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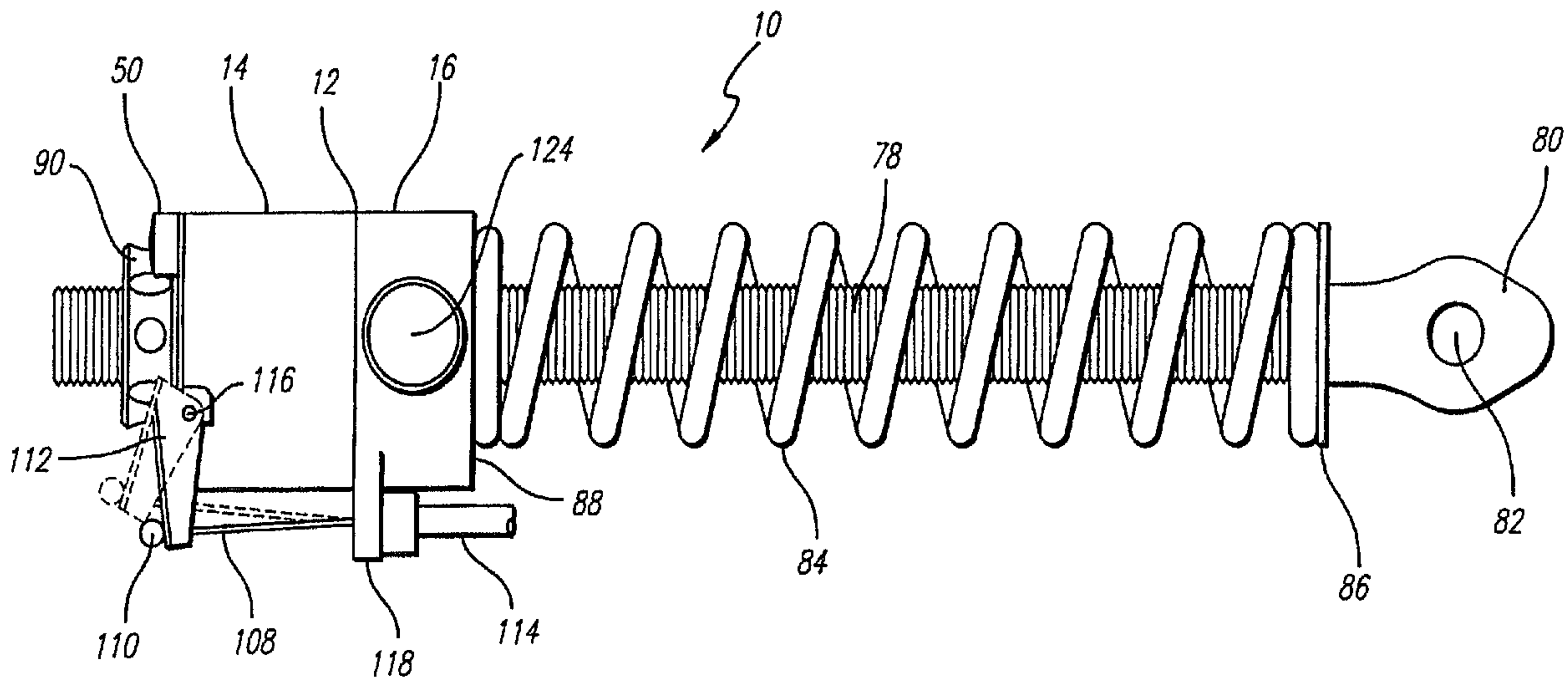

(57) Abrégé/Abstract:
The actuator includes a housing (12) and a gear nut (64) within the housing (12). A leadscrew (78) on which the gear nut (64) is threaded traverses the housing (12). As the leadscrew (78) moves axially, the gear nut (64) rotates. To prevent misalignment between the gear nut (64) and leadscrew (78), the gear nut's outer walls (74 and 76) and bearing surfaces (30 and 46) within the housing (12) permit the gear nut's axis of rotation to pivot in any direction along with any pivoting of the leadscrew (78), while allowing the gear nut (64) to rotate about the leadscrew (78). Therefore, if the leadscrew (78) is not aligned with the housing (12), the leadscrew will pivot the gear nut (64) so that the gear nut (64) remains aligned with the leadscrew (78) and movement of the leadscrew (78) can continue.

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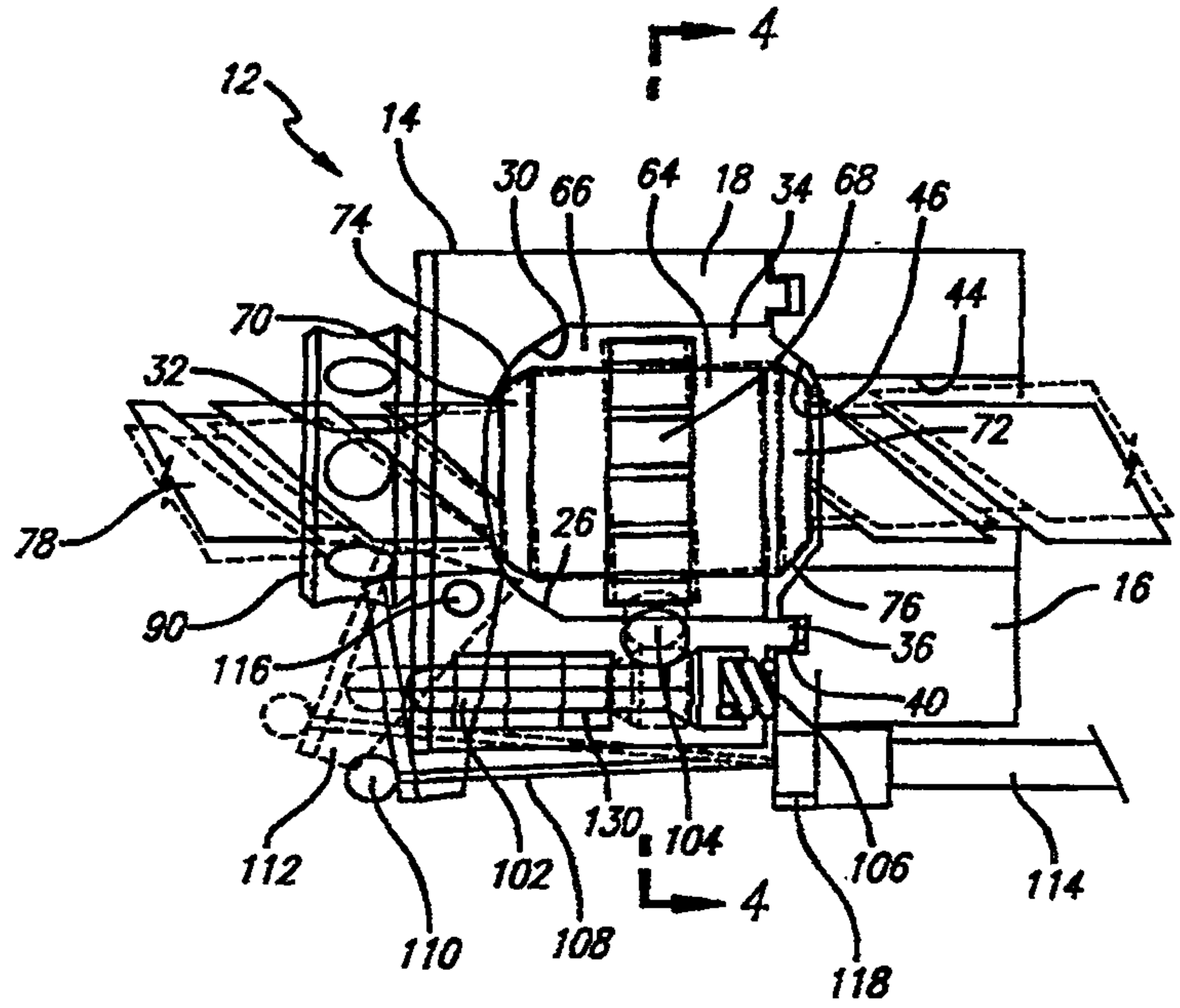
(54) Title: ACTUATOR THAT ADJUSTS TO SIDE LOADS AUTOMATICALLY BY PIVOTING INTERNALLY

(57) Abstract

The actuator includes a housing (12) and a gear nut (64) within the housing (12). A leadscrew (78) on which the gear nut (64) is threaded traverses the housing (12). As the leadscrew (78) moves axially, the gear nut (64) rotates. To prevent misalignment between the gear nut (64) and leadscrew (78), the gear nut's outer walls (74 and 76) and bearing surfaces (30 and 46) within the housing (12) permit the gear nut's axis of rotation to pivot in any direction along with any pivoting of the leadscrew (78), while allowing the gear nut (64) to rotate about the leadscrew (78). Therefore, if the leadscrew (78) is not aligned with the housing (12), the leadscrew will pivot the gear nut (64) so that the gear nut (64) remains aligned with the leadscrew (78) and movement of the leadscrew (78) can continue.



Actuator That Adjusts to Side Loads Automatically by Pivoting Internally

Background of The Invention:

1. *Field of the Invention:* The present invention relates to seat actuators, primarily those used for vehicle seat recliners and possibly seat positioners.

2. *State of the Art:* As safety concerns for automobile and truck passengers increase, vehicle seats have become more complex. Linear actuators for allowing vehicle seats to move and the seat back to pivot are becoming increasingly complicated. One proposed linear actuator uses a leadscrew or threaded shaft. As it moves forward or backward axially due to the seat being reclined, a threaded gear nut or spin nut rotates about the leadscrew. The spin nut has a clutch that disengages the leadscrew when the user manually activates a recline lever. When the user releases the recline lever the clutch engages the shaft and prevents rotation of the spinning nut. That locks the leadscrew from further axial movement. *Griswold*, U.S. Pat. No. 5,320,413 (1994), *Rees* U.S. Pat. No. 4,881,775 (1989), and *Périou* U.S. Pat. No. 4,799,734 (1989), are examples of patents teaching this or similar types of seat actuators.

If a linear actuator is out of alignment, it can malfunction. That is, if the leadscrew is out of alignment (i.e., aligned up, down, to the side or at any angle to the gear nut), the gear nut does not spin freely around the leadscrew. Consequently, the leadscrew does not move freely backward and forward.

It has been proposed to use a gimbal mount for the entire mechanism as a way to overcome misalignment. The gimbal is expensive to manufacture and may require additional threaded fasteners that also are costly to make. Additionally, because of the added parts and the complexity of the gimbal mount, installation costs are high.

SUMMARY OF THE INVENTION:

The present invention discloses and provides a high-load linear actuator that compensates for installation and other misalignments.

The actuator includes a leadscrew that traverses the actuator housing. A gear nut within the housing surrounds and is threaded onto the leadscrew. As the leadscrew moves axially through the housing, the gear nut rotates. A ball, which is manually controlled by the user of the seat, moves in a slot radially to the gear nut. The ball can engage or disengage castellations on the gear nut. When the ball partially projects from the slot, the ball engages a gear nut castellation. The nut does not turn because the slot prevents the ball from rotating with the gear nut. Therefore, the leadscrew cannot move axially and the actuator is locked.

To prevent misalignment between the gear nut and leadscrew, the gear nut can pivot up, down, to the side or at an angle within the housing. Therefore, if the leadscrew is not aligned with the housing, the leadscrew pivots the gear nut so that the gear nut remains aligned with the leadscrew. To accomplish pivoting, the gear nut has spherical ends or inserts with spherical end surfaces, and the housing has inner walls that are spherical. The inserts or spherical radii of the gear nut itself, against the inner walls, therefore, allow gear nut rotation, and they can slide relative to each other so that the gear nut can follow the leadscrew's orientation. The spherical radii, in contact with each other also allow the gear nut to spin.

In accordance with another preferred embodiment, the gear nut includes ends or inserts which have a spherical surface. The gear nut is mounted for rotation on a conical support surface. This arrangement results in a relatively small gear nut/support surface contact area.

The actuator has a two-piece housing. The housing sections can be tightened relative to each other to squeeze against the spherical gear nut or its inserts. This minimizes "chuck," which is undesired movement of the leadscrew while the unit is locked. Alternatively, a housing may be provided with a threaded opening and cap arrangement that performs substantially the same function.

Accordingly, the present invention provides a linear actuator comprising a housing including an open space defined by curved inwardly facing walls, a leadscrew traversing the housing, a gear nut in the housing around the leadscrew and rotating in response to axial movement of the leadscrew relative to the gear nut, the gear nut defining curved outer walls, at least a portion of each of the curved outer walls of the gear nut being in spaced relation to an adjacent curved inwardly facing wall of the housing, the housing mounting the leadscrew for pivoting to change the axis of rotation of the gear nut within the housing.

The present invention also provides a linear actuator comprising:

a) a housing having an open central section, an end wall having a spherical surface over at least part of the end wall, a mounting block at the opposite end of the end wall, the mounting block having a spherical surface over at least part of the mounting block, the spherical surfaces of the end wall and the mounting block facing each other, the end wall and the mounting block each having a central hole opposite each other;

b) a gear nut in the housing extending between the spherical surfaces of the end wall and mounting block, the gear nut having a central opening and curved end surfaces and being located within the housing such that at least a portion of each of the curved end surfaces is in spaced relation to the respective adjacent spherical surface of end wall or mounting block; and

c) a leadscrew traversing the housing and threaded through the gear nut, the gear nut being against the spherical surfaces and rotating about the leadscrew in response to axial movement of the leadscrew through the housing;

d) the gear nut pivoting to change the axis of rotation of the gear nut relative to the housing.

The present invention also provides a linear actuator, comprising:

a housing having an open central section, and end wall having a spherical surface over at least part of the end wall, a mounting block at the opposite end of the end wall, the mounting block having a spherical surface over at least part of the mounting block, the spherical surfaces of the end wall and the mounting block facing each other, the end wall and the mounting block each having a central hole opposite each other;

a gear nut in the housing extending between the spherical surfaces of the end wall and mounting block, the gear nut having a central opening and castellations extending around the gear nut;

a leadscrew traversing the housing and threaded through the gear nut, the gear nut being against the spherical surfaces and rotating about the leadscrew in response to axial movement of the leadscrew through the housing;

a groove in the housing extending toward the castellations;

a ball moveable within the groove between a position partially projecting from the groove and extending into a castellation and a position retracted from a castellation; and

a piston in the housing in contact with the ball, the piston having portions of different diameters, the piston moving in the housing from a position in which the smaller diameter portion is adjacent the ball to allow the ball to retract from a castellation and a wider diameter portion pushing the ball toward the castellation;

wherein the gear nut pivots to change the axis of rotation of the gear nut relative to the housing.

In a further aspect, the present invention provides a linear actuator, comprising:

a housing;

a leadscrew traversing the housing;

a gear nut, located substantially within the housing and around the leadscrew, rotating in response to axial movement of the leadscrew relative to the gear nut, and including first and second longitudinal end portions having curved surfaces which define a gear nut end surface curvature; and

first and second bearing surfaces respectively engaging the first end second longitudinal end surfaces of the gear nut such that the gear nut is capable of pivoting to change the axis of rotation of the gear nut, the bearing surfaces being rotatable and defining a bearing surface curvature which is different than the gear nut end surface curvature.

In a further aspect, the present invention provides a linear actuator, comprising:

a housing;

a leadscrew traversing the housing;

a gear nut, located substantially within the housing and around the leadscrew, rotating in response to axial movement of the leadscrew relative to the gear nut, and including a plurality of circumferentially-spaced castellations and first and second longitudinal end portions defining a gear nut end surface curvature;

first and second bearing surfaces respectively engaging the first end second longitudinal end surfaces of the gear nut such that the gear nut is capable of pivoting to change the axis of rotation of the gear nut, the bearing surfaces defining a bearing surface curvature; and

a locking mechanism including a pivotable lever adapted to move between a locked position wherein the lever engages one of the castellations and an unlocked position, and a biasing device adapted to bias the lever to the locked position.

The present invention also provides a linear actuator, comprising:

a housing;

a leadscrew traversing the housing;

a gear nut, located substantially within the housing and around the leadscrew, rotating in response to axial movement of the leadscrew relative to the gear nut, and including a plurality of circumferentially-spaced castellations;

first and second bearing surfaces respectively engaging the first and second longitudinal end surfaces of the gear nut; and

a locking assembly including a pivotable lever adapted to move between a locked position wherein the lever engages one of the castellations and an unlocked position, a biasing device adapted to bias the lever to the locked position, a first actuator operably connected to the lever and adapted to move the lever to the unlocked position when at least a portion of the first actuator is moved in a first direction, and a second actuator operably connected to the lever and adapted to move the lever to the unlocked position when at least a portion of the second actuator is moved in a second direction, the second direction being different than the first direction.

In a further aspect, the present invention provides a linear actuator, comprising:

a housing including an open space defined by curved inwardly facing walls;

a leadscrew traversing the housing; and

a gear nut in the housing around the leadscrew and rotating in response to axial movement of the leadscrew relative to the gear nut, the gear nut defining curved outer walls which rotate relative to the respective curved inwardly facing walls of the housing;

wherein the gear nut pivots to change the axis of rotation of the gear nut relative to the housing.

In a further aspect, the present invention also provides a linear actuator, comprising:

a housing including a first portion having a curved inwardly facing wall and a second portion having a curved inwardly facing wall, the first and second housing portions defining separate structural elements;

a leadscrew traversing the housing;

a gear nut in the housing around the leadscrew and rotating in response to axial movement of the leadscrew relative to the gear nut, the gear nut defining curved outer walls, at least a portion of each of the curved outer walls of the gear nut being in spaced relation to an adjacent curved inwardly facing wall of the housing; and

an adjustment mechanism associated with the first and second housing portions for selectively adjusting the distance therebetween;

wherein the gear nut pivots to change the axis of rotation of the gear nut relative to the housing.

The invention may be understood more clearly from the detailed description of the preferred embodiment that follows.

Brief Description of the Drawings:

Fig. 1 is a side view of a linear actuator in accordance with one embodiment of the present invention.

Fig. 2 is an end view of the linear actuator shown in Fig. 1 as seen from the left side of Fig. 1 with the stop ring removed to reveal certain aspects of the actuator.

Fig. 3 is a side, sectional view of a portion of the linear actuator shown in Fig. 1.

Fig. 4 is a sectional view through plane 4 – 4 of Fig. 3.

Fig. 5 is a top, partial sectional view of a linear actuator in accordance with another embodiment of the present invention.

Fig. 6 is an end view of the gear nut shown in Fig. 5.

Fig. 7 is a side, partial sectional view of the linear actuator shown in Fig. 5.

Fig. 8 is a side, partial sectional view of the gear nut and bearing assemblies shown in Fig. 5.

Fig. 9 is a side, partial sectional view of a linear actuator in accordance with another embodiment of the present invention.

Fig. 10 is a partial side view of an exemplary locking assembly.

Fig. 11 is a partial side view of another exemplary locking assembly.

Fig. 12 is a side view of the spindle and lever shown in Fig. 11

FIGS. 13 and 14 are side views of still another exemplary locking assembly.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS:

The linear actuator **10** of the present invention includes a housing **12** (FIGS. 1 and 3). In the exemplary embodiment, the housing is formed of plastic, but it may also be formed of die cast metal or of some metal and some plastic sections.

Housing **12** has two major sections, a plastic main section **14** and a metal mounting block **16** (FIGS. 1 and 3). Upstanding wall **18** and end wall **26** form main section **14**. The end wall's inner surface **30** is spherical. Upstanding wall **18** forms a cylinder at the open end **34** of the main housing (FIGS. 3 and 4), which curves into the spherical end **30** (FIG. 3). End wall **26** also has a tapered hole **32** extending through it (FIG. 3).

As FIG. 3 shows, upstanding wall **18** has a circumferential projection **36**. When mounting block **16** is mounted over the open end **34** of main housing **12**, projection **36** projects into a corresponding circumferential groove or trepan **40** on the mounting block (FIG. 3). An arrangement other than circumferential projections and grooves can be used to mount the housing and the mounting block together. For example, short pegs may fit into indentations. Small springs (not shown) could mount in a groove or indentation to bias the housing and mounting block apart.

The mounting block also has a spherical inner surface **46** (FIG. 3) and a central tapered hole or bore **44**. Surfaces **30** and **46** are approximately the same or are part of the same sphere. That is, the surfaces in theory have a common center and nearly, if not, equal radii.

Four bolts **48**, **50**, **52** and **54** (FIG. 2) extend through bores **56**, **58**, **60** and **62** (FIG. 4) in the mounting block. The bolts thread into threaded bores (not shown) in the end of the mounting block. Rivets, self-tapping screws and similar fasteners could replace the bolts and threaded bores. Also, the exemplary embodiment uses four bolts, but more or fewer could be used.

Gear nut **64** (FIGS. 3 and 4) fits within space **66** inside the open end **34** of main housing **14** and extends between the main housing's spherical wall **30** and the spherical wall **46** of mounting block **16**. The gear nut is generally cylindrical (FIG. 3) with a larger diameter central ring **68**. Optional nylon or other low friction annular inserts **70** and **72** attach to the end of the gear nut. The inserts are open in their centers and have spherical end surfaces **74** and **76** (FIG. 3). These spherical surfaces conform to spherical walls **30** and **46** of the main housing and mounting block in that all surfaces have nearly the same center and radius. Accordingly, the gear nut can pivot with the longitudinal axis of the leadscrew in any direction within space **66**. All spherical walls **30**, **46**, **70** and **72** should be smooth to reduce friction.

Using plastic or partially plastic inserts or bearings decreases the cost of the gear nut. Alternatively, the gear nut could be a powdered metal part, metal injection molding or machined to have spherical ends.

A shaft or leadscrew transverses the housing. In the exemplary embodiment (FIGS. 1 and 3), leadscrew **78** has an ACME thread. One choice for the leadscrew is ⅝ in (16 mm [metric conversions are rounded and approximate]) diameter with a 4 threads per inch pitch and four starts. Only FIG. 3 shows the threads of the leadscrew, and they are not drawn to scale. The design of the seat that incorporates the actuator of the present invention determines the leadscrew's length. One end of the leadscrew is flattened to form a tang **80** (FIG. 1). A center opening **82** in the tang allows that end of the actuator to be attached to part of the seat assembly.

As FIG. 1 shows, a return spring **84**, which surrounds the leadscrew, extends between washer **86** and wall **88** of mounting block **16**. Other arrangements that do not use the washer may be used. The spring is in compression to bias the leadscrew to the right in FIG. 1. Stop ring **90** is crimped on the left end (FIGS. 1 and 3) of the leadscrew to prevent the leadscrew from being withdrawn from the housing. One can employ alternate methods, such as a formed end on the leadscrew after it is installed, to accomplish the same goal without the stop ring.

Gear nut **64** is open at **92** at its center. See FIG. 4. The gear nut also has internal threads that correspond with the leadscrew's threads. Also, inserts **74** and **76** have openings that are aligned with the gear nut's opening so that the leadscrew passes freely through the inserts.

As the leadscrew moves axially (because of a force on tang **80**), the gear nut rotates within space **66** (FIG. 3). The gear nut's ring 68 has circumferentially spaced castellations **94** (FIG. 4), sixteen in the exemplary embodiment. A ball **98** in housing groove **100** can move into a castellation. When that occurs, the gear nut cannot rotate. FIG. 4 shows the ball in the locked position. A piston **102** (FIGS. 3 and 4) which is mounted in the housing, has a section with a larger diameter **104** that can be positioned below ball **98**. FIG. 4 shows that part of the piston passes through part of groove **100**.

Spring **106** biases the piston to the left (FIG. 3). A wire **108** attaches to bracket **112** on the left end of housing **12** (FIGS. 1 and 3). The bracket pivots on pin or projection **116** on the housing and rests against piston **102**. The bracket has a slot **120** (FIG. 2) that receives wire **108**. A stop **110** on the end of the wire secures the wire to the bracket. When one manipulates an actuator such as a handle or button (not shown), the actuator pulls the wire **108** to the right (FIGS. 1 and 3). As a result, bracket **112** pushes piston **102** to the right (FIG. 3) and causes a narrower diameter section **130** of the piston to move under ball **98**. Consequently, the ball moves out of its castellation and gear nut **64** freely rotates. Therefore, leadscrew **78** can move axially. Upon release of the handle, spring bias pushes piston **102** to the left (FIG. 3) and returns bracket to its left-most position. When the piston moves to the left, its raised portion **104** pushes ball **98** into a castellation. As Fig. 4 shows, ball **98** remains partially within groove **100**. Therefore, the ball cannot rotate with the gear. Therefore, when the ball is in a castellation, the ball/groove connection prevents gear nut rotation. This locks the leadscrew.

One could substitute a pivoting or rocking member with a appropriate end in place of ball **98**. Also, slots or grooves could substitute for the rounded castellations **94**. One could also use various clutch mechanisms to secure and release the leadscrew. Applicant refers to United States Patent No. 5,778,733 issued July 14, 1998 and assigned to P.L. Porter Co., the assignee of the present application for additional discussions about alternative spinning nut structures.

The wire **108** leads to cable **114**, which is attached to bracket **118** (having apertures **119a** and **119b**) on part of the bottom of the mounting block **16** (FIGS. 1, 3 and 4). The other end of the wire attaches remotely to an actuator accessible to the user of the seat. Bracket **118** could house a second cable with a second wire **109** to a second actuator. See FIG. 2 which shows 2 stops **110** and **111** on the end of the wires. For example, one handle could be within reach of the person sitting in the seat, and the second handle could be within reach of a rear seat passenger or person entering a car who needs to pivot the seat back to enter the rear seat area.

A pair of bosses **122** and **124** are a part of and project from the sides of mounting block **16** (FIGS. 1, 2 and 4). For strength, the bosses preferably are metal. Each may have a 120° conical indentation **126** (FIG. 2). Mounting hardware on the vehicle seat (not shown) accepts and restrains the bosses so that the bosses can pivot while constrained by the hardware. This allows the actuator to pivot about an axis through the bosses.

If the leadscrew **78** is not properly aligned with gear nut **64**, the leadscrew would tend to bind as it moved through the gear nut. See FIG. 3, which shows the leadscrew in orientations relative to the housing. In the present invention, any leadscrew misalignment pivots the gear nut with the leadscrew (See FIG. 3) as the spherical surfaces **74** and **76** of inserts **70** and **72** slide along and spin against the spherical inner walls **30** and **46**. Therefore, the leadscrew and gear nut remain aligned and do not bind.

The spherical surfaces **74** and **76** of inserts **70** and **72** must apply proper force to spherical inner walls **30** and **46**. This is accomplished by tightening bolts **48**, **50**, **52** and **54** or other comparable fasteners properly. Proper tightening minimizes "chuck," the undesired movement of the leadscrew or gear nut relative to the rest of the locked assembly.

Other exemplary embodiments of the present invention are illustrated in FIGS. 5-14. In the exemplary embodiment shown in FIGS. 5-8, which is generally represented by reference numeral **132**, a gear nut **134** is located within a housing **136** that includes a main section **138** and a threaded end cap **140**. The end cap threads mate with corresponding threads on the inner surface of the main section (threads not shown). The gear nut **134** has internal threads which engage a leadscrew **135** (see FIG. 8 - threads not shown) in the manner described above. The interior of the housing **136** includes a pair of bearing assemblies **142** and **144** which support the gear nut **134**.

Referring more specifically to FIG. 8, the longitudinal end surfaces **146** and **148** of the gear nut **134** have a curved shape, as do the respective interior surfaces of the bearing assemblies **142** and **144**. As noted above, the curved end surfaces **146** and **148** of the gear nut **134** may be formed through molding, machining or by adding inserts **147** and **149** (as shown) with the appropriate curvature. In the embodiment illustrated in FIGS. 5-8, the interior surfaces of the bearing assemblies **142** and **144** are in the form of low friction inserts **150** and **152** that are press-fit into the bearing assemblies. The low friction inserts **150** and **152** rotate with the gear nut **134**. The remaining portions of the bearing assemblies consist of respective inner races **154** and **156**, groups of ball bearings **158** and **160**, and outer races **162** and **164**. Here too, the inserts may be eliminated, if desired, and replaced by suitably surfaced inner races. The curved end surfaces **146** and **148** of the gear nut **134** define respective spherical surfaces (be they formed by molding, machining or through the use of inserts). The surfaces of the inserts **150** and **152** have a conical tapered shape. If the leadscrew is not properly aligned, the spherical surface portions of the gear nut **134** will slide along the respective conical surfaces of the inserts **150** and **152**, thereby maintaining gear nut/leadscrew alignment and preventing binding.

In the exemplary embodiment shown in FIGS. 1-4, the spherical surfaces of the gear nut **64** are in contact with housing spherical surfaces **34** and **46**. By contrast, in the exemplary embodiment shown in FIGS. 5-8, the gear nut **134** includes spherical surfaces, while the surfaces of the inserts **150** and **152** have a conical tapered shape. The contact area between the gear nut **134** and the bearing assemblies **142** and **144** is, therefore, substantially less than the contact area between the gear nut **64** and the housing surfaces **34** and **46**. The contact surface between the gear nut **134** and each of the bearing assemblies **142** and **144** is essentially a thin line which circles the gear nut curved end surfaces **146** and **148**. This remains true as misalignment of the leadscrew causes the gear nut **134** to pivot with respect to the bearing assemblies **142** and **144**. Thus, as the leadscrew moves in and out of alignment, the gear nut **134** will experience less frictional resistance to pivoting than will the gear nut **64**.

With respect to assembly of the unit, the threaded end cap **140** allows the gear nut **134** and bearing assemblies **142** and **144** to be easily placed within the housing main section **138**. Thereafter, the threaded end cap may be used to apply the proper force to the bearing assemblies so as to minimize "chuck." The end cap **140** may then be locked in place by any suitable method such as, for example, the use of adhesive or deforming small, adjacent portions of the cap **140** and the main body section **138**. Such an arrangement is easier to assemble and easier to adjust for friction and chuck than one which relies on tightening bolts to join respective sections of a housing.

As shown by way of example in FIGS. 5-7, rotation of the gear nut **134** may be prevented with a locking assembly **166** that is adapted to engage one of the castellations **168** on the gear nut. The locking assembly **166** includes a locking lever **170** that rotates with a spindle **172** between an engaged (or locked) orientation and disengaged (or unlocked) orientation. The locking lever **170** and spindle **172** are preferably separate structural elements that are connected to one another by any suitable method such as, for example, keying or splining. The spindle **172** includes splines **173** that are used to attach the spindle to an operating lever or handle (not shown). This spindle and handle arrangement eliminates the need for the wires and cables discussed above. In the illustrated embodiment, one surface of the locking lever **170** engages the castellations **168**, while another surface of the locking lever is engaged by a plunger **174** that has a suitable cam surface. The plunger **174** is biased in the direction of the locking lever **170** by a spring **176** or other resilient element. The plunger **174** and spring **176** maintain the locking lever **170** in the engaged orientation. Operation of the handle (and, therefore, rotation of the spindle **172**) will overcome the force of the biasing spring **176** and cause the locking lever **170** to move out of engagement with the gear nut **134**, thereby allowing the gear nut to rotate.

Another exemplary locking assembly **178** is shown in FIGS. 9-12. Here, a locking lever **180** is pivotably mounted on the exterior of a housing **182** such that one end **180a** extends through an opening in the housing. As the locking lever **180** pivots, it moves between a locked position where end **180a** engages the castellations **168** and an unlocked position where the end is disengaged. The locking lever **180** is biased to the locked position by a resilient element, such as a spring **184** (shown in FIGS. 10 and 11) that is attached to the housing **182** and to an end **180b** of the lever. Referring more specifically to FIGS. 9 and 10, the lever may be pulled to the unlocked position by a cable (or cables) **186** when mounted for rotation on a rod **187**. The cable **186** is secured to the locking lever **180** by a ball **189** and is guided by a guide **191**. The ball **189** prevents the cable **186** from being pulled through the lever **180**. Alternatively, as shown in FIGS. 11 and 12, the lever **180** may be attached to a spindle **188**. The locking lever **180** will rotate with the spindle **188** when a handle (not shown) is operated. The handle may be connected to the spindle **188** through the use of splines **190**, or any other suitable fastening device. The locking lever **180** may be connected to the spindle **188** in the same or similar manner.

As shown by way of example in FIG. 9, the present invention may also include a leadscrew guide **192**. The leadscrew guide **192** guides the leadscrew **135** and helps maintain the alignment thereof. The guide may also be used to mount a return spring and prevent the return spring from rubbing against the leadscrew. Additionally, the leadscrew guide **192** acts as a stop to prevent the leadscrew head **194** from moving past the end of the guide.

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The exemplary guide **192** includes an insert portion **194** which is inserted into an aperture in the housing **182** (or **136**) during assembly.

In accordance with another advantageous aspect of the invention, and as illustrated for example in FIGS. 13 and 14, a locking assembly **196** can be actuated by two cables which approach a linear actuator **198** (preferably one of the actuators described above) from different directions. More specifically, the locking assembly **196** includes a locking lever **200** (preferably of the type shown in FIG. 10) that is biased to the locked position shown in FIG. 13 by a spring **202**. This prevents rotation of a gear nut (not shown) within the linear actuator **198**. The locking lever **200** can be moved to the unlocked position shown in FIG. 14 by a first cable **204** which connects the locking lever to an actuator at a first location. In the exemplary embodiment, the cable **204** is secured to the locking lever **200** by a ball **206** and guided by a guide **208**. The cable **204** is also covered by a protective covering, or conduit **210**.

A second cable **212** and conduit **214** arrangement allows the locking lever **200** to be actuated from a second location. One end of the cable **212** is secured to an anchor **216** by a ball **218**. From there, the cable **212** passes through an opening in the locking lever **200**, through a guide **220**, and then on to the second location. The guide **220** also holds the conduit **214** and prevents the conduit from moving relative to the actuator while allowing movement of the cable **212** within the conduit. A fitting **222** may, if desired, be placed between the end of the conduit **214** and the locking lever **200** in order to protect the end of the conduit from wear. Otherwise, the end of the conduit **214** will abut the locking lever **200**.

As illustrated for example in FIG. 13, the cable **212** and conduit **214** are bent when the locking assembly **196** is in the locked orientation. In other words, there is slack in the cable **212** and conduit **214**. The cable **212** is straightened on both sides of the locking lever (i.e. the slack is removed) when the cable is pulled due to actuation of a handle, lever or other suitable device at the second location. (See FIG. 14.) The straightening of the cable **212** causes the conduit **214** to straighten out. As the conduit **214** straightens, it overcomes the biasing force of spring **202** and pushes the locking lever **200**

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to the unlocked position shown in FIG. 14. The conduit **214** is preferably formed at least in part from a plastic material and the stiffness of the conduit must be such that it is flexible enough to bend with the cable **212** under the biasing force of the spring **202**, yet stiff enough to straighten out with the cable when the cable is pulled.

There are a number of practical applications for a locking assembly that can be actuated by two cables which approach a linear actuator from different directions. For example, the front seats of automobiles are typically capable of both reclining for passenger comfort and folding forward to allow a passenger in the back seat to exit. Use of the locking assembly **196** would allow the seat's linear actuator, which locks the seat in place, to be unlocked from different locations. One seat release handle may be located next to the seat cushion of the front seat, while another handle may be located in close proximity to the back seat. As a result, a person sitting in the back seat will be able to release the front seat and exit the vehicle without having to reach forward and find the seat release handle next to the front seat's cushion (which is often blocked from view by the front seat itself).

The embodiments that have been described are manually activated. They could be electrically operated with some modifications. For example, instead of having castellations, the gear nut could be a helical gear that a mating gear or worm could drive. Locking the driving motor would lock the gear nut. Another modification concerns the mounting of ball **98**. Instead of relying on gravity to remove the ball from a castellation, the ball could be spring mounted.

Other numerous modifications and alternate embodiments will occur to those skilled in the art. Therefore, applicant intends that the invention be limited only in terms of the appended claims.

CLAIMS

I CLAIM:

1. A linear actuator comprising a housing including an open space defined by curved inwardly facing walls, a leadscrew traversing the housing, a gear nut in the housing around the leadscrew and rotating in response to axial movement of the leadscrew relative to the gear nut, the gear nut defining curved outer walls, at least a portion of each of the curved outer walls of the gear nut being in spaced relation to an adjacent curved inwardly facing wall of the housing, the housing mounting the leadscrew for pivoting to change the axis of rotation of the gear nut within the housing.

2. The linear actuator of claim 1 wherein the inwardly facing walls of the housing have curvature corresponding to the curvature of the outer walls of the gear nut, and the gear nut pivots relative to the curved walls of the housing.

3. The linear actuator of claim 2 wherein the curved walls of the housing and the gear nut are spherical.

4. A linear actuator comprising:

a. a housing having an open central section, an end wall having a spherical surface over at least part of the end wall, a mounting block at the opposite end of the end wall, the mounting block having a spherical surface over at least part of the mounting block, the spherical surfaces of the end wall and the mounting block facing each other, the end wall and the mounting block each having a central hole opposite each other;

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b. a gear nut in the housing extending between the spherical surfaces of the end wall and mounting block, the gear nut having a central opening and curved end surfaces and being located within the housing such that at least a portion of each of the curved end surfaces is in spaced relation to the respective adjacent spherical surface of end wall or mounting block; and

c. a leadscrew traversing the housing and threaded through the gear nut, the gear nut being against the spherical surfaces and rotating about the leadscrew in response to axial movement of the leadscrew through the housing;

d. the gear nut pivoting to change the axis of rotation of the gear nut relative to the housing.

5. The linear actuator of claim 4 wherein the curved end surfaces of the gear nut comprise spherical outer walls.

6. The linear actuator of claim 5 wherein inserts form at least one spherical outer wall.

7. A linear actuator, comprising:

a housing having an open central section, an end wall having a spherical surface over at least part of the end wall, a mounting block at the opposite end of the end wall, the mounting block having a spherical surface over at least part of the mounting block, the spherical surfaces of the end wall and the mounting block facing each other, the end wall and the mounting block each having a central hole opposite each other;

a gear nut in the housing extending between the spherical surfaces of the end wall and mounting block, the gear nut having a central opening and castellations extending around the gear nut;

a leadscrew traversing the housing and threaded through the gear nut, the gear nut being against the spherical surfaces and rotating about

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the leadscrew in response to axial movement of the leadscrew through the housing;

a groove in the housing extending toward the castellations;

a ball moveable within the groove between a position partially projecting from the groove and extending into a castellation and a position retracted from a castellation; and

a piston in the housing in contact with the ball, the piston having portions of different diameters, the piston moving in the housing from a position in which the smaller diameter portion is adjacent the ball to allow the ball to retract from a castellation and a wider diameter portion pushing the ball toward the castellation;

wherein the gear nut pivots to change the axis of rotation of the gear nut relative to the housing.

8. The linear actuator of claim 7 further comprising a spring in the housing and operably connected to the piston, the spring biasing the piston to position the wider diameter portion in contact with the ball.

9. The linear actuator of claim 4 wherein the central holes are tapered.

10. A linear actuator, comprising:

a housing;

a leadscrew traversing the housing;

a gear nut, located substantially within the housing and around the leadscrew, rotating in response to axial movement of the leadscrew relative to the gear nut, and including first and second longitudinal end portions having curved surfaces which define a gear nut end surface curvature; and

first and second bearing surfaces respectively engaging the first end second longitudinal end surfaces of the gear nut such that the gear nut is capable of pivoting to change the axis of rotation of the gear nut, the

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bearing surfaces being rotatable and defining a bearing surface curvature which is different than the gear nut end surface curvature.

11. A linear actuator as claimed in claim 10, wherein one of the gear nut end surface curvature and the bearing surface curvature is substantially spherical and the other of the gear nut end surface curvature and the bearing surface curvature is substantially conical.

12. A linear actuator as claimed in claim 11, wherein the gear nut end surface curvature is substantially spherical.

13. A linear actuator as claimed in claim 10, wherein the first and second bearing surfaces are associated with first and second bearing assemblies.

14. A linear actuator as claimed in claim 13, wherein the first and second bearing assemblies include respective fixed portions and respective rotating portions.

15. A linear actuator as claimed in claim 14, wherein the first and second bearing surfaces comprise first and second inserts which are respectively secured to the rotating portions of the first and second bearing assemblies.

16. A linear actuator as claimed in claim 10, wherein the first and second end portions of the gear nut and the first and second bearing surfaces define respective contact areas therebetween, each contact area being in the form of a thin line that circles a respective gear nut end portion.

17. A linear actuator as claimed in claim 10, wherein the housing comprises a main section defining a threaded opening and threaded end cap

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adapted to engage the opening and apply a variable force to at least one of the first bearing surface, the second bearing surface, and the gear nut.

18. A linear actuator, comprising:

a housing;

a leadscrew traversing the housing;

a gear nut, located substantially within the housing and around the leadscrew, rotating in response to axial movement of the leadscrew relative to the gear nut, and including a plurality of circumferentially-spaced castellations and first and second longitudinal end portions defining a gear nut end surface curvature;

first and second bearing surfaces respectively engaging the first end second longitudinal end surfaces of the gear nut such that the gear nut is capable of pivoting to change the axis of rotation of the gear nut, the bearing surfaces defining a bearing surface curvature; and

a locking mechanism including a pivotable lever adapted to move between a locked position wherein the lever engages one of the castellations and an unlocked position, and a biasing device adapted to bias the lever to the locked position.

19. A linear actuator as claimed in claim 18, wherein the lever is mounted on a rotatable spindle.

20. A linear actuator as claimed in claim 18, wherein the lever is located substantially within the housing.

21. A linear actuator as claimed in claim 18, wherein the biasing device comprises a plunger adapted to engage a portion of the lever and a resilient element adapted to apply a biasing force to the plunger.

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22. A linear actuator as claimed in claim 18, wherein the housing includes a lever opening, a first portion of the lever is located within the housing, and a second portion of the lever is located outside the housing.

23. A linear actuator as claimed in claim 22, wherein the lever pivots about an axis located substantially outside the housing.

24. A linear actuator as claimed in claim 22, wherein the biasing device comprises a resilient element having a first portion attached to the housing and a second portion attached to the lever.

25. A linear actuator as claimed in claim 22, wherein the lever is mounted on a rotatable spindle.

26. A linear actuator as claimed in claim 22, wherein the lever is operably connected to an actuating cable.

27. A linear actuator as claimed in claim 18, wherein the gear nut end surface curvature is different than the bearing surface curvature.

28. A linear actuator as claimed in claim 18, wherein the gear nut end surface curvature is substantially spherical and the bearing surface curvature is substantially conical.

29. A linear actuator as claimed in claim 18, wherein the housing comprises a main section defining a threaded opening and threaded end cap adapted to engage the opening and apply a variable force to at least one of the first bearing surface, the second bearing surface, and the gear nut.

30. A linear actuator, comprising:
a housing;
a leadscrew traversing the housing;

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a gear nut, located substantially within the housing and around the leadscrew, rotating in response to axial movement of the leadscrew relative to the gear nut, and including a plurality of circumferentially-spaced castellations;

first and second bearing surfaces respectively engaging the first and second longitudinal end surfaces of the gear nut; and

a locking assembly including a pivotable lever adapted to move between a locked position wherein the lever engages one of the castellations and an unlocked position, a biasing device adapted to bias the lever to the locked position, a first actuator operably connected to the lever and adapted to move the lever to the unlocked position when at least a portion of the first actuator is moved in a first direction, and a second actuator operably connected to the lever and adapted to move the lever to the unlocked position when at least a portion of the second actuator is moved in a second direction, the second direction being different than the first direction.

31. A linear actuator as claimed in claim 30, wherein the first actuator comprises a cable and a conduit through which the cable extends.

32. A linear actuator as claimed in claim 31, wherein the conduit defines an end portion which substantially abuts the lever, a substantially fixed portion and a portion therebetween, and wherein the portion of the conduit between the end portion and the fixed portion is deformed when the lever is in the locked position.

33. A linear actuator as claimed in claim 32, wherein the cable defines an end portion that is prevented from moving in the first direction and a portion that extends from the end portion, through the lever and to a guide, and wherein at least some of the conduit between the end conduit portion and the fixed conduit portion is between the lever and the guide.

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34. A linear actuator as claimed in claim 33, wherein the intermediate portion of the cable is deformed when the lever is in the locked position.

35. A linear actuator as claimed in claim 30, wherein the first and second longitudinal end portions of the gear nut define a gear nut end surface curvature, the bearing surfaces define a bearing surface curvature, and the gear nut is capable of pivoting to change the axis of rotation of the gear nut.

36. A linear actuator, comprising:

a housing including an open space defined by curved inwardly facing walls;

a leadscrew traversing the housing; and

a gear nut in the housing around the leadscrew and rotating in response to axial movement of the leadscrew relative to the gear nut, the gear nut defining curved outer walls which rotate relative to the respective curved inwardly facing walls of the housing;

wherein the gear nut pivots to change the axis of rotation of the gear nut relative to the housing.

37. A linear actuator as claimed in claim 36, wherein the inwardly facing walls of the housing have curvature corresponding to the curvature of the outer walls of the gear nut, and the gear nut pivots relative to the curved walls of the housing.

38. A linear actuator as claimed in claim 37, wherein the curved walls of the housing and gear nut are spherical.

39. A linear actuator as claimed in claim 36, further comprising:
castellations extending around the gear nut;

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an object moveable between a position extending into a castellation and a position retracted from a castellation;

a piston associated with the housing and having a cam surface capable of contacting the object, the piston moving relative to the housing from a position which allows the object to retract from a castellation and a position which pushes the object toward a castellation.

40. A linear actuator, comprising:

a housing including a first portion having a curved inwardly facing wall and a second portion having a curved inwardly facing wall, the first and second housing portions defining separate structural elements;

a leadscrew traversing the housing;

a gear nut in the housing around the leadscrew and rotating in response to axial movement of the leadscrew relative to the gear nut, the gear nut defining curved outer walls, at least a portion of each of the curved outer walls of the gear nut being in spaced relation to an adjacent curved inwardly facing wall of the housing; and

an adjustment mechanism associated with the first and second housing portions for selectively adjusting the distance therebetween;

wherein the gear nut pivots to change the axis of rotation of the gear nut relative to the housing.

41. A linear actuator as claimed in claim 40, wherein the adjustment mechanism comprises a plurality of bolts.

42. A linear actuator as claimed in claim 40, wherein the inwardly facing walls of the housing have curvature corresponding to the curvature of the outer walls of the gear nut, and the gear nut pivots relative to the curved walls of the housing.

43. A linear actuator as claimed in claim 42, wherein the curved walls of the housing and gear nut are spherical.

44. A linear actuator as claimed in claim 40, further comprising:
castellations extending around the gear nut;

an object moveable between a position extending into a castellation and a position retracted from a castellation;

a piston associated with the housing and having a cam surface capable of contacting the object, the piston moving relative to the housing from a position which allows the object to retract from a castellation and a position which pushes the object toward a castellation.

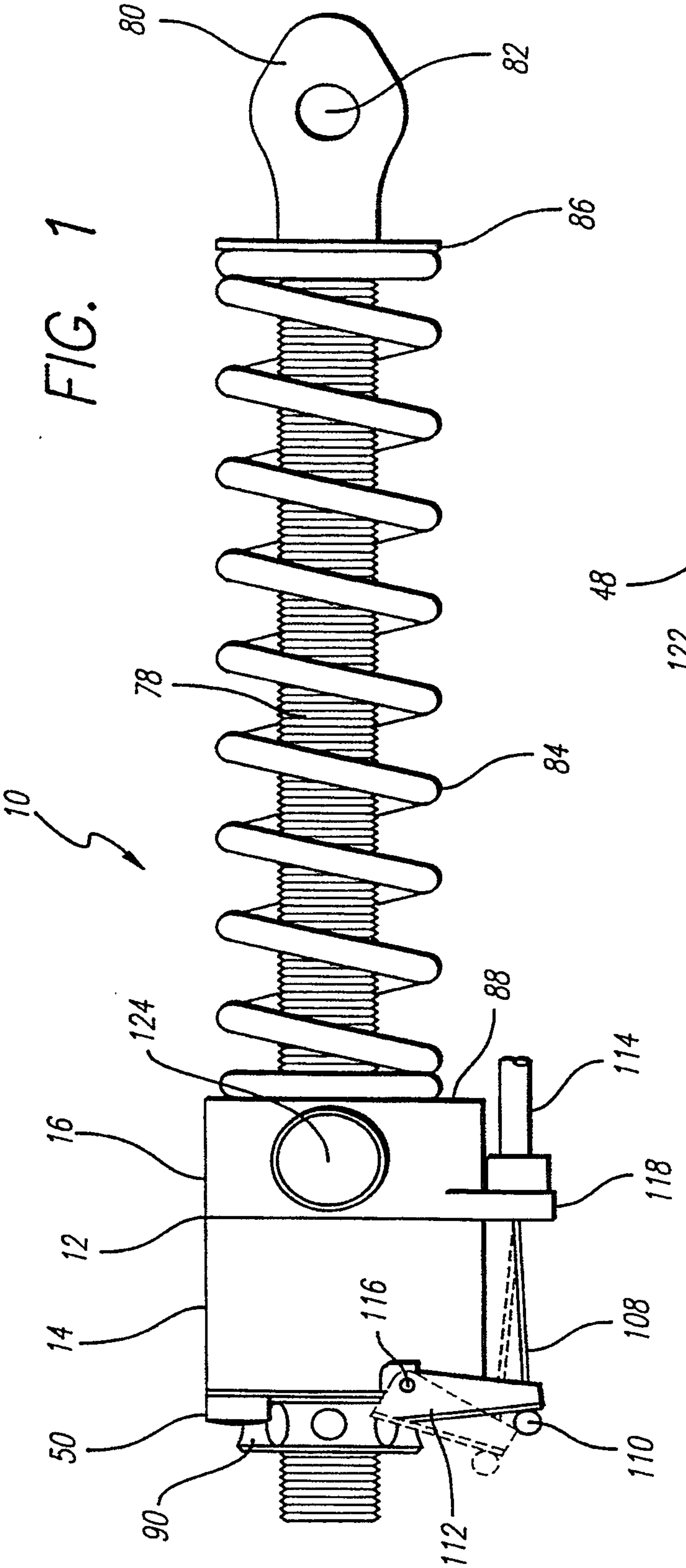
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FIG. 1

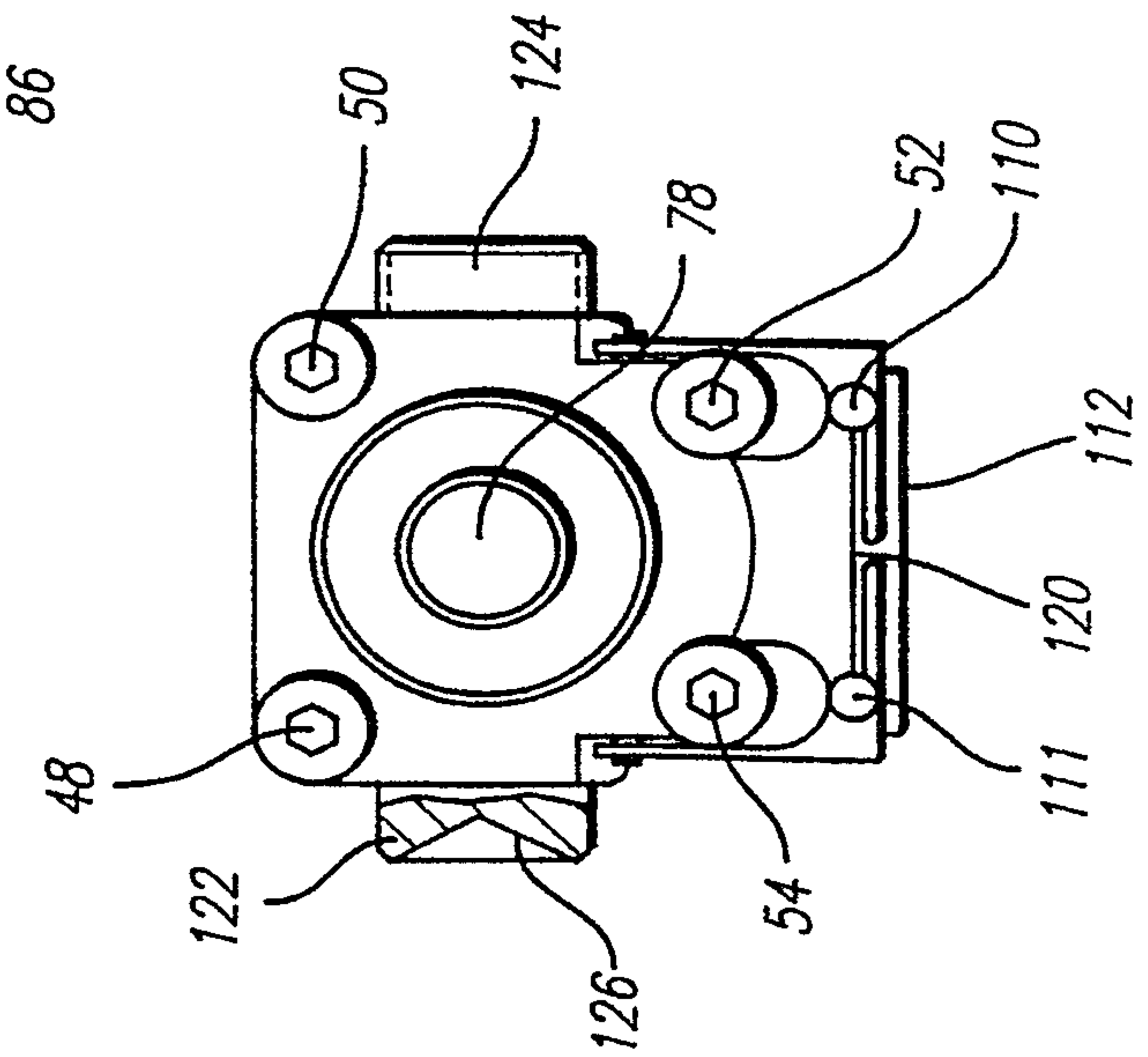
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FIG. 2

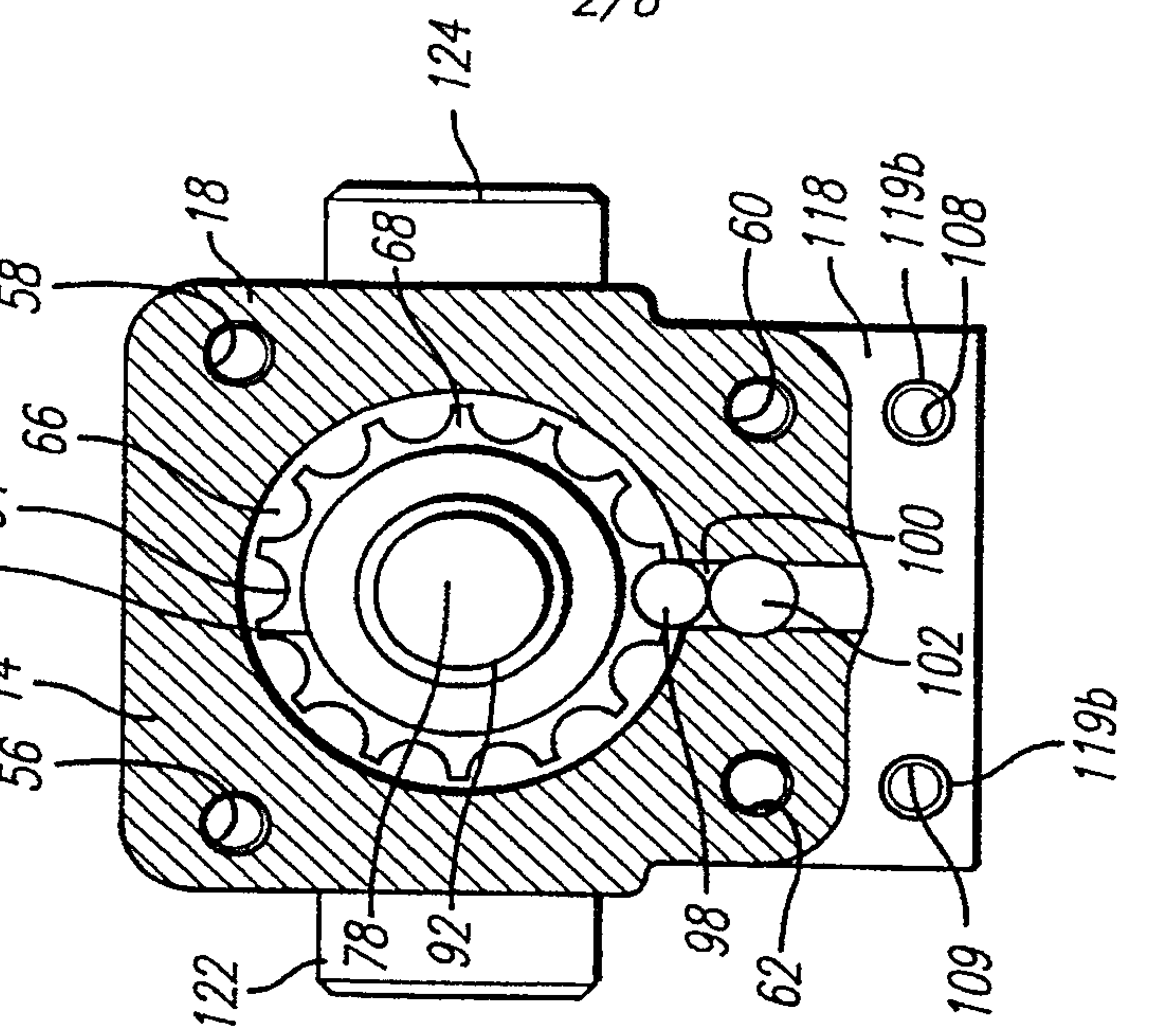
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FIG. 4

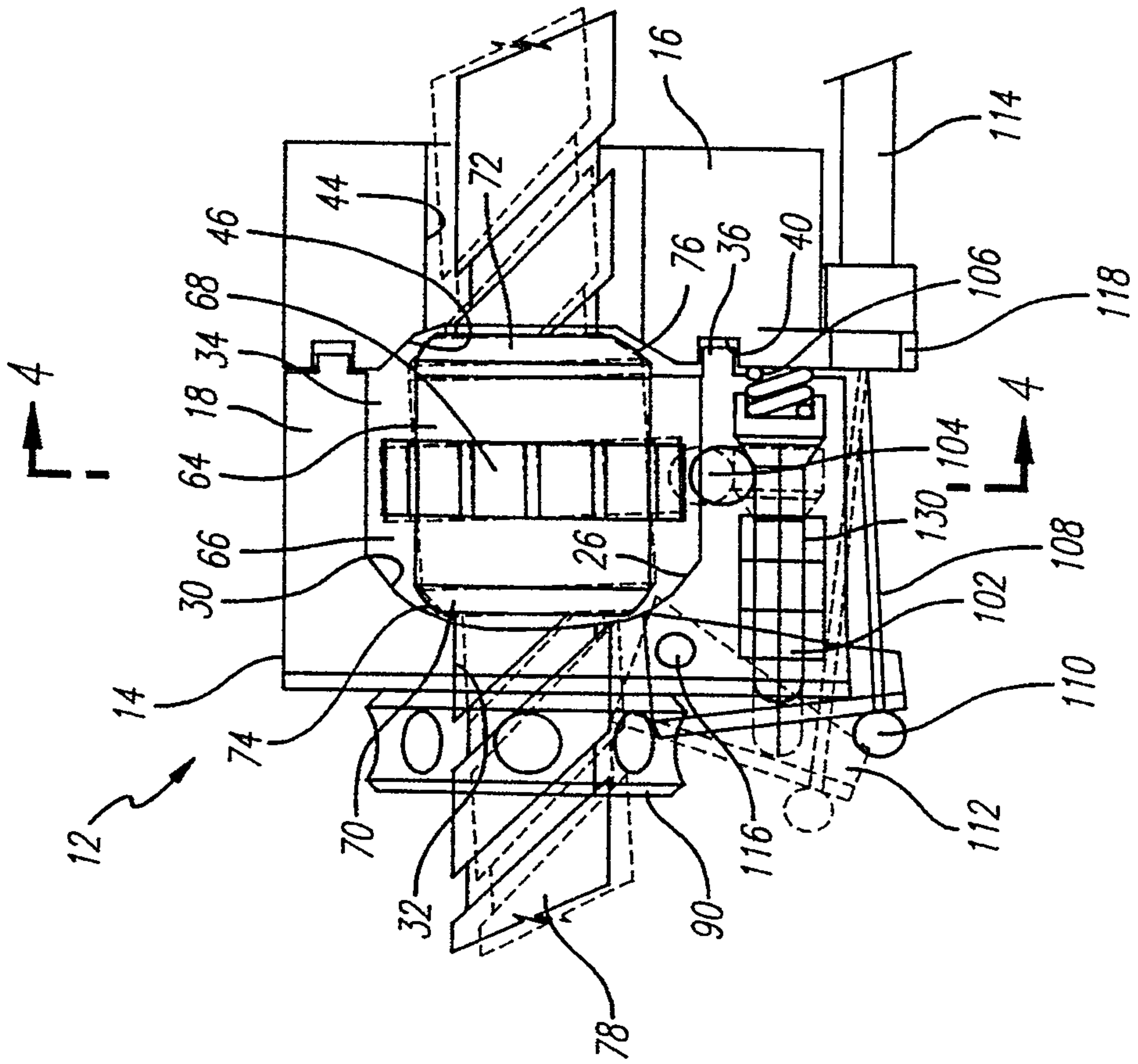
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FIG. 3

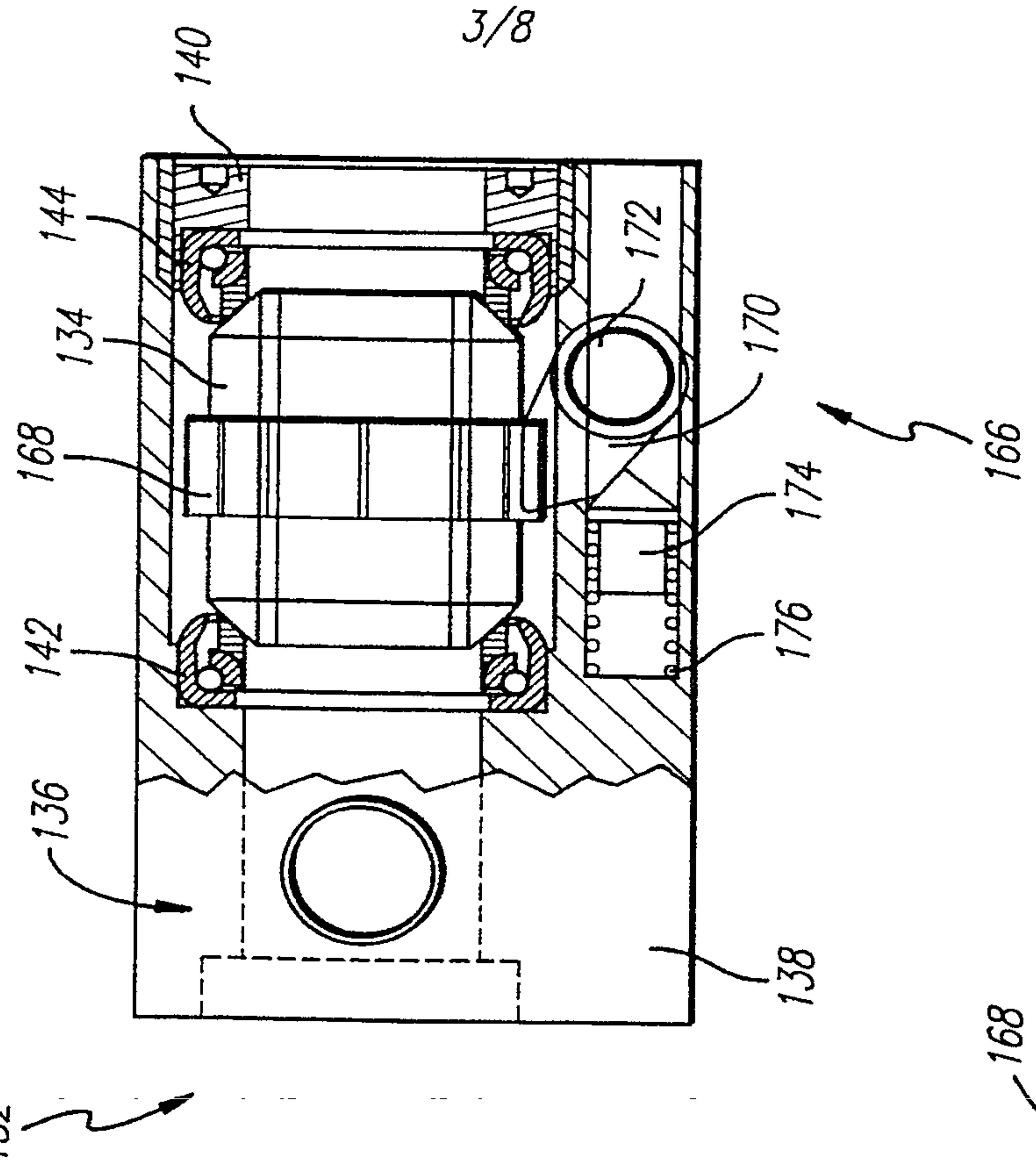

FIG. 7

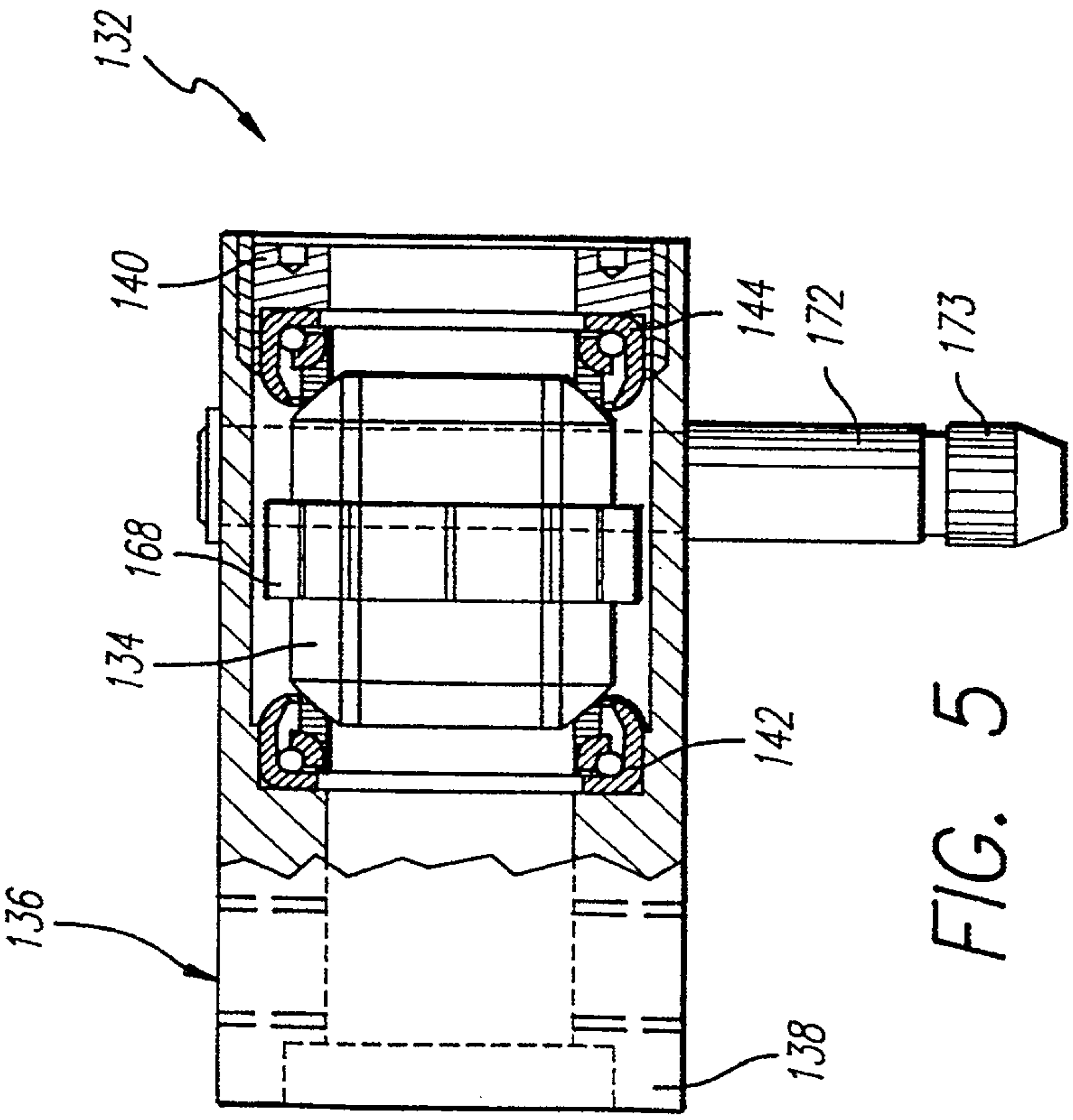

FIG. 5

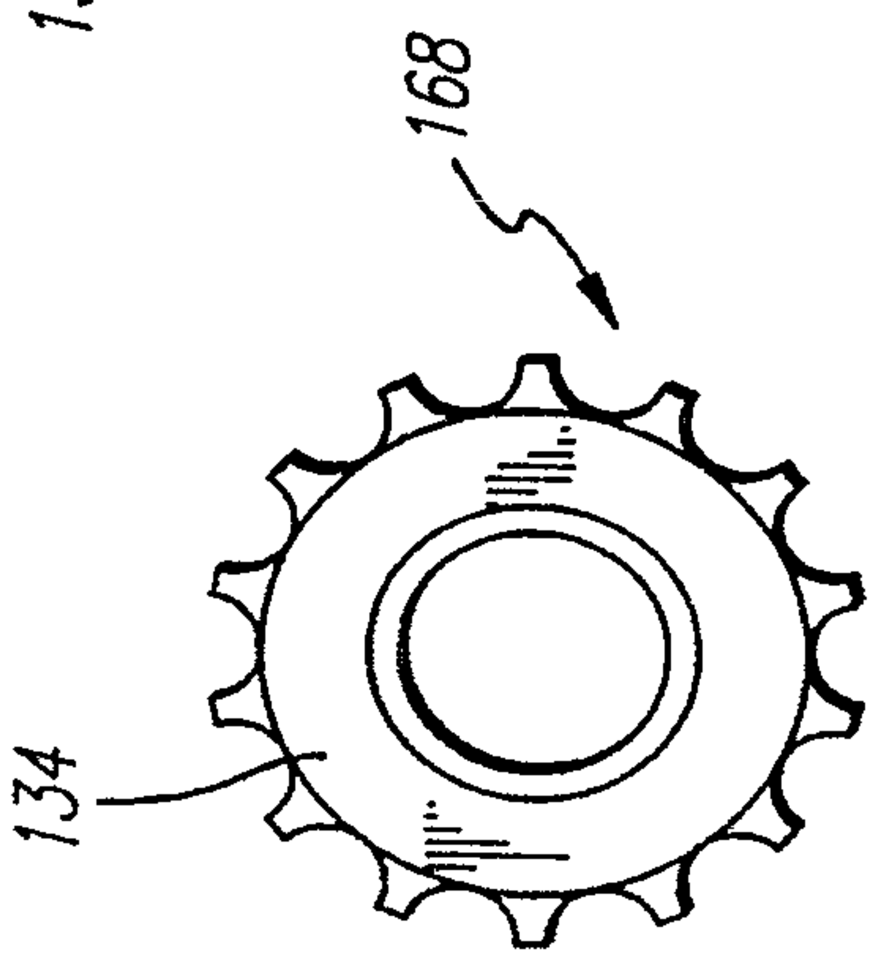

FIG. 6

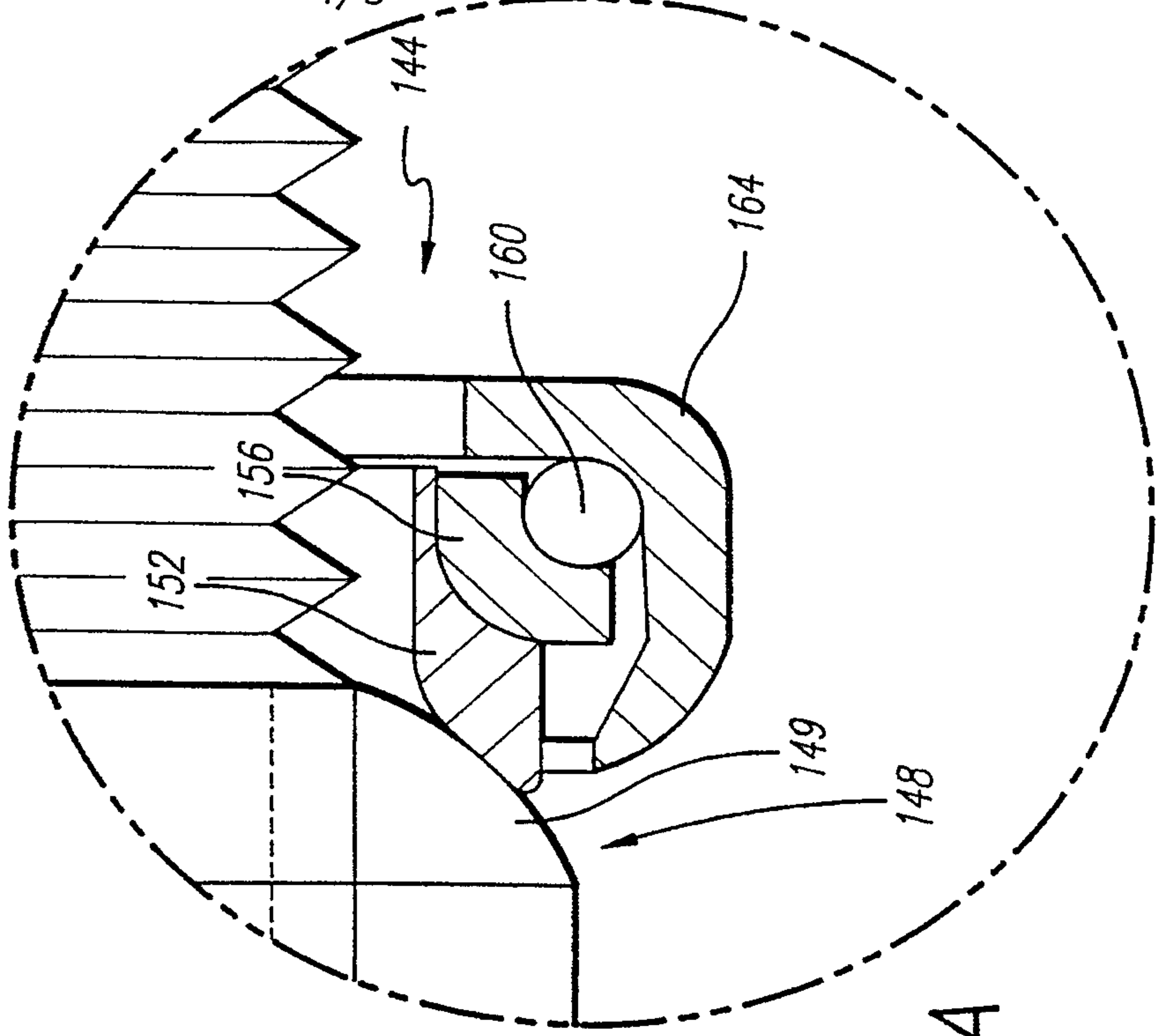
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FIG. 8A

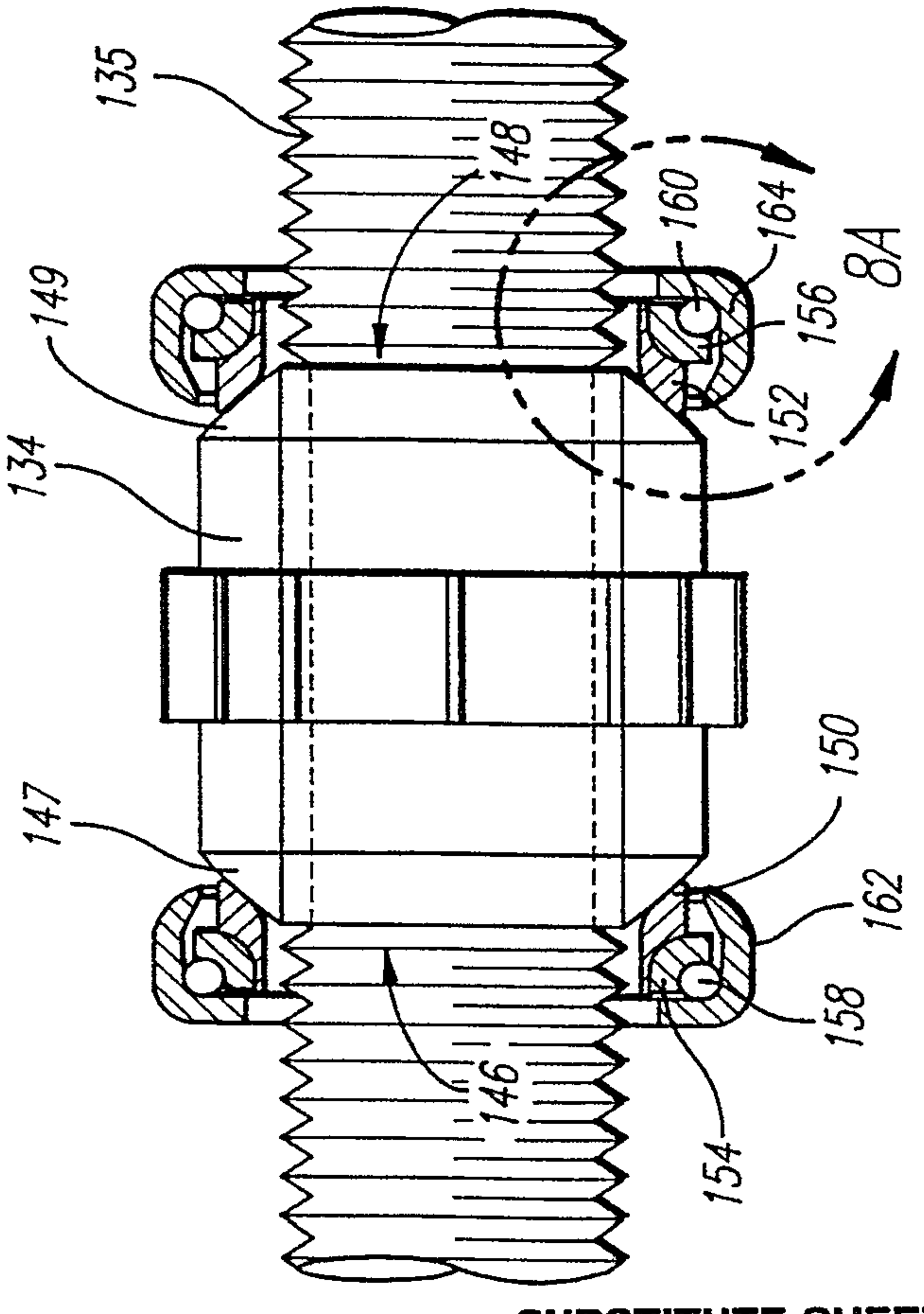
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FIG. 8

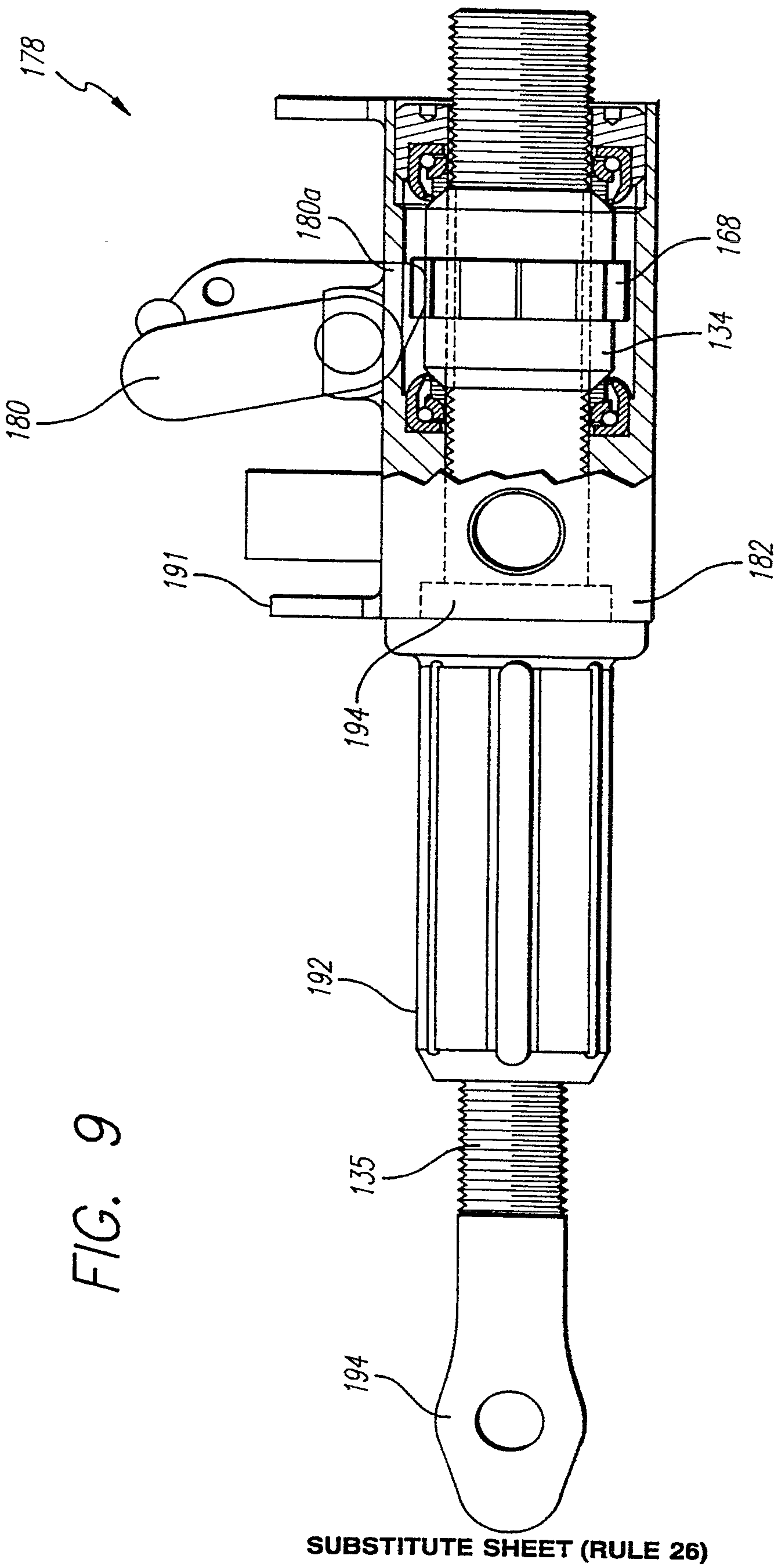


FIG. 9

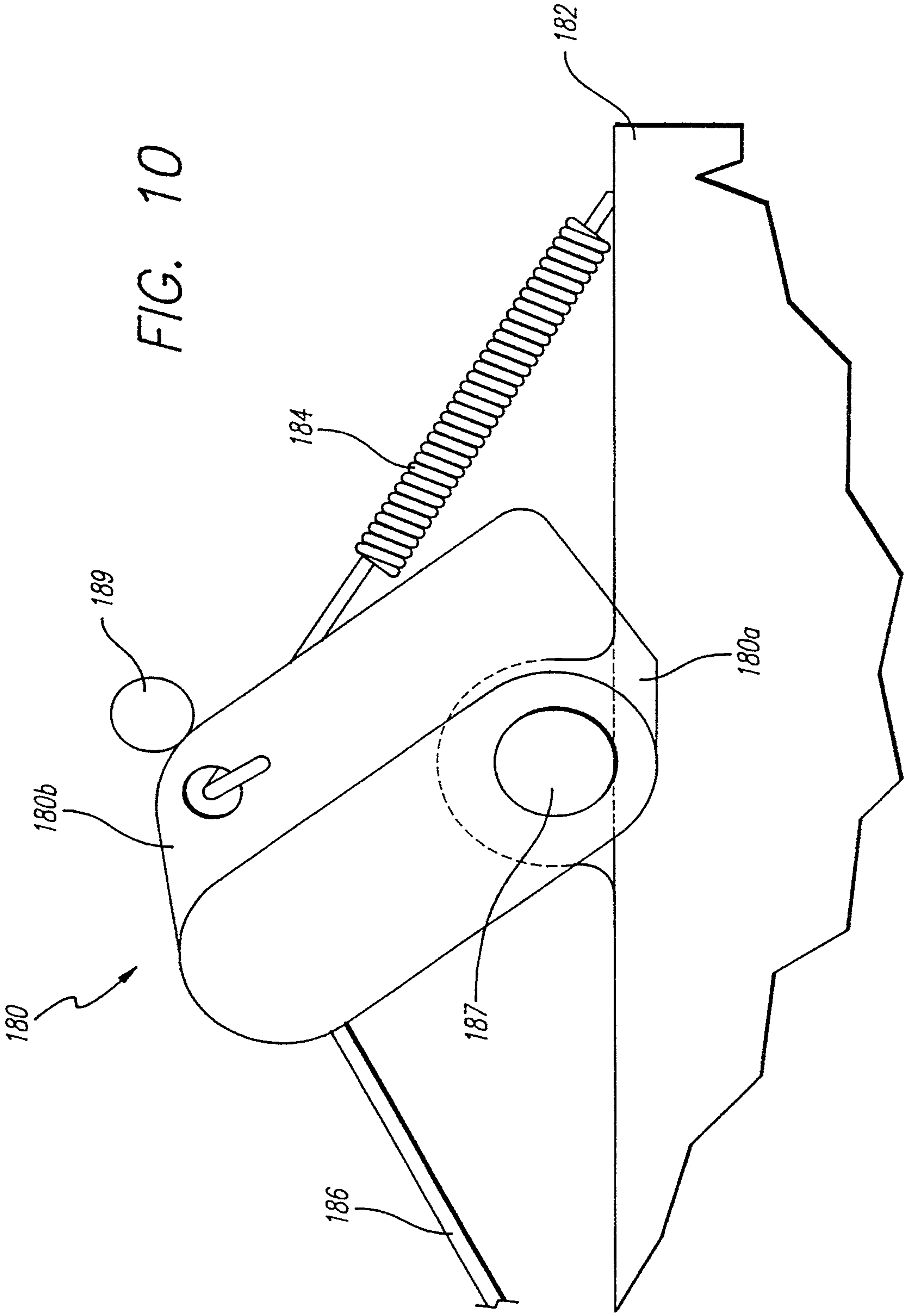


FIG. 10

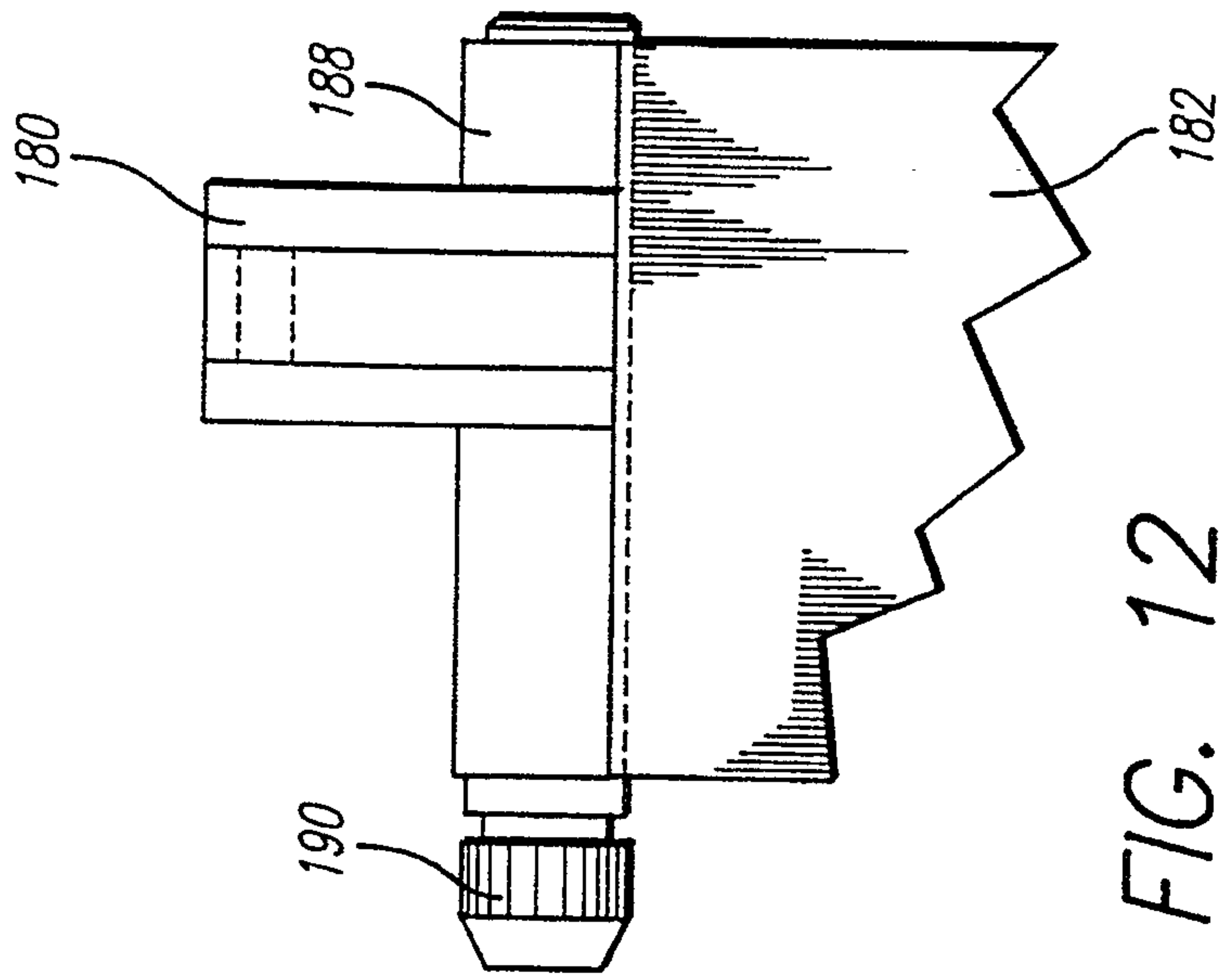


FIG. 12

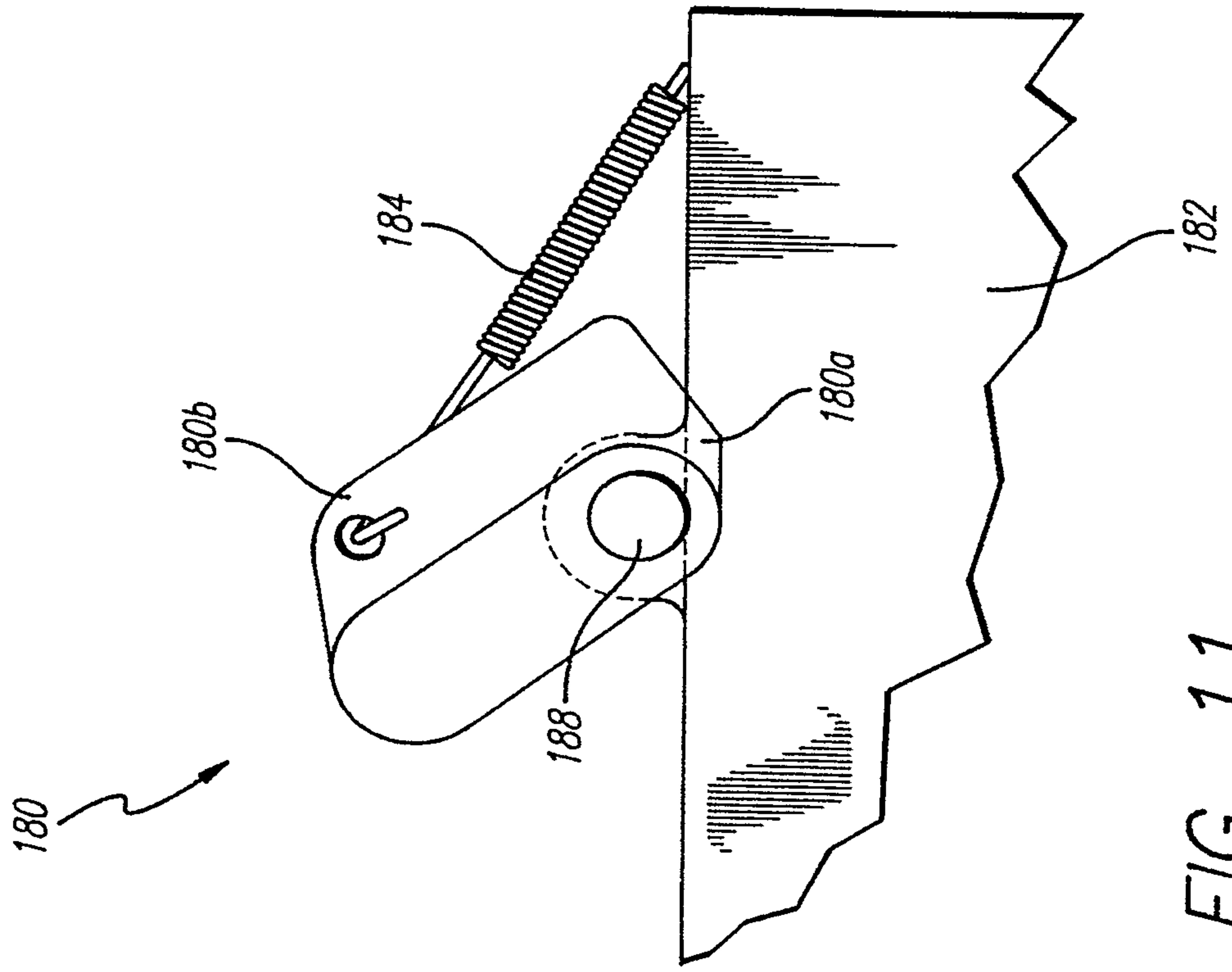
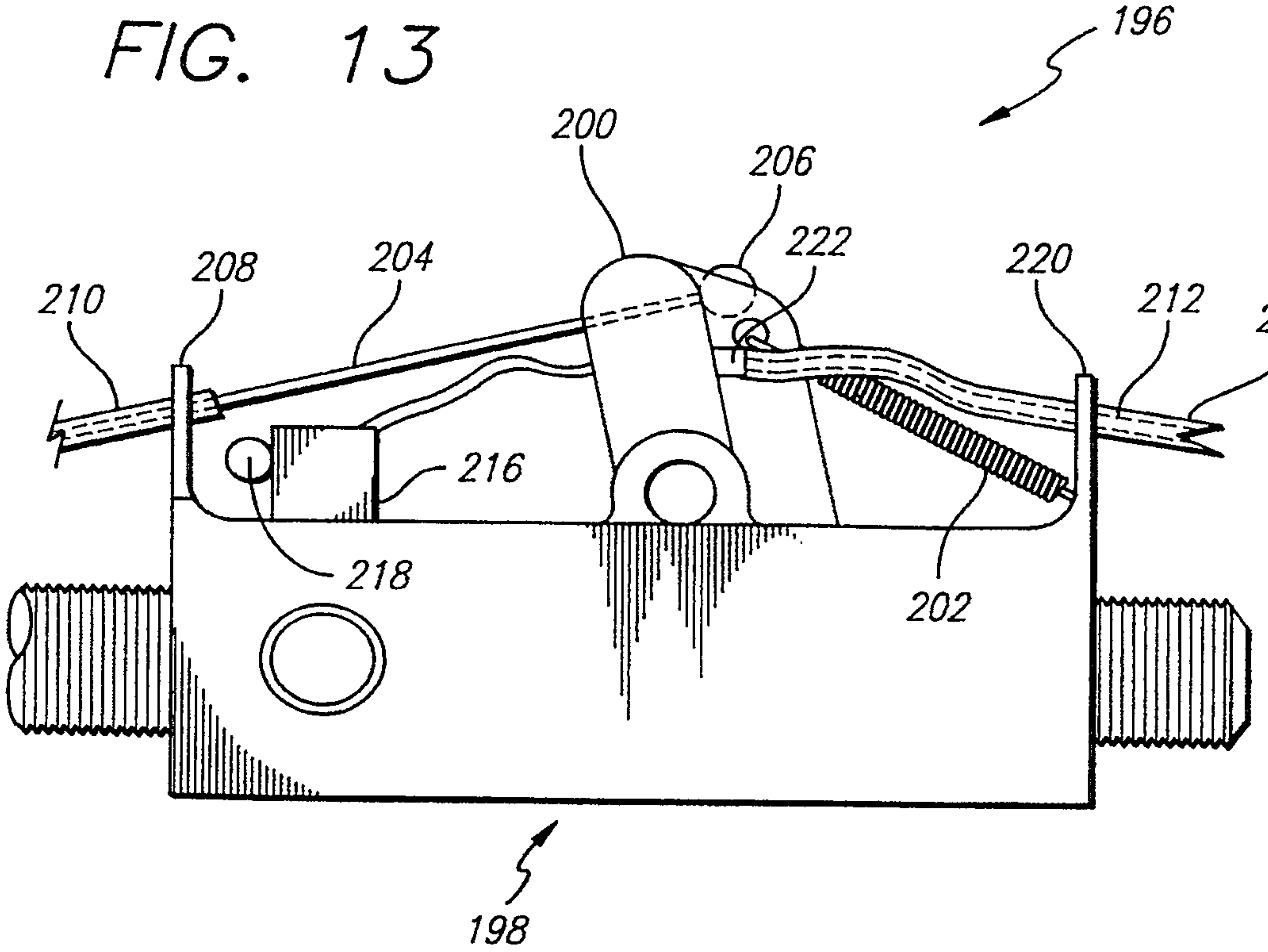


FIG. 11

FIG. 13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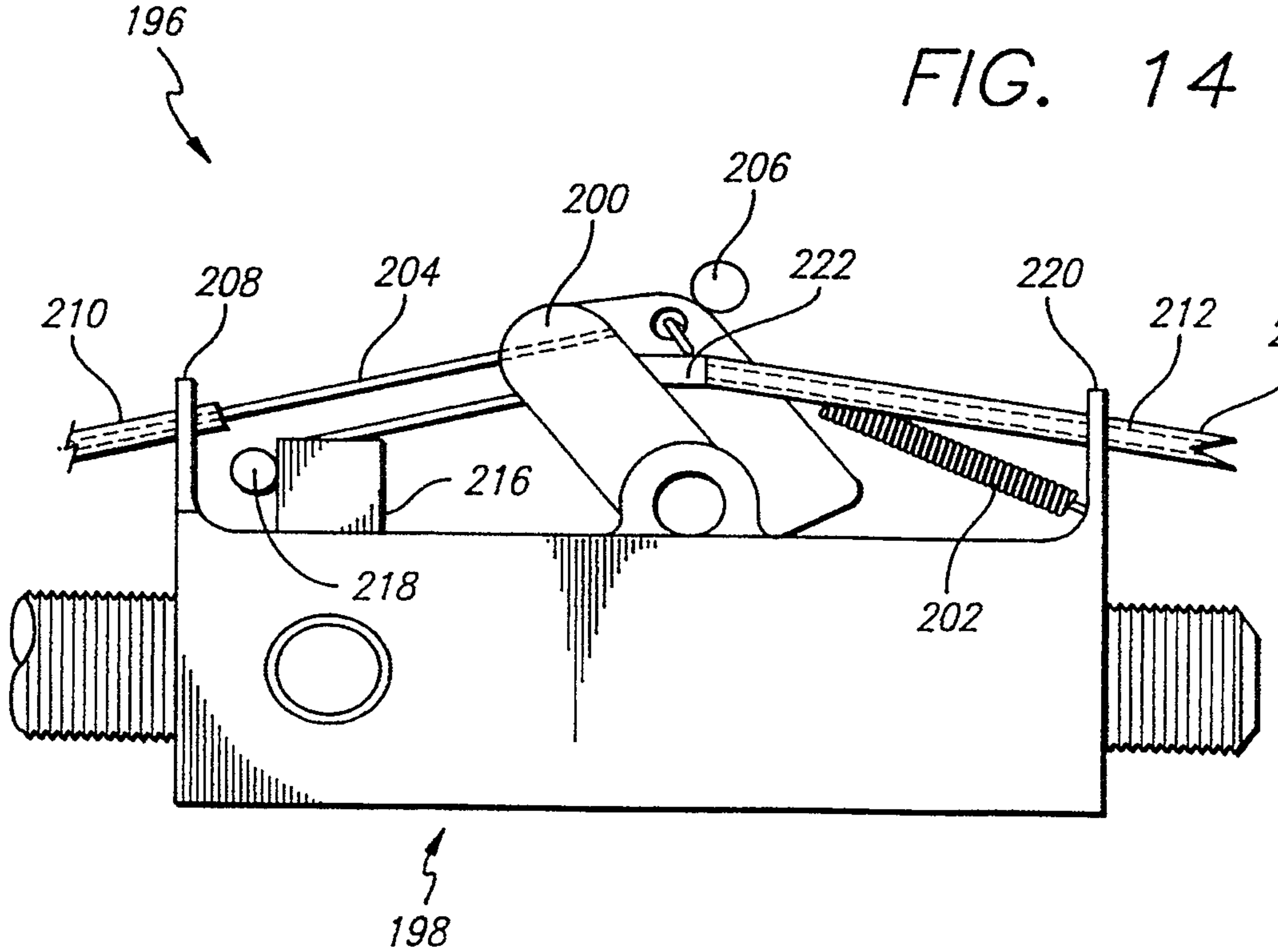
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FIG. 14

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