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(54) **Air percussion drilling assembly for directional drillig applications.**

(57) An air percussion hammer drill is disclosed for operation in an earthen formation. The air compression hammer mechanism comprises a piston that reciprocates while simultaneously rotating within its housing. A hammer drill bit slidably keyed to the bottom of the piston transfers the impact energy to the formation and rotates during operation independent of an attached drill string. The air percussion hammer assembly is therefore ideally suited to directional drilling activities.

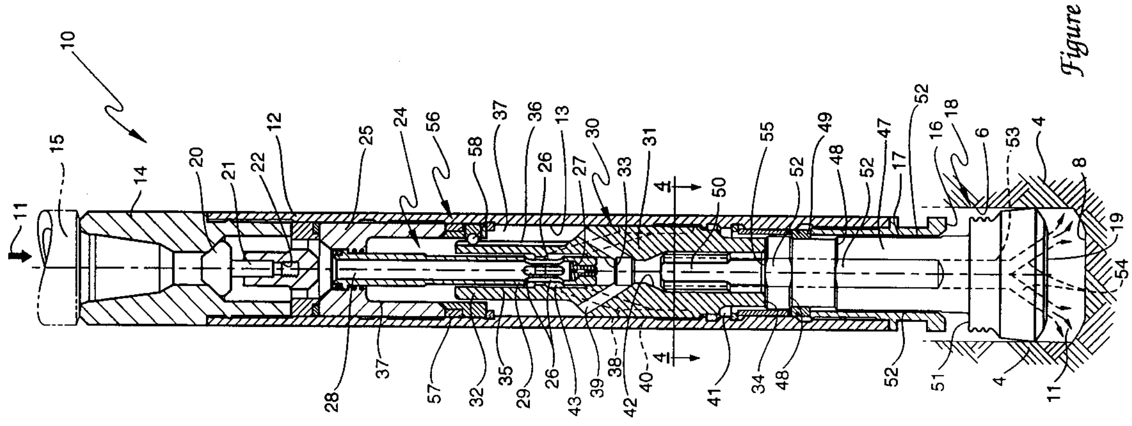

Figure 1

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Background

This invention relates to an air compression hammer drilling tool. More particularly, this invention relates to a downhole air compression hammer tool for directional drilling operations. The hammer impacts while simultaneously rotating the bit, thereby assuring maximum penetration of the bit in an earthen formation independent of the rotation of the drill string.

In percussion drilling the rock cutting mechanism is of an impacting nature rather than shearing. Therefore, the drill bit rotational parameters, e.g. torque and rpm, are not relevant from a rock formation breaking point of view, except for the necessity that the cutting elements of the bit need to be "indexed" to fresh rock formations. In straight hole air drilling, and especially in mining, this need is achieved by rotating the drill string slowly. This is accomplished in conventional hammer bit operations by incorporating longitudinal splines which key the bit body to a cylindrical sleeve at the bottom of the hammer (commonly known as the driver sub). The drill string rotation is then transferred to the hammer bit itself. Experience has proven that the bit optimum rotational speed is approximately 20 rpm for an impact frequency of 1600 bpm (beats per minute). This rotational speed translates to an angular displacement of approximately 4 to 5 degrees per impact of the bit against the rock formation. Another way to express this rotation is the cutters positioned on the outer row of the hammer bit move at the approximate rate of one half the cutter diameter per stroke of the hammer.

An example of a typical hammer bit connected to a rotatable drill string is described in U.S. Patent Number 4,932,483. The downhole hammer comprises a top sub and a drill bit separated by a tubular housing incorporating a piston chamber therebetween. A feed tube is mounted to the top sub and extends concentrically into the piston chamber. A piston is slidably received within the housing and over the feed tube. Fluid porting is provided in the feed tube and the piston to sequentially admit fluid in a first space between the piston and top sub to drive the piston towards the drill bit support and to a second space between the piston and the drill bit support to drive the piston towards the top sub.

Rotary motion is provided to the hammer assembly and drill bit by the attached drill string powered by a rotary table typically mounted on the rig platform. The rotation of the drill string in the conventional hammer bit operation described above, takes away the ability to turn, build, or drop angle which is fundamental in directional drilling operations. A method for rotating the hammer bit without rotating the drill string is instrumental in any directional drilling or steerable system. Such a rotation can be accomplished by a motor mechanism positioned above the hammer that induces rotational motion to the bit itself.

The air percussion hammer tool taught in this specification has particular application for use with the technology taught in U.S. Patent No. Re. 33,751 entitled SYSTEM AND METHOD FOR CONTROLLED DIRECTIONAL DRILLING, which describes a technique for controlled directional drilling utilizing a system approach to design the hardware for drilling according to the well plan. The bend angle of a bent housing, connected between the bit and downhole motor, the diameter of a plurality of stabilizers and placement of the stabilizers with respect to the drill bit are selected and predetermined on the basis of the desired well plan. With the use of a measurement while drilling sub, the direction of the progressing borehole is tracked from the surface. Direction changes as required are controlled from the surface simply by controlling rotation of the drillstring. For curved path drilling, only the downhole motor or the air percussion hammer of the present invention is rotated, causing the borehole to travel along the curve determined by the bend angle in the bent housing and the diameter and location of the concentric stabilizers. When straight hole drilling is required, both the downhole motor or air percussion hammer and the entire drill string are rotated, effectively nullifying the effect of the bend angle in the bent housing.

Summary of the Invention

An air percussion hammer for directional drilling operations has a cylindrical housing having an upstream end connectable to a drill string component and a downstream end with means for mounting a hammer bit. A piston is slidably retained within the housing has a downstream end for striking a hammer bit mounted on the end of the housing. Pneumatic porting in the housing provides fluid flow for alternately driving the piston upwardly in the housing and driving the piston downwardly in the housing for striking a hammer bit. Means are provided for rotating the piston during the downward stroke of the piston and preventing rotation of the piston during the upward stroke of the piston. The hammer bit is keyed to the piston for permitting relative longitudinal movement of the hammer bit while preventing relative rotation between the hammer bit and the piston.

The air percussion hammer converts axial motion of a reciprocating piston to rotary motion of a hammer bit as the bit works in a borehole.

The kinetic energy of the reciprocating piston is employed to rotate the bit. The linear motion of the piston is converted into rotational motion by using one or more helical grooves formed by the piston body. To prevent the piston from oscillating in the rotary mode, an indexing clutch mechanism is provided to induce rotation of the bit in one direction only.

The upper portion of the hammer bit (normally splined) is replaced by a shaft that is slidably engaged with and keyed to a complementarily shaped female receptacle or bore formed by the lower portion of a piston. The shaft of the hammer is, therefore, slidably engaged at all times to the base of the piston and is so designed to be rotated by the piston with a minimum of drag. Thus, axial motion between the piston and bit body is allowed but relative rotational motion is not, i.e. the bit would rotate if the piston rotates and vice versa.

One or more longitudinal helical grooves are machined on the piston upper section. These grooves are keyed to an inner race of a "sprag" clutch assembly via dowel pins or spherical balls. The outer race of this clutch assembly is locked to the inner bore of a cylindrical hammer housing. The clutch sprags are set to clockwise motion and to prevent counter-clockwise rotational movement of the inner race with respect to the outer race.

The downward motion of the piston, (the piston being coupled to the clutch through interaction between the helical groove, the engaged ball and the clutch) mandates either a counter-clockwise rotation of the inner race or a clockwise rotation of the piston. Since counter-clockwise rotation of the inner race is not possible, the piston must rotate clockwise when the piston moves downward. Similarly, the upward motion of the piston requires either the clockwise rotation of the inner race or the counter-clockwise rotation of the piston. Since the friction against the clockwise rotation of the inner race is significantly less than that against the piston/bit rotation, the inner race rotates clockwise and allows the piston to move straight upward. Therefore, on the downstroke of the piston the bit is forced to rotate clockwise; while on the upstroke the inner race rotates instead, thereby preventing the bit from "turning back".

An air percussion hammer apparatus with means for rotating the hammer bit while its piston reciprocates in a housing independent of an attached drill string is disclosed. The bit rotating means comprises a cylindrical housing having an open upstream end connectable to a drill string component and a downstream end comprising means for mounting a hammer bit.

A pneumatic feed tube has an open upstream end and a substantially closed downstream end, the upstream end of the feed tube being concentric with and fixed within the housing. The feed tube is positioned near the upstream end of the housing, the downstream end of the feed tube has one or more metered openings between the ends of the feed tube.

A piston body is slidably retained within the housing. The piston body has upstream and downstream open ends with the upstream end being concentrically retained and slidably engaged with the downstream end of the feed tube. The downstream end of the piston forms a hammer striking surface. The piston further has at least one axially oriented helical groove in an outside wall of the upstream end of the piston and a pair of pneumatic communication ports between an outside wall of the piston and an interior chamber formed by the piston.

More specifically, one of the ports leads between an interior chamber formed by the piston and the downstream end of the feed tube to a chamber formed between the upstream end of the piston and the cylindrical housing. The other of the ports leads from an interior chamber formed between an exterior wall of the piston and the housing and the downstream open end of the piston. One or the other of the ports in the body sequentially registers with the metered openings in the feed tube when the reciprocating piston is moved into alignment therewith during an operating cycle of the apparatus. A hammer bit body is slidably contained within the downstream end of the cylindrical housing. The bit body has an upstream shaft end adapted to slidably engage the bore formed in the downstream portion of the piston. Means are provided between the shaft of the bit and the bore of the piston to slidably key the shaft to the piston so that the bit rotates with the piston.

A clutch means is contained within the housing and is positioned adjacent to and interconnected with the helical groove formed in the piston. The clutch mean serves to rotate the piston and the bit keyed thereto, incrementally and in one direction only, each time the piston reciprocates within the cylindrical housing during operation of the air percussion hammer.

An advantage of the present invention over the prior art hammer tools is the ability to rotate the bit independent of any rotation of the drill string.

Brief Description of the Drawings

The above noted features and advantages of the present invention will be more fully understood upon a study of the following description in conjunction with the detailed drawings wherein:

FIGURE 1 is a cross-sectional view of the steerable hammer mechanism and bit connected to a drill string which may be part of a bent housing sub-assembly;

FIGURE 2 is a perspective view of the hammer drive piston illustrating the helix grooves formed in the top section of the piston and the various pneumatic ports formed therein;

FIGURE 3 is a cross-sectional view of the hammer mechanism with the bit cutter end contacting the formation, the piston being at the top of its stroke; FIGURE 4 is a cross section taken through 4-4 of FIGURE 1 illustrating the inner and outer air passages formed by the hammer bit body;

FIGURE 5 is a cross section taken through 5-5 of FIGURE 3 showing the relationship formed between the bit body and the shank of the hammer bit;

FIGURE 6 is a cross section taken through 6-6 of FIGURE 3 illustrating the clutch mechanism including the helical groove and ball engaging system that results in bit rotary motion converted from piston reciprocating motion;

FIGURE 7 is a cross section taken through 7-7 of FIGURE 3 illustrating the sprags housed within the clutch that prevent the piston from oscillating, the clutch mechanism insuring that the piston always rotates in a single direction;

FIGURE 8 is a cross-sectional view of the percussion mechanism at the termination of one complete cycle;

FIGURE 9 is a partially cutaway view of an alternative embodiment of the hammer rotary drive means; and

FIGURE 10 is a view taken through 10-10 of FIGURE 9 illustrating the sliding ball track mechanism between the piston and the hammer bit.

Description

FIGURE 1 illustrates an air percussion drilling assembly generally designated as 10. The air percussion apparatus consists of a cylindrical housing 12 that forms an upstream threaded female end 14 adapted to be connected to, for example, a drill string 15. The drill string may comprise a conventional bent housing sub-assembly utilized in a directional drilling operation (not shown). A hammer bit generally designated as 18 is slidably retained within the opposite or downstream end 16 of cylindrical housing 12.

A check valve 20 is retained within housing 12 adjacent threaded end 14. Valve body 21 is biased closed by valve spring 22 when the percussion apparatus is not functioning or the apparatus is "tripped" out of the borehole to prevent water or formation detritus from backing up the drill string.

A pneumatic feed tube generally designated as 24, is mounted within a feed tube support member 25; the support member being secured within housing 12. An interior chamber 28 communicates with the drill string 15 at an upstream end of the housing 12 and with slotted, axially aligned openings 26 formed in the feed tube wall at an opposite end of the tube 24. A small diameter choke 27 substantially closes off the downstream end of the tube just below the slotted openings 26.

A pneumatic piston generally designated as 30 slidably engages a cylinder wall 13 formed by the housing 12. The body 31 of the piston 30 has an upper, reduced diameter cylindrical segment 32. An inner cylindrical wall 33 in the piston overlaps and partially engages the outside wall 29 of the concentric feed tube 24. An annular chamber 35 within segment 32 provides a pneumatic conduit for pressurized air to the slots 26 formed in feed tube 24, depending upon the axial position of the piston 30 within housing 12. The piston body 31 also has diagonal ports or conduits 38 and 39 that communicate with slots 26 in the feed tube 24. The ports direct pressurized air either to slots 40 formed in the piston 30 and from there to a chamber 41 formed below the piston 30 in the housing 12 or to an annular chamber 37 above the piston, depending on the axial position of the piston as the mechanism cycles through its operating modes.

FIGURE 1 illustrates the hammer bit 18 positioned above a borehole bottom 8; the bit being suspended from a retaining ring 49 attached to the inside wall 13 near the bottom of the housing 12. As long as the bit remains off bottom 8, pressurized air 11 is directed down the drill string 15 into the chamber 28 formed in the feed tube 24. The air is then directed through slots 26 to the upper annular chamber 35 and from there to chamber 37. Ports 39 in the piston 30 then direct the pressurized air to an air passage 53 formed through the center of hammer bit 18 then out through one or more nozzles 54 formed in the bit cutting face. The air under pressure serves to clean the rock chip debris and other detritus such as accumulated water from the borehole bottom 8 prior to commencement of further drilling operations.

As the air percussion assembly 10 is lowered down the borehole 6 formed in earthen formation 4, the bit 18 contacts the bottom 8 (Fig. 3). The bit 18 and piston 30 is subsequently pushed back into housing 12 a distance wherein a shoulder 51 formed on the bit 18 contacts a rim 16 formed on the housing 12. Upon contact, air is shut off to chambers 35 and 37 when the piston moves over the fixed feed tube 24. The pressurized air is then redirected down through the diagonal ports 38 to slotted channels 40 and into chamber 41 below piston 30. The piston is then forcibly accelerated up cylinder walls 13 separating the impact surface 34 formed at the bottom of the piston from the top of the hammer bit 18 as illustrated in Fig. 1. The momentum of the piston mass carries the piston 30 to the upper end of chamber 37. Pressurized air is then redirected to the top of the piston (chamber 37) through slots 26 in feed tube 24 into piston ports 39. The piston then is accelerated down cylinder walls 13; end 34 of the piston subsequently impacting end 55 of the hammer bit 18 thereby completing the cycle (Fig. 8).

FIGURE 3 depicts the piston 30 at the top of its travel within the cylindrical sleeve 13 formed by the housing wall prior to being accelerated toward the impact surface 55 of the hammer bit 18. As the piston moves downward toward the hammer bit, a clutch mechanism generally designated as 56, engages a ball 58 with a helical groove 36 formed in the upper reduced diameter section 32 of piston 30 (FIG. 2). The piston moves in a clockwise direction as it moves down toward the hammer bit and, since the hammer bit is keyed to the piston by a flattened shaft 50, the bit moves rotationally in concert with the piston. When the piston is cycled in the reverse or upward direction, the clutch slips hence preventing the piston (and hammer bit) from rotating in a counter-clockwise direction. The piston and hammer bit therefore is rotationally indexed in a clockwise direction only.

The piston and hammer is preferably rotated on the downstroke of the piston for the following reasons; there is tremendous formation resistance imparted to the piston hammer mechanism on the upward cycle of the piston due to the fact that the lower chamber 41 is charged, forcing impact surfaces 34 and 55 apart and driving the cutting face 19 of the hammer bit into the formation, thereby resisting the turning or rotational force exerted on the piston by the ball 58 in the helical groove 36. Therefore, if the rotational forces were exerted on the piston and the bit on the downstroke, the bit is released from the formation and the rotational forces easily rotate or index the bit to its new position without unnecessary wear on the various sliding surfaces.

FIGURE 4 illustrates a section taken through housing 12 (Fig. 1) showing the piston 30 with the flattened shaft 50 of the hammer 18 slidably retained within a sleeve 42 formed by the piston. The generally rectangular shaped shaft 50 with rounded ends, for example, is slidably retained within the complementarily shaped sleeve 42 formed in the piston 30. Thus, the hammer is keyed to the piston and rotates therewith. The central air passage 53 communicates with the nozzles 54 formed in the cutter face 19 of hammer 18.

One may also utilize conventional hammer bit splines as a means to key the shank of the hammer bit to the piston without departing from the scope of this invention.

FIGURE 5 depicts a section through the hammer body 47 slidably retained in a cylindrical sleeve 17 fastened to the lower housing 12. Air passages 52 in the body 47 allow air under pressure to escape around the hammer body when the apparatus 10 is suspended above the borehole bottom 8 (Fig. 1). As heretofore mentioned, a free flow of air prevents debris (and water) from contaminating the air percussion apparatus while the mechanism is being tripped in and out of the borehole.

FIGURE 6 details part of the clutch mechanism 56. This view locates the helical groove engaging balls 58 at the bottom of the helix 36 in the shank 32 of the piston 30 (Fig. 3). The balls 58 are each retained in a ball race 59; the race 59 being secured within ball and clutch housing 60.

FIGURE 7 is a view taken through the clutch mechanism primarily comprising a multiplicity of "sprags" or clutch dogs 57 that allow rotation in one direction only. Since rotation preferably occurs only on the piston downstroke, the clutch dogs 57 engage the walls and prevent circumferential rotation of the ball races. The balls within the helical tracks 36 result in a clockwise rotation of the piston and hammer bit as heretofore described. On the upstroke of the piston the clutch releases the ball driver mechanism. The piston then travels up the housing 12 without rotation.

FIGURE 8 illustrates the percussion tool 10 at the completion of an operating cycle. The hammer has been rotated or indexed the preferred 4 to 5 degrees prior to impact of the cutting face 19 of the hammer bit with the formation bottom 8. Since the hammer bit rotates independent of the drill string, it does not matter whether the drill string rotates, hence the air percussion tool is ideal for directional drilling operations wherein a bent housing sub-assembly is normally incorporated.

FIGURES 9 and 10 illustrate an alternative piston shank sliding engagement mechanism. The piston 130 forms an internal sleeve 142 with, for example, three parallel, axially aligned semi-circular grooves 120 degrees apart formed in the sleeve wall of the body. The shank 150 of hammer bit 118 retains three ball bearings 160 that are aligned with each of the complementary grooves 143 formed in the piston body 131. The shank of the hammer bit then is slidably "splined" to the piston with a minimum of drag.

It will of course be realized that various modifications can be made in the design and operation of the present invention without departing from the spirit thereof. Thus, while the principal preferred construction and mode of operation of the invention have been explained in what is now considered to represent its best embodiments, it should be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

Claims

1. An air percussion hammer comprising:

a cylindrical housing having an upstream end connectable to a drill string component and a downstream end including means for mounting a hammer bit;

a piston slidably retained within the housing, a downstream end of the piston including a surface for striking a hammer bit mounted on the end of the housing;

fluid porting in the housing for alternately driving the piston upwardly in the housing and driving the piston downwardly in the housing for striking a hammer bit, and characterized by:

means for rotating the piston during the downward stroke of the piston;

clutch means for preventing rotation of the piston during the upward stroke of the piston; and

keying means for permitting relative longitudinal movement while preventing relative rotation between the hammer bit and the piston.

2. An air percussion hammer as recited in claim 1 wherein the hammer bit is mounted for reciprocal movement in the housing and characterized by means for venting fluid from the hammer when the hammer bit is relatively down in the housing and for applying fluid pressure for driving the piston when the hammer bit is relatively up in the housing.

3. An air percussion hammer as recited in any of the preceding claims wherein the hammer bit is slidably contained within the downstream end of the cylindrical housing, the hammer bit comprising an upstream shaft end axially slidable within the piston, the shaft end of the hammer being rotationally keyed to the piston by an engagement means such that the hammer bit rotates in concert with the piston.

4. An air percussion hammer as recited in any of the preceding claims wherein the clutch means comprises at least a pair of spherically shaped detents for slidably engaging complementary shaped helical grooves in the upstream end of the piston.

5. An air percussion hammer as recited in any of the preceding claims wherein the keying means for permitting relative longitudinal movement while preventing relative rotation between the hammer bit and the piston comprises three spherically shaped detents between the upstream end of the shank of the hammer and the inside of the piston, the detents being positioned about 120 degrees apart and slidably engaged with complementary shaped longitudinally extending grooves.

6. An air percussion hammer as recited in any of the preceding claims wherein the means for rotating the piston during the downward stroke of the piston comprises a helical groove in the piston with a helix angle and length sufficient for rotating the piston approximately five degrees per cycle of the piston.

7. An air percussion hammer as recited in any of the preceding claims wherein the means for rotating the piston during the downward stroke of the piston comprises a helical groove in the piston and a ball bearing engaging the housing and the helical groove.

8. An air percussion hammer as recited in claim 7 wherein there are three helical grooves formed in the upstream end of the piston 120 degrees apart, each of the grooves being engaged with a ball bearing retained within the housing.

9. An air percussion hammer as recited in any one of the preceding claims wherein the means for rotating the piston during the downward stroke of the piston and means for preventing rotation of the piston during the upward stroke of the piston comprises:

a pneumatic feed tube having an open upstream end and a substantially closed downstream end, the feed tube being concentric with and fixed within the housing, the second end of the feed tube having one or more openings between the first and second ends of the feed tube;

the piston having open ends, an upstream end of the piston being reduced in diameter and slidably engaged around the second end of the feed tube, a downstream end of the piston being engaged with the interior of the housing and including a hammer striking surface;

at least one axially oriented helical groove in an outside wall of the reduced diameter upstream end of the piston;

at least a pair of pneumatic communication ports through the piston, one of said ports leading between an interior chamber in the piston and a chamber formed between the open upstream end of the piston and the cylindrical housing, the other of said ports leading between a chamber formed between an exterior wall of the piston and the inside of the housing adjacent to the downstream end of the piston, one or the other of the ports in the body sequentially registering with the openings in the feed tube when the reciprocating piston is moved into alignment therewith during an operating cycle of the hammer; and

clutch means contained within the housing adjacent to and interconnected with such a helical groove in the reduced diameter end of the piston, for rotating the piston and the hammer engaged therewith incrementally and in one direction only, each time the piston oscillates within the cylindrical housing during operation of the hammer.

10. A method of rotating a hammer rock bit of an air percussion hammer bit apparatus while it reciprocates in a housing, the rotation of the bit being independent of an attached drill string comprising the steps of;

forming a cylindrical housing an open upstream end connectable to a drill string component and a downstream end containing a hammer bit, the hammer bit being free to reciprocate longitudinally in the housing;

mounting a longitudinally movable annular piston in the housing defining a first chamber having an upstream end and a downstream end having a hammer striking surface, and including a helical groove in an outside wall of the piston;

alternately

passing air from a chamber above the upstream end of the piston to the inside of the piston, and

passing air from the inside of the piston to a chamber outside of the piston adjacent to the downstream end of the piston, for reciprocating the piston in the housing and striking the hammer bit;

engaging the helical groove with a detent for rotating the piston during a downward stroke of the piston;

rotating the hammer bit in concert with the piston;

and

preventing rotation of the piston during an upward stroke of the piston.

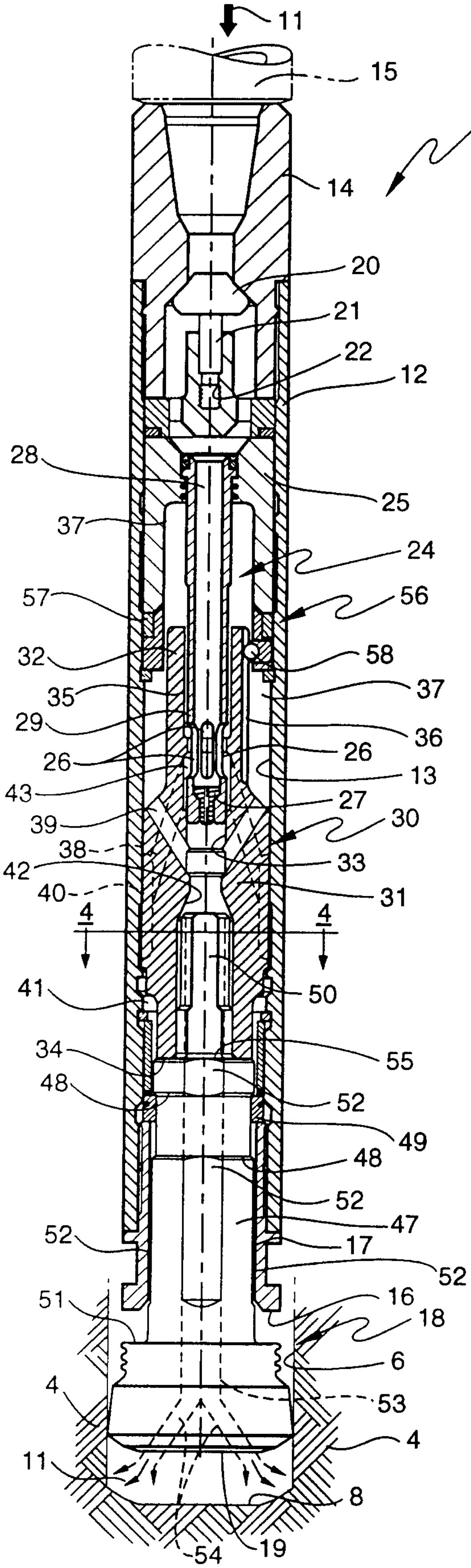


Figure 1

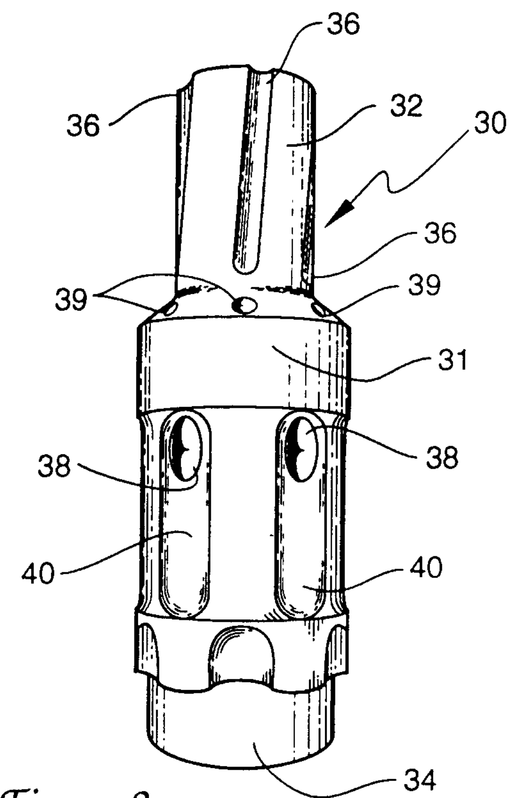
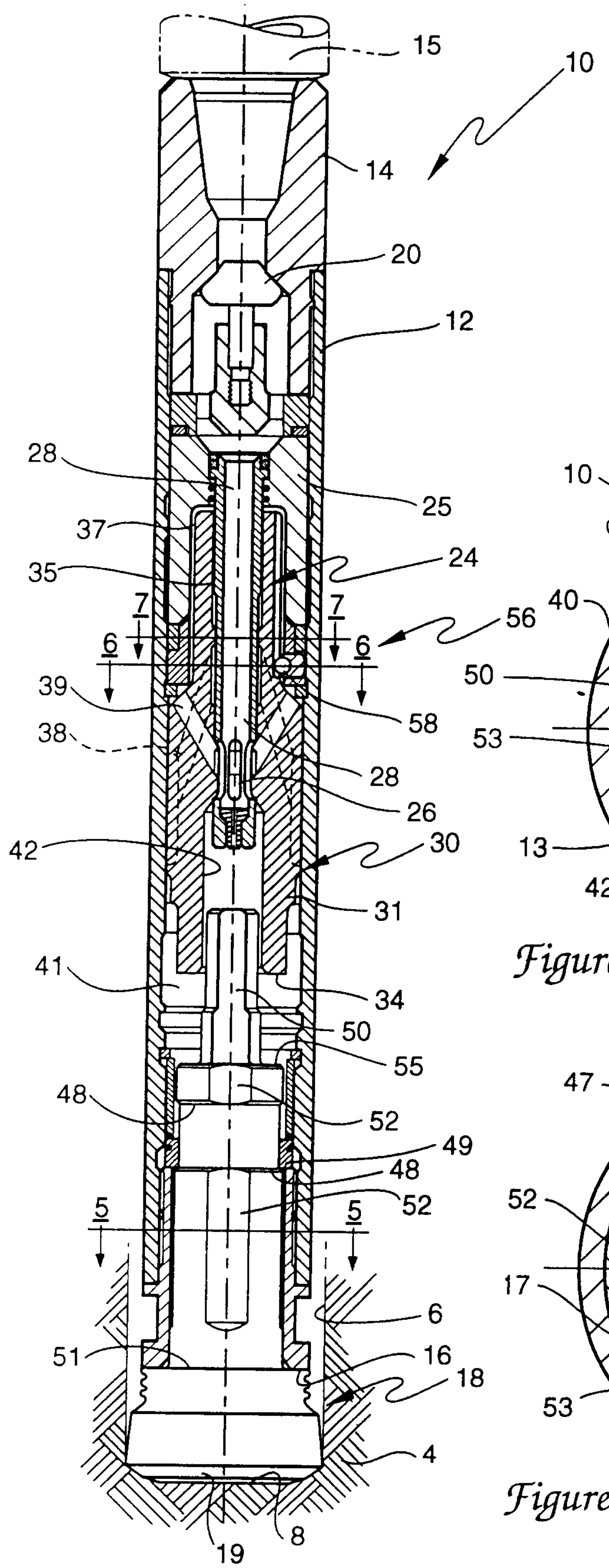


Figure 2

Figure 3



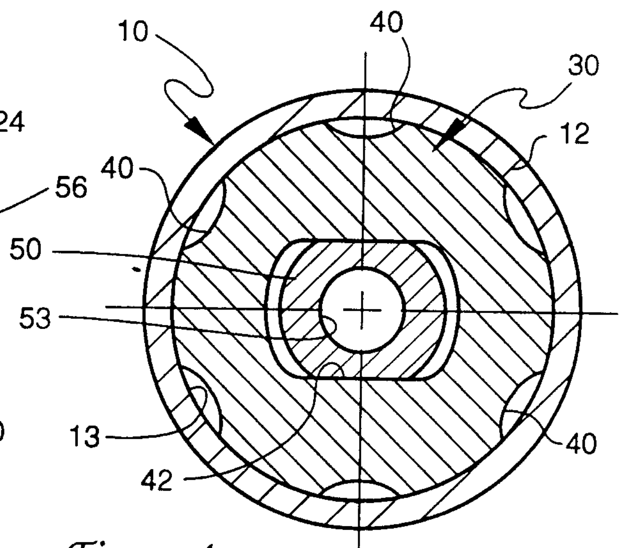


Figure 4

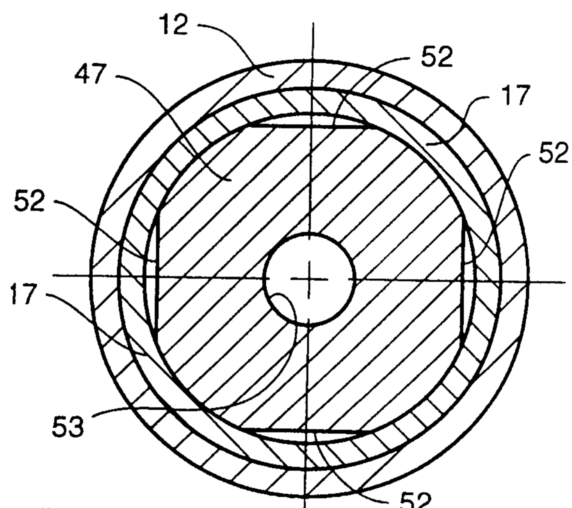
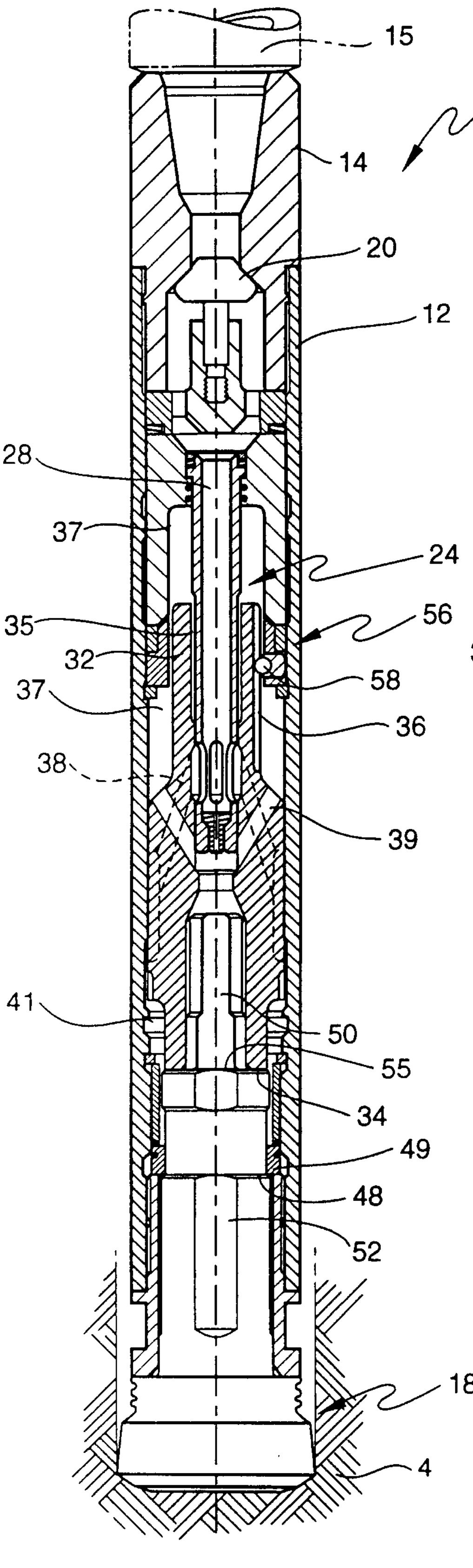


Figure 5

Figure 8



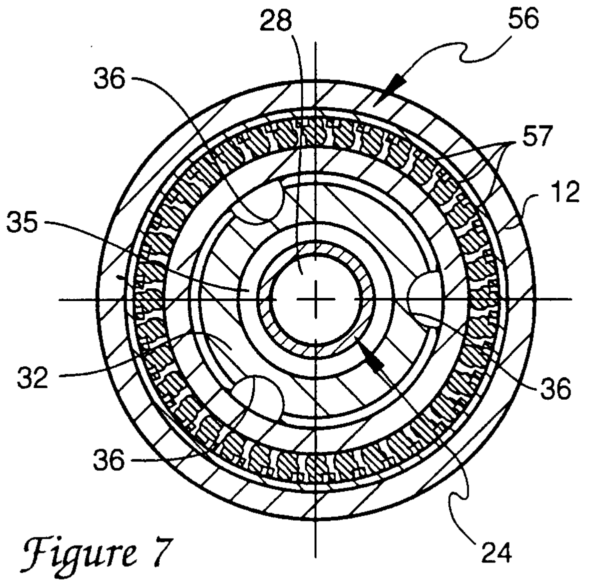


Figure 7

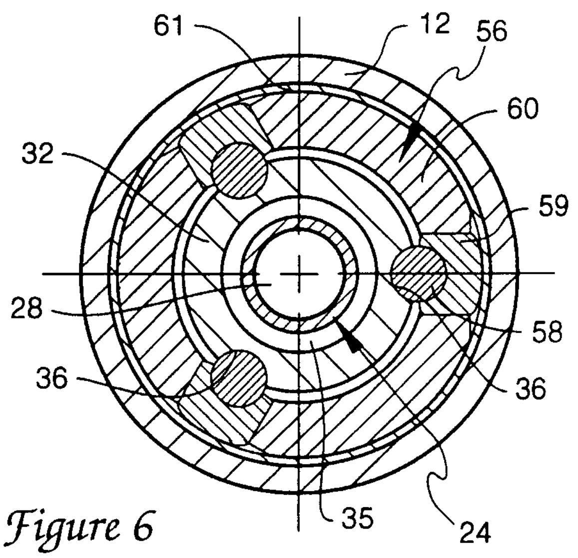


Figure 6

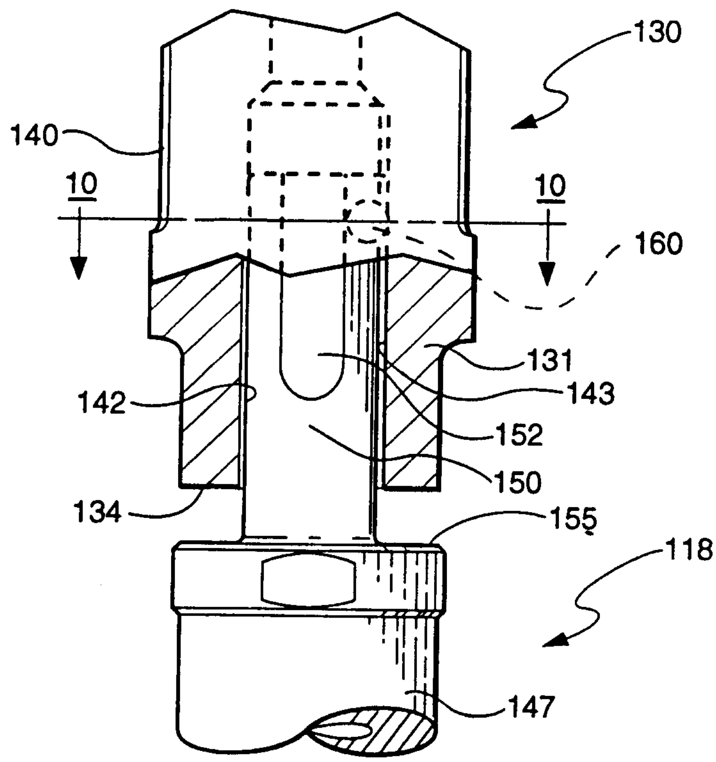


Figure 9

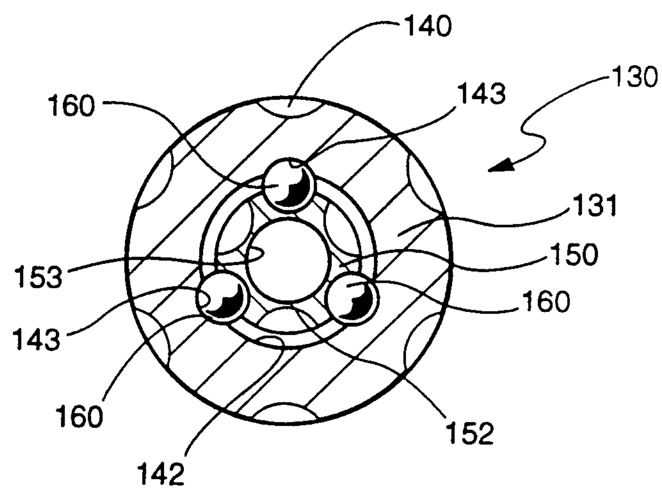


Figure 10

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 11 1146

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
A	US-A-4 958 691 (HIPP) * column 5, line 1 - line 55; claims 8,9; figures 1-6 *	1,4,6-10	E21B4/16 E21B4/14
A	US-A-4 705 118 (ENNIS) * column 2, line 1 - column 4, line 25; figures 2-5 *	1-4,9,10	
A	US-A-4 819 739 (FULLER) * the whole document *	1,9,10	
A	US-A-4 924 948 (CHUANG) * column 3, line 28 - line 33; figures 1,2 *	1	
A	US-A-3 978 931 (SUDNISHNIKOV) * column 4, line 32 - line 47; figure 1 *	1,10	
A	US-A-3 912 023 (AMTSBERG)		
A	US-A-4 209 070 (SUDNISHNIKOV)		

TECHNICAL FIELDS SEARCHED (Int.Cl.5)

E21B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10 November 1993	FONSECA FERNANDEZ, H

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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