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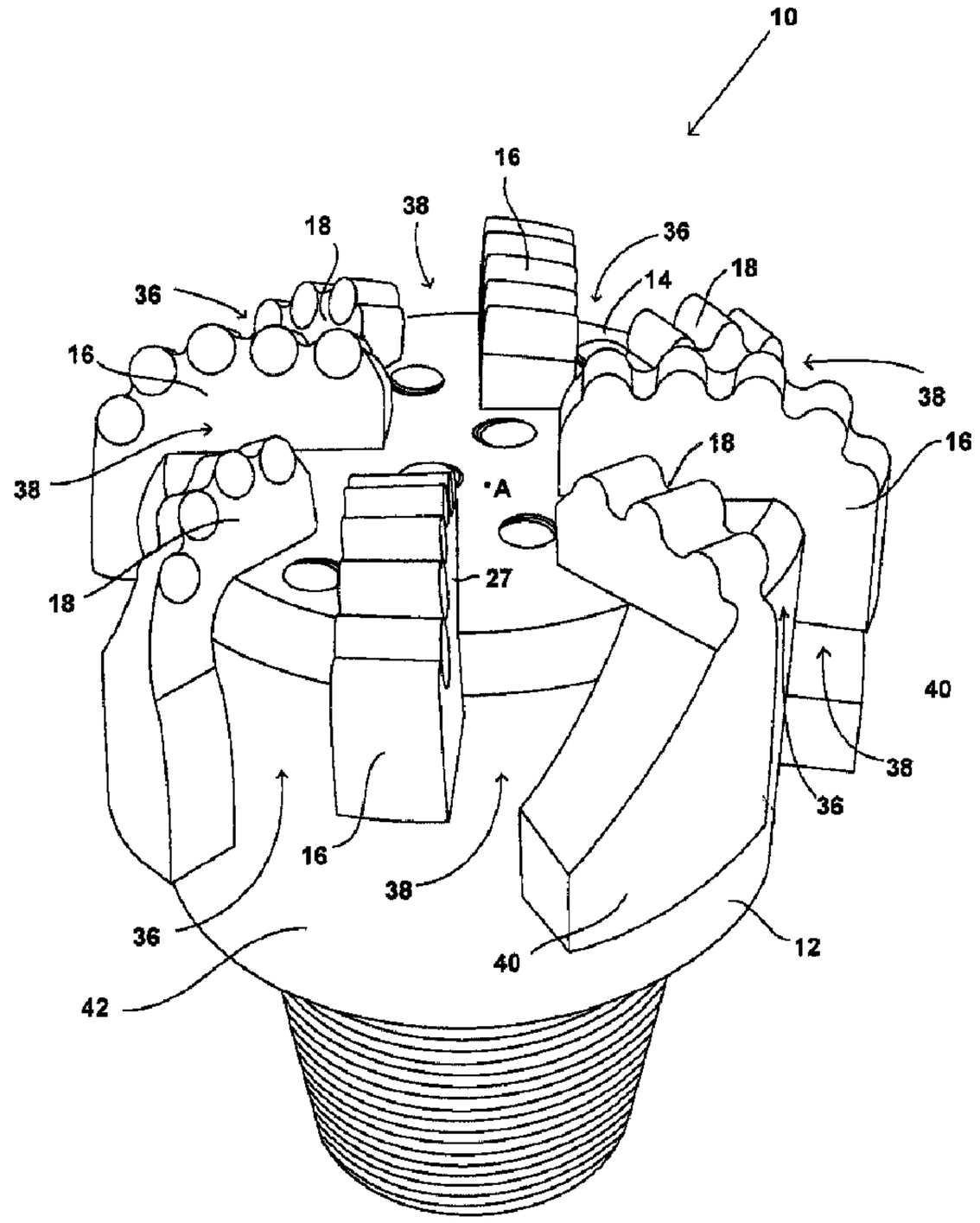
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(54) Titre : TREPAN
(54) Title: DRILL BIT



(57) Abrégé/Abstract:
A drill bit is made from a shank, lid and blades. Junk slots with higher resistance to flow are provided to force drilling fluid between cutters on adjacent blades to improve cleaning. Blades are canted back, and openings at a high angle are provided to further enhance cleaning. The use of a lid facilitates high angle openings.

ABSTRACT OF THE DISCLOSURE

A drill bit is made from a shank, lid and blades. Junk slots with higher resistance to flow are provided to force drilling fluid between cutters on adjacent blades to improve cleaning. Blades are canted back, and openings at a high angle are provided to further enhance cleaning. The use of a lid facilitates high angle openings.

DRILL BIT

BACKGROUND OF THE INVENTION

01 A challenge in underground drilling is to provide a drill bit with extended life, that cuts quickly through earth formations of various types and that avoids balling up of cuttings in the vicinity of the drill bit. The balling up of cuttings in the vicinity of the drill bit may cause the drill bit to cease cutting as the cutting elements no longer contact the earth formation.

02 Modern drilling bits typically are formed of a body, blades extending from the body, mostly forwardly but also extending somewhat radially outward of the body, and polycrystalline diamond cutters (PDCs) embedded in the cutting faces of the blades. Two main types of PDC drill bits on the market are the matrix body and steel body. Matrix body bits are one piece construction and are made in a mould as for example disclosed in United States patent #6,823,952. The material is a mixture of steel and tungsten carbide. Steel body bits are also one piece construction but are cut on a lathe and made from 4140 steel, 4145 steel or a similar material. The blades on PDC bits are typically set in a vertical plane, or may be canted forward slightly towards the cutting surface. Some bits have forward sweeping cutting elements, as for example disclosed in United States patent no. 5,443,565. The PDC cutting elements provide hard wearing surfaces that cut the formation. Junk slots between the blades provide pathways for the removal of cuttings away from the bit face into the annular space of the wellbore. Most PDC bits make the junk slot area as wide and as obstruction free as possible for the pathway to remove cuttings. To further assist in removal of cuttings, drill bits are provided with openings or nozzles in the forward end of the drill bit that direct fluid jets between the blade surfaces. The drilling fluid, which is also typically used in a mud motor to power the drill bit, passes through the inside of the drill bit, through the nozzles and the junk slots, and draws cuttings away from the drill bit towards the surface.

03 In a further problem with PDC type drill bits, cutter surfaces often fail as a result of high temperatures created from friction between the cutter and the rock it is cutting. When a PDC cutter reaches a critical temperature known as the thermal degradation temperature, the diamond surface will separate from the tungsten carbide substrate. The thermal degradation temperature ranges from 300^0C to 700^0C. Heat is removed from the bit face and the cutters by

the drilling fluid as it removes the cuttings from the surface of the drill bit. Heat is also transferred through the tungsten carbide cutter into the blade and bit body. Tungsten carbide is a much better conductor of heat than steel. Therefore the transfer of heat away from the cutters into the blades and bit body is not very efficient.

SUMMARY OF THE INVENTION

04 According to an aspect of this invention, there is provided a drill bit, and a method of manufacturing a drill bit, that uses the design of junk slots between the blades of the drill bit to enhance removal of cuttings from the drill bit. In a method of construction of a drill bit, according to an aspect of the invention, a drill bit is made of a shank, lid welded to the shank and blades welded in slots in the lid.

05 According to further aspects of the invention, junk slot impingement is used to increase cuttings removal through alternating junk slots. Provision of high angle nozzles in the forward end of the drill bit, which is facilitated by the method of construction, also assists in cuttings removal. According to a further aspect of the invention, a drill bit with PDC cutters is provided with a cooling feature to remove heat from the PDC cutters more efficiently. A high conductivity conduit leading from the cutters guides heat away from the cutters into the blade and hence into the bit body.

06 These and other aspects of the invention are set out in the claims, which are incorporated here by reference.

BRIEF DESCRIPTION OF THE FIGURES

07 Preferred embodiments of the invention will now be described with reference to the figures, in which like reference characters denote like elements, by way of example, and in which:

Fig. 1 is perspective view of a drill bit according to the invention;

Fig. 2 is a view of a shank for use with the drill bit of Fig. 1;

Fig. 3 is a perspective view of a cutting end of a lid for use with the drill bit of Fig. 1;

Fig. 4 is a perspective view of the opposed end to the cutting end of the lid of Fig. 3;

Figs. 5A-5D illustrate method of making a blade for use with the drill bit of Fig. 1;

Fig. 6 shows a method of assembling blades into the drill bit of Fig. 1;

Fig. 7 is a cross-section through a blade showing a cooling feature according to an aspect of the invention;

Fig. 8 is a cross-section through the bit showing a nozzle aspect of the invention;

Fig. 9 illustrates offset cutters on succeeding blades; and

Fig. 10 is a section through a blade and cutter showing a soft metal insert behind the cutter.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

08 In the claims, the word "comprising" is used in its inclusive sense and does not exclude other elements being present. The indefinite article "a" before a claim feature does not exclude more than one of the feature being present.

09 Referring to Fig. 1, there is shown a drill bit 10 formed of a threaded shank 12, lid 14 and blades 16, 18 extending out from the cutting end of the drill bit 10. The shank 12 is threaded in conventional fashion for threading onto a downhole end of a drill string. There should be at least four and preferably eight blades 16, 18. The blades 16, 18 alternate between primary blades 16 and secondary blades 18. The drill bit 10 is intended to be rotated counterclockwise in use when taking a view of the cutting, bladed, end or face of the drill bit, which would be clockwise looking in the downhole direction in use. The operational direction of rotation defines a forward and rearward direction. The blades 16, 18 are preferably canted rearward at an angle of about 5° to 10° to the vertical (the central axis A of the drill bit 10 is vertical in a desired operating position). The shank 12, lid 14 and blades 16, 18 are manufactured separately from steel using a machine lathe type of construction and then welded into one unit, for example using electric arc welding. Not seen in Fig. 1, but shown in Fig. 2, is a cylindrical central passage 20 in the shank 12 that widens towards the lid 14 and supplies drilling fluid to the cutting end of the drill bit 10. The shank 12 is made from circular steel bar stock on a machine lathe. The passage 20 is drilled through the shank 12. The shank 12 is a cylindrical body having a central axis indicated by the arrow A about which the drill bit 10 rotates.

10 Referring to Figs. 3 and 4, the lid 14 is shown separately from the shank 12 and blades 16, 18. The lid 14 has openings 22 passing from the shank end 14A to the cutting end 14B of the lid 14. Nozzles 24 are inserted in the openings 22. The nozzles 24 are hardened tubes, made for example of tungsten carbide, that protect the steel of the lid 14 from excessive wear from drilling fluid. Typically, there are as many openings 22 as there are blades 16, 18 and the exit of each opening in the cutting end 14B is located at an inward end of a corresponding blade 16, 18, adjacent the forward face of the blade 16, 18. The openings 22 are oriented at an angle to the central axis A preferably greater than 15°, and for openings closer to the central axis of the drill bit, greater than 30°, and directed so that fluid exiting the nozzles 24 flows between adjacent blades 16, 18. The greater the angle of an opening 22, the more the fluid is directed between the corresponding blades. The nearer the opening 22 is to the central axis A of the drill bit, the greater the angle of the opening to the central axis. The openings 22 may be drilled through the lid 14 after it has been machined into the general shape shown in Figs. 3 and 4. Use of a lid 14 facilitates a high angle of the nozzles 24 as opposed to a one piece design, which makes high angle nozzles difficult to achieve. The nozzles 24 provide a flow path for drilling fluid pumped through the central passage 20 of the shank 12. The nozzles 24 may be provided for example in different sizes, such as 10 mm for the primary blades 16 and 7.5 mm for the secondary blades 18.

11 As shown in Figs. 1, 3 and 6, rectangular slots 26, 28 are provided in the cutting end 14B of the lid 14 for the blades 16, 18. The blades 16, 18 are secured in the slots for example by welding. The blades 16, 18 and the corresponding slots 26, 28 may have a front edge 27 that is parallel to but offset rearward from a radius extending outward from the central axis A. The amount of offset may be in the order of 2-4 mm. The blades 16, 18 may be provided with laminated steel backings welded to the lid 14 to strengthen the blades 16, 18 and dampen vibrations of the blades 16, 18. The underside 30 of the lid 14 (Fig. 4) in the area around the nozzles 24 is coated with a tungsten carbide material to protect the area from erosion as the drilling fluid is pumped through the nozzles 24. The lid 14 is also made from circular steel bar stock on a machine lathe. The under side of the lid 14 is milled to a diameter suitable for the intended use and the openings 22 are drilled through the lid for the nozzle inserts 24.

12 Referring to Figs. 5A-5D, a blade 16 (or 18) is made from steel flat bar stock of a suitable width, thickness and length for the intended application. Multiple holes 32, depending on the required number of cutters, are drilled in the blade 16, and the blade 16 is then cut along the line B in Fig. 5C to yield cutter holes. Polycrystalline diamond cutters 34 are inserted in the holes 32 and soldered in place. The blade 16 is coated with a tungsten carbide hard metal to protect the blade from erosion. The cutters 34 are shown in Figs. 1, 5A-5C and 6 as fully penetrating the blades, but in practice there will be a small amount of steel left behind the cutters 34, as shown in Fig. 5D.

13 Referring again to Fig. 1, junk slots 36, 38 are formed by each pair of adjacent blades. Each blade 16, 18 separates adjacent junk slots 36, 38. The junk slots alternate in pairs 36, 38 around the cutting end 14B. Each pair of junk slots 36, 38 includes an impeded junk slot 38 with a higher resistance to fluid flow and an unimpeded junk slot 36 with a lower resistance to fluid flow, with an intervening blade 16 between the pair of junk slots 36, 38. In operation, the junk slot 38 of each pair of junk slots with higher resistance to fluid flow forces drilling fluid from the junk slot 38 with higher resistance into the junk slot 36 with lower resistance. Drilling fluid exiting the nozzles 24 is forced by the resistance of the junk slots 38 across the intervening blade 16 and between the cutters 34 of the intervening blade 16. The drilling fluid passes across the intervening blade through openings created by previous cutters, which may be ensured by radially offsetting and overlapping the cutters 34 on succeeding blades. The amount of offset and overlap may be varied. Increasing overlap creates a more aggressive cutting action, at the expense of decreasing the size of the flow path between the cutters. Thus, for cutters of radius R, the cutters on one blade may be spaced by R/2 and the centers of cutters on succeeding blades offset by 3R/4. When the blades 16, 18 alternate between primary blades 16 and secondary blades 18, the primary blades 16 are the intervening blades.

14 The higher resistance of the junk slots 38 may be caused by a variety of means. For example, the resistance may be caused by a restriction in the junk slot 38, such as an enlargement or extension 40 of a secondary blade 18 rearward. The extension 40 may sweep circumferentially under the intervening or primary blade 16 as shown in Fig. 1. The extension 40 may be machined from a steel flat bar stock and welded to the outer periphery of the shank

12 and lid 14. The extension 40 is shaped to be continuous with the blade 18. The radially outward surface of the extensions 40 may be fluted in conventional fashion for a stabilizer.

15 As seen in Fig. 1, the blades 16, 18 extend axially forward of the cutting end 14B to engage an earth formation during drilling. The blades 16, 18 also extend radially outward from the cutting end 14B and extend axially rearward along the outer periphery 42 of the drill bit body to form stabilizers. The blades 16, 18 include blades that extend axially rearward for different distances, and in the preferred embodiment alternate between longer blades 18 and shorter blades 16. As seen in Fig. 3, the blades 16, 18 and the corresponding slots 26, 28 are also oriented on the cutting end 14B of the drill bit body such that a linear extension of the blade passes behind the central axis in the direction of rotation in operation. The linear extension may be part of the blade itself or an extrapolation of a blade that terminates inwardly of the central axis. Such off-center orientation of the blades, where the blades do not all point towards the same center, assists in stabilizing the drill bit.

16 As the cutters 34 rotate around the central axis A, and cut into an earth formation, they leave gouges in the formation. Cutters 34 on succeeding blades deepen the gouge. It is conventional for cutters 34 on succeeding blades to overlap, and typically the gouges created by cutters of succeeding blades lie midway between the gouges of the preceding blades. In a preferred embodiment shown in Fig. 9, the cutters 34 in succeeding blades preferably differentially overlap cutters in preceding blades in the direction of rotation such that a cutter on a succeeding blade overlaps more of one, outer, cutter, on a preceding blade than it overlaps an adjacent, inner, cutter on a preceding cutter. The overlap of the outer cutter should be more than 25% but less than 100%, for example 60-75% of the outer cutter. In Fig. 9, cutters 34A are in a leading or preceding blade in the direction of rotation. Cutters 34B are in the following or succeeding blade. The cross-hatched areas 37 indicates the areas being cut by the following blades. The hatched area 35 in the path of the cutters 34A shows where cuttings from the drilling activity of the following blades may slide sideways away from the cutters and be cleared from the cutting area. With the overlap system described here, the cutters of a preceding blade cut a slot in the formation through which fluids can pass during cutting by the cutters of a succeeding blade.

17 The cutters, which are cylindrical or conical objects having an axis of rotation, are oriented on the respective blades with their axes of rotation tangential to a circle centered on the central axis A of the drill bit. The cutters 34 are also preferably oriented on the respective blades with their cutting faces parallel to the forward faces of the blades, or may be canted outward from the center of rotation by a side rake of 4°-11°. Inner cutters may have a side rake of 6-11°, while cutters at the gauge may have a side rake of 6°. With the blades behind center and canted rearward, and the cutters on circle, vibration of the blades during use tends to sweep particles away from the cutting face and help prevent balling. It is preferred to keep the number of cutters 34 on the periphery or gauge of the drill bit to a minimum required to make a good gauge in the hole, with the cutters 34 concentrated on the forward cutting end 14A. For example, for given gauge there need only be a single cutter set at the outside edge of each of the primary blades to produce that gauge. There need not be multiple cutters 34 running axially rearward along the outer periphery of the blades.

18 Once the components are manufactured they are assembled. The lid 14 is welded to the shank 12 and the weld is ground smooth. The blades 16, 18 are set in the rectangular slots 26, 28 in the top of the lid and welded in place as shown in Fig. 6.

19 With the design of the drill bit shown in Figs. 1-5D, greater angle can be achieved on the nozzle orientation because the nozzle holes 22 are drilled from the underside of the lid 14 before it is welded to the shank 12. The nozzle orientation is important to the cleaning characteristics of PDC bits. If the nozzles 24 can be oriented at the correct angle, cleaning is enhanced, thus the bit will drill faster and cutter wear life is extended. In addition, with the method of manufacture shown in Fig. 6, the blades 16, 18 can be easily replaced, unlike with a matrix body or one piece steel body bit. When the blade of a one piece steel or matrix body bit is damaged, the bit may be un-repairable. To remove one of the blades 16, 18, the weld is cut using a grinder, the blade is heated up and pops out or is easily pulled out. Use of a lid 14 allows more blades to be used.

20 As shown in Fig. 1, the blades 16, 18 are canted back away from the cutting structure. This improves cleaning and cuttings removal. The faster cuttings can be moved away from the blades the higher the rate of penetration (ROP) will be. This prevents bit balling. Moving the cuttings away from the blades quickly also prevents regrinding of the cuttings, which can

increase the temperature of the cutters. Increased temperature can cause premature cutter failure.

21 The flow restrictor 40, which also acts as a stabilizer, creates pressure between the primary and secondary blades 16, 18 for more efficient cuttings removal. The flow restrictor actually forces cross flow across the blades 16 between the cutters 34. That is, the cuttings are forced between the spaces in the cutters 34. This actually works better than trying to get all the cuttings to leave the bit face via the junk slot area. The higher resistance may be achieved by other means such as putting the secondary blades closer to the primary blades. This will create a higher pressure in the narrow passage between the primary and secondary blades. More generally, the concept is to force the cuttings to crossflow between the cutters 34 on every second blade.

22 As shown in Fig. 5D and Fig. 7, during blade construction small diameter holes (conduits) 46 are drilled from the base of the blades 16, 18 and terminate in the tops of the blades 16, 18 below the cutters 34 but in heat conducting proximity to the cutters 34, for example 1-4 millimeters away. Heat conducting proximity means sufficiently close to provide a cooling effect to the cutters 34. The hollow conduits 46 are then filled with a material with high heat conductivity, at least higher than the heat conductivity of the blade material, such as copper. This high conductivity conduit can remove heat quickly form the PDC cutters 34 and dissipate the heat into the surrounding blade. The ends of the heat conducting conduits 46 near the cutters 34 may have small holes, not filled with the high heat conductivity material, drilled through the blade from the cutter to the metal in the conduit. Fig. 10 also shows a backing part 48 of the blade 16 behind the cutter 34, and the hardened cutting surface 50 of the cutter. A softer metal such as brass 52 may be placed between the cutter 34 and the backing part 48 to help reduce cutter vibration, as shown in Fig. 10.

23 Immaterial modifications may be made to the embodiments of the invention described here without departing from the invention.

What is claimed is:

1. A drill bit, comprising:

a drill bit body having a cutting end and a central flow passage;

plural blades extending out from the cutting end of the drill bit body;

cutters in each one of the plural blades;

nozzles in the drill bit body passing through the cutting end, and providing a flow path between the central flow passage and the cutting end;

plural junk slots in the drill bit body, each blade of the plural blades separating adjacent junk slots;

the junk slots alternating in pairs around the cutting end, each pair of junk slots including a junk slot with a higher resistance to fluid flow and a junk slot with a lower resistance to fluid flow, with an intervening blade between the pair of junk slots, such that, in operation, the junk slot of each pair of junk slots with higher resistance to fluid flow forces drilling fluid from the junk slot with higher resistance into the junk slot with lower resistance, the drilling fluid being forced across the intervening blade and between the cutters of the intervening blade.

2. The drill bit of claim 1 in which the blades alternate between primary blades and secondary blades, and the primary blades are the intervening blades.

3. The drill bit of claim 2 in which each junk slot with higher resistance incorporates a restriction in the junk slot.

4. The drill bit of claim 3 in which the restrictions comprise an extension of a blade.

5. The drill bit of claim 4 in which each restriction comprises an extension of a secondary blade.

6. The drill bit of claim 5 in which each restriction of a pair of junk slots sweeps circumferentially under the intervening blade.

7. The drill bit of claim 1 in which each blade is canted backward.

8. The drill bit of claim 1 in which the drill bit body has a rotational axis, and the nozzles are oriented at an angle greater than 15° to the rotational axis and directed to force drilling fluid between the blades.

9. The drill bit of claim 8 in which the drill bit body includes a shank, and the cutting end of the drill bit body is formed of a lid welded to the shank.

10. The drill bit of claim 9 in which the blades are welded into slots in the lid.

11. A drill bit, comprising:

a drill bit body having a cutting end, a central flow passage and a rotational axis;

plural blades extending out from the cutting end of the drill bit body;

cutters in each one of the plural blades;

nozzles in the drill bit body passing through the cutting end, and providing a flow path between the central flow passage and the cutting end, the nozzles being oriented at an angle greater than 15° to the rotational axis and directed to force drilling fluid between ~~across~~ the blades; and

plural junk slots in the drill bit body, each blade of the plural blades separating adjacent junk slots.

12. The drill bit of claim 11 in which the drill bit body includes a shank, and the cutting end of the drill bit body is formed of a lid welded to the shank.

13. The drill bit of claim 13 in which the blades are welded into slots in the lid.

14. The drill bit of claim 12 in which each blade is canted backward.

15. A drill bit, comprising:

a drill bit body having a shank, a cutting end, a central flow passage and a rotational axis;

the cutting end of the drill bit body being formed of a lid welded to the shank;

plural blades extending out from the lid;

cutters in each one of the plural blades;

nozzles in the drill bit body passing through the cutting end, and providing a flow path between the central flow passage and the cutting end; and

plural junk slots in the drill bit body, each blade of the plural blades separating adjacent junk slots.

16. A drill bit, comprising:

a drill bit body having a cutting end and a central flow passage;

plural blades extending out from the cutting end of the drill bit body;

cutters in each one of the plural blades;

nozzles in the drill bit body passing through the cutting end, and providing a flow path between the central flow passage and the cutting end; and

plural junk slots in the drill bit body, each blade of the plural blades separating adjacent junk slots, the plural junk slots including junk slots with unimpeded flow paths for removal of cuttings and junk slots with impeded flow paths for removal of cuttings.

17. The drill bit of claim 16 in which the junk slots with unimpeded flow paths alternate with the junk slots with impeded flow paths.

18. A drill bit, comprising:

a drill bit body having a cutting end, a central flow passage and an outer periphery;

plural blades extending out from the cutting end of the drill bit body, the plural blades extending forward of the cutting end, radially outward from the cutting end and along the outer periphery of the drill bit body to form a stabilizer;

the plural blades including blades extending along the outer periphery of the drill bit body for different distances;

cutters in each one of the plural blades;

nozzles in the drill bit body passing through the cutting end, and providing a flow path between the central flow passage and the cutting end; and

plural junk slots in the drill bit body, each blade of the plural blades separating adjacent junk slots.

19. The drill bit of claim 18 in which the plural blades alternate between shorter blades and longer blades in length extending along the outer periphery of the drill bit body.

20. The drill bit of claim 19 in which each blade of one set of blades in the plural blades curves under a respective adjacent blade.

21. A drill bit, comprising:

a drill bit body having a cutting end, a central flow passage and a central axis;

plural blades extending out from the cutting end of the drill bit body;

each blade of the plural blades being oriented on the cutting end of the drill bit body such that a linear extension of the blade would pass behind the central axis;

cutters in each one of the plural blades;

nozzles in the drill bit body passing through the cutting end, and providing a flow path between the central flow passage and the cutting end; and

plural junk slots in the drill bit body, each blade of the plural blades separating adjacent junk slots.

22. The drill bit of claim 21 in which the blades are canted rearward.

23. A drill bit, comprising:

a drill bit body having a cutting end and a central flow passage;

plural blades extending out from the cutting end of the drill bit body;

cutters in each one of the plural blades, cutters in succeeding blades overlapping cutters in preceding blades in the direction of rotation by more than 25% and less than 100%, each cutter in a succeeding blade overlapping only one cutter in the corresponding preceding blade;

nozzles in the drill bit body passing through the cutting end, and providing a flow path between the central flow passage and the cutting end; and

plural junk slots in the drill bit body, each blade of the plural blades separating adjacent junk slots

24. A drill bit, comprising:

a drill bit body having a cutting end, a central flow passage and a rotational axis;

plural blades extending out from the cutting end of the drill bit body, the blades being made of material having a first heat conductivity;

cutters in each one of the plural blades;

nozzles in the drill bit body passing through the cutting end, and providing a flow path between the central flow passage and the cutting end, the nozzles being directed to force drilling fluid between the blades;

heat conducting conduits in each blade, each heat conducting conduit terminating in heat conducting proximity to a cutter on the respective blade, the heat conducting conduits leading into the blade away from the cutters, and the heat conducting conduits being made of a material having a second heat conductivity, the second heat conductivity being higher than the first heat conductivity; and

plural junk slots in the drill bit body, each blade of the plural blades separating adjacent junk slots.

25. A method of making a drill bit, the method comprising the steps of:

separately machining a shank and lid for the shank;

forming slots in the lid for blades;

welding the lid to the shank; and

welding blades into the slots in the lid.

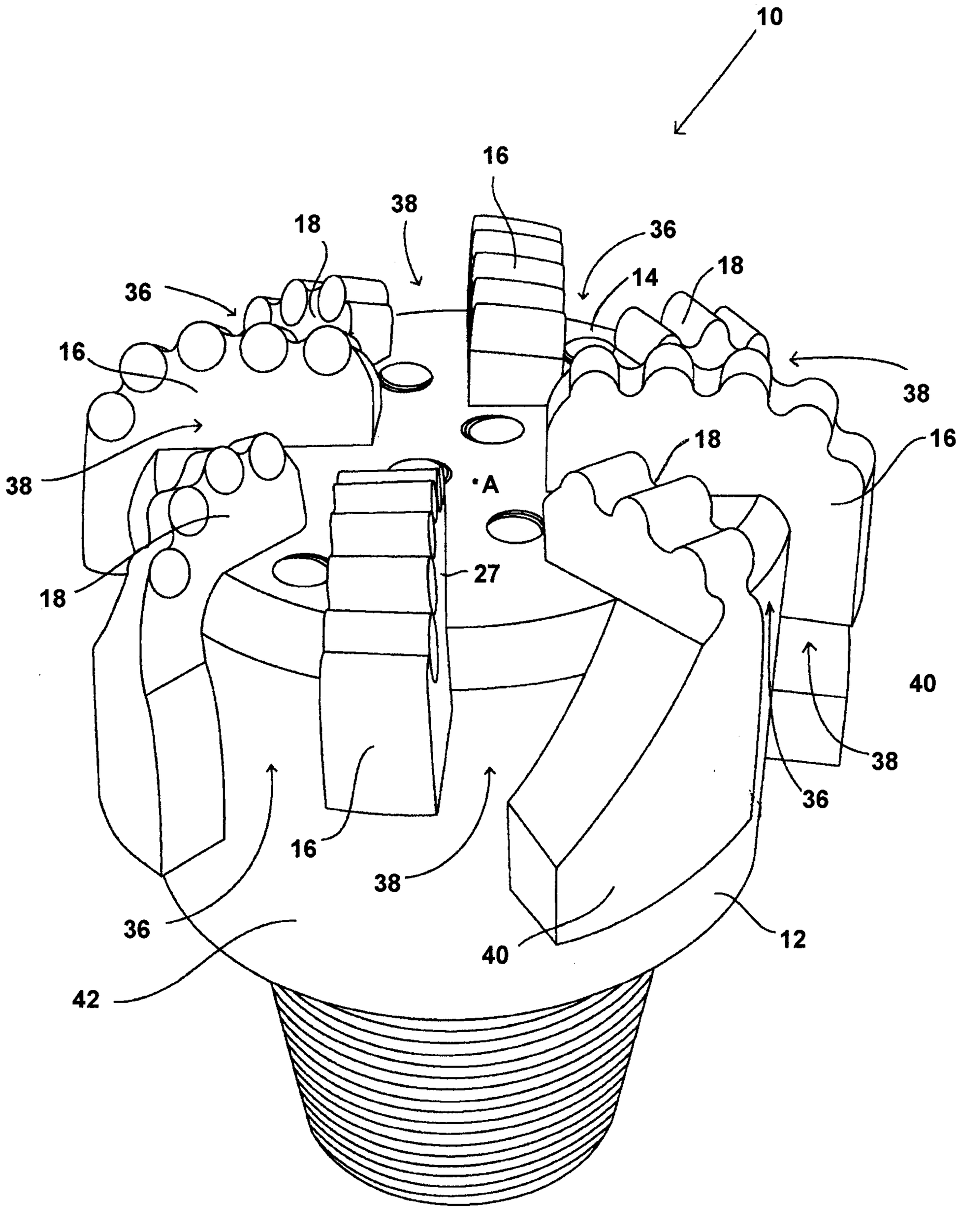


FIG. 1

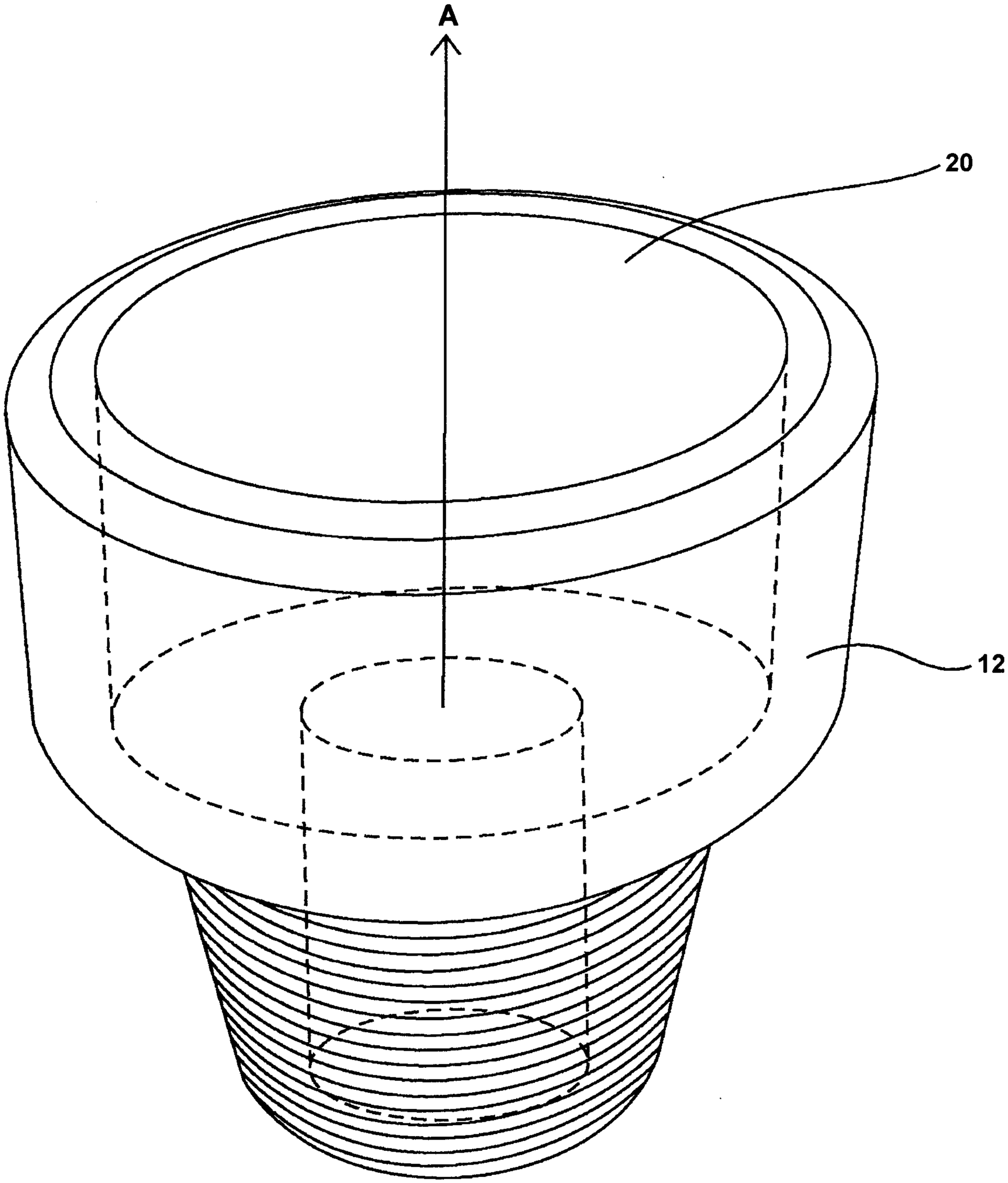


FIG. 2

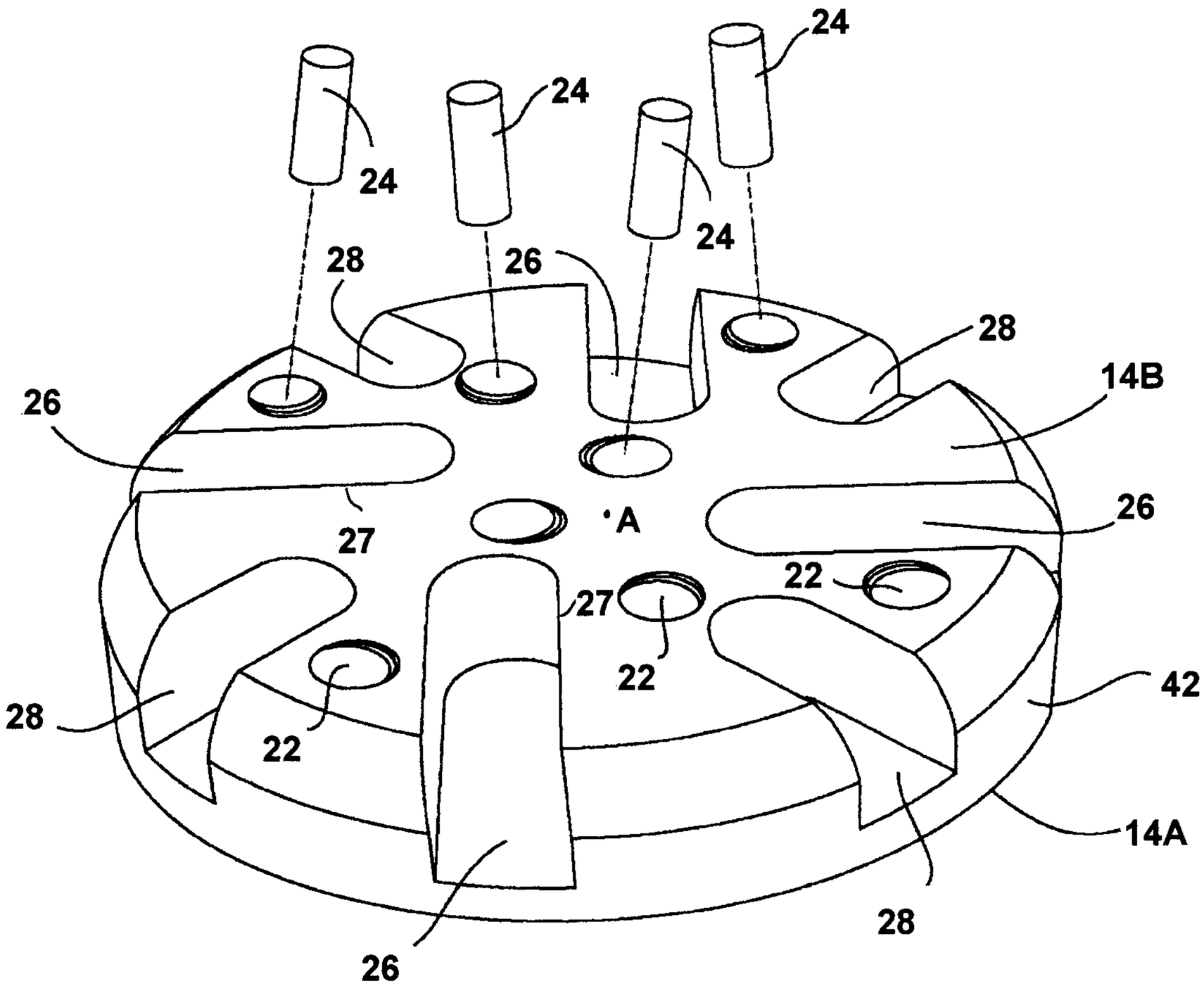

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14B
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14A
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FIG. 3

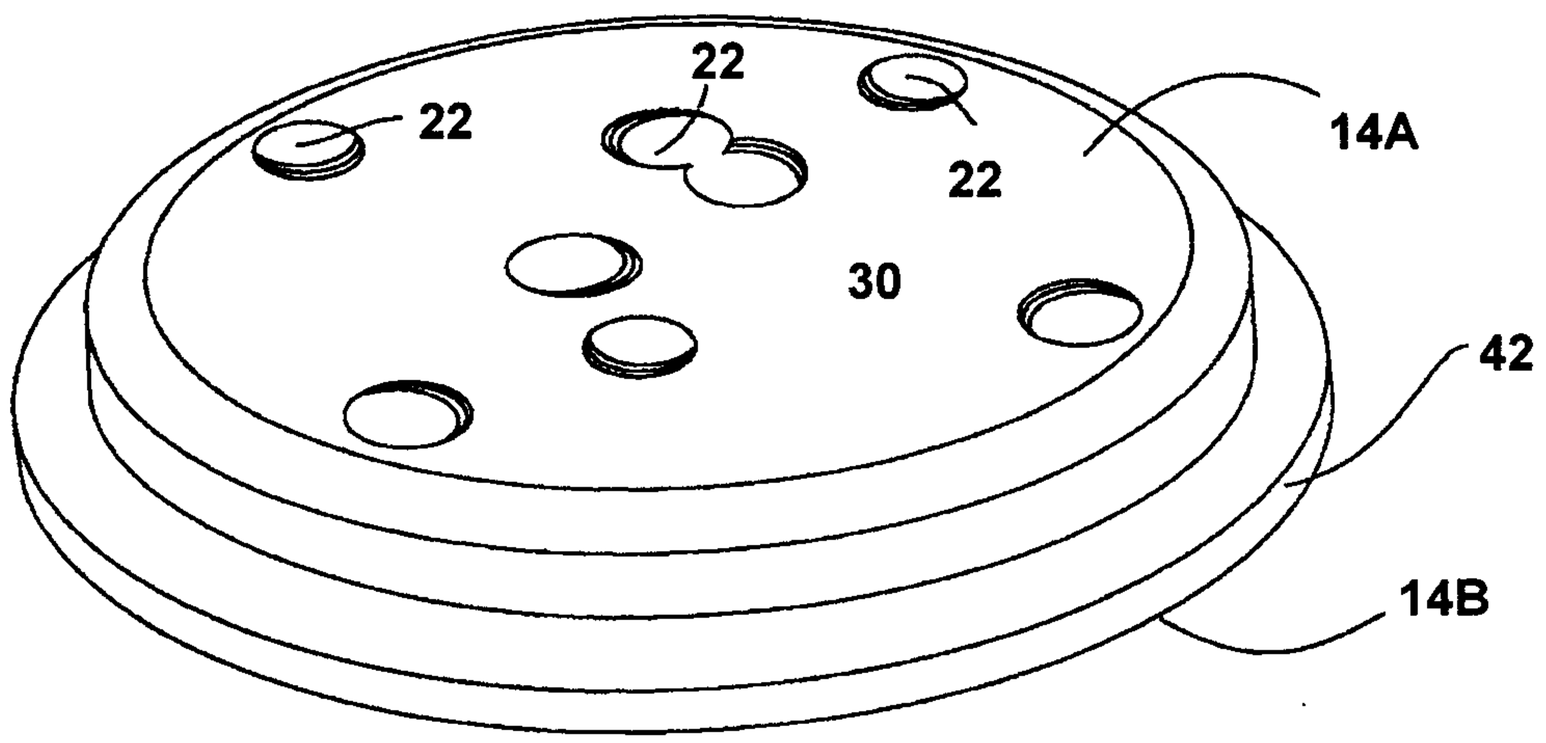

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14A
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14B

FIG. 4

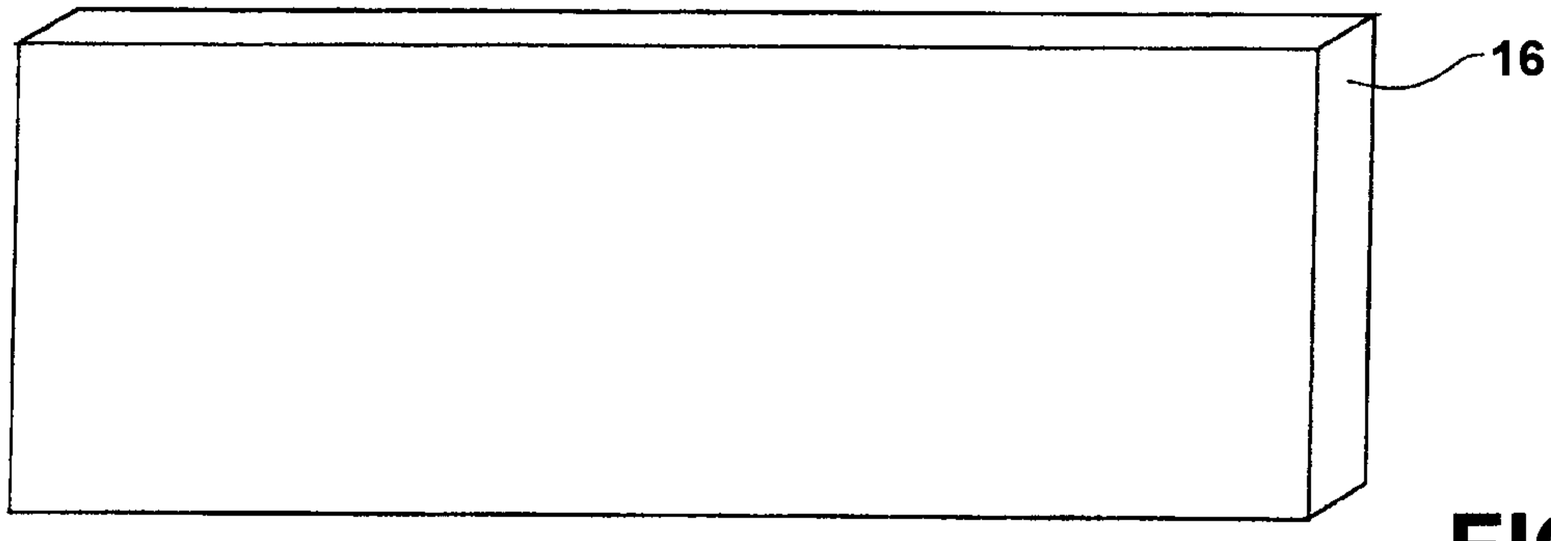


FIG. 5A

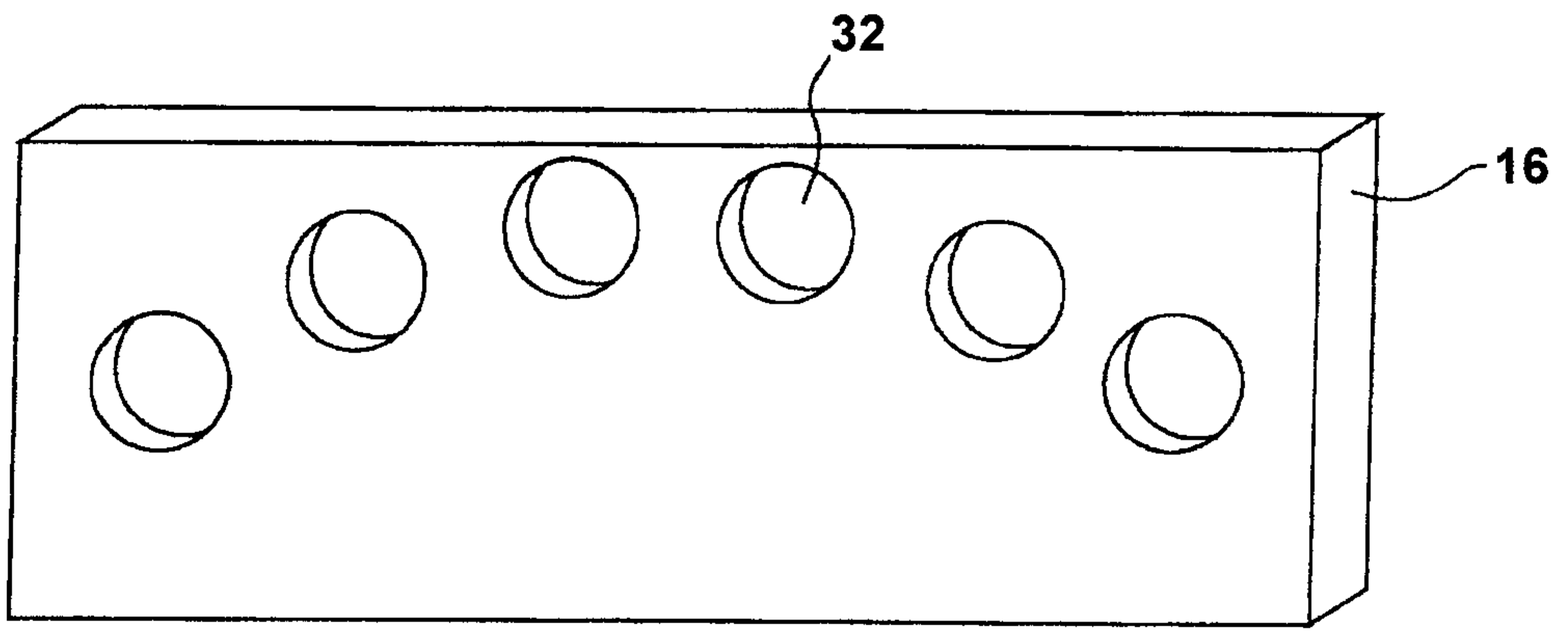


FIG. 5B

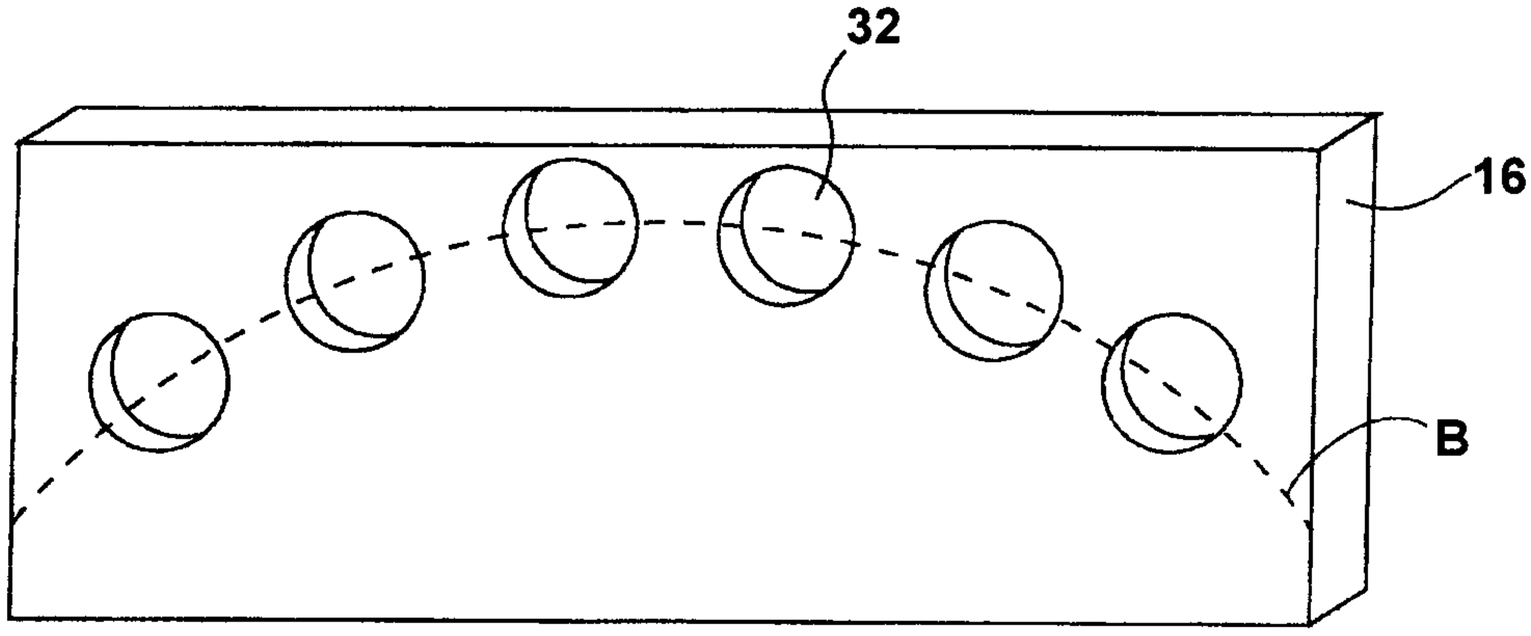


FIG. 5C

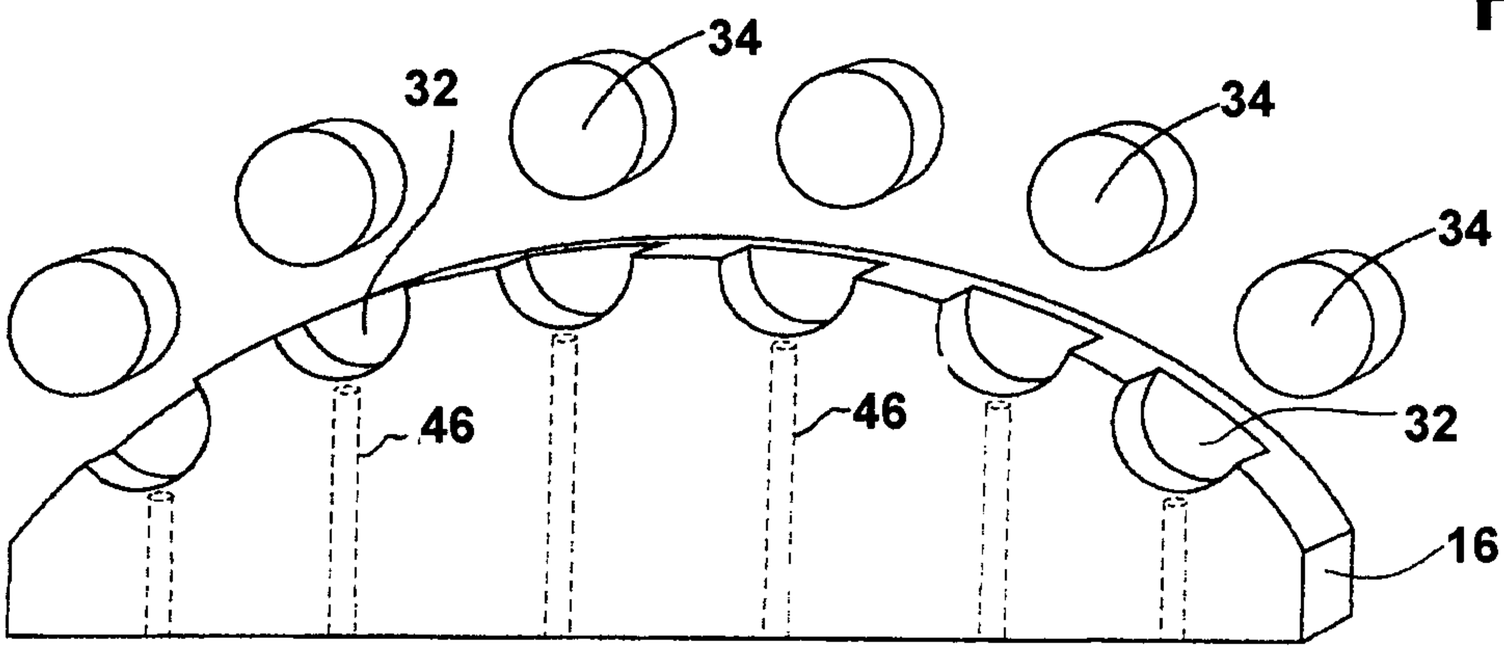


FIG. 5D

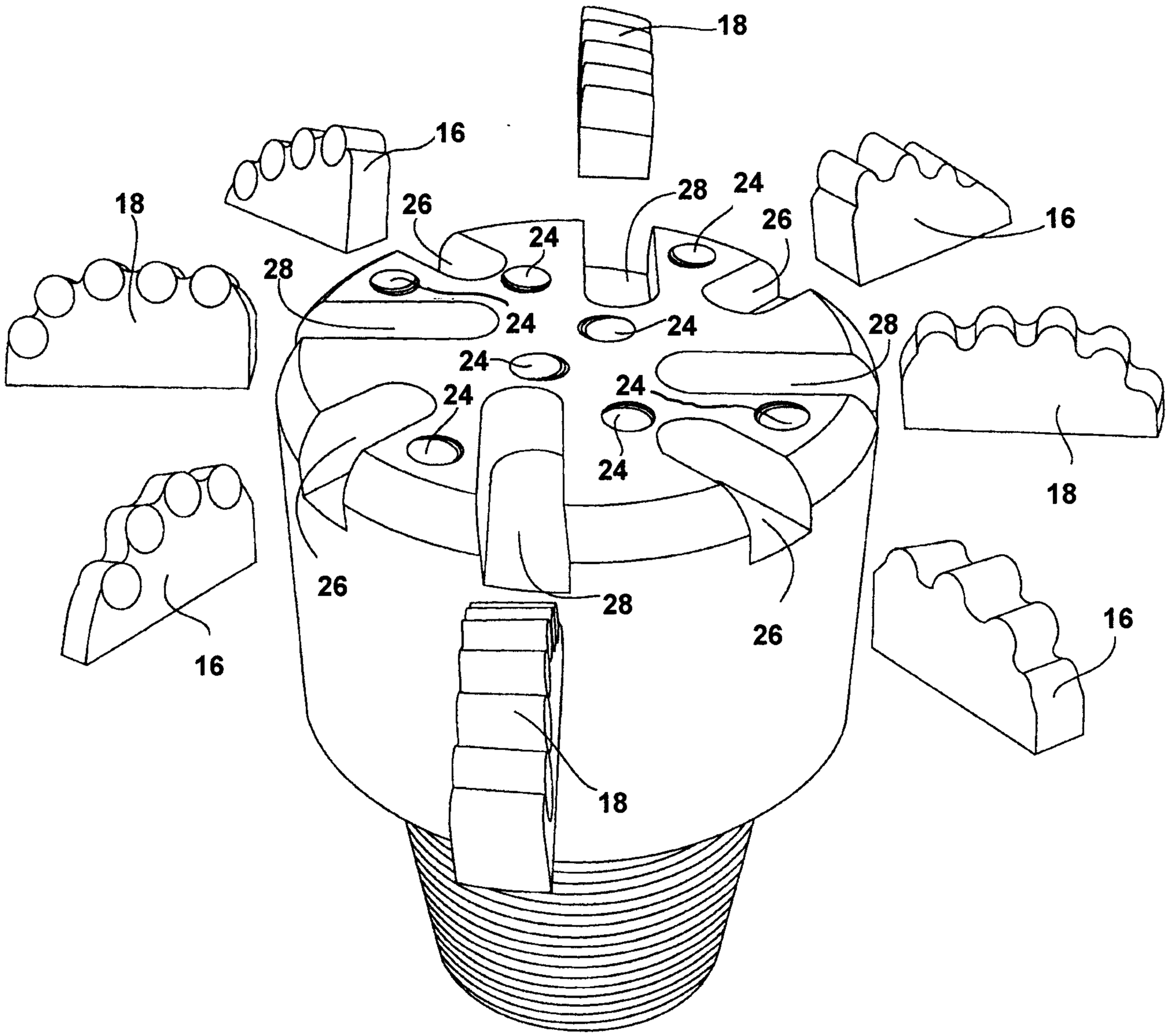


FIG. 6

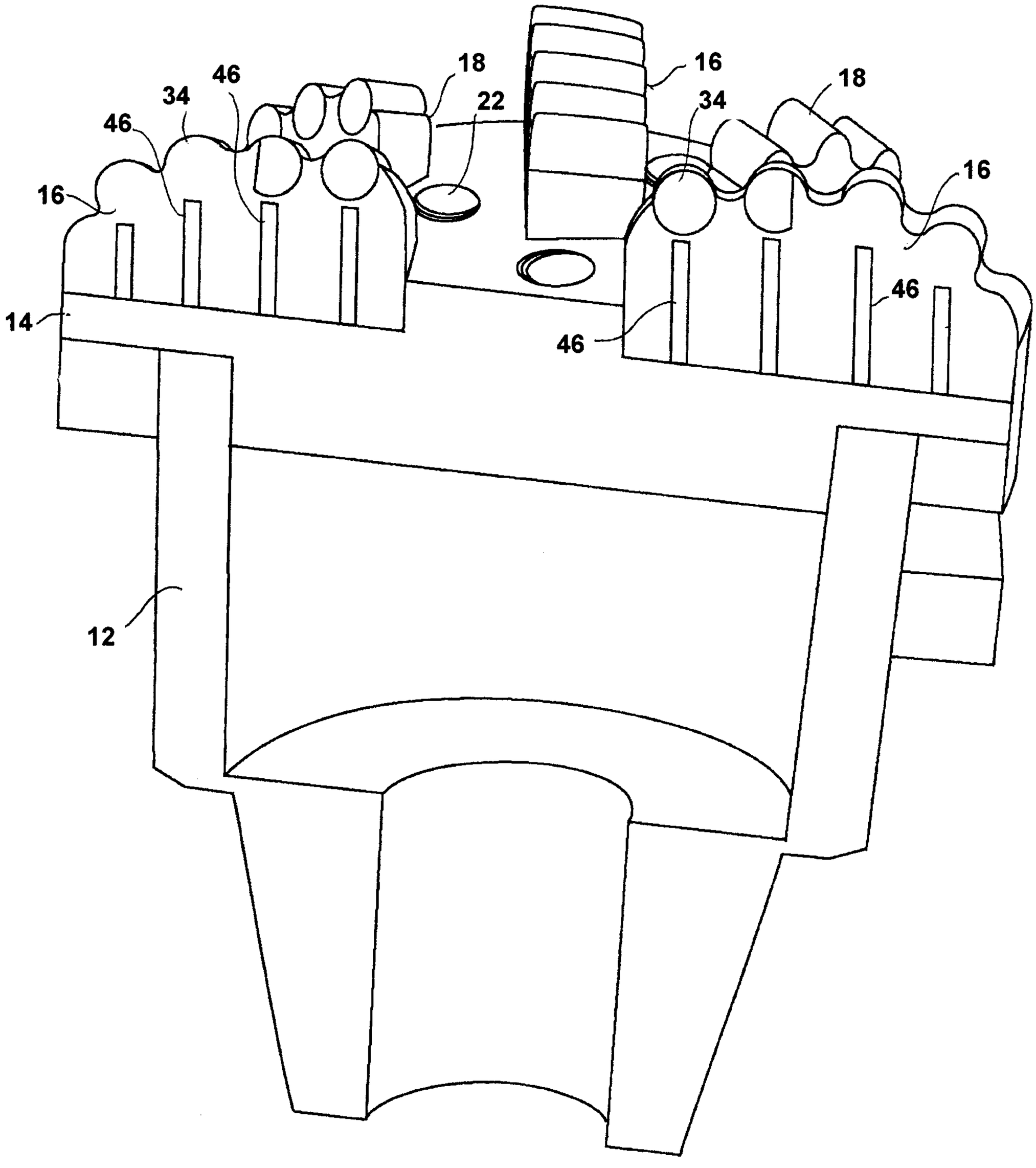


FIG. 7

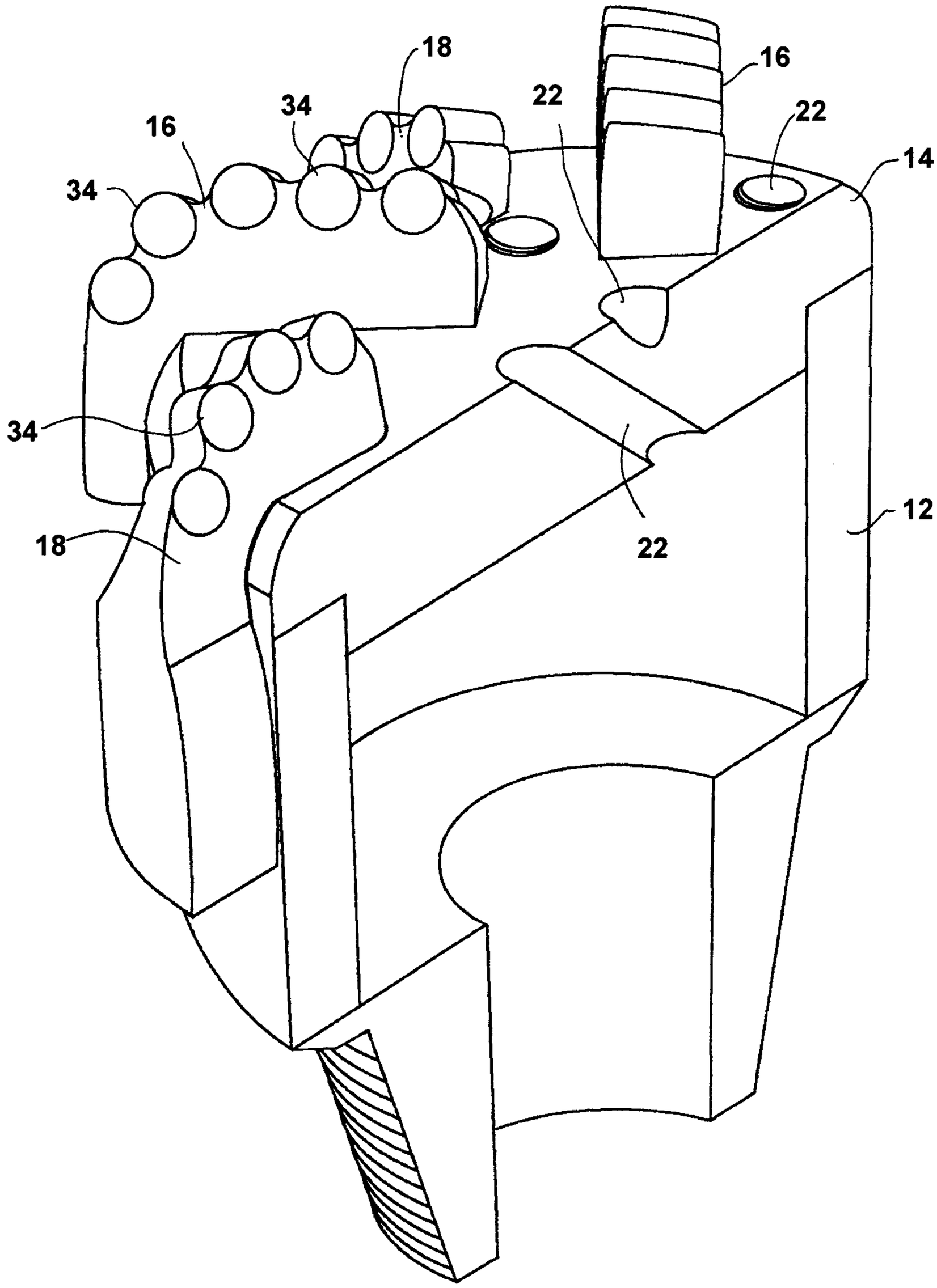


FIG. 8

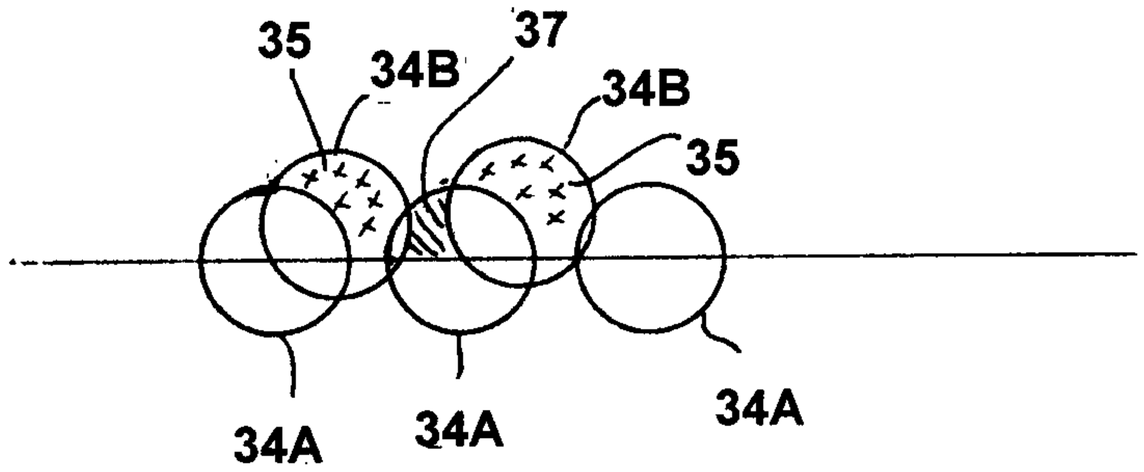


FIG. 9

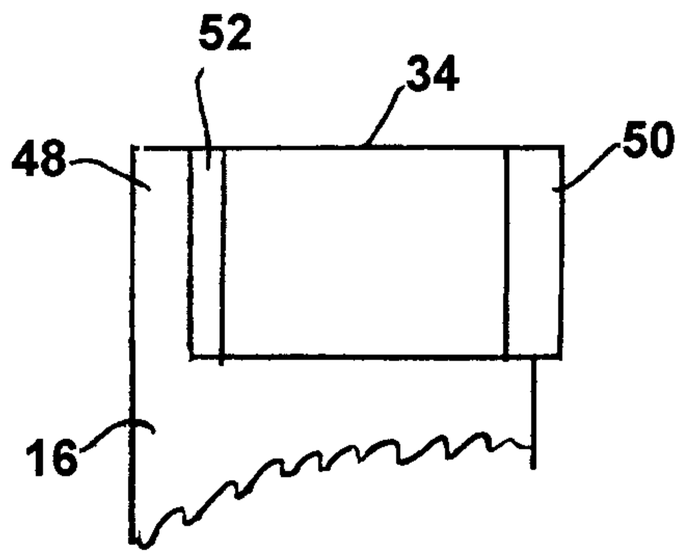
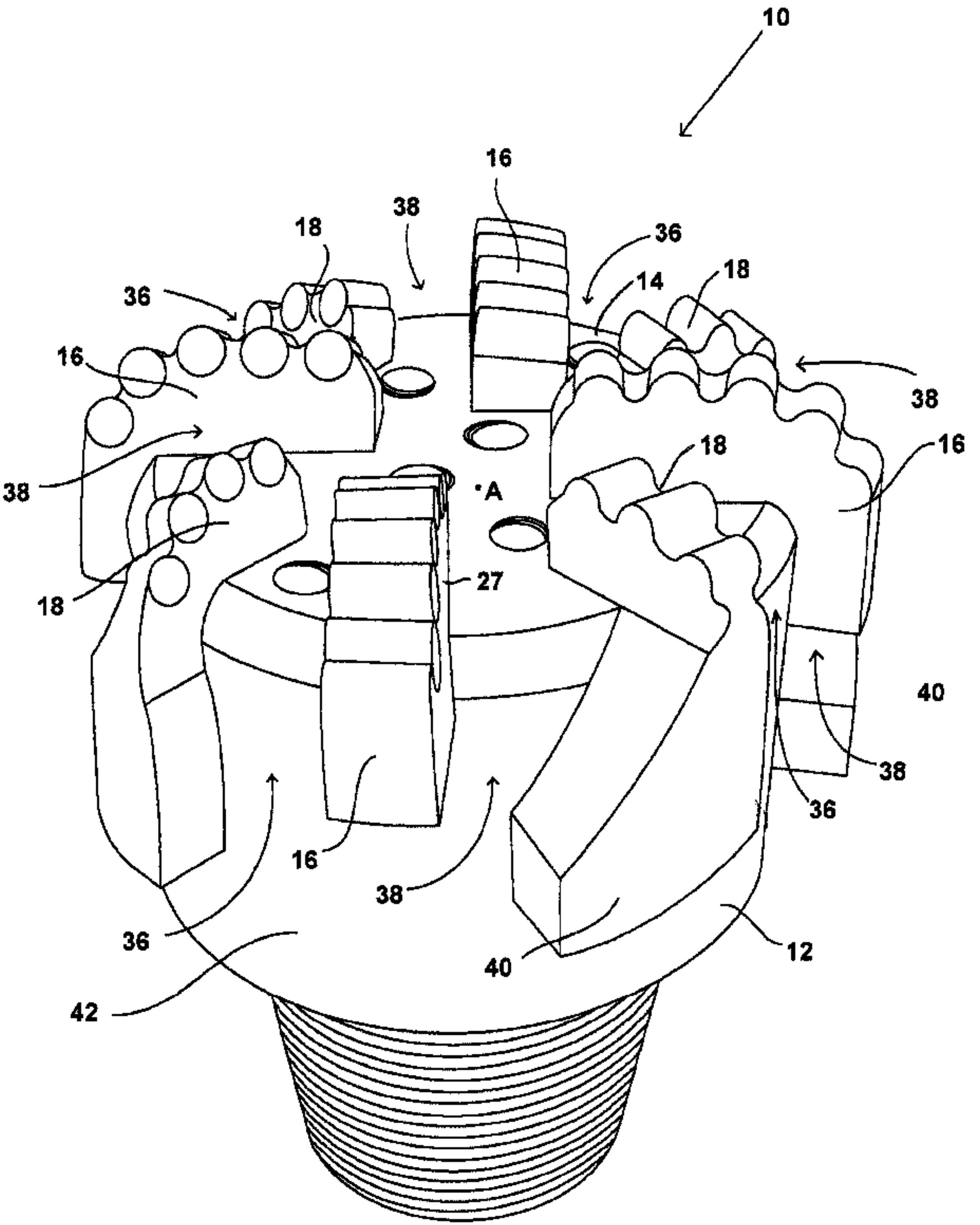


FIG. 10


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