thus, near the outer gage 54 where linear speeds of bit 42 are greater, the inter-kerf spacing is less. This spacing increases as the radial distance of the triad from the center of the drill string decreases. In this way compensation is made for the greater rock-cutting rate imposed upon the third tooth of the triad, such as tooth 48b, as one moves outwardly from the center of the bit to outer gage 54. In fact, if desired, the inter-kerf spacing can be made inversely proportional to the radial distance of the third tooth, such as tooth 48b.

Turn to Figure 5 wherein a plan view of a second embodiment is illustrated. The bit, generally denoted by reference numeral 41, is again divided into three sectors of 120 degrees by radial waterways 47. Each sector includes a triad of cutters. For example, the radially innermost triad is comprised of a pair of teeth 49a and an azimuthally following tooth 49b radially disposed between pair of teeth 49a. The mid-radial triad 57 and outermost triad 53 are similarly constituted. Gage protection teeth 51 are also disposed on the inner and outer gages.

The second embodiment of Figure 5 differs from that of Figure 4 in that the second tooth of pair 49a of teeth is azimuthally disposed approximately 15 degrees behind the leading face of the first tooth of parir 49a. Third clearing tooth 49b is azimuthally disposed approximately 30 degrees behind the leading face of the second tooth of pair 49a.

Turn now to Figure 6 wherein another embodiment of the invention is illustrated, showing in plan view a mining bit, generally denoted by reference numeral 60. Once again mining bit 60 is divided into three sectors as defined by radial waterways 62. Gage protecting teeth 64 are provided as before, however, within each sector the triad of teeth are arranged so that the first kerf cutting tooth 66 is followed by the clearing tooth 68 and hence by the second kerf cutting tooth 70. In the embodiment of Figure 6, leading kerf cutting tooth 66 is the radially innermost tooth of the triad of teeth 66-70, while the second kerf cutting tooth 70 is the radially outermost tooth of the triad.

In the illustrated embodiment, the first kerf cutting tooth 66 is azimuthally displaced behind the center of waterway 62 by approximately 35 degrees. Clearing tooth 68 is then azimuthally displaced behind the leading edge of tooth 66 by approximately 30 degrees. Finally, the second kerf cutting tooth 70 has its leading edge azimuthally displaced behind the center of clearing tooth 68 by approximately 20 degrees. As described before in connection with the embodiment of Figure 4, the radial displacement of teeth 66, 68 and 70 is adjusted so that clearing tooth 68 lies in the halfspace between the kerf cutting teeth 66 and 70. The radial displacement between azimuthally offset teeth 66 and 70 is equal to or less than the radial effective cutting width of clearing tooth 68, which may be slightly larger or smaller than the actual physical radial dimension of clearing tooth 68. For the purposes of this specification, "effective cutting width" of a tooth is defined as the maximum radial dimension of rock land between two concentric kerfs or kerf cutting teeth, which a cutter can remove in a single pass. Thus, the magnitude of effective cutting width will depend on tooth design, the nature of the rock and other drilling parameters. The inter-kerf distance between teeth 66 and 70 is similarly adjusted to compensate for the greater cutting rate experienced near outer gage 72 as contrasted to that experienced near inner gage 74 as previously described in connection with the embodiment of Figure 4.

Finally, the annular swath cut into the rock formation by the triad of teeth 66, 68 and 70 overlaps with the swath cut by the triad of teeth 76 and 78 also disposed on bit face 80 of bit 60 in a manner similar to that discussed above.

Turn now to Figure 7 where yet another embodiment of the invention is illustrated. Here a mining bit, generally denoted by reference numeral 82, again is organized into three sectors defined by radial waterways 84. Each sector includes a plurality of gage protection teeth 86. Here, clearing tooth 92 azimuthally precedes the following kerf cutters. For example, the leading kerf cutting tooth 88 is associated with a second kerf cutting tooth 90 and a leading clearing tooth 92. Again, teeth 88 and 90 are tangentiallly set BallaSet type teeth, and clearing tooth 92 is a axially or stud mounted cylindrical polycrystalline diamond cutter. In the illustrated embodiment, clearing tooth 92 is azimuthally displaced behind its preceding waterway by approximately 30 degrees. The leading edge of the second kerf cutting tooth 90 is azimuthally displaced behind clearing tooth 92 by approximately 20 degrees, while the first kerf cutting tooth

88 has its leading edge azimuthally displaced in front of second kerf cutting tooth 90 by approximately 35 degrees.

As in the embodiments of Figures 4-6, kerfing teeth 88 and 90 are tangentially set BallaSet type teeth, while clearing tooth 92 is a stud set, cylindrical, polycrystalline diamond element. Teeth 96 form a second triad and teeth 98 a third triad in a similar manner. Each of the triad of teeth 98, 96 and 88-92 are, as described before, radially disposed across bit face 94 to cut overlapping annular swaths ranging from outer gage 100 to inner gage 102. The triads are also characterized by the variable inter-kerf spacing across bit face 94 as previously described.

Mining bits 41, 42, 60 and 82 as depicted and described above in connection with Figures 5, 6 and 7 respectively, were test drilled into rock and a drilling rate established. In the test run in question, the design of mining bit 60 of Figure 6 exhibited the highest drill rate, bit 41 of Figure 5 a drilling rate approximately two thirds less, and the design of bit 82 of Figure 7 the lowest driling rate. It is not entirely well understood why the triad placement of bit 60 is dramatically better than the triad placements of bits 41, 42 and 82. In fact the superior performance of an "in-between" design such as illustrated by bit 60 of Figure 6 is surprising, since conventional notions of kerf cutting would suggest that the design of bits 41 or 42 should have been optimal on the ground that the clearing tooth would be able to remove an unsupported and fully defined land between the kerfs.

Turn now to Figure 8 which shows a diagramatic plan view of a petroleum bit incorporating the invention. The petroleum bit, generally denoted by reference numeral 104, includes an inner crowfoot 106. The hydraulic fluid flows outwardly through spiral waterways 108 to a plurality of junk slots 110 defined into outer gage 112. Between waterways 108 are collectors 114. Collectors 114 and waterways 108 in turn define spiral lands 116 upon which the cutting elements are disposed (not shown in Figure 8).

A profile of petroleum bit 104 as depicted in Figure 8 and seen in cross-sectional sideview taken through line 9-9 of Figure 8 is shown in Figure 9. Crowfoot openings 106 here are seen inclined outwardly and in or near nose 118 of bit 104. Generally flat portion or flank 120 extends from nose 118 to shoulder 122 where the bit face extends into outer gage 112. A triad of teeth, collectively denoted by reference numeral 124, is diagrammatically depicted in enlarged scale on flank 120 where two BallaSet type teeth 126 with an interlying cylindrical cutter 128 is shown in cross section. The disposition of teeth according to the invention across the face of petroleum bit 104 can now be understood by turning to the plot detail as shown in Figure 10.

In the illustrated embodiment of Figure 10 the triad design of Figure 6 is implemented although any one of the embodiments could be employed through suitable substitution of BallaSet type teeth for cylindrical cutters and vice a versa. The plot detail of Figure 10 is a diagrammatic depiction of the disposition of teeth across the entire surface of bit 104 including the gage. The plot is taken as if the bit were cut from the outer gage to the center along any given radius and then laid out and stretched to form a flat strip. Therefore, in the projection of the plot detail of Figure 10 some distortion of proportion is unavoidable. Therefore Figure 10 must be understood as showing a logical relationship only and no implication should be drawn from the illustrated proportionate dispositions.

Petroleum bit 104 is divided into three sectors 130, 132 and 134. Each sector 130-134 includes two spiral lands 116a and 116b in the case of section 130, lands 116c and 116d in the case of section 132, and 116e and 116f in the case of section 134.

Turn now to section 130 which shows a plurality of tangentially set BallaSet type teeth such as tooth 136 and a plurality of cylindrical synthetic polycrystalline stud mounted teeth, such as tooth 138 disposed on land 116a and tooth 148a on land 116b. In addition to these types of teeth, a plurality of surface-set natural diamonds 140 are also included in the nose area 118 and in shoulder portion 122 as well as through out gage 112. Surface-set diamonds

140 are conventional and are provided for abrasion protection in a manner well noted in the art.

Now consider the first triad of kerf cutting teeth in section 130 beginning from nose 118. The first kerf cutter, tooth 136 leads and is radially disposed outward with respect to the interlying cylindrical cutter 138. The next kerf cutter of the triad is BallaSet•type tooth 142 which is the radially outermost tooth on second land 116b. The second triad of teeth also includes tooth 142, cylindrical polycrystalline diamond (pcd) tooth 144 and BallaSet type tooth 146 on land 116a. The triad of teeth continue to be interlaced between lands 116a and 116b toward shoulder 122. For example, the third triad also includes BallaSet tooth 146, cylindrical tooth 148 and BallaSet type tooth 150 each forming with respect to the other the type of relationship as depicted in Figure 6. The fourth triad includes BallaSet tooth 150, cylindrical tooth 152 and BallaSet type tooth 154 on land 116a. Thus, each BallaSet type tooth doubles as forming a kerfing cutter in adjacent triads of cutting teeth.

The disposition of teeth is completed by enumerating the following triads; BallaSet tooth 154, cylindrical tooth 156, and BallaSet tooth 158; BallaSet tooth 158, cylindrical tooth 160 and BallaSet tooth 162; BallaSet tooth 162, cylindrical tooth 164 and BallaSet tooth 166; BallaSet tooth 166, cylindrical tooth 168 and BallaSet tooth 170; BallaSet tooth 170, cylindrical tooth 172 and

BallaSet tooth 174; BallaSet tooth 174, and an omitted cylindrical tooth due to the presence of the junk slot, and BallaSet tooth 176; BallaSet tooth 176, cylindrical tooth 178 on land 116a, and finally BallaSet tooth 180.

In addition to the triad specifically listed above in section 130, additional cylindrical teeth, such as cylindrical cutters 182 on land 116a and BallaSet tooth 184 on the leading edge of land 116a may also be included to provide redundant cutting coverage according to conventional design principles.

Each of the sections 132 and 134 on bit 104 are similarly provided with triads of kerf cutting teeth on their paired lands in the same manner as described in connection with section 130. Furthermore, as described in the embodiments of Figures 4-7, the triads on adjacent sections 130-134 are offset with respect to the triads in the other sections to provide overlapping annular cutting swaths into the face of the rock formation, thereby ultimately providing cutter coverage from the center of the bit to the gage.

Many modifications and alterations may be made by those having ordinary skill in the art without departing from the spirit and scope of the invention. For example, although the plot diagram of Figure 10 as been illustrated in connection with the embodiment of Figure 6, a similar diagram could have been derived with respect to the triad embodiments illustrated in Figures 4, 5 or 7 as well.

Similarly, although the triad embodiments of Figures 4-10 each contemplate two BallaSet type cutters with a cylindrical clearing cutter, the invention is not limited to particular types of teeth or cutters for any one or all of the triad of cutting teeth. Furthermore, the azimuthal spacing specifically described in connection with the embodiments of Figures 4-7 is illustrative only and the actual spacing may vary with each application or within a single bit such as shown in the embodiment of Figure 10. Therefore, the illustrated embodiment has been set forth only by way of example and should not be taken as limiting the invention as defined in the following claims.

We claim:

1. An improvement in a rotating bit having a bit face including a plurality of polycrystalline diamond teeth comprising:

a plurality of triads of cutters, substantially all of the primary cutting teeth on said bit being included in at least one of said triads, each triad comprising:

at least a first and second polycrystalline diamond cutters for cutting kerfs;and

a third polycrystalline diamond tooth associated with said first and second polycrystalline diamond cutters and disposed therebetween for clearing material lying between said kerfs cut by said first and second teeth, said third tooth being azimuthally displaced with respect to at least one of said first and second teeth,

whereby cutting by kerfing with said first, second and third teeth acting in combination is optimized on said bit.

2. The improvement of Claim 1 wherein said first and second teeth are disposed on said bit face at substantially the same azimuthal position, said first and second teeth being radially spaced apart, and wherein said third tooth is azimuthally displaced behind said first and second teeth.

3. The improvement of Claim 1 wherein said first and second teeth are azimuthally and radially displaced from each other on said bit face of said bit.

4. The improvement of Claim 3 wherein said third tooth is azimuthally displaced behind said first tooth and in front of said second tooth.

5. The improvement of Claim 3 wherein said third tooth is azimuthally displaced behind both said first and second teeth.

6. The improvement of Claim 1 wherein said first and second teeth are arranged and configured to cut a kerf having a triangular cross section.

7. The improvement of Claim 6 wherein said third tooth is a synthetic polycrystalline cylindrically shaped diamond tooth.

8. The improvement of Claim 7 wherein said synthetic polycrystalline cylindrical shaped diamond tooth is generally axially mounted within said bit face of said bit and is a full cylinder.

9. The improvement of Claim 7 wherein said synthetic polycrystalline cylindrical shaped diamond tooth is generally axially mounted and is a longitudinal sectional segment of a cylinder.

10. The improvement of Claim 1 wherein each triad cuts a different radial annular swath as said bit rotates and wherein said corresponding annular swaths are partially overlapping.

11. The improvement of Claim 10 wherein radial spacing between said first and second tooth of each triad decreases as the distance of said triad from said center of said rotating bit increases.

12. The improvement of Claim 11 wherein said radial distance between said first and second tooth of each triad is inversely proportional to the distance of said triad from said center of said rotating bit.

13. The improvement of Claim 10 wherein the multiplicity of teeth are disposed on said bit face said bit thereby forming radially adjacent triads of teeth, said first tooth of one triad doubly serving as said second tooth of a radially adjacent triad whereby two radially adjacent triads comprise three kerf cutting teeth like said first and second teeth of each triad and two clearing teeth like said third tooth of each triad.

14. The improvement of Claim 1 wherein said first and second teeth are each arranged and configured to cut a kerf, said first and second teeth being angled with respect to the tangential plane to said bit face at the position of each said tooth, said angle of said first and second tooth with respect to the tangential plane of each said tooth at the location of said tooth on said bit face being equal, whereby a land defined by said kerfs, cut by said first and second teeth, is symmetrical.

15. A rotating bit comprising:

a bit body;

a bit face defined on at least a portion of said bit body;and

a plurality of synthetic polycrystalline diamond cutting elements disposed on said bit face, at least three of said plurality of polycrystalline diamond cutting elements disposed to form a kerf cutting triad, said kerf cutting triad comprised of a first and second kerf cutting tooth and a third clearing tooth, said third tooth azimuthally disposed behind at least one of said first and second kerf cutting teeth and radially disposed between the radial position of said first and second teeth on said bit face,

whereby cutting action of said triad through kerfing is optimized.

16. The rotating bit of Claim 15 wherein the radial distance between said first and second teeth is equal to or less than the effective cutting width of said third tooth.

17. The rotating bit of Claim 16 wherein said third tooth is azimuthally disposed on said bit face behind both said first and in front of said second tooth of said triad.

18. The rotating bit of Claim 17 wherein said first and second tooth are characterized by a generally triangular-shaped cross section of the cutting element and wherein said third tooth comprises a cylindrical cutting element.

19. A method of cutting with a rotating bit having a plurality of synthetic polycrystalline diamond elements disposed on said bit comprising the steps of cutting a plurality of annular swaths into a rock formation, each swath concentric with another swath and lying in a partially overlapping relationship, said step of cutting each•annular swath comprising the steps of:

cutting a first kerf in a rock formation with a first kerf cutting tooth; and

clearing a predetermined annular amount of rock with a third azimuthally following tooth, said first kerfing tooth corresponding to a third clearing tooth.

20. The method of Claim 19 further comprises the step of subsequently cutting a second kerf with an azimuthally following second kerf cutting tooth.

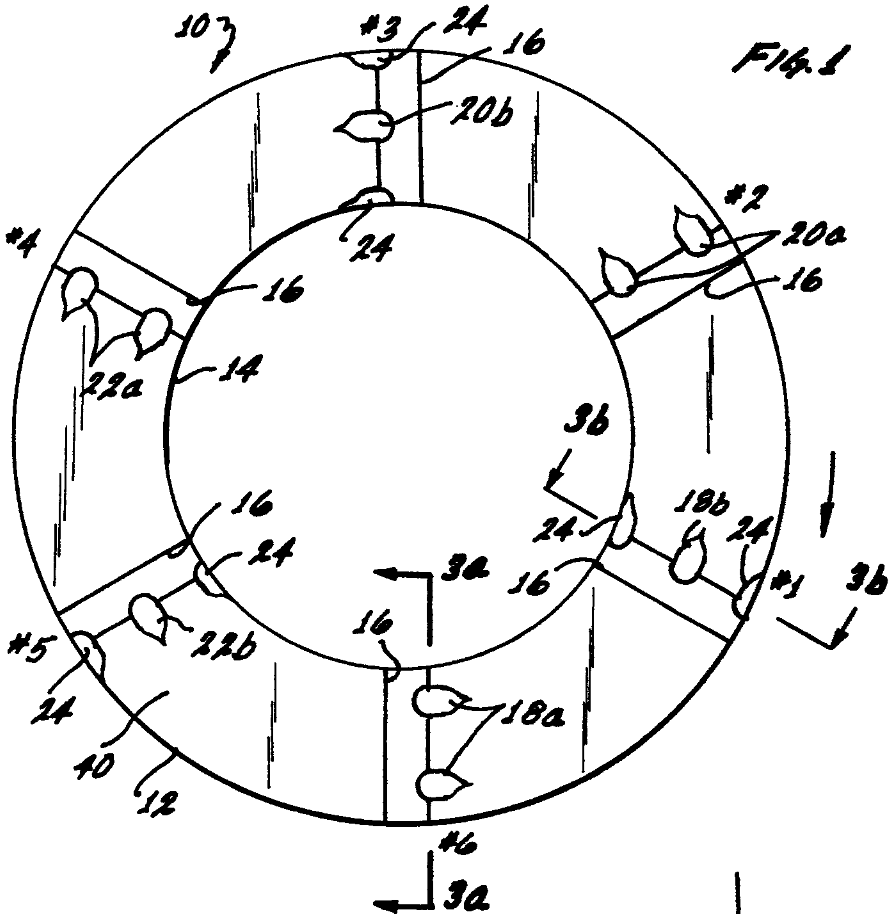
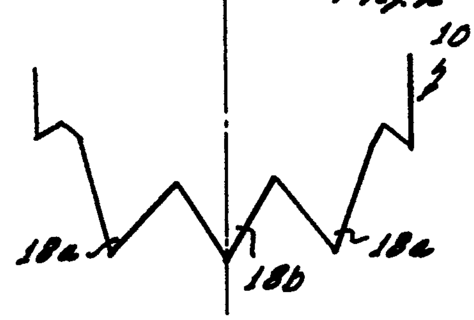


Fig. 1

Fig. 2



BIT POSITION #2, 4+6

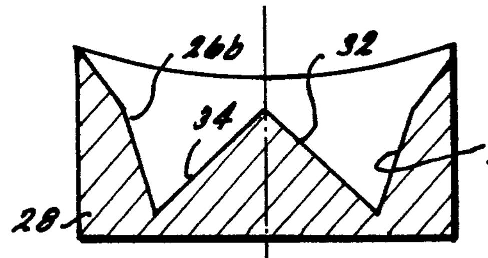


Fig. 3a

BIT POSITION #1, 3+5

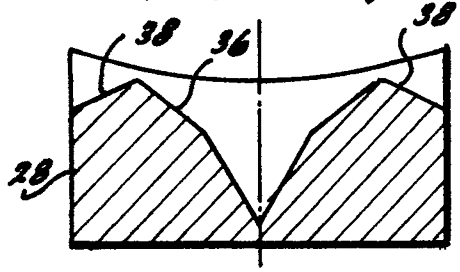


Fig. 3b

Fig.4

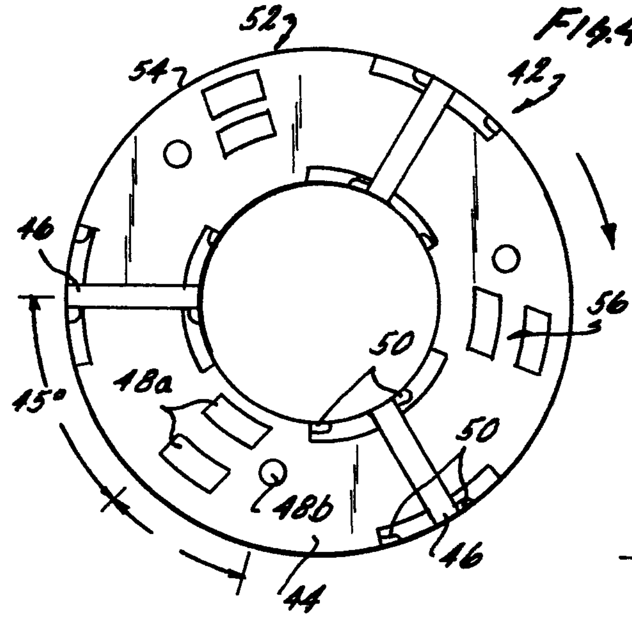


Fig.5

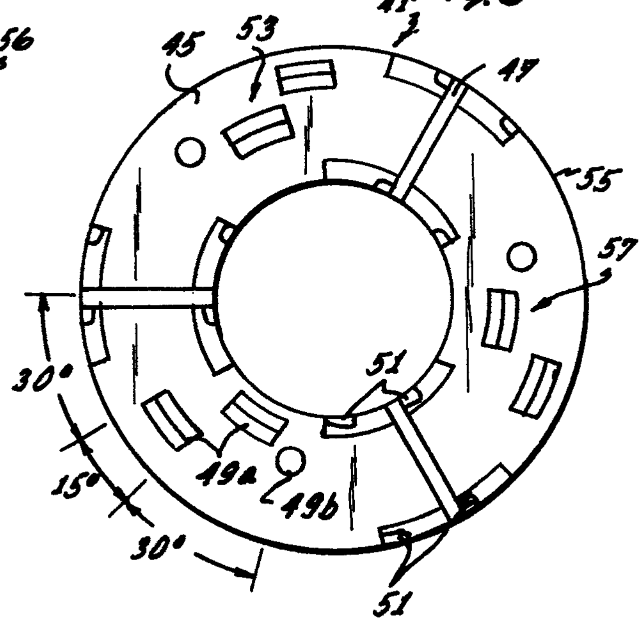
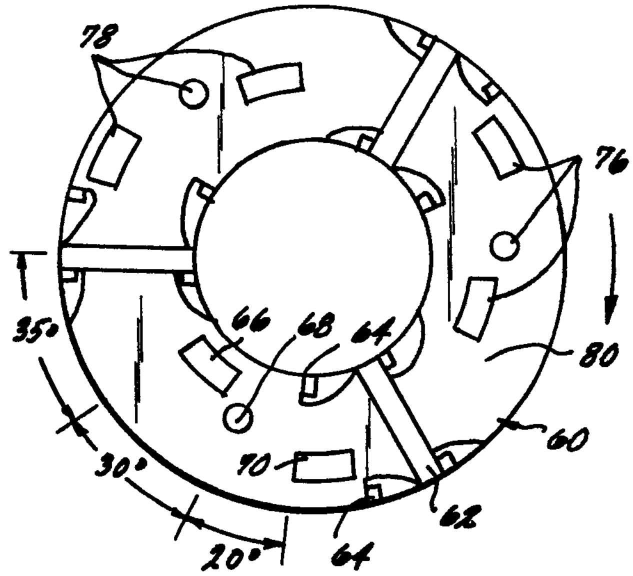


Fig.6



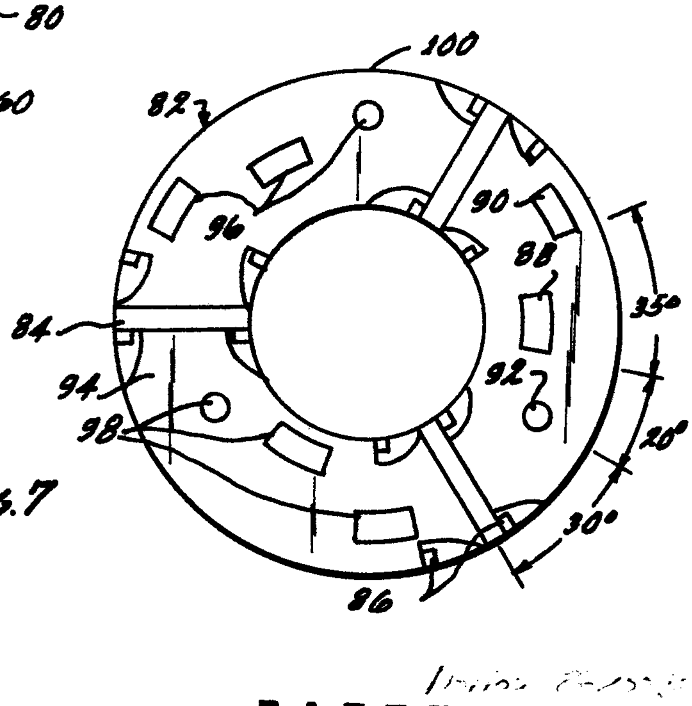


Fig.7

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FIG.8

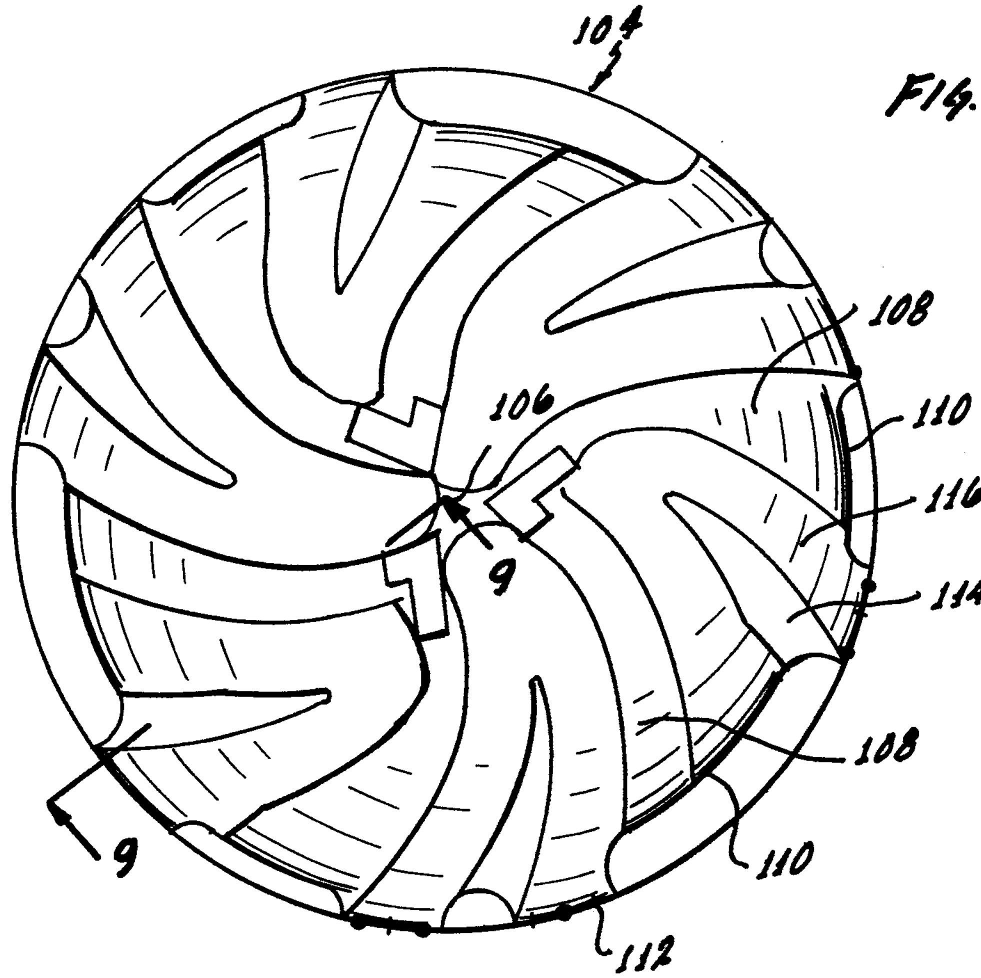
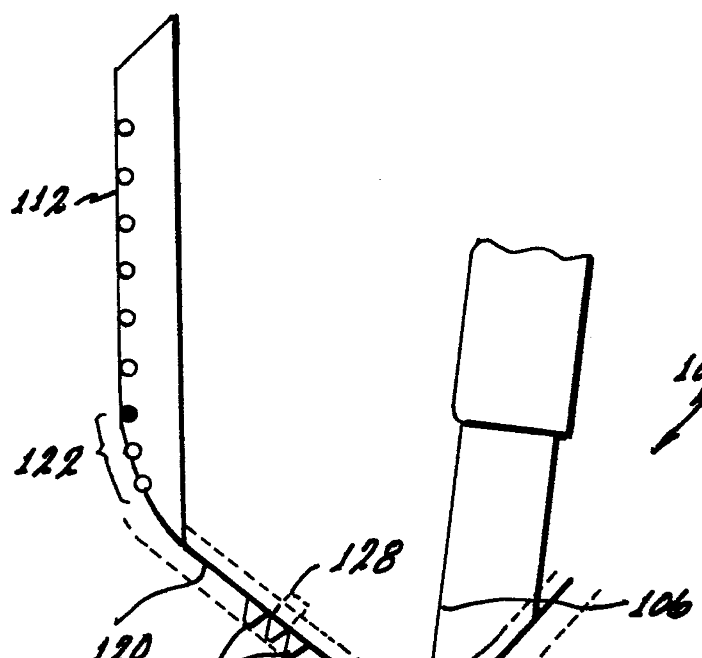


FIG.9



PATENTANWÄL
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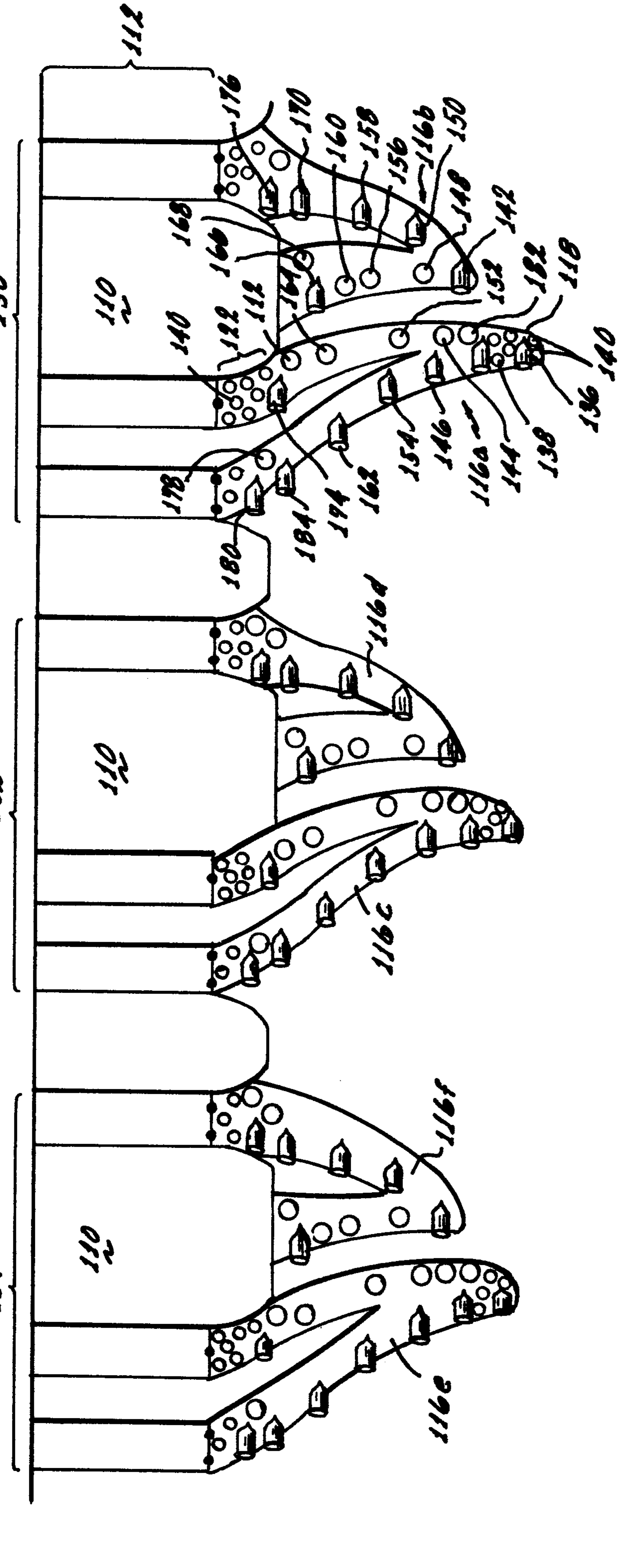
Dipl.-Ing. E. Bünemann
4500 Osnabrück · Großhandelsri

Fig. 10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European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 86 10 0988

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
			E 21 B 10/56
X	EP-A-0 127 077 (GRAPPENDORF) * Whole document * ---	1-20	
X	EP-A-0 121 802 (GRAPPENDORF) * Page 15, line 26 - page 17, line 18; figures 4,5 * ---	1-20	
X	EP-A-0 119 620 (MESKIN et al.) * Page 19, line 18 - page 20, line 10; figures 4,8 * ---	1-20	
X	EP-A-0 117 506 (MESKIN et al.) * Page 19, line 25 - page 21, line 3; figure 9 * ---	1-20	
A	GB-A-2 125 086 (CROW) * Figure 8 * ---	12	**TECHNICAL FIELDS SEARCHED (Int. Cl.4)**
P,X	WORLD OIL, vol. 200, no. 7, June 1985, pages 149-152,154, Houston, Texas, US; A. PARK: "Coring. Part 4-Bit considerations" * Figure 1, right-side * ---	1-20	E 21 B
A	FR-A-1 174 641 (AUDIBERT) ---		
A	DE-C- 377 460 (HUNDRIESER) -----		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	15-04-1986	BENZE W.E.

CATEGORY OF CITED DOCUMENTS

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