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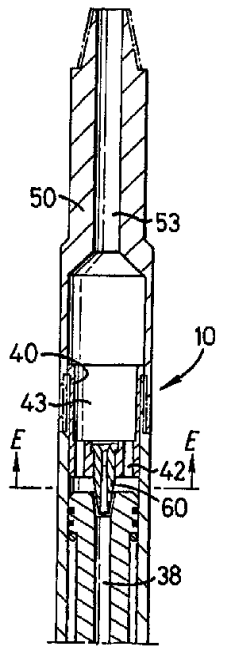
(54) Title: MILLING APPARATUS

(57) Abstract

Milling apparatus (10) comprises three blades (20) the lower part of which are pivotally monted to a mill body (12). The blades (20) pivot outwardly in response to downward movement of a wash tube (30) which contacts the blades (20). The blades (20) have a milling surface which, in use, is parallel to a central longitudinal axis of the mill body (12) so that "full sweep" milling can be achieved.



MILLING APPARATUS AND METHOD OF MILLING

This invention relates to a milling apparatus and a method of milling using said milling apparatus.

The prior art discloses various types of milling tools for removing a section of a tubular, for example casing previously installed in a well. These milling tools have movable cutting blades and are lowered into the well or casing. When the milling tool is in position the blades are biased against the wall of the tubular while the milling tool is rotated. Typically, a suitable drilling fluid is pumped down a central bore of the milling tool for discharge beneath the cutting blades and an upward flow of the discharged fluid in the annulus outside the milling tool removes from the well cuttings or chips resulting from the cutting operation.

US-A-1 919 881 and GB-A-987 659 both disclose milling apparatus which comprise a hollow mill body, at least one blade pivotally mounted within the hollow mill body, and means for pivoting the at least one block outwardly from the hollow mill. It will be noted that the blades have cutting edges shaped and disposed so that, in use, cutting through the casing is effected by a relatively small sharp triangular portion of the blade.

According to one aspect of the present invention there is provided a milling apparatus which comprises a hollow mill body, at least one blade pivotally mounted within the hollow mill body, and means for pivoting the at least one blade outwardly from the hollow mill, wherein said least one blade has a blade body and a cutting surface characterised in that when the blade is fully extended the cutting surface is substantially parallel to a longitudinal axis running through the hollow mill body.

The present invention provides a method of milling,

which method comprises the steps of introducing a milling apparatus in accordance with the present invention into a casing to be milled, positioning the milling apparatus at a desired location in the casing, moving the means for moving the at least one blade downwardly to move the at least one blade outwardly from the hollow mill body against an interior of the casing, and rotating the milling apparatus to mill the casing with the at least one blade.

Further features are set out in the dependent claims.

For a better understanding of the invention reference will now be made, by way of example, to the accompanying drawings, in which:

Fig. 1A is a side view, in cross-section, of a first embodiment of a milling apparatus according to the present invention in a first position;

Fig. 1B shows the milling apparatus of Fig. 1A in a second position;

Fig. 1C shows the milling apparatus of Fig. 1A in a third position;

Fig. 1D shows the milling apparatus of Fig. 1A in a fourth position;

Fig. 1E is a cross-sectional view taken on line E-E of Fig. 1D;

Fig. 1F is a cross-sectional view taken on line F-F of Fig. 1D;

Fig. 1G is a cross-sectional view taken on line G-G of Fig. 1D;

Fig. 1H is a cross-sectional view taken on line H-H of Fig. 1D;

Fig. 2A is a side view of a blade of the milling apparatus shown in Fig. 1A;

Fig. 2B is a front view of the blade of Fig. 2A;

Fig. 2C is a bottom view of the blade of Fig. 2A;

Fig. 3 is a perspective view of a second embodiment of a blade according to the present invention;

Fig. 4 is a perspective view of a third embodiment of a blade according to the present invention;

Fig. 5 is a perspective view of a fourth embodiment of a blade according to the present invention;

Fig. 6 is a perspective view of a fifth embodiment of a blade according to the present invention;

Fig. 7 is a perspective view of a sixth embodiment of a blade according to the present invention;

Fig. 8 is a side view in cross-section of a second

embodiment of a milling apparatus according to the present invention in a first position;

Fig. 9 is a view of the milling apparatus of Fig. 8 in a second position;

Fig. 10 is a simplified perspective view of the milling apparatus shown in Fig. 8;

Fig. 11A is a perspective view of a seventh embodiment of a blade according to the present invention;

Fig. 11B is a cross section view along line 11B-11B of Fig. 11A; and

Fig. 11C is a cross section view along line 11C-11C of Fig. 11A.

Referring to Figs. 1A - 1D, there is shown a milling apparatus 10 according to the present invention in a tubular T (e.g. pipe, casing or tubing). The milling apparatus 10 has a hollow mill body 12 with a threaded top end 14, a threaded bottom end 16, a top hollow chamber 13, a middle hollow chamber 15, and a fluid flow bore 17 with a bottom portion 19.

Three blades 20 are initially disposed in respective slots 21 in the hollow mill body 12, each with a bottom end 22 rotatably pinned by a pin 23 to the hollow mill body 12. Each blade has cutting or milling surfaces 24, 25, and 26 and interior surfaces generally designated by the numeral 27 and fully described below. A spring 65 urges each blade 20 inwardly.

A wash tube 30 has a top portion 31 movably disposed in the top hollow chamber 13 and biased upwardly by a spring 39 which abuts a top shoulder 32 of the wash tube 30 and an interior shoulder 18 of the hollow mill body 12. A top end 33 of the wash tube 30 has recesses 34 in which are disposed seals 35 (e.g. commercially available Polypak seals, O-rings, or combinations thereof) for sealing an interface between the exterior surface of the wash tube 30 and the interior surface of

the top hollow chamber 13. A shoulder 36 of the wash tube 30 is disposed to contact the interior shoulder 18 of the hollow mill body 12 to prevent further downward movement of the wash tube 30 (see Fig. 1B). In the preferred embodiment shown the wash tube 30 has a lower end 37 in the form of a conical, tapered nose for contacting and co-acting with the blades 20.

A fluid flow bore 38 extends through the wash tube 30 from top to bottom. Three circumferentially spaced hollow pins 28 extend through the hollow mill body 12 and abut respective flat surfaces 29 on the wash tube 30 to maintain the wash tube 30 in position in the hollow mill body 12. The wash tube 30 may have a circular cross-section with no, one, or more flat surfaces. The wash tube 30 can move up and down with respect to the pins 28.

A flow sleeve 40 is movably disposed in a chamber 51 in a top sub 50. The top sub 50 has a lower threaded end 52 which is threadedly mated to the threaded top end 14 of the hollow mill body 12. The flow sleeve 40 has a top shoulder 41 which abuts the threaded top end 14 of the hollow mill body 12 to prevent further downward movement of the flow sleeve 40. Flow holes 42 through the flow sleeve 40 are in fluid communication with an upper fluid flow bore 43 of the flow sleeve 40.

A fluid flow nozzle 60 is disposed in a central bore 44 of the flow sleeve 40. The flow nozzle 60 has a central fluid flow bore 61 which initially (Fig. 1A) is in fluid communication with the fluid flow bore 38 of the wash tube 30 and sealingly contacts the top of the wash tube 30. The top sub 50 has a central fluid flow bore 52 therethrough from top to bottom which is in fluid communication with the chamber 51. The internal diameter of the fluid flow nozzle 60 is sized to achieve a desired pressure drop across the nozzle and so that

the pressure is sufficiently high to depress the wash tube 30 and extend the blades 20 (e.g. see Fig. 1C).

In use, the milling system 10 is lowered to the position where it is desired to cut a section out of the tubular T on a workstring.

Initially the flow sleeve 40 and the wash tube 30 are held in the position shown in Fig. 1A by the force of the spring 39. Drilling fluid, for example mud is then pumped down the workstring which is rotated. When the force of the fluid reaches a level sufficient to overcome the force of the spring 39, the drilling fluid pushes on the flow sleeve 40 which pushes on the wash tube 30 moving it downwardly so that the lower end 37 of the wash tube 30 moves down between the blades 20 pushing them apart and out from their respective slots 21 (Fig. 1B). As the wash tube 30 moves further down within the hollow mill body 12, the blades 20 move further outwardly, rotating about the pins 23. The blades 20 gradually cut through the tubular T. The flow sleeve 40 and the wash tube 30 move progressively downwardly until the top shoulder 41 of the flow sleeve 40 abuts the top end 14 of the hollow mill body 12, and downward movement of the flow sleeve 40 ceases. At this point the blades 20 are fully extended and the tubular T has been cut. Fluid pressure on the top end 33 of the wash tube 30 moves it down to abut the interior shoulder 18 of the hollow body 12 as shown in Fig. 1D.

Referring to Fig. 1D, as the wash tube 30 moves down to its lowermost position, an enlarged fluid passageway opens up between the exterior of the fluid flow nozzle 60 and the interior of the top of the fluid flow bore 38 of the wash tube 30, allowing an indication that "cut out" has been achieved and allowing for greater fluid flow.

The wash tube 30 may have one or more fluid flow

passages 11 near its lower end so that fluid flows out to facilitate cuttings removal and inhibit cuttings from accumulating in the tool.

Fig. 1F shows one pin 28 threadedly and removably engaged in a hole 46 in the hollow mill body 12 with a small space between it and the flat surface 29.

Fig. 1G illustrates three blades 20 in extended position. The blades 20 are equispaced (every 120°) around the hollow mill body 12.

Fig. 1H shows three extended blades 20 and a plurality of stabilizers 55 projecting from the hollow mill body 12 and removably secured thereto with bolts 56 (Fig. 1A). Cutting inserts 57 cover the top end portion of the blades 20.

Figs. 2A - 2C show a blade 20 according to the present invention with its cutting/milling surface 25 disposed so that when the blade 20 is fully extended (as in Fig. 1D) the surface 25 is substantially parallel to a longitudinal axis running up and down through the hollow mill body 12. With this disposition a major part (and preferably substantially all) of the cutting surface 25 contacts the interior surface of the tubular for efficient and effective milling. A recess 70 moves about a pin 72 (Fig. 1A) to limit the extent of outward movement of the blade 20 from the hollow mill body 12. A hole 58 receives the pin 23 and a hole 59 receives a set screw (not shown). The blade's top end with the various cutting surfaces may be canted as shown in Fig. 2B (e.g. at a negative rake angle, e.g. about 5°) with respect to the body of the blade 20. The interior of the blade 20 comprises six interior surfaces 27a- 27f. These interior surfaces 27a-27fare sized, disposed, and configured for co-action with the exterior surface of the wash tube 30 to effect desired outward blade movement and disposition. Initially the nose 37 of the wash

tube 30 moves down against the interior surface 27a (see Fig. 1B). The wash tube's exterior surface then moves down against the interior surface 27b (see Fig. 1C). Then the wash tube's exterior surface moves down against the interior surface 27c. The interior surfaces 27d define a space which receives the nose 37 of the wash tube 30.

The cutting surfaces 24, 25, 26 may be heat treated and/or hardfaced; and/or part or all of such surfaces may have any cutting insert or inserts arranged on the blades as desired.

In certain aspects the milling apparatus 10 is used with a "shock sub" positioned above the top sub 50 to absorb shocks and reduce vibrations.

Figs. 3 - 6 show other configurations for the blades according to the present invention with different structures for securing their bottom ends to the hollow mill body 12.

Fig. 3 shows a blade 80 with a bottom 81 having a hole 82 therethrough for receiving a pin (not shown) for securing the blade to a hollow mill body. A bar stop 83 moves in a slot in the hollow mill body to abut a stop projecting from the hollow mill body to stop the blade's outward movement at a desired position.

Fig. 4 shows a blade 84 with a bottom 85, spaced apart tongues 86, and holes 87 for receiving a pin (not shown) for securing the blade 84 to a hollow mill body.

Fig. 5 shows a blade 95 like the blade 20.

Fig. 6 shows a blade 90 with a bottom 91 having projecting nubs 92 for receipt within corresponding sockets (not shown) in a mill body to secure the blade 90 in a hollow mill body. A stop 93 abuts a stop on a mill body to arrest blade outward movement and maintain desired extended blade position.

Fig. 7 shows a blade 100 with a blade body 102, two

cutting portions 104 and a spherical mounting end 106. The spherical mounting end 106 fits in an appropriately configured recess in a mill body (not shown) so that it is movable with respect to the body and held in the recess.

Any of the bodies shown in Figs. 2A, 3 - 6, or 8 may typically have two or three blades mounted in a single blade body; and the blade may have multiple side-by-side spaced-apart milling surfaces; e.g. the three milling surfaces 24, 25, 26.

Referring now to Figs. 8 - 10, a milling apparatus 200 according to the present invention is like the milling system 10 described above and identical numerals identify the same parts.

A plurality of blades 20 are initially disposed in respective slots 21 in the hollow mill body 12, and a plurality of blades 220 are initially disposed in respective slots 221 in the hollow mill body 12. Each blade 220 has a top 222 pivotably pinned with a pin 223 to the hollow mill body 12. By a "plurality of blades" is meant at least one blade 20 (with two, three, or four blades preferred) and at least one blade 220 (with two, three, or four preferred); and preferably for each blade 20 there is a blade 220.

Each blade 220 has a blade cutting portion 225, an interior surface 226 and an interior surface 227. Initially the exterior of the wash tube 30 moves parallel to the interior surface 226 (Fig. 8). Then the nose of the wash tube 30 contacts and moves along the interior surface 227, forcing the blades 220 out from their slots 221.

Figs. 11A - 11C show a blade 240 according to the present invention which has a body 241 with an end 242 (which can be a top end or a bottom end depending on which way the blade is used in a mill) having a hole 243

for receiving a pin to pin the blade 240 to a mill body. Another end 244 of the blade has two blade cutting elements 245 and 246 projecting therefrom. Interior surfaces 247, 248, and 249 are formed, sized and configured to co-act with a wash tube (like the wash tube 30) to move the blades 240 with respect to slots in which they initially rest in a mill body (like the mill body 12).

In the system 200, initially the flow sleeve 40 and the wash tube 30 are held up by the force of the spring 39. When the force of the fluid reaches a level sufficient to overcome the spring force, the fluid pushes on the flow sleeve 40 which pushes on the wash tube 30 moving it downwardly so that the lower nose end 37 of the wash tube 30 moves down between the blades 20 and 220 pushing them apart and out from their respective slots 21 and 221. As the wash tube 30 moves further down within the hollow mill body 12, the blades 20 and 220 move further outwardly, rotating about the pins 23 and 223 respectively. The shoulder 36 of the wash tube 30 moves towards the interior shoulder 18 of the hollow mill body 12 and outward movement of the blades 20 and 220 effected by the wash pipe 30 ceases (Fig. 9).

As shown in Fig. 11C the blade cutting element 245 will be the first element to contact a casing 250 (as shown by circular dotted line) in which the blade 240 on a mill (not shown) is being used. Thus blade damage during cutting is reduced. For all blades 240 on a mill, the blade cutting element 245 will be the first element to contact the casing. Part are all of the blade cutting elements and/or of the blade body of any blade disclosed herein may be hardfaced or otherwise treated with material such as matrix milling material and/or cutting inserts with or without one or more chipbreakers or chipbreaking surfaces.

The wash tube is conveniently made of multiple parts including an inlet and an outlet end made of wear resistant material, for example stainless steel, carbide, cobalt-based steels. The remaining mid-portion of the wash tube may be made of a softer steel or steel alloy.

The milling apparatus may be operated on a work-string or may be connected to a downhole motor which would typically be lowered on coil tubing. Appropriate stabilizers may be used with such an arrangement.

CLAIMS:

1. A milling apparatus which comprises a hollow mill body, at least one blade pivotally mounted within the hollow mill body, and means for pivoting the at least one blade outwardly from the hollow mill, wherein said least one blade has a blade body and a cutting surface characterised in that when the blade is fully extended the cutting surface is substantially parallel to a longitudinal axis running through the hollow mill body.

2. A milling apparatus as claimed in Claim 1, wherein the or each blade has a blade body, a top, a bottom, and a cutter with a cutting surface, and the bottom of said blade is pivotally mounted on said hollow mill body with said cutting surface thereabove.

3. A milling apparatus as claimed in Claim 1 or 2, wherein the means for moving the at least one blade from the body comprises a wash tube movably disposed in the hollow mill body above the at least one blade, the wash tube movable downwardly, in use, in response to the force of fluid flowing into the milling apparatus to contact the at least one blade and move the at least one blade outwardly from the hollow mill body as the at least one blade pivots outwardly.

4. A milling apparatus as claimed in Claim 3, further comprising spring means in the hollow mill body for yieldably urging the wash tube upwardly away from the at least one blade.

5. A milling apparatus as claimed in Claim 3 or 4, wherein the wash tube has a central fluid flow channel therethrough and the milling apparatus further comprising at least one fluid flow port through a lower end of the wash tube for flowing fluid past the at least one blade.

6. A milling apparatus as claimed in Claim 3, 4 or 5,

further comprising a first angled surface on an interior of the at least one blade, and a second angled surface on an exterior of a lower end of the wash tube for contacting the first angled surface on the interior of the at least one blade so that as the wash tube moves downwardly the at least one blade is moved outwardly from the hollow mill body by the wash tube.

7. A milling apparatus as claimed in Claim 6, further comprising a second surface on the interior of the at least one blade, the second surface disposed so that when the blade is moved to a milling position the second surface is substantially parallel to an exterior surface of the wash tube so that the at least one blade is held in the milling position by the wash tube.

8. A milling apparatus as claimed in Claim 3, 4, 5, 6 or 7, further comprising means for indicating when cut out has been achieved by the at least one blade.

9. A milling apparatus as claimed in Claim 8, wherein the wash tube has a tube central flow channel for the flow of fluid therethrough, and wherein the means for indicating when cut out has been achieved comprises a hollow tubular sleeve movably disposed in the hollow mill body above the wash tube, the hollow tubular sleeve movable by fluid flowing through the milling apparatus to contact the wash tube, the hollow tubular sleeve having a central member and a flow channel around the central member between an exterior surface of the central member and an interior surface of the hollow tubular sleeve, the central member having a central channel therethrough, and a flow nozzle secured in the central channel of the hollow tubular sleeve with a nozzle portion extending therefrom and directed toward the tube central flow

channel of the wash tube through which fluid flows through the wash tube, the flow nozzle receivable within the tube central flow channel.

10. A milling apparatus as claimed in any preceding claim, further comprising each of the at least one blade urged into the hollow mill body by a spring.

11. A milling apparatus as claimed in any preceding claim, further comprising stop means for limiting the movement of said at least one blade with respect to said hollow mill body.

12. A milling apparatus as claimed in any preceding claim, wherein the at least one blade is three blades disposed in the hollow mill body and spaced apart from each other.

13. A milling apparatus as claimed in any preceding claim, further comprising the cutting surface of the at least one blade comprising an upper cutting surface at a top of the cutting and extending outwardly from the blade body, a lower cutting surface at a bottom of the cutter and extending outwardly from the blade body and spaced apart from the upper cutting surface, and a middle cutting surface extending from the upper cutting surface to the lower cutting surface.

14. A milling apparatus as claimed in any preceding Claim, wherein said blade comprising a blade body with a top and a bottom, an interior surface, and an exterior surface, a milling surface on the exterior surface of the blade body, a first angled surface on an interior of the blade body for contacting and co-acting with a second angled surface on an exterior of a lower end of an actuating member in the milling apparatus, the second angled surface corresponding to and for contacting the first angled surface on the interior of the blade body so that, in use, as the actuating member moves downwardly the blade is moved outwardly from

the milling apparatus.

15. A milling apparatus as claimed in Claim 14, further comprising a second surface on the interior of the blade for contacting the actuating member so that when the blade is moved to a milling position the second surface is substantially parallel to an exterior surface of the actuating member so that the blade is held in the milling position by the actuating member.

16. A milling apparatus as claimed in Claim 14 or 15, wherein said blade further comprises stop means on the blade body for contacting another member to stop movement of the blade out from the milling apparatus.

17. A method of milling, which method comprises the steps of introducing a milling apparatus as claimed in any of Claims 1 to 16, into a casing to be milled, positioning the milling apparatus at a desired location in the casing, moving the means for moving the at least one blade downwardly to move the at least one blade outwardly from the hollow mill body against an interior of the casing, and rotating the milling apparatus to mill the casing with the at least one blade.

18. A method according to Claim 17, wherein the means for moving the at least one blade has a lower end and the method further comprising biasing the lower end of the means for moving the at least one blade against an interior of the at least one blade during milling.

19. A milling apparatus substantially as hereinbefore described with reference to the accompanying drawings.

20. A method of milling using the milling apparatus, in accordance with claim 19 substantially as hereinbefore described.

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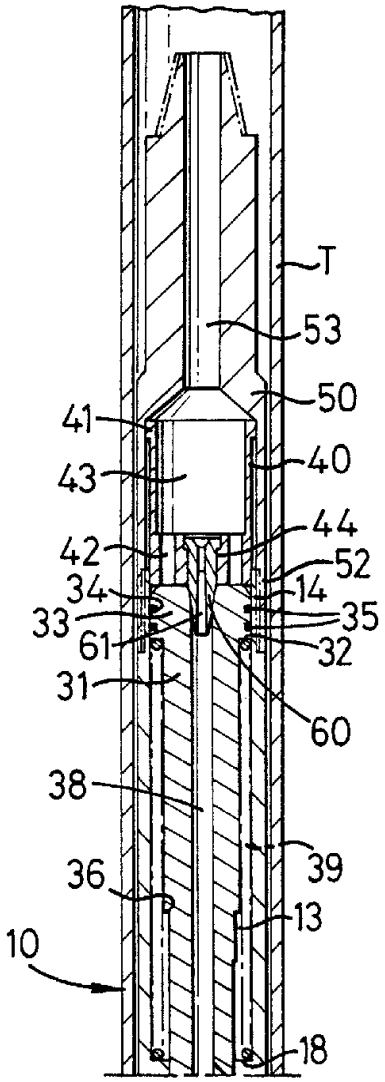
Patent Attorneys for the Applicant:

WEATHERFORD/LAMB, INC

FIG. 1A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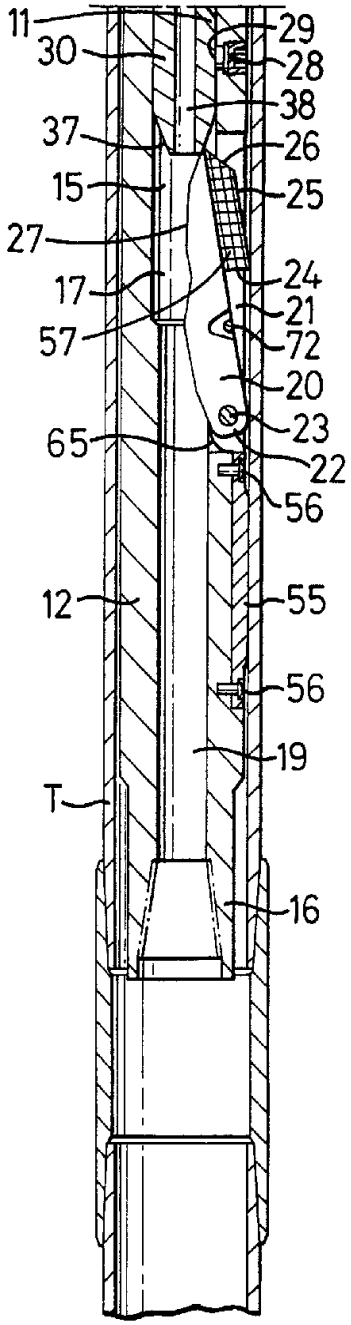
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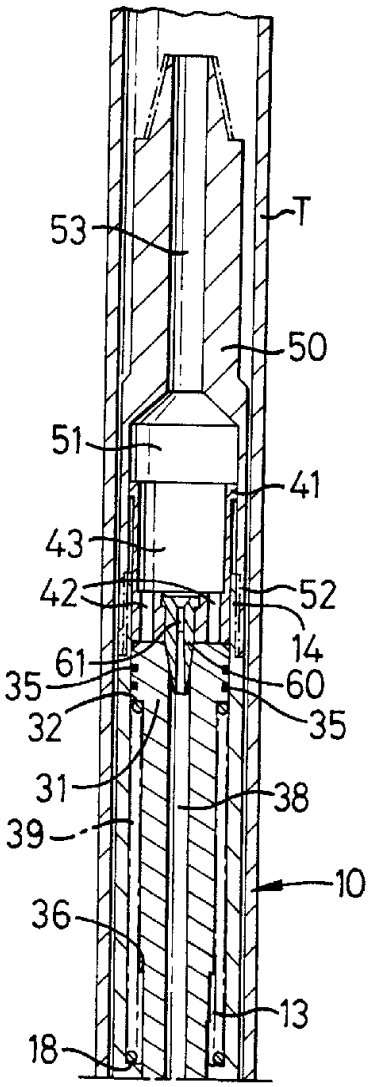
FIG. 1B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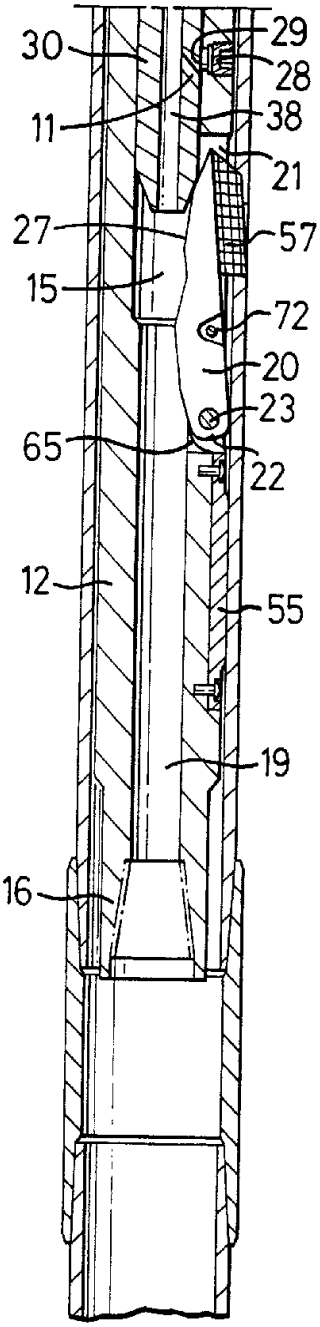
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FIG.1C

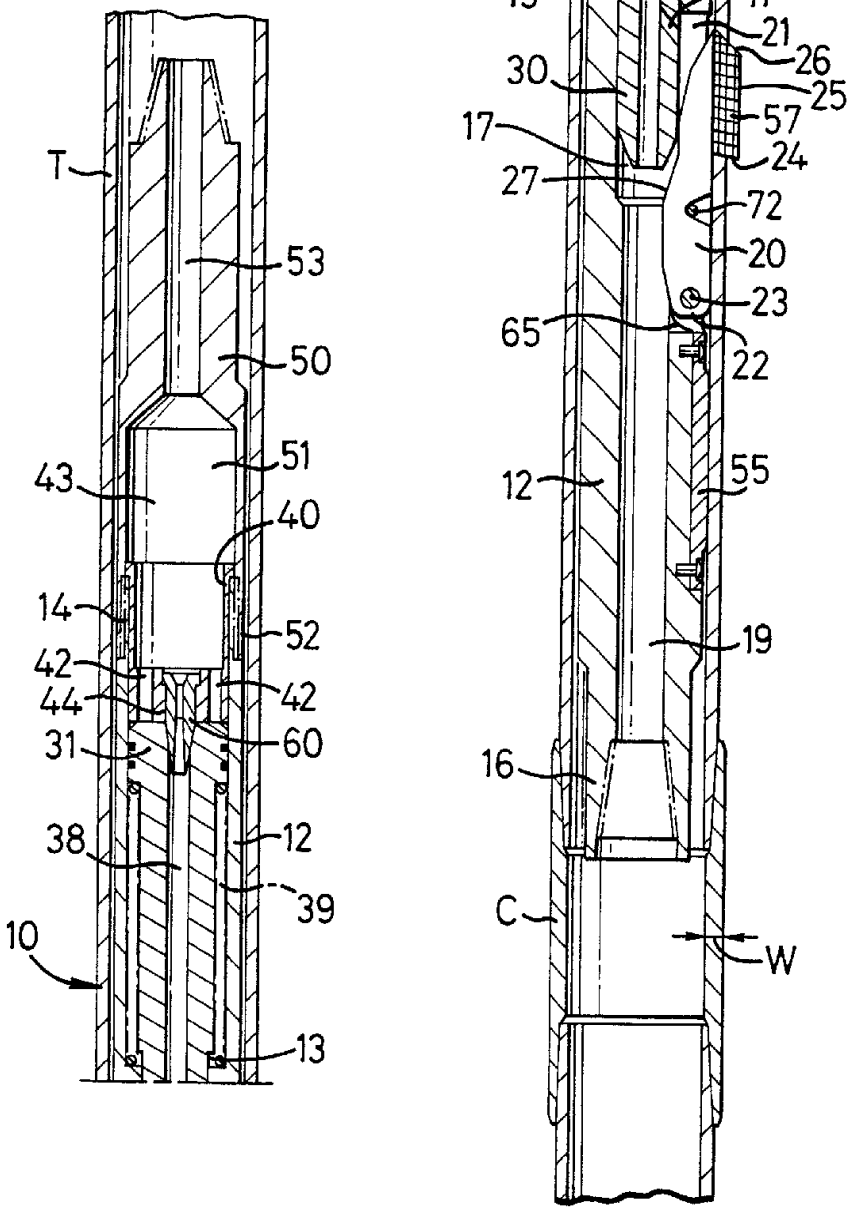
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FIG.1D

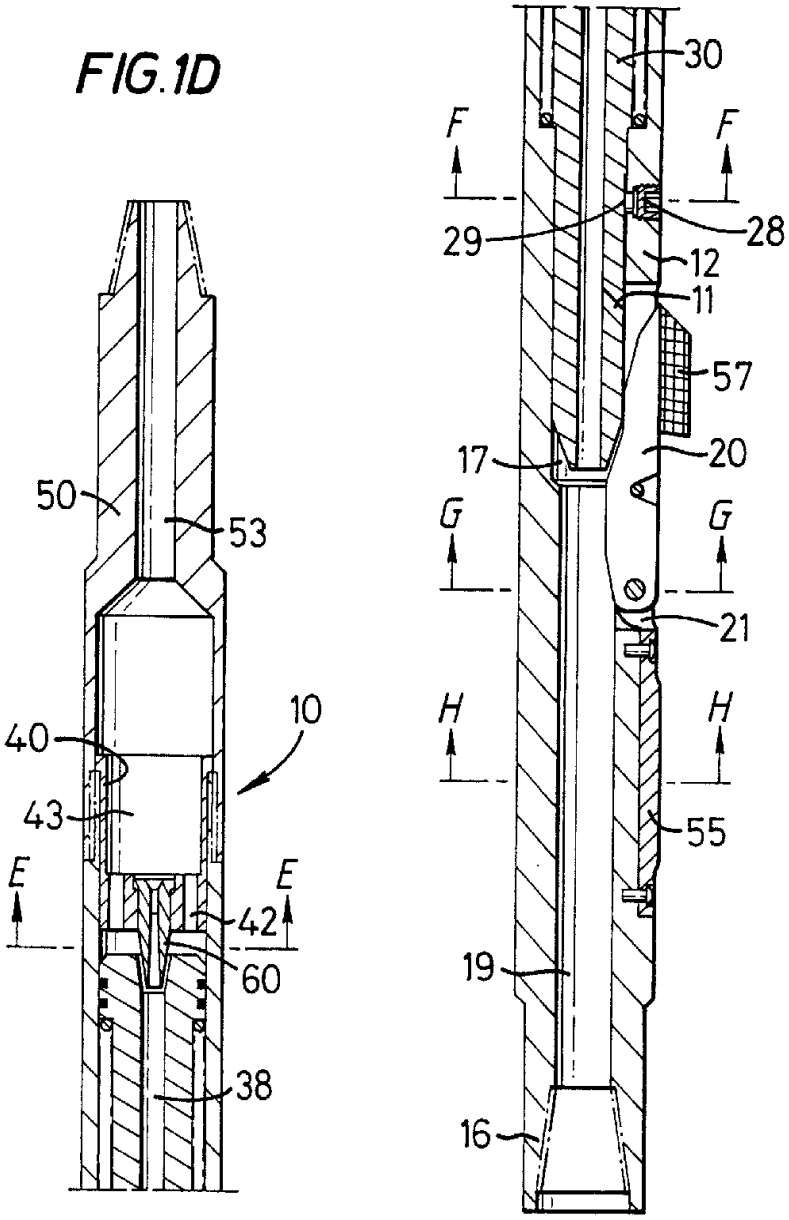
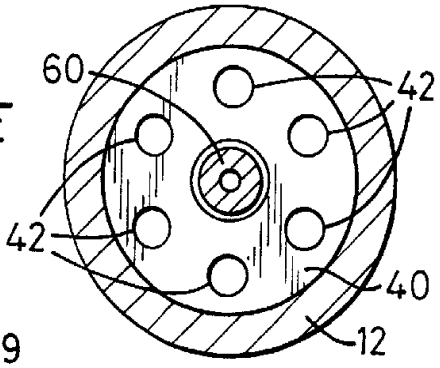


FIG.1E



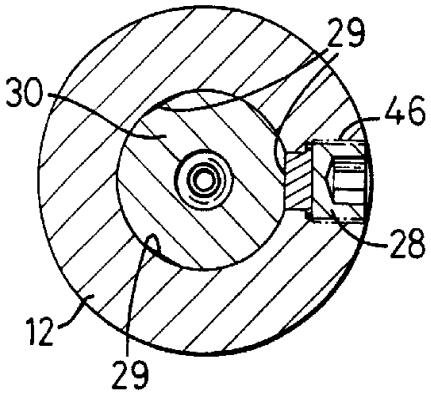


FIG.1F

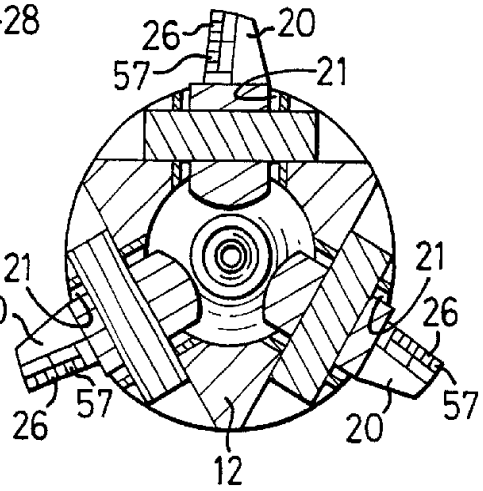


FIG.1G

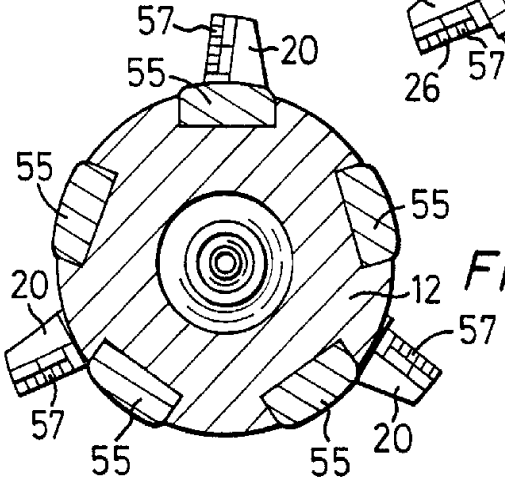


FIG.1H

FIG.2A

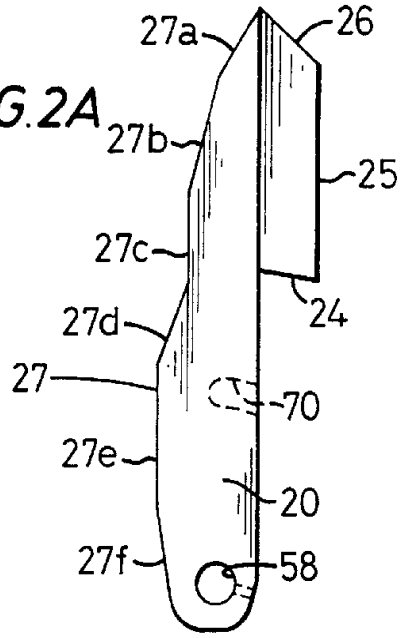


FIG.2B

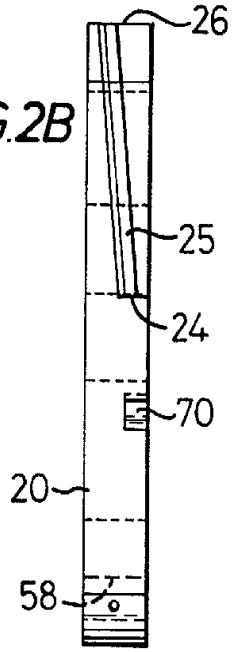


FIG.2C

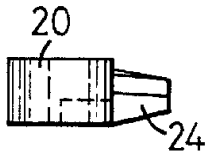


FIG.3

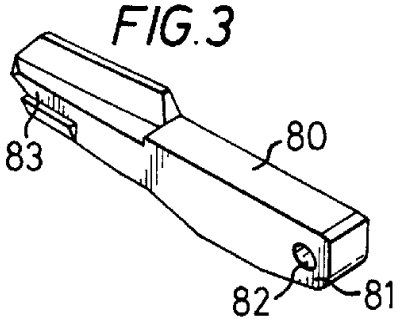


FIG.4

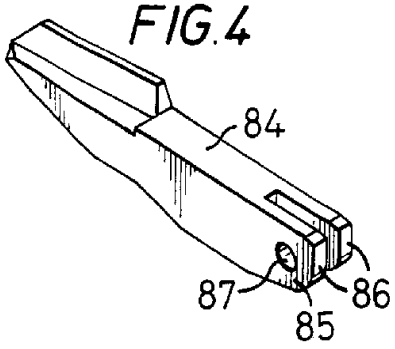
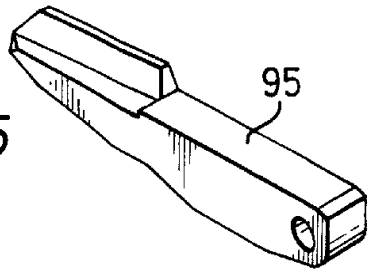


FIG.5



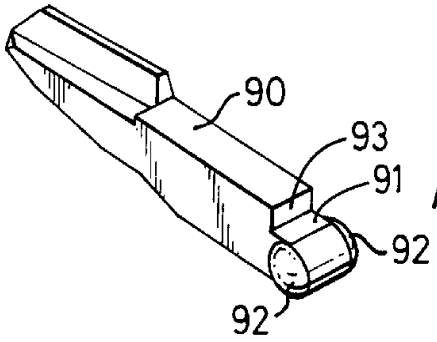


FIG.6

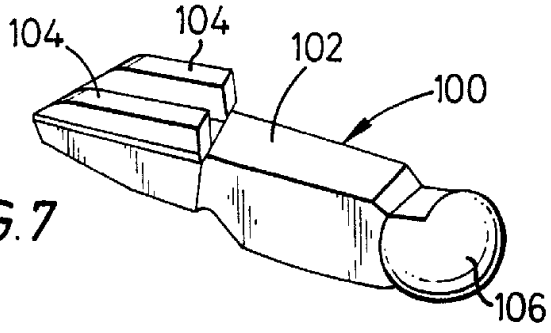
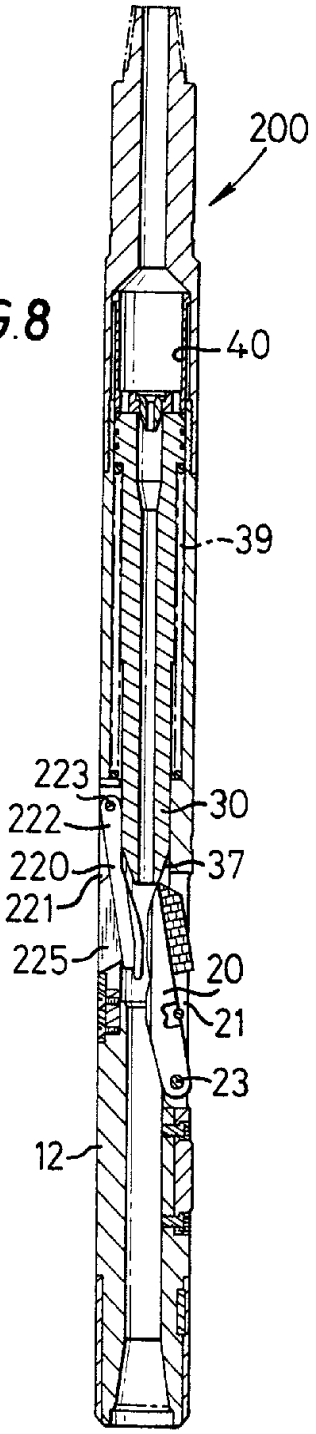


FIG.7

FIG.8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222
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FIG.9

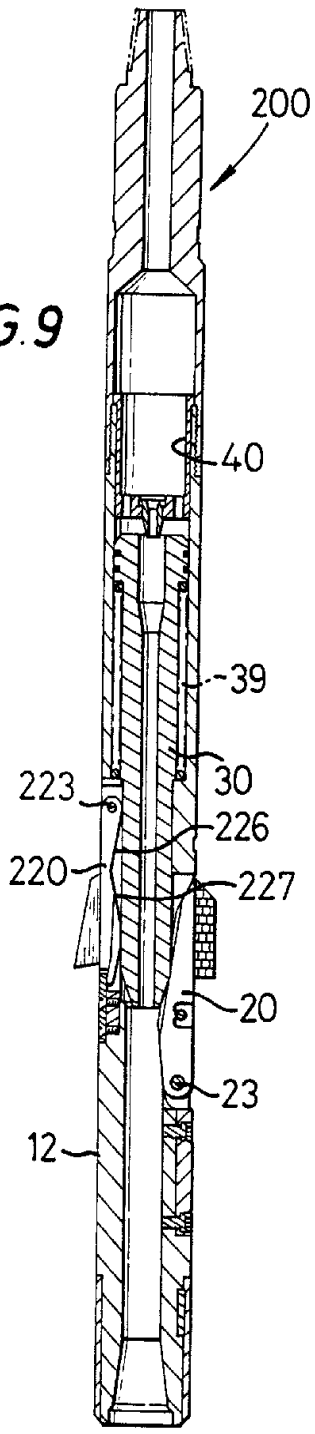
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FIG. 10

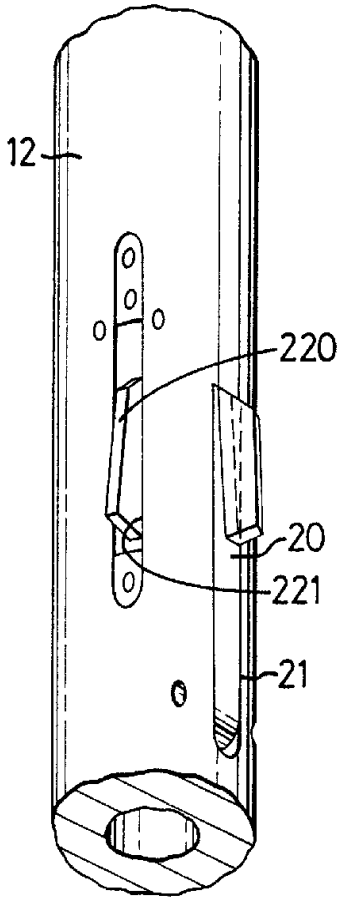

FIG. 11A

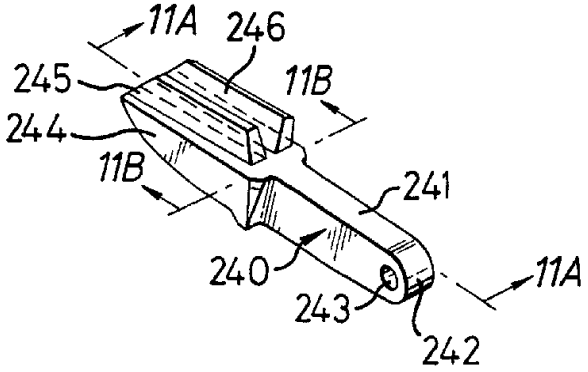

FIG. 11B

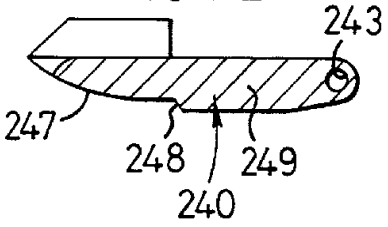

FIG. 11C