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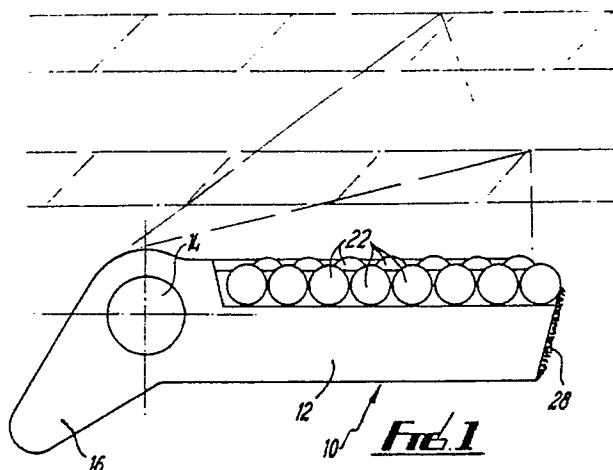
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54 **Casing cutters.**

57 There is described a casing cutter of the type having a pivotable milling arm which pivots outwards to trace a substantially conical path during rotation of the cutter. The milling arm is provided with an effective cutting edge which has an offset with respect to a notional axial reference line of the arm which passes through the pivot axis of the arm. The offset of each cutting edge is a distinct combination of circumferential offset and radial offset from the notional axial reference line so that a different effective cutting edge is presented to the casing to be cut when the cutter is used to cut a plurality of concentric casings of different diameters.



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Casing Cutters

This invention relates to casing cutters.

Hydrocarbon wells are commonly lined with steel tubing known as casing. Casing normally has one of a number of standardised internal diameters. At any given depth in a lined hydrocarbon well, there may be a single casing, or two or more concentrically nested casings of different diameters. On occasion, it may be necessary to sever installed casing, for example to enable its removal from the well. Cutters have been developed in the form of a tool rotated by a string to cut casing by milling action. Such a tool consists of three arms which can be pivoted outwards (like umbrella ribs) under the control of mud pressure in the string, so as to bear against the casing. The arms are coated with particles of tungsten carbide (secured by brazing) and mill through the casing as the tool is rotated by turning the string. However, when cutting through two or more nested casings at a given depth, such a tool requires to be pulled after cutting through an individual casing, and re-equipped with fresh milling arms. This procedure provides fresh cutting edges for each casing, but at the economic cost of having to trip between the successive cuttings of the concentric casings, and of also having to provide a set of new milling arms (or a complete replacement tool) for each casing. It is therefore an object of the invention to provide a casing cutter which obviates or mitigates these disadvantages.

According to a first aspect of the present invention there is provided a casing cutter of the type comprising at least one milling arm which in use pivots outwards of the cutter about a pivot axis to trace a substantially conical path during rotation of the cutter about a rotation axis, the cone angle of the conical path with respect to the rotation axis increasing with increasing diameter of a casing being cut in use of the cutter, the or each milling arm having a plurality of effective cutting edges each having a respective offset with respect to a notional axial reference line of the arm which passes through the respective pivot axis of that arm, the offset of each effective cutting edge being a distinct combination of circumferential offset and radial offset from the respective notional axial reference line whereby a different effective cutting edge is presented to each casing when the cutter is in use to cut a plurality of concentric casings of different diameters.

Each effective cutting edge may be a substantially continuous cutting edge, or each effective cutting edge may comprise a relatively large number of relatively small individual cutters mounted in a row to present respective individual cutting edges

which collectively form the effective cutting edge. The effective cutting edge may be substantially linear.

The casing cutter preferably has three milling arms which are preferably symmetrically arranged on the cutter. The pivot axes of the milling arms are preferably each tangential to a common circle co-axial with the rotation axis of the cutter. The cutter may contain a piston which is axially movable in response to hydraulic pressure within a string of which the cutter forms part in use of the cutter, the piston linking with each milling arm such that axial movement of the piston in one direction forces each milling arm to pivot outwards in concert.

In the preferred form of cutter wherein the pivot axes are tangential to a common circle, the notional axial reference line of each arm will not only pass through the respective pivot axis, but can also be selected to pass through the rotation axis of the cutter by being positioned to be coincident with the point of tangency of the pivot axis with the common circle. The reference lines of each arm will coincide on the rotation axis if each arm is pivoted outwardly of the cutter by an equal angle. With respect to such a selected notional axial reference line, the effective cutting edges of each arm are preferably each parallel but otherwise asymmetrical whereby the respective offset of each effective cutting edge on a given arm has the requisite distinction from the offset of each other effective cutting edge on that arm.

According to a second aspect of the present invention there is provided a milling arm for adapting a casing cutter to form a casing cutter in accordance with the first aspect of the invention, the milling arm being as defined in any of the preceding paragraphs relating to the first aspect of the invention.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

Fig. 1 is a side elevation of a first form of milling arm for use in a casing cutter in accordance with the invention;

Fig. 2 is a front elevation of the first form of milling arm as shown in Fig. 1;

Fig. 3 is two end elevations of the first form of milling arm as shown in Fig. 1;

Fig. 4 is a side elevation of a second form of milling arm for use in a casing cutter in accordance with the invention;

Fig. 5 is a front elevation of the second form of milling arm as shown in Fig. 4;

Fig. 6 is three end elevations of the second

form of milling arm as shown in Fig. 4; and

Fig. 7 is a half-sectioned elevation of a known form of casing cutter which can readily be modified to form a casing cutter in accordance with the invention.

Referring first to Figs. 1 and 2, the first form of milling arm 10 in accordance with the invention comprises a body 12 which incorporates and extends radially away from an integral pivot bore 14. The arm 10 also integrally incorporates a spur-like heel 16 which extends generally away from the body 12. In use of the arm 10, it will be mounted (in a symmetrical array along with (usually) two other identical such arms) on a respective pivot pin (not shown) passing through the pivot bore 14 on a pivot axis which is tangential to a circle centered on the rotational axis of the cutter as a whole. The heel 16 will lie inboard of the pivot bore 14 (radially inwards in the cutter) when the body 12 is fully retracted into the cutter to lie with its long axis generally parallel to the rotation axis of the cutter, and downward of the pivot bore 14.

When the tip of the heel 16 is pressed downwards, the body 12 will tend to pivot outwards of the cutter around the axis of the pivot bore 14 so as to bring the outer face of the body 12 into contact with the inner surface of a surrounding casing. The outer face of the body 12 carries two rows 18 and 20 of tungsten carbide "buttons" or frusto-conical inserts 22. Each of the rows 18 and 20 is formed by a respective channel milled longitudinally in the outer face of the body 12 (see especially the lower end view in Fig. 3). The inserts 22 are secured in the respective channels to the body 12 by brazing. Although each individual insert 22 presents only part of its larger circular edge as a cutting edge in use of the milling arm 10, the inserts 22 in each of the rows 18 and 20 collectively form a respective cutting edge which is substantially a straight line in its effect (analogous to the manner in which the variously profiled and set teeth of a hacksaw blade together form an effectively straight cutting edge).

Of particular significance is the fact that the rows 18 and 20 are asymmetrically arrayed on the body 12 (see especially Figs. 2 and 3). Considering a hypothetical reference line running along the length of the body 12 through the middle of its transverse section and selected so as to intersect the axis of the pivot bore 14 at right angles, it will be seen that the two effective cutting edges formed by the rows 18 and 20 of carbide buttons 22 are each parallel to this selected reference line, but with different offsets from the selected reference line. In particular, the effective cutting edge formed by the row 18 (see Fig. 3) is marginally radially inwards of the effective cutting edge formed by the row 20, but the edge formed by the row 18 is

circumferentially (or angularly) at a greater distance from the selected reference line than is the edge formed by the row 20. (Note that the terms "radial" and "circumferential" relate to these effective cutting edges when the casing cutter is fully assembled with the milling arms symmetrically mounted and fully retracted so that the selected reference lines lie parallel to the rotation axis of the cutter). Thus the effective cutting edge of the row 18 stands proud of the milling arm 10 when the arm 10 is at zero and low pivot angles relative to the casing cutter (as will be the situation when cutting smaller diameter casing) but the effective cutting edge of the row 20 will stand proud of the arm 10 at higher pivot angles (as will be the situation when cutting larger diameter casing). This changeover is illustrated as occurring from lower to upper views in Fig. 3.

The placement of the rows 18 and 20 on the milling arm 10 can be designed so that the changeover between instantaneously effective cutting edges occurs at an arm pivot angle corresponding to a diameter intermediate standard casing diameters, as is schematically illustrated in Fig. 1. Such a placement of the rows 18 and 20 will result in only one effective cutting edge being presented to cut an inner casing of two concentric casings, with a changeover to the other and hitherto unused effective cutting edge when cutting the outer casing of the two concentric casings. This results in improved cutting efficiency, and faster cutting of multiple casing. (These advantages are at least partially retained even if the nested and nominally concentric casings are in fact substantially eccentric).

Correctness of this design consideration (changeover of cutting edges between casing diameters) can be checked by ensuring that the plane formed by the locus of points equidistant from the two effective cutting edges intersects the plane including the selected reference line and the rotation axis of the cutter at a line which lies intermediate the lines corresponding to the lesser and greater diameters (respectively denoted as the points 24 and 26 in Fig. 3 where the aforementioned planes and lines appear as lines and points respectively owing to the effectively transverse sectional nature of Fig. 3 with respect to the foregoing three dimensional geometric analysis).

Different forms of design (and correspondingly different methods of checking their correctness) would apply if the effective cutting edges were not parallel to the selected reference line, or were not effectively straight over their entire length.

The outboard end of the body 12 (remote from the pivot bore 14) can be coated with a brazed-on layer 28 of tungsten carbide particles.

The inventive principle of providing the milling

arms with multiple cutting edges so arranged that a different cutting edge presents to each casing of a different diameter can be extended from the two-edges form of milling arm shown in Figs. 1 to 3 to a three-edges form of milling arm as shown in Figs. 4, 5, and 6. The three-edged form of milling arm differs fundamentally from the two-edged form only in that three rows of tungsten carbide inserts are brazed into respective channels in the outer face of the milling arm. The channels are differently offset such that the three effective cutting edges present in turn to casings of three different diameters, as shown in Fig. 6.

Fig. 7 is a half-sectioned longitudinal view of a known form of casing cutter, being the multi-string cutter of Tri-State Oil Tool Industries Inc. as described in their Manual No. 7008 of April 1985. This multi-string cutter has three so-called "knives" 30 which are pivoting arms whose outer edges are coated with a layer of brazed-on tungsten carbide particles. To modify this known form of casing cutter to provide a casing cutter in accordance with the invention, each of the three knives of the cutter is replaced by a milling arm, either as described above in Figs. 1 to 3 or in Figs. 4 to 6, or designed in accordance with the principles described above.

Thus, the milling arms in accordance with the invention can be manufactured by simple, standard procedures, and the casing cutters in accordance with the invention can be provided by a simple adaptation of existing casing cutters.

While certain modifications and variations of the invention have been described above, the invention is not restricted thereto, and other modifications and variations can be adopted without departing from the scope of the invention.

Claims

1. A casing cutter of the type comprising at least one milling arm which in use pivots outwards of the cutter about a pivot axis to trace a substantially conical path during rotation of the cutter about a rotation axis, the cone angle of the conical path with respect to the rotation axis increasing with increasing diameter of a casing being cut in use of the cutter, the or each milling arm having a plurality of effective cutting edges each having a respective offset with respect to a notional axial reference line of the arm which passes through the respective pivot axis of that arm, the offset of each effective cutting edge being a distinct combination of circumferential offset and radial offset from the respective notional axial reference line whereby a different effective cutting edge is presented to each casing when the cutter is in use to cut a plurality of concentric casings of different diameters.

2. A casing cutter as claimed in Claim 1, wherein each effective cutting edge is a substantially continuous cutting edge.

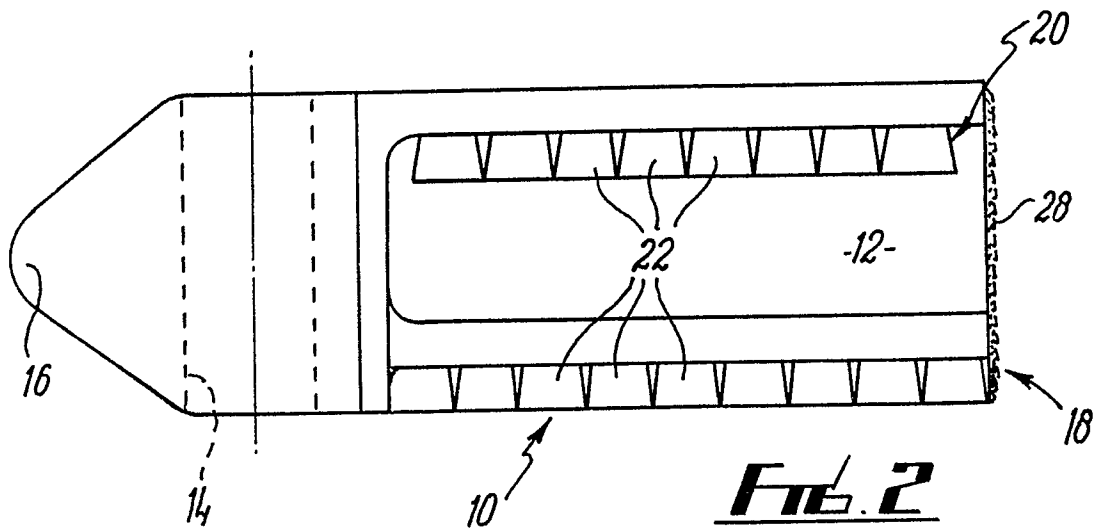
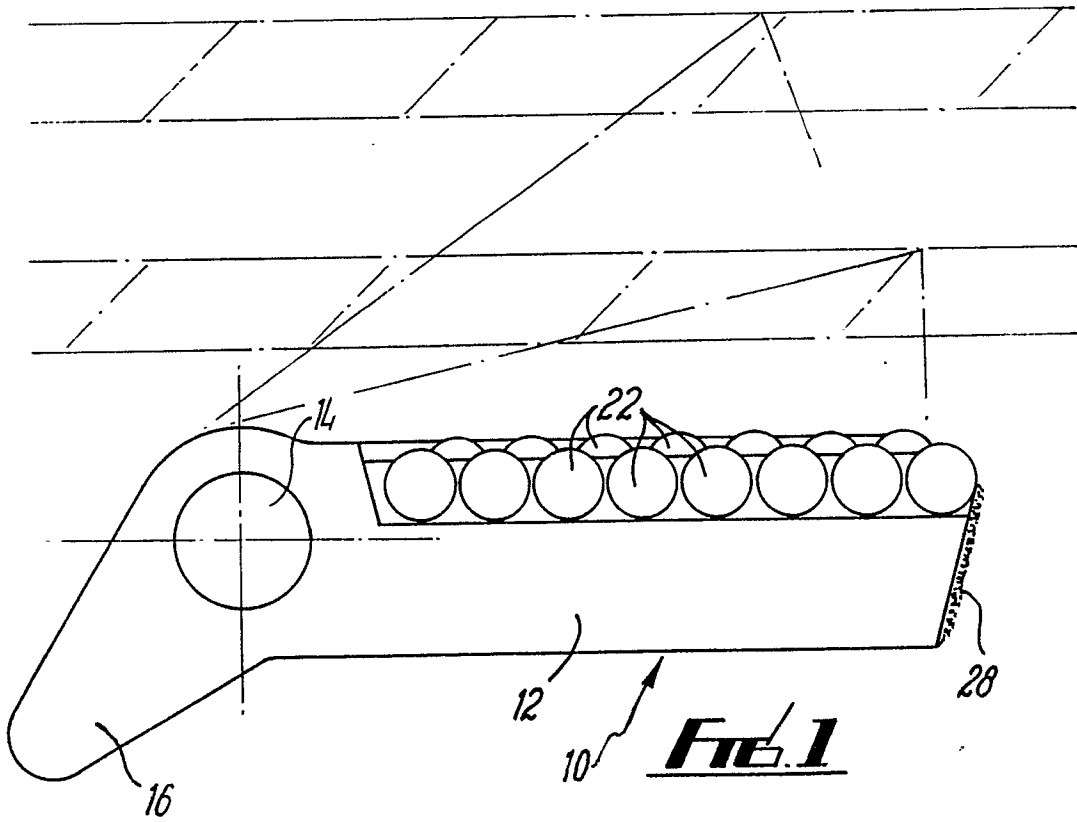
3. A casing cutter as claimed in Claim 1, wherein each effective cutting edge comprises a number of individual cutters mounted in a row to present respective individual cutting edges which collectively form said effective cutting edge.

4. A casing cutter as claimed in any preceding claim, wherein the effective casing edge is substantially linear.

5. A casing cutter as claimed in any preceding claim, wherein the cutter has three milling arms symmetrically arranged on the cutter.

6. A casing cutter as claimed in any preceding claim, wherein the pivot axes of the milling arms are tangential to a common circle co-axial with the rotation axis of the cutter.

7. A casing cutter as claimed in any preceding claim, and including a piston axially movable in response to hydraulic pressure within a drill string of which a cutter forms part in use of the cutter, the piston linking with each milling arm so that axial movement of the piston in one direction forces each milling arm to pivot outwards.



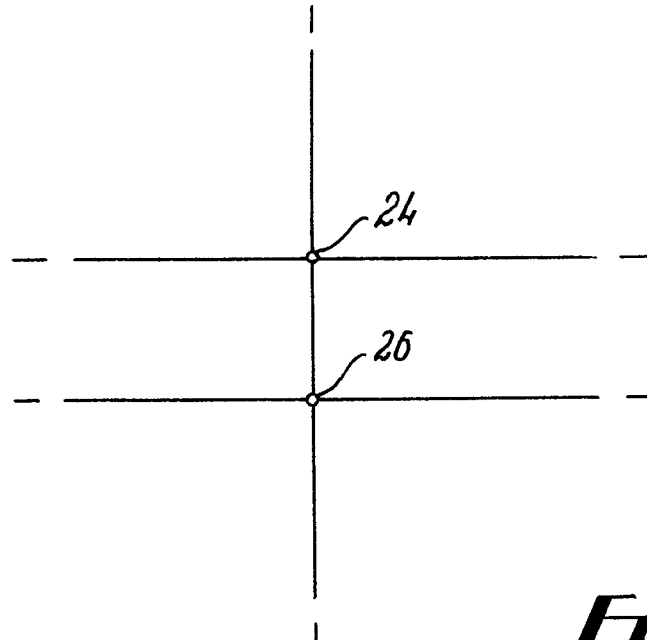
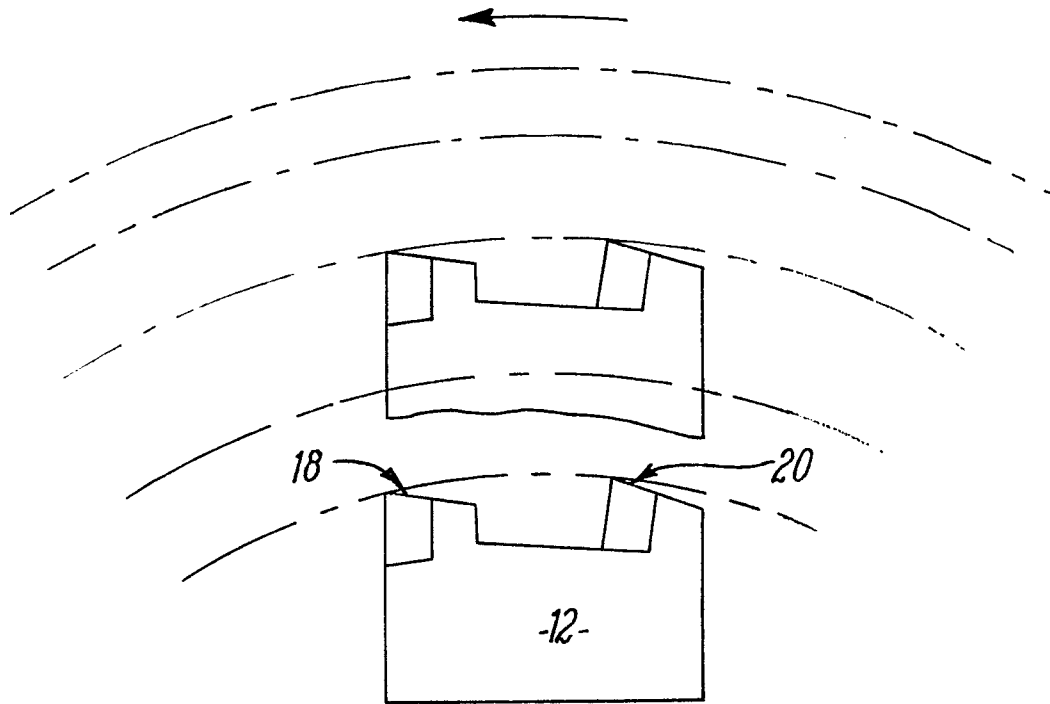


FIG. 3

Fig. 4

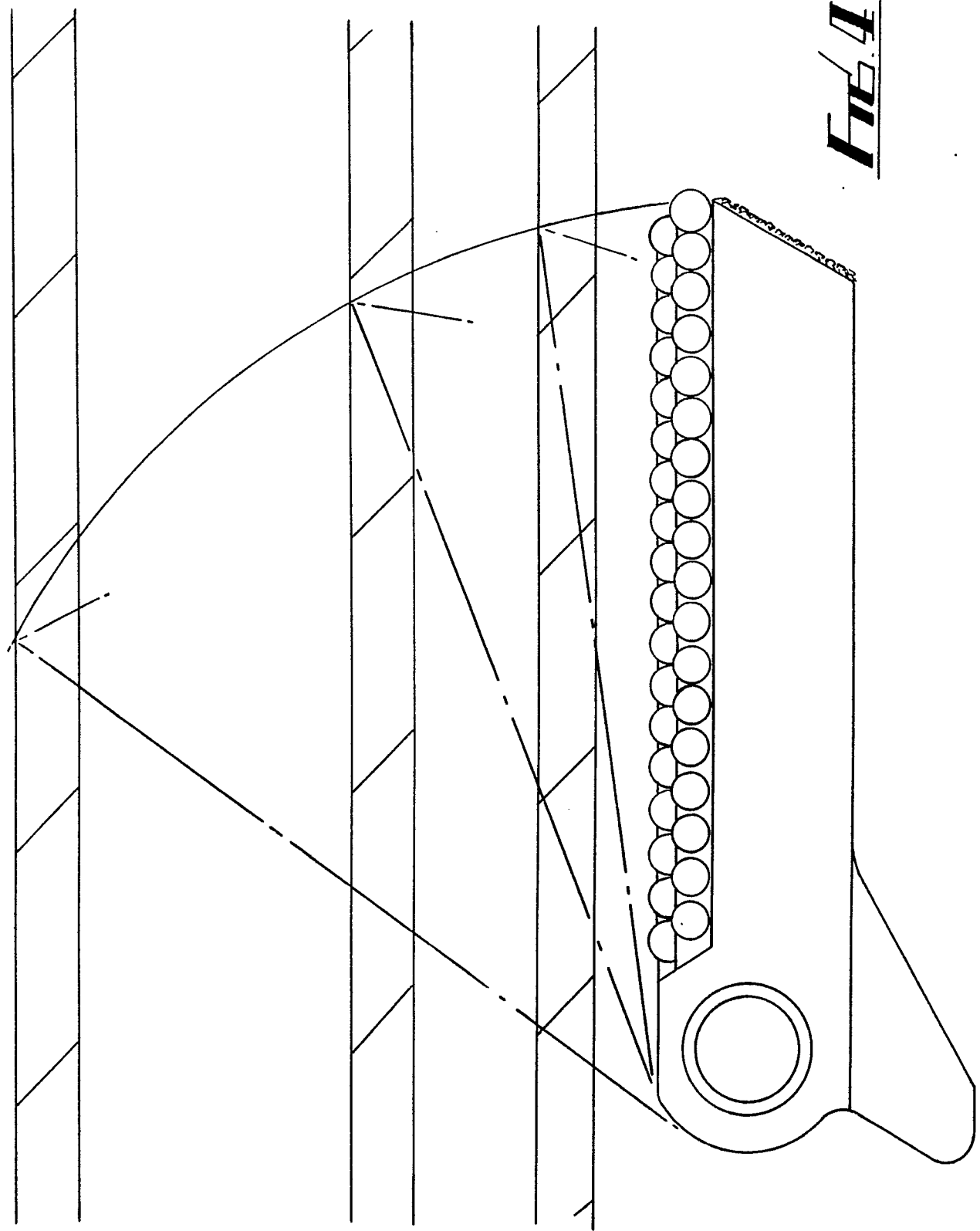
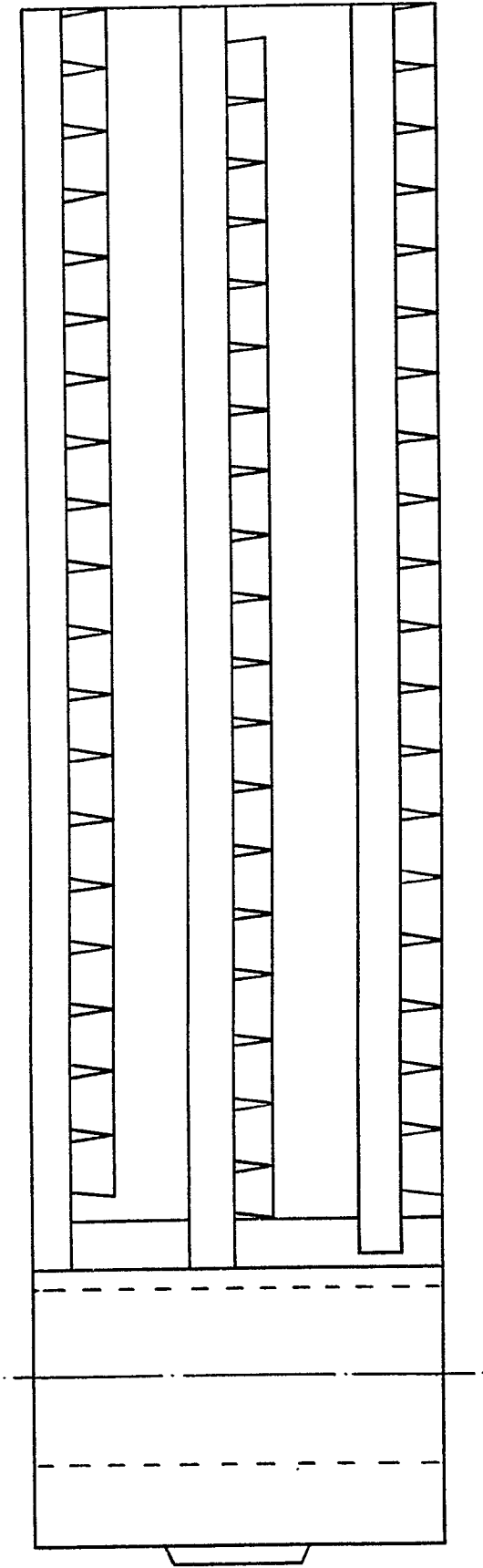
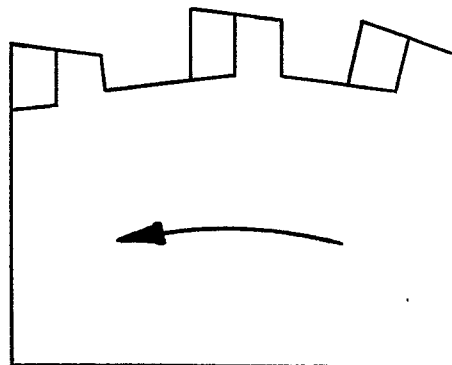
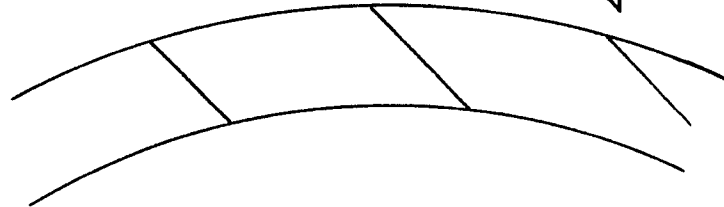


Fig. 5





File 6

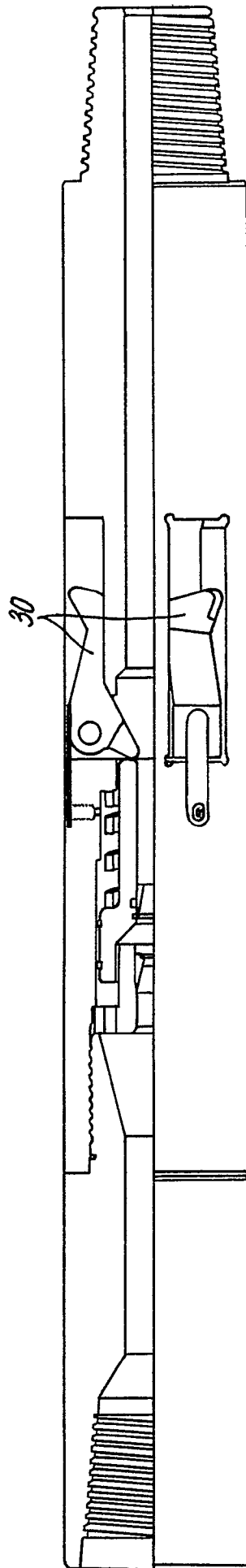


Fig. 7