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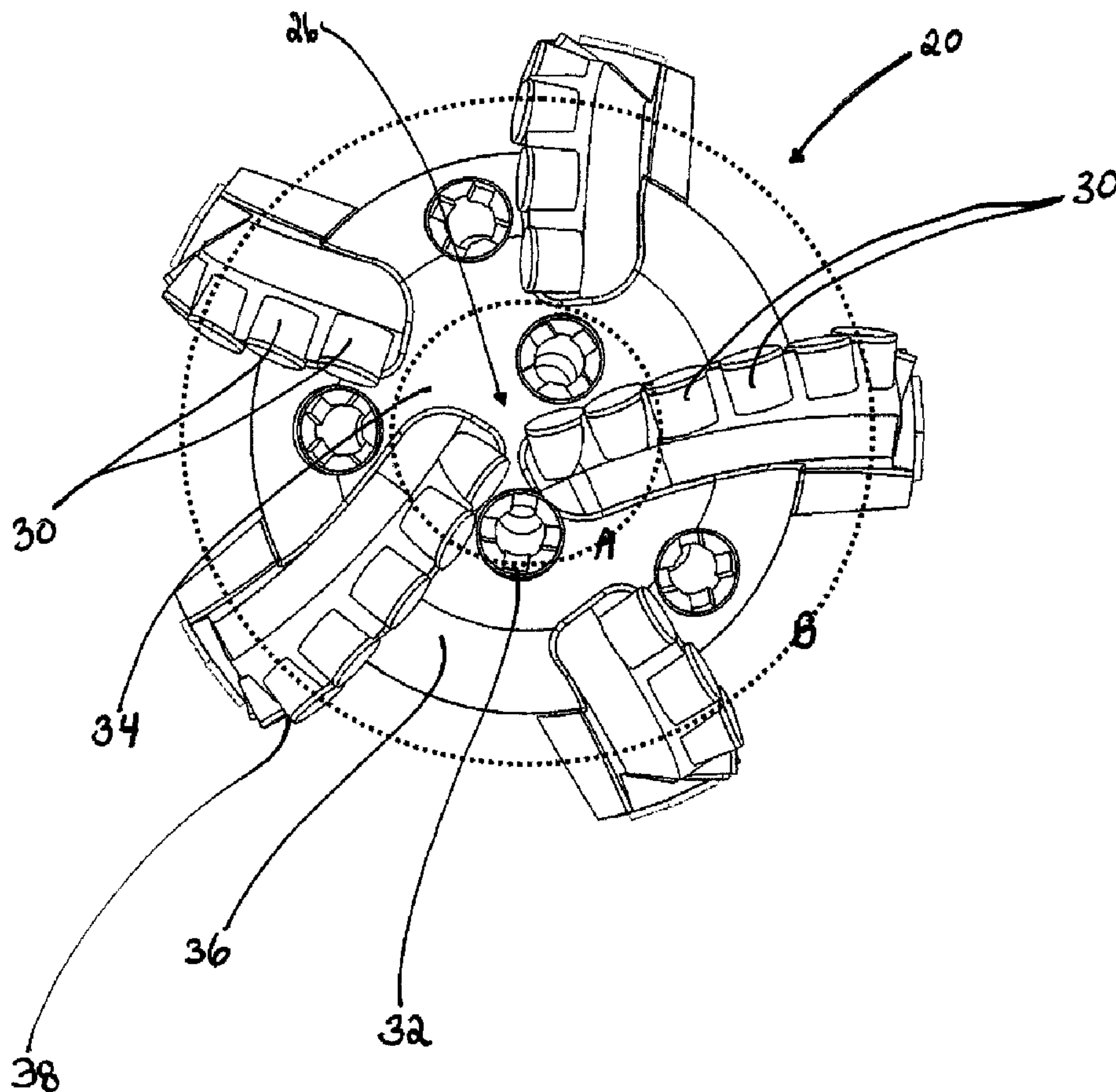
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(54) Title: SHEAR CUTTER DRILL BIT



(57) Abrégé/Abstract:

A shear cutter drill bit for drilling a subterranean formation is provided having a bit body; a bit face on the bit body having at least a center zone, an efficiency zone, and an outer zone, the efficiency zone being located between the center zone and the outer zone;



(57) **Abrégé(suite)/Abstract(continued):**

and a plurality of cutters having a backrake angle located on the bit face; wherein a majority of the cutters located in the efficiency zone of the bit face have a more aggressive backrake angle than a majority of the cutters located in the center zone of the bit face and a majority of the cutter located in the outer zone of the bit face.

ABSTRACT

A shear cutter drill bit for drilling a subterranean formation is provided having a bit body; a bit face on the bit body having at least a center zone, an efficiency zone, and an outer zone, the efficiency zone being located between the center zone and the outer zone; and a plurality of cutters having a backrake angle located on the bit face; wherein
5 a majority of the cutters located in the efficiency zone of the bit face have a more aggressive backrake angle than a majority of the cutters located in the center zone of the bit face and a majority of the cutter located in the outer zone of the bit face.

SHEAR CUTTER DRILL BIT

FIELD OF THE INVENTION

The present application relates generally to shear cutter drill bits for drilling subterranean formations. More specifically, a high rate of penetration (ROP) shear
5 cutter drill bit is provided having cutters arranged at low backrake.

BACKGROUND OF THE INVENTION

Shear cutter drill bits have a plurality of fixed cutters, usually comprising polycrystalline diamond compacts ("PDCs"), located on the bit face that are set at a fixed backrake angle. The drill bit is attached to the end of a drill string and is rotated by
10 either rotating the drill string from surface or by using a downhole motor to form a borehole in a subterranean formation.

The rate of penetration (ROP), which generally defines how fast a given drill bit drills, and the durability of a drill bit depends on a number of factors, for example, cutter densities, number of cutters, size of cutters, number of blades, arrangement of cutters
15 on the bit face, and the individual cutter's backrake angle. A drill bit that drills with a high ROP is generally referred to as an aggressive drill bit. The overall aggressiveness of a drill bit is generally defined by the aggressiveness of the cutters disposed on the face of the bit, *i.e.*, how aggressively each cutter will bite into the formation. One of the primary factors that determine the aggressiveness of an individual cutter is the backrake
20 angle at which it is set. Backrake is defined as the angle between the axis of the cutter and the formation that it is cutting, and, in general, the smaller the backrake angle, the more aggressive the cutter.

Traditionally, the industry has used relatively high backrake angles, as bits with higher backrake tend to suffer less damage than bits with lower backrake. The industry
25 standard has been to have cutters with backrake angles above 20°. It is generally believed that drill bits having cutters with backrakes lower than 20° will be too aggressive, which will lead to premature cutter breakage. It is further believed that drill bits with low backrake have poor durability as they present less diamond surface area at

the cutter – rock interface. However, use of such high backrake cutters results in relatively unaggressive drill bits requires greater weight on bit ("WOB") in order to achieve a higher ROP.

5 U.S. Patent 7,000,715 describes a drill bit having cutters with higher backrakes primarily located in the center of the bit, with the backrakes getting generally lower with increasing radial position of the cutters on the bit face, with the lowest backrake cutters being positioned on the shoulder of the bit. However, having cutters with the lowest backrake present on the shoulder of the bit may lead to premature cutter breakage. In addition to the higher likelihood of breakage on the low backrake shoulder cutters, 10 breakage also becomes more of an issue in the other regions of the bit, in particular, the nose region, due to excessive axial loading on these regions. U.S. Patent 7,000,715 also describes a 'fast-drilling' drill bit having cutters with the lowest backrake located in the center of the bit, with the backrakes getting generally higher with increasing radial position of the cutters on the bit face, with the highest backrake cutters being positioned 15 on the shoulder of the bit. However, having cutters with the lowest backrake present in the center of the bit may also lead to premature cutter breakage, and having higher backrake further out on the profile inhibits the bit's ability to drill at a high ROP. Further, in general, it has been discovered that it is the cutters in the nose region that dictate the efficiency of the overall cutting action of the bit rather than the cutters located outside of 20 the nose region.

There is a need for a shear cutter drill bit which can drill with a very high ROP without compromising the durability of the bit (*i.e.*, minimizing cutter breakage). The present applicants have discovered that providing a specific arrangement of cutters with low backrakes on the drill bit face will result in fast (aggressive) drill bits that are still 25 durable.

SUMMARY OF THE INVENTION

In one broad aspect, the present application provides a shear cutter drill bit for drilling a subterranean formation, having:

- a bit body;
 - a bit face on the bit body having at least a center zone, an efficiency zone, and an outer zone, the efficiency zone being located between the center zone and the outer zone; and
- 5 • a plurality of cutters having a backrake angle located on the bit face;

wherein a majority of the cutters located in the efficiency zone of the bit face have a more aggressive backrake angle than a majority of the cutters located in the center zone of the bit face and a majority of the cutter located in the outer zone of the bit face.

10 In one embodiment, the majority of the cutters located in the efficiency zone have a backrake angle less than 20°. In another embodiment, the majority of the cutters located in the efficiency zone have a backrake angle less than 15°. In another embodiment, the majority of the cutters located in the efficiency zone have a backrake angle less than 10°. In another embodiment, the majority of the cutters located in the efficiency zone have a backrake angle less than 5°.

15 In another broad aspect, the present application provides a shear cutter drill bit where a majority of the cutters located in the efficiency zone have the most aggressive backrake angles, the majority of the cutters located in the center zone have intermediately aggressive backrake angles, and the majority of the cutters located in the outer zone have the least aggressive backrake angles. In one embodiment, the
20 majority of the cutters located in the efficiency zone have a backrake angle in the range of about 5° to about 15°, the majority of the cutters located in the center zone have a backrake angle in the range of about 15° to about 20°, and the majority of the cutters located in the outer zone have a backrake angle in the range of about 15° to about 30°.

25 In another broad aspect, the application provides a method for drilling a subterranean formation, comprising:

- providing a shear cutter drill bit for drilling a subterranean formation, the shear cutter drill bit having a bit body, a bit face on the bit body having at least a center

zone, an efficiency zone and an outer zone, the efficiency zone being located between the center zone and the outer zone, and a plurality of cutters having a backrake angle located on the bit face, wherein a majority of the cutters located in the efficiency zone of the bit face have a more aggressive backrake angle than a majority of the cutters located in the center zone of the bit face and a majority of the cutters located in the outer zone of the bit face;

- positioning the face of the drill bit towards the subterranean formation so that at least one of the center zone, efficiency zone and outer zone contacts the subterranean formation; and
- rotating the drill bit while applying a weight on the drill bit so as to penetrate the subterranean formation;

wherein the weight applied to the drill bit is less than the weight needed to be applied to a conventional shear cutter drill bit for obtaining the same rate of penetration.

Other features will become apparent from the following detailed description. It should be understood, however, that the detailed description and the specific embodiments, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates an end view of an embodiment of a shear cutter drill bit according to the invention.

Figure 2 illustrates the side perspective view of the drill bit embodiment shown in Figure 1.

Figure 3 illustrates a side view of a cutter as used in an embodiment of the invention depicting the cutter backrake.

Figure 4 is a side cross-sectional elevation of an embodiment of a five bladed shear cutter drill bit according to the invention.

Figure 5 graphically illustrates a profile of the drill bit embodiment shown in Figure 4 highlighting cutter height versus bit radius.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

While the invention is described below with reference to what are presently considered to be the preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments. To the contrary, the invention herein is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

The applicants have discovered that the cutters of a shear cutter drill bit that are located generally in a region adjacent to the cone region of the bit and which extends partially into the shoulder region of the drill bit appear to have the greatest impact on the overall efficiency of the shearing action of the drill bit. This region is referred to hereinafter as the "efficiency zone". It is understood by a person skilled in the art that the cone region of a drill bit generally refers to the center region of the drill bit (hereinafter referred to as the "center zone") and that the shoulder region generally refers to the region that starts where the profile angle is approximately 15°, the profile angle being defined as the angle between a line drawn perpendicular to the bit profile and the centerline of the bit when viewing the bit from a profile view.

Of course, it is understood to those skilled in the art that the beginning of the efficiency zone will vary according to a number of variables: the intended RPM of the application, the type of rock being drilled, the overall size of the drill bit, the shape of the drill bit profile, etc. However, for example purposes only, and not meant to be limiting, the efficiency zone generally starts at a radius of approximately 1" from the centerline of the drill bit and, in general, the efficiency zone ends where the profile angle is approximately 45° in the shoulder region.

It was further discovered that the beginning of the efficiency zone generally correlates to a radial distance where the relative surface speed of the cutters becomes more significant. The cutters located in the center zone (*i.e.*, closest to center of the bit) move at a very slow surface speed (surface speed being defined as $2\pi R\omega$, where "R" is the radial distance of the tip of the cutter to the center of the bit, and ω is the angular velocity – or RPM) with respect to the formation because they are positioned at such a small radial distance from the center of the bit. As a result of that slow surface speed, and as a result of the fact that these cutters are drilling rock that has been stress relieved, the cutters in the center generally have a reduced effect on the efficiency of the cutting structure. As the bit drills through formation, the rock left in the center of the bit no longer has the stress of the rock around it to support it, and when rock is under less stress, it is much easier to drill. In other words, the cutters do not need to be very aggressive in the center zone for the overall drill bit to be aggressive.

Cutters located on the opposite side of the efficiency zone, *i.e.*, those cutters in the shoulder and gage region past the efficiency zone (hereinafter referred to as the "outer zone"), are oriented generally more laterally than axially, and therefore have less effect on the efficiency of the axial cutting action (*i.e.*, the ability of the bit to drill ahead). Because the cutters located in the outer zone are the furthest away from the center of the cutter, these cutters have a higher surface speed with respect to the formation. Thus, cutters in the outer zone will still remove rock relatively fast even if they are not set at a particularly aggressive backrake angle, due to this increased surface speed.

Conversely, cutters in the efficiency zone are generally oriented more axially than laterally, and therefore have a greater effect on the efficiency of the axial cutting action. The rock being removed by the cutters near the nose of the bit is still supported by rock on three sides and, as such, is much harder to drill. Thus, it is desirable that the cutters in this zone be as aggressive as possible, *i.e.*, have the lowest backrake, and that these lower backrake cutters extend past the beginning of the shoulder of the bit. Hence, the cutters in the efficiency zone will have the greatest effect on the overall ROP of the drill bit.

There may be additional advantages in having the cutters located in the center zone and outer zone set at a less aggressive angle. For example, the cutters in the center zone tend to be more susceptible to impact damage and, in particular, can easily break if set at a low backrake. Thus, setting the cutters in the center zone at higher
5 backrake angles will tend to minimize such potential breakage without significantly affecting the overall drilling speed and efficiency of the drill bit.

With respect to the cutters in the outer zone, it is believed that having a high backrake on these cutters may help balance the axial loads on all of the cutters. Since the cutters in the efficiency zone will generally see the greatest amount of axial load (if
10 all of the cutters on the drill bit were set at the same backrake), and since those cutters are set at the most aggressive backrake, by increasing the backrake on the cutters outside the efficiency zone it effectively increases the axial load on those cutters outside the efficiency zone, therefore helping to protect the cutters in the efficiency zone from excessive axial loading leading to cutter breakage.

Another possible advantage with high backrake angles on cutters in the outer zone may be that the cutters in that region tend to see the most damage from any lateral vibration or lateral movement of the bit. Since lateral vibration is a common
15 problem with shear cutter drill bits, the overall performance of such drill bits may be improved by having the cutters in the outer zone at a higher backrake to prevent any breakage resulting from lateral movement/vibration.
20

Hence, since the efficiency of the overall cutting action of the bit is dictated by cutters in the efficiency zone, the cutters outside that zone (either inside of it or outside of it) have less effect on the efficiency of the cutting action, and therefore less effect on the resulting ROP of the bit for a given WOB (weight on bit). Thus, according to one
25 embodiment of the invention, the majority of the cutters located in the efficiency zone will have a more aggressive backrake angle than the majority of the cutters located in the center zone and the majority of the cutters located in the outer zone.

An embodiment of the invention will now be described with reference to Figures 1-5. With reference first to Figures 1 and 2, shear cutter drill bit 20 comprises bit body

22 having a shank portion 24 and a bit face 26. A plurality of generally radially oriented blades 28 generally define bit face 26 and each blade 28 further comprising a plurality of cutting elements or cutters 30, each cutter having a particular backrake angle and disposed about the blades surface in a conventional fashion, e.g., by brazing or force fitting. The most common type of cutters used in the industry are cutters cylindrical in shape such as PDCs

The backrake angle of a cutter is defined as the angle between the axis of the cutter and the formation that it is cutting, measured perpendicular to the profile of the drill bit. This can be seen more clearly with reference to Figure 3. In Figure 3, the formation is represented by flat horizontal line 10, the axis of the cutter by hatched line 12, and the backrake angle of the cutter is the angle between the axis of the cutter and the formation (θ).

Drill bit 20 further comprises a plurality of nozzles or jets 32, which provide drilling fluid to the bit face 22. In Figure 1, drill bit face 22 is shown divided into three distinct regions by concentric hatched circles A and B, forming center zone 34, efficiency zone 36 and outer zone 38. Those cutters present in the efficiency zone 36 have been marked with an asterisk (*) in Figure 2.

With reference now to Figure 4, the profile of bit face 26 of drill bit 20 as shown in Figures 1 and 2 is illustrated, including blades 28 upon which a plurality of cutters 30 are oriented. The axis of the drill bit 20 is represented by hatched line 40 and the profile terminates at gage 42. Although all of the cutters 30 are depicted as being oriented on a single blade 28, Figure 4 merely depicts the position of cutters 30 relative to one another with respect to both the longitudinal axis 40 of the bit 20 and a vertical position 44 along longitudinal axis 40. In actuality, cutters 30 are carried on various blades 28, the cutter positions having been rotated in a single plane for clarity. Zone 34, which extends from the axial line 40 to hatched line A, is the center zone and it can be seen from the profile that, in this embodiment, there are four cutters 30 in the center zone. Zone 36, which is the efficiency zone, extends from hatched line A to hatched line B,

and includes the nose point C. Zone 34, the outer zone, extends from hatched line B to gage 42.

The profile of the blades 30 in Figure 4 can be seen in more detail in Figure 5. The x axis is taken along the longitudinal axis and generally represents the distance of each cutter from the center of the bit or the bit radius. The y axis generally represents the height of the cutters. In this embodiment, the individual cutters have been labeled 30A to 30CC, for a total of 29 cutters. Cutters 30A, 30B and 30C are present in the center zone and in this embodiment have a backrake angle of about 15°. Cutters 30D to 30O are present in the efficiency zone and in this embodiment have a backrake angle of about 10°. Cutters 30P to 30CC are present in the outer zone. In this embodiment, cutters 30P to 30S have a backrake angle of about 15°, cutters 30T to 30W have a backrake angle of 20°, and cutters 30X to 30AA have a backrake angle of about 30°.

It is understood, however, that the embodiment in Figure 5 is only one example of a shear cutter drill bit of the invention. According to the invention, generally, more than half of the cutters present in efficiency zone will have a backrake angle of about 20° or less, in some instances about 15° or less, in some instances about 10° or less, or in some instances about 5° or less. The majority of the other cutters, which are located in the center zone and the outer zone, will have higher backrake angles than the majority of those in the efficiency zone.

For example, in another embodiment, the majority of the cutters located in the efficiency zone have a backrake angle in the range of about 5° to about 15°; the majority of the cutters located in the center zone have a backrake angle in the range of about 15° to about 20°, and the majority of the cutters located in the outer zone have a backrake angle in the range of about 15° to about 25°. In another embodiment, the majority of the cutters in the outer zone have a backrake angle of about 20° to about 30°.

The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to those embodiments will be readily apparent to those skilled in the art, and the generic

principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein, but is to be accorded the full scope consistent with the claims, wherein reference to an element in the singular, such as by use of the
5 article "a" or "an" is not intended to mean "one and only one" unless specifically so stated, but rather "one or more". All structural and functional equivalents to the elements of the various embodiments described throughout the disclosure that are known or later come to be known to those of ordinary skill in the art are intended to be encompassed by the elements of the claims. Moreover, nothing disclosed herein is
10 intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims.

WE CLAIM:

1. A shear cutter drill bit for drilling a subterranean formation, comprising:

a bit body;

a bit face on the bit body having at least a center zone, an efficiency zone and an
5 outer zone, the efficiency zone being located between the center zone and the outer
zone; and

a plurality of cutters having a backrake angle located on the bit face;

wherein a majority of the cutters located in the efficiency zone of the bit face have a
more aggressive backrake angle than a majority of the cutters located in the center
10 zone of the bit face and a majority of the cutters located in the outer zone of the bit face.

2. The drill bit as claimed in claim 1, wherein the majority of the cutters located in
the efficiency zone have a backrake angle less than 20°.

3. The drill bit as claimed in claim 1, wherein the majority of the cutters located in
the efficiency zone have a backrake angle less than 15°.

15 4. The drill bit as claimed in claim 1, wherein the majority of the cutters located in
the efficiency zone have a backrake angle less than 10°.

5. The drill bit as claimed in claim 1, wherein the majority of the cutters located in
the efficiency zone have a backrake angle less than 5°.

6. The drill bit as claimed in claim 1, wherein the majority of the cutters located in the
20 efficiency zone have the most aggressive backrake angles, the majority of the cutters
located in the center zone have intermediately aggressive backrake angles, and the
majority of the cutters located in the outer zone have the least aggressive backrake
angles.

7. The drill bit as claimed in claim 1, wherein the majority of the cutters located in the efficiency zone have a backrake angle in the range of about 5° to about 15°, the majority of the cutters located in the center zone have a backrake angle in the range of about 15° to about 20°, and the majority of the cutters located in the outer zone have a backrake angle in the range of about 15° to about 30°.
8. The drill bit as claimed in claim 1, wherein the majority of the cutters located in the efficiency zone have a backrake angle in the range of about 5° to about 15°, the majority of the cutters located in the center zone have a backrake angle in the range of about 15° to about 20°, and the majority of the cutters located in the outer zone have a backrake angle in the range of about 20° to about 30°.
9. The drill bit as claimed in claim 1, wherein the majority of the cutters located in the efficiency zone have a backrake angle in the range of about 10°, the majority of the cutters located in the center zone have a backrake angle of about 15°, and the majority of the cutters located in the outer zone have a backrake angle in the range of about 15° to about 30°.
10. The drill bit as claimed in claim 1, the bit face comprising at least one blade, wherein the cutters are located on the at least one blade.
11. A method for drilling a subterranean formation, comprising:
- providing a shear cutter drill bit for drilling a subterranean formation, the shear cutter drill bit comprising:
 - a bit body;
 - a bit face on the bit body having at least a center zone, an efficiency zone and an outer zone, the efficiency zone being located between the center zone and the outer zone; and
 - a plurality of cutters having a backrake angle located on the bit face;
 - wherein a majority of the cutters located in the efficiency zone of the bit face have a more aggressive backrake angle than a majority of the cutters located in

the center zone of the bit face and a majority of the cutters located in the outer zone of the bit face;

positioning the face of the drill bit towards the subterranean formation so that at least one of the center zone, efficiency zone and outer zone contacts the subterranean
5 formation;

rotating the drill bit while applying a weight on the drill bit so as to penetrate the subterranean formation;

wherein the weight applied to the drill bit is less than the weight needed to be applied to a conventional shear cutter drill bit for obtaining the same rate of penetration.

10 12. The method as claimed in claim 11, wherein the majority of the cutters located in the efficiency zone have a backrake angle less than 20°.

13. The method as claimed in claim 11, wherein the majority of the cutters located in the efficiency zone have a backrake angle less than 15°.

14. The method as claimed in claim 11, wherein the majority of the cutters located in
15 the efficiency zone have a backrake angle less than 10°.

15. The method as claimed in claim 11, wherein the majority of the cutters located in the efficiency zone have a backrake angle less than 5°.

16. The method as claimed in claim 11, wherein the majority of the cutters located in the efficiency zone have the most aggressive backrake angles, the majority of
20 the cutters located in the center zone have intermediately aggressive backrake angles, and the majority of the cutters located in the outer zone have the least aggressive backrake angles.

17. The method as claimed in claim 11, wherein the majority of the cutters located in the efficiency zone have a backrake angle in the range of about 5° to about 15°, the
25 majority of the cutters located in the center zone have a backrake angle in the range of

about 15° to about 20°, and the majority of the cutters located in the outer zone have a backrake angle in the range of about 15° to about 30°.

18. The method as claimed in claim 11, wherein the majority of the cutters located in the efficiency zone have a backrake angle in the range of about 5° to about 15°, the
5 majority of the cutters located in the center zone have a backrake angle in the range of about 15° to about 20°, and the majority of the cutters located in the outer zone have a backrake angle in the range of about 20° to about 30°.

19. The method as claimed in claim 11, wherein the majority of the cutters located in the efficiency zone have a backrake angle in the range of about 10°, the majority of
10 the cutters located in the center zone have a backrake angle of about 15°, and the majority of the cutters located in the outer zone have a backrake angle in the range of about 15° to about 30°.

20. The method as claimed in claim 11, wherein the bit face comprising at least one blade and the cutters are located on the at least one blade.

FIG. 1

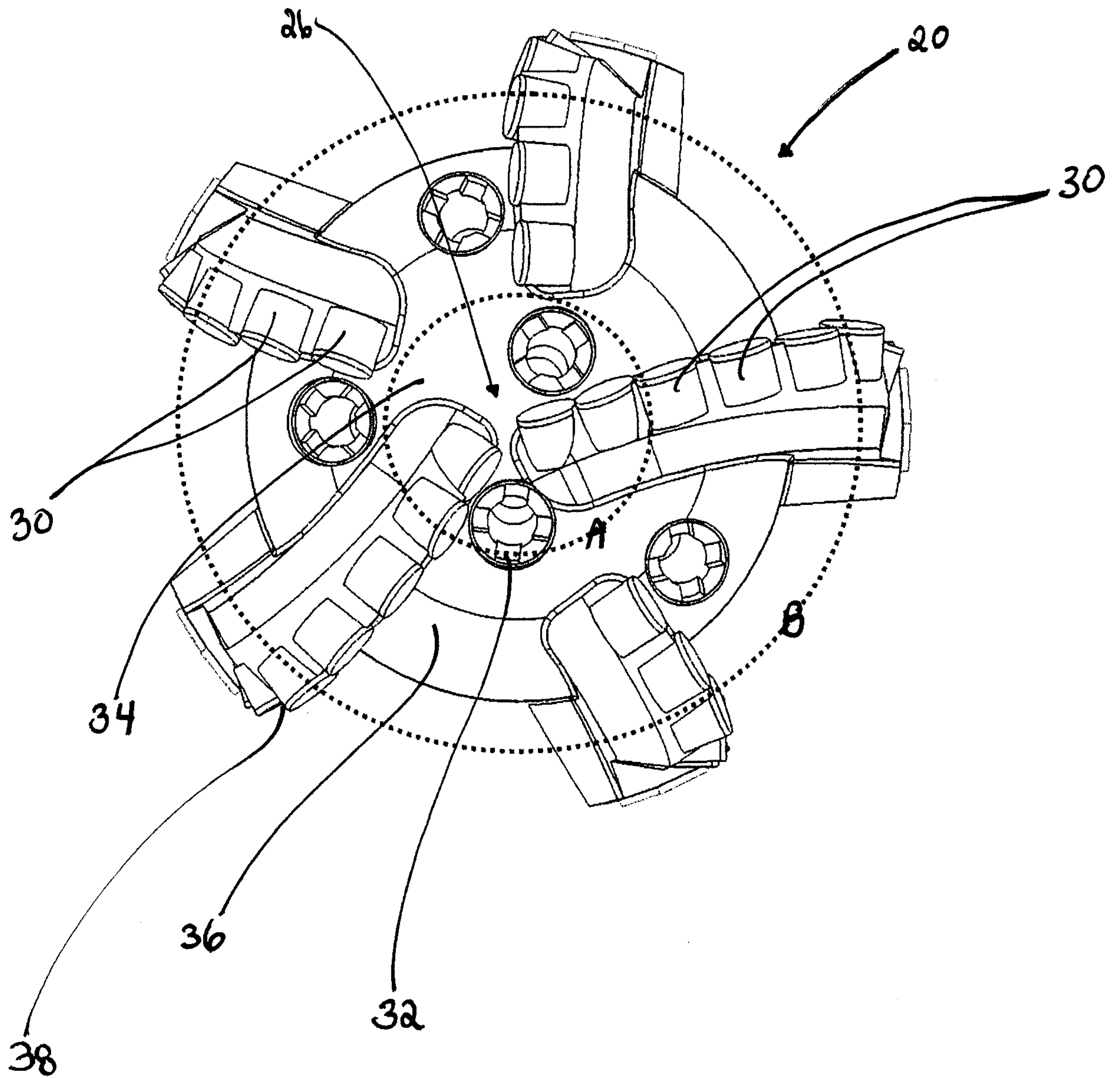


FIG. 2

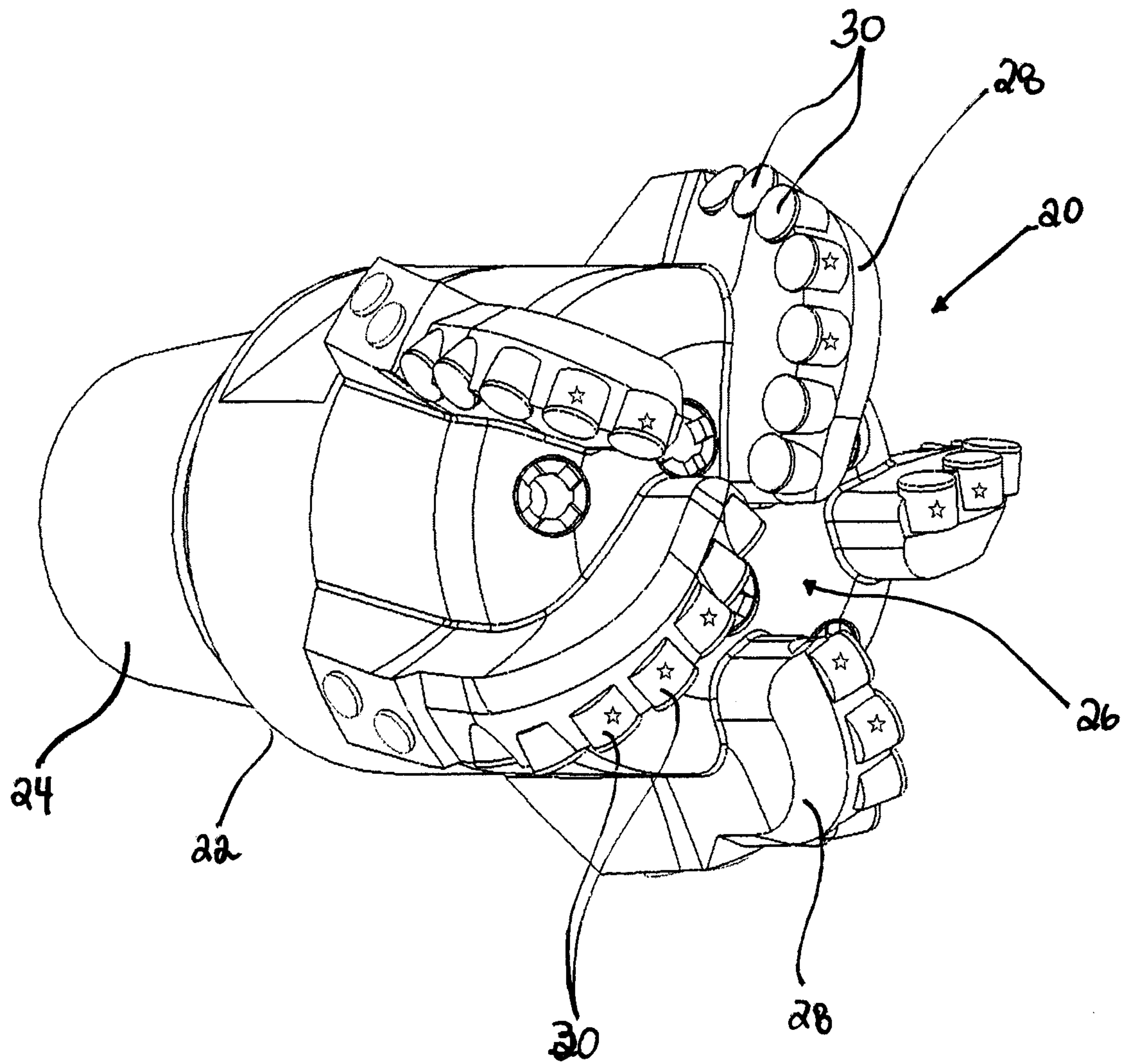


FIG. 3

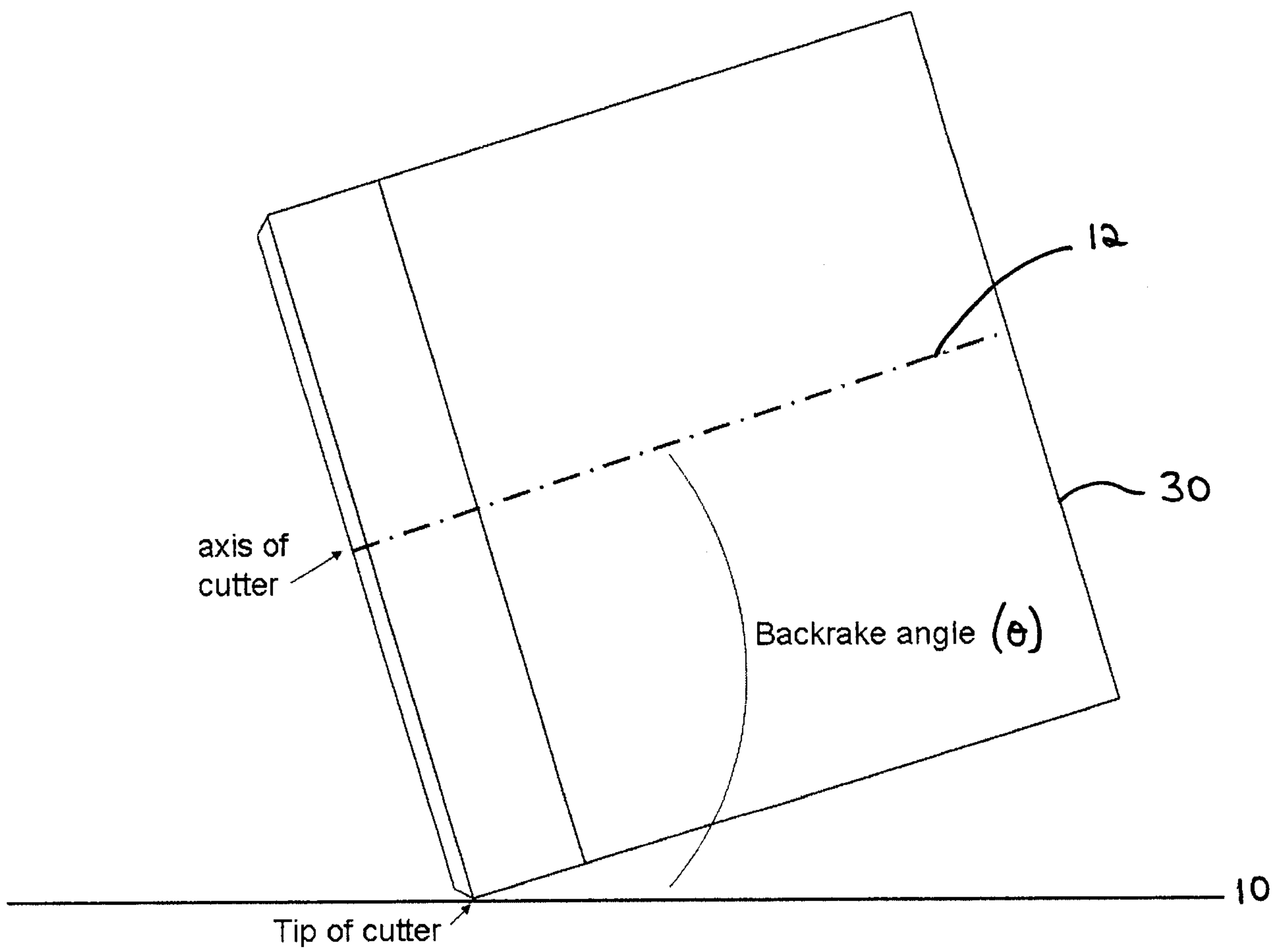


FIG. 4

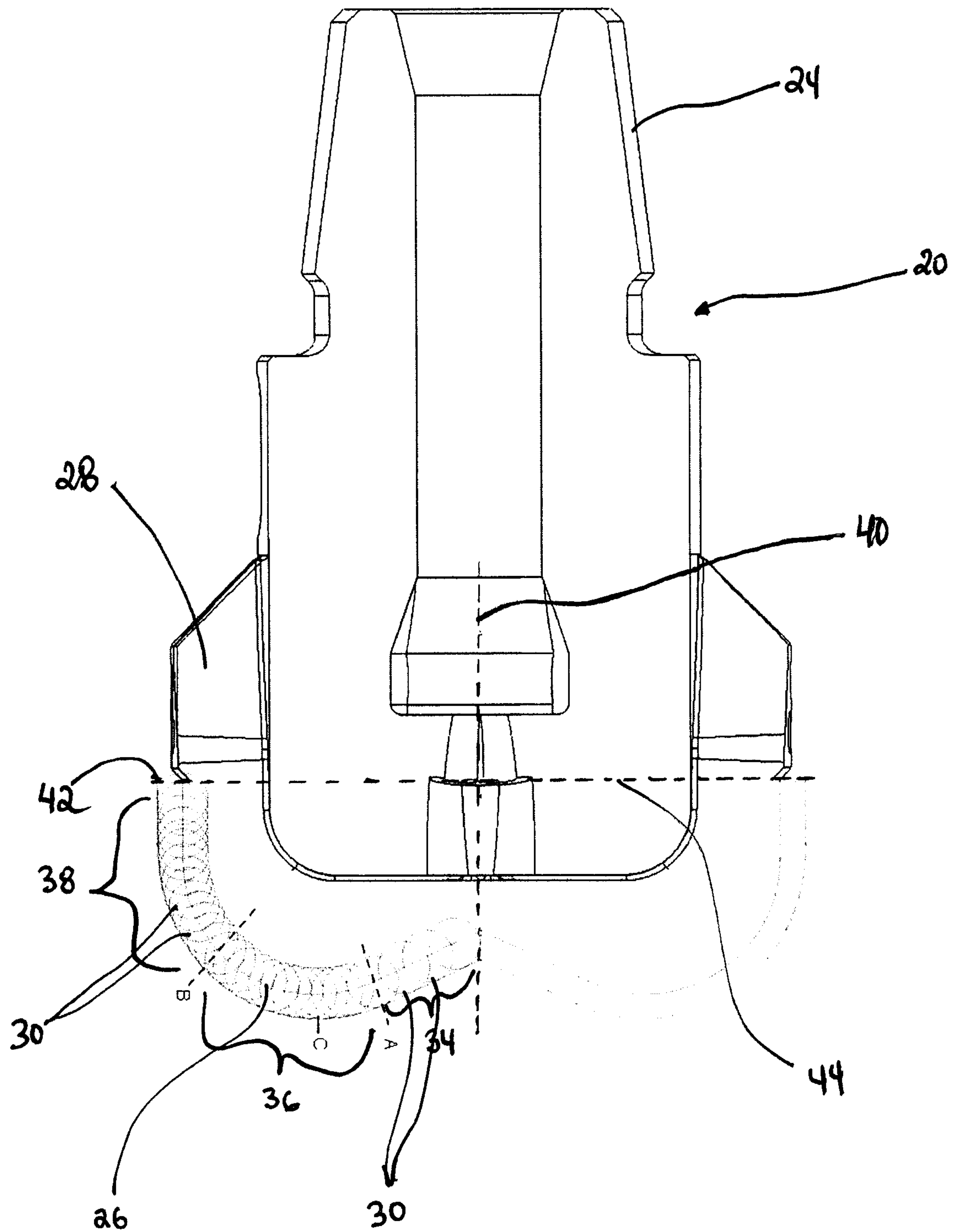


FIG. 5

