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(51) INT CL:
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B25F 5/02 (2006.01)

(52) UK CL (Edition X):
B4C C1A1 C1C C11X C20 C7

(56) Documents Cited:
GB 1343206 A **GB 0306148 A**
US 5161623 A

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UK CL (Edition X) **B4C**
INT CL **B23D, B25D**
Other:

(54) Abstract Title: **Drive mechanism for power tool**

(57) A drive mechanism for a hammer drill comprises a hollow piston 558 having a cylindrical bearing that receives a crank pin in order to cause the hollow piston 558 to reciprocate inside a spindle, Figure 25, 548. A plurality of longitudinal ridges 559 are formed on the outer surface of the hollow piston 558 to reduce the surface area of contact between the hollow piston 558 and the spindle, Figure 25, 548, and a plurality of grooves 561 are formed in the gaps between the ridges. The grooves 561 retain lubricant 558 in order to reduce frictional contact between the hollow piston 558 and the spindle Figure 25, 548.

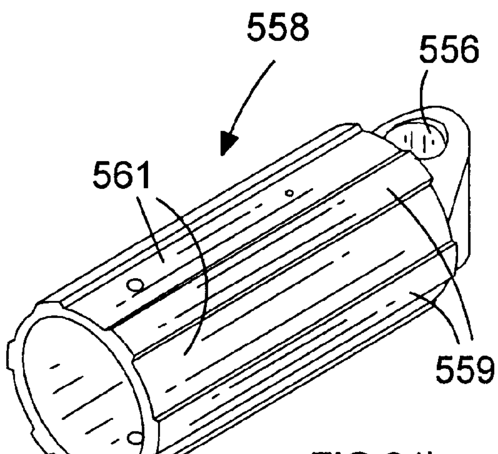

FIG.24b

GB 2 421 700 A

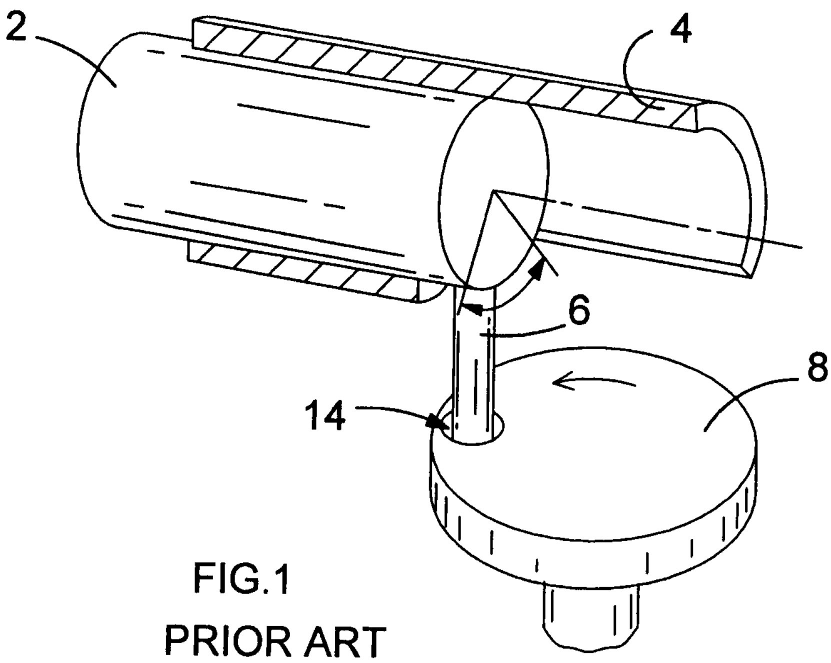

FIG.1
PRIOR ART

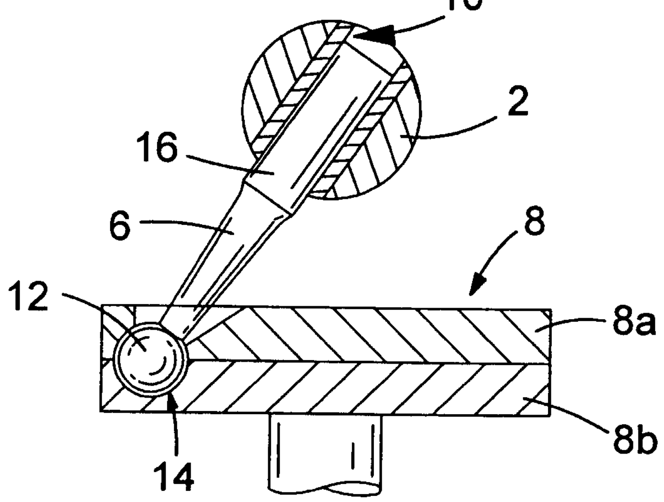

FIG.2
PRIOR ART

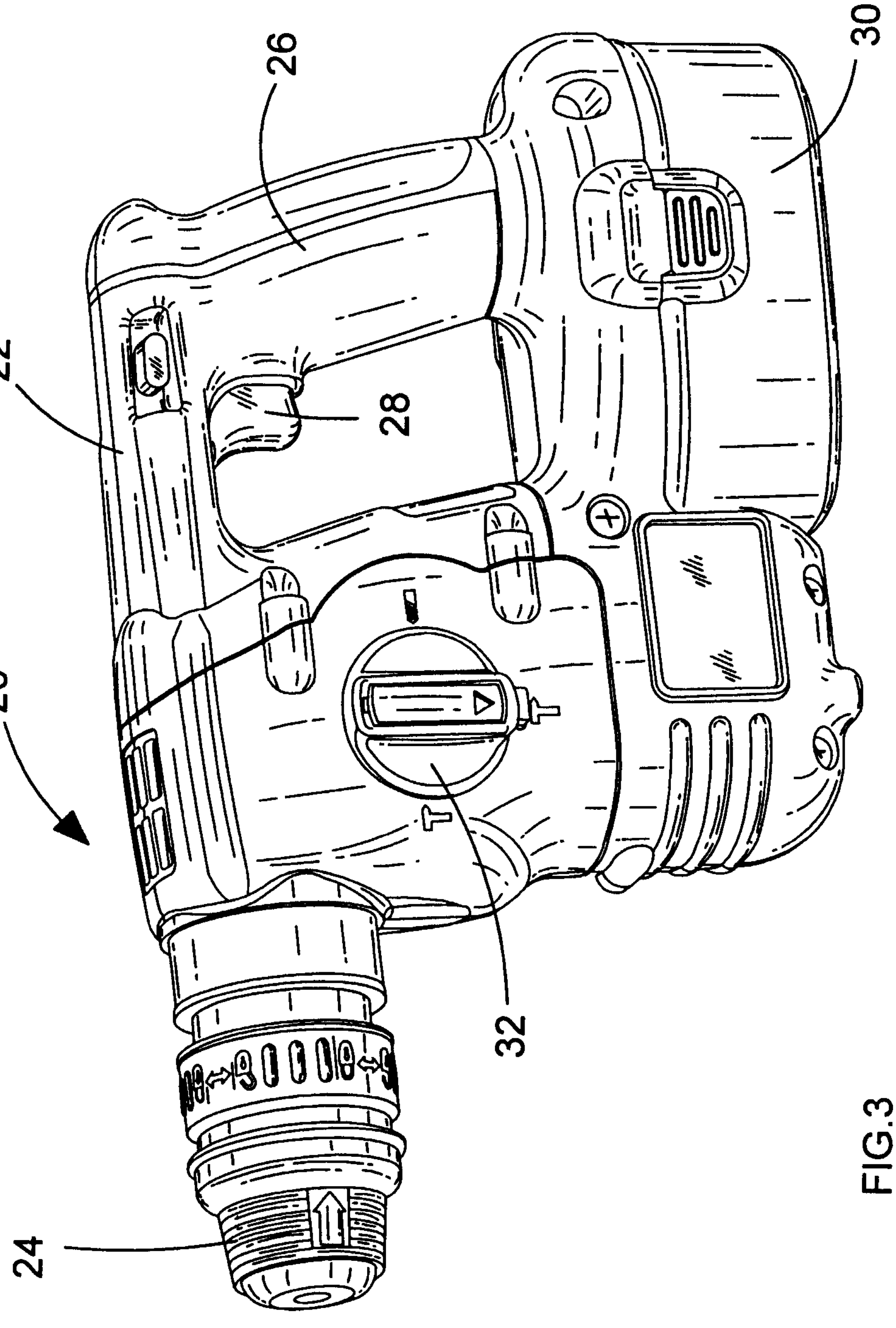

FIG.3

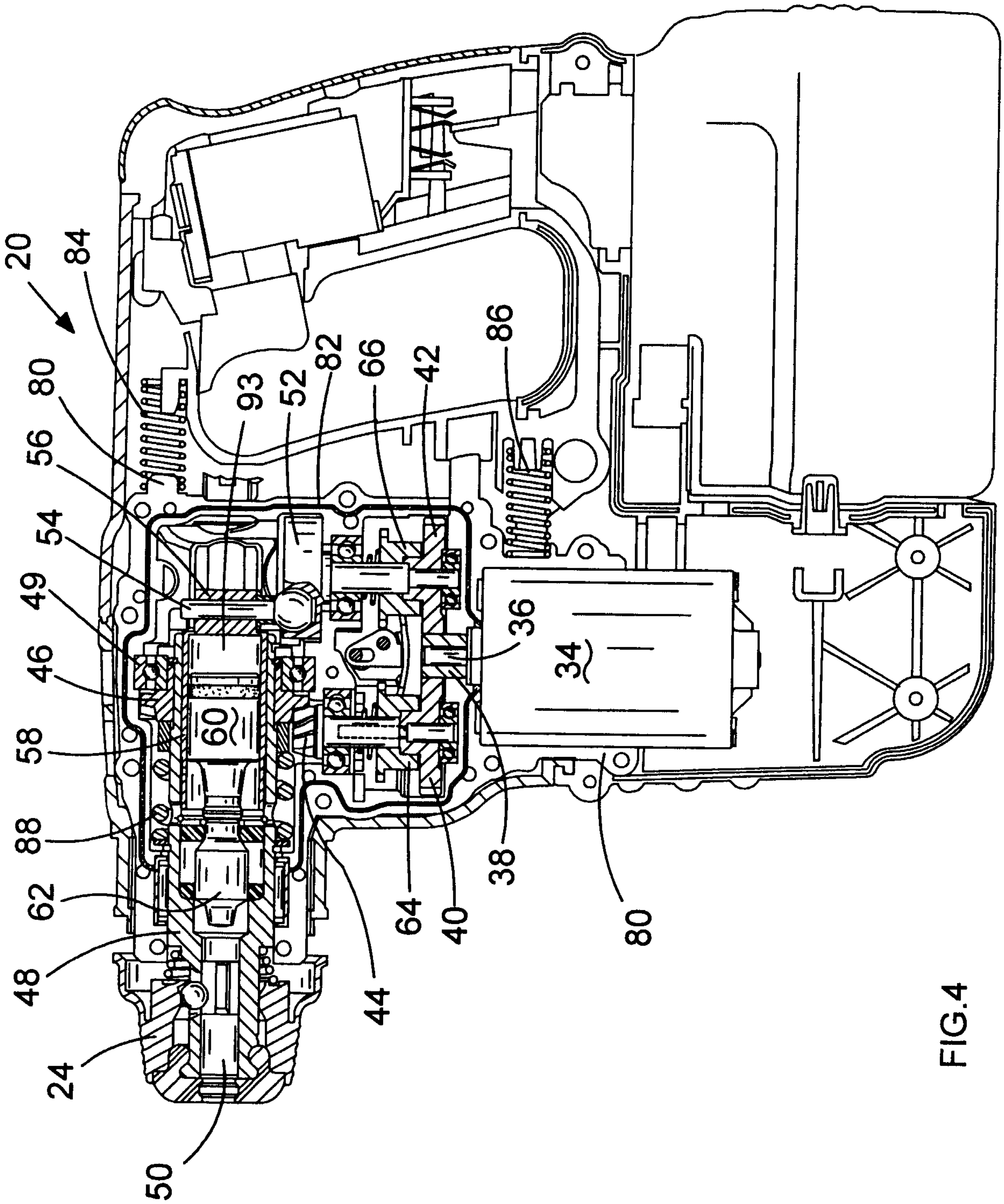
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FIG.4

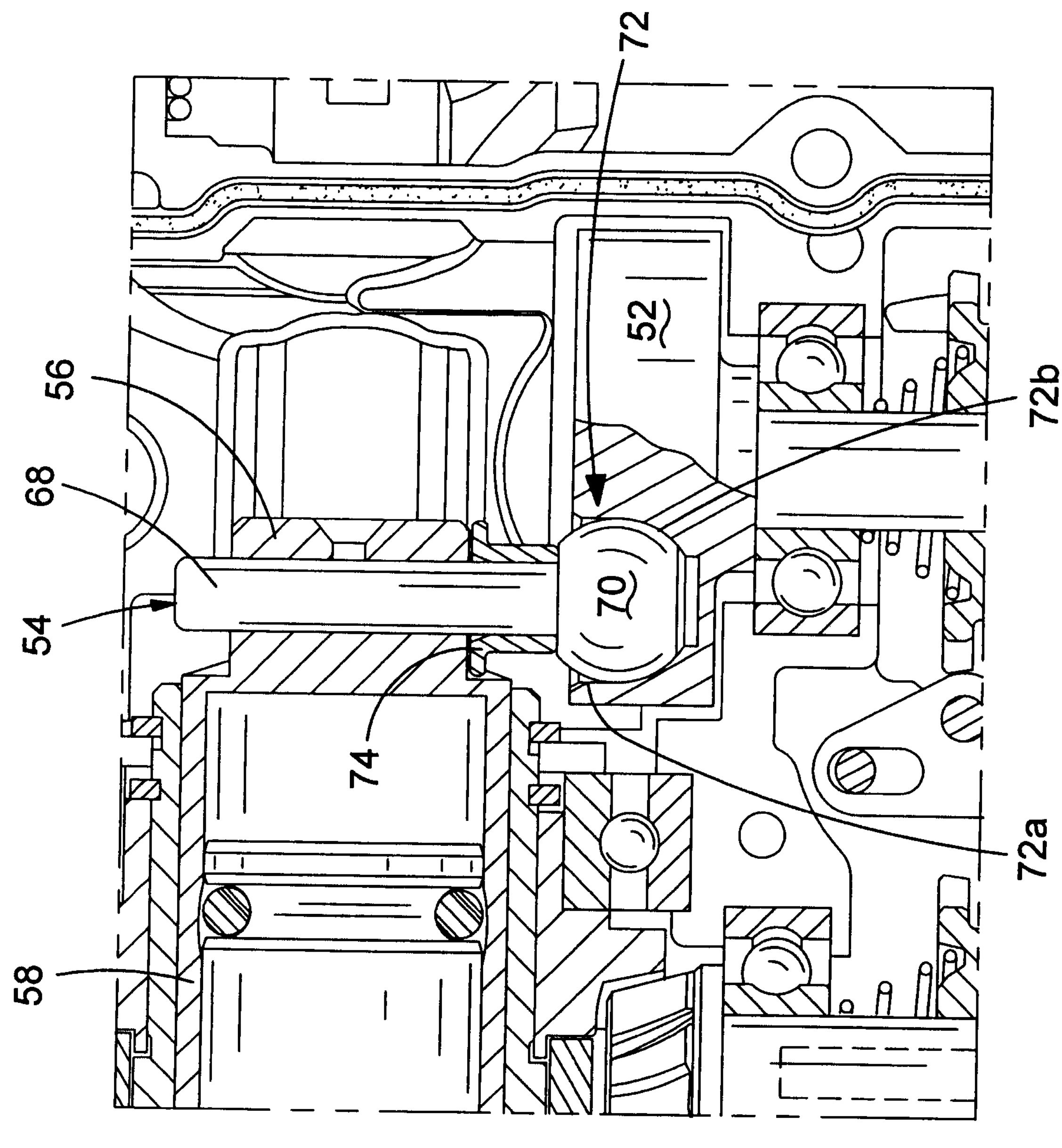

FIG.5

11 -3 05

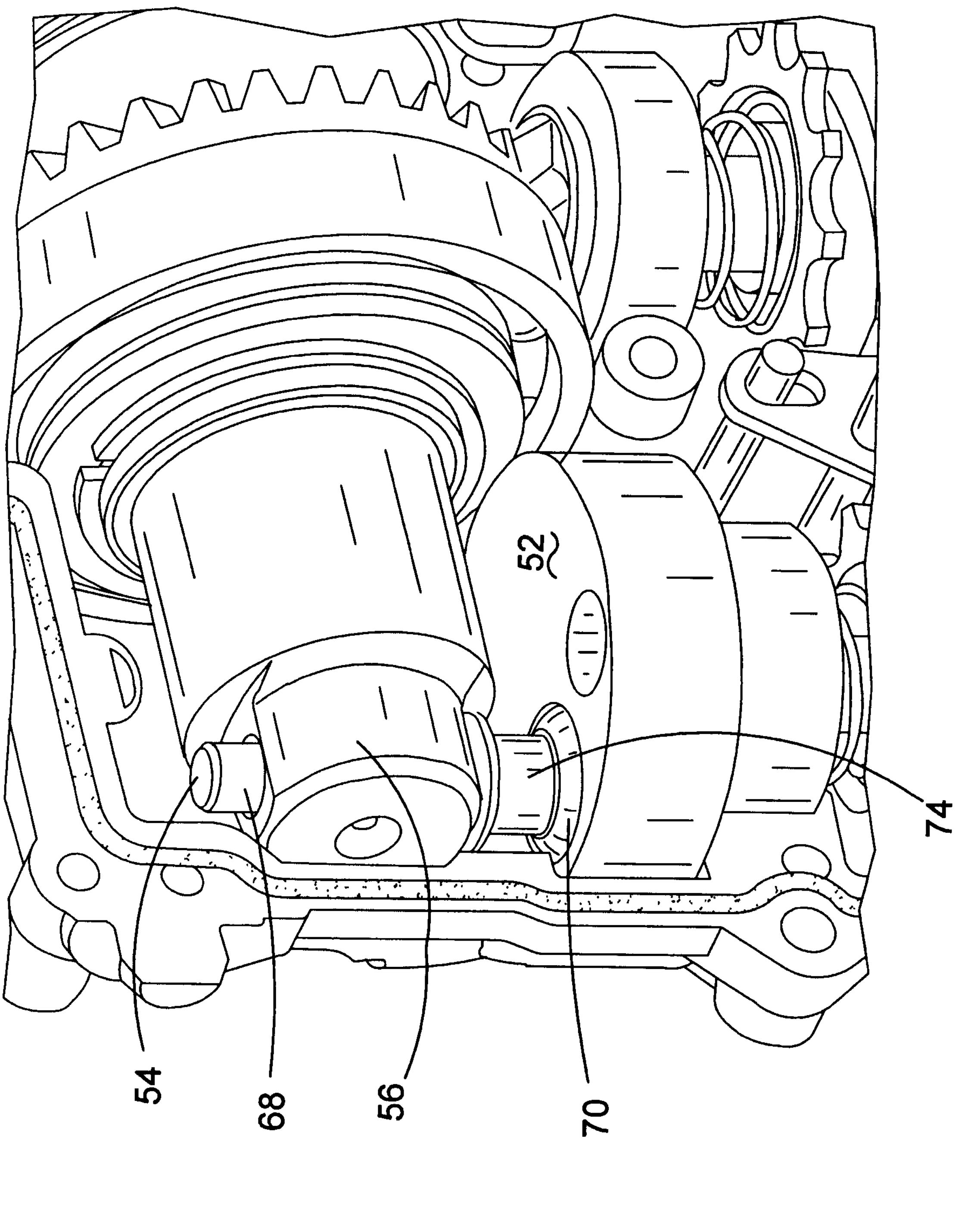

FIG.6

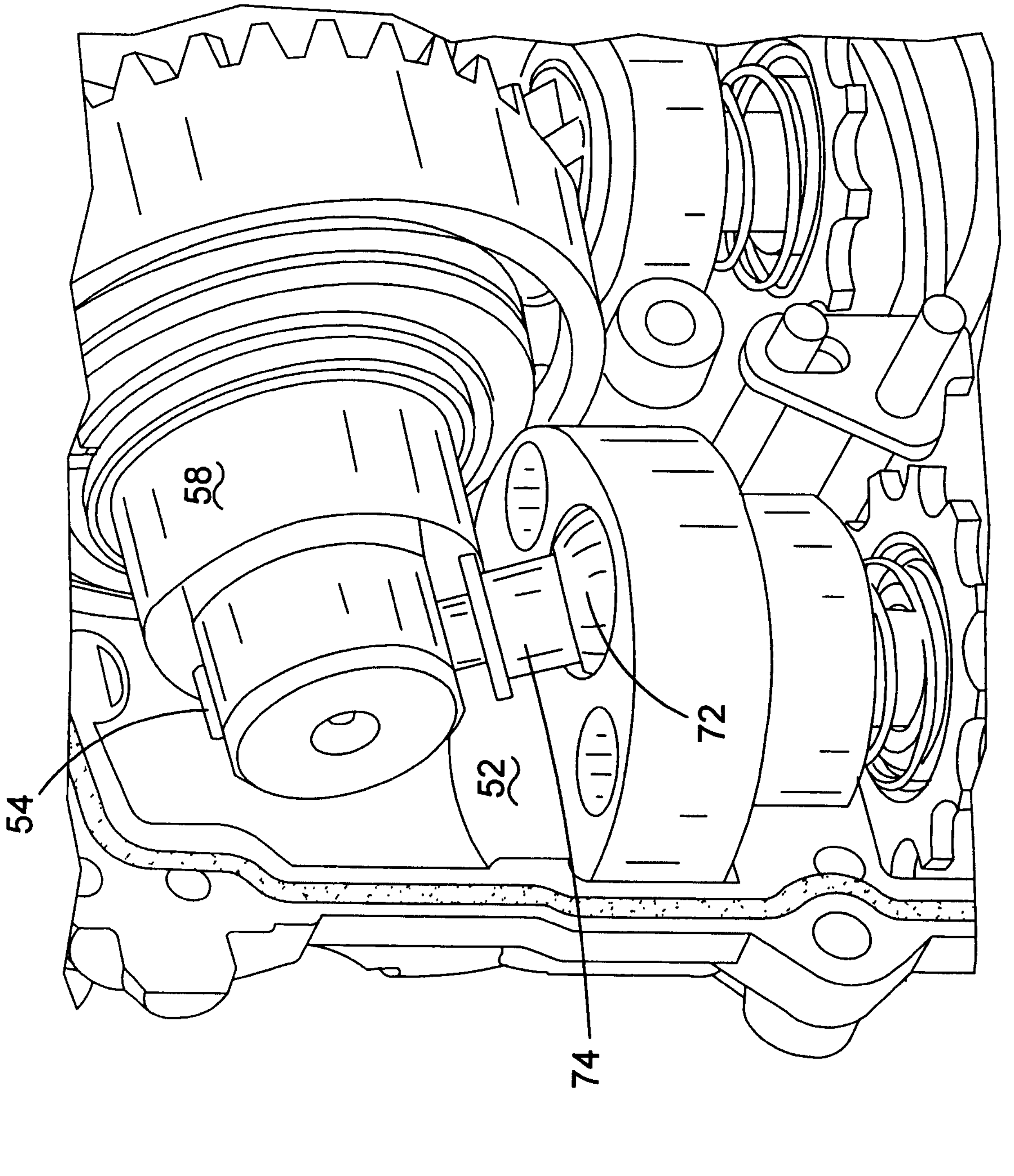

FIG.7

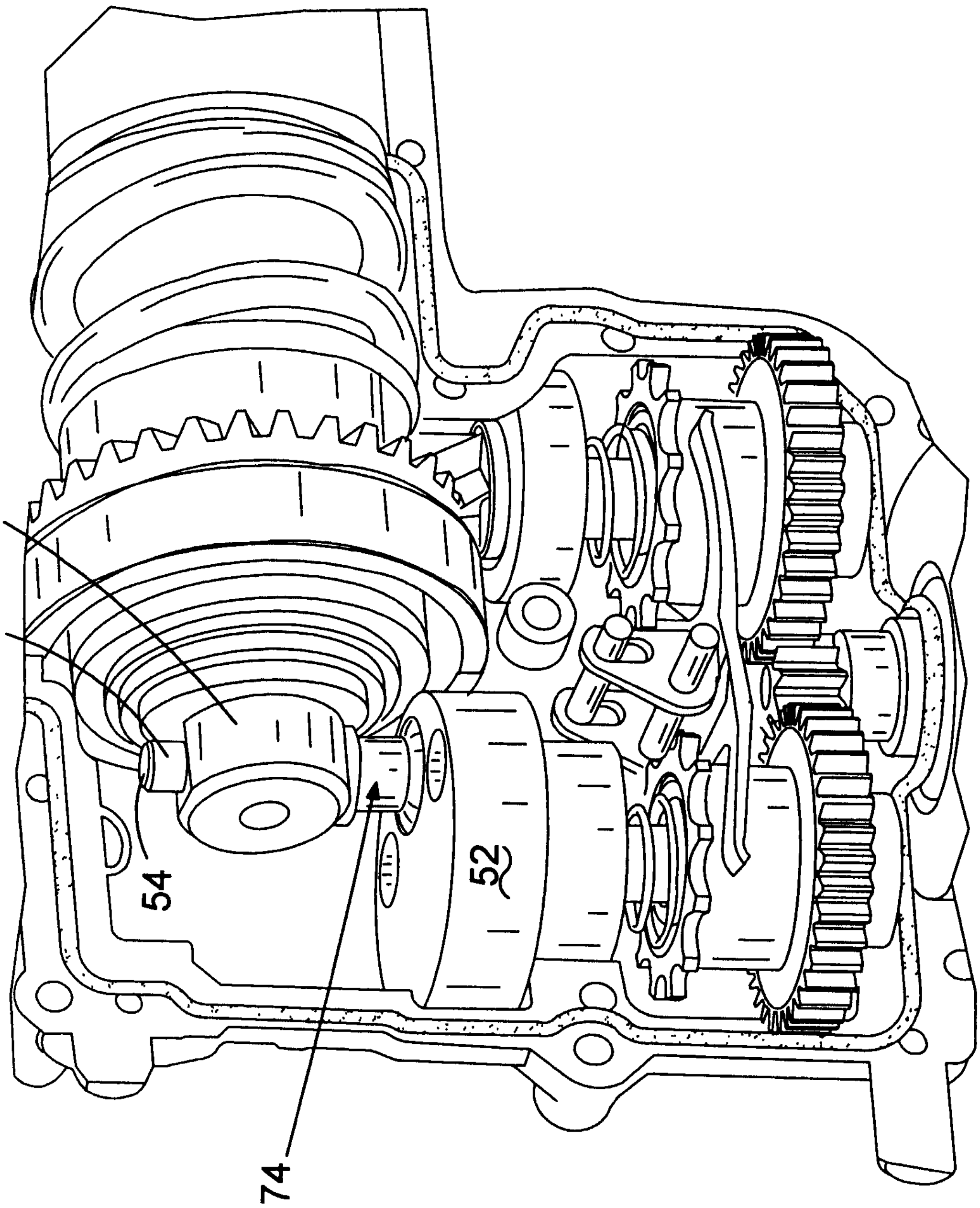

FIG.8

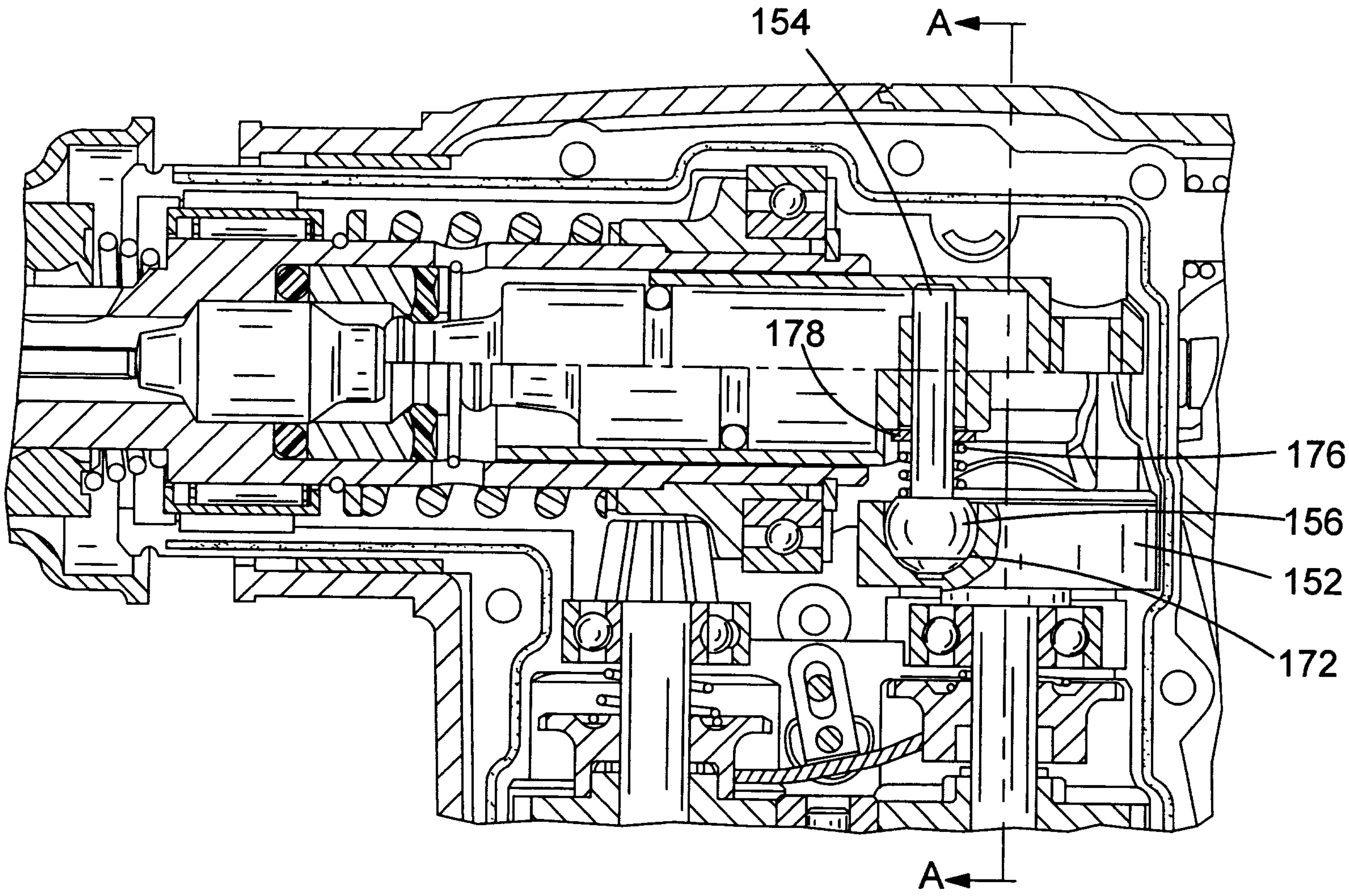

FIG.9

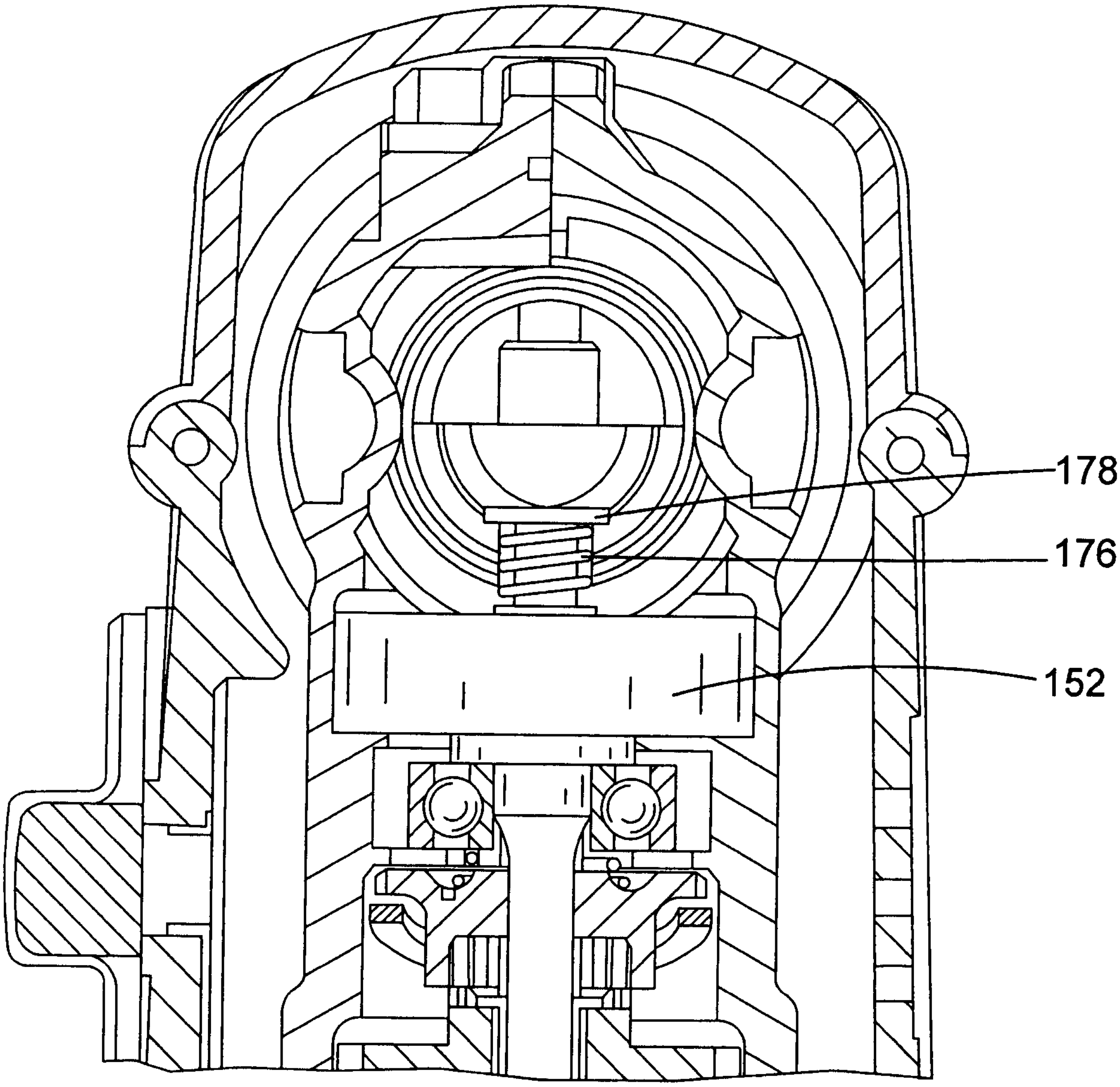

FIG.10

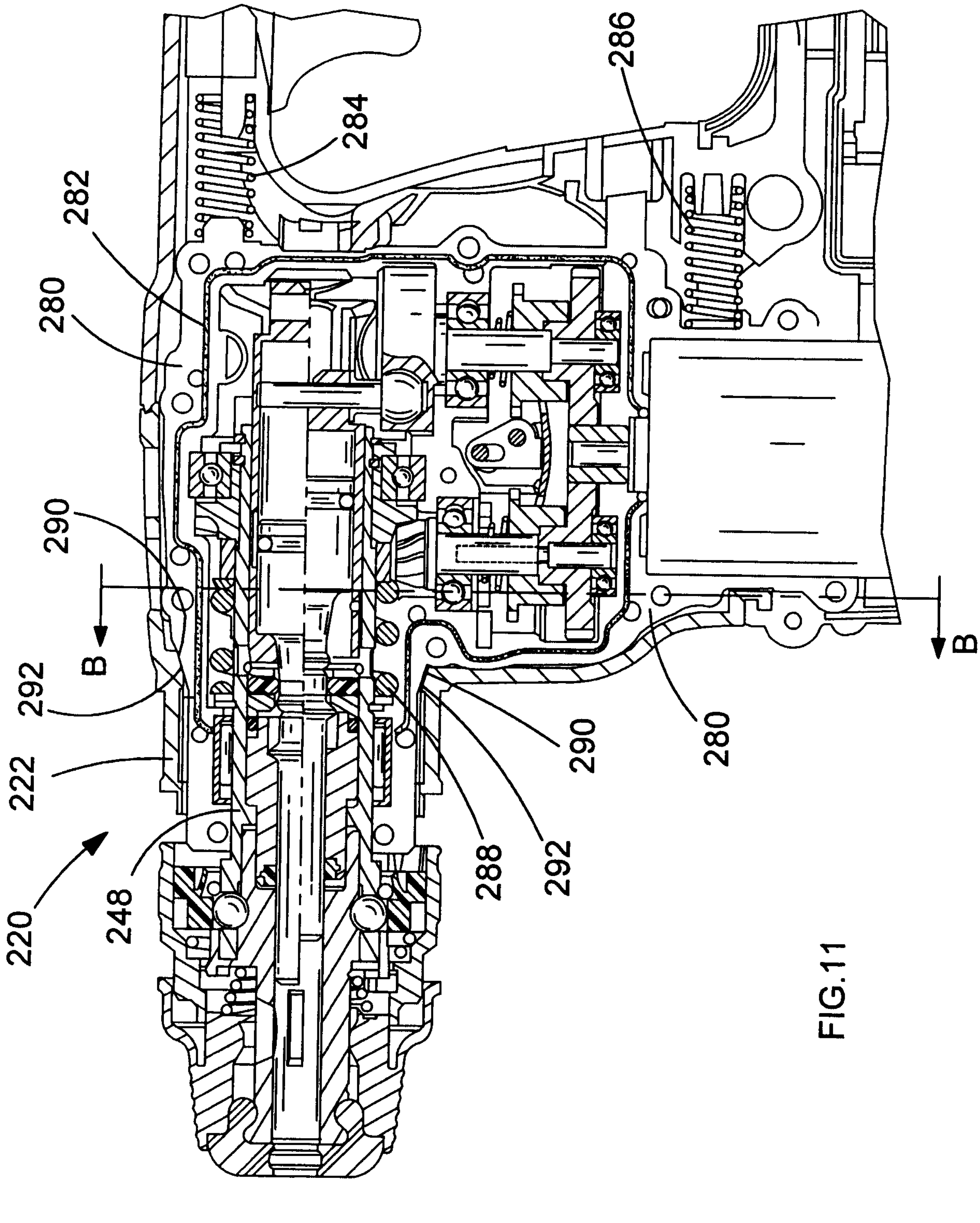

FIG.11

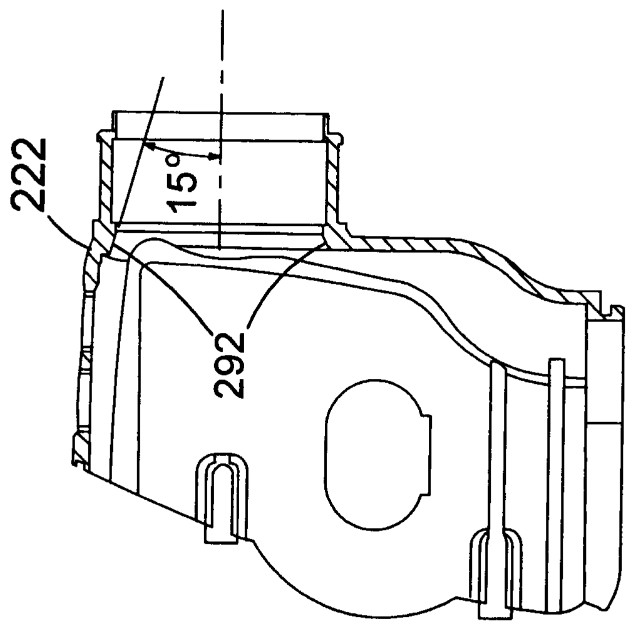

FIG.13

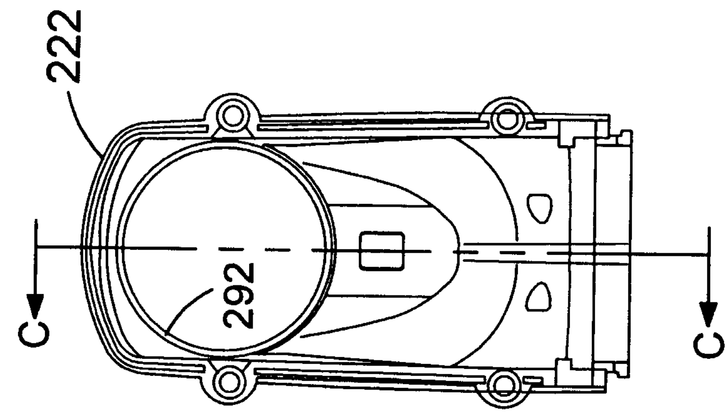

FIG.12

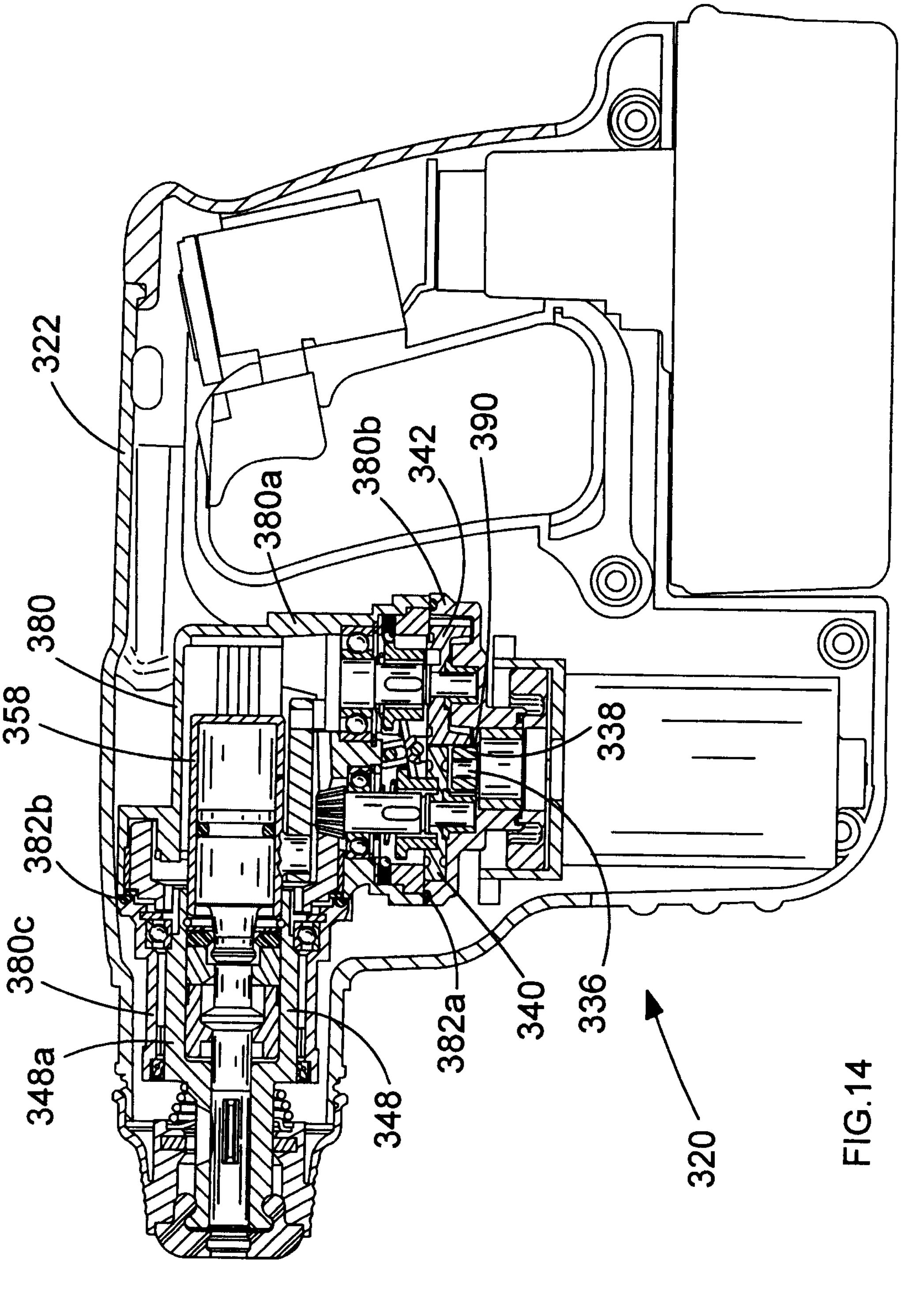
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FIG.14

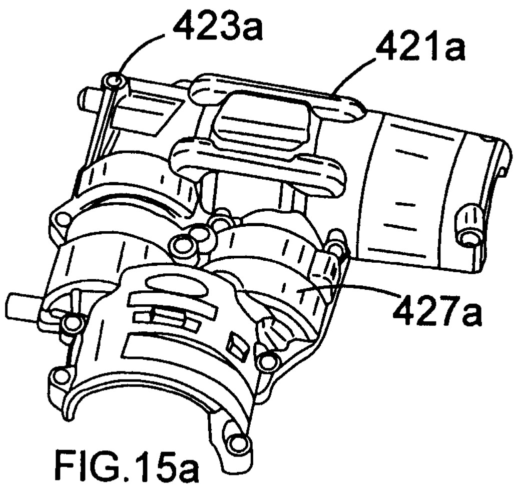

FIG.15a

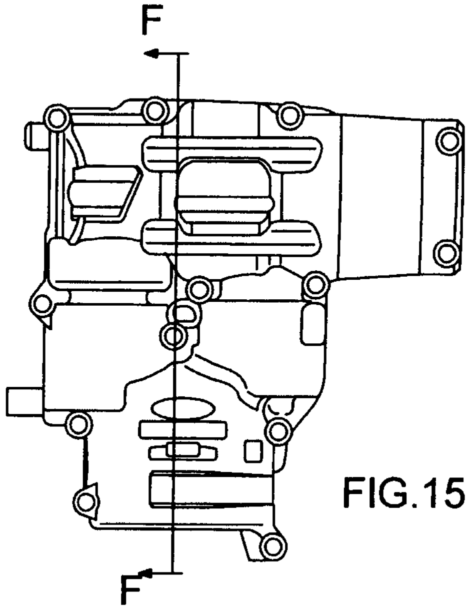

FIG.15b

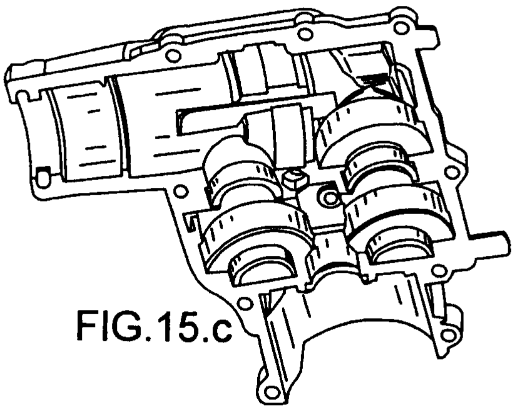

FIG.15.c

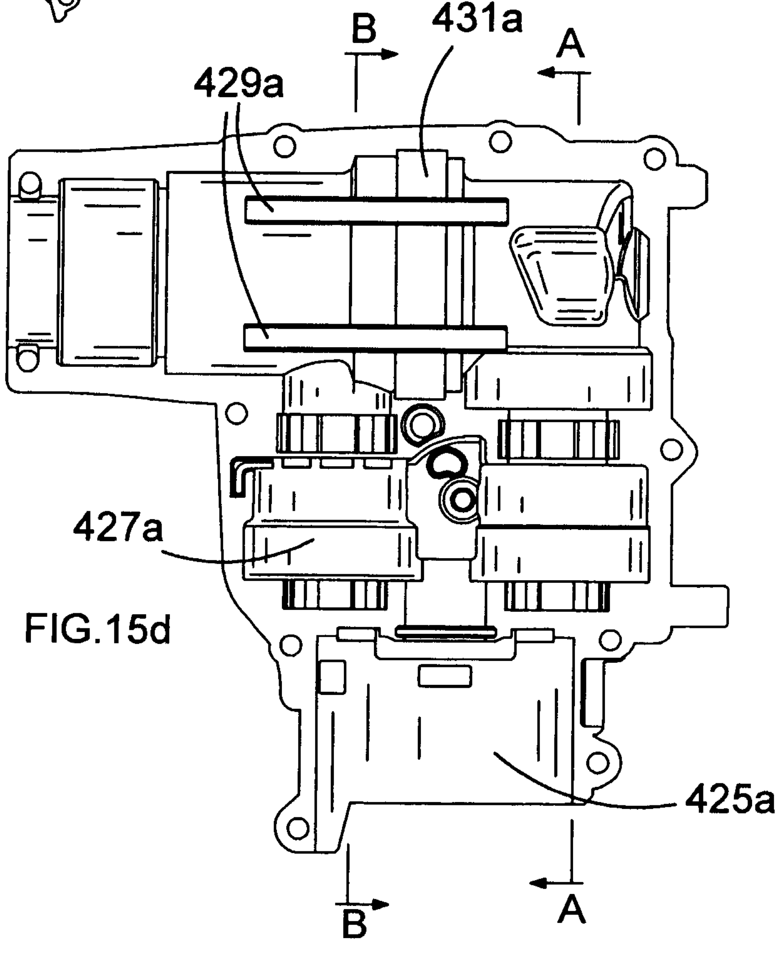

FIG.15d

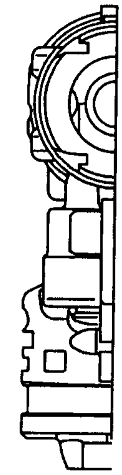

FIG.15e

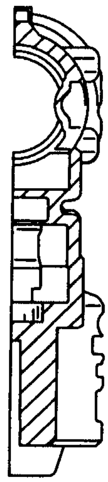

FIG.15f

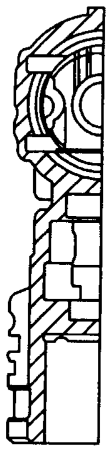

FIG.15g

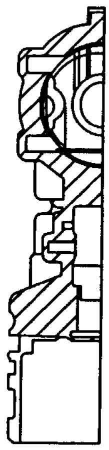

FIG.15h

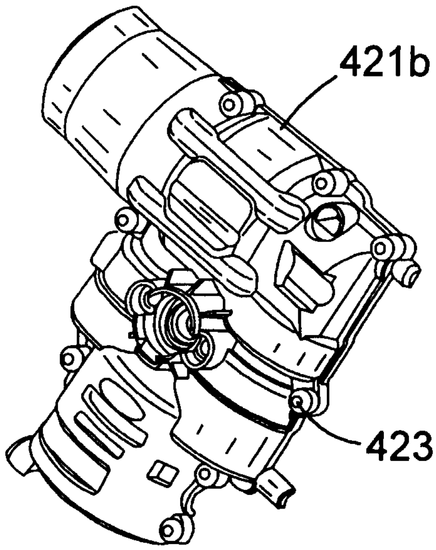

FIG.16a

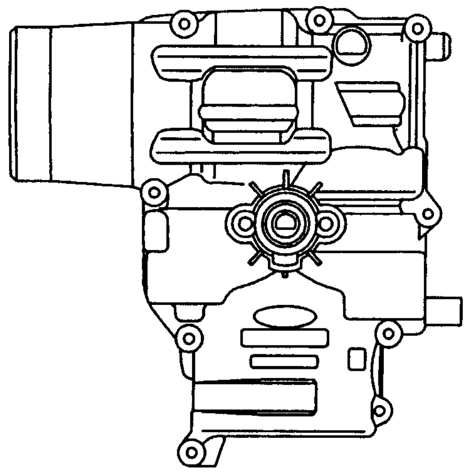

FIG.16b

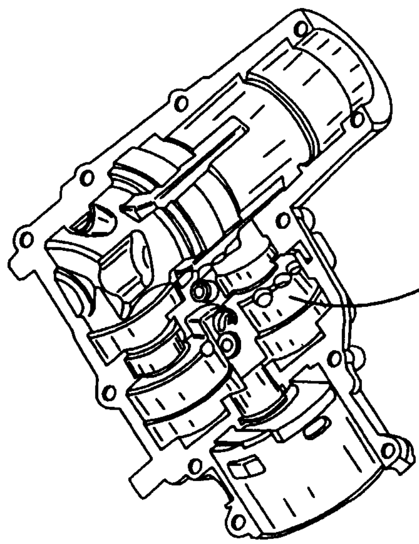

FIG.16c

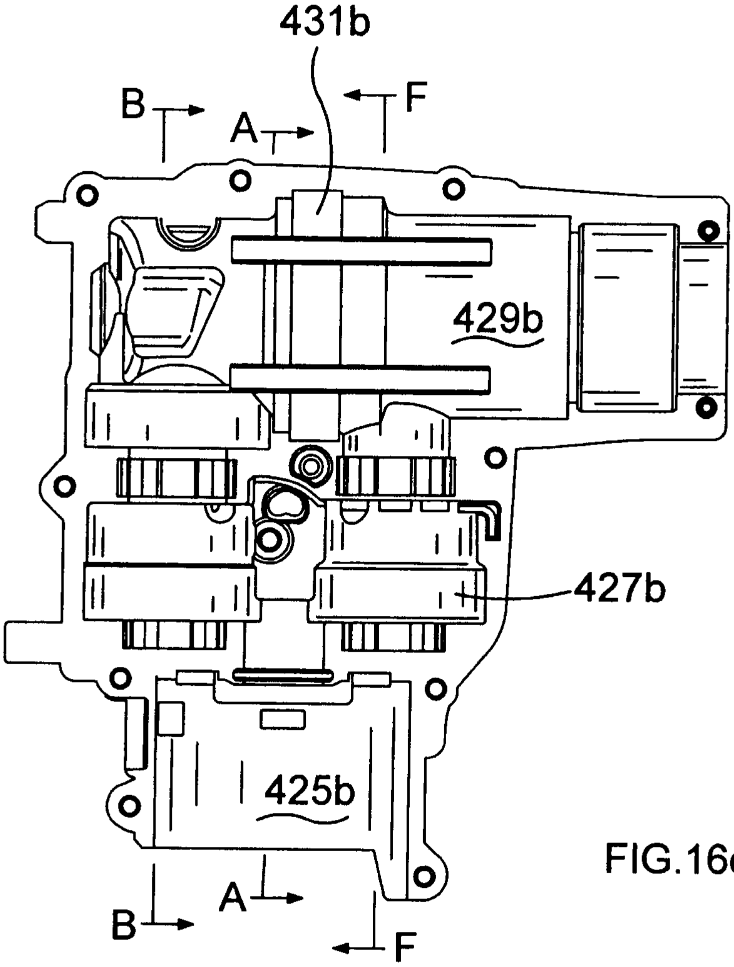

FIG.16d

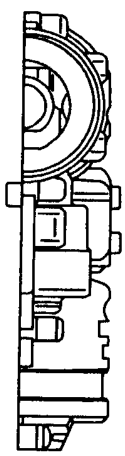

FIG.16e

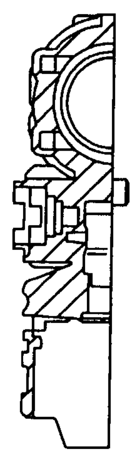

FIG.16f

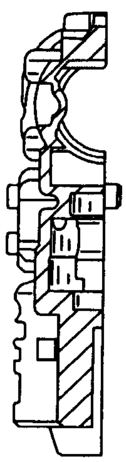

FIG.16g

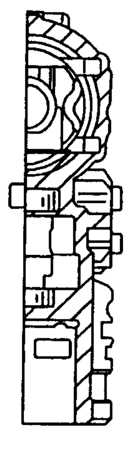

FIG.16h

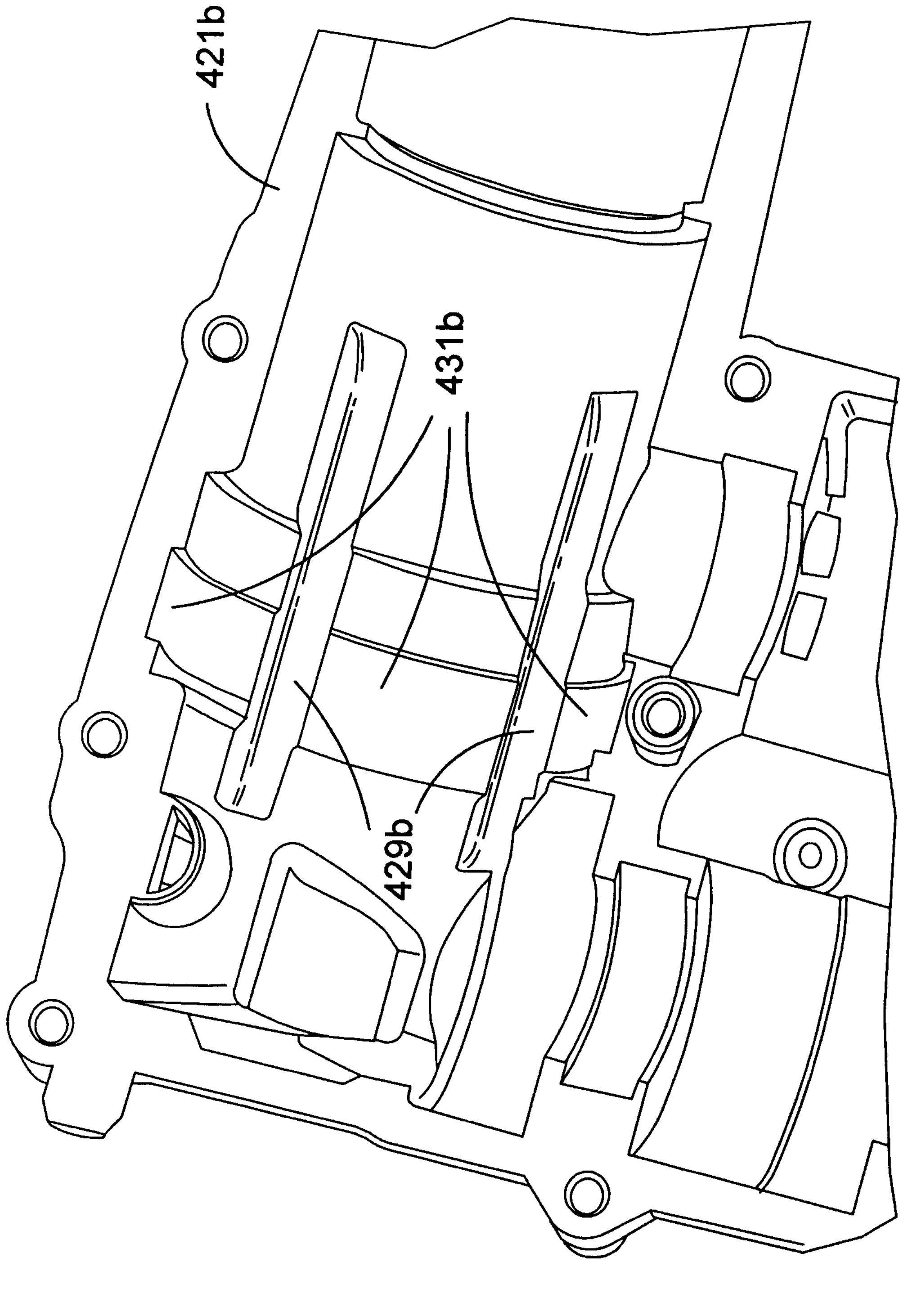

FIG.17

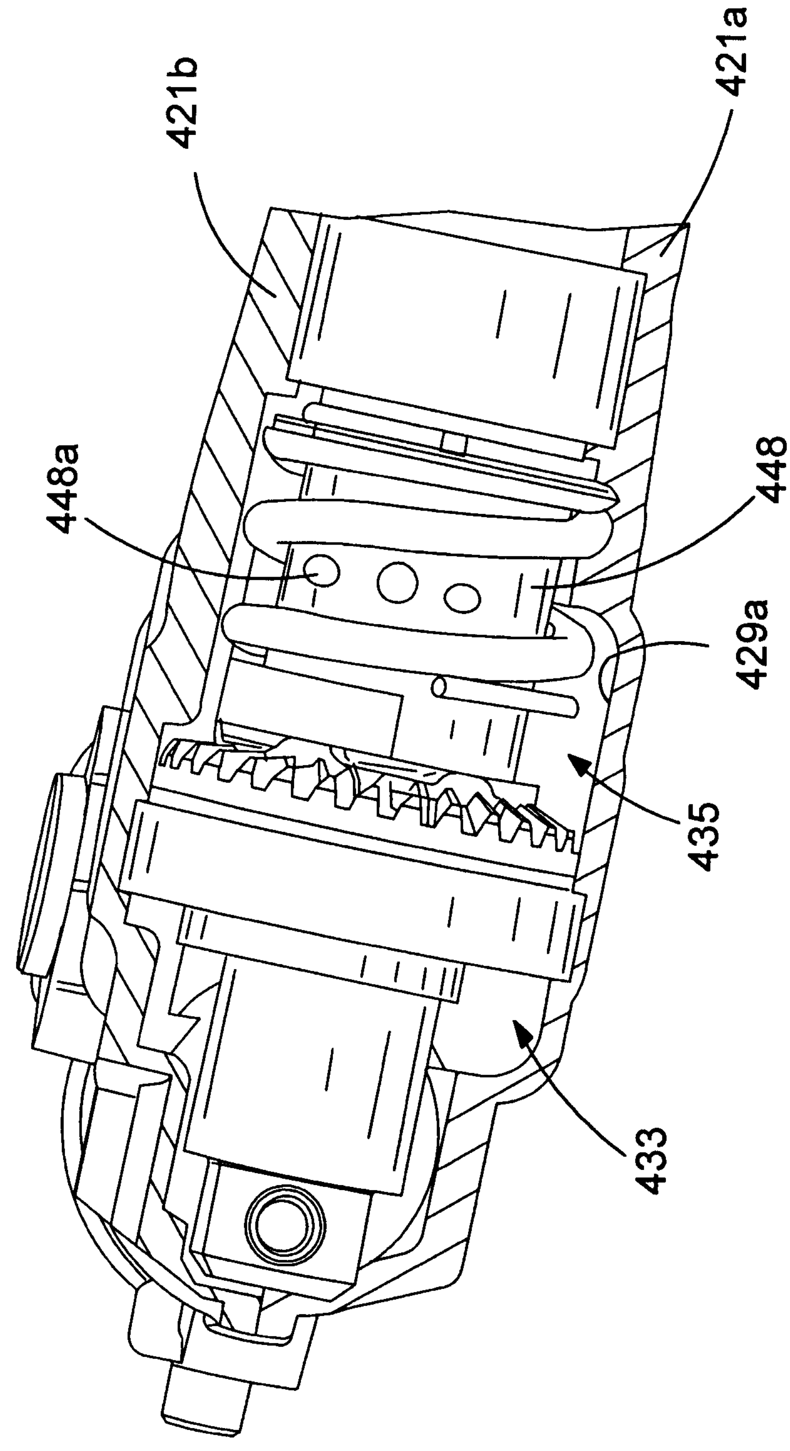

FIG.18

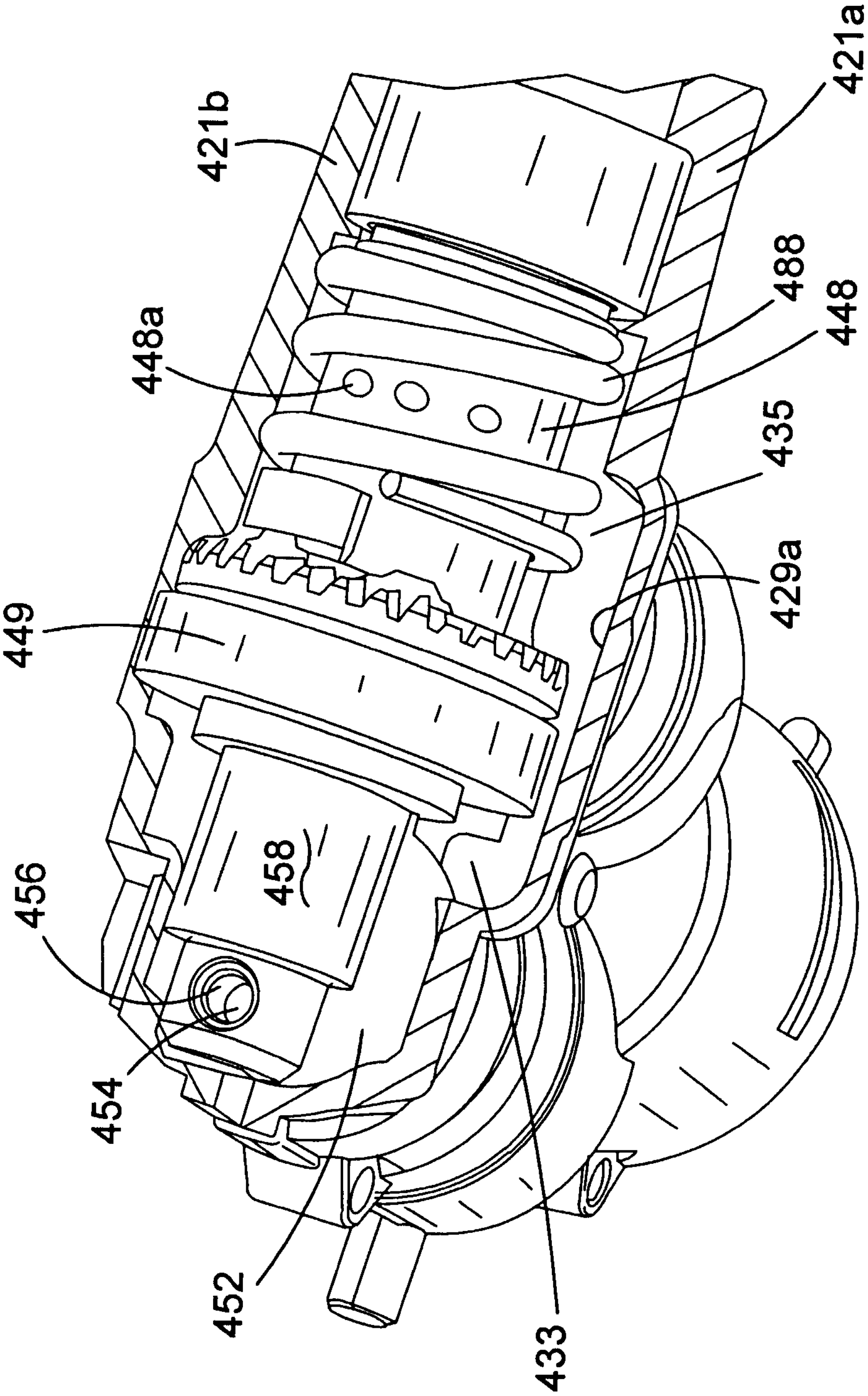

FIG.19

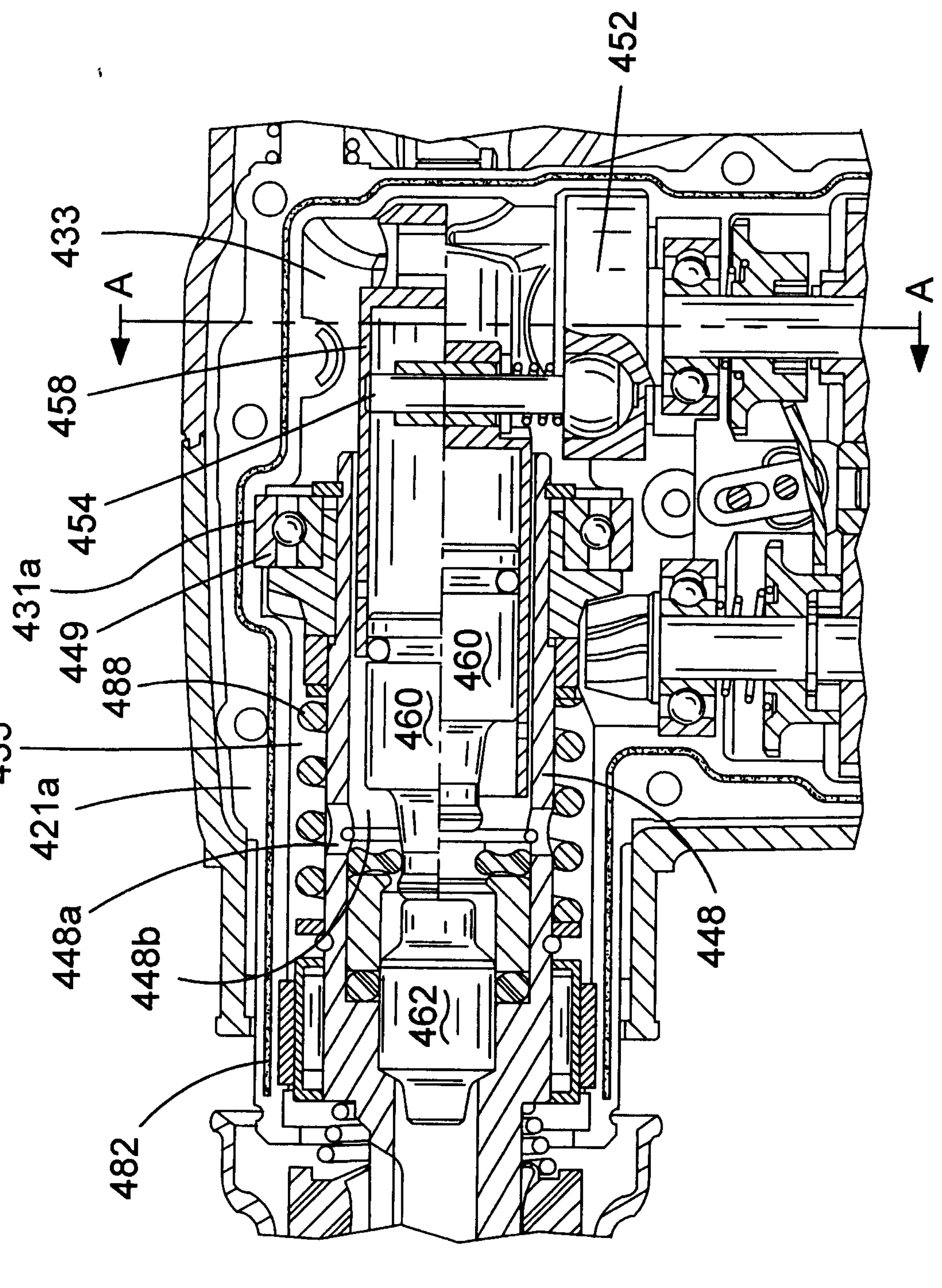
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FIG.20

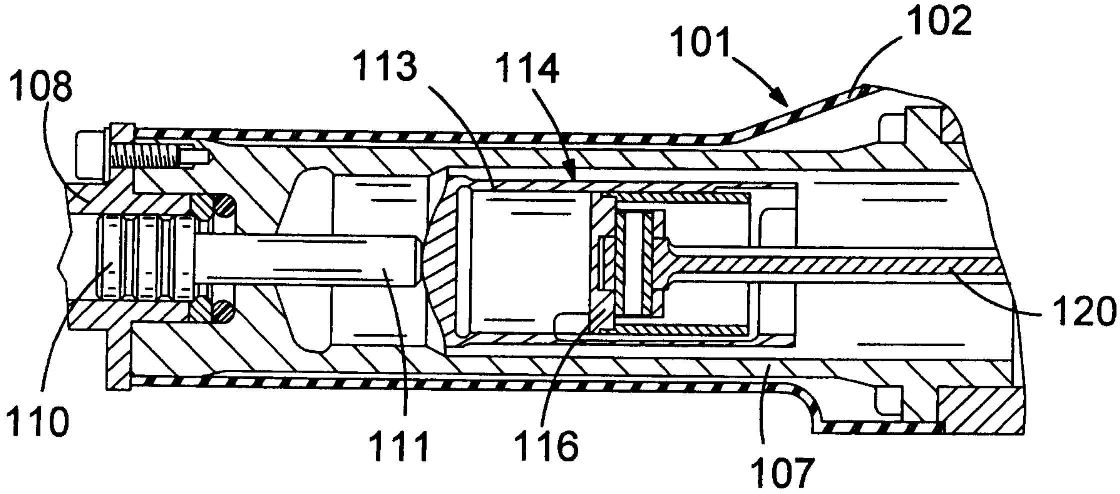

FIG.21
PRIOR ART

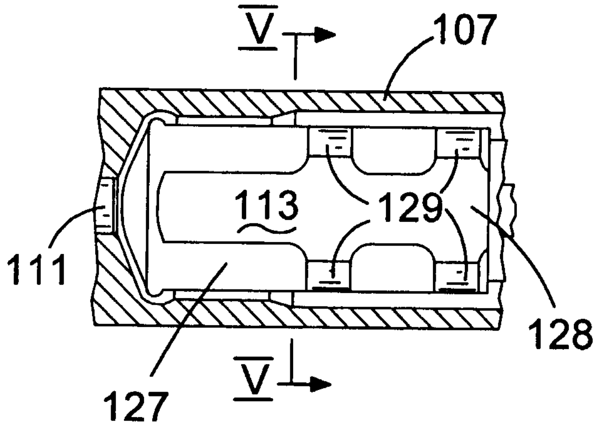

FIG.22
PRIOR ART

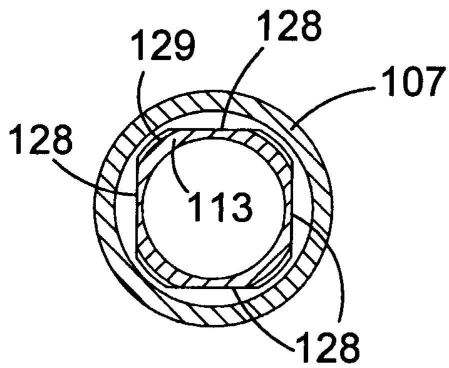

FIG.23
PRIOR ART

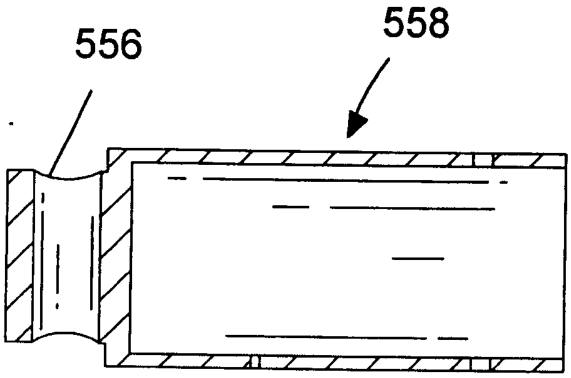

FIG.24a

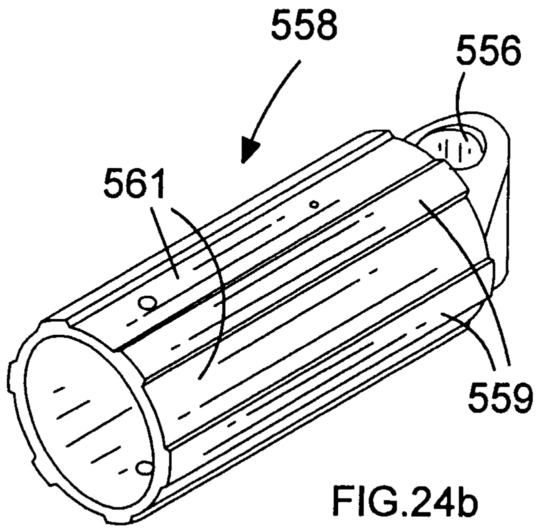

FIG.24b

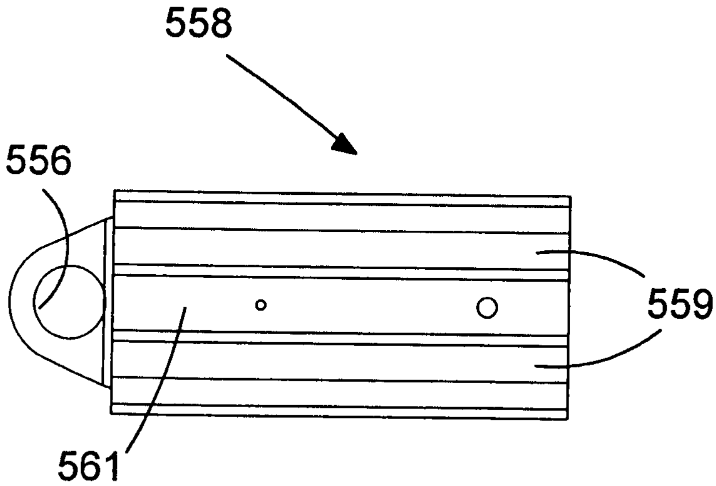

FIG.24c

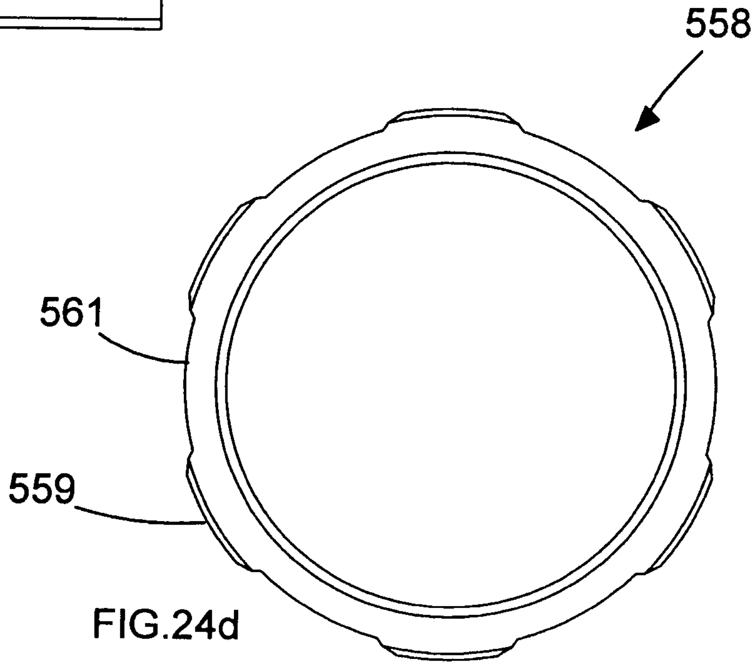

FIG.24d

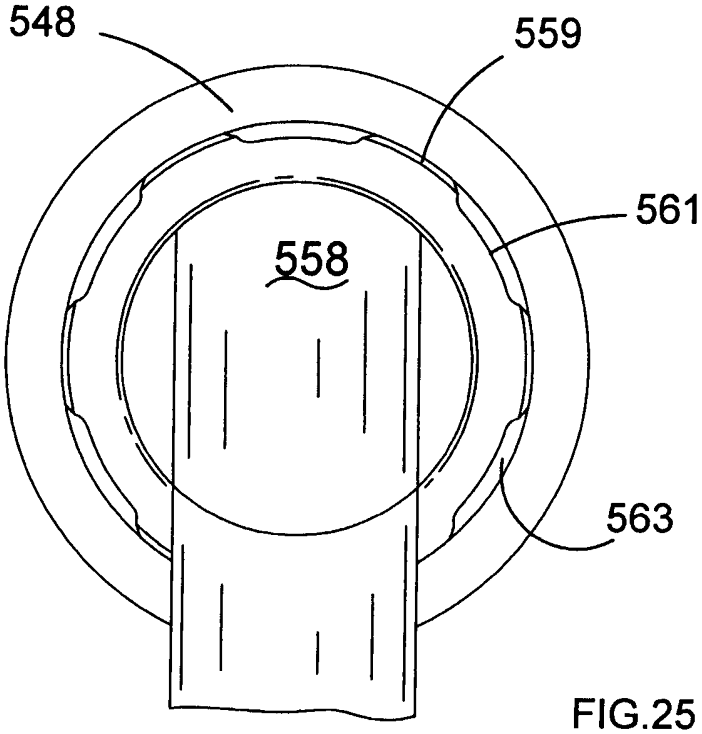

FIG.25

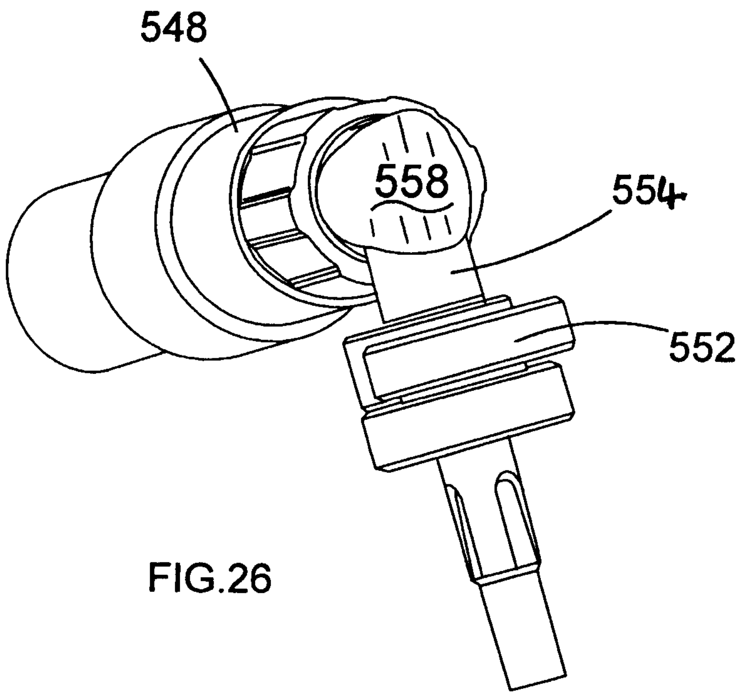

FIG.26

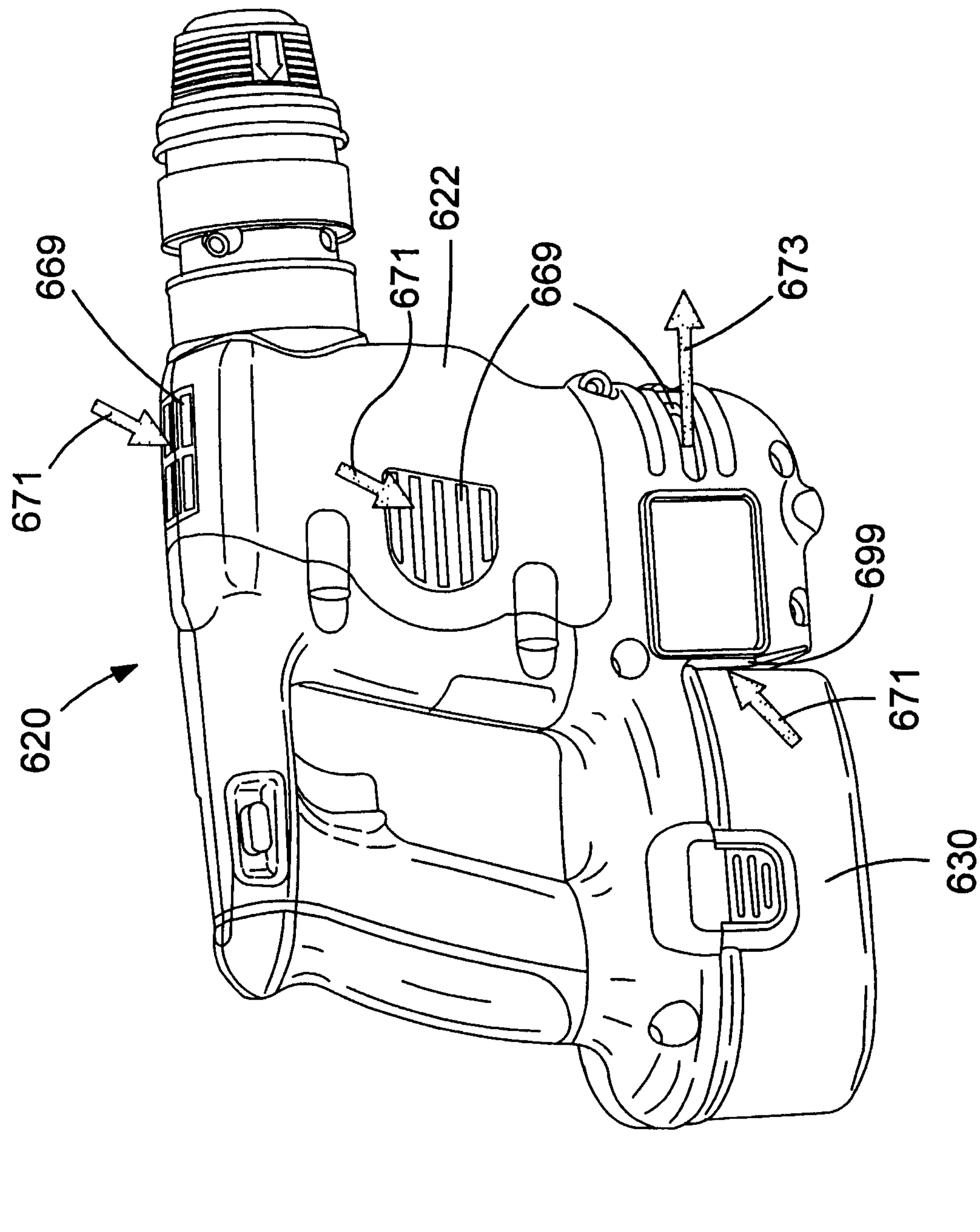

FIG.27

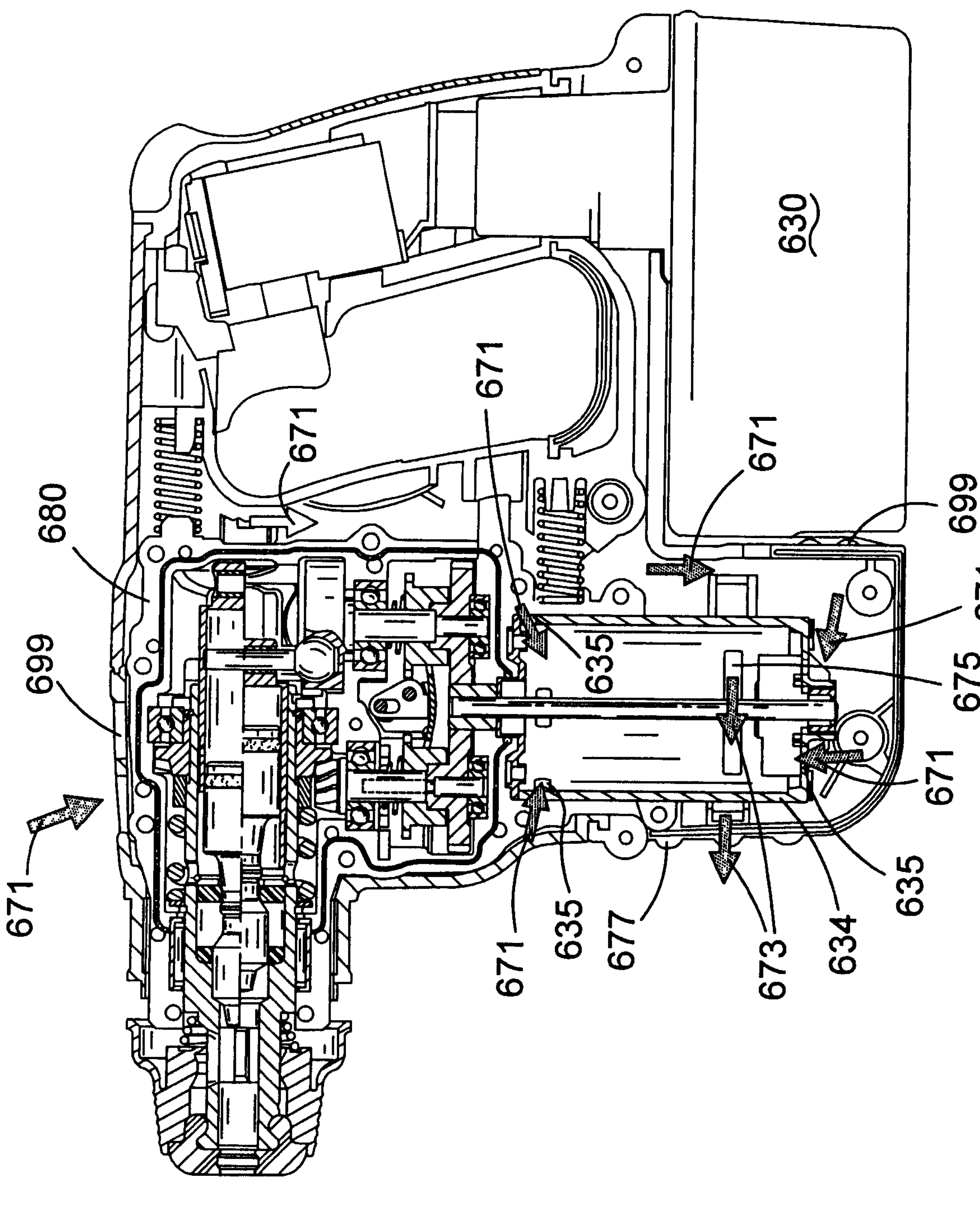
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FIG.28

DRIVE MECHANISM FOR POWER TOOL

The present invention relates to a drive mechanism for a power tool, and to a power tool incorporating such a mechanism. The invention relates particularly, but not exclusively, to a drive mechanism for a hammer drill and to a hammer drill incorporating such a mechanism.

Hammer drills are power tools that can generally operate in three modes of operation. Hammer drills have a tool bit that can be operated in a hammer mode, a rotary mode and a combined hammering and rotary mode. For the hammer and combined hammer and rotary mode, it is necessary to convert the rotary motion of the output shaft of the tool motor into a reciprocating motion of a piston, as the piston is used to create an air spring effect to act on a ram which converts the reciprocating motion of the piston into a hammering action.

A mechanism for converting the rotary motion of the output shaft of a motor into a hammering action is described in GB1343206. Referring to Figure 21 which shows a cross sectional view of the drive mechanism of GB1343206, Figure 22 which shows a partial cross sectional view of the drive mechanism of Figure 21 and Figure 23 which shows a cross sectional view taken along line V-V of Figure 22, an electric hammer 101 has a motor housing 102 with a driving motor and a gear unit (not shown). A hollow cylindrical guide sleeve 107 has a tool holder 108 that slidably holds a piston-like impact body 110 and a cylindrical shaft 111, which receives impacts from a cup-shaped striker 113.

A piston 114 is slidably disposed inside the cup shaped striker 113, which is slidably mounted in the guide sleeve 107. The piston 114 comprises a rod 120, which is driven by the motor to cause the piston head 116 to reciprocate inside the cup shaped striker 113. This causes an air spring effect to occur forwardly of the piston head 116 so that the striker 113 is caused to reciprocate under the air spring effect. The reciprocation of the striker 113 is transmitted to the impact body shaft 111 and the impact body 110 to cause a hammer action that is transmitted to a tool bit (not shown).

Referring to Figures 22 and 23, the outer surface of the striker 113 comprises a plurality of flat surfaces 128 and a plurality of part-cylindrical surfaces 129. The part-cylindrical surfaces 129 slidably engage the internal cylindrical surface of the guide sleeve 107. The flat surfaces 128 do not engage the internal cylindrical surface of the guide sleeve 107 and effectively reduce the area of contact between the striker 113 and the guide sleeve 107. This reduces friction between the striker 113 and guide sleeve 107 to increase the efficiency of the drive mechanism.

The drive mechanism of GB1343206 suffers from the drawback that the gaps between the flat surfaces 128 and the internal cylindrical surface of the guide sleeve 107 are relatively large, and can play no part in the function of the drive mechanism other than reduce surface area contact and perhaps assist air-flow inside the drive mechanism of GB1343206.

Preferred embodiments of the present invention seek to overcome the above disadvantages of the prior art.

According to an aspect of the present invention, there is provided a drive mechanism for a power tool having a housing and a motor disposed in the housing and having an output shaft for actuating a working member of the tool, the drive mechanism comprising:-

a reciprocating member adapted to be slidably mounted relative to said housing in a sleeve member, the reciprocating member adapted to be caused to execute reciprocating movement relative to said sleeve member in response to rotation of the output shaft, wherein said reciprocating member and/or sleeve member comprises a plurality of respective protrusions formed on a surface thereof, said plurality of protrusions adapted to slidably engage the other of the reciprocating member and/or sleeve member to reduce the area of contact between said reciprocating member and said sleeve member, and wherein said protrusions are adapted to hold lubricant between said reciprocating member and said sleeve member.

By providing a plurality of protrusions on the reciprocating member and/or sleeve member and which are adapted to slidably engage the other of the reciprocating member and the sleeve member such that the protrusions are adapted to hold lubricant between the reciprocating member and the sleeve member, this provides the advantage of reducing frictional contact between the reciprocating member and the sleeve. This reduces energy consumption by the motor and increases battery life of a battery-powered tool.

In particular, it has been found that a greater amount of power is required during the start-up phase of the drive mechanism. A reduction in the frictional contact between the hollow piston and the spindle at the start-up phase, by virtue of a ready supply of lubricant held by the protrusions, significantly reduces the overall amount of power used by the drive mechanism and therefore helps to increase battery life.

In a preferred embodiment, said sleeve member is substantially hollow cylindrical and said plurality of protrusions comprises a plurality of longitudinal ridges formed on an outer circumferential surface of the reciprocating member and said ridges define a plurality of convex curvilinear grooves, wherein the grooves circumscribe a cylinder of slightly reduced diameter than that of the outer circumferential surface of the reciprocating member so that the grooves are adapted to hold lubricant between said reciprocating member and said sleeve member.

In an alternative embodiment, said reciprocating member is substantially hollow cylindrical and said plurality of protrusions comprises a plurality of longitudinal ridges formed on an inner circumferential surface of the sleeve member and said ridges define a plurality of concave curvilinear grooves, wherein the grooves circumscribe a cylinder of slightly increased diameter than that of the inner circumferential surface of the sleeve member so that the grooves are adapted to hold lubricant between said reciprocating member and said sleeve member.

Either of the two alternative embodiments has the advantage that the depth of the grooves between the ridges is relatively shallow and can retain sufficient lubricant of normal viscosity to lubricate movement between the reciprocating and sleeve members whether the hammer drill is in operation or inactive. This means that lubricant is available during start-up phase and throughout its normal use thereby reducing wear and power consumption.

The reciprocating member may be a hollow piston having a ram slidably disposed therein, wherein the ram is adapted to impart impacts to a working member of the tool as a result of the reciprocating movement of said hollow piston.

The sleeve member may be a spindle adapted to rotate relative to the hollow piston in response to rotation of the motor output shaft to cause a working member of the tool in use to rotate

According to another aspect of the present invention, there is provided a power tool comprising a housing, a motor disposed in the housing and having an output shaft for actuating a working member of the tool, and a drive mechanism as defined above.

In a preferred embodiment, the power tool is a hammer drill.

Preferred embodiment of the present invention will now be described by way of example only and not in any limitative sense, with reference to the accompanying drawings in which: -

Figure 1 is a partially cut away perspective view of a prior art drive mechanism for a hammer drill;

Figure 2 is a cross-sectional view of the drive mechanism of Figure 1;

Figure 3 is a perspective view of a hammer drill of a first embodiment of the present invention;

Figure 4 is a side cross-sectional view of the hammer drill of Figure 3;

Figure 5 is an enlarged side cross-sectional view of part of the hammer drill of Figure 4;

Figure 6 is a partially cut away perspective view of part of the piston drive mechanism of Figure 3 in its rearmost position;

Figure 7 is a partially cut away perspective view of part of the piston drive mechanism of Figure 3 advanced through a quarter of a cycle of reciprocation from the position shown in Figure 6;

Figure 8 is a partially cut away cross section of part of the piston drive mechanism of Figure 3 advanced through half a cycle from the position shown in Figure 6 to its foremost position;

Figure 9 is a side cross-sectional view of a piston drive mechanism for a hammer drill of a second embodiment of the present invention;

Figure 10 is an enlarged cross-sectional view taken along line A-A of Figure 9;

Figure 11 is a side cross-sectional view of part of a hammer drill of a third embodiment of the present invention;

Figure 12 is a cross-sectional view taken along line B-B of Figure 11, with parts of the transmission mechanism removed for clarity;

Figure 13 is a cross section taken along line C-C of Figure 12;

Figure 14 is a side cross-sectional view of a hammer drill of a fourth embodiment of the present invention;

Figure 15a is a perspective view from outside of a right clamshell half of a two part transmission housing of a hammer drill of a fifth embodiment of the present invention;

Figure 15b is a side view of the outside of the clamshell half of Figure 15a;

Figure 15c is a perspective view of the inside of the clamshell half of Figure 15a;

Figure 15d is a side view of the inside of the clamshell half of Figure 15a;

Figure 15e is a front view of the clamshell half of Figure 15a;

Figure 15f is a cross-sectional view taken along line A-A of Figure 15d;

Figure 15g is a cross-sectional view taken along line B-B of Figure 15d;

Figure 15h is a cross-sectional view along line F-F of Figure 15b;

Figure 16a is a perspective view from the outside of a left clamshell half corresponding to the right clamshell half of Figures 15a to 15h;

Figure 16b is a side view of the outside of the clamshell half of Figure 16a;

Figure 16c is a perspective view of the inside of the clamshell half of Figure 16a;

Figure 16d is a side view of the inside of the clamshell half of Figure 16a;

Figure 16e is a front view of the clamshell half of Figure 16a;

Figure 16f is a cross-sectional view along line A-A of Figure 16d;

Figure 16g is a cross-sectional view taken along line B-B of Figure 16d;

Figure 16h is a cross-sectional view taken along line F-F of Figure 16d;

Figure 17 is an enlarged perspective view of the inside of the clamshell half of Figure 16;

Figure 18 is a partially cut away top view of part of a hammer drill incorporating the clamshell halves of Figures 15 and 16;

Figure 19 is a partially cut away perspective view of part of the hammer drill of Figure 18;

Figure 20 is another side cross-sectional view of the piston drive mechanism;

Figure 21 is a cross-sectional view of a prior art piston drive mechanism;

Figure 22 is an enlarged partial cross-sectional view of the piston drive mechanism of Figure 21;

Figure 23 is a cross-sectional view along line V-V of Figure 22;

Figure 24a is a cross-sectional view of a hollow piston of a hammer drill of a sixth embodiment of the present invention;

Figure 24b is a perspective view from the side of the hollow piston of Figure 24a;

Figure 24c is a top view of the hollow piston of Figure 24a;

Figure 24d is a view from the front of the hollow piston of Figure 24a;

Figure 25 is a rear view of a piston drive mechanism incorporating the hollow piston of Figures 24a to 24d mounted in a spindle;

Figure 26 is a perspective view from the rear of the piston drive mechanism of Figure 25;

Figure 27 is a side view of a hammer drill of a seventh embodiment of the present invention; and

Figure 28 is a side cross-sectional view of the hammer drill of Figure 26.

Referring to Figure 3, a battery-powered hammer drill comprises a tool housing 22 and a chuck 24 for holding a drill bit (not shown). The tool housing 22 forms a handle 26 having a trigger 28 for activating the hammer drill 20. A battery pack 30 is releasably attached to the bottom of the tool housing 22. A mode selector knob 32 is provided for selecting between a hammer only mode, a rotary only mode and a combined hammer and rotary mode of operation of the drill bit.

Referring to Figure 4, an electric motor 34 is provided in the tool housing 22 and has a rotary output shaft 36. A pinion 38 is formed on the end of output shaft 36, the pinion 38 meshing with a first drive gear 40 of a rotary drive mechanism and a second drive gear 42 of a hammer drive mechanism.

The rotary drive mechanism shall be described as follows. A first bevel gear 44 is driven by the first drive gear 40. The first bevel gear 44 meshes with a second bevel gear 46. The second bevel gear 46 is mounted on a spindle 48. Rotation of the second bevel gear 46 is transmitted to the spindle 48 via a clutch mechanism including an overload spring 88. The spindle 48 is mounted for rotation about its longitudinal axis by a spherical ball bearing race 49. A drill bit (not shown) can be inserted into the chuck 24 and connected to the forward end 50 of spindle 48. The spindle 48 and the drill bit rotate when the hammer drill 20 is in a rotary mode or in a combined hammer and rotary mode. The clutch mechanism prevents excessive torques being transmitted from the drill bit and the spindle 48 to the motor 34.

The hammer drive mechanism shall now be described as follows. The pinion 38 of motor output shaft 36 meshes with a second drive gear 42 such that rotation of the second drive gear 42 causes rotation of a crank plate 52. A crank pin 54 is driven by the crank plate 52 and slidably engages a cylindrical bearing 56 disposed on the end of a hollow piston 58. The hollow piston 58 is slidably mounted in the spindle 48 such that rotation of the crank plate 52 causes reciprocation of hollow piston 58 in the spindle 48. A ram 60 is slidably disposed inside hollow piston 58. Reciprocation of the hollow piston 58 causes the ram 60 to reciprocate with the hollow piston 58 as a result of expansion and contraction of an air cushion 93, as will be familiar to persons skilled in the art. Reciprocation of the ram 60 causes the ram 60 to impact a beat piece 62 which in turn transfers impacts to the drill bit (not shown) in the chuck 24 when the hammer drill operating in a hammer mode or a in combined hammer and rotary mode.

A mode change mechanism includes a first and a second drive sleeves 64, 66 which selectively couple the first and second drive gears 40, 42 respectively, to the first bevel gear 44 and the crank plate 52, respectively, in order to allow a user to select between either the hammer only mode, the rotary only mode or the combined hammer and rotary mode. The mode change mechanism is the subject of UK patent application no. 0428215.8.

A transmission mechanism comprises the rotary drive mechanism, the hammer drive mechanism and the mode change mechanism. The transmission mechanism is disposed inside a transmission housing 80. The transmission housing 80 also supports the electric motor 34. The transmission housing is formed from two clamshell halves of durable plastics material or cast metal, the two clamshell halves compressing an o-ring 82 therebetween. The o-ring 82 seals the transmission housing 80 to prevent dust and dirt from entering the transmission housing and damaging the moving parts of the transmission mechanism.

The transmission housing 80 is slidably mounted inside the tool housing 22 on parallel rails (not shown) and is supported against to the tool housing 22 by first and second damping springs 84 and 86 disposed at its rearward end. The transmission housing 80 can therefore move by a small amount relative to tool housing 22 in order to reduce transmission of vibration to the user during operation of the hammer drill 20. The spring co-efficients of the first and second damping springs 84 and 86 are chosen so that the transmission housing 80 slides to a point generally mid-way between its limits of forward and rearward travel when the hammer drill 20 is used in normal operating conditions. This is a point of equilibrium where the forward bias of the damping springs 84 and 86 equals the rearward force on the transmission housing 80 caused by the user placing the hammer drill 20 against a workpiece and leaning against the tool housing 22.

Referring to Figure 5, the hammer drive mechanism will be described in more detail. The crank pin 54 comprises a cylindrical link member 68 rigidly connected to a part-spherical bearing 70. The part-spherical bearing 70 is slidably and rotatably disposed in a cup-shaped recess 72 formed in the crank plate 52. The cup-shaped recess 72 has an upper cylindrical portion 72a and a lower generally semi-spherical portion 72b. The upper cylindrical portion 72a and a lower semi-spherical portion 72b have the same maximum diameter which is slightly greater than that of the part-spherical bearing 70. As a result, the part-spherical bearing 70 can be easily inserted into the cup-shaped recess. The crank pin 4 can pivot, rotate and slide vertically relative to the crank plate whilst the part-spherical bearing remains within the confines of the cup-shaped recess 72.

The cylindrical link member 68 is slidably disposed in a cylindrical bearing 56 formed in the end of the hollow piston 58. Sliding friction in the cup-shaped recess 72 is slightly greater than in the cylindrical bearing 56. The cylindrical link member 68 therefore slides up and down in the cylindrical bearing 56 while the part-spherical bearing rocks back and forth in the cup-shaped recess. A cylindrical collar member 74 surrounds the cylindrical link member 68 of the crank pin 54 and can slide between a lower position in which it abuts the upper surface of the part-spherical bearing 70 and an upper position in which it abuts and the underside of the cylindrical bearing 56. The collar member 74 is precautionary feature that limits movement of the part-spherical bearing 70 towards the cylindrical bearing 56 so that it is impossible for the crank pin 54 and its the part-spherical bearing 70 to move totally out of engagement with the cup-shaped recess 72. The cylindrical collar member 74 can be mounted to the crank pin 54 after construction of the crank plate 52 and crank pin 54 assembly.

Referring to Figures 6 to 8, as the crank plate 52 rotates in the anti-clockwise direction from the upright position shown in Figure 6, to the position shown in Figure 7, it can be seen that the crank pin 54 pushes the hollow piston 58 forwardly and also tilts to one side. As the crank pin 54 tilts, the cylindrical link member 68 slides downwardly in the cylindrical bearing 56. As the crank plate 52 rotates from the position of Figure 7 to the position of Figure 8 to push the hollow piston 58 to its foremost position, the crank pin 54 re-adopts an upright position and the cylindrical link member 68 of the crank pin 54 slides upwardly inside cylindrical bearing 56. It can be seen that by engagement of the collar member 74 with the underside of the cylindrical bearing 56 and the top of the part-spherical bearing 70, the crank pin 54 is prevented from moving too far inside the cylindrical bearing and out of engagement with the crank plate 52. There is therefore no need for an interference fit to trap the crank pin into engagement with the crank plate, which significantly simplifies assembly of the drive mechanism.

A hammer drill of a second embodiment of the invention is shown in Figure 9 and 10, with parts common to the embodiment of Figures 3 to 8 denoted by like reference numerals but increased by 100.

Crank pin 154 is of the same construction as the embodiment of Figures 3 to 8. However, in the embodiment of Figures 9 and 10 the collar member 176 is a coil spring. A washer 178 is provided between the collar coil spring 176 and the cylindrical bearing 156. The collar coil spring 176 has the further advantage of biasing the part-spherical bearing 170 of the crank pin 154 into engagement with the cup-shaped recess 172 of the crank plate 152 so that the part-spherical bearing is prevented from even partially moving out of engagement with the crank plate 152.

A hammer drill of a third embodiment of the invention is shown in Figures 11 to 13, with parts common to the embodiment of Figures 3 to 8 denoted by like reference numerals but increased by 200.

The transmission housing 280 is formed from two clamshell halves of durable plastics or cast metal material. The two clamshell halves trap and compress an O-ring 282 therebetween. The transmission housing 280 is supported by first and second damping springs 284 and 286 at its rearward end. The transmission housing 280 is also mounted on parallel rails (not shown) disposed within the tool housing 222 such that the transmission housing 280 can slide a small distance relative to the tool housing 222 backwards and forwards in the direction of the longitudinal axis of the spindle 248.

The spring coefficients of damping springs 284 and 286 are chosen so that the transmission housing 280 slides to a point generally mid-way between its limits of forward and backward travel when the hammer drill is used in normal operating conditions. This is a point of equilibrium where the forward bias of the damping springs 284 and 286 equals the rearward force on the transmission housing 280 caused by the user placing the hammer drill 220 against a workpiece and leaning against the tool housing 222.

The forward end of the transmission housing 280 has a generally part-conical portion 290, which abuts a corresponding part-conical portion 292 formed on the tool housing 222. The part conical portions 290 and 292 form an angle of approximately 15° with the longitudinal axis of the spindle 248. The interface defined by the part-conical portions 290 and 292 defines a stop at which the transmission housing 280 rests against the tool housing 222 when the hammer drill 220 is in its inoperative condition. When the hammer drill 220 is being used in normal operating conditions, a gap opens up between the surfaces of the part-conical portions 290 and 292 which helps to damp axial and lateral vibrations that would otherwise be directly transmitted from the tool bit (not shown) to the user holding the hammer drill 220. Naturally, this gap slightly increases as the transmission housing moves backwards against the bias of the damping springs 282, 286. This helps to damp the increased axial and lateral vibrations which may arise when the user applies greater forward pressure to the hammer drill 220. However, the gap is sufficiently small that the hammer drill 220 and the transmission housing 280 can always be adequately controlled by the user via the interface between the part-conical portions 290, 292 which maintains alignment of the transmission housing 280 with the tool housing 222.

A hammer drill of a fourth embodiment of the invention is shown in Figure 14, with parts common to the embodiment of Figures 3 to 8 denoted by like reference numerals but increased by 300.

The hammer drill 320 has a tool housing 322. In this embodiment, the transmission housing 380 is formed from three housing portions. A generally L-shaped first housing portion 380a accommodates the transmission mechanism except for the first and second gears 340, 342 and the front end 348a of the spindle 348. The bottom end of the first housing portion 380a is mounted upon a second housing portion 380b such that a first O-ring 382a is trapped between the two portions to prevent the ingress of dust and dirt. The second housing portion 380b holds the lower parts of the transmission mechanism inside the first housing portion 380a and accommodates the first and second gears 340, 342. The second housing portion 380b has a motor output aperture 390 to allow the motor output shaft 336 access to the inside of the transmission housing and to enable the pinion 338 to drive the first and second gears 340, 342 of the transmission mechanism. A third housing portion 380c is mounted to the front end of the first housing portion 380a such that a second O-ring 382b is trapped between the two portions to prevent the ingress of dust and dirt. The third housing portion 380c holds the front parts of the transmission mechanism inside the first housing portion 380a and accommodates the front end 348a of the spindle.

The generally L-shaped first transmission housing portion 380a allows the transmission mechanism to be fully assembled inside the first transmission housing portion 380a from both its ends. For example, the hollow piston and spindle assemblies can be inserted into the front end of the first transmission housing portion 380a, and the first transmission housing portion 380a can then be turned through 90° and the various gears and mode change mechanism can be inserted through the bottom end and dropped into place to engage the spindle 348 and hollow piston 358. The second and third transmission housing portions 380b and 380c can then be mounted to the first transmission housing portion 380a in order to cap off the open ends of the first transmission housing portion 380a.

The first transmission housing portion 380a can be used as a standard platform (including standard hammer drive, rotary drive and mode change mechanisms) for several power tools, and the second and third transmission housing portions 380b and 380c changed to accommodate motors and spindles of differing sizes.

A hammer drill of a fifth embodiment of the invention has a transmission housing shown in Figures 15 to 20, with parts common to the embodiment of Figures 3 to 8 denoted by like reference numerals but increased by 400.

Referring to Figures 15 and 16, a transmission housing is formed from a right clamshell half 421a and a left clamshell half 421b formed from injection moulded high-grade strong plastics material. The clamshell halves 421a, 421b each have a plurality of threaded holes 423a, 423b respectively adapted to receive screws (not shown) such that the clamshell halves 421a, 421b can be joined together to form the transmission housing which encapsulates the transmission mechanism.

The two-part transmission housing is adapted to hold all the components of the transmission mechanism. Various indentations are moulded in the clamshell halves to provide support for these components. For example, first drive gear indentations 427a and 427b are shaped to support the first drive gear 40. A motor support portion 425a and 425b is adapted to support and partially encapsulate the top part of the electric motor 34.

The transmission housing is slidably mounted on a pair of guide rails (not shown) in the tool housing 22. As the transmission housing is disposed inside of the tool housing 22 and out of sight of the user, high-grade strong plastics material can be used in the construction of the transmission housing. This type of material is normally not suitable for external use on a power tool due to its unattractive colour and texture. High-grade strong plastics material also generally has better vibration and noise damping properties than metal. Strengthening ribs (not shown) can also be moulded into the plastics material to increase the strength of the transmission housing.

Referring to Figures 15 to 20, each of the clamshell halves 421a and 421b includes integrally formed overflow channels 429a and 429b. The clamshell halves also include respective ball bearing race support recesses 431a and 431b which are adapted to hold the ball bearing race 49 to support the spindle 48.

Referring in particular to Figures 18 to 20, the clam shell halves 421a and 421b mate to define a first transmission housing chamber 433 and a second transmission housing chamber 435 disposed on either side of the ball bearing race 449. The first and second transmission housing chambers 433 and 435 are interconnected by channels 429a and 429b. The rear end of the hollow piston 458, cylindrical bearing 456, the crank pin 454 and crank plate 452 are disposed in the first transmission housing chamber 433. The majority of the spindle 448 and the over-load spring 458 are disposed in the second transmission housing chamber 435. Part of the spindle 448 in the second transmission housing chamber has a circumferential array of vent holes 448a. The vent holes 448a allow communication between the second transmission housing chamber 435 and a spindle chamber 448b located inside the spindle 448 in front of the hollow piston 458 and the ram 460.

In hammer mode, the hollow piston 458 is caused to reciprocate by the crank plate 452. When the hollow piston 458 moves into the first transmission housing chamber 433 air pressure in the first transmission housing chamber 433 increases due to the reduction in the volume of first transmission housing chamber caused by the arrival of the hollow piston. At the same time, the hollow piston 458 and the ram 460 move out of the spindle 448. This causes a decrease in air pressure in the spindle chamber 448b due to the increase in volume in the spindle chamber caused by the departure of the hollow piston and the ram. The second transmission housing chamber 435 is in communication with the spindle chamber 448b, via the vent holes 448b, and so the air pressure in the second transmission housing chamber 435 decreases too. The air pressure difference is equalised by air flowing from the first transmission housing chamber 433 through the overflow channels 429a and 429b and into the second transmission housing chamber 435 and the spindle chamber 448b.

Conversely, when the hollow piston 458 goes into the spindle 448, air pressure in the first transmission housing chamber 433 decreases due to the increase in the volume of first transmission housing chamber caused by the departure of the hollow piston. At the same time, this causes an increase in air pressure in the spindle chamber 448b due to the decrease in volume in the spindle chamber caused by the arrival of the hollow piston and the ram. As mentioned above, the second transmission housing chamber 435 is in communication with the spindle chamber 448b, via the vent holes 448b, and so the air pressure in the second transmission housing chamber 435 increases too. The air pressure difference is equalised by air flowing back from the second transmission housing chamber 435 and the spindle chamber 448b through the overflow channels 429a and 429b and into the first transmission housing chamber 433.

As a result of this cyclic back and forth movement of air in the overflow channels 429a, 429b, compression of the air is eliminated, or significantly reduced, during reciprocation of the hollow piston 58. As such, the hammer drive mechanism does less work and loses less energy through inadvertently compressing trapped air. This increases the efficiency of the motor and the battery life of the hammer drill.

A hammer drill of a sixth embodiment of the invention has a hammer drive mechanism shown in Figures 24 to 26, with parts common to the embodiment of Figures 3 to 8 as denoted by like reference numerals but increased by 500.

Referring to Figures 24 to 26, a hollow piston 558 comprises a cylindrical bearing 556 that is adapted to receive a crank pin 554 in order to cause the hollow piston 558 to reciprocate inside the spindle 548. A ram (not shown) is slidably disposed inside the hollow piston 558 such that the ram is caused to execute a hammering action due to the air spring effect created inside hollow piston 558. A plurality of longitudinal ridges 559 are formed on the outer circumferential surface of the generally cylindrically-shaped hollow piston 558 to reduce the surface area of contact between the hollow piston 558 and the generally cylindrically-shaped spindle 548. A plurality of convex curvilinear shaped grooves 561 are formed in the gaps between the ridges. The grooves 561 circumscribe a cylinder of slightly reduced diameter than that of the outer circumferential surface of the hollow piston 558. As such, the grooves 561 are shallow enough to retain lubricant of normal viscosity throughout normal operation of the hammer drive mechanism.

The hollow piston 558 is slidably disposed inside the spindle 548. Rotation of crank plate 552 causes the crank pin 554 to act on cylindrical bearing 556 such that the hollow piston 558 reciprocates inside of the spindle 548. The spindle 548 may also rotate about the hollow piston 558. The longitudinal ridges 559 formed on the outer surface of the hollow piston 558 slidingly engage the inner surface of the spindle 548. It can be seen that the area of contact between the hollow piston 558 and the spindle 548 is reduced due to the engagement of only the ridges 559 with the inner surface of the spindle 548. The lubricant 563 contained in the grooves 561 reduces friction between the spindle 548 and the hollow piston 558. Air may also pass between the hollow piston 558 and the spindle, via the space created by the grooves 561, thereby improving cooling of the transmission mechanism. This air passage through the grooves may also assist in the equalisation of air pressure in the first and second transmission housing chambers 433, 435 already discussed under the heading of the fifth embodiment.

A hammer drill of a seventh embodiment of the invention having a motor cooling system is shown in Figures 27 and 28, with parts common to the embodiment of Figures 3 to 8 denoted by like reference numerals but increased by 600.

A hammer drill 620 comprises a tool housing 622 in which a plurality of air vents 669 is formed. The air vents are adapted to either receive cool air from outside of the hammer drill or expel warm air from the inside of the hammer drill.

Referring to Figure 28, a motor cooling fan (not shown) is disposed on the axis of the motor 634 in a position that is between the upper field coil (not shown) and the lower commutator (not shown) of the motor 634. A transmission housing 680, which may be of the two-part type or the three-part type described above, substantially encapsulates the transmission mechanism.

During operation of the power tool the cooling fan is driven by the motor. The cooling fan draws air axially through the motor and expels the air radially outwardly through holes 675 formed in the outer housing 677 of the motor 634. The cooling fan is vertically aligned with the holes 675 to make the radial expulsion of air easier. This causes air to be drawn in through the air vents 669 formed on the top of the housing 622, in the side of the housing 622 and between the housing 622 and the battery pack 630. The cool air follows a path through the tool housing 622 shown by cool air arrows 671. The cool air flows around the outside of the transmission housing 680 but inside the tool housing 622 such that air does not pass through the transmission mechanism which is sealed to prevent ingress of dirt.

A plurality of motor openings 635 are formed in the outer housing 677 of the motor 634 to enable cool air to pass into the motor to cool the motor. As a result of the position of the cooling fan, cool air is drawn across both the field coils of the motor and the motor commutator such that each of these components is individually cooled by air flowing downwards over the field coils and upwards over the commutator. Warm air is expelled through a front vent 669 in the front of the housing following a path shown by warm air arrows 673. The front vent 699 is vertically aligned with the holes 675 in the outer housing 677 of the motor 634. Warm air may also be expelled through a rear vent 699 that is disposed between the tool housing 622 and the releasable battery pack 630.

It will be appreciated by persons skilled in the art that the above embodiment has been described by way of example only and not in any limitative sense, and that various alterations and modifications are possible without departure from the scope of the invention as defined by the appended claims.

CLAIMS

1. A drive mechanism for a power tool having a housing and a motor disposed in the housing and having an output shaft for actuating a working member of the tool, the drive mechanism comprising:-
a reciprocating member adapted to be slidably mounted relative to said housing in a sleeve member, the reciprocating member adapted to be caused to execute reciprocating movement relative to said sleeve member in response to rotation of the output shaft, wherein said reciprocating member and/or sleeve member comprises a plurality of respective protrusions formed on a surface thereof, said plurality of protrusions adapted to slidably engage the other of the reciprocating member and/or sleeve member to reduce the area of contact between said reciprocating member and said sleeve member, and wherein said protrusions are adapted to hold lubricant between said reciprocating member and said sleeve member.

2. A mechanism according to claim 1, wherein said sleeve member is substantially hollow cylindrical and said plurality of protrusions comprises a plurality of longitudinal ridges formed on an outer circumferential surface of the reciprocating member and said ridges define a plurality of convex curvilinear grooves, wherein the grooves circumscribe a cylinder of slightly reduced diameter than that of the outer circumferential surface of the reciprocating member so that the grooves are adapted to hold lubricant between said reciprocating member and said sleeve member.

3. A mechanism according to claim 1, wherein said reciprocating member is substantially hollow cylindrical and said plurality of protrusions comprises a plurality of longitudinal ridges formed on an inner circumferential surface of the sleeve member and said ridges define a plurality of concave curvilinear grooves, wherein the grooves circumscribe a cylinder of slightly increased diameter than that of the inner circumferential surface of the sleeve member so that the grooves are adapted to hold lubricant between said reciprocating member and said sleeve member.

4. A mechanism according to any one of the preceding claims, wherein the reciprocating member is a hollow piston having a ram slidably disposed therein,

wherein the ram is adapted to impart impacts to a working member of the tool as a result of the reciprocating movement of said hollow piston.

5. A mechanism according to claim 4, wherein the sleeve member is a spindle adapted to rotate relative to the hollow piston in response to rotation of the motor output shaft to cause a working member of the tool in use to rotate

6. A drive mechanism for a power tool having a housing and a motor disposed in the housing and having an output shaft for actuating a working member of the tool, the drive mechanism substantially as hereinbefore described with reference to Figures 3 to 12 and 24 to 28 of the accompanying drawings.

7. A power tool comprising a housing, a motor disposed in the housing and having an output shaft for actuating a working member of the tool, and a drive mechanism according to any one of the preceding claims.

8. A power tool according to claim 7, wherein the power tool is a hammer drill.

The Patent Office

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Application No: GB0510937.6 **Examiner:** Miss Marian Challis

Claims searched: 1-9 **Date of search:** 10 January 2006

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1,4,5,7,8	GB 306148 A (CHICAGO) Figures 1 and 2
X	1,4,5,7,8	GB 1343206 A (BOSCH) Figures 1-5
X	1,5,7,8	US 5161623 A (ERLACH) Figures 1-2

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