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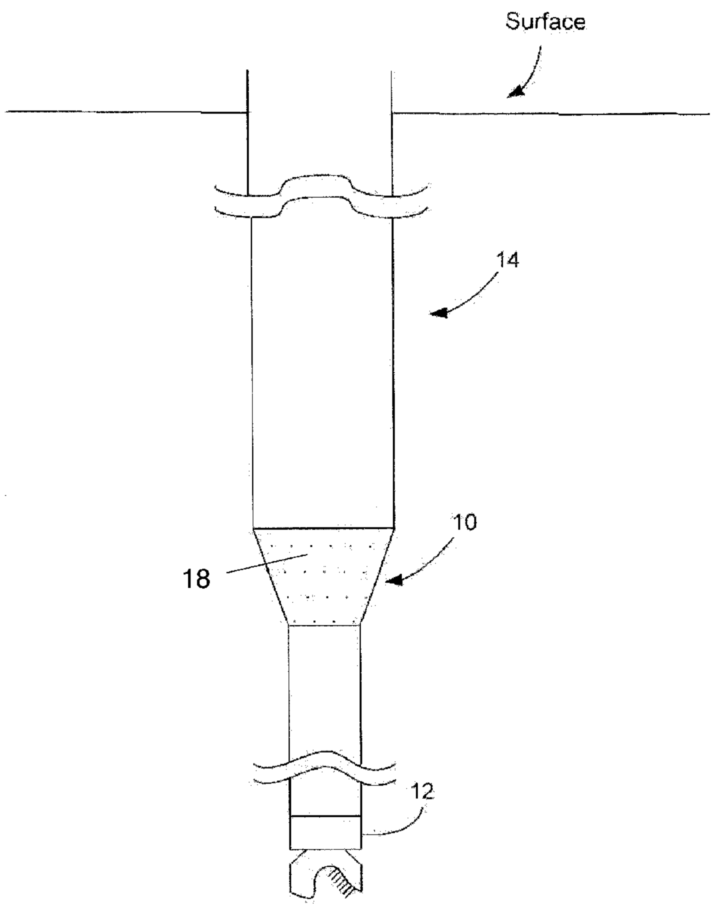
(54) Title: TAPERED REAMER BIT



(57) Abstract: A tapered reamer bit which achieves a reaming function at least in part by tension fracturing a geographic formation such that the resulting fragments of the formation are forced upward and/or backward and without relying on multiple rotatably positionable cylinders disposed on the reamer bit. Because of the tooth placement of the tapered reamer bit, a rotational force applied thereto results in a downward/forward force while reaming out a hole through a geographic formation.

WO 2007/115264 A2

TAPERED REAMER BIT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to and the benefit of the filing of U.S. Provisional Patent Application Serial No. 60/788,244, entitled "Tapered Reamer Drill Bit", filed on March 31, 2006, and the specification thereof is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention (Technical Field):

The present invention relates to downhole tools. Particularly, the present invention relates to a reamer bit which is capable of generating a downward/forward force from a rotational force. Accordingly, embodiments of the present invention can provide adequate downward/forward forces even with little force provided by the weight of a drill string.

Description of Related Art:

Note that the following discussion refers to a number of publications by author(s) and year of publication, and that due to recent publication dates certain publications are not to be considered as prior art vis-a-vis the present invention. Discussion of such publications herein is given for more complete background and is not to be construed as an admission that such publications are prior art for patentability determination purposes.

Reamer bits have been known and used for decades. U.S. Patent Publication No. 2006/0096788, by Virtanen, published May 11, 2006, discloses a conically-shaped reamer assembly wherein buttons disposed on a lower, outer, surface thereof help to guide the reamer within the pilot hole created by a pilot hole bit. Because it is desirable to provide a reamer with a self-advancing feature, so that less downward force is required to be exerted thereon, some known self-advancing reamer bits have been provided. U.S. Patent No. 4,000,783 to Hug, and U.S. Patent No. 4,031,974 to Peterson, for example, describe self-advancing reamer bits. These and other known self-advancing reamer bits, however, rely on a plurality of substantially cylindrically-shaped tooth-bearing members disposed in a conical formation. Such known self-advancing reamers have numerous setbacks and/or limitations. One of the primary problems of such known systems is that they employ numerous rotating members, the failure of any one of which can easily result in a significant delay in the drilling procedure, thus greatly enhancing the cost of the drilling procedure. Further, because the known self-advancing reamers rely on multiple rotatably positionable cylinders, each of which comprises multiple teeth disposed circumferentially therearound, the physical dimensions of such known self-advancing reamer bits thus precludes the construction of reamer bits comprising small diameters. Still further, because, one or more passageways must be provided for the drilling fluid or gas to be used in the drilling process, the physical dimensions of such known self-advancing reamer bits thus constricts the flow of such drilling fluids or gasses, thus resulting in lower flow rates and/or increased fluid or gas supply pressures, all of which are particularly undesirable.

There is thus a present need for a reamer bit which can provide a self-advancing feature without the inherent limitations associated with designs relying on multiple rotatably positionable cylinders.

BRIEF SUMMARY OF THE INVENTION

An embodiment of the present invention relates to a tapered reamer bit having a tapered outer surface, one or more teeth attached to the reamer bit at a pitch angle relative to a plane perpendicular to the axis of the reamer, the teeth attached to the reamer at a tilt such that the teeth are disposed at an angle relative to the normal of the outer surface of the tapered reamer bit. The pitch angle preferably comprises an angle of about 1° to about 15°, and more preferably from about 3° to about 8°.

The plurality of teeth can optionally comprise different pitch angles, and the pitch angles most preferably vary from about 3.6° to about 4° across a length of the tapered reamer bit. The angle relative to the normal preferably comprises an angle of about 5° to about 25°, and more preferably comprises an angle of about 10° to about 20°, and most preferably comprises an angle of about 15°.

One or more of the teeth preferably comprise a groove axially disposed along a length thereof. Each of the teeth preferably maintains a consistent distance from the other teeth when at rest and when in use.

An embodiment of the present invention relates to a self-advancing reamer bit which has a single, continuous, outer surface with a plurality of teeth protruding therefrom, the teeth disposed such that rotation of the reamer bit causes the teeth to exert an upward force on a material to be reamed, thus resulting in a downward force exerted on the reamer bit.

An embodiment of the present invention relates to a method for reaming a hole in a substrate or subsurface formation by rotating a reamer bit having a single, continuous outer surface with a plurality of teeth protruding therefrom and exerting an upward force on a subsurface formation with one or more of teeth until one or more fragments of the subsurface formation break free from the formation and are forced upwardly, thus producing a downward force on the reamer.

The method also preferably includes maintaining a consistent distance between each of the teeth. The teeth are preferably disposed at a plurality of pitch angles relative to a plane that is perpendicular to the axis of the reamer.

Objects, advantages and novel features, and further scope of applicability of the present invention will be set forth in part in the detailed description to follow, taken in conjunction with the accompanying drawings, and in part will become apparent to those skilled in the art upon examination of the following, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The accompanying drawings, which are incorporated into and form a part of the specification, illustrate one or more embodiments of the present invention and, together with the description, serve to explain the principles of the invention. The drawings are only for the purpose of illustrating one or more preferred embodiments of the invention and are not to be construed as limiting the invention. In the drawings:

Fig. 1A is a side view illustrating a tapered reamer bit in accordance with an embodiment of the present invention wherein the reamer bit is disposed within a well bore between a pilot bit and a drill string;

Fig. 1B is a cut-away side view illustrating a tapered reamer bit in accordance with an embodiment of the present invention;

Fig. 2 is drawing illustrating a flattened tooth placement map of a preferred embodiment of the present invention;

Fig. 3 is a drawing illustrating a tooth according to an embodiment of the present invention;

Figs. 4 and 5 are drawings illustrating alternative embodiments of teeth that can be used in accordance with an embodiment of the present invention wherein the teeth are illustrated at different stages of wear;

Fig. 6 is a drawing illustrating multiple configurations of some of the possible tooth configurations that can be used in accordance with the present invention;

Fig. 7 is a drawing illustrating an embodiment of the present invention wherein jetting ports are disposed near teeth; and

Fig. 8 is a graph illustrating one example of possible rates of penetration of the reamer bit for different revolutions per minute (RPM) for a selected group of spiral-pitch rates as determined by the tooth edge pitch angle and a hold back breaking action.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to a reamer bit, particularly to a reamer bit which converts a rotational force into a downward force based upon the type and placement of teeth disposed thereon.

The term "downward" as used throughout the specification and claims is used for the sake of simplicity and is not to be limited to only downward directions, but also includes any forward direction in which the drill collars and drill pipe and (sometimes referred to herein as "drill string") are intended to move (for example, including but not limited to horizontal and/or diagonal directions when drilling horizontally or in an off-set manner). Accordingly, the term "downward" can include any desired drilling direction. The term "upward" is hereby defined as a direction which is at least substantially the opposite of a "downward" direction.

Referring now to the Figures generally, and Fig. 1 particularly, tapered reamer bit **10** can preferably enlarge a drill hole created by pilot drill bit **12** and can provide a downward drilling force for the necessary weight-on-bit (WOB), to achieve a desired drilling rate-of-penetration (ROP). This downward force is preferably achieved while maintaining tension forces on drill string **14** above tapered reamer bit **10**. Accordingly, no compression forces from drill string **14** are necessarily required from the weight of the drill collars and drill pipe. This downward drilling force on pilot-hole drill bit **12**, as provided by tapered reamer bit **10**, provides particularly desirable results when drilling at or near horizontal or when drilling holes at relatively shallow depths where the weight of drill string **14** is not adequate to provide the necessary horizontal forward force on drill bit **12** to achieve a desired rate-of-penetration (ROP).

Although virtually any truncated cone shape can be used in the construction of tapered reamer bit **14**, long, tapered, truncated cone, **16** is most preferably provided. Fig. 2 illustrates a most preferred bit location for the large surface area of a most preferred tapered cone on which a very large number (for example, 161 teeth in the Fig. 2 example) of tension teeth **18** are disposed, most preferably in a removably positionable manner. Fig. 2 further illustrates a most preferred embodiment of the present invention wherein pitch angles for teeth **18** gradually range from 3.6° to about 4° down a length of tapered reamer bit **10.**

Fig. 3 illustrates front, top, and side-views of an example of a preferred embodiment for tension teeth **18** for insertion into tapered reamer bit **10** to achieve tension fracturing of drill chips from a tapered well-bore wall at the reamer surface. Groove **20** is preferably disposed within tension teeth **18**. In this embodiment, tooth 18 is preferably held in place with the use of a notch-shaped protrusion of tapered reamer bit 10 which notch-shaped protrusion interacts with groove 20 and thus prevents rotation of teeth 18 when in use. In a preferred embodiment of the present invention, each of teeth **18** also preferably comprise tip **22** which preferably comprises a hardened material. Fig. 4 illustrates a preferred wear pattern for this embodiment of tension teeth **18**.

Fig. 5 illustrates front, top, and side-views of several alternative embodiments of tension teeth **18** for use with tapered reamer bit **10**. Fig. 6 illustrates preferred wear patterns for a tension tooth having an angled upper portion.

The tension fracturing provided by tapered reamer bit **10**, is preferably achieved by setting the edge of each tooth **18** at a pitch angle of about 1° to about 15° and most preferably at a pitch angle of about 3° to about 8° relative to a plane perpendicular to the axis of tapered reamer bit **10**. Also, while virtually any range of revolutions per minute (RPM) of reamer bit **10** can provide desirable results, a normal range of rotation speeds typically used in conjunction with typical reamer bits is most preferably maintained. At the edge of tooth **18**, the pitch angle provided enables the edge of tooth **18** to grip the tapered well-bore wall and push a fragment of rock upward, until the fragment breaks away due to tension fracturing and/or shearing. The upward force that teeth **18** apply to the well-bore wall to create chip tension fracturing preferably results in an equal and opposite downward force applied to each of teeth **18** and thus to tapered reamer bit **10**.

As best illustrated in Fig. 4, in addition to a pitch angle of about 1° to about 15° and most preferably at a pitch angle of about 3° to about 8° relative to a plane perpendicular to the axis of tapered reamer bit **10**, tooth **18** is also preferably tilted relative to the normal of an outer surface of tapered reamer bit **10** by about 5° to about 25°, and more preferably by about 10° to about 20°, and most preferably by about 15°. This tilt preferably presents the sharp edge of tooth **18** to the bore surface at substantially all times, until tooth **18** has completely worn away its sharp edge. Providing a tilt to tooth **18** of about 5° to about 25°relative to the normal of an outer surface of tapered reamer bit **10** provides a much longer usefully tooth life because the sharp edge is worn incrementally and not all at once. Tooth **18** can be made from a variety of hard and tough materials known to those skilled in the art to provide the best performance for a given drilling application.

The sum total of the downward forces on all of teeth **18** of reamer bit **10** preferably results in a substantial downward force on tapered reamer bit **10** as well as drill string **14** connected thereto and to any pilot bits and/or down-hole tools connected to drill string **14** or to tapered reamer bit **10**. The downward force generated by tapered reamer bit **10** can optionally be diminished by a driller or by a drilling automation/computer system, by applying a hold-back breaking action to drill string **14** at the drill-site, thus achieving a most preferred net downward force applied to the bottom-hole drilling assembly and/or pilot-hole drill bit **12**.

In one embodiment, a series of tapered reamer bits of the present invention, each with a variation of the drill-tooth edge pitch angle and tooth shape, is optionally supplied by the reamer bit manufacturer so that a driller can select the most favorable reamer bit design for the type of material being drilled.

In an alternative embodiment of the present invention, a mechanism for adjusting the tooth pitch angle either subsurface while drilling or at the surface on the drill site is preferably provided. In one embodiment wherein the pitch angle of the teeth is adjustable while drilling, each adjustable tooth is preferably mounted on a fixture that is free to rotate through a limited angle. One or more mechanical linkages preferable connect the adjustable teeth. An electric motor or actuator, hydraulic motor or actuator, or pneumatic motor or actuator is preferably disposed within or near the reamer bit and is preferably selectively activated such that it is able to move the linkage and thus rotate the teeth a desired quantity as can optionally be determined by the control system.

Alternatively, the pitch angle of the teeth on the reamer bit can be adjusted downhole so that the bit creates an upward force on the reamer, instead of a downward force, as it rotates in a downward direction to enable the bit to cut its way out of the hole when the drill string is being withdrawn from the hole.

In an embodiment of the present invention wherein the pitch angle of the teeth is adjustable when the reamer bit is accessible at a surface location of a drill site, each adjustable tooth is preferably mounted on a plate or other similar structure that is free to rotate through a limited angle. One or more mechanical linkages preferably connect the adjustable teeth. In this embodiment, a mechanical adjustor is preferably unlocked and adjusted to move the linkage to rotate the teeth the desired amount. In an alternative embodiment wherein the pitch angle of the teeth is adjustable when the reamer bit is accessible at a surface location of a drill site, each tooth is preferably mounted on a fixture that is free to rotate through a limited angle. In this embodiment, after unlocking the tooth locking mechanism, each tooth is preferably individually adjustable in angle.

In an alternative embodiment of the invention, the cutting edge of the teeth are preferably configured such that the reamer bit can be operated in reverse rotation, with a mud turbine or mud motor, for example, to cut its way out of the rock as it reverses out of the hole, thus preventing the reamer bit from becoming jammed in the hole.

The need for durable and rugged construction of drill bits, reamer bits, and bottom-hole drilling assemblies favors the selection of reamer bits from a multiplicity of reamer bits with the desired pitch angles established by a manufacturer during factory production. In a preferred embodiment, illustrated in Fig. 7, tapered reamer bit **10** preferably comprises passages and jets **24** for drilling fluid to provide jetting at or near teeth **18** to clean solids out from between teeth **18**. In addition, embodiments of the tapered reamer bit of the present invention can optionally incorporate a multiplicity of types of teeth to accomplish multiple functions on the same bit, combining, for example, cutting teeth and grinding teeth on the same bit.

Typically, the primary variables, which are most easily controlled by a driller to optimize the drilling rate, are the control of drill-bit RPM and the downward force on the drill bit provided by a holdback braking action. When tapered reamer bit **10** is used in a shallow location, or when used in a substantially non-vertical orientation which locations and orientations provide a less-than-desired downward force on a bit, a driller is preferably able to adjust the downward force on the bit by adjusting the rotation speed and/or the holdback braking. This is because the net downward force created by tapered reamer bit **10** is a combination of the downward force generated by the teeth interacting with an interior of the well-bore surface, plus the downward force generated by the weight of the drill string, minus the driller-controlled, hold-back braking action.

Fig. 8 illustrates the drilling rate-of-penetration (ROP) as a function of reamer-bit RPM (rate-of-rotation) for each of several spiral-pitch rates as determined by the reamer-tooth-edge pitch angle and the driller's hold-back braking action. Although the pitch angle of each tooth relative to a plane perpendicular to the axis of the tapered reamer bit are related to a spiral angle of the reamer bit in general, because the teeth not only pull the reamer bit downward, but also fracture and force upward fragments of the material being reamed, the pitch angle of each tooth is not necessarily equal to the spiral angle of the reamer bit in general. And the magnitude of the deviation between the tooth pitch angle and the spiral angle of the reamer bit will necessarily vary to a greater or lesser degree depending upon the physical characteristics of different material to be reamed. Note that in Fig. 8 *can range from about* 0.5° *to about* 2.0°, and most preferably *about* 0.5° *to about* 1.0°, whereas the reamer-tooth-edge pitch angle of the reamer bit, preferably selected by the driller from a drill-site consignment inventory can range from about 1° to 20° and more preferably from about 3° to about 8°. The driller's selection of the reamer bit with the best tooth design and edge pitch angle from a drill-site bit inventory will determine the spiral-pitch penetration rate in revolutions per inch, as illustrated in Fig. 8 and the consequent rate-of-penetration (ROP) as a function of RPM and the material to be reamed.

Those skilled in the art will readily recognize that the tapered reamer bit of the present invention can be constructed to any desired size such that any size of pilot hole can be reamed to any desired diameter. Often, however, the tapered reamer bit of the present invention will be constructed to have outer dimensions which enable it to enlarge a pilot hole from about 8.5" in diameter to about 12.25" in diameter.

The subject invention can be used with rigid drill pipe where the entire drill string is rotated from the surface by a top-drive, kelly, or similar rotation mechanism. The subject invention can also be used with a downhole rotary mechanism such as a mud motor or mud turbine that is fastened on non-rotating (or rotating) drill pipe or flexible tubing and the rotation is then provided by the downhole mudmotor, mud turbine, or other rotationally motive force

Although the invention has been described in detail with particular reference to these preferred embodiments, other embodiments can achieve the same results. Variations and modifications of the present invention will be obvious to those skilled in the art and it is intended to cover in the appended claims all such modifications and equivalents. The entire disclosures of all references, applications, patents, and publications cited above and/or in the attachments, and of the corresponding application(s), are hereby incorporated by reference.

CLAIMS

What is claimed is:

1. A tapered reamer bit comprising:

a tapered outer surface;

one or more teeth attached to said reamer bit at a pitch angle relative to a plane perpendicular to an axis of said reamer bit;

said teeth attached to said reamer bit at a tilt such that said teeth are disposed at an angle relative to a normal of said outer surface of said tapered reamer bit.

2. The tapered reamer bit of claim 1 wherein said pitch angle comprises an angle of about 1° to about 15°.

3. The tapered reamer bit of claim 2 wherein said pitch angle comprises an angle of about 3° to about 8°.

4. The tapered reamer bit of claim 1 wherein a plurality of said teeth comprise different pitch angles.

5. The tapered reamer bit of claim 4 wherein said pitch angles vary from about 3.6° to about 4° across a length of said tapered reamer bit.

6. The tapered reamer bit of claim 1 wherein said angle relative to a normal comprises an angle of about 5° to about 25°.

7. The tapered reamer bit of claim 6 wherein said angle relative to a normal comprises an angle of about 10° to about 20°.

8. The tapered reamer bit of claim 7 wherein said angle relative to a normal comprises an angle of about 15°.

9. The tapered reamer bit of claim 1 wherein one or more of said teeth comprise a groove axially disposed along a length thereof.

10. The tapered reamer bit of claim 1 wherein each of said teeth maintains a consistent distance from the other teeth when at rest and when in use.

11. A self-advancing reamer bit comprising:

a single, continuous, outer surface with a plurality of teeth protruding therefrom;

said teeth disposed such that rotation of said reamer bit causes teeth to exert an upward force on a material to be reamed, thus resulting in a downward force exerted on said reamer bit.

12. The tapered reamer bit of claim 11 wherein said teeth protrude from said reamer bit at a pitch angle relative to a plane perpendicular to an axis of said reamer.

13. The tapered reamer bit of claim 12 wherein said pitch angle comprises an angle of about 1° to about 15°.

14. The tapered reamer bit of claim 13 wherein said pitch angle comprises an angle of about 3° to about 8°.

15. The tapered reamer bit of claim 12 wherein a plurality of said teeth comprise different pitch angles.

16. The tapered reamer bit of claim 15 wherein said pitch angles varies from about 3.6° to about 4° across a length of said tapered reamer bit.

17. The tapered reamer bit of claim 11 wherein said teeth are at an angle relative to a normal of said outer surface of said reamer bit.

18. The tapered reamer bit of claim 17 wherein said angle comprises an angle of about 5° to about 25°.

19. The tapered reamer bit of claim 17 wherein said angle relative to the normal comprises an angle of about 10° to about 20°

20. The tapered reamer bit of claim 19 wherein said angle relative to the normal comprises an angle of about 15°.

21. A method for reaming a hole in a subsurface formation comprising:

rotating a reamer bit comprising a single, continuous outer surface with a plurality of teeth protruding therefrom; and

exerting an upward force on a subsurface formation with one or more of teeth until one or more fragments of the subsurface formation break free from the formation and are forced upwardly, thus producing a downward force on the reamer.

22. The method of claim 21 comprising maintaining a consistent distance between each of the teeth.

23. The method of claim 21 comprising disposing the teeth at a plurality of pitch angles relative to a plane that is perpendicular to the axis of the reamer.

24. The method of claim 21 composing disposing the teeth at one or more angles relative to a normal of the outer surface of the reamer bit.

25. The method of claim 23 wherein at least one of the pitch angles comprises an angle of about 1° to about 15°.

26. The method of claim 25 wherein at least one of the pitch angles comprises an angle of about 5° to about 25°.

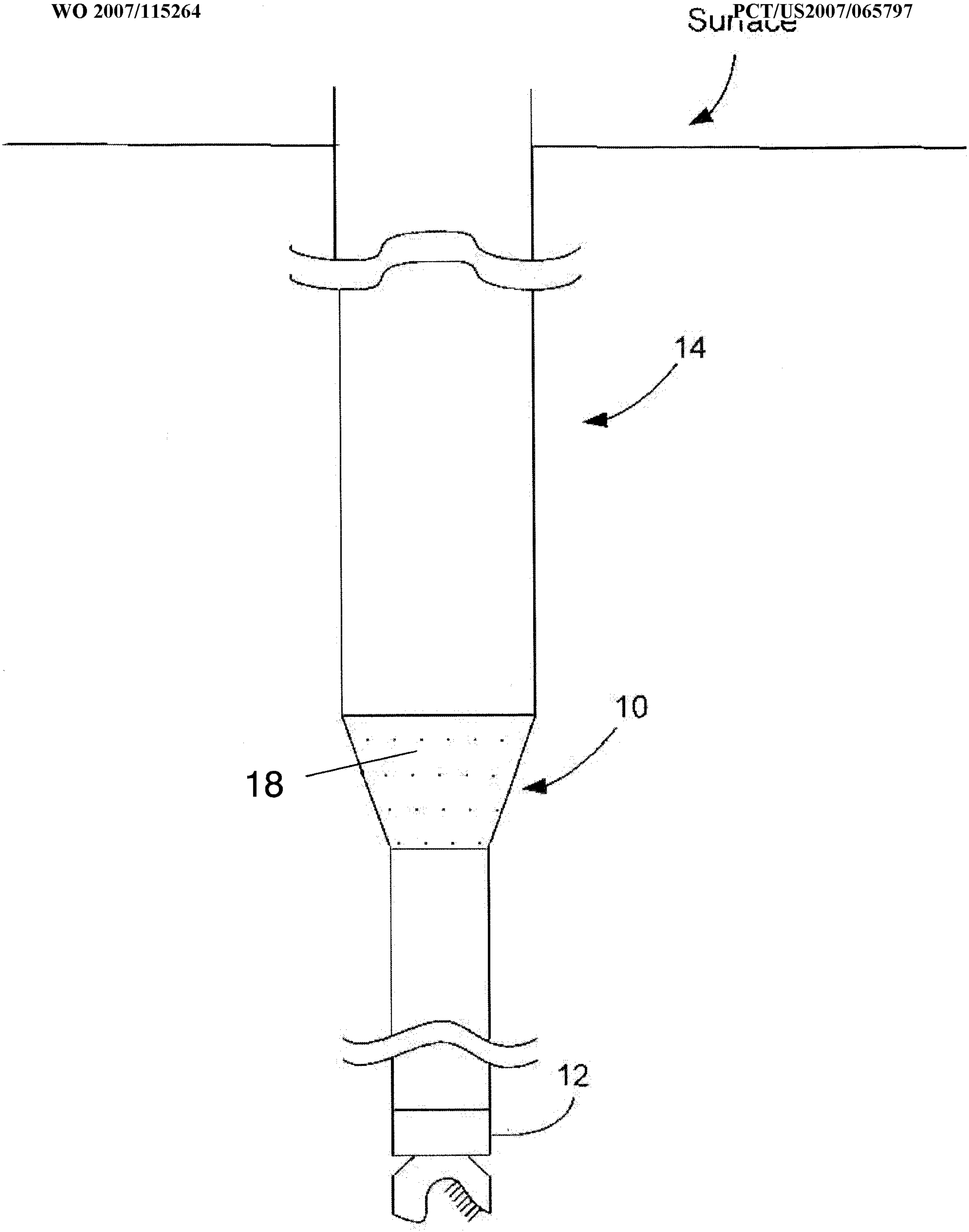


Fig. 1A

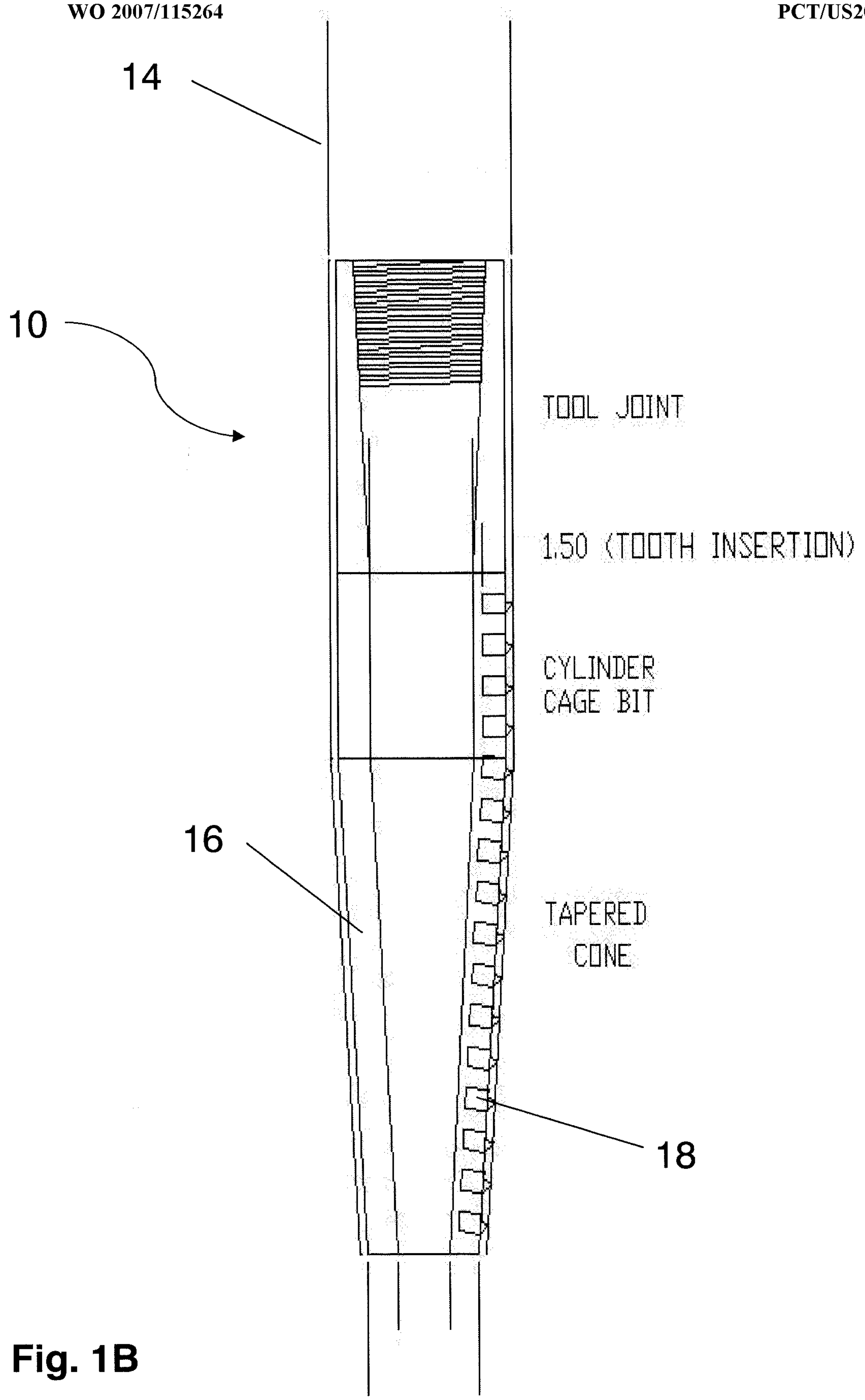

14
10
TOOL JOINT
1.50 (TOOTH INSERTION)
CYLINDER
CAGE BIT
16
TAPERED
CONE
18

Fig. 1B

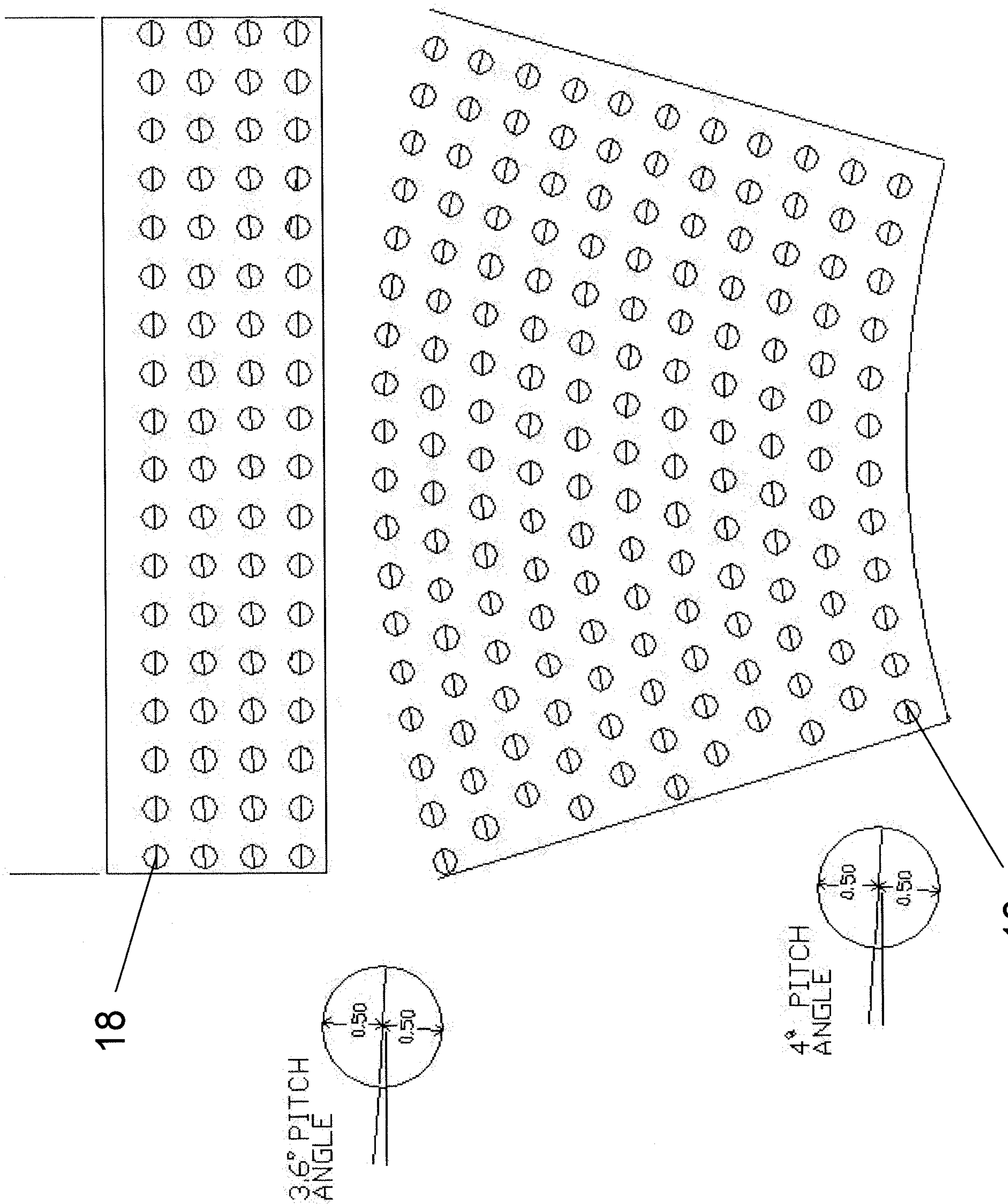


Fig. 2

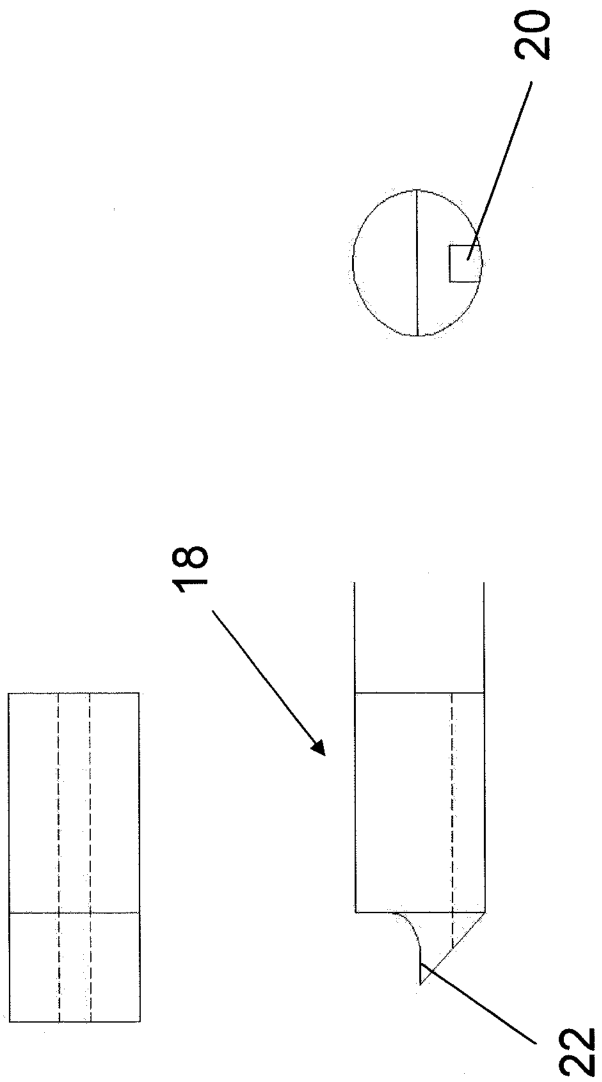


Fig. 3

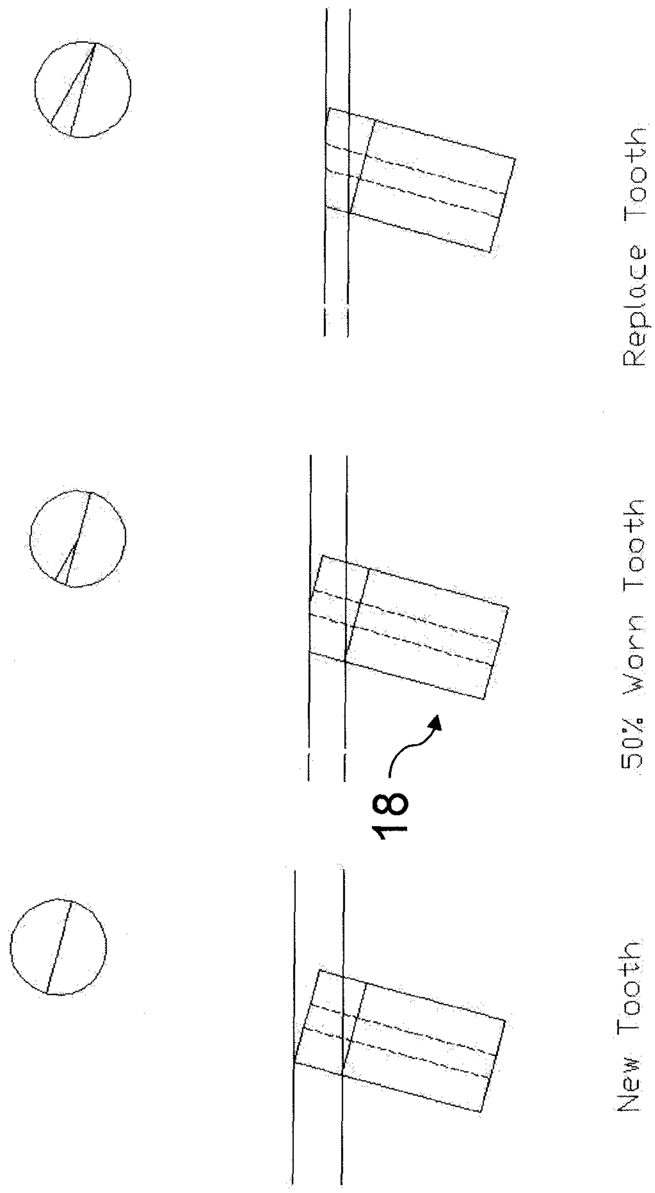


Fig. 4

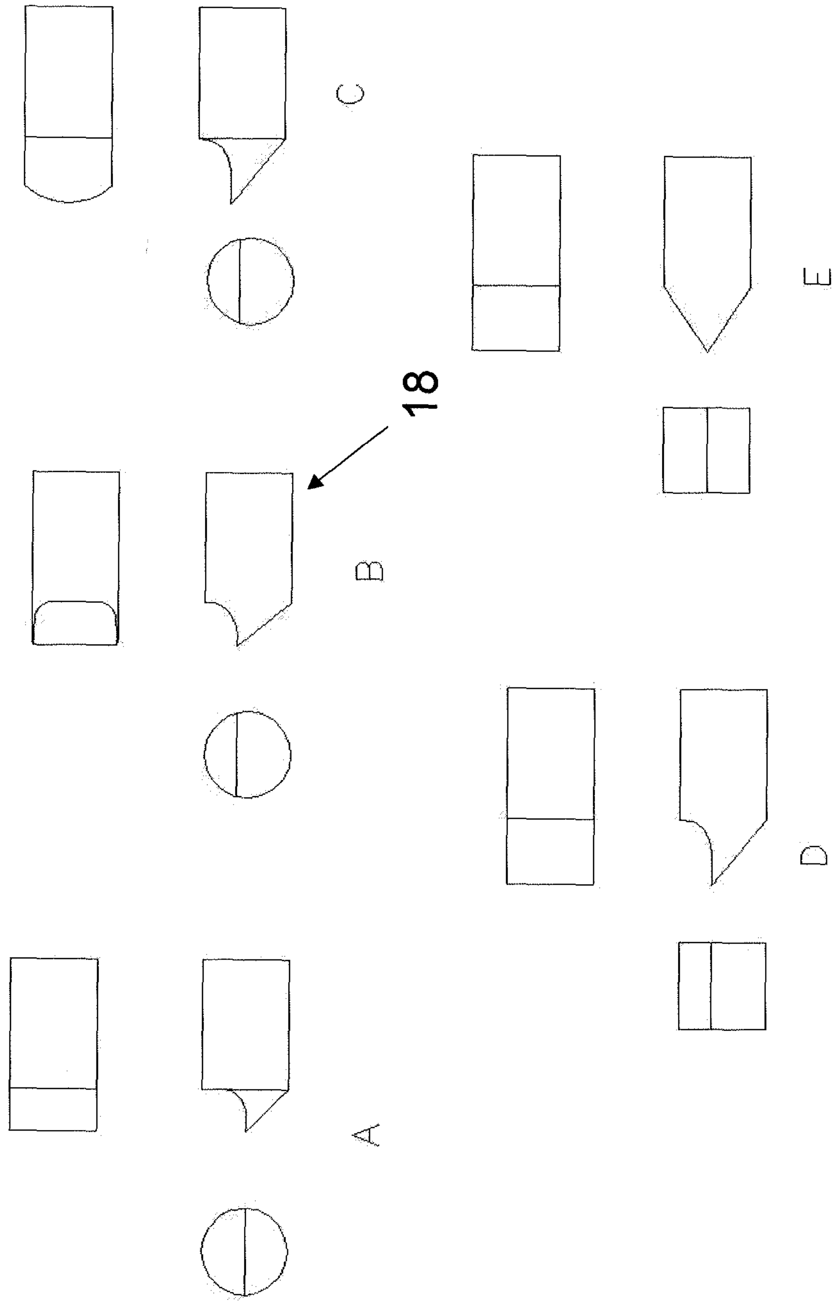


Fig. 5

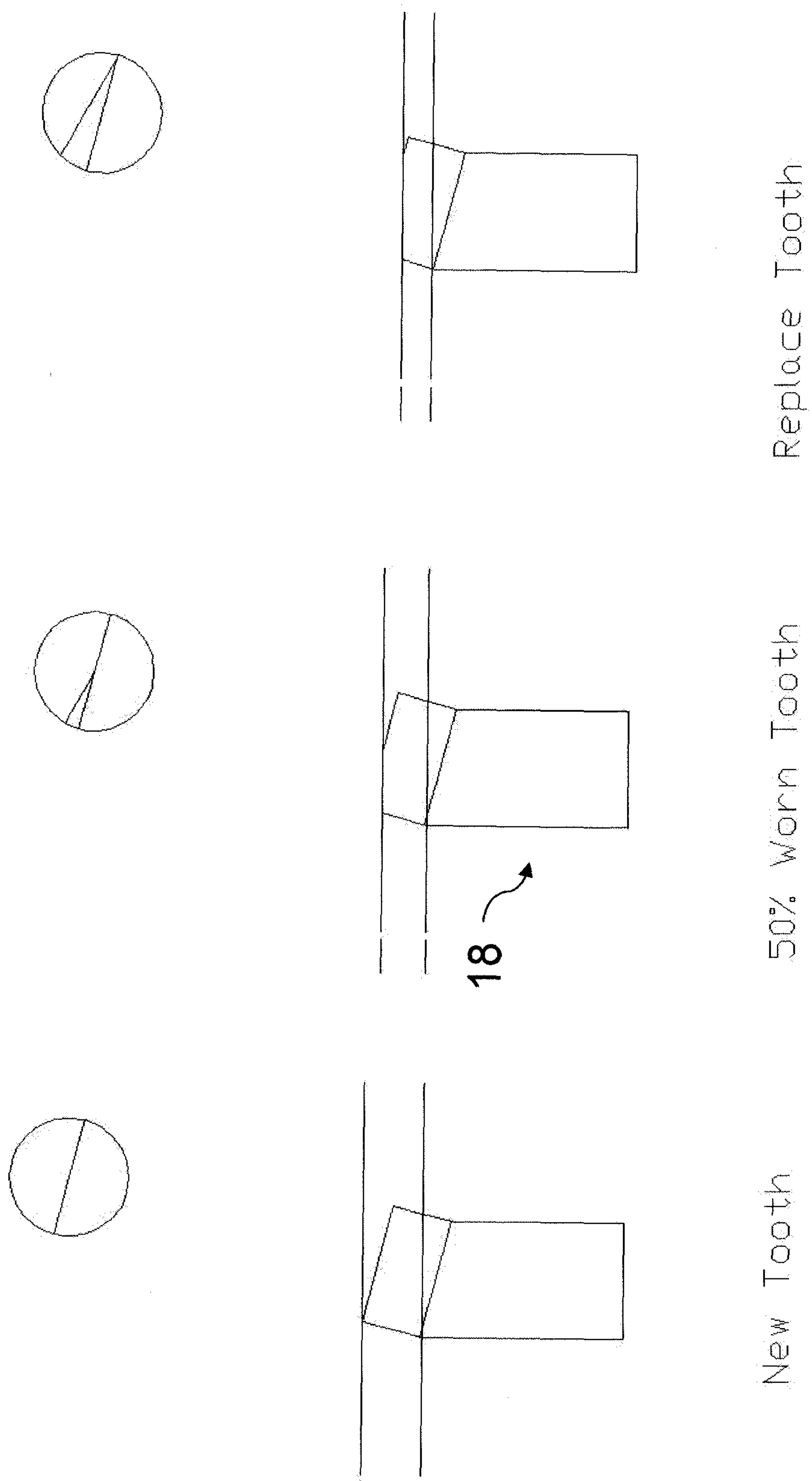


Fig. 6

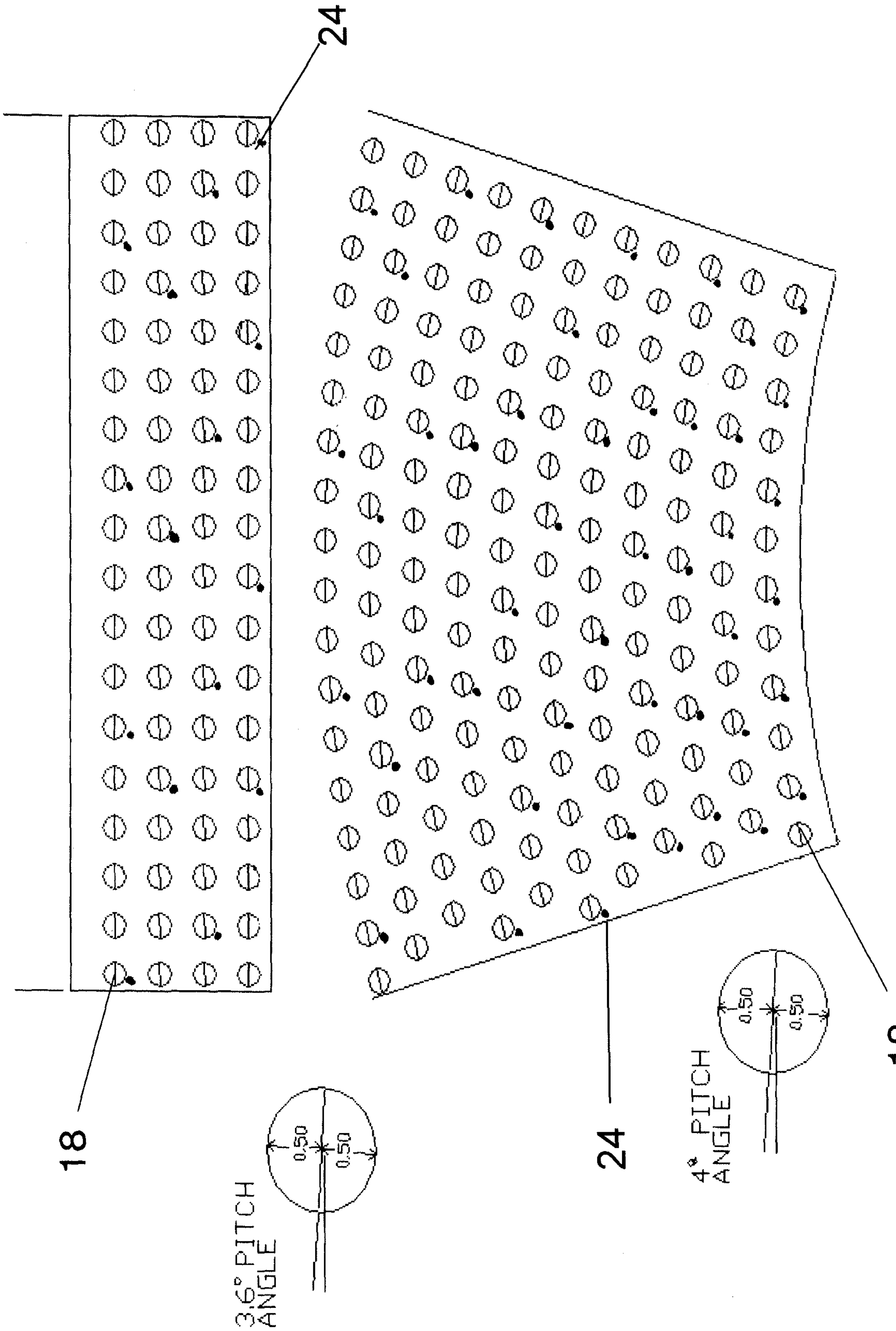


Fig. 7

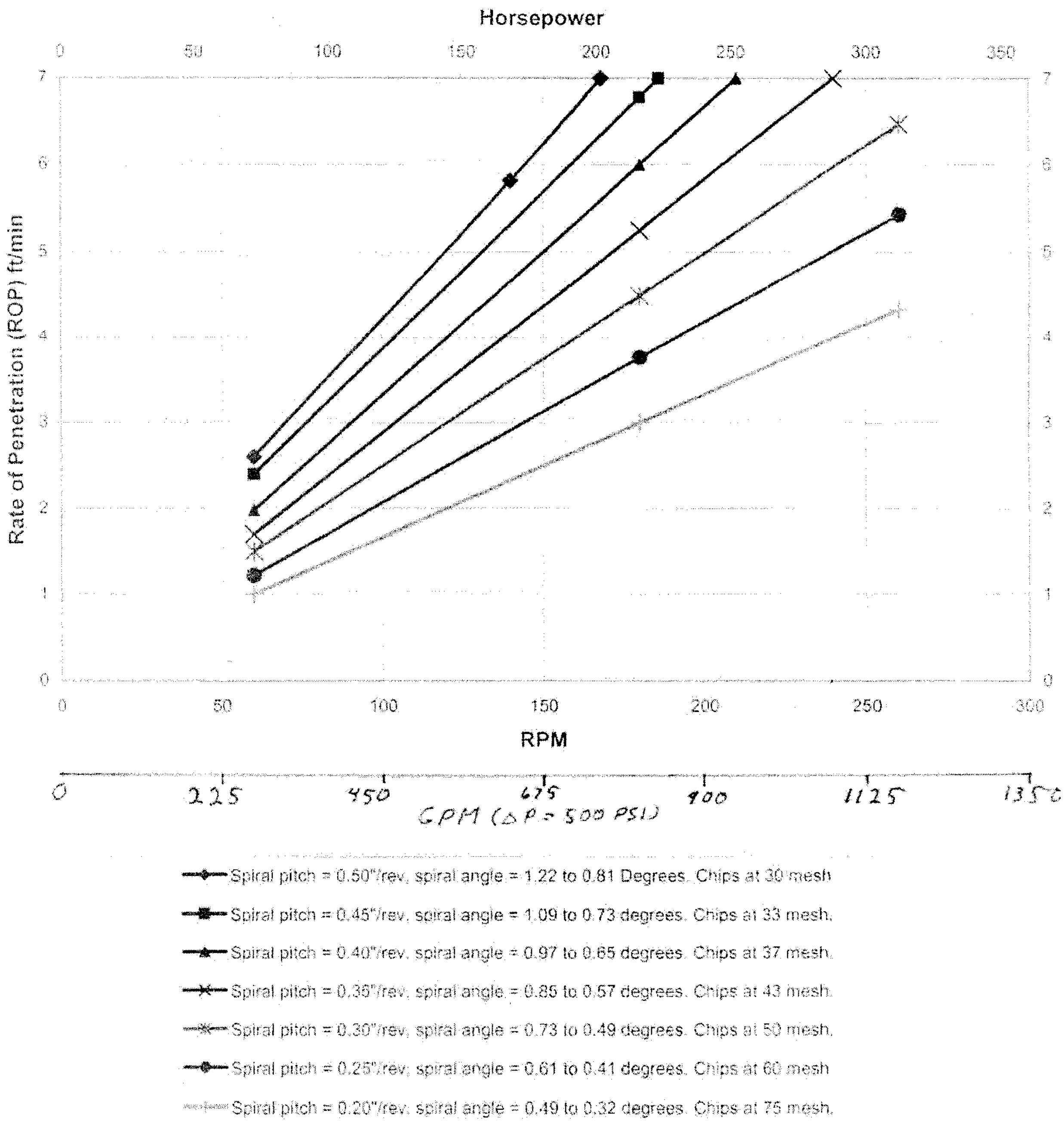

Horsepower
0
50
100
150
200
250
300
350
Rate of Penetration (ROP) ft/min
0
1
2
3
4
5
6
7
RPM
0
50
100
150
200
250
300
0
225
450
675
900
1125
1350
GPM (ΔP = 500 PSI)
Spiral pitch = 0.50"/rev, spiral angle = 1.22 to 0.81 Degrees. Chips at 30 mesh
Spiral pitch = 0.45"/rev, spiral angle = 1.09 to 0.73 degrees. Chips at 33 mesh.
Spiral pitch = 0.40"/rev, spiral angle = 0.97 to 0.65 degrees. Chips at 37 mesh.
Spiral pitch = 0.35"/rev, spiral angle = 0.85 to 0.57 degrees. Chips at 43 mesh.
Spiral pitch = 0.30"/rev, spiral angle = 0.73 to 0.49 degrees. Chips at 50 mesh.
Spiral pitch = 0.25"/rev, spiral angle = 0.61 to 0.41 degrees. Chips at 60 mesh
Spiral pitch = 0.20"/rev, spiral angle = 0.49 to 0.32 degrees. Chips at 75 mesh.

Fig. 8