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(54) Rotary drag bits.

(57) A rotary drag bit (11) has cutters (19) rotatably mounted to fixtures (21) with journals. The cutters (19) are constantly forced to rotate or precess by the interaction between the earth formation and the cutter (19). The cutters (19) are fixed in skewed or offset positions on a cutting face (17) of a rotary drill bit head (11). These cutters (19) act as drag or shear cutters when they are operated in an earth formation.

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Description

ROTARY DRAG BITS

The present invention relates to rotary drag bits. More particularly, but not exclusively it relates to drag type rotary drill bits having cutters mounted to a cutting end of the drill bit, each of the cutters being rotatably secured to fixtures extending from the cutting end of the rotary drill bit.

There are a number of issued patents that relate to drag type rock bits as well as rock bits that are combination drag bits and rotary cone bits.

All the prior art drill bits have failed to provide a relatively inexpensive drag bit with long-lasting cutters that is not susceptible to early failure as the result of overheating or that prevent the balling of the cutters and the consequent reduction in the penetration rate.

It is an object of this invention to provide a practical and inexpensive means to prolong the life of synthetic diamond and other hard cutting faces by limiting the cutting time of each segment against a borehole bottom.

Another object of this invention is to provide a means to prevent "balling" of the bit (build-up of debris adjacent the cutting face of the cutting segment).

These and other objects of the invention are accomplished by skewing the face of a rotatable cutting disc insert at an offset angle to the radii from the axis of rotation of the rotary drill head. The cutting elements are rotatably mounted to a saddle, or insert base. Rotation of the bit will cause the cutting elements to slowly precess as they contact the borehole formation. This limits the exposure of the cutting discs, limiting the heat build-up that is particularly damaging.

To improve heat dissipation when using diamond cutting elements, a plurality of diamond inserts or natural diamond particles are embedded in the cutting face of a disc, the disc being rotatably secured within a saddle or support structure. As the bit body is rotated by the rotary table, downhole motor or any other prime mover connected to a drill string and drill bit, the cutter discs are caused to rotate due to the skewed angle of the saddle with respect to the radii from the axis of rotation of the drill string. Each of the multiplicity of cutter segments, equidistantly or randomly spaced as required around a disc, are exposed as the cutter disc slowly rotates.

Since fluid nozzles are fixed in the bit body, fluid is directed toward the borehole bottom and, as the cutters rotate, the fluid washes and cools the synthetic or natural diamond segments or particles adjacent the bottom of borehole.

In order to provide a rotating cutter element sturdy enough to withstand downhole conditions yet be capable of slowly precessing the cutter, a cutting disc is rotated on a journal that is supported by a pair of journal blocks. Such a structure provides for a larger diameter cutting disc causing slower rotation and consequent longer life. This arrangement also permits selectability of the role of the cutter disc to provide for compressive or shear cutting forces on the formation.

A rotary drag bit embodying the present invention will now be described, by way of example, with reference to the accompanying diagrammatic drawings, in which:

Figure 1 is a perspective of a rock bit having cutters structured to rotate;

Figure 2 is a perspective of the rear of one of the cutter elements from the rock bit of Figure 1;

Figure 3 is a cross-section along 3-3 of Figure 2;

Figure 4 is a top plan view of a cutter and its placement on the head of the rock bit;

Figure 5 is a perspective of a rock bit having a preferred embodiment of cutters structured according to the present invention;

Figure 6 is a cross-section of one of the cutter elements shown in Figure 5;

Figure 7 is a plan frontal view of an alternate embodiment of a cutting disc according to the present invention;

Figure 8 is a plan frontal view of an alternate cutting disc according to the present invention;

Figure 9 is a perspective of a rock bit showing an alternate preferred embodiment of cutter elements according to the present invention;

Figure 10 is a top view of the drag bit head showing placement of cutter elements according to the present invention;

Figure 11 is a side perspective of the drag bit and cutter elements shown in Figure 10;

Figure 12 is a side plan view of a cutter element that could be used in Figures 9, 10 and 11;

Figure 13 is an end view of the cutter element shown in Figure 12;

Figure 14 is a side plan view of an alternate preferred embodiment showing an alternate mounting for a disc cutter element according to the present invention;

Figure 15 is a perspective of a rock bit showing an alternate preferred embodiment of cutter elements according to the present invention;

Figure 16 is a side plan view of a cutter element used in the rock bit of Figure 15;

Figure 17 is an end view of the cutter element of Figure 16;

Figure 18 is a side plan view, partially broken away, of another embodiment of a cutter element;

Figure 19 is an end view of the cutter element of Figure 18; and

Figure 20 is a front view of the cutter element of Figure 18.

Referring first to Figure 1, a drag bit, generally designated as 11, is modified to accommodate the cutter elements of the present invention. Drag bit 11 consists essentially of body 15 having a cutter face end 17 and a pin end 13. The pin end 13 is the shank of the bit that connects to a drill string for rotation (not shown). Although Figure 1 illustrates cutter face end 17 in an upward direction from the pin end 13, it will be understood by all those skilled in the art that the face end, when in the hole will be in a downward direction from pin end 13. The reader should bear this in mind as he follows through the descriptive portion of this patent specification.

Mounted on the cutter face 17 of rock bit 15 is a plurality of cutter elements, generally designated as 19, which generally lie on radial lines extending from the center of the face 17 of the drag bit 15. Each of the cutter elements 19 are comprised of an insert base or saddle 21 and a cutter segment 22.

The insert base 21 is preferaby a tungsten carbide block having an aperture 24 therethrough (Figure 3). The base of the saddle 21 is preferably keyed with a slot 27 which fits into an aperture and mating key formed in the face 17 of the drill bit. The saddle 21 may be press- or interference-fitted into an aperture formed in the face or may be fastened by brazing or some other convenient fastening means.

The cutter segment 22 is rotatably mounted within the aperture 24 of the saddle 21. The structure of the cutter element 19 preferably comprises a support crank 25, which rotates within the journal aperture 24, bearing primarily against conical surface 24', formed on the end of the crank 25. The end of the crank 25 supports cutter element 22 mounted thereon. The crank 25 is contained within saddle block 21 by a keeper sleeve 23 tapered as shown in Figure 3. The keeper is, for example, brazed on to the shaft of crank 25 to maintain the crank and cutter in place within the saddle.

As shown in Figure 3, which is cross-section along 3-3 of Figure 2, the saddle 21 has an aperture 24 therethrough which is a journaled bearing for the crank 25. The aperture 24 is tapered at both ends (12 and 14) in a manner which provides for both a rotary bearing and a thrust bearing surface. Tapered end 14 may support, for example, a conically shaped bearing sleeve 30. The sleeve may be fabricated from, for example, aluminium bronze, copper alloys or a spinodal alloy, all of which are suitable bearing materials.

Moreover, all of the bearing surfaces 12, 14 and 24 may be lined with a sleeve of bearing material as set forth above (not shown).

In a preferred embodiment, the cutter element 22 consists of a wafer of synthetic diamonds such as described in US Patent No. 4,253,533, for example. As shown in Figure 3, the cutting wafer 22 is at a negative rake angle "A" which is the result of the face 28 of saddle 21 being slanted as shown. This negative rate angle creates a compressive cutting force against the bottom 16 of the borehole which tends to crush more than slide away the earth formation.

The saddle 21 of each of the cutter elements 19 is mounted on face 17 of bit 11 along a radial line 32 (Figure 4). The vertical centre 20 of cutting face 22 intersects the circumferential movement arc 31 and the perpendicular plane 29. However, the cutting face 22 does not lie on a plane that is parallel to the radius 32. It is, instead, skewed at an offset angle 33 from the radius 32. This skew angle preferably is at a significant angle. The amount of skew is chosen on the basis of the speed at which the cutting face is to rotate. The smaller the angle of skew, the slower the rotation of cutting element 22. Whether the cutting element 22 turns clockwise or counterclockwise is a matter of choice. The important limit is that it is skewed from the radius of plane 32, causing forces to be exerted on the cutting element 22 as a result of the rotation of the drill face 17 which rotates the crank or body 25 of the cutter to rotate within the journal 24 in the saddle 21 (Figure 3).

As a result of this rotation, a continually new diametrical portion of cutting element 22 is exposed to the earth formation being scraped away thereby helping to keep the cutting element 22, which is preferably synthetic diamond, cool and relatively clear of debris. Keeping this cutting element 22 cool prolongs the life of the cutting wafer a substantial amount, thereby creating a more effective drag bit with a considerably extended life span. As is well known, diamond subjected to extended periods of high heat concentration will cause the diamond to disintegrate thus continual movement minimizes heat concentration on the cutting edge of element 22.

Referring now to Figure 5 which illustrates a preferred embodiment for the cutter elements according to the present invention, a drag bit 35 is shown having a bit face 39 at the end opposite threaded pin end 37. The cutting elements, generally designated as 41, are as effective as the cutting elements 19 shown in Figure 1. They have cutting face 43 at one end of the journal, a saddle 42 and a keeper 45 at the other end of the journal. Each of the elements are mounted along a radial line which extends from the centre of the face 39 of the drag bit 35 (not shown). The face 43 is not covered with a cutting material. Only the circumference of the face 43 has a cutting material 51 equidistantly spaced and inserted therein (Figure 6).

As can be seen in Figure 6, a saddle 42 has a slanting face 47 with a journal 24 therethrough which is slanted (44 and 46) at the face and backsides to provide both thrust and rotary bearing surfaces. The crank 49 is constructed differently than the crank 25 of Figure 3 in that it is composed of a series of parts. The first part is a shaft 50 which provides a rotary bearing surface 26, preferably of tungsten carbide material which is cast at an end 48 of shaft 50 into cutting face 43, also preferably of tungsten carbide material. The face 43 has attached around its perimeter a plurality of equidistantly spaced cutter segments 51 of polycrystalline diamond cutting elements, for example, which are fastened directly into the matrix of the cutting end 43. The other end of the shaft 50 has brazed thereon a shaft keeper element 45. The cutting element, as shown in Figure 6, provides for compressive cutting forces primarily due to the negative rake angle as shown with respect to Figure 3.

Referring now to Figures 7 and 8, alternate configurations for the cutting face 43 are illustrated. Primarily what is shown is that the particular structure for the individual cutting segments 51, mounted along the circumference of the cutting face 43, need not be cylindrical. Figure 7 shows cylindrical inserts 51. Figure 8 shows triangular prisms 52 inserted into the circumference of the cutting face 43. Other shapes could also be used as desired. In addition, for example, these cutting segments are spaced so that the entire circumference of the cutting face is covered by the cutting segment material.

Referring now to Figures 9, 10 and 11, other alternate preferred embodiments of the cutters built according to the present invention for use in a drag bit 57 are illustrated. Drag bit 57 has a face 61 opposite to pin end 59. Mounted on face 61 is a plurality of cutter elements 67 mounted for rotation about a shaft rotatively secured to journal blocks 63 and 65. The cutting face 73 of the cutter 67 is oriented relative to a radius extending from the centre of the face 61 of the drag bit 57, as more clearly shown in Figure 10. The desired skew angle of cutting face 73 on each of the cutters 67 is skewed in the same manner as the cutting face 22 of cutting element 19 (Figure 4). Figure 10 also illustrates fluid nozzles 77 located in the face 61 of drill bit 57 which causes drilling fluid to be washed across the cutting elements 73 to cool and clean them as they precess during operation of the bit in a borehole.

Referring now to Figures 12 and 13, an alternate structure for cutting elements 67 is illustrated. Figure 12 illustrates the cutting face 73 of the cutter 67 which has a plurality of circular shaped cylinders 75 embedded around its perimeter in the manner shown. End 74 of cylinders 75 serves as the cutting face for cutter 67. The cutter 67 is mounted to a pair of bearing blocks 69 and 71 which provide both a thrust and a rotary bearing surface (not shown). The cutter 67 rotates around the shaft which is held by bearing blocks 69 and 72. The shaft may either be journalled into bearing block 69 and 71 or may be fixedly attached into bearing block 69 and 71 with the cutter elements 67 rotating around the fixed shaft. The latter arrangement is preferred.

The cutter 67 comes to an apex 78 which is on the plane passing through the geometric centre of the cutter 67. The sloped surfaces 73 and 74 are part of a truncated conical section that slopes away from the apex 78. One end 74 of the cylinder cutting members 75 are mounted into and exposed at the cuting face side 73 while a small portion of the side of the cylinders 75 are exposed at the opposite side 79. Rotation of the cutter 67 causes different cutting cylinders 75 to come into contact with the formation being gouged away as the drill bit head rotates.

The cutter 67 is preferably of tungsten carbide. The cylindrical shaped cutter elements 75 are preferably of synthetic diamond which are held fast in the matrix of the tungsten carbide cutter structure 67. The mounting or bearing block 69, 71 are also preferably of tungsten carbide or similar high strength material held fast to the face 61 of drill bit 57, either by press-fit or some other well known technique, such as brazing for example.

Refer now to Figure 14. Another altnernate preferred embodiment of a cutter element according to the present invention is illustrated. This embodiment is constructed to provide a positive rake angle "B" thereby providing true shear forces for slicing away the earth formation 88. A pair of bearing blocks 85 and 83 are utilized and are fastened to the bit face 90. Mounted for rotation with these bearing blocks is a truncated cone shaped cutter 92 having a cutting face 94 which is the base of the cone. The sides of the cone 91 are sloped at an angle 93 that is less than ninety degrees. The axis of rotation 89 of the cone cutter 92 is at an angle to the face 90 of the drill bit, creating a positive rake angle "B" with respect to the earth formation 88. The cone cutter 92 rotates about the axis of rotation as explained above. The journal blocks 85 and 83 are shaped to provide for both thrust and rotary bearing surfaces. The cone cutter 92 is preferably constructed of a hard material such as tungsten carbide. In the alternative, cutter elements may be located along its circumference in the manner illustrated for the embodiments of Figures 7-13.

Referring now to Figures 15, 16 and 17, an alternate preferred embodiment of a drag bit with cutter elements according to the present invention is illustrated. Drag bit 103 has a face 101 opposite pin end 105. Mounted on the face 101 is a plurality of disc-shaped cutters, generally designated as 107, each mounted to a pair of journal blocks 109 and 111. The orientation of the cutting faces 112 of cutter elements 113 of cutters 107 is the same as the orientation of the cutters shown in Figures 9, 10 and 11.

The cutter elements 113 mounted in the cylindrical cutter 115 is an arcuate segment that is, for example, three-quarters of an inch between radial sides 117 and 119. The inlaid segments 113 are approximately five-eights of an inch thick. The diameter of the cylinder 115 for this size of cutting segment is preferably four inches. The material variations of the cutter elements 113, the cylindrical cutter 115 and the mounting blocks 109 and 111 are explained above. The cutting face 113 of the disc-shaped cutter 107 is preferably mounted at a negative rake angle "C" of up to forty-five degrees from the perpendicular to the face 101 of the drag bit in certain situations.

Referring now to Figures 18, 19 and 20, which illustrate another embodiment for the cutter elements according to the present invention. The cutting elements, generally designated as 241, are effective in particularly hard formations. This particular embodiment has a toroidally shaped cutting face 243 at one end of the journal generally designated as 249. A saddle 242 is provided for journal 249 which provides a bearing surface 240 thereby. A journal keeper 245 is provided at end 250 of journal 249. At the opposite end of journal 249 is cutter end 243, the peripheral edge of which is rounded or toroidally shaped at periphery 252. The back side 260 of cutter end 243 is conically shaped and provides a bearing surface which mates against a complementary mating surface 244 in saddle 242. Bearing sleeves may be provided as set forth relative to Figure 3. The conical surfaces 260 and 244 serve to take the brunt of the thrust from the rotating cutter head 243 during operation of the cutter in a borehole. Similar conically shaped bearing surface 246 formed in saddle 242 is provided having complementary surfaces on the keeper 245 which retains the rotating cutter within the saddle 242. The rounded toroid surface 252 of cutter end 248 of the shaft 249 is covered with embedded natural or synthetic diamonds 251, the diamonds being mechanically fixed within a matrix of, for example, tungsten carbide applied to the end 248 of the shaft 249. This process is well known within the art. The multiplicity of natural or synthetic diamonds 251 covering the rounded peripheral edge 252 are particularly effective in hard formations as previously indicated. The cutter elements 241 are skewed from the radius of a plane as previously described which causes rotational forces to be exerted on the cutter elements 243.

As stated before, a continually new diametrical portion of the cutter element 241 is exposed to the earth formation being abraded away thereby helping to keep the cutter elements 241 cool and clear of debris. The multiplicity of natural or synthetic diamond chips 251 are vulnerable to heat as are the foregoing cutter elements, hence continual rotation of the cutter head 243 within its saddle block 242 is important to maintain the integrity of the diamonds on cutter end 243.

Figure 19 illustrates the rear side of the cutter elements 241 showing the multiplicity of natural or synthetic diamonds 251 completely covering the rounded toroid surface 252 of end 243.

Figure 20 illustrates a front face view of the cutter element 241 showing the outer toroidally shaped surface 252 covered with natural diamonds 251. The centre portion of the cutter end 243 is free of diamond cutter segments since it does not significantly contact any of the formation.

The end 240 of saddle 242 is preferably interference-fitted within a hold formed in the face of a drag bit as previously described (not shown).

Claims

1. A rotary drag bit for drilling wells comprising a bit body rotatable about a central axis and including means for connecting the bit body to a drill string, said bit body having a face opposite to the drill string connection, and a plurality of drag cutters mounted on said face along respective radial lines emanating from said central axis and at different respective distances from the central axis for collectively scraping the formation across substantially the entire bottom of a borehole being drilled, each drag cutter comprising: a mounting block with bearing means at the end remote from the face of the bit body, and a cutter element with journal means mounted for rotation relative to said bearing means, said cutter element having a plurality of cutting segments embedded in a circumferential cutting face, the cutting face being skewed at an angle from a radial line from the central axis to the cutter element so that the cutter element precesses as the cutting face contacts the borehole formation.

2. A rotary drag bit according to Claim 1 wherein the mounting block comprises a saddle supporting both ends of a shaft and wherein the cutting element is mounted on the shaft between the ends supported by the saddle.

3. A rotary drag bit according to Claim 2 wherein the shaft extends parallel to the face of the bit body.

4. A rotary drag bit according to any preceding claim wherein the bearing means comprises an aperture in the mounting block and wherein the journal means comprises a shaft extending through the aperture, with the cutting face being at one end of the shaft.

5. A rotary drag bit according to any preceding claim wherein the cutting face is skewed so that the side nearest the central axis of rotation extends further forward than the side remote from the central axis.

6. A rotary drag bit according to any preceding claim wherein the axis of said bearing means is at an acute angle to the face of the bit body.

7. A rotary drag bit according to any preceding claim wherein the cutting face is toroidally shaped.

8. A rotary drag bit according to Claim 7 wherein the cutting face has a multiplicity of diamond particles embedded in at least the toroidal surface.

9. A rotary drag bit according to any preceding claim, wherein each mounting block comprises a tungsten carbide body inserted in the face of the bit body.

10. A rotary drag bit according to any preceding claim, wherein the cutter element comprises a generally disc-shaped tungsten carbide cutter having diamond cutters on its perimeter.

11. A rotary drag bit according to any preceding claim wherein the cutting segments comprise a multiplicity of diamond particles embedded in a tungsten carbide matrix.

12. A rotary drag bit according to any preceding claim wherein the cutting segments comprise generally cylindrical segments having at least a face of diamond.

13. A rotary drag bit according to any preceding claim wherein the cutting segments are generally triangular shaped prisms with at least one exposed end being diamond.

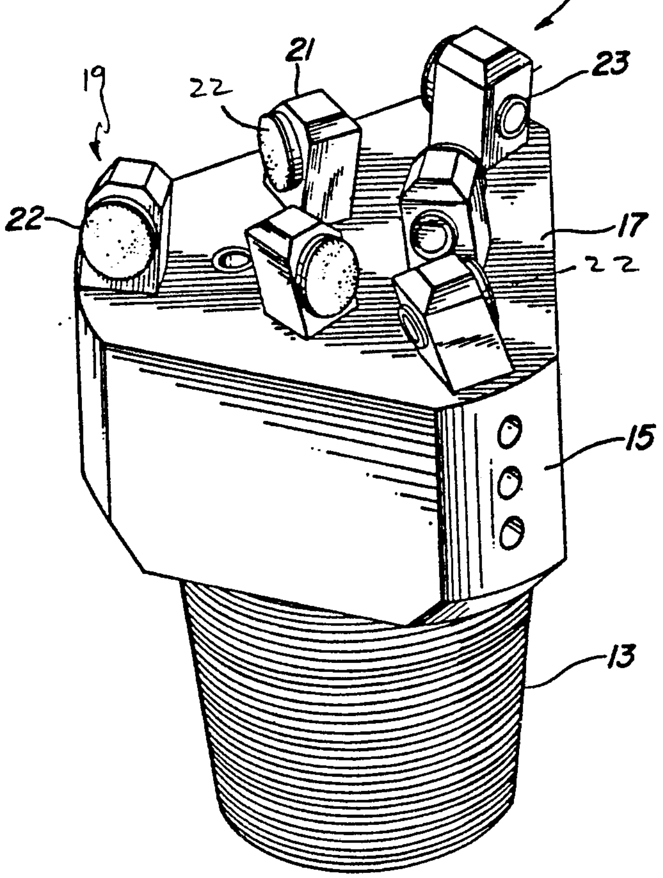


FIG. 1

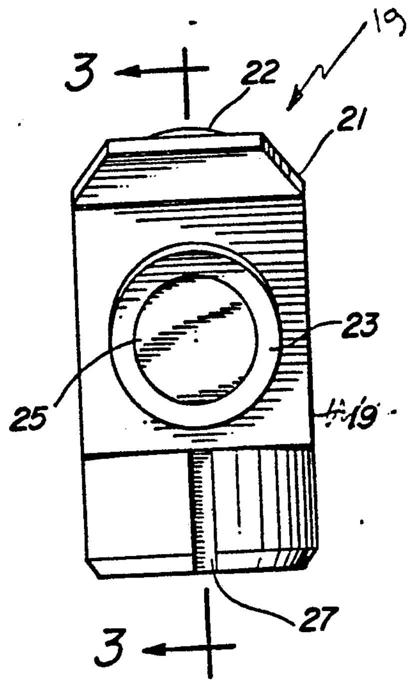


FIG. 2

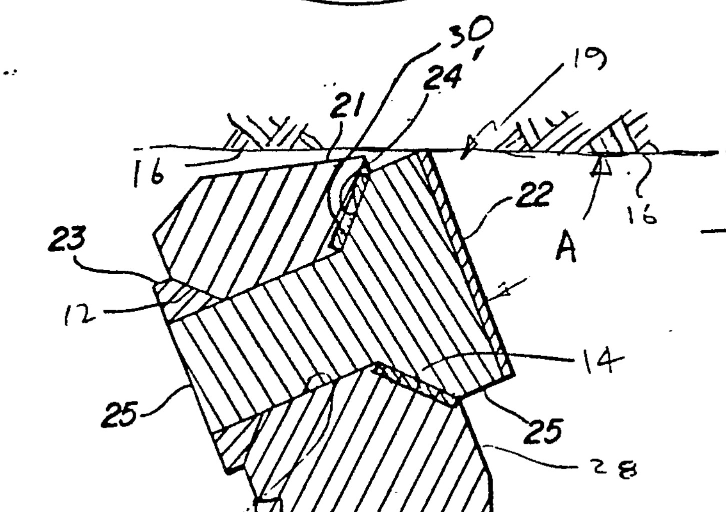


FIG. 3

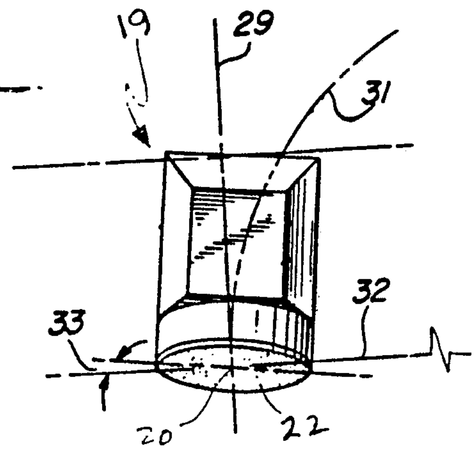
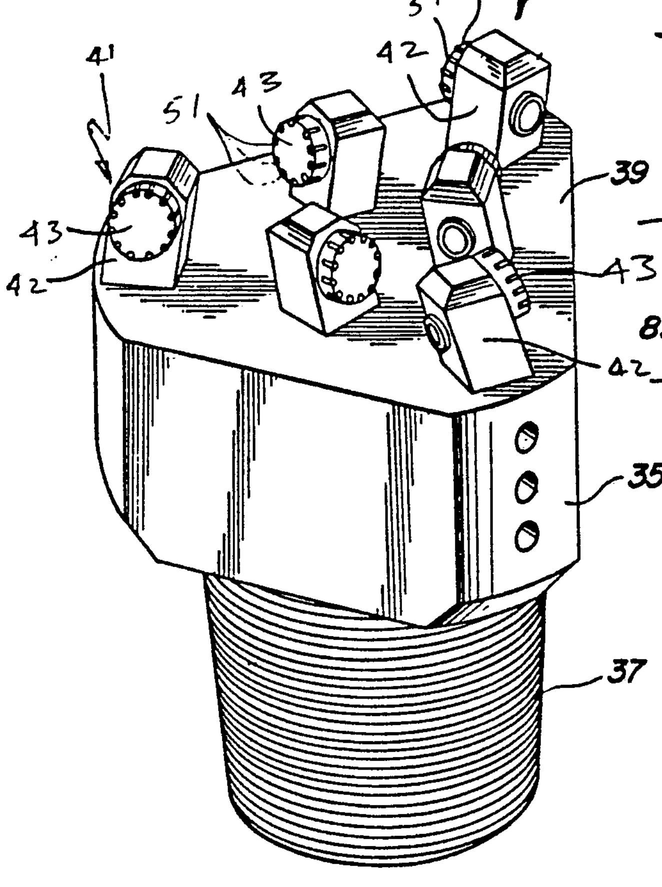


FIG. 4

FIG. 5



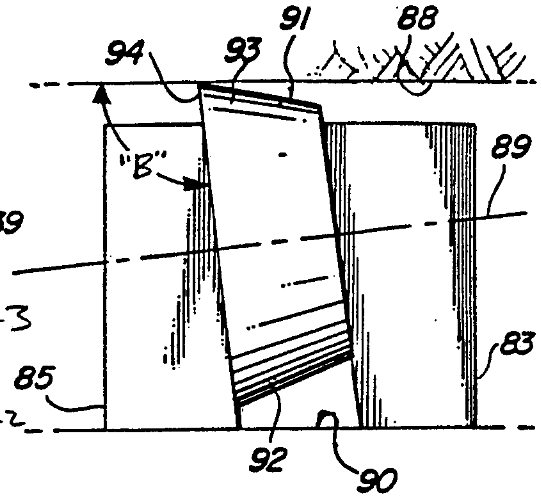


FIG. 14

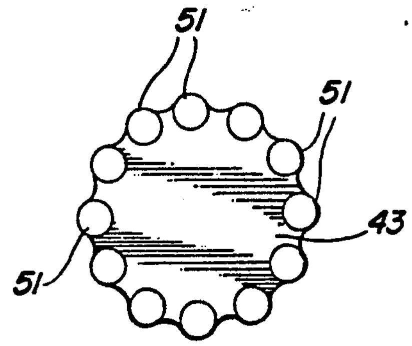
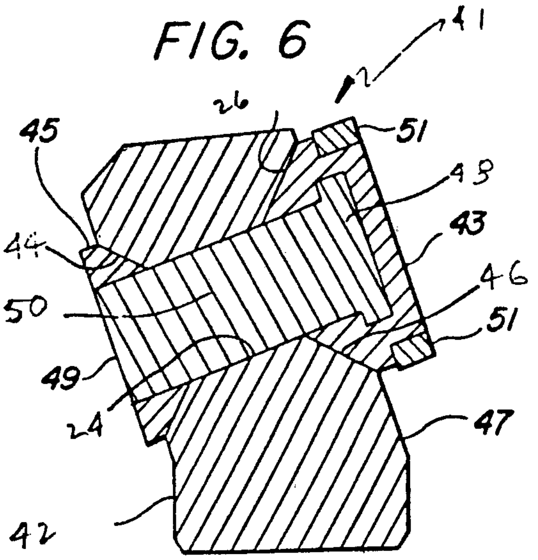


FIG. 7

FIG. 6



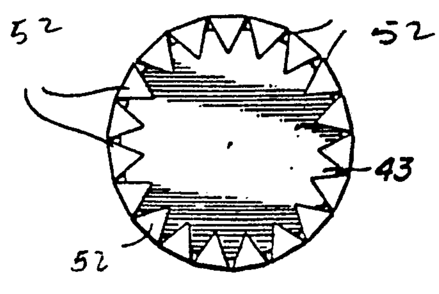


FIG. 8

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FIG. 9

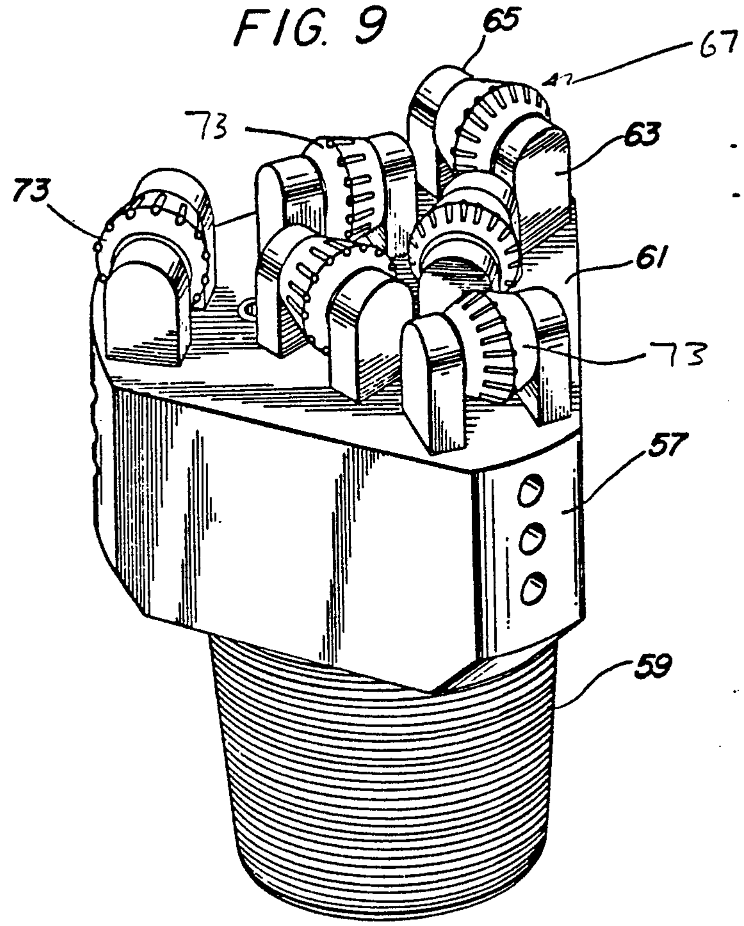


FIG. 10

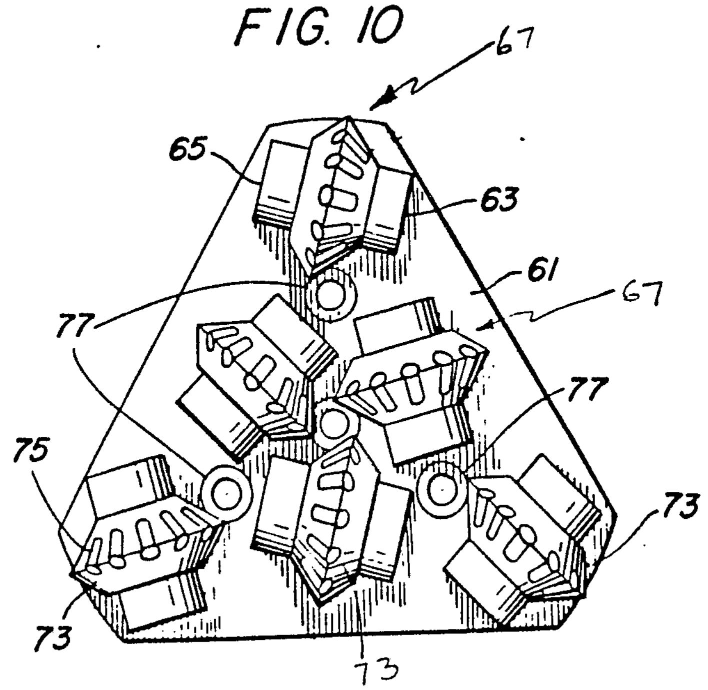


FIG. 11

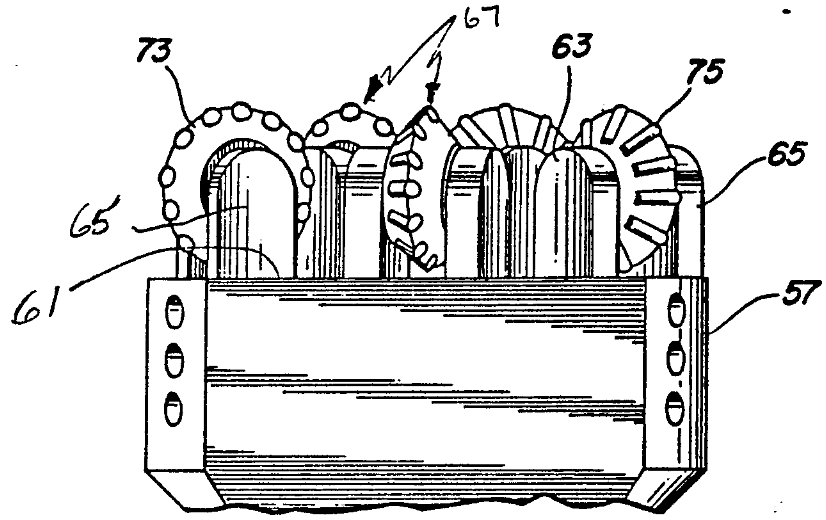


FIG. 12

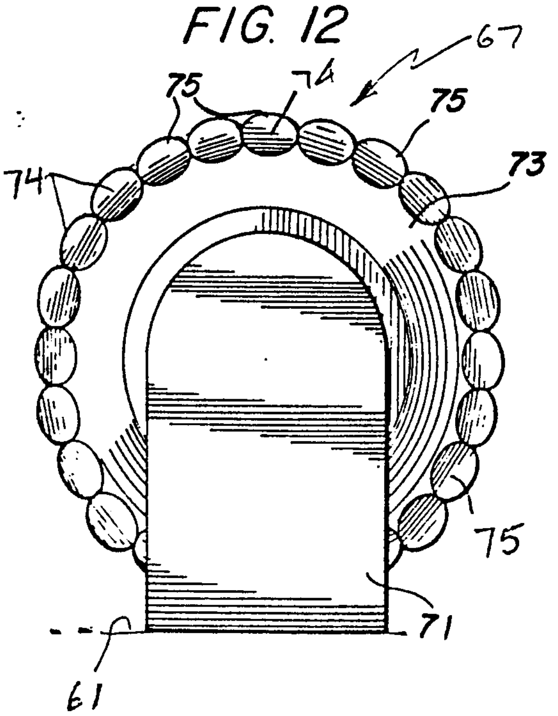
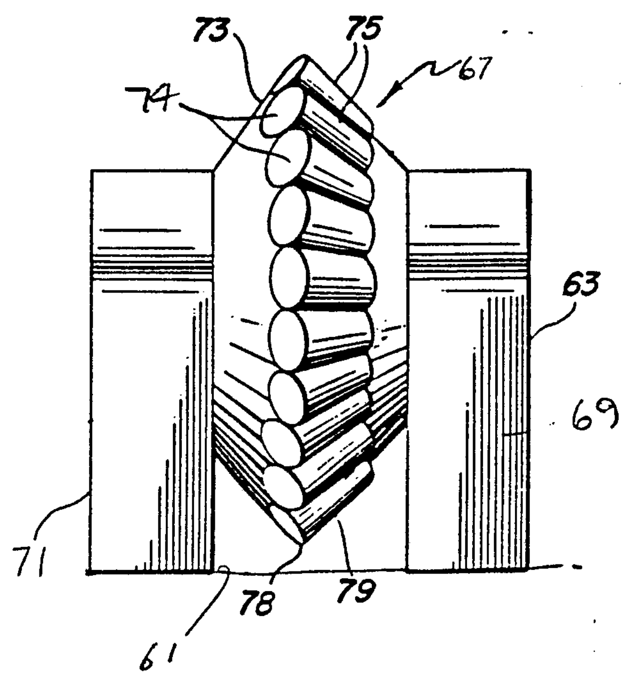


FIG. 13



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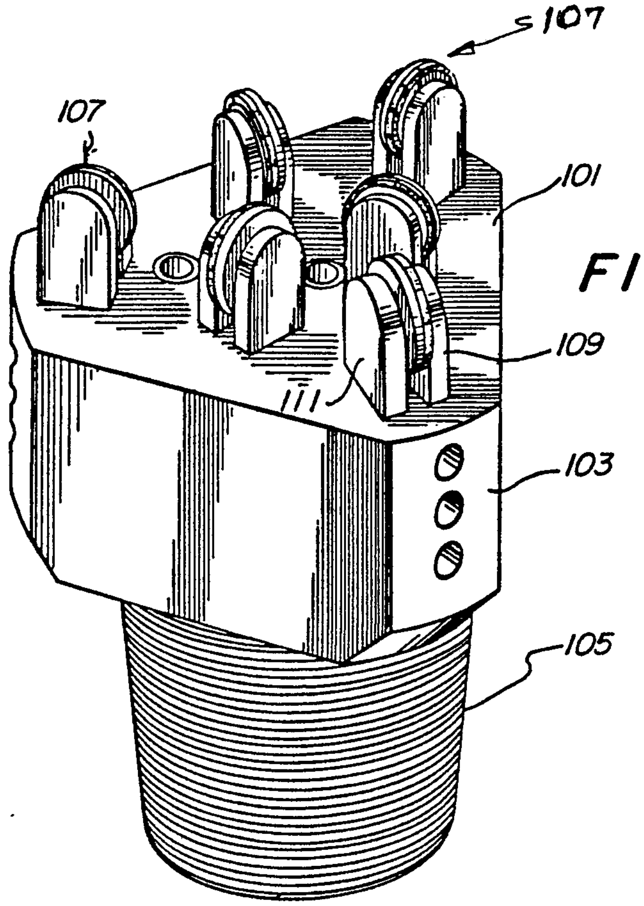

FIG. 15

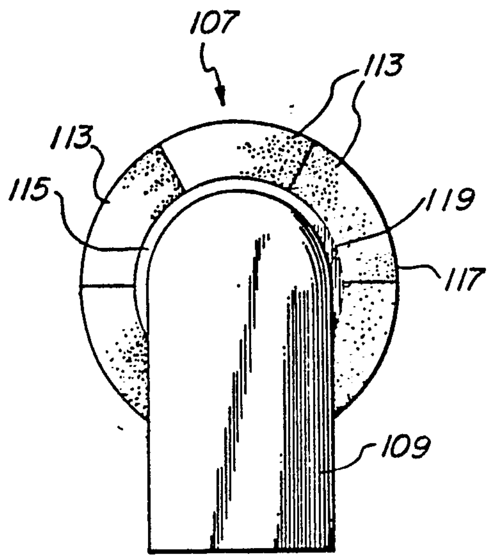

FIG. 16

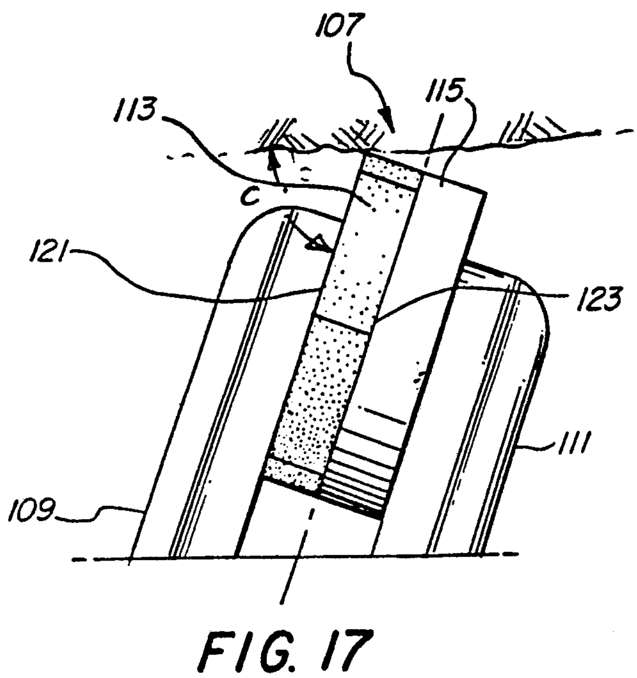

FIG. 17

FIG. 18

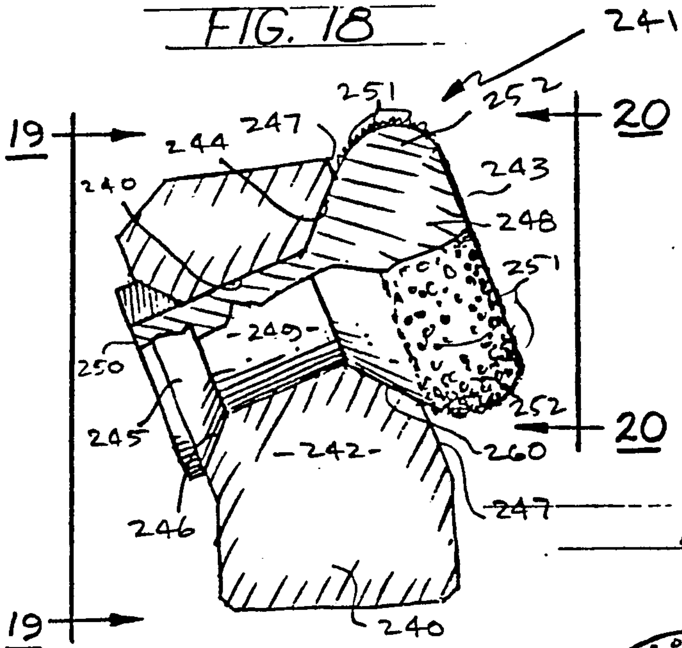

FIG. 19

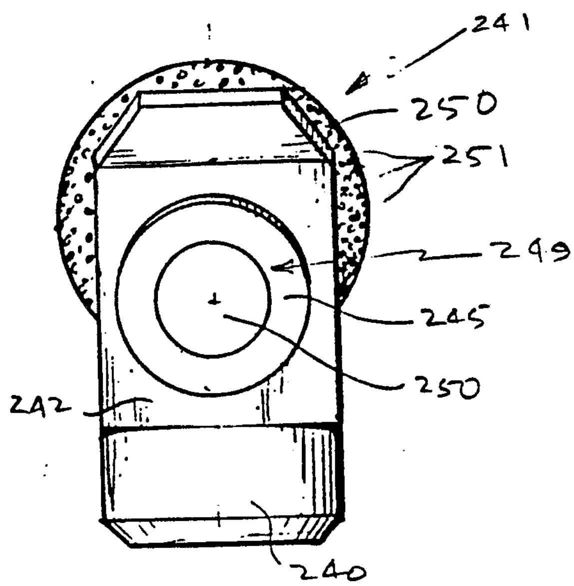

FIG. 20