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(54) Drilling apparatus.

(57) The invention provides a drill pipe rotary drive mechanism for an earth drilling apparatus comprising a housing, a drive member mounted in the housing for rotation therein about a rotary axis and having an axial bore opening at each end to the exterior of the housing, and a drive mechanism in the housing for rotatably driving the drive member. A drive coupling tool is adapted to be readily removably mounted in the drive member so that the drive mechanism can be used for rotatably driving different types of earth drilling tools, the coupling tool having a tubular body portion telescopingly removably mounted in the axial bore of the drive member, the body portion having an axial opening extending therethrough for reception of a portion of the length of the drill pipe, a flange at one end of the body portion for abutting engagement with one end of the drive member for axially locating the coupling tool in the drive member, the coupling tool being adapted to be non-rotatably coupled to a drilling tool and to the drive member.

The invention also provides a dual-wall drill pipe section comprising an outer pipe member having a box end formed with an internal thread and a pin end formed with an external thread for engagement with the box end of another outer pipe member, the bore of one of the ends of the outer pipe member is formed with a shoulder and a circumferential, inwardly facing groove axially spaced from the shoulder, an inner pipe member concentrically disposed within the outer pipe member so as to define an annular passage between the inner and outer pipe members, spacer members connected to each end of the inner pipe member and disposed in the annular passage for maintaining concentricity between the inner and outer pipe members, the spacer members at one end of the inner pipe being formed with a shoulder for abutting engagement with the shoulder of the outer pipe member so as to axially locate and support the inner pipe member within the outer pipe member, and at least one spring member connected to the inner pipe member and having a portion engageable with the groove of the outer pipe member for resiliently and frictionally retaining the inner pipe member within the outer pipe member during drilling, storage and handling of an assembled pipe section.

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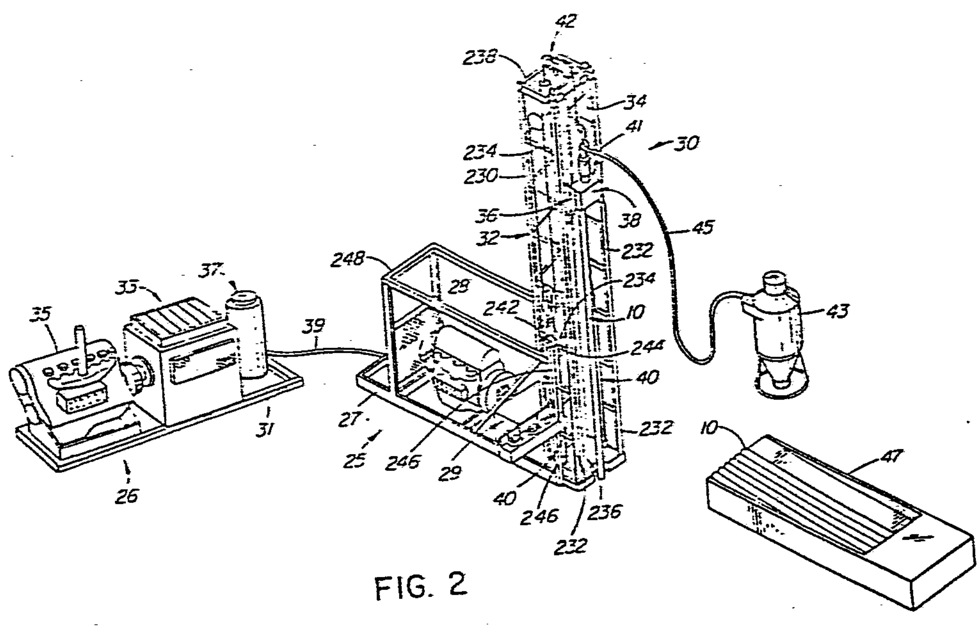

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FIG. 2

DRILLING APPARATUS

This invention relates to an apparatus for drilling in earth formations and, more particularly, to a drill rig for use in mineral exploration and the like. The invention also relates to a dual-wall pipe section for use in a drill string for drilling in earth formations.

As is well know, there are various types of earth drilling techniques, including those known as dual tube drilling, wire-line drilling, diamond drilling, conventional drilling and drilling with augers. Heretofore, drill rigs or apparatus have been especially designed for each different type of drilling and substantial changes of the drill rig were necessary in order to change from one type of drilling to another type of drilling. Further, many conventional drill rigs were specifically adapted for driving one size of drill string. Again, substantial modifications of the apparatus are necessary to adapt the apparatus for a different size of drill string. A still further drawback of conventional drill rigs is that they are not adapted for carrying out all of the functions which are necessary to drive and extract a drill string.

With transportation costs rising at an ever increasing rate and mineral exploration being extended to more remote areas, including mountainous regions, it is becoming more difficult and costly to transport drilling equipment and personnel to the drill site. For reasons which are apparent, the helicopter has received much favor as a mode of transportation. However, because of their limited carrying capacity, helicopters are unable to transport heavier conventional drilling rigs to remote locations, particularly those in elevated regions. Thus, there is a need for lighter drilling equipment which can more readily be transported by helicopter or trucks.

The present invention provides an arrangement which is easily and quickly modified for assembling drill string and drilling a bore hole, dismantling a drill string and use with different sizes of drill pipe.

The foregoing are achieved by the provision of a drill pipe drive mechanism adapted to rotatably drive any one of a plurality of removable generally tubular drill pipe coupling tools. The mechanism includes a housing and a coupling tool drive member or spindle rotatably and drivingly mounted in the housing. The spindle extends through the housing and is formed with an axial opening having means, such as splines or the like, for telescopingly receiving and non-rotatably coupling the drive spindles to any one of the coupling tools.

The invention provides generally two categories of drill pipe coupling tools. The first category is intended primarily for use in assembling and driving a drill string into an earth formation while the second category is intended primarily for use in dismantling and extracting a drill string from an earth formation. Each tool of both categories differ from one another in that it is specifically constructed for coupling to a drill pipe of a particularly outside diameter. However, all of the tools have substantially the same exterior configuration so that all can be mounted in and driven by the drive spindle without any modification of the drive mechanism.

Each coupling tool also includes an axial opening through which a portion of a drill pipe extends. One end, the upper end, of the tools is formed with an outwardly extending flange which is abuttingly engagable with the upper end of the drive spindle. The other end, the lower end, is formed to receive means for removably retaining the tool operatively disposed in the drive spindle. In addition, the flange and retaining means cooperate to define predetermined limits of axial travel of the coupling tools with respect to the drive spindle during assembly and disassembly of drill pipe sections as will be described in greater detail later.

When it is desired to assemble and drive a drill string, a coupling tool of the appropriate size of the first category is selected and simply telescopingly inserted with the upper end of the drive spindle opening until the flange seats onto the upper end of the spindle and then the retaining means is attached to the lower end of the tool. When it is desired to drive pipe of a different size or dismantle the drill string, the retaining means is simply removed from the tool mounted in the drive spindle, the tool telescopingly removed and the replacement or substitute tool inserted in the manner described above. Thus, it will be seen that the modification of the drive mechanism for different functions or sizes of pipe is extremely simple and therefore the arrangement considerably reduces labor cost associated with such modification.

In order to render the drilling rig capable of transportation by helicopter, the drilling rig is constructed in at least two modules so that each module can be independently transported to the drilling site. One module consists of an air compressor, including a compressed air reservoir and prime mover, for supplying air down the drill string as is well known. Another module consists of a mast assembly including a drill pipe drive mechanism and a hydraulic system, including prime mover, a hydraulic pump and controls, and fluid reservoir. The mast assembly is also constructed as an integral unit which is removably mounted on the module. Thus, if a particular vehicle or helicopter does not have the capacity to carry the entire module, the mast assembly can readily be removed and transported independently. Further, the drive mechanism actuating means is arranged in such a manner as to reduce the strength requirements of the mast and thereby reduce the overall weight of the module.

Dual-walled drill pipe used for drilling bore holes in earth formations are well known. Generally, bore holes are formed by rotating or percussively-rotating a drill string, which may be up to several hundred feet in length, into an earth formation using a drilling apparatus or rig. The drill string is comprised of an outer pipe string, to the lower end of which is connected a drill bit, and an inner pipe string. The inner and outer pipe strings together define an annular passageway for communicating fluid, such as air, to the bottom of the bore hole while the inner pipe string defines a bore which serves to return the air and cutting bits to the surface.

The outer pipe string is formed by a plurality of serially, threadedly connected lengths of pipe. The outer pipe string serves to transfer rotary and/or percussive forces to the cutting or drill bit and absorb axial forces such as those imposed when extracting the drill string from the bore hole. The axial forces may be substantial depending upon the length of the drill string. Accordingly, the outer pipe string is a high strength assembly which must be designed to withstand these loads.

The inner pipe string is also formed by a plurality of serially, connected lengths of pipe, although not threadedly connected. The primary function of the inner pipe string is to define the two above-mentioned fluid passageways. It need not transfer rotary or percussive forces to the drill bit and, accordingly, need not meet the high strength requirements of the outer pipe string. Thus, it may be constructed of thinner-walled tube.

In order to minimize the strength requirements and, hence the size of the inner pipe, it is known to premount and secure an inner pipe to an associated outer pipe so as to form a dual-wall drill pipe section or assembly. In this manner, the weight of each inner pipe is transferred directly to its adjacent outer pipe. A drawback of this arrangement is that if either the inner or outer pipe is damaged, it is difficult to separate the two lengths of pipe so as to replace the damaged pipe. On the other hand, if the inner pipe is simply vertically supported within the outer pipe, the assembly may be difficult to handle prior to erecting or subsequent to dismantling a drill string because of the tendency of the two pipes to telescopically slide with respect to one another.

This is a need, therefore, for a dual-wall drill string section or assembly in which the inner pipe member is removably mounted within the outer pipe member so as to facilitate separation of the two pipe members in the event that one of the two members is damaged and must be replaced and yet positively retained therein to facilitate handling. The assembly must also be arranged so that no rotary forces are transmitted from the outer pipe member to the inner pipe member during drilling.

The present invention seeks to provide a dual-walled drill pipe arrangement which overcomes the aforementioned difficulties and, in particular, an arrangement which minimizes the wall thickness of the inner pipe string and facilitates the storage, handling and assembling of drill strings. In accordance with one aspect of the invention, the inner and outer pipe members are formed with cooperating shoulders which when engaged serve to locate an inner pipe member within an associated outer pipe member and transfer the weight of the inner pipe member and any other axial loads applied to the inner pipe member directly to its associated outer pipe member. As a result, the lower inner pipe members of the inner drill string need not absorb any more load than the inner pipe members at the upper end of the bore holes thereby considerably reducing the strength requirements and cost of the inner pipe string. In accordance with another aspect of the present invention, there is provided means releasably retaining the inner pipe member within the outer pipe member thus permitting preassembly of dual-walled drill pipe sections and facilitating storage and handling of drill pipe sections and assembling and dismantling of drill strings.

The present invention is generally defined as a dual-walled drill pipe section comprising, in combination, an outer pipe member having an internally threaded box end and an externally threaded pin end, and an inner pipe member telescopingly movable inwardly and outwardly of the outer pipe member and defining therewith a generally tubular fluid passage. Recess means is formed on one of the members within the passage and means associated with the outer of the members is engageable with the recess means for releasably retaining the inner pipe member within the outer pipe member.

These and other features of the invention will become more apparent from the following description in which reference is made to the appended drawings wherein:

Figure 1 is a view illustrating a form of drill pipe with which the present drill rig is adapted to be used;

Figure 2 is a diagrammatic, perspective view illustrating the various components of the drill rig of the present invention;

Figure 3 is a side elevational view of the carriage and pipe drive mechanism;

Figure 4 is a rear elevational view of the assembly of Figure 3;

Figure 5 is a partial cross-sectional view of a portion of the pipe drive mechanism;

Figure 5a is a partially broken elevational view of an air swivel discharge device connected to a coupling tool and the inner pipe member of a dual-wall drill pipe;

Figure 6 is a partially broken top view of the pipe drive mechanism illustrated in Figure 5;

Figure 7 is a top view of a pipe engaging tool used for dismantling or "breaking" a pipe joint;

Figure 8 is a cross-sectional view taken along line 8-8 of Figure 7.

Figures 9 and 10 are views similar to Figures 7 and 8 respectively but illustrating a tool for use with a smaller size of pipe;

Figure 11 is a cross-sectional view of a pipe drive tool similar to that illustrated in Figure 5 but for use with smaller drill pipe;

Figures 12 and 13 are a top and edge view, respectively, of a split ring for use in retaining a pipe engaging tool on the top drive;

Figures 14 and 15 are a top and cross-sectional view taken along line 15-15, respectively, of a thrust retainer ring associated with the split ring;

Figure 16 is a side, partially cross-sectional view of the carriage;

Figure 17 is a front view of the carriage and top drive assembly;

Figures 18 and 19 are side and front views, respectively, of a carriage actuating mechanism pull-up assembly showing the mast in dotted and dashed lines;

Figures 20 and 21 are views similar to Figures 18 and 19 but illustrating a carriage actuating mechanism pull-down assembly;

Figures 22 and 23 are views similar to Figures 18 and 19, respectively, but illustrating the hoist mechanism;

Figure 24a is a longitudinal cross-sectional view of a hoist plug for use in elevating a drill string;

Figure 24b is a bottom view of the hoist plug of Figure 24a;

Figure 25 is a top view of the break-out wrench mechanism illustrating the wrench operatively engaged with a section of pipe.

Figure 26 is a broken, partial cross-sectional view of a drill pipe section of the present invention;

Figure 27 is a broken, cross-sectional view of the outer pipe member of the drill pipe of the present invention;

Figure 28 is a broken, cross-sectional view of the inner pipe member of the drill pipe section of the present invention;

Figure 29 is a top end view of the inner pipe member illustrated in Figure 28;

Figure 30 is a bottom view of the inner pipe member illustrated in Figure 28;

Figure 31 is an edge view of the inner pipe member resiliently retaining together the inner and outer pipe members; and

Figure 32 is a top view of the string illustrated in Figure 31.

The primary function of the drill rig of the present invention is to assemble and rotatably drive a drill string into an earth formation at a desired drilling site and extract and dismantle the drill string. A drill string is comprised of serially connected lengths of drill pipe. Each length of pipe is threaded at each end for threaded engagement with one end of an adjacent pipe.

As shown in Figure 1, one end of the pipe 10 is formed with internal thread and is referred to as a "box" 12. The other end of the pipe is formed with an external thread, referred to as a "pin" 14. A cutting bit (not shown) is connected to the lowermost pipe section.

Adjacent the box and pin of each pipe section are a pair of flattened diametrically opposed recesses or slots. The slots are provided for threadedly engaging and disengaging ("breaking") a pair of pipe sections. The slots adjacent the box are engageable with a hydraulic break-out wrench and called "box end break-out slots" 16, while the slots adjacent the pin, called "pin end break-out slots" 18, are engageable with pivoted dogs of a break-out tool removably mounted in the pipe drive mechanism.

While not limited thereto, the present invention is particularly intended for use with double or dual-wall pipe sections wherein an inner pipe 20 is concentrically mounted within the above described pipe in a well known manner. The inner and outer pipe members together define an annular passageway 22 for communicating a fluid, such as air, from the surface to the cutting bit and the inner pipe defines a bore 24 for communicating the fluid and cuttings to the surface.

The major components of the drill rig are provided by two separate modules 25 and 26, each having a weight which is readily transportable by helicopter. Module 25 includes a sled or base 27 on which are mounted a mast assembly 30, a prime mover 28, such as a diesel engine, a hydraulic system 29 including a hydraulic pump and reservoir for supplying pressured fluid to various hydraulic cylinders and motors of a mast assembly 30. Module 26 includes a sled 31 carrying a compressed air system 33, including an engine 35, a compressor and reservoir 37, for supplying pressurized air via conduit 39 to an air swivel discharge device 41 mounted on a drill pipe drive mechanism of assembly 30. The discharge device, in turn, supplies air to passageway 22 as explained earlier. The air swivel discharge device also connects the outlet of bore 24 of inner pipe 20 to a cyclone 43 via conduit 45 in a manner well known to those skilled in this art. Lengths of pipe sections 10 are stored in a pipe rack 47 as shown in Figure 2.

The mast assembly 30 (Figure 2) includes a mast 32 having a track 34, a carriage 36 movable along the track, a drill pipe rotary drive mechanism 38 mounted on the carriage, a carriage actuating mechanism 40 mounted on the mast, a hoist mechanism 42 for hoisting the drill string or the drive mechanism mounted on the mast and a "break-out wrench" mechanism 44 (Figure 25) mounted on the base of the mast. Each of these components are described in greater detail hereinafter. The following description outlines the general features and purposes of these components.

The mast 32 operatively supports the other above-mentioned components of the assembly 30. It is operatively supported in a vertical position. The track 34 extends longitudinally of the mast and is comprised of a pair of facing channels disposed at two adjacent corners at the front side of the mast. The mast is illustrated in detail in Figures 2 and 18-23 (in phantom lines).

The carriage 36 is connected to actuating mechanism 40 for vertical movement along track 34. Its primary function is to support the pipe drive mechanism 38. Carriage 36 is best illustrated in Figures 3, 4, 16 and 17.

The rotary pipe drive mechanism 38, hereinafter called "top drive", defines a rotary axis and is mounted on the carriage for movement therewith longitudinally of the mast and pivotal movement about a horizontal axis between a first position and a second position. The first position is the normal operating position of the top drive wherein the rotary axis is substantially vertical and the top drive rotatably drives a pipe coupling tool for driving a drill string, threadedly engages or disengages a pair of pipe sections or hoists the drill string as will be explained in greater detail later. The second position is the position in which the top drive is disposed when pipe is added and removed. In this position, the top drive is disposed about 90° from the first position with the underside of the top drive facing outwardly away from the mast and the rotary axis is substantially horizontal. A detent mechanism is provided for resiliently retaining the top drive in either position. The top drive is illustrated in Figures 3-6.

The carriage actuating mechanism 40 is generally comprised of a pair of hydraulic cylinders disposed on opposite sides of the mast, adjacent the side on which the carriage is moveable, and mounted on the base of the mast. The hydraulic cylinders are operatively connected to the carriage by cables arranged for selectively, reversibly actuating the carriage. The actuating mechanism is best illustrated in Figures 18-21.

The hoist mechanism 42 is generally comprised of a single hydraulic cylinder disposed adjacent the side of the mast opposite the side on which the carriage is mounted and is mounted on the crown of the mast. The hoist mechanism is selectively connectable to either the upper length of pipe of drill string or the top drive for raising the drill string, as will be explained in greater detail hereinafter. The hoist mechanism is best illustrated in Figures 22 and 23.

The break-out wrench mechanism 44 is a hydraulically actuated, extendable and retractable wrench for selectively engaging a pipe section and preventing rotation thereof during assembly and disassembly of a drill string. The break-out mechanism is best illustrated in Figure 25.

ROTARY PIPE DRIVE MECHANISM - TOP DRIVE

The top drive 38, illustrated in Figures 3-6, is generally comprised of a transmission or gear

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box 50, a speed reducer 52, and a hydraulic motor 54. The speed reducer 52 is drivingly connected to the input shaft 56 of the gear box and bolted to the gear box casing 58 while the hydraulic motor 54, which is preferably of the reversible, variable displacement type, is drivingly connected and bolted to the speed reducer 52, as shown in Figures 3 and 4. The motor is connected to hydraulic system 29 via appropriate conduits 53 (Figure 4). The speed reducer and motor are of conventional construction and accordingly are neither illustrated nor described in detail herein.

Casing 58 is generally of box-shaped configuration and houses a drive pinion 60, which in the illustrated embodiment is integral with input shaft 56, a crown gear 62 which meshingly engages with pinion 60 and a tubular drive spindle 64 bolted to crown gear 62. As will be described more fully later, the drive spindle is adapted to removably receive and drive any one of the several pipe engaging or coupling devices so that the top drive can be quickly and readily modified to drive pipe of different sizes and carry out functions other than driving the drill string including threadedly engaging and disengaging adjacent pipe sections and hoisting the drill string.

Drive spindle 64 is formed with a radially outwardly extending flange 66 adjacent its midportion, which flange is abuttingly engaged with and secured by bolts 68 to a radially inwardly extending flange 70 of crown gear 62, as best shown in Figure 5. The drive spindle 64 and crown gear 62 are rotatably mounted in the casing 58 by upper and lower ball bearing assemblies 72 and 74. Upper and lower oil seals 76 and 78 are disposed between each end of the drive spindle 64 and bore 80 of the casing 58 as shown in Figure 5. The oil seals are protected and retained in position by upper and lower oil seal guard rings 82 and 84 bolted to casing 58.

Drive spindle 64 is also formed with a bore 86 which telescopingly and removably receives the pipe coupling devices. Bore 86 is formed with at least one, but preferably a plurality of longitudinally extending keyways 88. As will be explained later, upper annular edge 90 of spindle 64 serves to support the removable pipe coupling tools.

It will be seen that actuation of motor 54 effects rotation of shaft 56 and pinion 60 in one direction and rotation of crown gear 62 and spindle 64 in the opposite direction. Reverse rotation of the motor results in reverse of the motor results in reverse rotation of the spindle and, inasmuch as the motor is of the variable displacement type, the spindle can be driven at various speeds and used for various purposes such as rotatably driving a drill string and making and breaking tool joints between adjacent pipe sections.

PIPE COUPLING TOOLS

Figures 5 and 7-11 illustrate pipe coupling devices or tools which form an important part of the present invention. The tool generally designated by reference numeral 100 in Figures 5 and 11 is used primarily for rotatably driving a drill string and threadedly engaging adjacent, axially aligned pipe sections. The tool generally designated by reference numeral 170 in Figures

7-10 is intended for use primarily as a break-out tool, i.e., for threadedly disengaging adjacent pipe sections. However, both tools can also be used for hoisting the drill string.

Drive tool 100 is generally comprised of a cylindrical body portion 102 having an internal thread 104 at its lower end 106, at least one, but preferably a plurality of longitudinal, equally spaced keys 108, and a radially outwardly extending flange 110 at its upper end 112. An externally threaded neck portion 114 extends axially from the upper end of tool 100. An external radially outwardly facing circumferential slot 116 is formed adjacent the lower end 106 of the tool.

Thread 104 is formed to threadedly receive one end of a cylindrical tool known as a "saver sub". A saver sub is generally a short length of pipe externally threaded at both ends and is normally used at locations where extensive threading and unthreading occurs. Thus, the relatively inexpensive save sub takes most of the wear. The other end of the save sub is threadedly received in the box end of a length of drill pipe. It will be understood that the lower end of the tool 100 could be formed with an external thread adapted to be connected directly to the box end of a drill pipe thereby obviating the need of a saver sub if so desired.

In the embodiment shown, the keys 108 are formed by welding elongated steel bars 118 in four elongated, longitudinal slots 120 formed on the outer cylindrical periphery of the tool 100. The keys are received in keyways 88 of drive spindle 64 and serve to transmit torque from the drive spindle 64 to the body portion of the tool. The term axial splines used hereinafter is intended to refer to any arrangement which non-rotatably couples two components while permitting relative axial movement therebetween.

Flange 110 defines a radial annular shoulder 122 which abuttingly engages upper annular edge 90 of spindle 64. Thus, the tool is thereby vertically supported in the top drive by the spindle 64. In addition to serving as the means of supporting the tool in the top drive, the flange serves as a "flinger" - a means whereby contaminants, such as dirt, are centrifugally propelled away from the upper oil seals 76.

Threaded neck portion 114 is adapted to be threadedly connected to an air discharge swivel 41, as illustrated in phantom in Figure 5a. The neck 114 defines an opening 124 to receive an inner pipe section, as also shown in Figure 5a, which is sealingly connected to the air discharge swivel and provides an annular passageway between the inner pipe and opening 124 for communicating air to passageway 22. As explained earlier, an air discharge swivel is a device for connecting a supply of air to annular passageway 22 and bore 24 of the inner pipe to an exhaust conduit which, in turn, is connected to a cyclone 43 for separating air from cuttings while the drill string rotates. Air swivel discharge devices are well known and therefore are not described in detail herein. In practice, a pipe coupling tool 100 remains connected to the air discharge swivel unless a tool for use with a different sized pipe is required. In such case, the tool is simply threadedly removed and the desired tool is threaded onto the air discharge swivel.

A split thrust ring 130 and a retaining ring 132 are provided for preventing inadvertent removal of the drive tool 100 and for limiting longitudinal or axial travel of the tool 100 relative to the top drive. As will be described in greater detail later, such movement is desirable when threadedly engaging adjacent lengths of pipe.

As shown in Figures 12 and 13, split ring 130 is comprised of a pair of arcuate arms 134,134 connected at one end for pivotal movement about a pin 136. In the position shown in Figure 13, arms 134,134 define a cylindrical surface 138 whose diameter is slightly larger than the inner diameter of peripheral slot or groove 116 of tool 100. Thus, ring 130 is adapted to be fitted into the slot 116 and is readily removable therefrom by pivotally manipulating arms 134,134.

Retaining ring 132, shown in Figures 14 and 15, is provided to prevent separation of arms 134,134 of the split ring yet permit quick removal of the split ring from the tool and the tool from the top drive. Ring 132 is formed with a skirt portion 140 and an annular shoulder portion 142. Shoulder portion 142 defines axial opening 144 which telescopingly receives body portion 102 of tool 100. Opening 144 is formed with four keyways 146 for slidingly receiving keys 108 of the tool. The skirt portion 140 is formed with an opening 147 sized to loosely receive the outer periphery of split ring 130 as shown in Figure 5. The retainer ring 132 is maintained in the position shown in Figure 5 by gravity.

Thus, in order to remove the drive tool from the top drive, retaining ring 132 is telescopingly moved upwardly, as viewed in Figure 5, the split ring 130 is removed from slot 116 by opening or separating arms 134,134 and ring 132 is slid downwardly and away from the tool. The tool (and its associated air discharge swivel) is then free to be removed from the top drive by moving it axially upwardly and outwardly of the drive spindle. The reverse procedure is adopted to operatively locate a tool in the top drive.

The distance between the shoulder 122 of the drive tool 100 and the upper surface 148 of ring 132 is arranged to be longer than the axial length of the drive spindle 64 by an amount at least equal to the length of the thread of the box (or pin) of a drill pipe. This avoids the need of incrementally lowering the top drive when the top drive is used to thread an additional pipe section to the drill string in a manner to be described later. However, it is pointed out that during such procedure, assuming a length of pipe has been mounted on the saver sub attached to the drive tool and the pin end of the drill pipe has been aligned with and brought into abutting engagement with the box end of the upper pipe of the drill string, the top drive is lowered until the lower end of the drive spindle 64 abuts surface 148 of ring 132. Then, the drive spindle 64 is rotated in a clockwise direction (viewed downwardly in Figure 5). Such rotation threadedly engages the pin of the pipe being added to the upper box of the drill string. As this occurs, the pipe being added and the drive tool move downwardly relative to the top drive so that no vertical adjustment of the position of the top drive is required during this operation.

Coupling tool 150 illustrated in Figure 11 is in all material respects the same as that illustrated in Figure 5 except that it is constructed for use with drill pipe of smaller outside diameter. Specifically, the body portion 152, keys 154, annular flange 156, neck portion 158 and peripheral slot 160 are identical to those of tool 100 so that tool 150 cooperates with drive spindle 64 and split and retaining rings 130 and 132 in precisely the same manner as tool 100. However, an insert 162 replaces internal thread 104 of tool 100 and provides an internal thread 164 of smaller diameter than thread 104 for use with smaller drill pipe. As shown, insert 162 is welded to the body portion.

It will be understood that in addition to transferring torque to the drill string, the above described coupling tools can be used to transmit axial forces to the drill string in situations where hoisting effort is required. Thus, should the drill string become jammed, as sometimes occurs the carriage actuating mechanism is actuated so as to apply a vertical force to the carriage which force is transmitted to the top drive casing. The force is in turn transmitted to the drive spindle, via the ball bearing assemblies and then to the drive tool flange, body portion and drill pipe.

Figures 7 and 8 illustrate a "break-out" tool 170 intended for use in threadedly disengaging two pipe sections and, hoisting the drill string in the event that additional hoisting effort is required to release a jammed drill string.

Break-out tool 170 is constructed so as to be received in and rotatably driven by drive spindle 64 in the same manner as drive tool 100. Thus, tool 170 is formed with a tubular body portion 172 having four equally spaced keys 174 and a peripheral slot 176 adjacent lower end 178 thereof for reception of split ring 130 and retaining ring 132. The upper end 180 is formed with a flange 182 having an annular shoulder 184 for abutting engagement with upper edge 90 of drive spindle 64 and application of an upward thrust to the tool when required. As with tools 100 and 150, the length of tool 170 is such so as to permit axial travel of the tool relative to drive spindle 64 and thereby avoid the need of incrementally raising the top drive as a pipe section is unthreaded. Further, tool 170 is mounted on and removed from the drive spindle 64 in precisely the same manner as tools 100 and 150.

The body portion is formed with an axial bore or opening 186 adapted to telescopingly receive a length of pipe section as shown in dotted lines in Figure 8.

Secured to flange 182 by bolts 185 are a pair of concentric annular discs 187 and 188 between which are confined a pair of diametrically opposed dogs 190. Each dog 190 is formed with a cylindrical portion 192 from the opposite ends of which extend stub shafts or pins 194 received for pivotal movement in blind bores 196 formed in abutting surfaces 198 and 200 of discs 187 and 188 respectively. Also formed in discs 187 and 188 adjacent each bore 196 are chambers 202 which receive torsion or spiral springs 204 which serve to bias dogs 190 toward the solid line position shown in Figure 8.

Extending radially outwardly and longitudinally of each dog 190 is a jaw portion 206 adapted to be received in previously mentioned pin end break-out slots 18 of a pipe section as shown in Figure 8.

The break-out tool 208 illustrated in Figures 9 and 10 is in all material respects the same as the tool illustrated in Figures 7 and 8 except that it is used with a pipe section of smaller outside diameter. This tool utilizes the same tubular body portion 172 but discs 210 and 212 having a smaller inside diameter and locating the dogs 214 closer together are utilized. In addition an inner cylindrical tube 216 is concentrically disposed within the tubular body position. As shown, the upper end of the inner tube is welded to the lower disc 212 while a spacer block 213 is disposed between the lower end of the inner tube 216 and the body portion 172.

When it is desired to remove the drill string from the bore hole, the drive tool 100 and air discharge swivel 43 are removed from the top drive in the manner previously explained and the break-out tool 170 is operatively positioned on the top drive as also previously explained with respect to drive tool 100. The carriage actuating mechanism is then actuated to lower the carriage, and hence the top drive, to a position adjacent the bottom of the mast. It will be understood that the top drive will remain in this position during the break-out operation unless the hoist mechanism is incapable of raising the drill string in which case the carriage actuating mechanism is used to provide additional vertical thrust.

It will also be understood that the break-out wrench has been engaged with the box end break-out slots 16 of the uppermost pipe section of the drill string and supports the drill string, at least in part. So arranged, the rig is ready for the break-out operation.

A hoist plug, secured to the free end of a cable connected to the hoist mechanism to be described in greater detail later, is passed through the break-out tool bore 186 and threaded into the box end of the uppermost pipe section of the drill string. The hoist mechanism is then actuated slightly so as to remove the weight of drill string from the break-out wrench and the wrench is retracted. The hoist mechanism is thereafter actuated to raise the drill string the length of a pipe section. As the drill string is raised, the periphery of the drill pipe surface pivots the dogs 190 to the dotted line position shown in Figure 8 against the bias of torsion springs 204. Once the pin end break-out slots 18 reach dogs 190, the dogs snap into the slots to the solid line position shown in Figure 8 assuming the slots are properly angularly aligned with the dogs. If not, the break-out tool and drill pipe are rotated slightly by actuating the top drive. The hoist mechanism is then lowered slightly until the upper flattened surface 206 of the dogs engage the upper transverse edges 210 of slots 18. This vertically aligns the box end break-out slots of the next pipe section with the break-out wrench which is then extended to engage such slots. It may be necessary to rotate the drill string by actuating the top drive in order to angularly align the box end break-out slots with the wrench. Once so engaged, the wrench prevents rotation of the drill string.

The top drive is then reversely rotated thereby reversing rotating the uppermost pipe section, via drive spindle 64 and break-out tool 190. As the upper pipe section is rotated, its pin unthreads from the box of the next lower pipe section and the pipe moves upwardly under the influence of the threads as well as that of a spring mechanism associated with the hoist mechanism. Further, dogs 190 move relatively downwardly in the pin end break-out slots 18 and thus slots 18 must be of sufficient length to accommodate such movement.

Once the upper pipe section has been separated from the next pipe section, the hoist mechanism is actuated to raise the separated pipe section free of the top drive. The hoist is then actuated to lower the pipe section which is placed in a pipe rack 47 (Figure 2) disposed adjacent the drill rig. The hoist plug is removed from the pipe section and the operation is repeated until the drill string is completely dismantled.

THE MAST

As shown in Figure 2, the mast 32 is an elongated parallel-piped structure defined by two rear tubular steel corner posts 230, two front posts 232 constructed of channel members, whose open sides face one another and define track 34, and intermediate tubular steel braces 234. The mast is also formed with a base 236 and a crown 238.

As also shown in Figure 2, the mast is disposed in an upright position during use. However, the mast is adapted to be pivoted to a horizontal position during transport on sled or skid 27. This is achieved by a pair of outwardly projecting pins 242 welded or otherwise secured to a brace member 234, as shown. The pins 242 are received in cradles 244 of support posts 246 associated with sled 27. A support bracket 248 supports the upper end of the mast during transport and a wedge lock at the base of the mast will maintain the mast in its upright position during use.

THE CARRIAGE

The carriage 36 is comprised of two sections 250 and 252 which are mirror images of one another. Section 250 is associated with and supports the left side of the top drive and while section 252 is associated with and supports the right side of the top drive. While the following description is referrable to section 250, it is to be understood that the description is equally applicable to section 252.

With reference to Figures 3, 4, 16 and 17, carriage section 250 includes an elongated outer plate 254 having rollers 256 and 258 rotatably mounted at its opposite ends. Rollers 256 and 258 are disposed for movement within the channel shaped members defining track 34. Spaced laterally inwardly of plate 254 is an inner plate 260 connected to plate 254 by laterally extending, spaced connector plates 262,262. Inner plate 260 is formed with an arcuate, rearwardly extending detent plate 264 having an arcuate guide surface 266 and recesses 268 and 270 spaced approximately 90° apart.

Extending between plates 254 and 260 is a pivot pin 272 having an inwardly disposed head 274. The opposite end of pin 272 is welded or otherwise secured to plates 254 and 260. Pin 272 extends inwardly beyond inner plate 260 and defines between plate 260 and head 274 a journal portion received in a two part support and pivot block 276 bolted to the casing of the top drive. Thus, the top drive is supported for pivotal movement about the axis of pins 272 between a first and a second position. In the first position, illustrated in Figures 3 and 4, the rotary axis of drive spindle is vertically disposed and the top drive may be used for the previously described operations. The second position of the top drive facilitates the addition of lengths of pipe to the top drive. In this position, the top drive is disposed about 90° about the axis of pins 272 from the first position with the underside of top drive facing away from the mast. When so disposed a length of pipe section may be threaded onto the saver sub attached to the drive tool by either manually rotating the pipe or slowly rotating the top drive.

Secured to the underside of the top drive casing is a detent roller assembly 280 which houses a spring biased roller 282 (Figure 16). Roller 282 engages guide surface 266 of detent portion 264 of plate 260. Recesses 268 and 270 define the first and second positions respectively of the top drive. The load of the spring within detent roller assembly 280 may be adjusted by nut 284.

A torque and guide member 286 engageable with detent roller assembly 280 positively locates the top drive in the first position.

Secured to one of the pivot blocks 276 is an air swivel torque slide 288 for preventing rotation of the outer housing of the air discharge swivel.

CARRIAGE ACTUATING MECHANISM

The carriage actuating mechanism 40 is comprised of a "pull-up" assembly 300 (Figures 18 and 19) and a "pull-down" assembly 302 (Figures 20 and 21). Both assemblies are actuated by the same two hydraulic cylinders 304,304 vertically disposed on laterally opposed sides of the mast 32. The two cylinders are secured to the base of the mast by a support bracket 306 (see Figures 18 and 20). Attached to the free end of the piston rod of each cylinder is a pulley assembly 307 having pulleys 308 and 310.

With reference to Figures 18 and 19, the pull-up assembly includes a cable 312 having one end 314 secured to one section of the carriage in the manner shown in Figures 16 and 17. Cable 312 is trained about pulley 308 of one pulley assembly 307, pulleys 316 and 318 (Figure 19) rotatably mounted in the mast base, and pulley 308 of the other pulley assembly 307. The other end 319 of cable 312 is then releasably connected to the other section of the carriage as also shown in Figures 16 and 17. A turnbuckle 322 is provided for adjustably tensioning the cable.

Thus, it will be seen that when cylinders 304 are actuated in unison to extend the piston rods, the ends 314 and 319 of cable 312 will move upwardly and thereby apply a vertical thrust to the top drive. It will be noted that the top drive will move upwardly at twice the rate of the piston rods.

With reference to Figures 20 and 21, the pull-down assembly 302 is comprised of two cables 330 and 332 each associated in an identical manner with one of the hydraulic cylinders 304. One end 334 of each cable is adjustably and removably connected to the crown of the mast, as best shown in Figure 20, while the other end 336 of each cable is removably secured to a respective section of the carriage, as shown in Figures 16 and 17.

From end 334, each cable extends downwardly and trained about upper pulley 310 of pulley assembly 307, upwardly and trained about pulley 338 rotatably mounted on the crown, and downwardly and trained about pulley 340 rotatably mounted in the mast base.

Thus, when cylinders 304 are actuated in unison to retract their respective piston rods, ends 336 of the cables 330 and 332 move downwardly and apply a downward thrust or force to the carriage and, hence, the top drive.

Two important features are to be noted. Firstly, it is known that the capacity of hydraulic cylinders is larger when its piston rod is extended than when it is retracted. In the present instance, the larger capacity of the cylinders is utilized for pulling up where higher capacity is required. Secondly, the hydraulic cylinders are mounted on the base rather than on the crown as is known. Thus, the mast need not absorb as much of a load and may therefore be made lighter, it being understood that weight is an important consideration in helicopter transportable drill rigs.

It will be understood that means is provided for vertically guiding the piston rods.

THE HOIST MECHANISM

The hoist or haul-out mechanism 42 is illustrated in Figures 22 and 23 and is comprised of a single inverted, vertically extending hydraulic cylinder 350 mounted on the mast crown adjacent the rear side 352 (remote from the top drive) of the mast. A pulley 354 is secured to the end of the piston rod 356 of the cylinder. A pivot head assembly 358 pivotally mounted atop the mast crown, as shown in Figure 23, is comprised of a pair of spaced arms 360 connected at one end 362 to the crown and centrally supported by a compression spring assembly 364. A stop 363 is provided to limit downward travel of the assembly. A pair of pulleys 366 and 368 are rotatably mounted on arms 360 as shown.

A cable 370 has one end 372 connected to the crown and its intermediate portion trained about pulleys 354, 366 and 368. The other end 374 of the cable 370 is fitted with a hook (not shown) or the like for connection to a hoist plug 376 or a bail (not shown) secured to the upper end of the air discharge swivel.

The pivot head assembly 358 is provided to maintain cable 370 in tension during the break-out operation as well as maintain an upward force on the pipe section being removed without incrementally raising the hoist mechanism.

Hoist plug 376 is illustrated in Figures 24a and 24b and is comprised of a tubular body portion 377 having an externally threaded lower end portion 378 which is threadedly engageable with the box end of a drill pipe section. A shaft 379 having a head 380 at its lower end and a thread 381 at its upper end is disposed in body portion 377. Head 380 bears against a thrust bearing 382 which in turn bears against an internal shoulder 383 in the plug body. An oil seal 384 and retaining ring 385 close the lower end 378 of the plug. A clevis 386 is threaded onto upper end 381 of shaft 379 against a ball bearing 387. A removable clevis pin 388 is mounted in the clevis as shown for securing the end 374 of cable 370 to the hoist plug. The body portion is formed with a spoked, ringed handle 389 at its upper end for manually rotating the body portion with respect to the shaft. As best shown in Figure 24b, threaded portion 378 is formed with a pair of opposed flattened surfaces 390 so that the lower end of the plug can be passed between the dogs 190 of a break-out tool 170 without moving the dogs.

Thus, when it is desired to use the hoist mechanism, end 374 of cable 370 is secured to clevis 386 and the lower end 378 of the plug is passed through bore 186 of tool 170 and threadedly engaged with the box of the uppermost drill pipe section of the drill string to be raised by rotating handle 389 and hence plug body 377. Cylinder 350 is then actuated to extend piston rod 356, and raise end 374 of cable 370, the hoist plug 376 and drill string. Once the upper drill pipe section of the drill string has been removed from the drill string and the top drive, piston rod 356 is retracted to lower the drill pipe section, the drill pipe section is unthreaded from the hoist plug section and placed in the pipe rack.

THE BREAK-OUT WRENCH ASSEMBLY

The break-out wrench assembly is illustrated in Figure 25 which is a top view of the mast base. The assembly includes a wrench member 400 having a wrench head 402 and an elongated body portion 404. Wrench member is slidably mounted on the upper surface 406 of the mast base for reciprocation from a first extended position illustrated in Figure 25 whereat the wrench is in engagement with a section of pipe and a second, retracted position whereat the wrench is clear of the drill string permitting rotation and/or axial movement of the latter.

Wrench head 402 is formed with a pair of opposed flattened surfaces 408 slidingly engageable with the box end break-out slots 16 of a pipe section. The wrench member is guided for reciprocal movement by a bracket 410 bolted to surface 406 and associated with body portion 404 and a pair of guides 412 secured to surface 406 and associated wing projections 414 extending from head 402. As shown in dotted lines in Figure 25, a bar 416 secured to body portion 404, extends through a slot 418 in surface 406 into the mast base and is connected to a hydraulic cylinder 420 disposed within the base. The wrench head is supported by a surface 422 of a pipe guide member 424 formed in the mast base.

OPERATION

ASSEMBLING DRILL STRING AND DRILLING

Initially, the carriage actuating mechanism 40 is actuated to move the top drive mechanism 38 to a convenient lower position on the mast. An air discharge swivel mechanism having an appropriate pipe coupling tool 100 or 150 attached thereto is inserted into the bore 86 in spindle 64. The split thrust ring 130 and retaining ring 132 are then assembled on the pipe coupling tool.

The top drive 38 is manually pivoted about pins 272 from its first position to its second position. The top drive is maintained in the second position by the detent assembly. It should be noted at this point that the pins 272 extend through or near the centroid of the top drive, speed reducer, motor and air discharge swivel so that relatively little effort is required to move the top drive between its two positions.

An appropriate cutting bit is connected to the down hole end of the first drill pipe and the box end of such pipe is threaded onto the saver sub extending from the drive tool either by manually rotating the drill pipe or rotating the top drive while the pipe section is held stationary.

The carriage actuating mechanism is actuated to raise the top drive to the upper end of the mast 32. As the top drive rises, the weight of the pipe overcomes the effort of the spring detent assembly and the pipe moves towards a vertical position. The stop 286 engages the detent housing and thereby positively locates the top drive in its first, driving position.

The lower end of the pipe is placed above the pipe guide in the mast base and the carriage actuating mechanism is actuated to lower the top drive until the cutting bit engages the ground. The carriage actuating mechanism is deactivated and the rig is ready for drilling.

Motor 54 is actuated to begin the drilling operation. The drilling continues until the box end break-out slots 16 are vertically aligned with the break-out wrench. Hydraulic cylinder 406 is actuated to extend break-out wrench 400. The top drive is rotated if necessary in order to angularly align the box and break-out slots with the flattened surfaces 408 of wrench 400. Thus, the portion of the drill string in the bore hole is held against rotation. Motor 54 of the top drive is reversed so as to threadedly disengage the saver sub from the box of the drill pipe. Thereafter, the carriage actuating mechanism is activated to raise the top drive slightly. The top drive is then pivoted to its second position and is ready to repeat the foregoing procedure.

The mode of adding the second and subsequent pipe sections to the drill string is substantially the same as the mode of adding the first pipe.

A new length of pipe is threaded onto the saver sub as explained previously. The top drive is raised until the pin of the new pipe clears the box of the pipe already in place. The top drive is then lowered while the pin of the new pipe enters the box of the pipe already in place and the lower edge of the drive spindle abuttingly engages the upper surface 148 of retaining ring 132. The top drive is then rotated until the new

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pipe is fully threadedly engaged with the pipe already in place. It will be noted that as the new pipe is being threaded, it moves downwardly with respect to the top drive by virtue of the longitudinal clearance originally provided between the drive tool and the drive spindle so that it is not necessary to incrementally lower the top drive as the new pipe section is being threaded.

In the event that the drill string becomes jammed in the bore hole, the carriage actuating mechanism is actuated to apply an upward thrust to the drill strip via the top drive and coupling tool. Should the carriage actuating mechanism be incapable of raising the drill string, the hoist mechanism is attached to a bail (not shown) on the air discharge swivel or the top drive and it is actuated to apply an additional upward thrust to the drill string. Once the drill string is cleared, the hoist mechanism is disconnected and the top drive motor is activated to ream the bore hole and continue drilling.

DISASSEMBLING A DRILL STRING

When it is desired to remove the drill string from the bore hole, the break-out wrench is engaged with the box end break-out slots 16 of the uppermost pipe section of the drill string and the top drive is reversely rotated so as to disengage the saver sub from the box end of the uppermost pipe of the drill string. The top drive is then raised to a convenient position whereat the air discharge swivel and its accompanying pipe coupling tool 100 (or 150) are removed by removing split thrust ring 130 and retaining ring 132 as previously explained. Following this, a break-out tool 170 is inserted into the drive spindle 64 and the split thrust ring and retainer ring are assembled threon so as to retain the break-out tool operatively disposed on the top drive.

The top drive is then lowered to a position adjacent the lower end of the mast. A hoist plug 380 is then secured to the end 374 of cable 370 of the hoist mechanism, extended through the opening in the break-out tool 170 and threadedly engaged with the threads in the box end of the uppermost pipe of the drill string. Thereafter, the hoist mechanism is actuated to raise the drill string slightly so as to move the weight of the drill string from the break-out wrench. The break-out wrench is retracted and the hoist mechanism is actuated to raise the drill string the length of a drill pipe. As this occurs, the drill string passes through axial bore 186 of the break-out tool and the dogs 190 are pivoted outwardly of bore 186 against the bias of spring 204. The drill string is raised until the box end break-out slots of the next pipe are vertically aligned with the break-out wrench and the dogs 190 are vertically aligned with the pin end break-out slots. As previously explained, it may be necessary to rotate the top drive so as to angularly align the dogs 190 and break-out wrench 400 with the pin end break-out slots 18 and box end break-out slots 16, respectively. At this point, it is to be noted that shoulder 184 of flange 182 of break-out tool 170 abuttingly engages annular surface 90 of drive spindle 64 and the dogs 190 are disposed at the upper end of the longitudinally elongated pin and break-out slots. Additionally, the compression spring assembly 364 of pivot head assembly 358 of the hoist mechanism are compressed and upwardly bias the drill

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string. Thus, as the top drive is reversely rotated, the upper drill pipe is unthreaded from the drill string and moves upwardly both under the influence of the action of unthreading and the bias of the compression spring assembly. Further, it will be noted that dogs 190 move relatively downwardly of the pin end break-out slots and the break-out tool moves axially upwardly relative to the top drive. As previously explained, incremental vertical adjustment of the top drive is not necessary.

Once the upper drill pipe has been completely unthreaded, the hoist mechanism is retracted and the decoupled pipe is placed in the pipe rack. The above described procedure is then repeated until the drill string is fully dismantled.

DUAL WALL DRILL PIPE

With reference to FIG. 26, the dual-wall drill pipe section of the present invention, generally designated by reference numeral 510, is generally comprised of an outer pipe member 512 and an inner pipe member 514. The inner and outer pipe members together define an annular passageway 516 which serves to communicate a fluid, such as air, from the surface to the cutting bit at the bottom of a bore hole. The inner pipe member defines a fluid passageway 518 for communicating the fluid and cutting chips from the bottom of the bore hole to the surface.

The dual-wall drill pipe section of the present invention provides an arrangement whereby the inner and outer pipe members are resiliently retained together during handling. Further, the pipe section of the present invention provides an arrangement whereby each outer pipe member supports its associated inner pipe member so as to minimize the strength requirements of the inner pipe member as well as failure of the inner pipe tubing. Still further, the drill pipe arrangement of the present invention is arranged such that that portion of the inner pipe which protrudes from the outer pipe section during storage and handling is effectively and conveniently reinforced so as to again minimize damage to the inner tubing.

With particular reference to FIG. 27 of the drawings, the outer pipe is generally comprised of three components in order to facilitate manufacture of the outer pipe member. In particular, the outer pipe member is comprised of a box 520, an elongated tube 522 and a pin 524. The three components are of uniform outside diameter as shown.

The box 520 includes an internal thread 526 at its free end while the pin 524 is formed with an external thread 528 for engagement with the thread 526 of the box of another outer pipe member. The opposite end of the box 530 is formed with a portion 520 of reduced diameter for reception in one end of tube 522. Similarly, the end of pin 524 remote from thread 528 is formed with a portion 532 of reduced diameter for reception within the opposite end of the tube 522. The box 520 and pin 524 are welded to their respective ends of tube 522 as by welds 534 and 536, respectively.

The bore of box 520 is stepped at 538 and 540 so as to define a first bore portion 542 of reduced diameter and a second bore portion 544 of reduced diameter. The steps 538 and 540 are chamfered so as to facilitate insertion of the inner pipe member within the outer pipe member.

As will become clearer later, step or shoulder 538 serves to transmit axial loads which may be imparted on the inner pipe member directly to the outer pipe member. Step 540 is provided in order to provide adequate wall thickness in the vicinity of a pair of opposed flattened, transverse recesses 546. As is explained supra, the recesses are provided for engagement with pipe coupling tools associated with the drill rig for dismantling a drill string. Similarly, the pin 524 is formed with opposed, flattened transverse recesses 548.

Reduced diameter portion 542 of the box 520 is also formed with a circumferential inwardly facing groove 550 which in the preferred form of the invention is arcuate in cross-section. Groove 550 is engageable with leaf springs mounted on the inner pipe member as will become clearer hereinafter.

With reference to FIG. 28 of the drawings, inner pipe member 514 is formed with spacer means at each end thereof for maintaining concentricity between the inner and outer pipe members.

The spacer means 560 disposed at the upper ends 562 of the inner pipe 514 is comprised of four pairs of elongated, longitudinally extending spacer members or plate 564. As best shown in FIG. 29, the four pairs of spacer members are equally angularly spaced about inner pipe 514. Each pair of spacer members 564 define a radially outwardly facing channel or chamber 566 in which is disposed an elongated leaf spring 568 as shown in FIG. 26.

Each spacer member is of the form of a bar of metal or plate welded to the outer periphery of inner pipe 514 and having an outer edge 570 which conforms to the shape of the inner bore of the outer pipe and dimensioned with respect to the axis of the inner pipe so as to be in sliding contact with the bore of the outer pipe. Members 564 each define a shoulder 572 abuttingly engageable with shoulder 538 of the outer pipe whereby the inner pipe is vertically supported in the outer pipe when the pipe section is held in an upright position.

As shown in FIGS. 31 and 32, each leaf spring 568 is generally V-shaped in edge view and has a pair of arms 575 and 576 which diverge from one another from an apex 577 shaped to mate with arcuate grooves 550 in outer pipe 512. The end of arm 575 is formed with an eye 578 for receiving a transverse pin 580 (FIG. 26) extending between the upper ends of a pair of spacer members 564. End 586 of arm 576 is formed to abuttingly engage and, to a limited extent, slide along the outer periphery of inner pipe 514. To prevent spring 568 from moving about and facilitate assembly of the pipe section, a transverse pin 588 is provided at the lower ends of spacer member 564 so as to confine end 586 of the arm 576 between pin 588 and the inner pipe, as best shown in FIG. 26.

Thus, when the inner pipe member 514 is inserted into the box end of outer pipe member 512 and telescopically moved inwardly thereof, springs 568 are radially inwardly depressed until apices 557 reach and engage groove 550. So positioned, leaf springs 568 serve to frictionally and releasably retain the inner pipe member 514 within an outer pipe member 512 thereby facilitating storage and handling of the assembly.

Secured to the lower ends 590 of the inner pipe member 514 is a tubular connector member 592 having a bore 594 formed with an annular rib 596 defining opposed annular shoulders 598 and 600. Rib 596 defines an upper bore portion 602 and a lower bore portion 604. Bore portion 602 telescopingly receives the lower end 590 of tube 514 to which the upper end of the connector is welded at 606 as shown in FIG. 28. The lower bore portion 604 of bore 594 is adapted to telescopingly and sealingly receive the upper end 562 of another inner pipe member. A pair of O-rings 608 disposed in grooves 610 serve to seal adjacent ends of connected inner pipe members.

Extending longitudinally upwardly from the connector member 592 are a plurality of equally angularly spaced spacer members 612 which serve to both concentrically dispose the lower end 590 of the inner pipe member 514 within the outer pipe member 512 and reinforce lower end 590 of inner pipe member 514. As is indicated in FIG. 26, the lower end of the inner pipe projects axially outwardly of the lower end of the outer pipe member and, thus, is subject to damage during storage and handling. However, spacer members 512 and connector 592 serve to protect and reinforce the end of the inner pipe member.

In order to assemble a pipe section, the lower end 590 of an inner pipe member is inserted into the box end 520 of an outer pipe member and telescopingly moved along the outer pipe member until projection 584 of the leaf springs 568 enter and resiliently engage groove 550 in box 520 of the outer pipe member 512 and shoulders 538 and 572 of the outer and inner pipe members, respectively, abuttingly engage. When so assembled, springs 568 serve to retain the inner pipe member within the outer pipe member, even if the pipe section is inverted. In order to dismantle a pipe section, an axial, upwardly directed force of a magnitude which is sufficient to radially inwardly depress springs 568 is applied to the lower end 590 of the inner pipe member. The inner pipe member may then be readily telescopingly removed from the outer pipe member.

In order to assemble a drill string formed of the above described assembled pipe sections, the lower end 590 of the inner pipe member is inserted into the box end of a drill string and telescopingly moved downwardly therewithin until the pin 524 of the pipe section being assembled engages the upper box 520 of the drill string. Thereafter, the pipe section being assembled is rotated with respect to the drill string so as to threadedly engage the pin 524 of the new section with the box 520 of the drill string.

It will be appreciated that the spacer member 564 and springs 568 need not necessarily be disposed at the upper end of the inner pipe. Indeed, they may be disposed at the lower end of the pipe with the pin 524 suitably modified to receive these members. In this case, the connector member 592 and spacer member 612 would be disposed at the upper end of the inner pipe.

1. A dual-wall drill pipe section, characterized by:

an outer pipe member (512) having an internally threaded box end (520) and an externally threaded pin end (524);

an inner pipe member adapted to be concentrically disposed within said outer pipe member and defining therewith an annular fluid passage (615); and

means (572) interposed between said inner and outer pipe members for frictionally and releasably retaining said inner pipe member within said outer pipe member prior to assembly of said section in a drill string.

2. A drill pipe section as defined in claim 1, characterized by:

said retaining means including recess means (50) formed on one of said pipe members and means (68) associated with the other of said pipe members releasably engageable with said recess means, said recess means preferably being (i) a circumferential recess formed in the bore of said outer pipe member, and said recess preferably being arcuate in longitudinal section of said outer pipe member, said associated means preferably being spring means connected to the outer periphery of said inner pipe member, said spring means preferably being generally V-shaped, ahd having an apex (577) engageable with said recess means, the end (578) of one of the arms (575) of said spring means (568) being pivotally connected to said inner pipe member; or (ii) a circumferential recess (550) formed in the bore of said outer pipe member;

said retaining means being at least one V-shaped spring (568) means connected to the outer periphery of said inner pipe member and its apex (577) formed to seat in said recess; and

said spring means (568) being inwardly depressed and biased by said bore of said outer pipe member when said inner pipe member is telescopingly inserted into the bore; said recess preferably being arcuate in longitudinal section of said outer pipe member and said apex (577) having an arcuate, convex protruberance matingly engageable with said recess;

3. A drill pipe section as defined in claim 1 or 2, characterized by said inner and outer pipe members having abuttingly engageable shoulder means (538) for longitudinally locating said inner pipe member (514) within said outer pipe member (512) and transferring axial loads applied in a downward direction to said inner pipe member to said outer pipe member; and

4. A drill pipe section as defined in claim 1, 2 or 3, characterized by one of said pipe members having spacing means (612) adapted to be disposed within said passage for maintaining concentricity between said inner and outer pipe members.

5. A dual-wall drill pipe section for a drill string, formed from a plurality of serially connected drill pipe sections, for use in drilling in earth formations, said drill pipe section characterized by:

an outer pipe member (512) having an internally threaded box end (520), an externally threaded pin end (524), internal shoulder means (546) extending inwardly of the bore of said outer member and recess means formed in said bore;

an inner pipe member (514) adapted to be concentrically disposed within and telescopingly moveable inwardly and outwardly of said outer pipe member (512), external shoulder means (572) extending outwardly of the outer periphery of said inner pipe member and being engageable with said internal shoulder means for axially locating said inner pipe member and for supporting said inner pipe member in said outer pipe member when said section is in an upright position; and

means (560) secured to the outer periphery of said inner pipe member and engageable with said recess means for frictionally retaining said inner pipe member within said outer pipe member.

6. A drill pipe section as defined in claim 5 characterized by: said retaining means including a plurality of generally V-shaped leaf springs (568), the end of one arm of each said spring being secured to the outer periphery of said inner pipe member, and the of the other arm (576) of each said spring being abuttingly and slidingly engageable with the outer periphery of said inner pipe member and the apex (577) of each said spring means being spaced from said periphery and frictionally engageable with said recess means (550), said recess means preferably (i) being a circumferential recess or (ii) arcuate in longitudinal cross section, said apex (577) of each said spring preferably being shaped to mate with said recess, and

7. A drill pipe section as defined in claim 5 or 6, characterized by: further including spacer means (560) secured to each end of said periphery of said inner pipe member and being abuttingly engageable with said bore of said outer

pipe member for maintaining concentricity between said inner and outer members, said spacer menas preferably including a plurality of angularly spaced longitudinally extending plates (564) extending outwardly of said periphery and each having a longitudinal surface abuttingly engageable with said bore of said outer pipe member, and if desired, further including pin means (588) extending between pairs of said plates at one end of each inner pipe member, said end of said one arm of each said leaf spring being connected to said pin means for pivotal movement thereabout, said external shoulder means preferably being formed on said plates at one end of said inner pipe member, and, if desired, further including a connector member (592) secured to one end of said inner pipe member for sealingly connecting said one end to the other end of another inner pipe member.

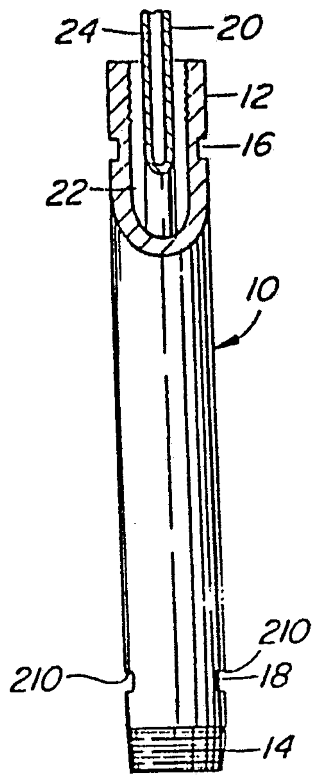
8. A dual-wall drill pipe section for a drill string formed of a plurality of serially connected drill pipe sections for drilling in earth formation, said drill pipe sections characterized by

an outer pipe member (512) having a bore, an internally threaded box end (520) defining an upper end, an externally threaded pin end (524) defining a lower end threaded engageable with the box end of an adjacent outer pipe member, a concentric conical shoulder (546) in said bore adjacent said box end and a concentric circumferential recess in said bore axially downwardly spaced from said shoulder;

an inner pipe member (514) adapted to be concentrically disposed within and telescopingly moveable inwardly and outwardly of said outer pipe member (512) and defining therewith a first annular fluid passage (516) and having a bore defining a second fluid passage (518), first spacer means extending from the outer periphery of said inner pipe member adjacent one end thereof defining the upper end, said first spacer means including a plurality of pairs of spaced longitudinally extending plates (564) each having an outer longitudinal surface abuttingly engageable with said bore of said outer member, each said plate having a tapered shoulder (572) abuttingly engageable with said conical shoulder for locating and supporting said inner pipe member within said outer pipe member, second spacer means (612) extending from the outer periphery of said inner pipe member adjacent the other end thereof, said second spacer manes comprising a plurality of spaced longitudinally extending plates abuttingly engageable with said bore of said outer pipe member; and

means for resiliently retaining said inner pipe member within said outer pipe member, said retaining means including a generally V-shaped leaf spring (568) disposed between the plates defining said pairs of plates, the upper end (578) of one arm (575) of each leaf spring being pivotally connected to its associated pair of plates about a transverse axis, the lower end (586) of the other arm (576) of each said leaf spring being abuttingly engageable with and longitudinally slidable along said periphery and the apex (577) of each said leaf being spaced outwardly of said periphery, shapted to mate with said recess and being engageable with said recess

(550) when said shoulders are abuttingly engaged for releasably retaining said inner pipe member within said outer pipe member.


24
20
12
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22
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14

FIG. 1

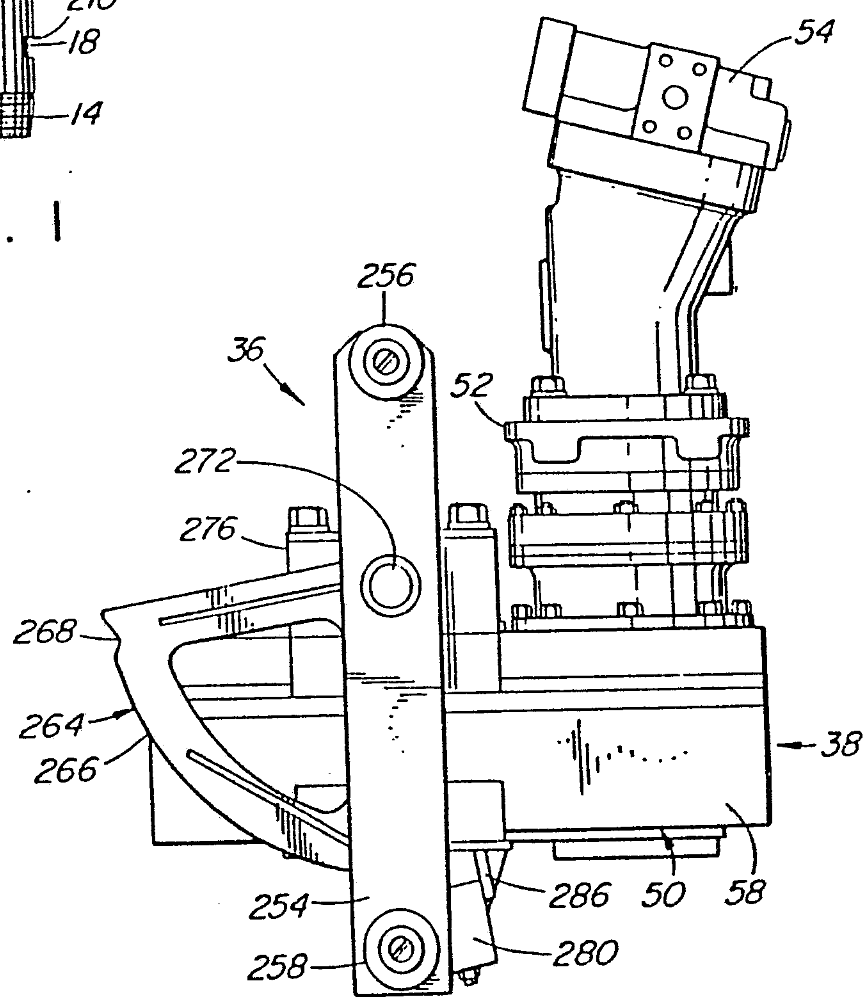
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FIG. 3

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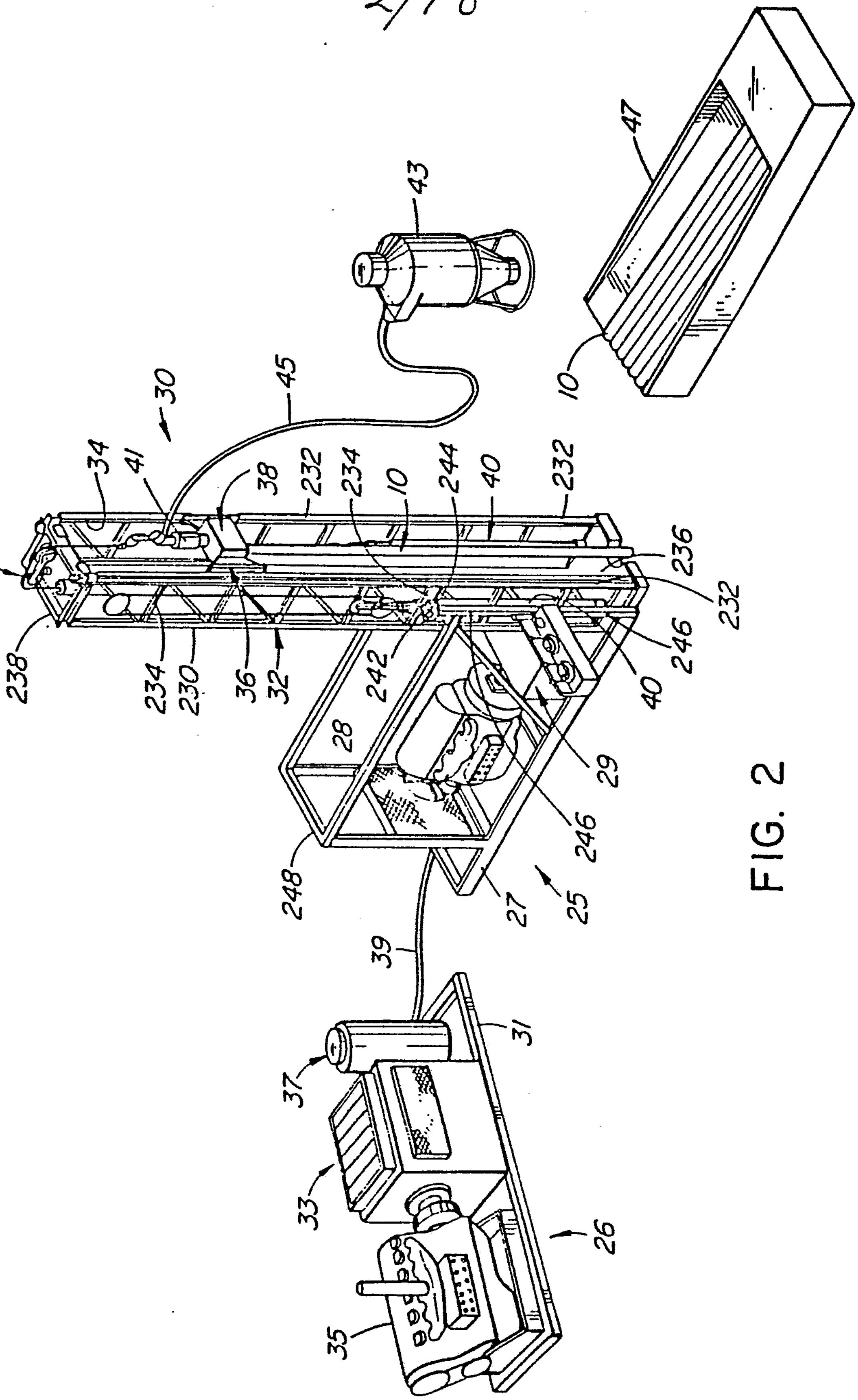
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FIG. 2

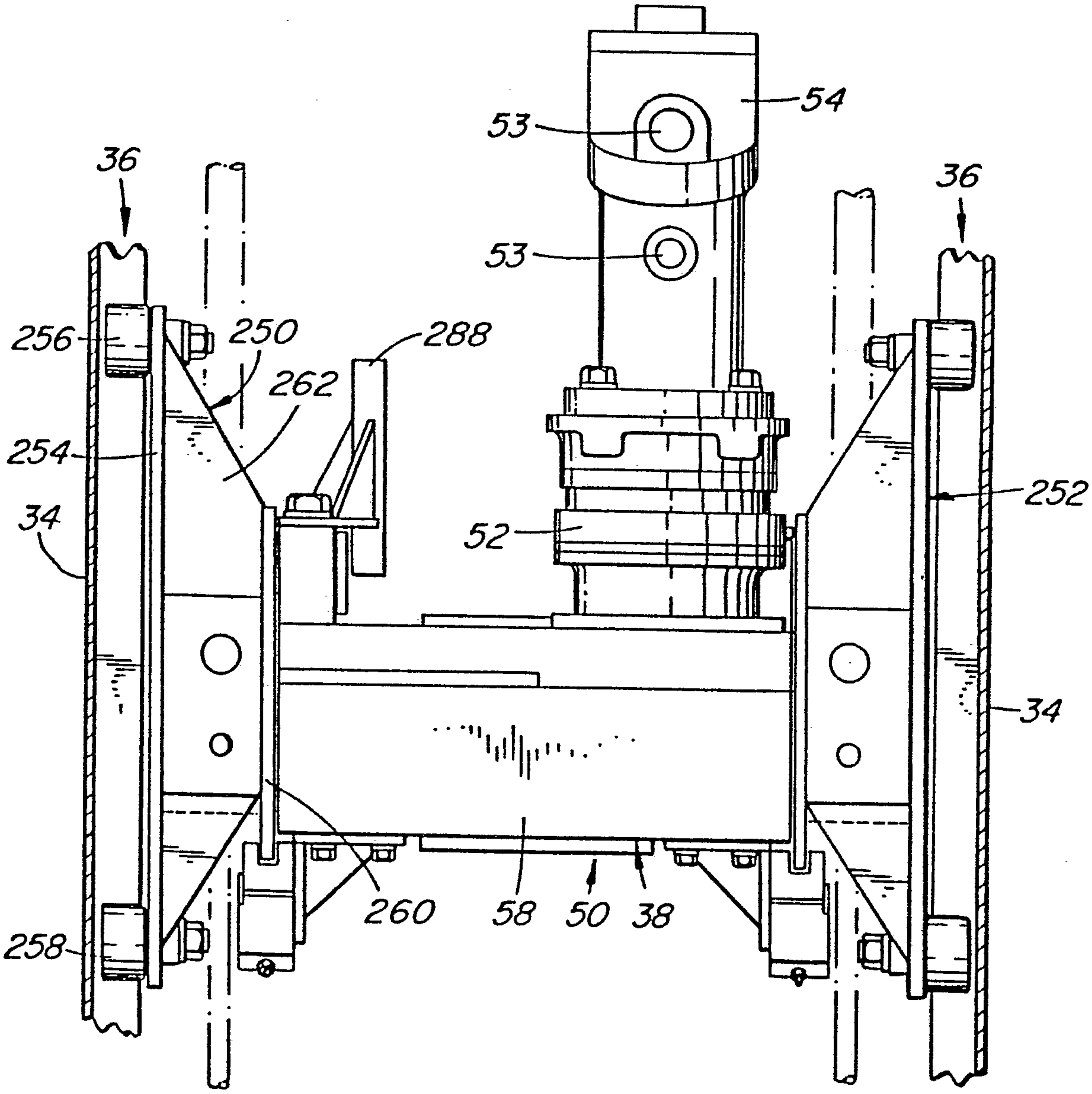

FIG. 4

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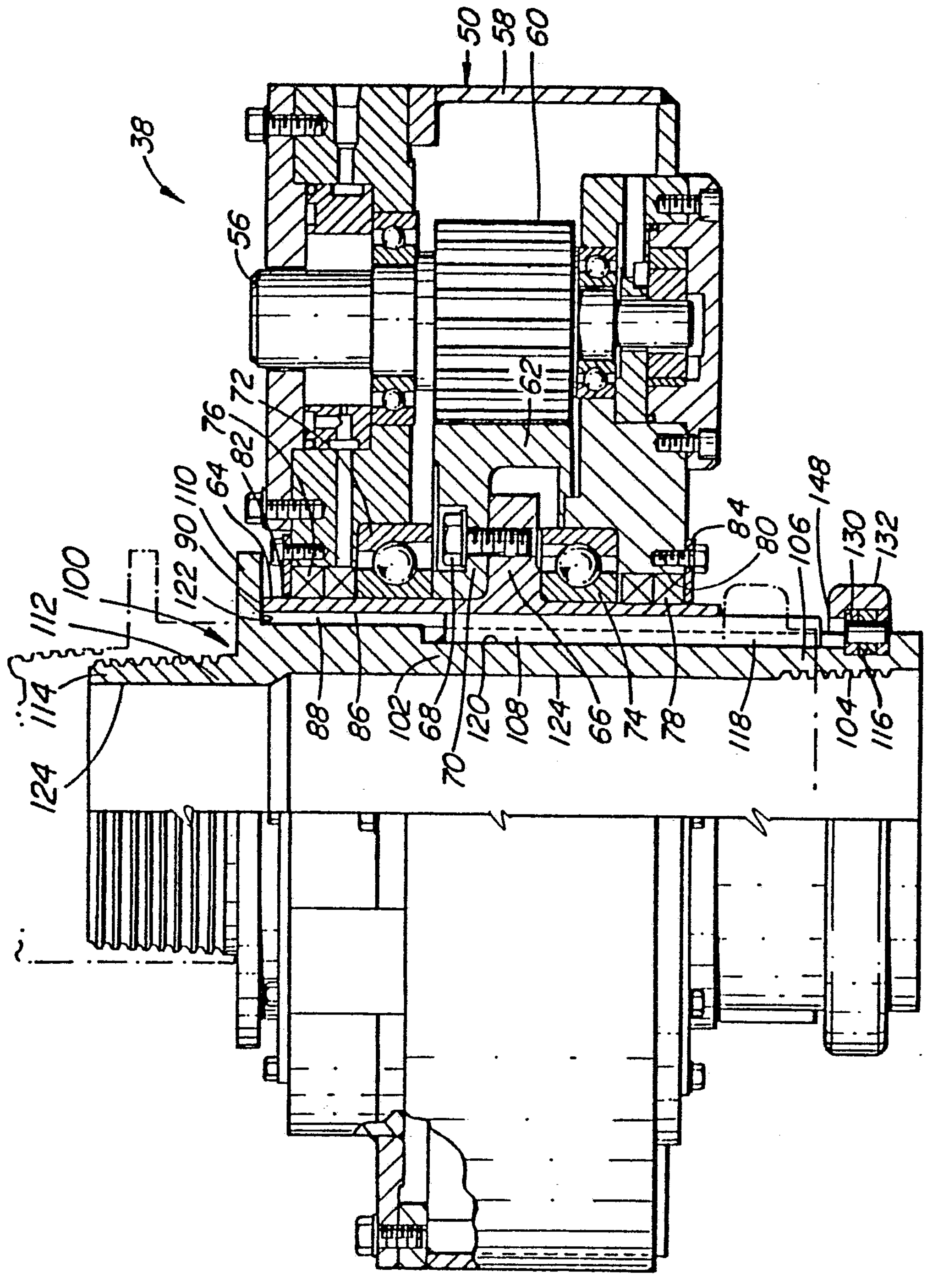

FIG. 5

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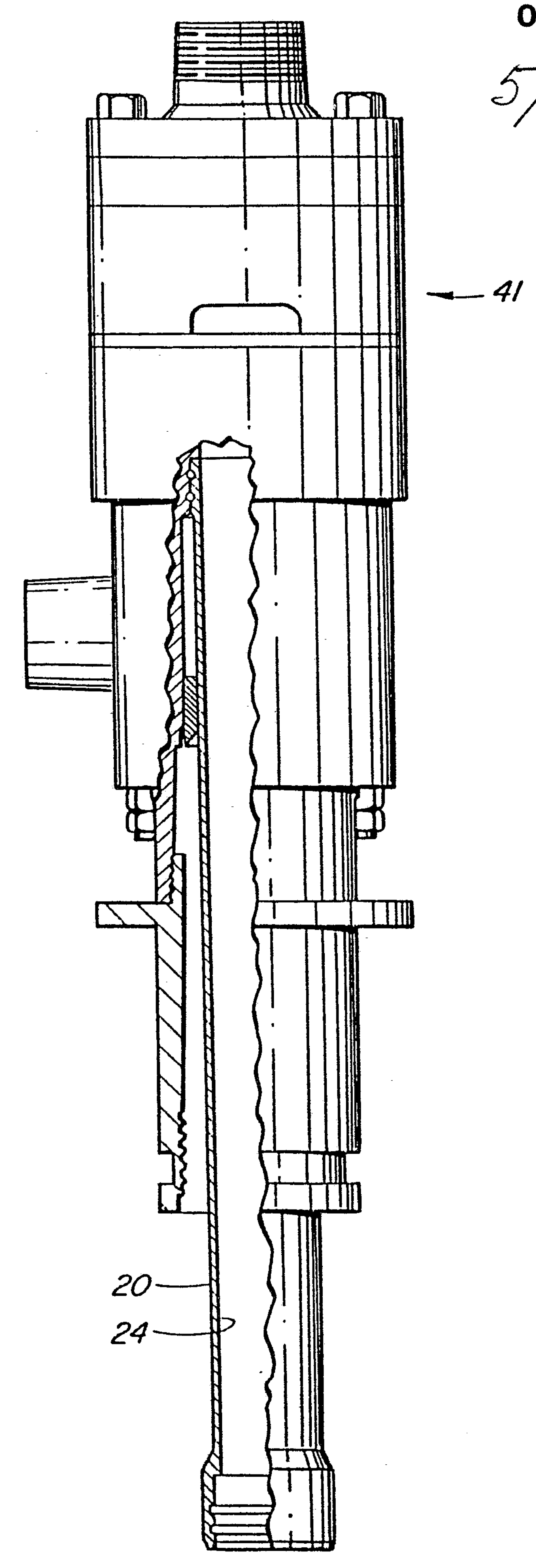

FIG. 5a

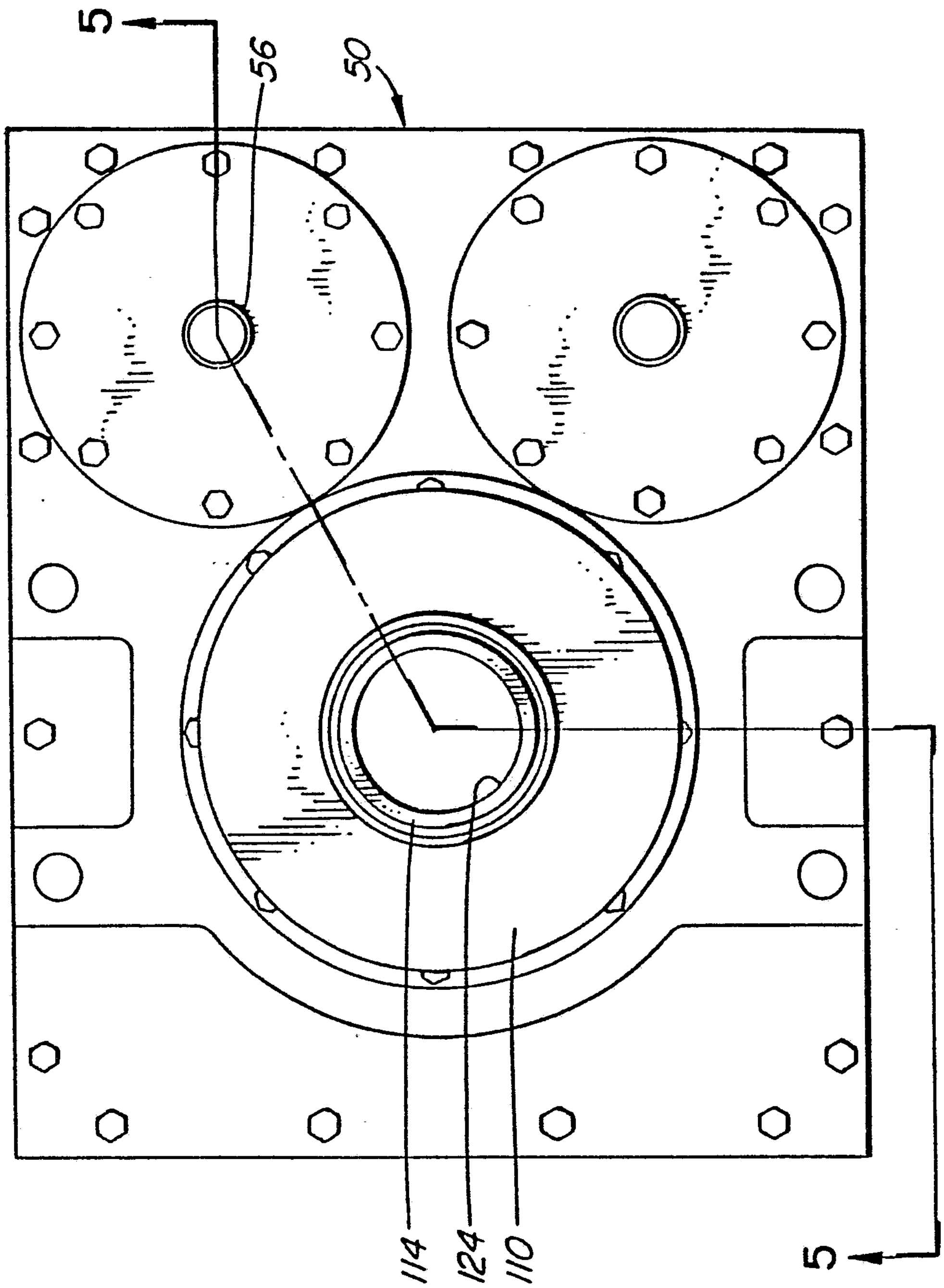

FIG. 6

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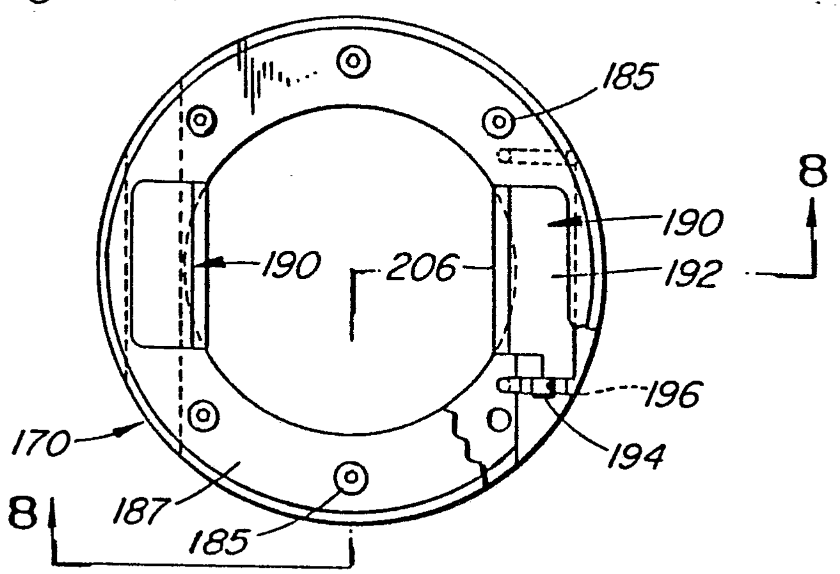

FIG. 7

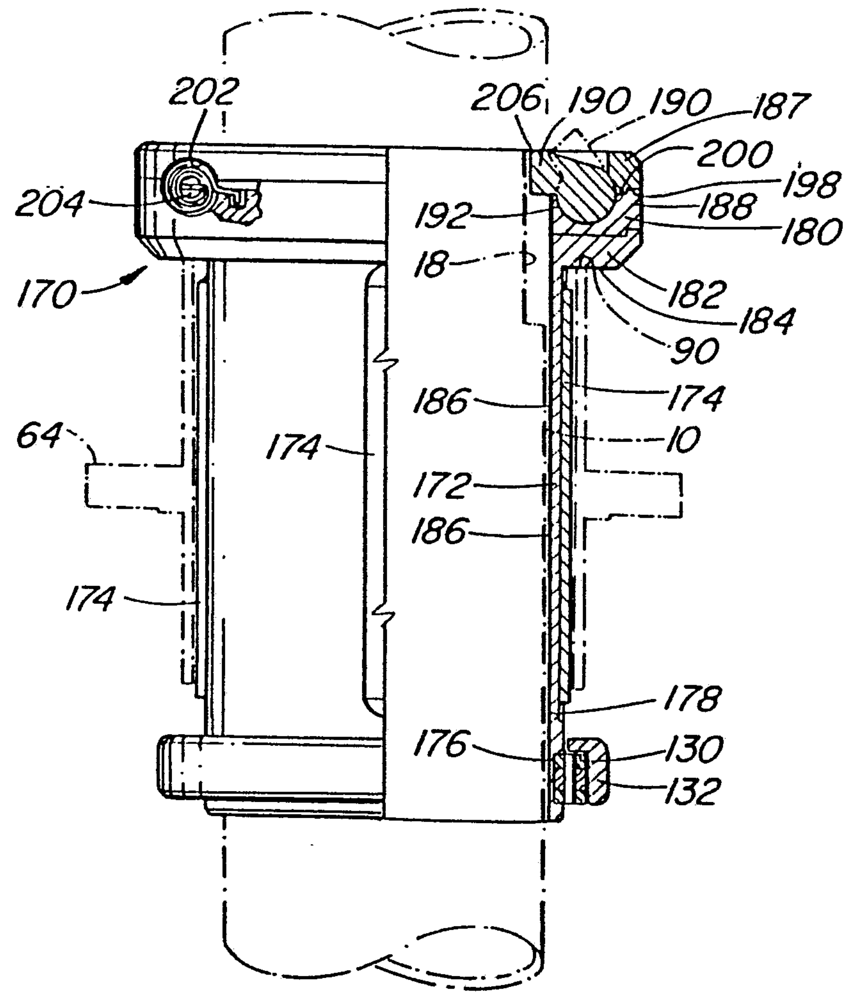

FIG. 8

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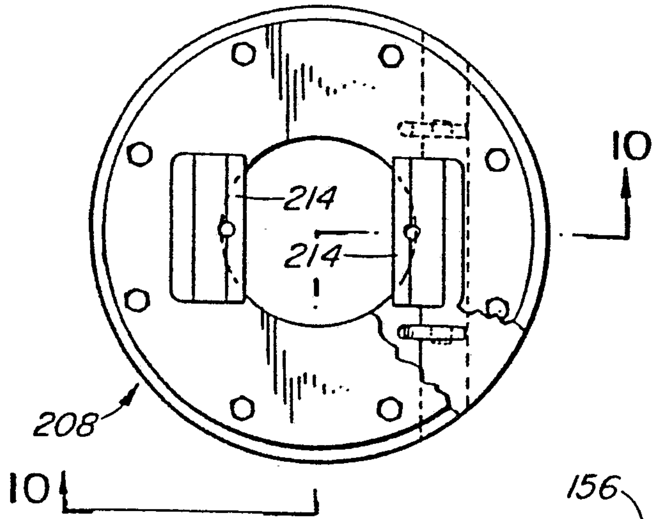

FIG. 9

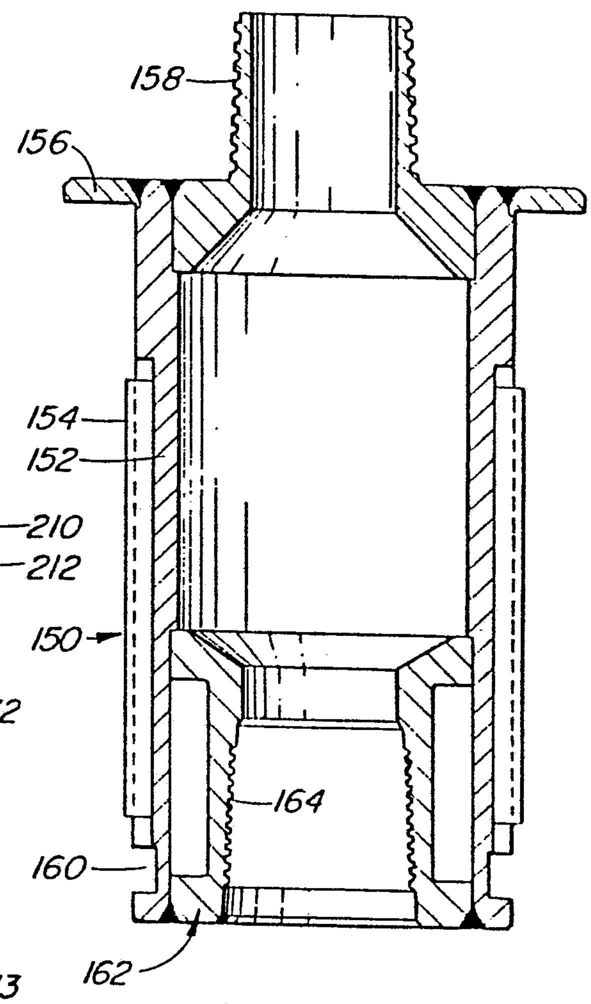

FIG. 11

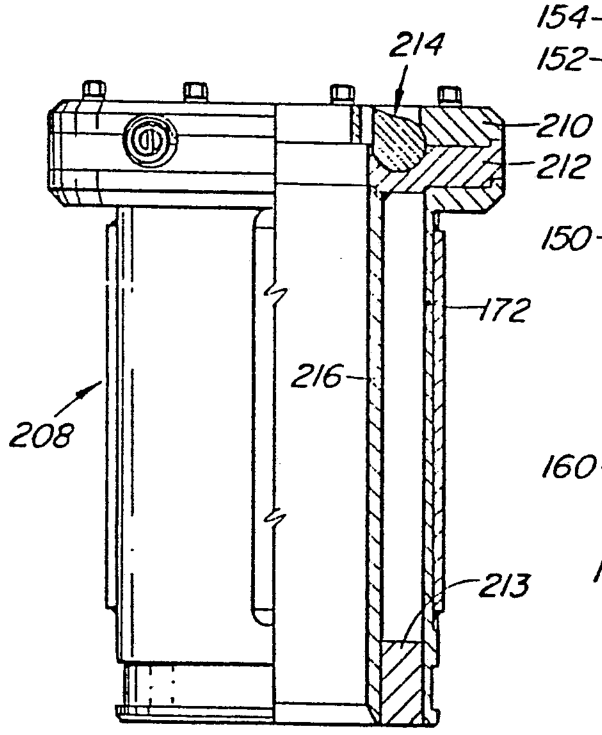

FIG. 10

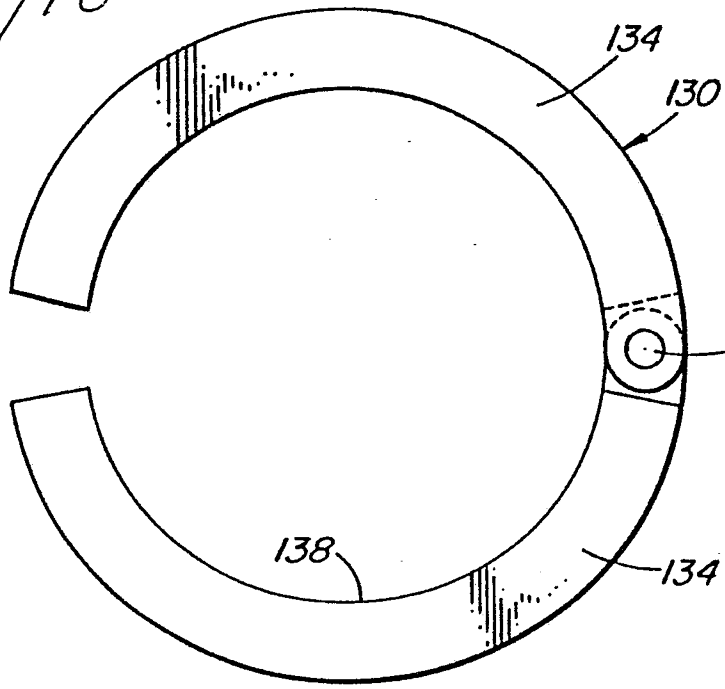

FIG. 12

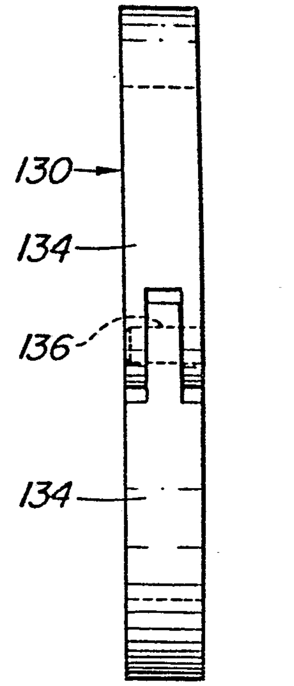

FIG. 13

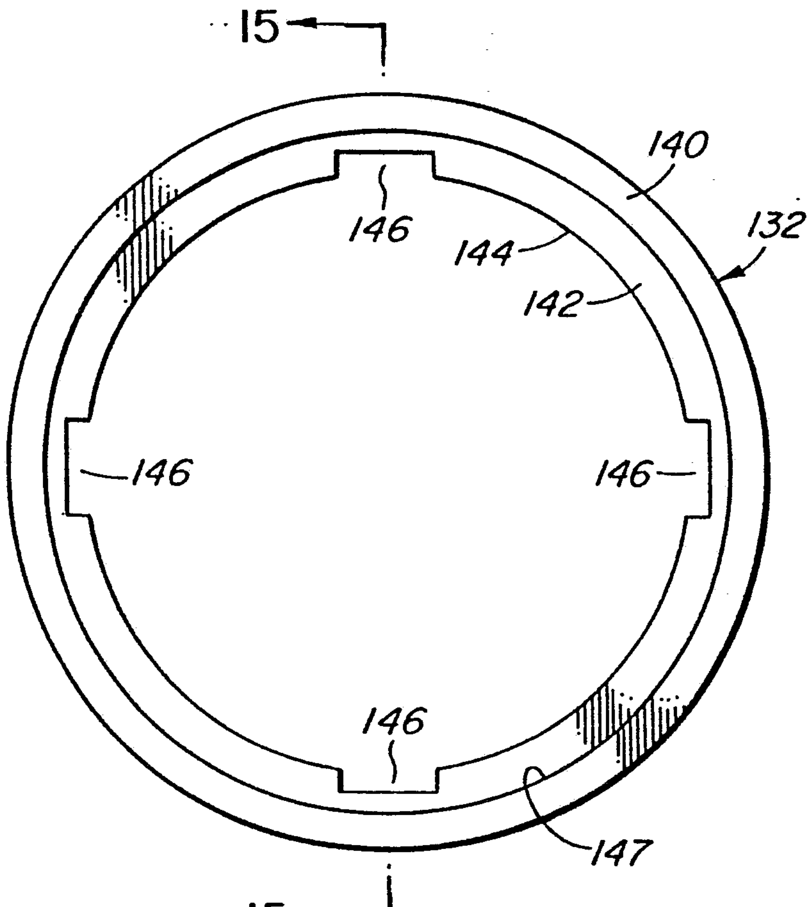

FIG. 14

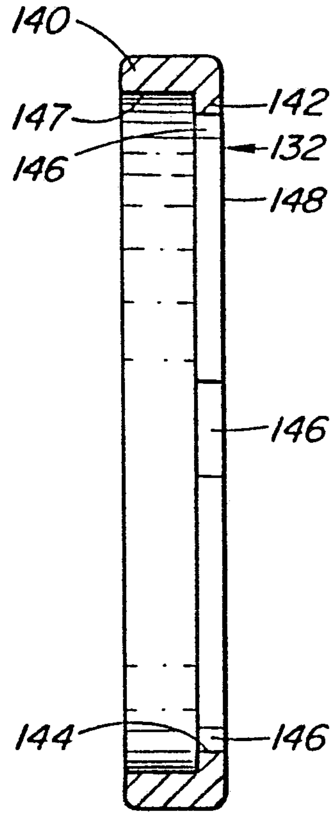

FIG. 15

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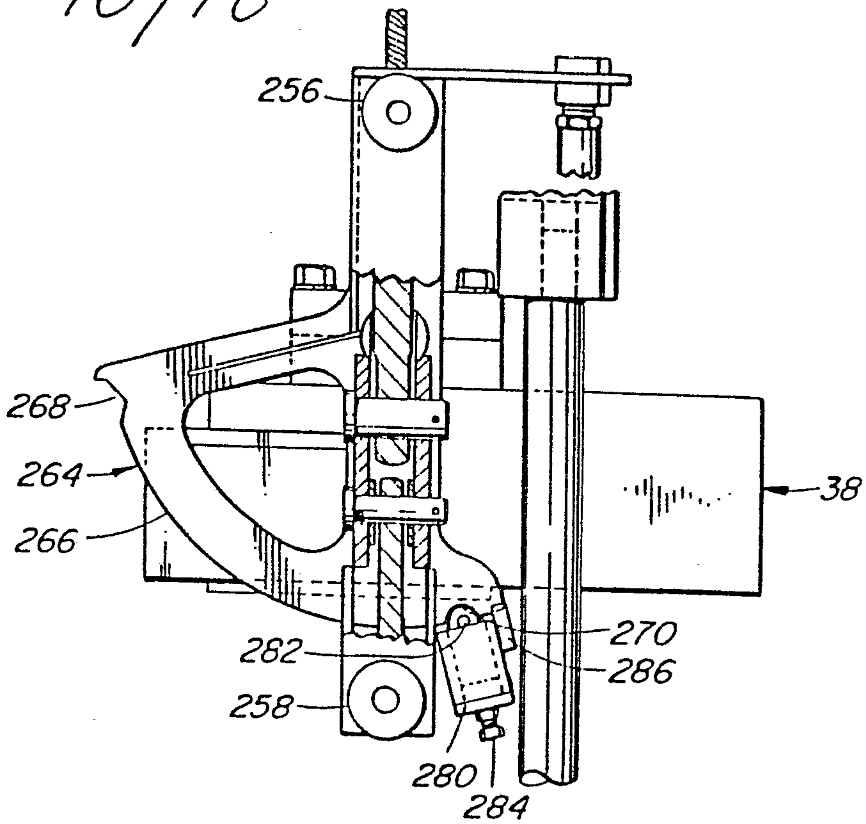

FIG. 16

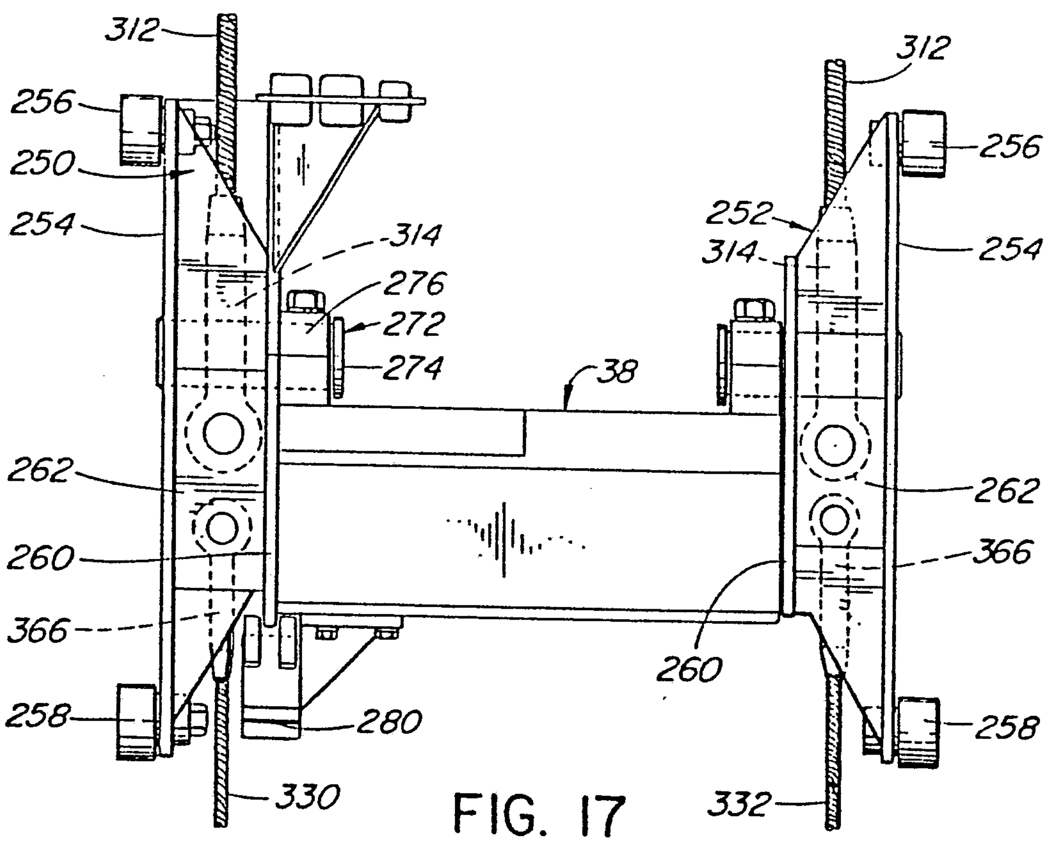

FIG. 17

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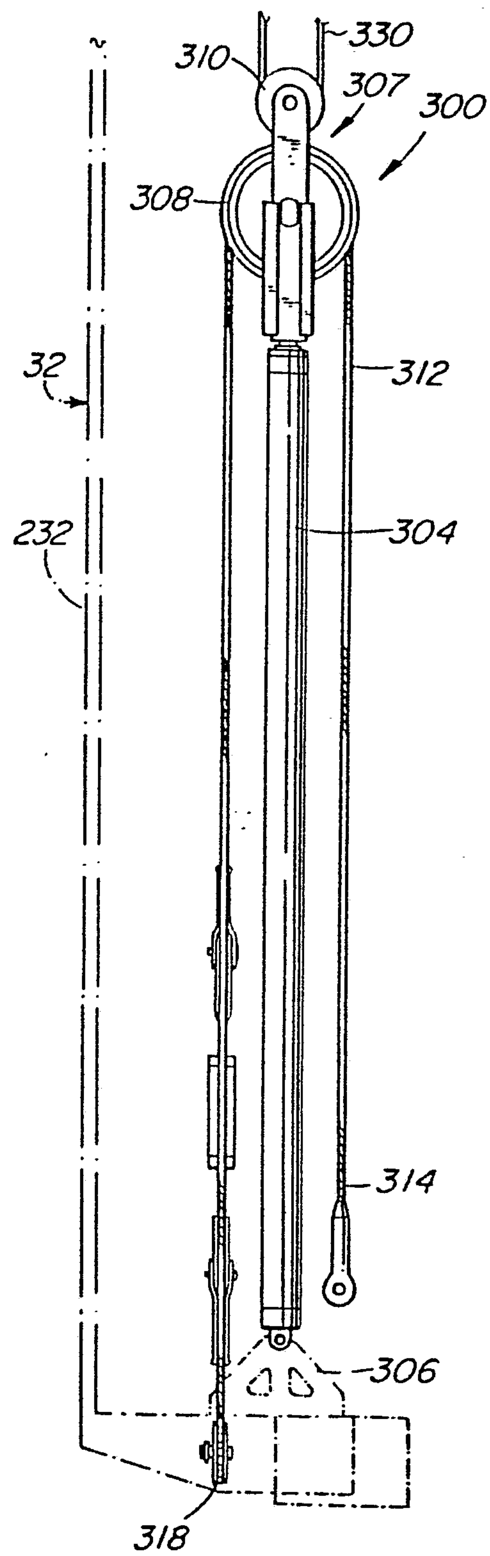

FIG. 18

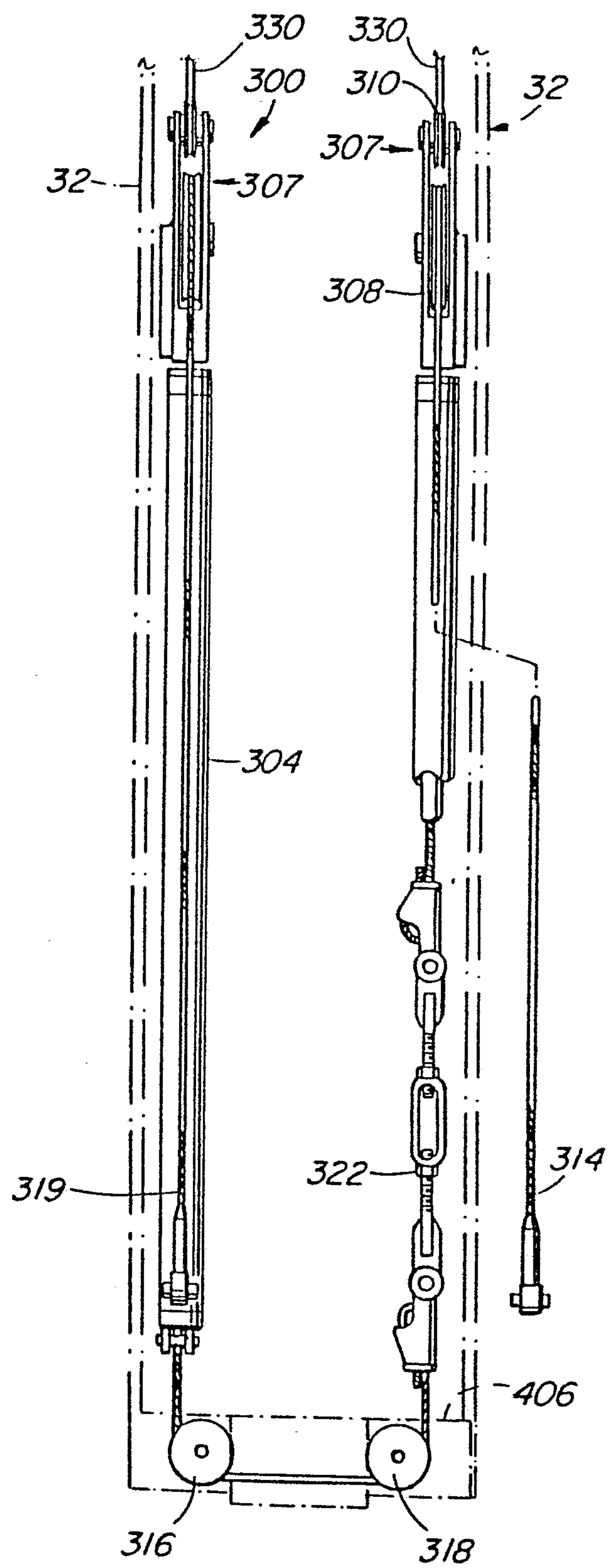

FIG. 19

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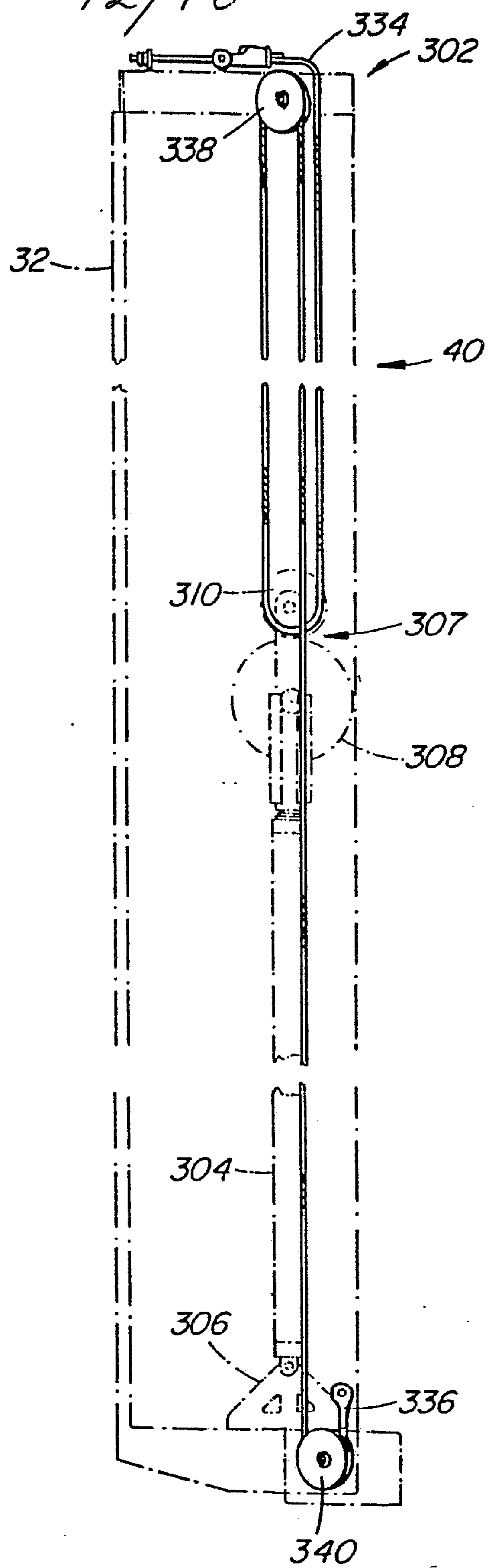

FIG. 20

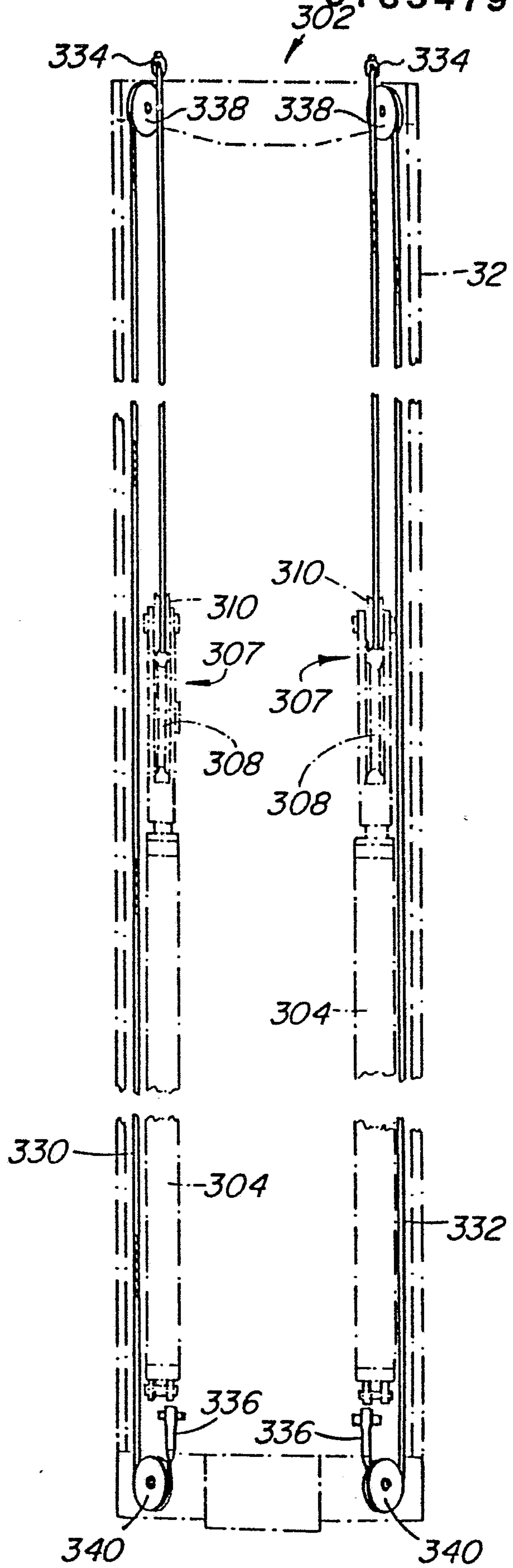

FIG. 21

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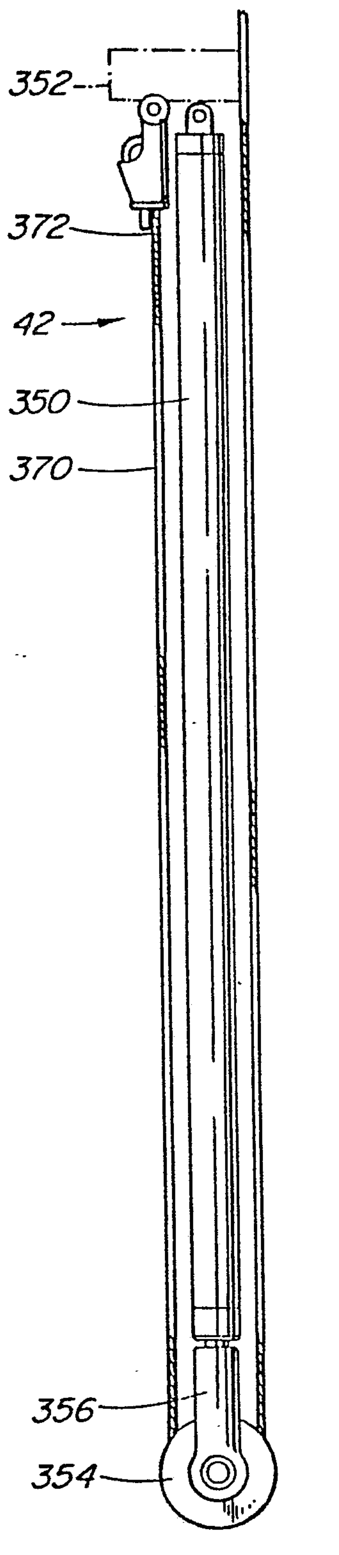

FIG. 22

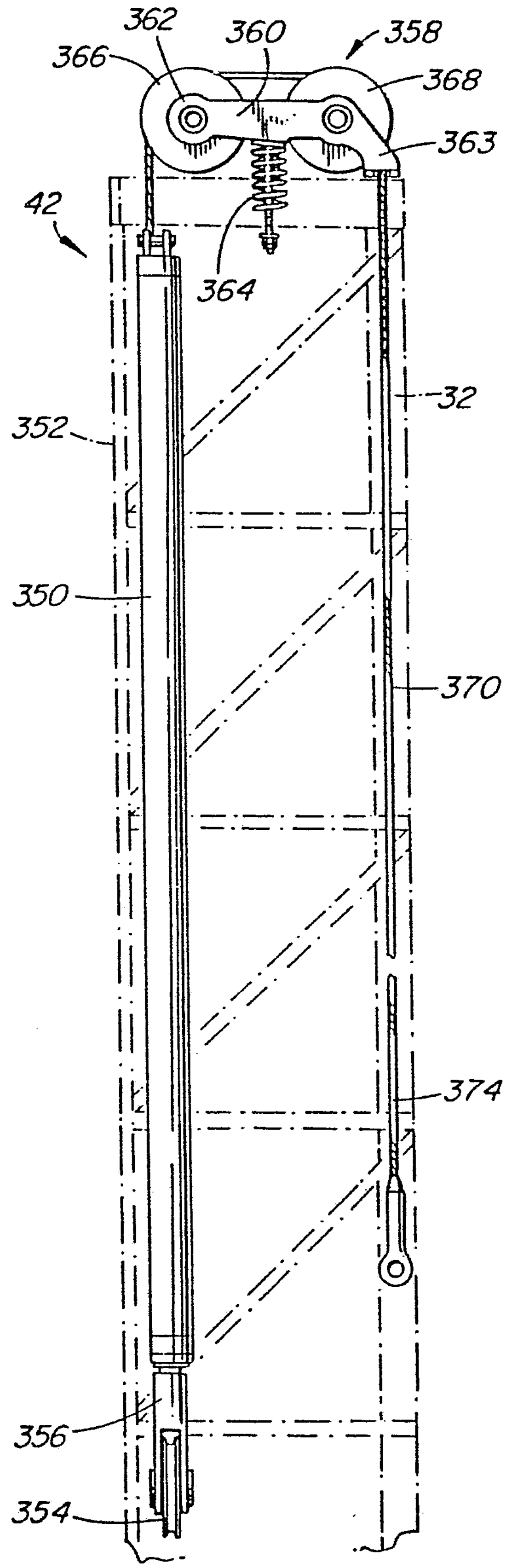

FIG. 23

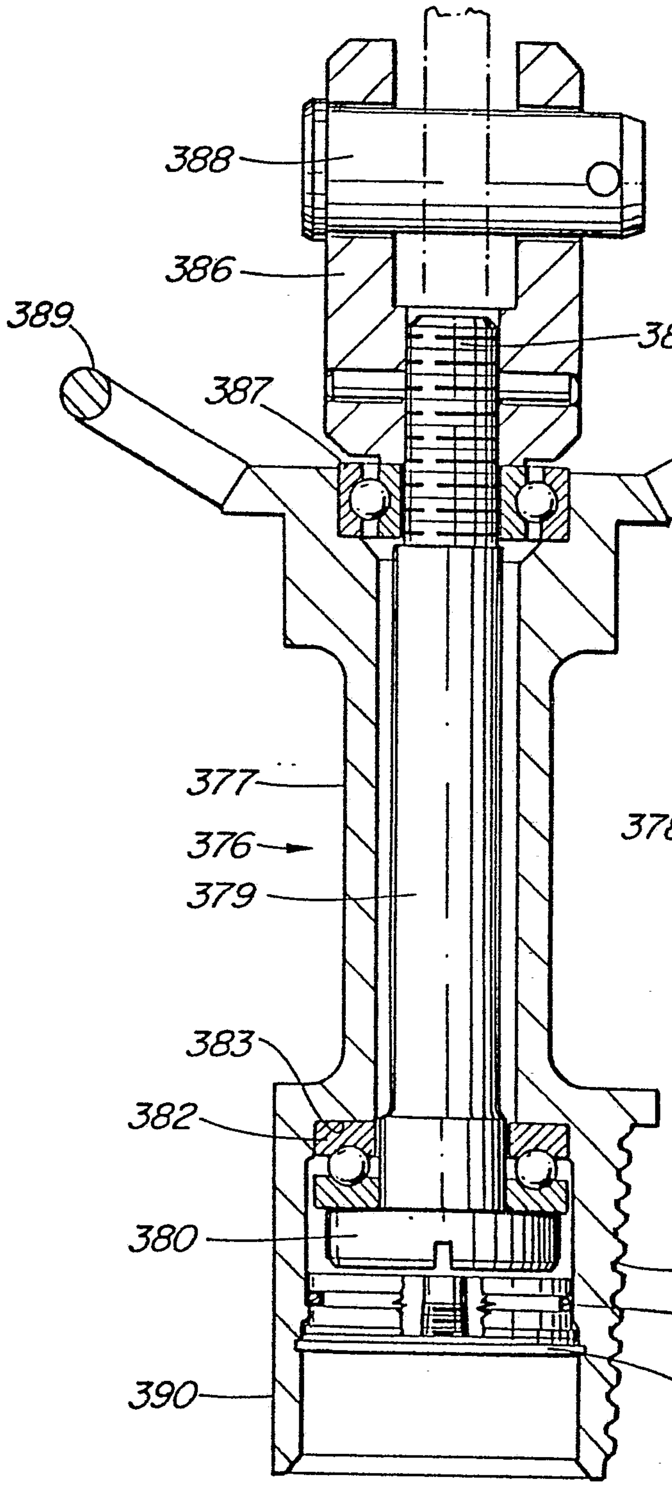

FIG. 24a

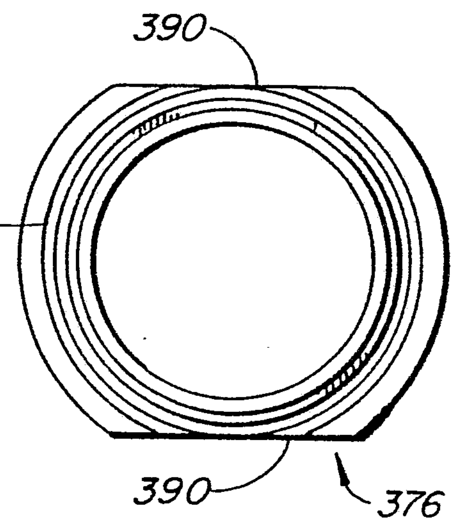

FIG. 24b

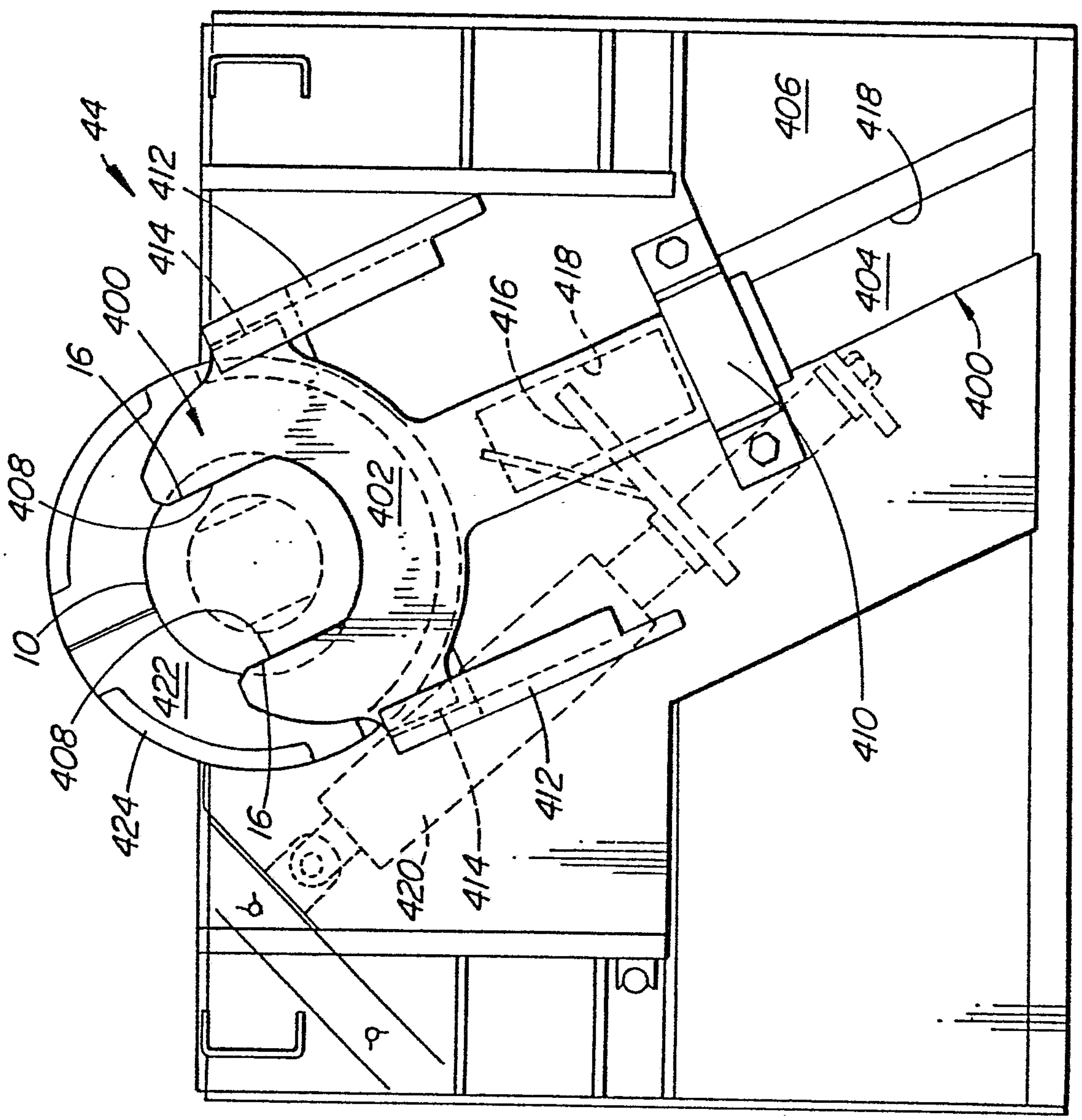
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FIG. 25

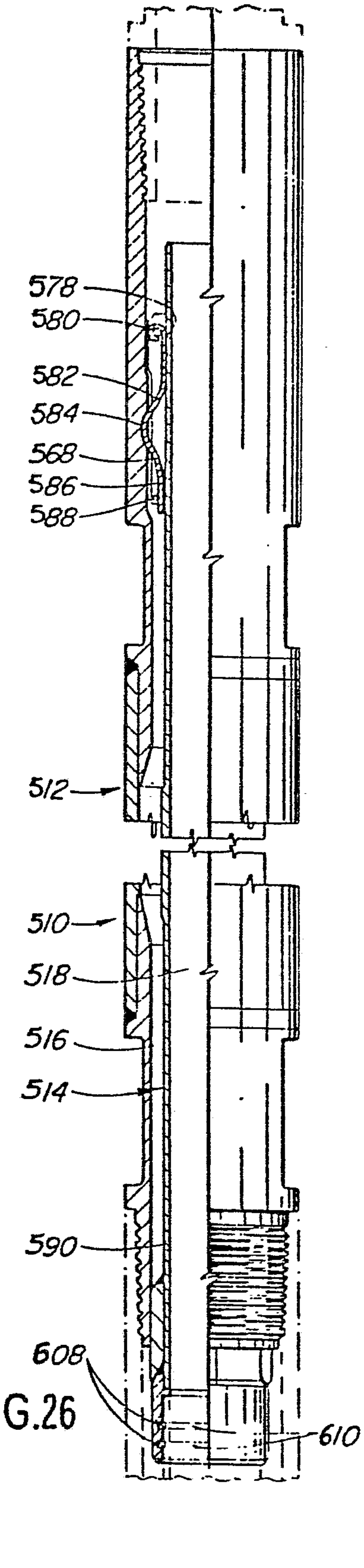
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FIG.26

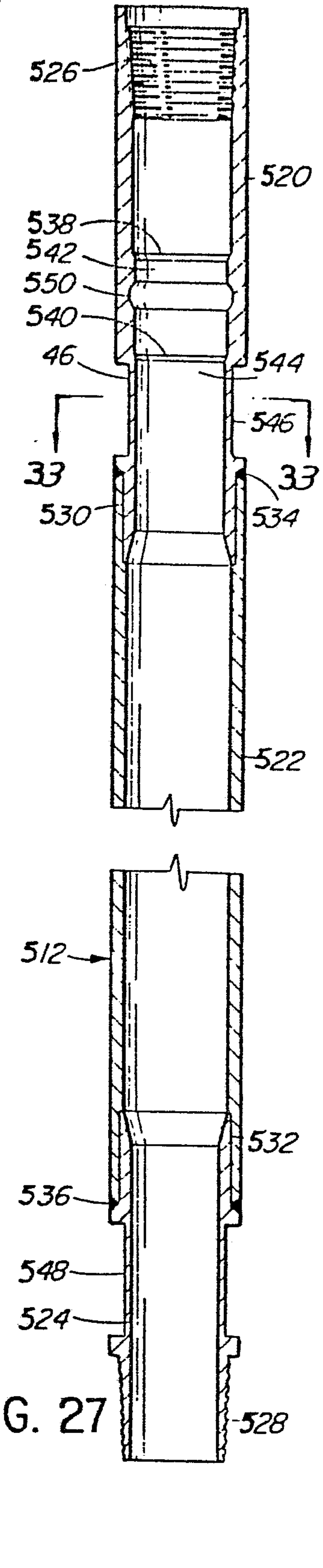
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FIG. 27

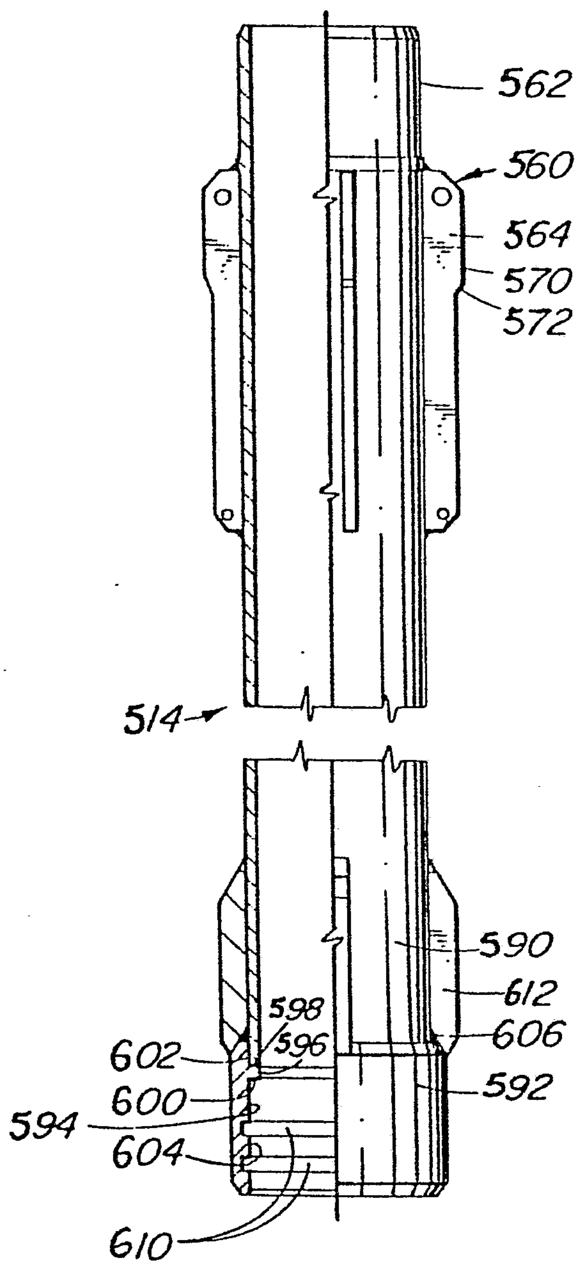

FIG.28

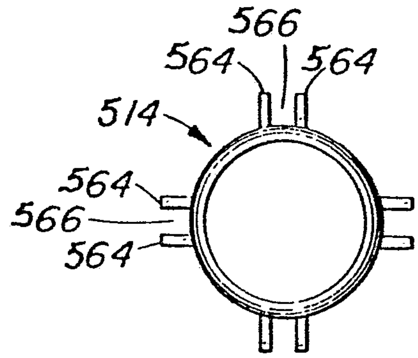

FIG. 29

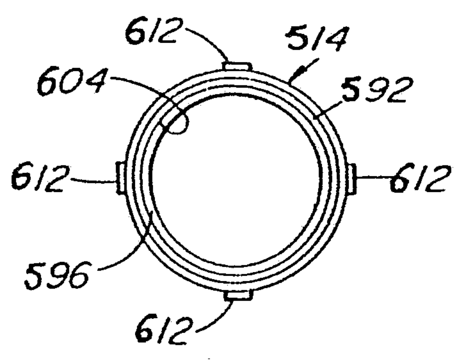

FIG. 30

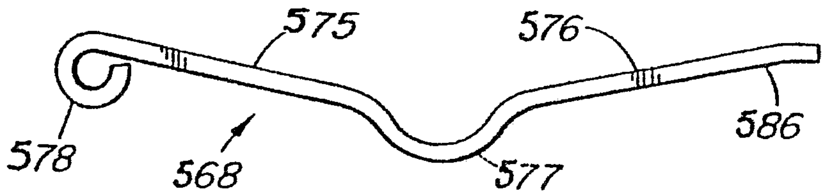

FIG. 31

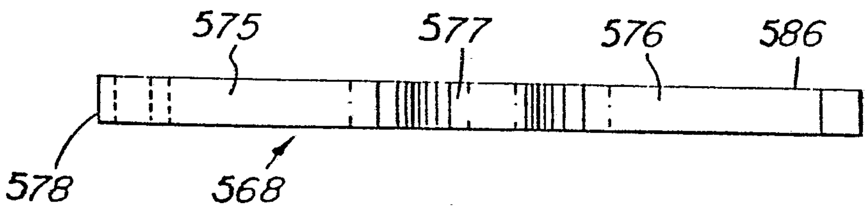

FIG. 32

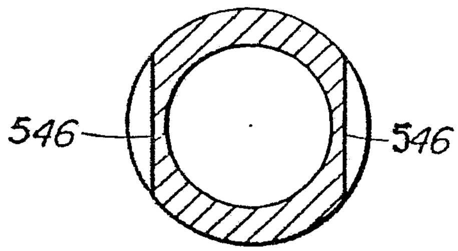

FIG. 33