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(54) **EXPANDABLE SPINAL FUSION IMPLANT,  
RELATED INSTRUMENTS AND METHODS**

**Publication Classification**

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**Jeremy Malik**, San Diego, CA (US);  
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(US); **David Hannah**, San Diego, CA  
(US)

(21) Appl. No.: **16/433,215**

(22) Filed: **Jun. 6, 2019**

**Related U.S. Application Data**

- (63) Continuation of application No. 15/265,300, filed on Sep. 14, 2016, now Pat. No. 10,350,084, which is a continuation of application No. 14/060,558, filed on Oct. 22, 2013, now Pat. No. 9,445,918.
- (60) Provisional application No. 61/793,626, filed on Mar. 15, 2013, provisional application No. 61/717,003, filed on Oct. 22, 2012.

(51) **Int. Cl.**

*A61F 2/44* (2006.01)

*A61B 17/88* (2006.01)

*A61F 2/46* (2006.01)

*A61F 2/30* (2006.01)

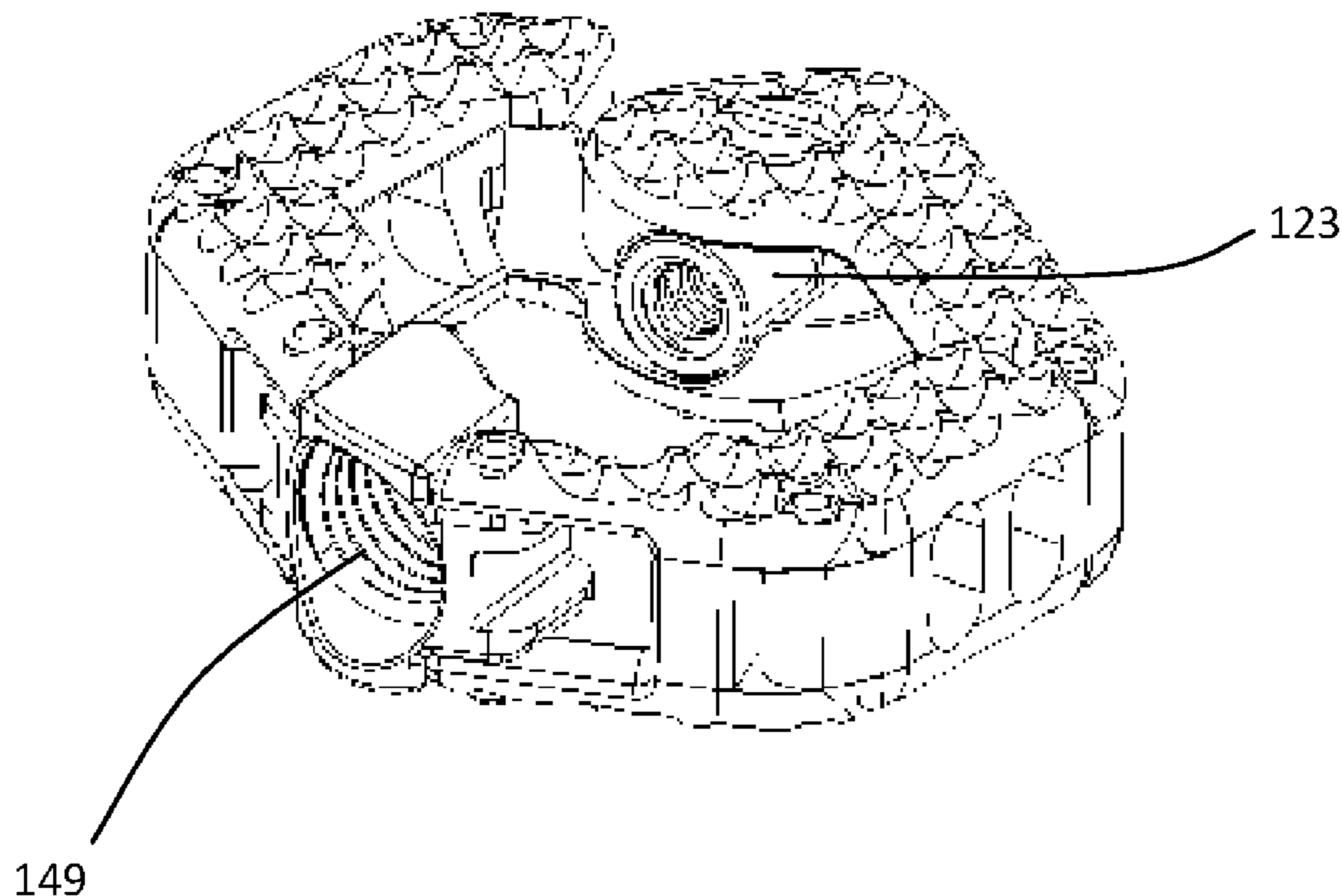
(52) **U.S. Cl.**

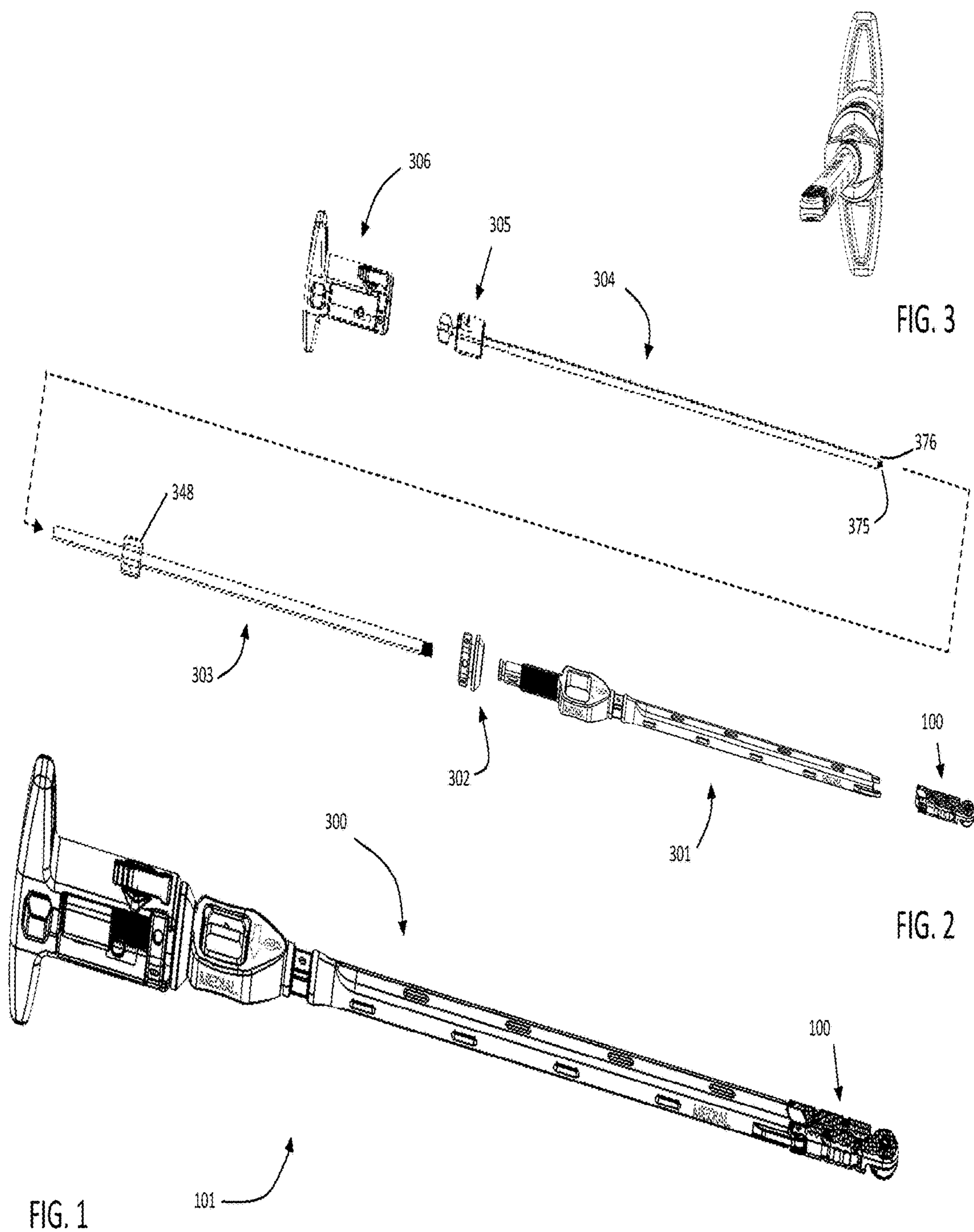
CPC .... *A61F 2/4465* (2013.01); *A61F 2002/2835*  
(2013.01); *A61F 2/4601* (2013.01); *A61F*  
*2/4611* (2013.01); *A61F 2/4684* (2013.01);  
*A61B 17/8819* (2013.01); *A61F 2/30771*  
(2013.01); *A61F 2/4455* (2013.01); *A61F*  
*2002/30831* (2013.01); *A61F 2002/30579*  
(2013.01); *A61F 2002/30505* (2013.01); *A61F*  
*2002/30494* (2013.01); *A61F 2002/30471*  
(2013.01); *A61F 2002/302* (2013.01); *A61B*  
*17/8833* (2013.01)

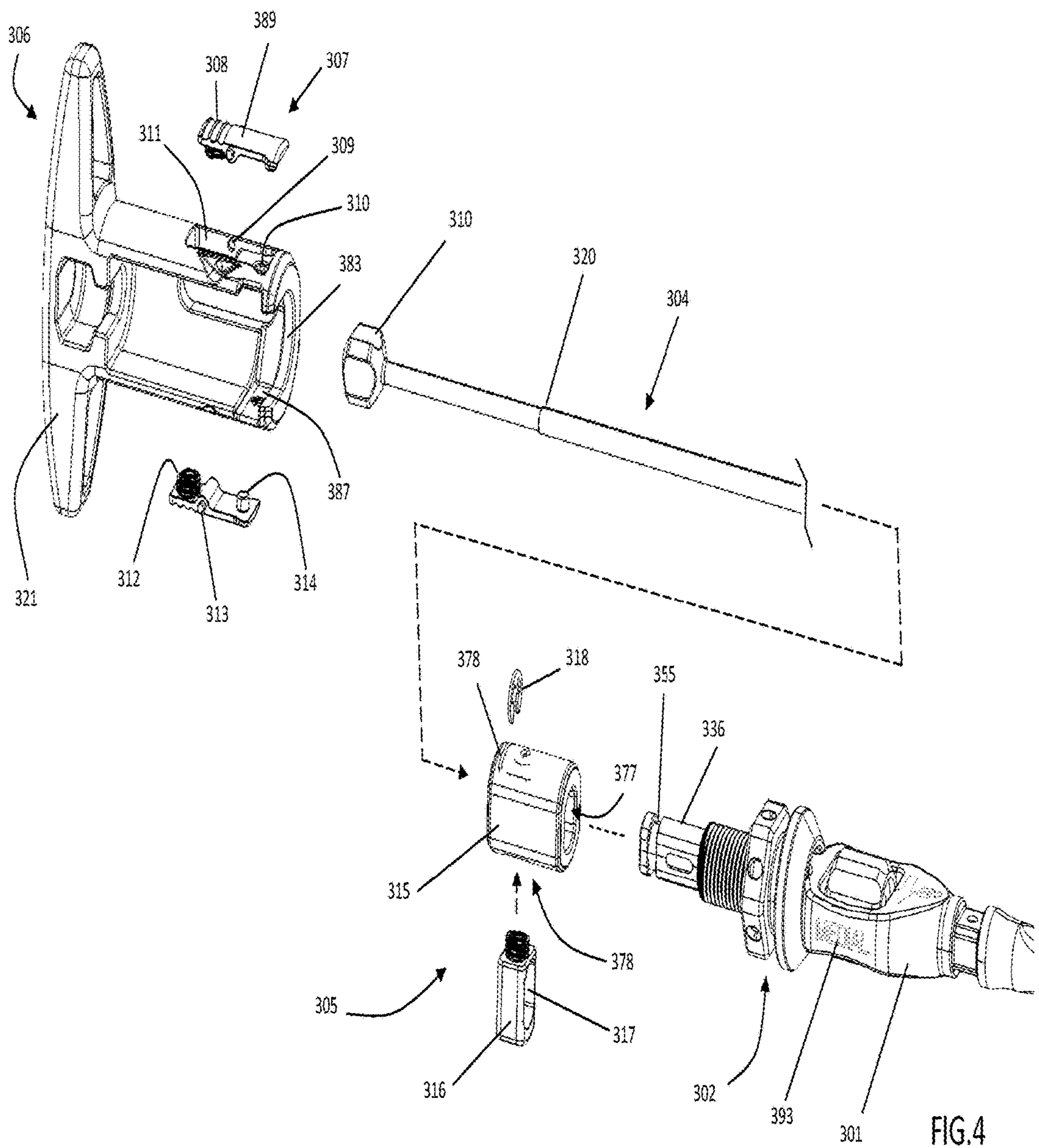
(57)

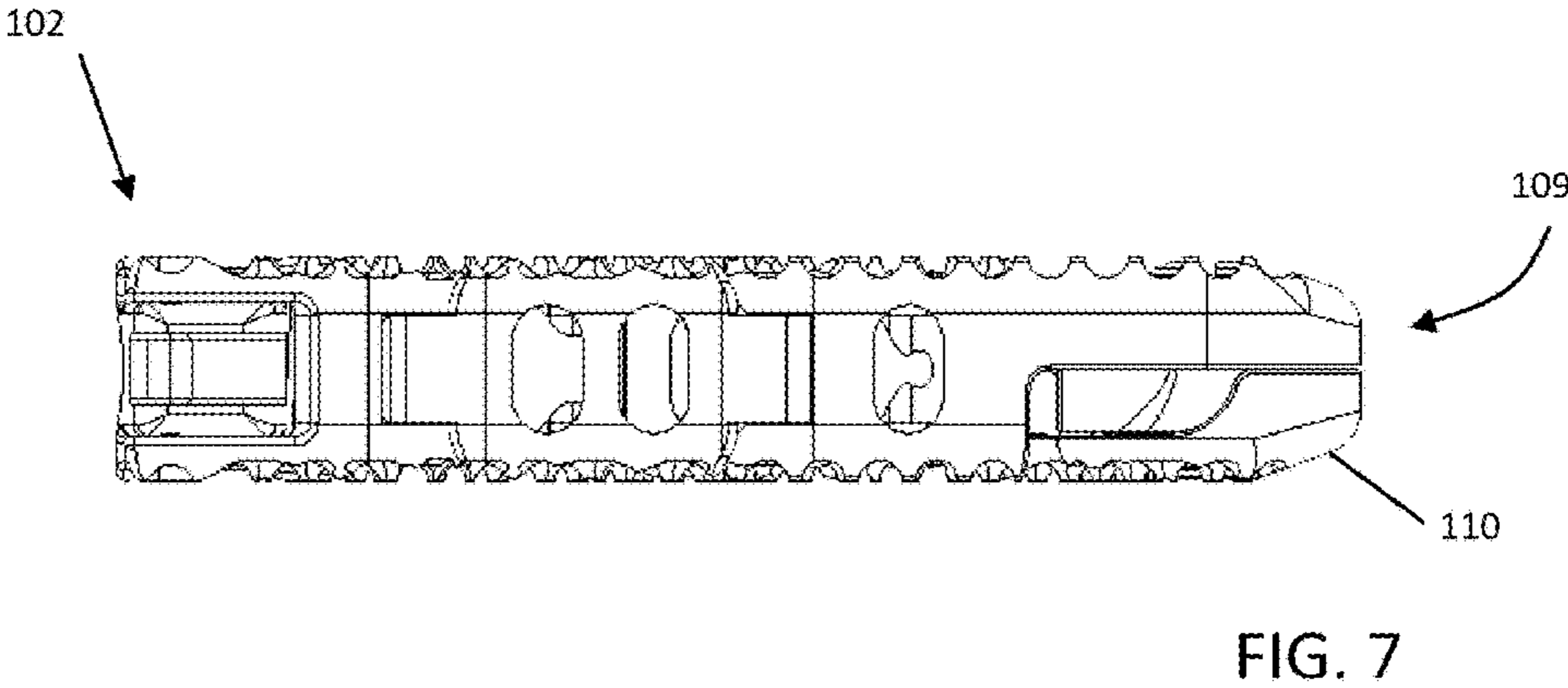
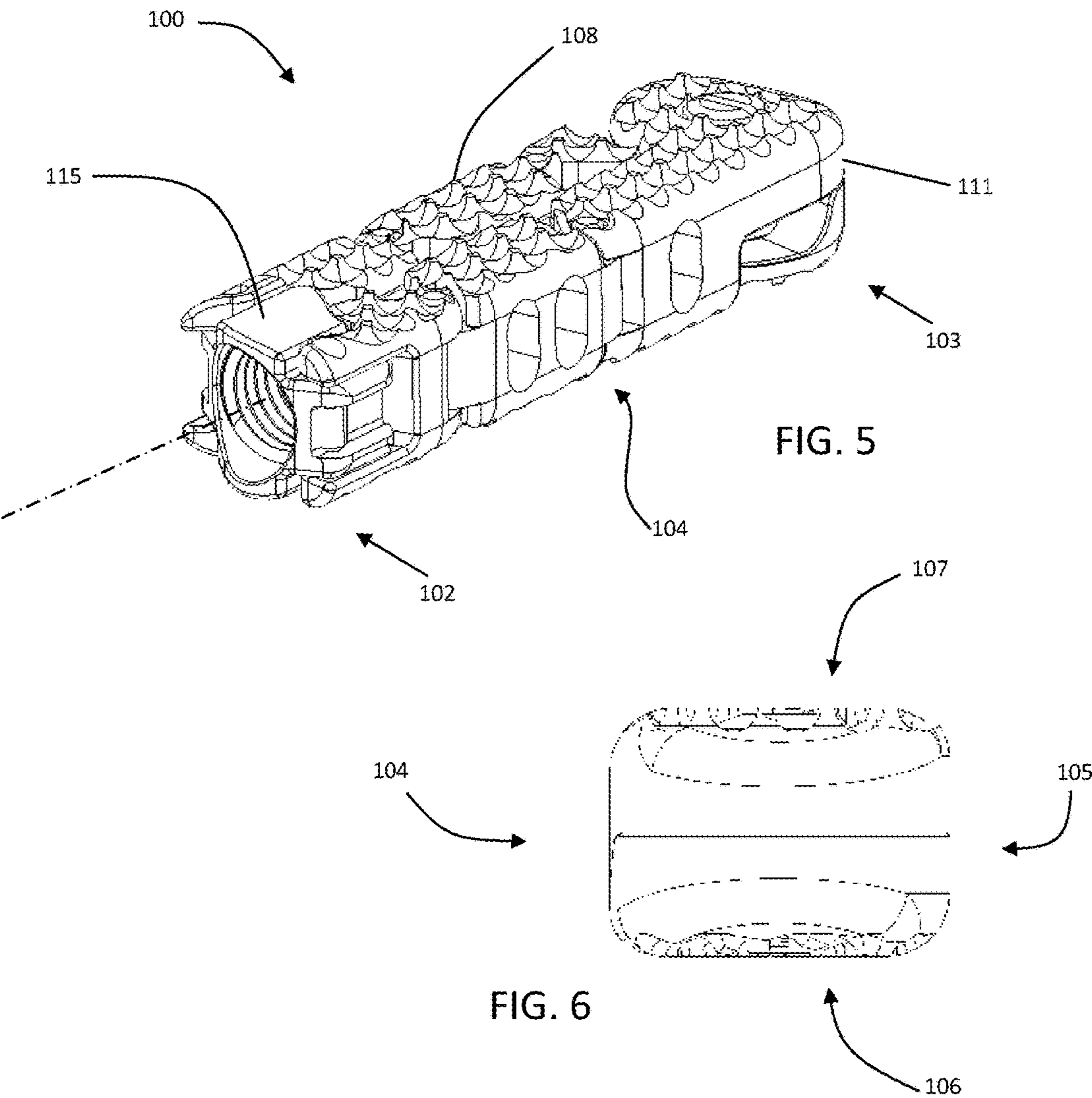
**ABSTRACT**

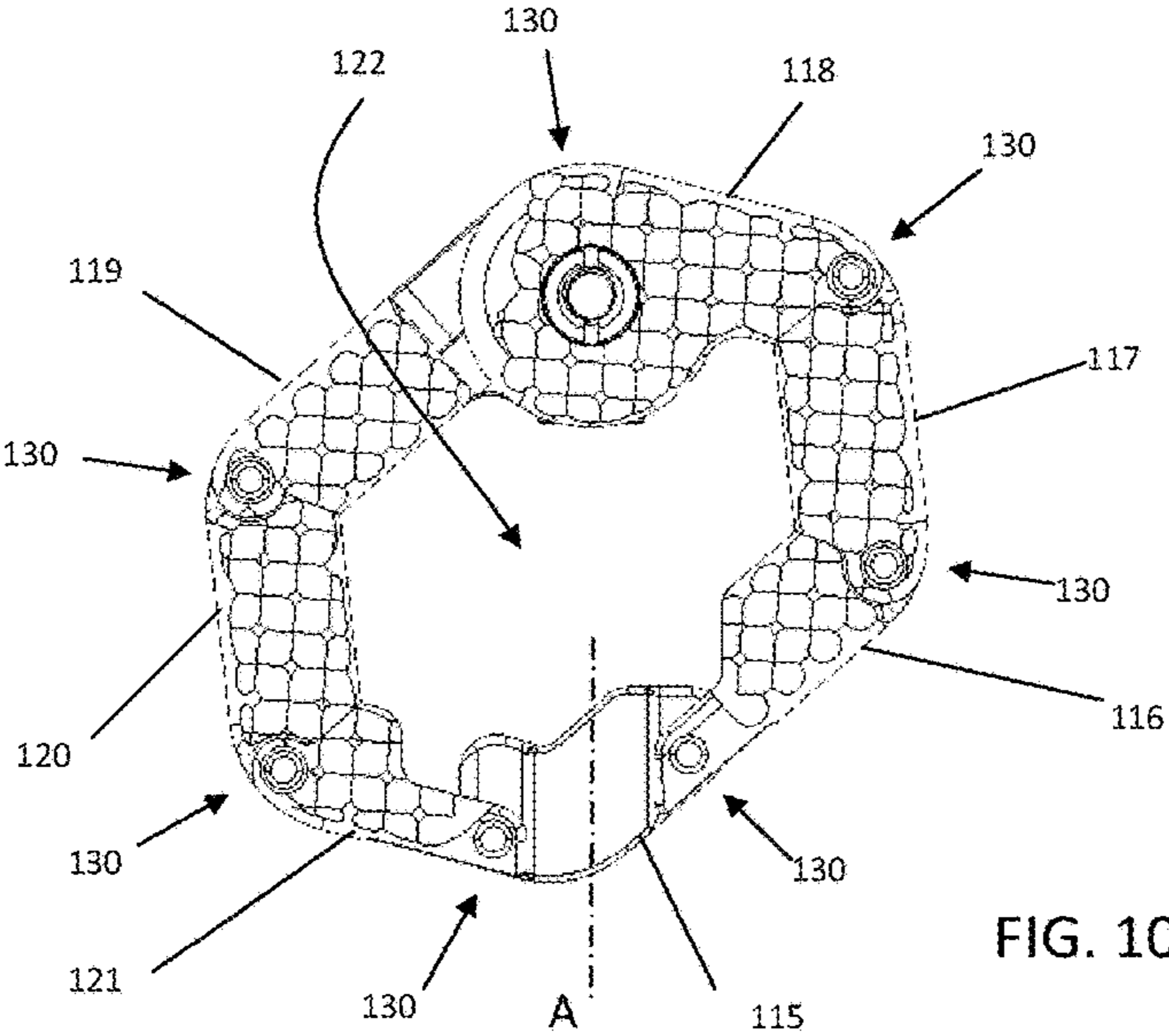
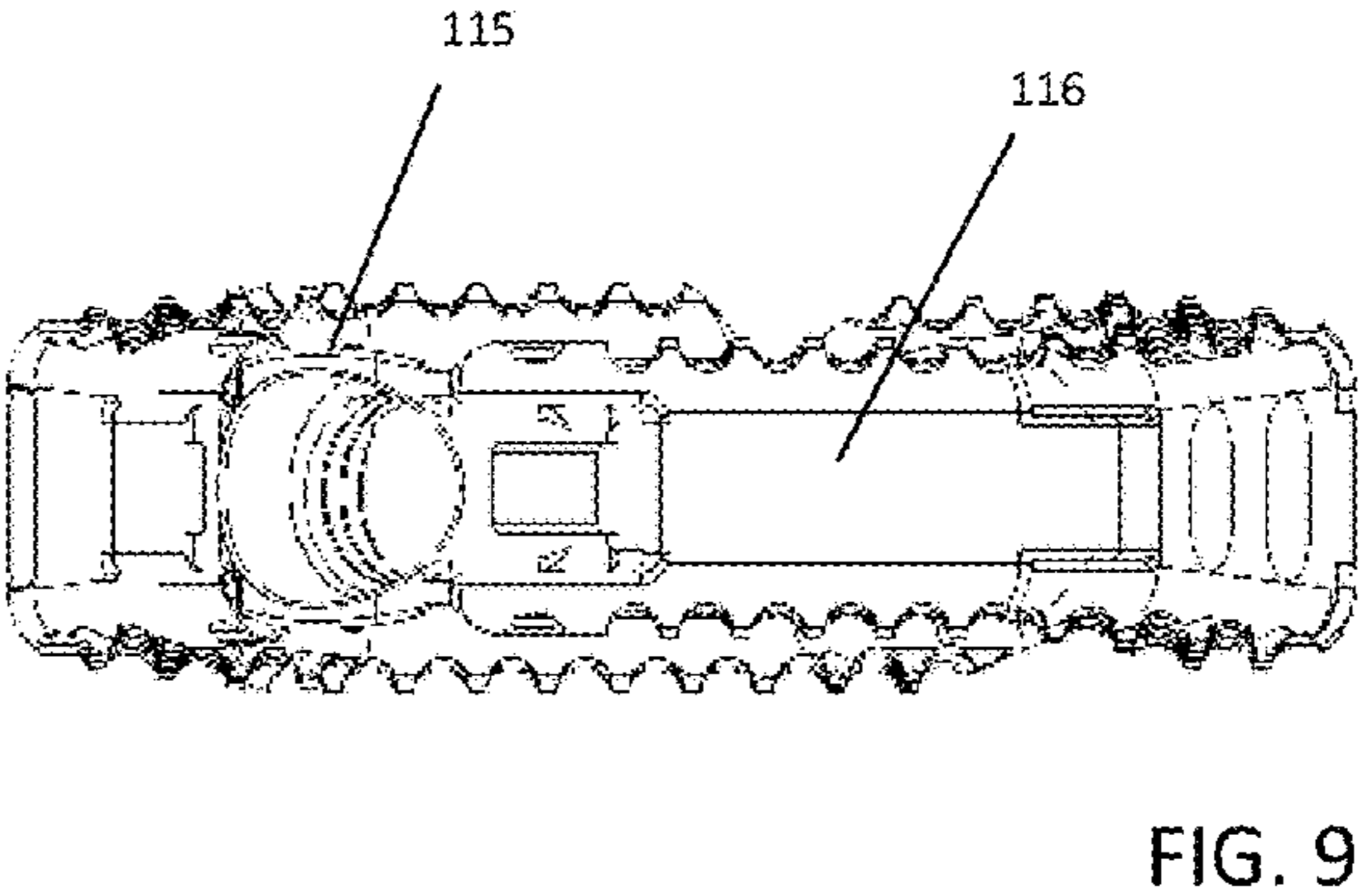
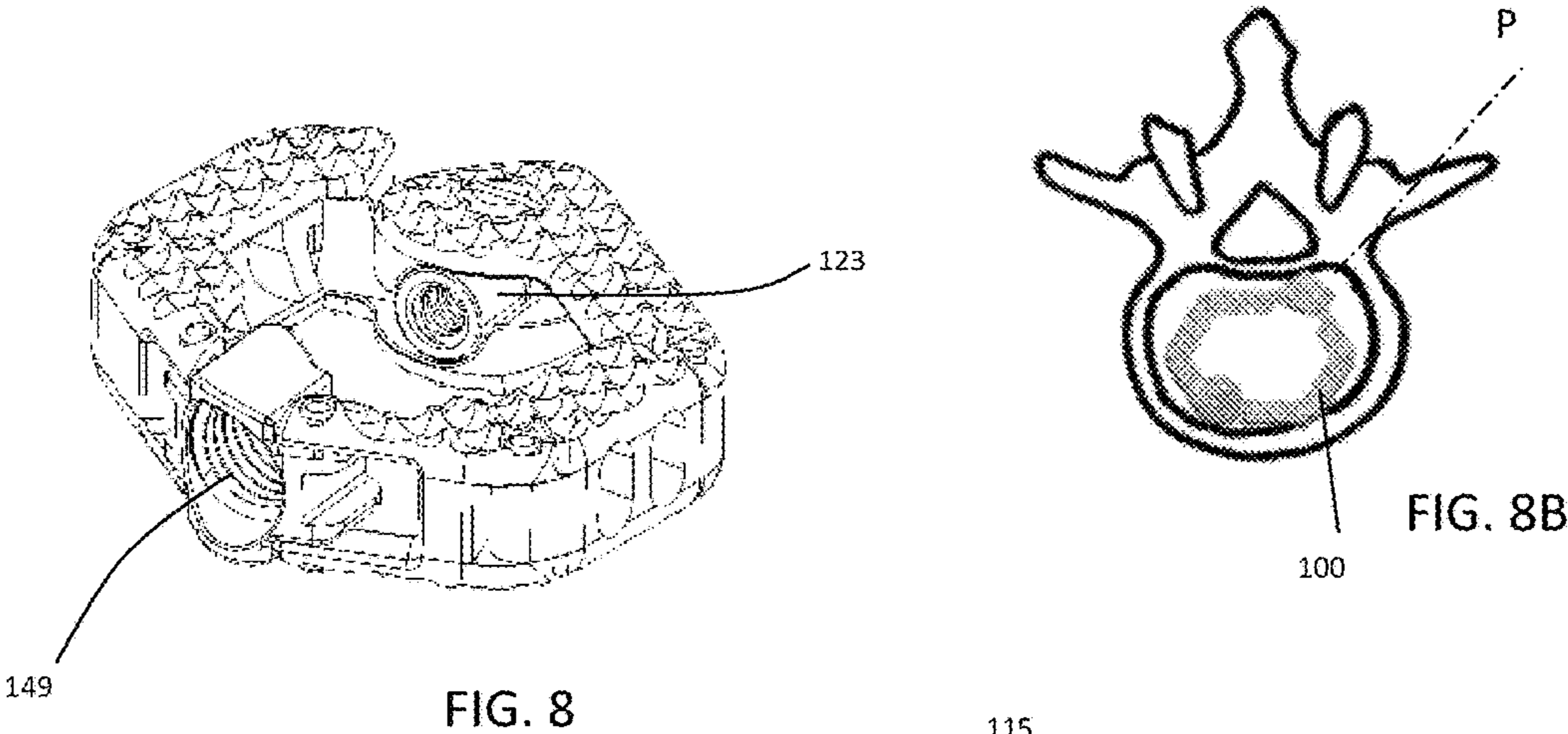
A system for performing interbody fusion surgery including an expandable intervertebral spacer and specialized instruments for choosing the correct size of implant, implanting the device within the intervertebral space, and for delivery of bone graft or bone substitute to the interior of the implant.











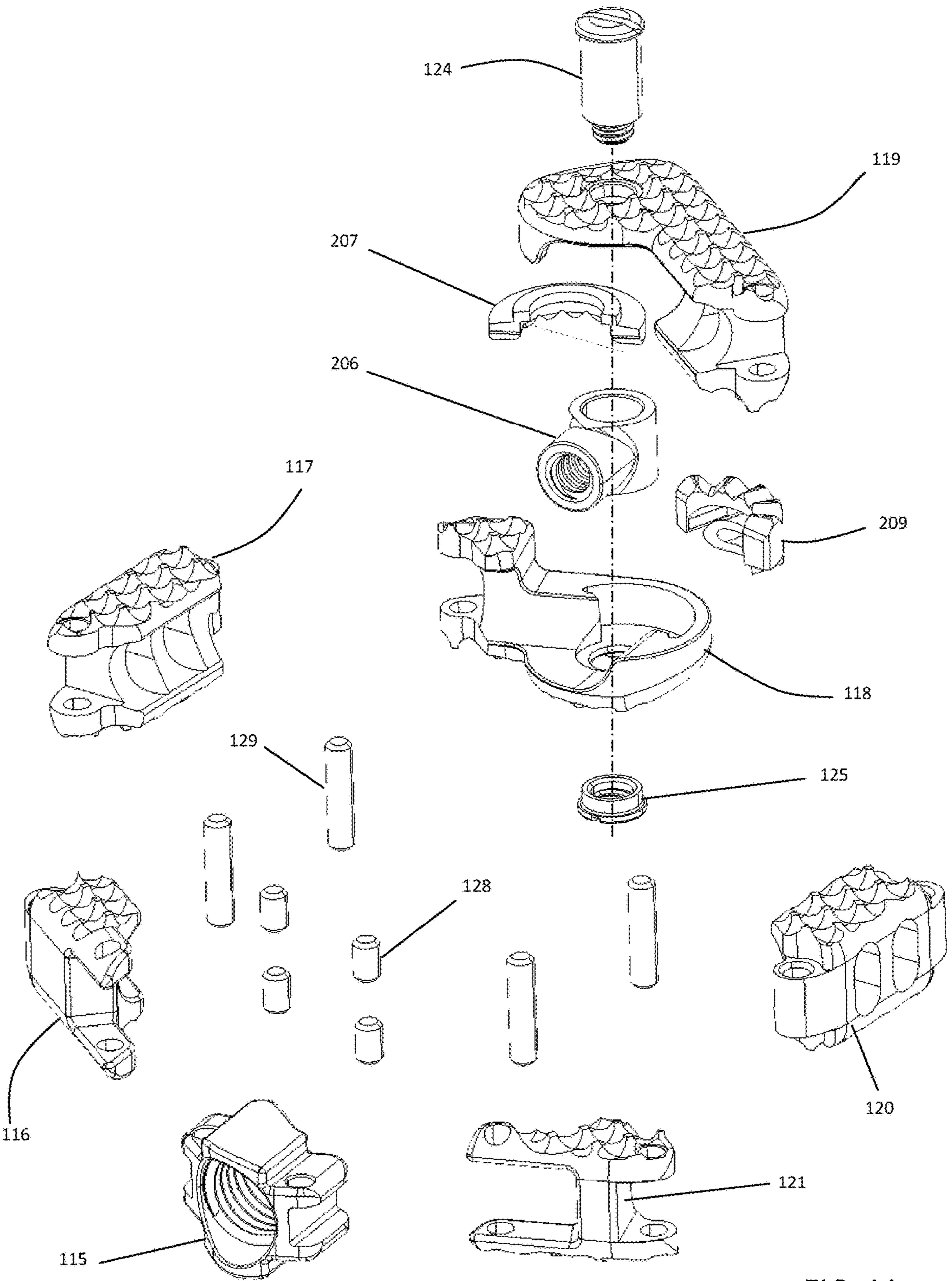


FIG. 11

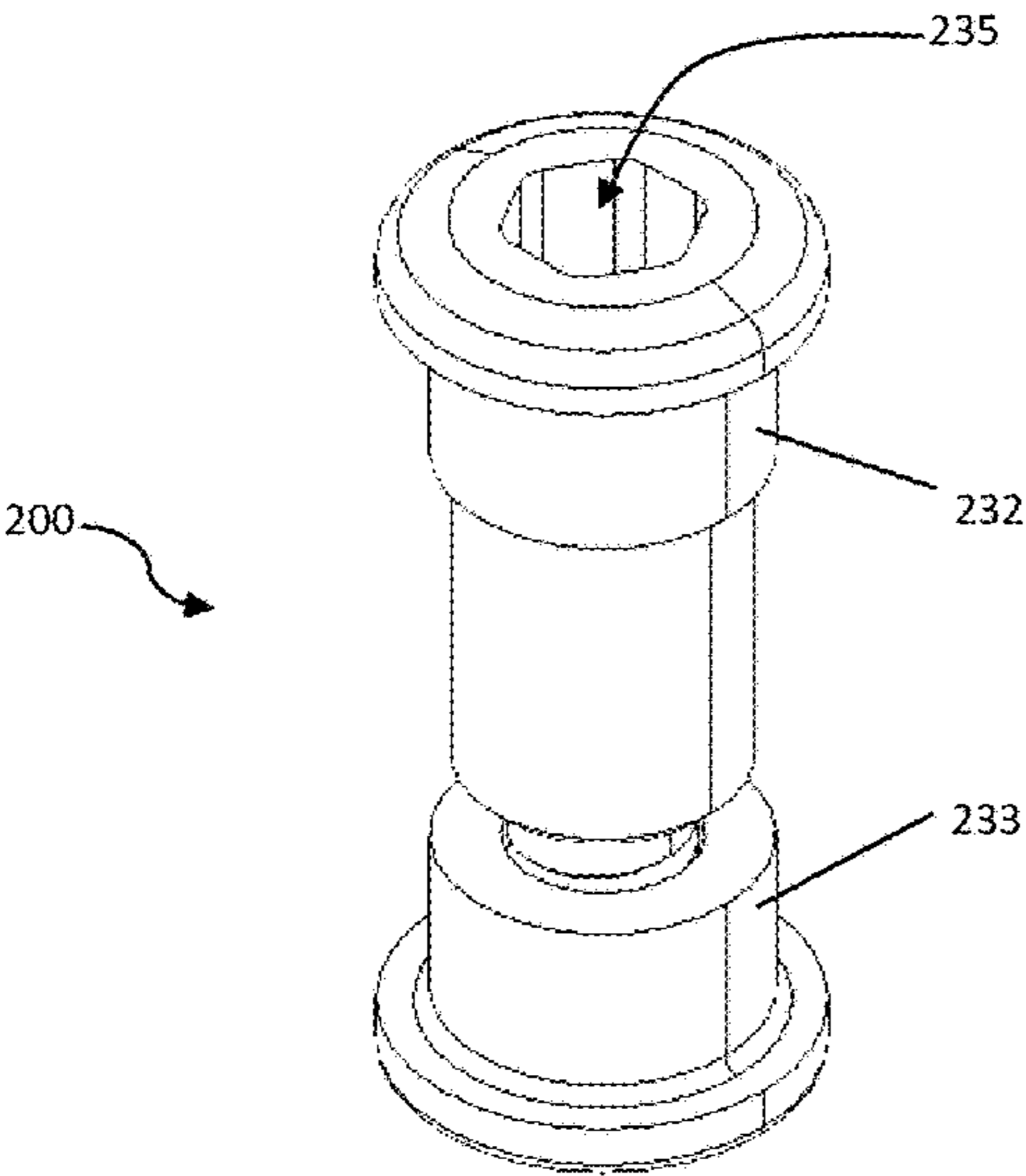


FIG. 12

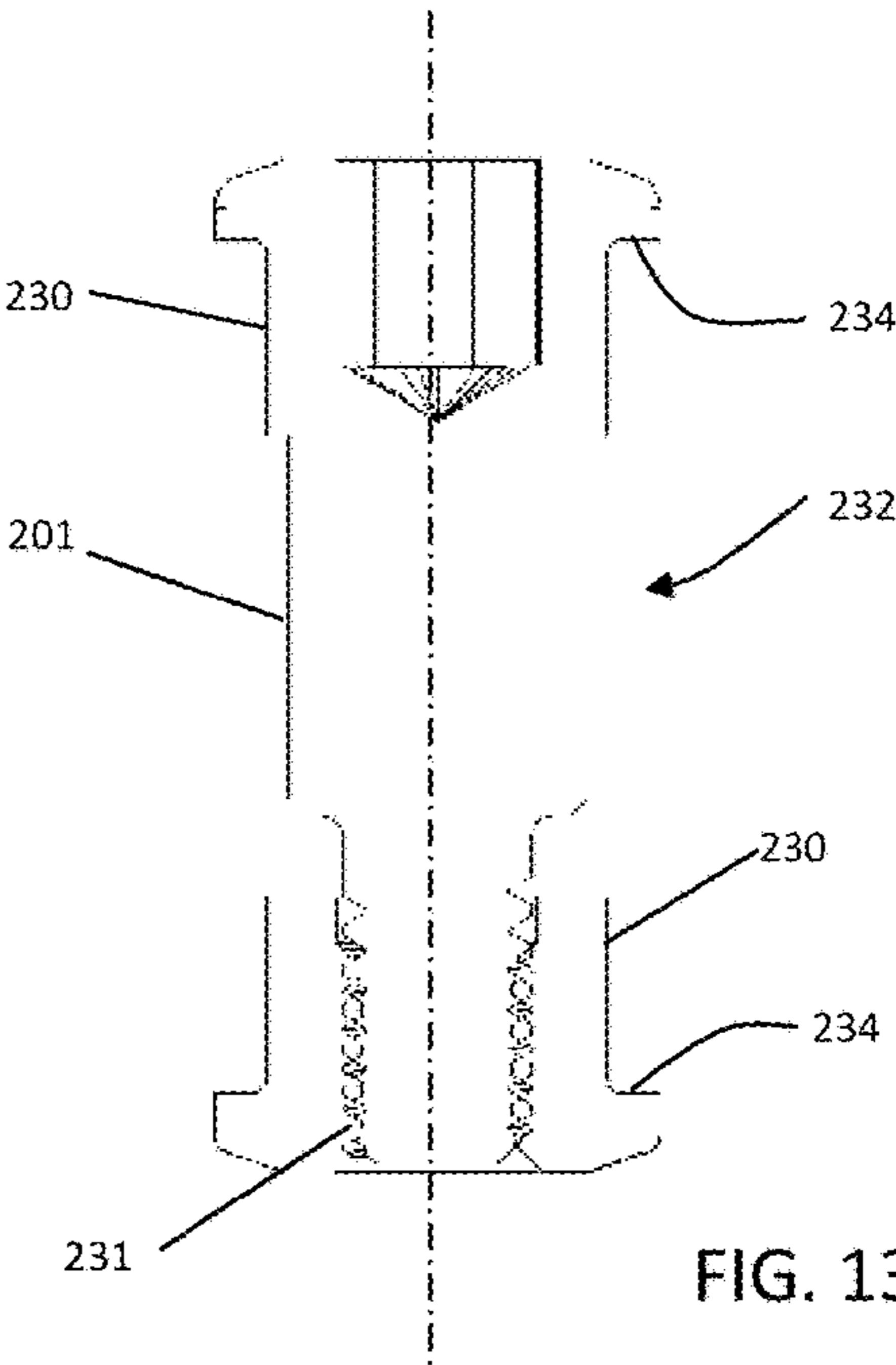


FIG. 13

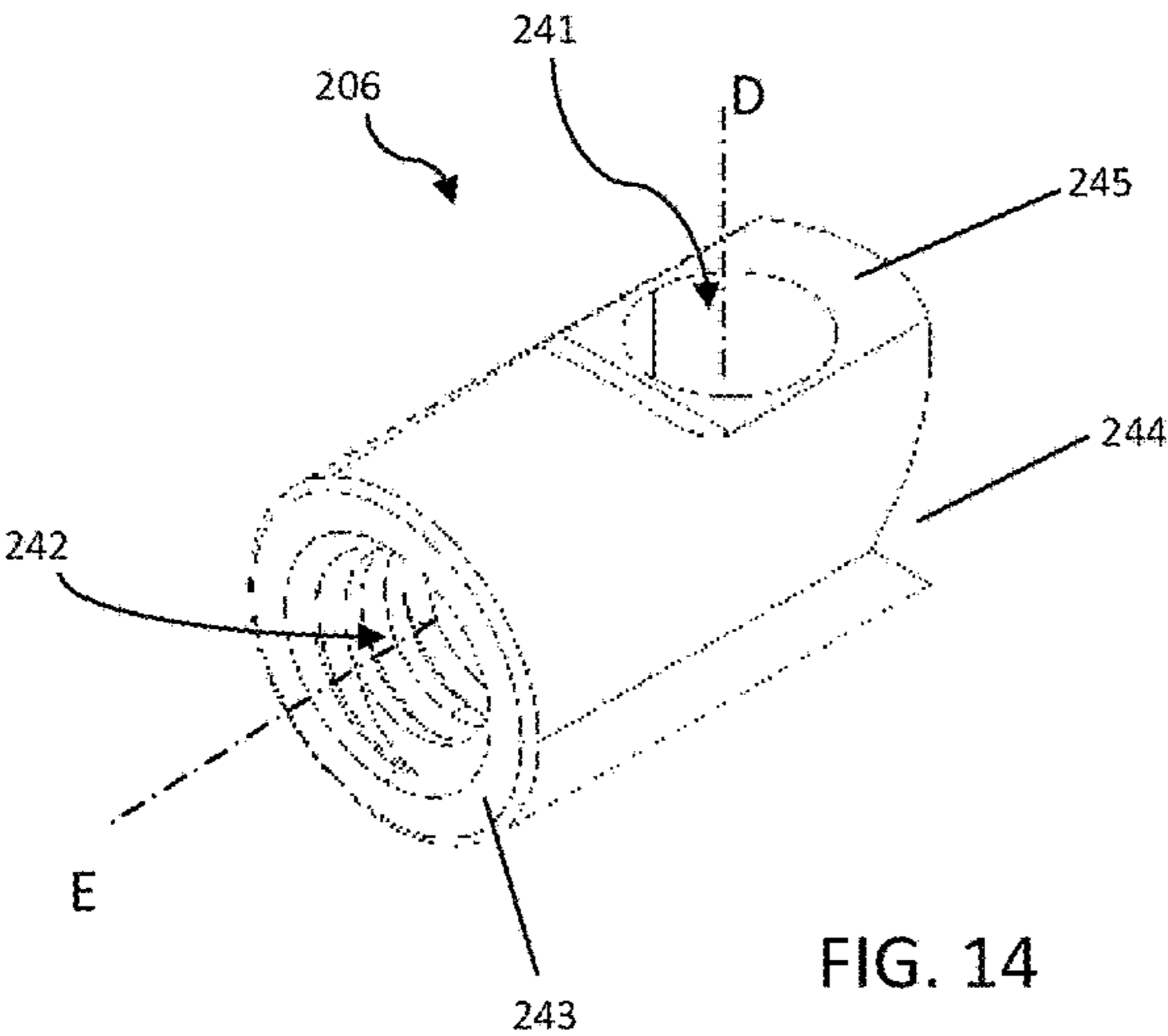


FIG. 14

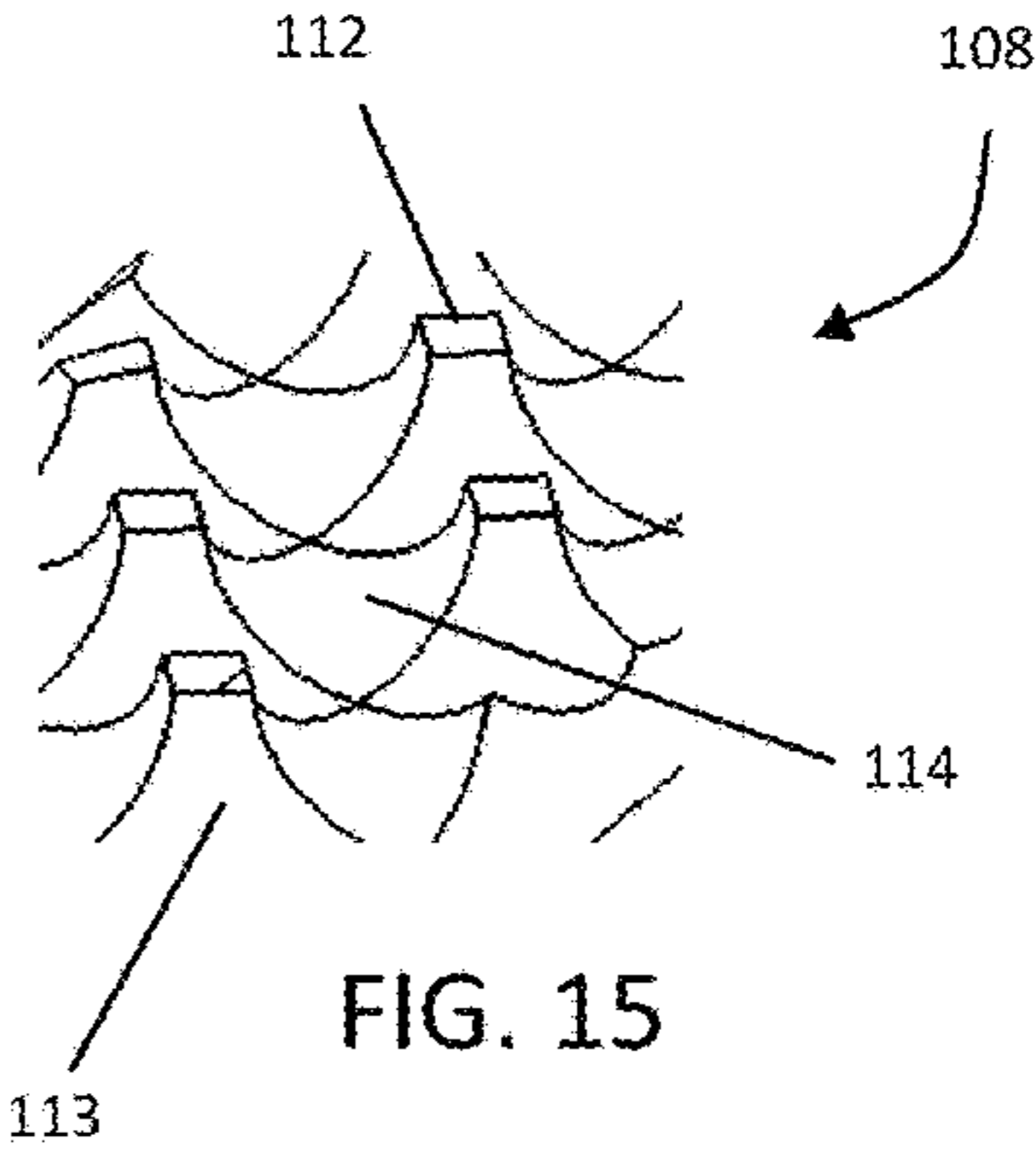
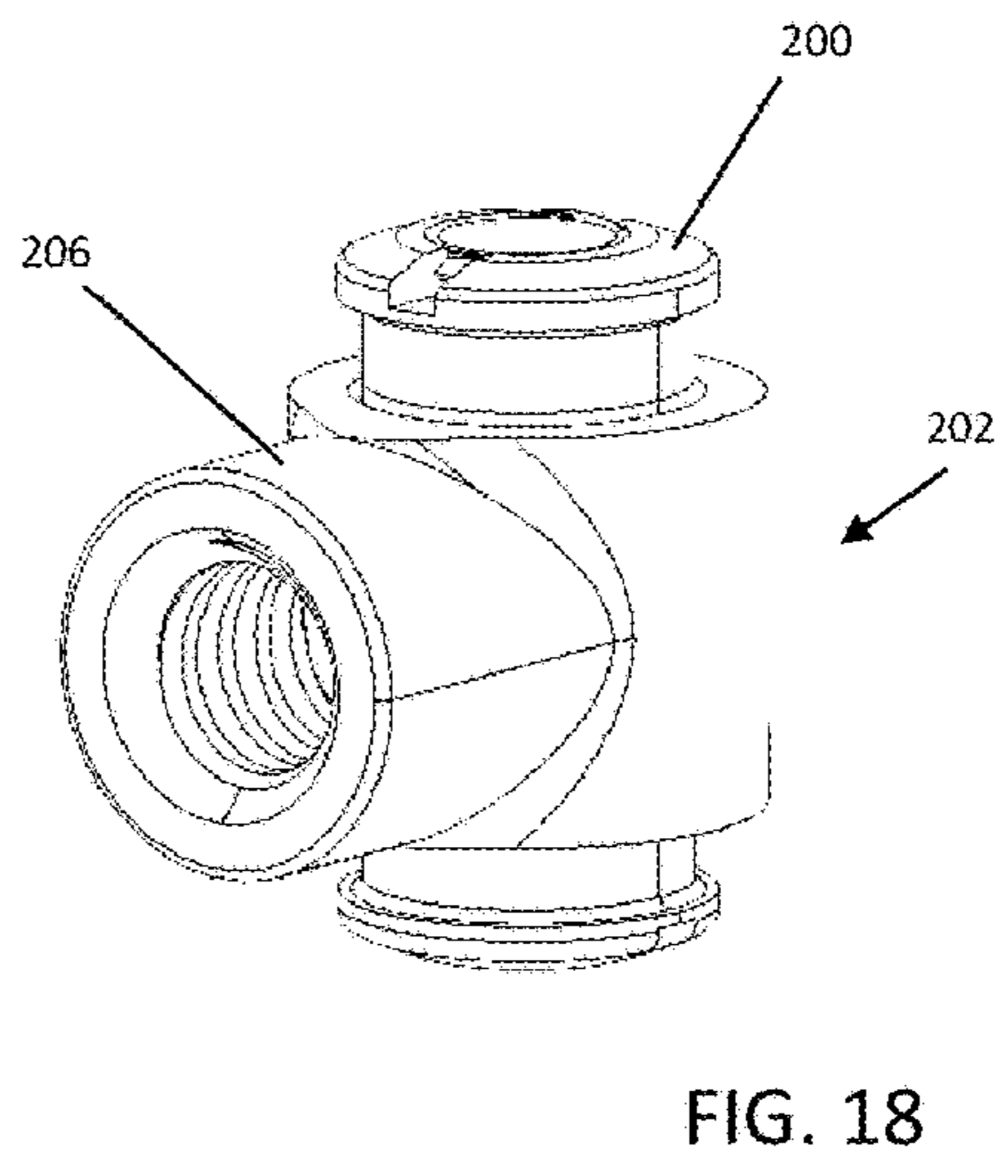
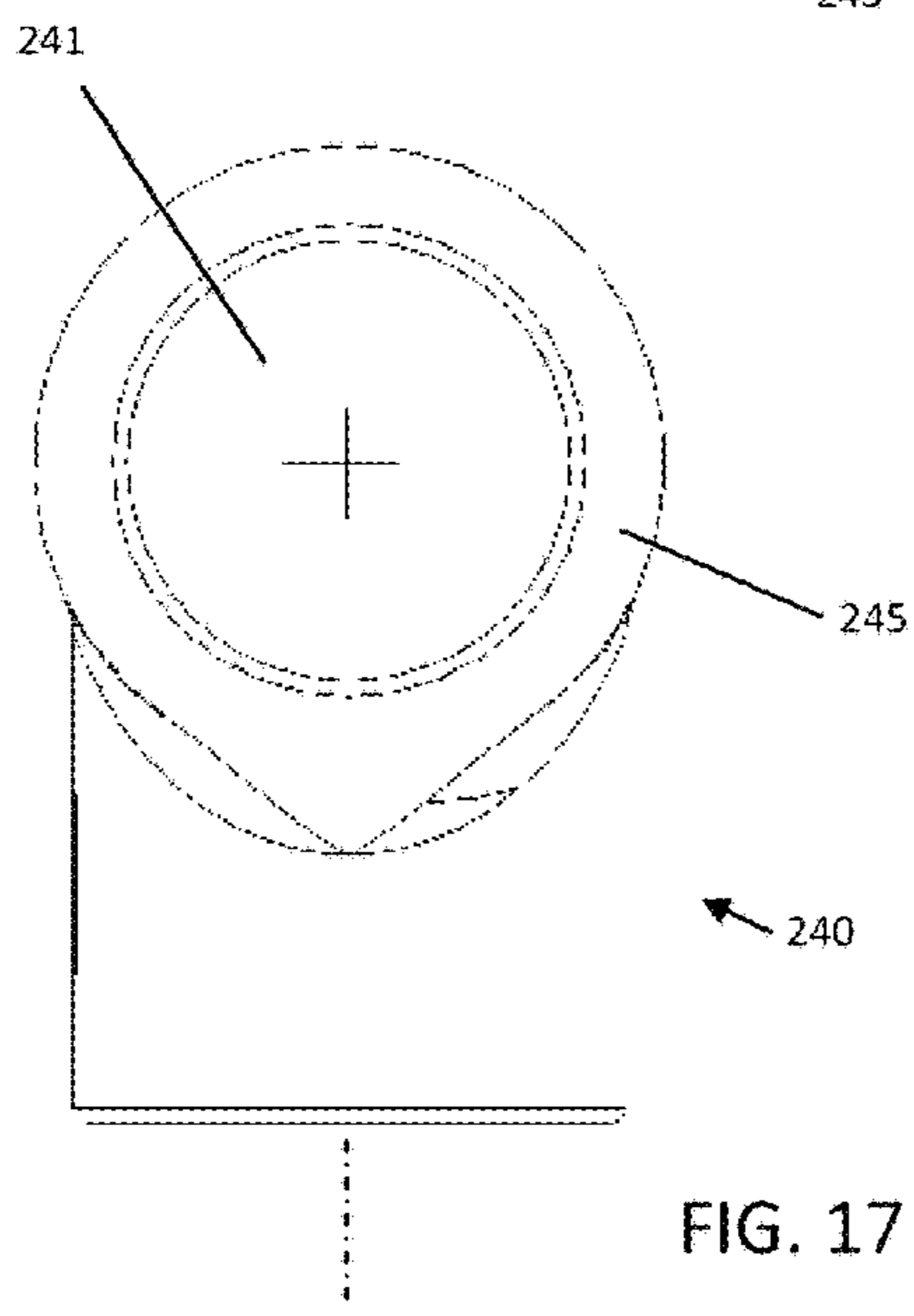
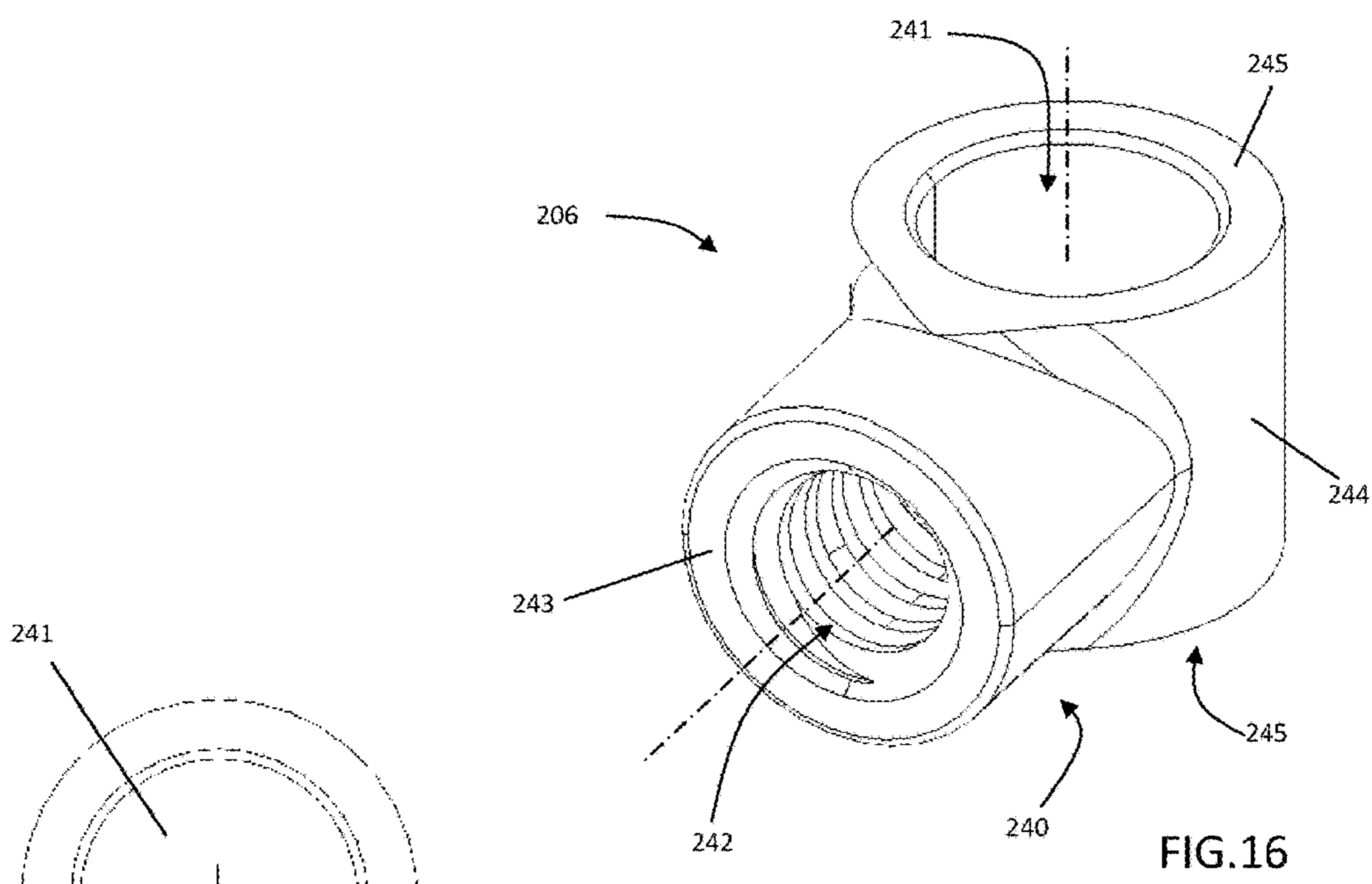


FIG. 15



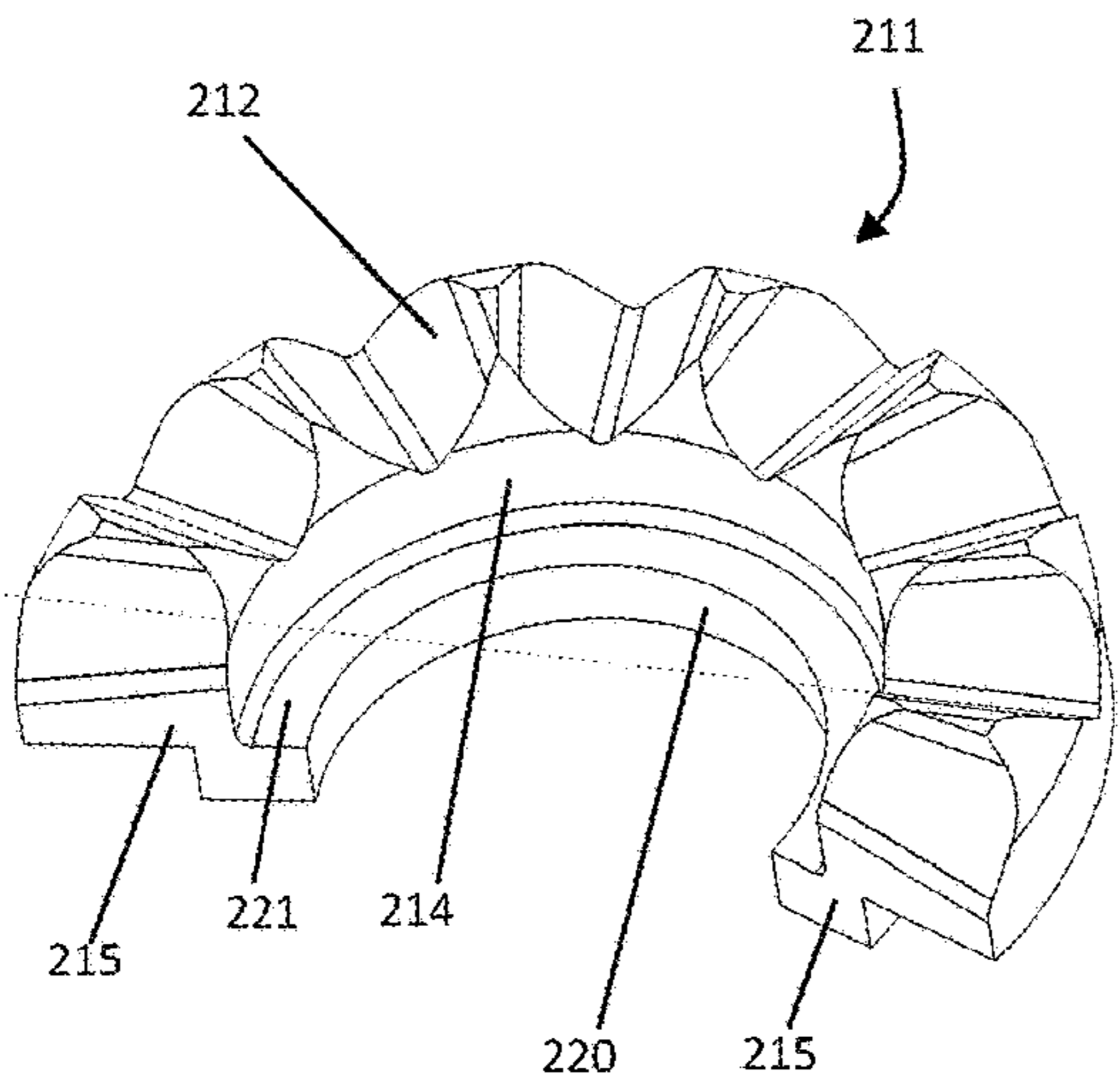


FIG. 19

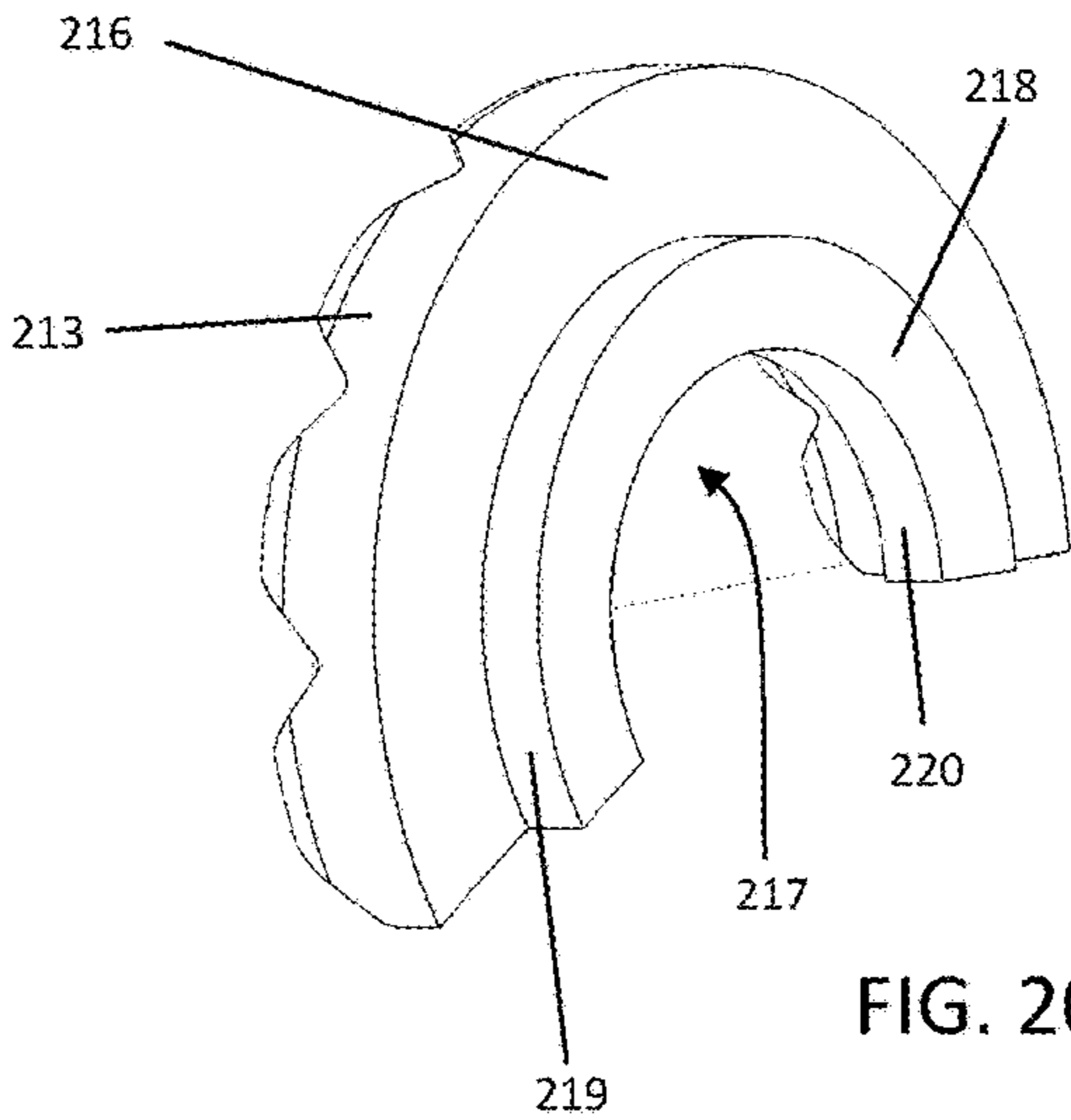


FIG. 20

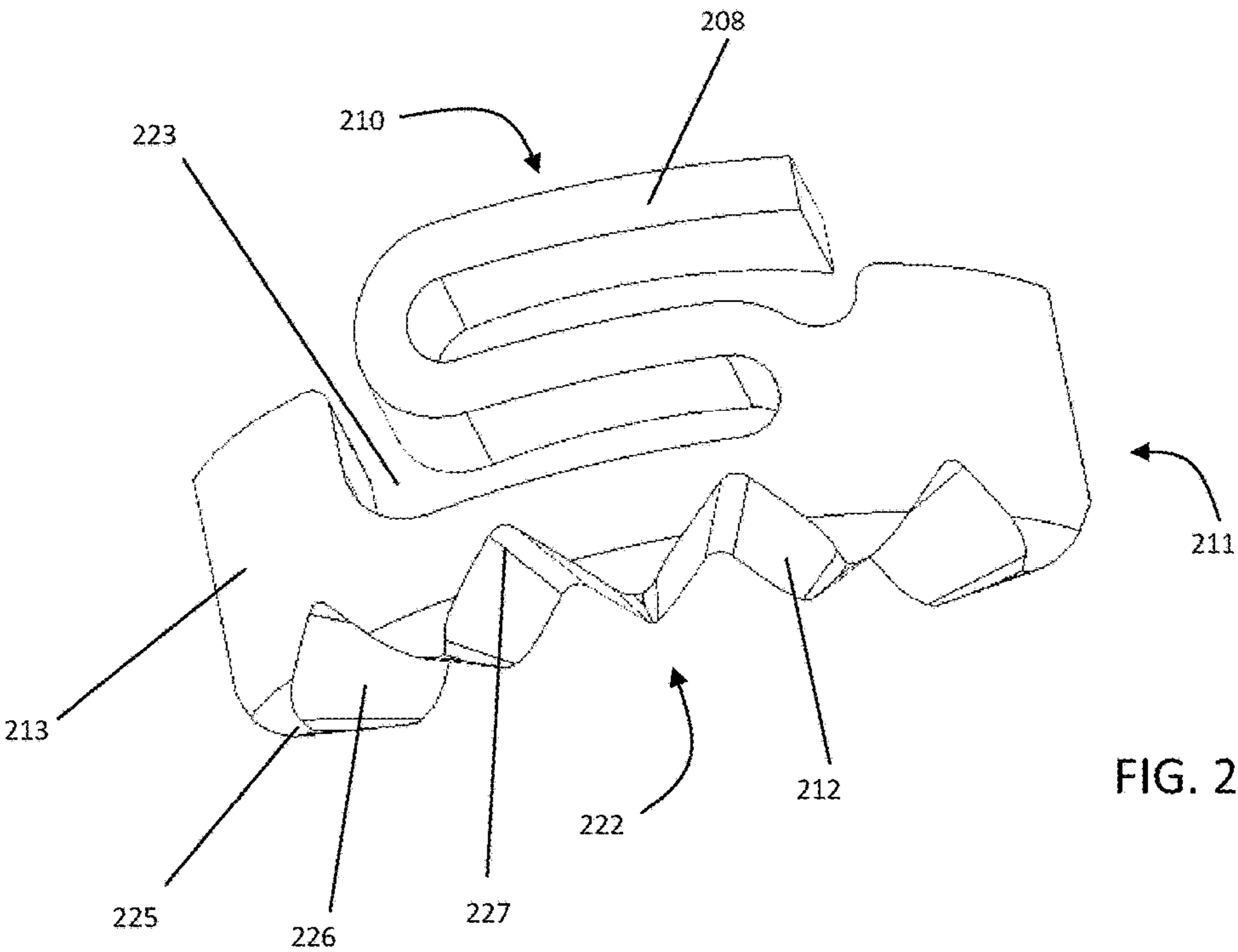
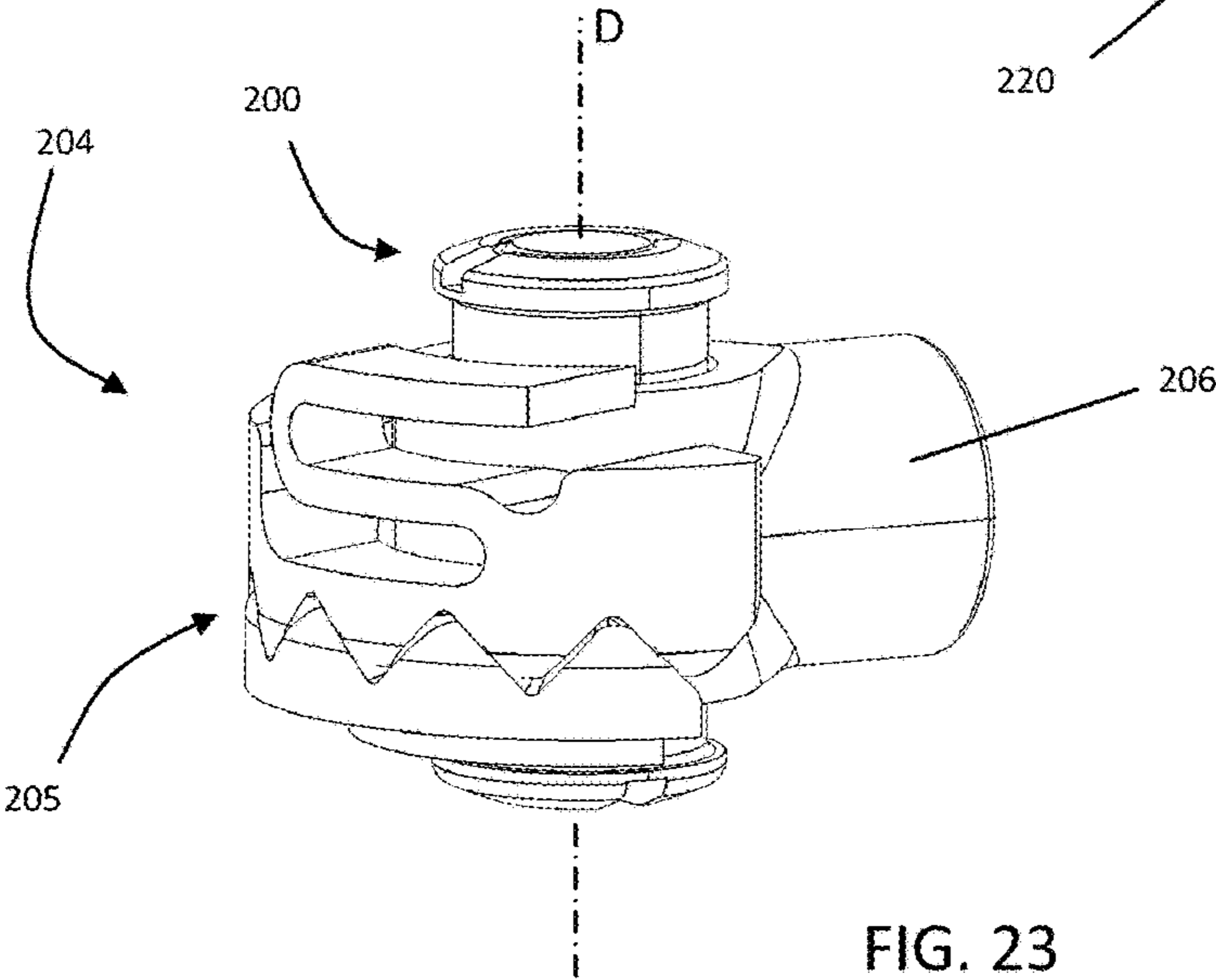
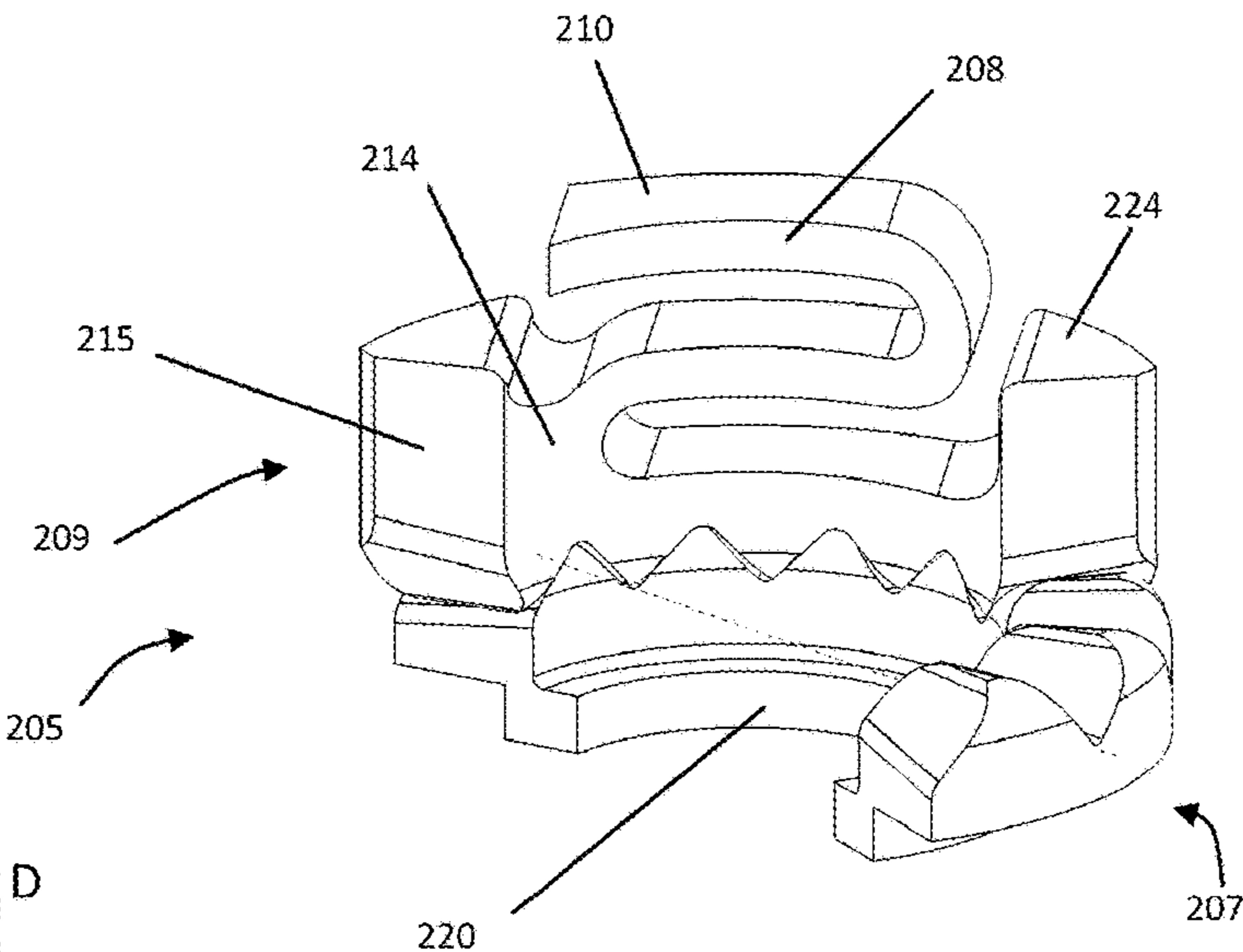
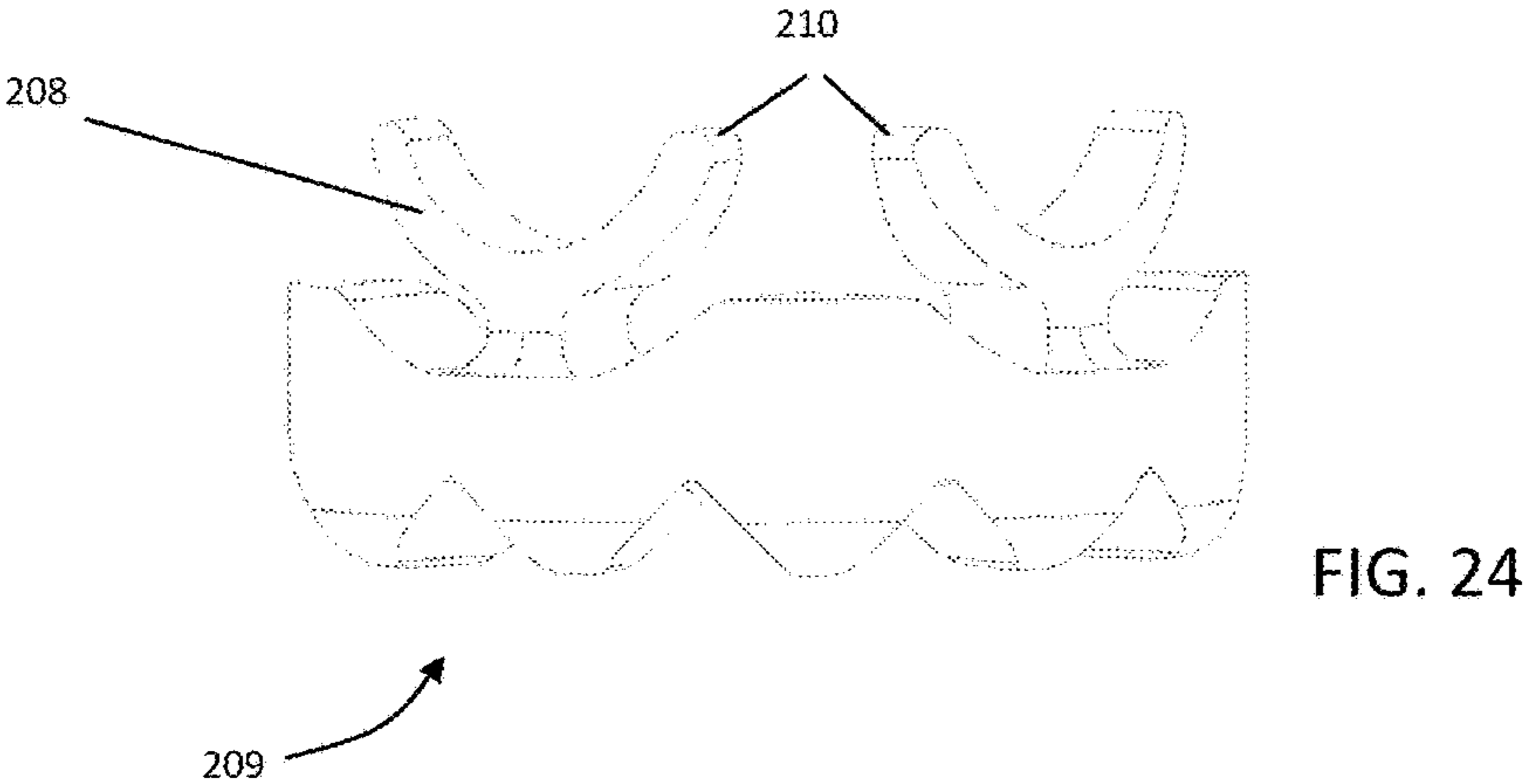
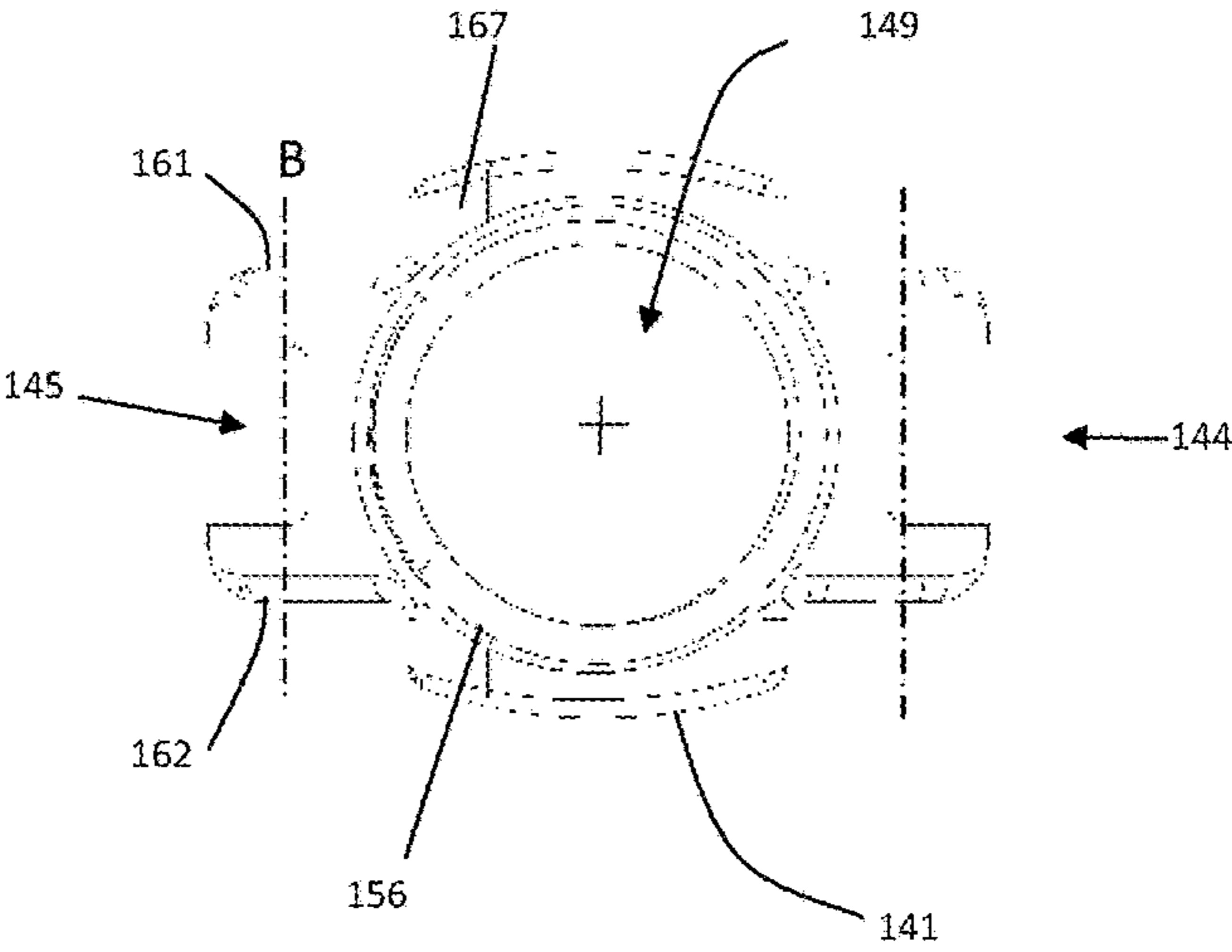
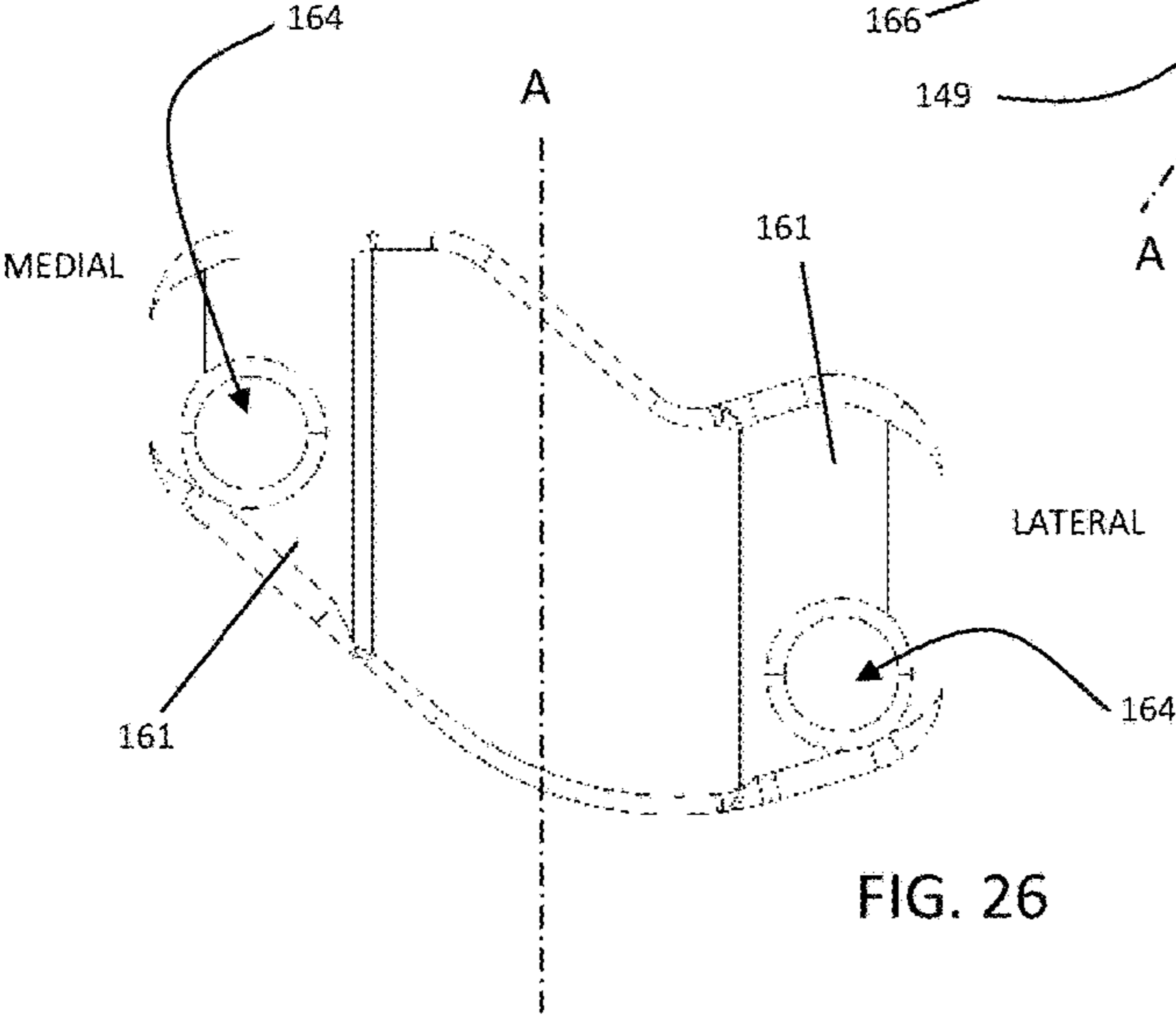
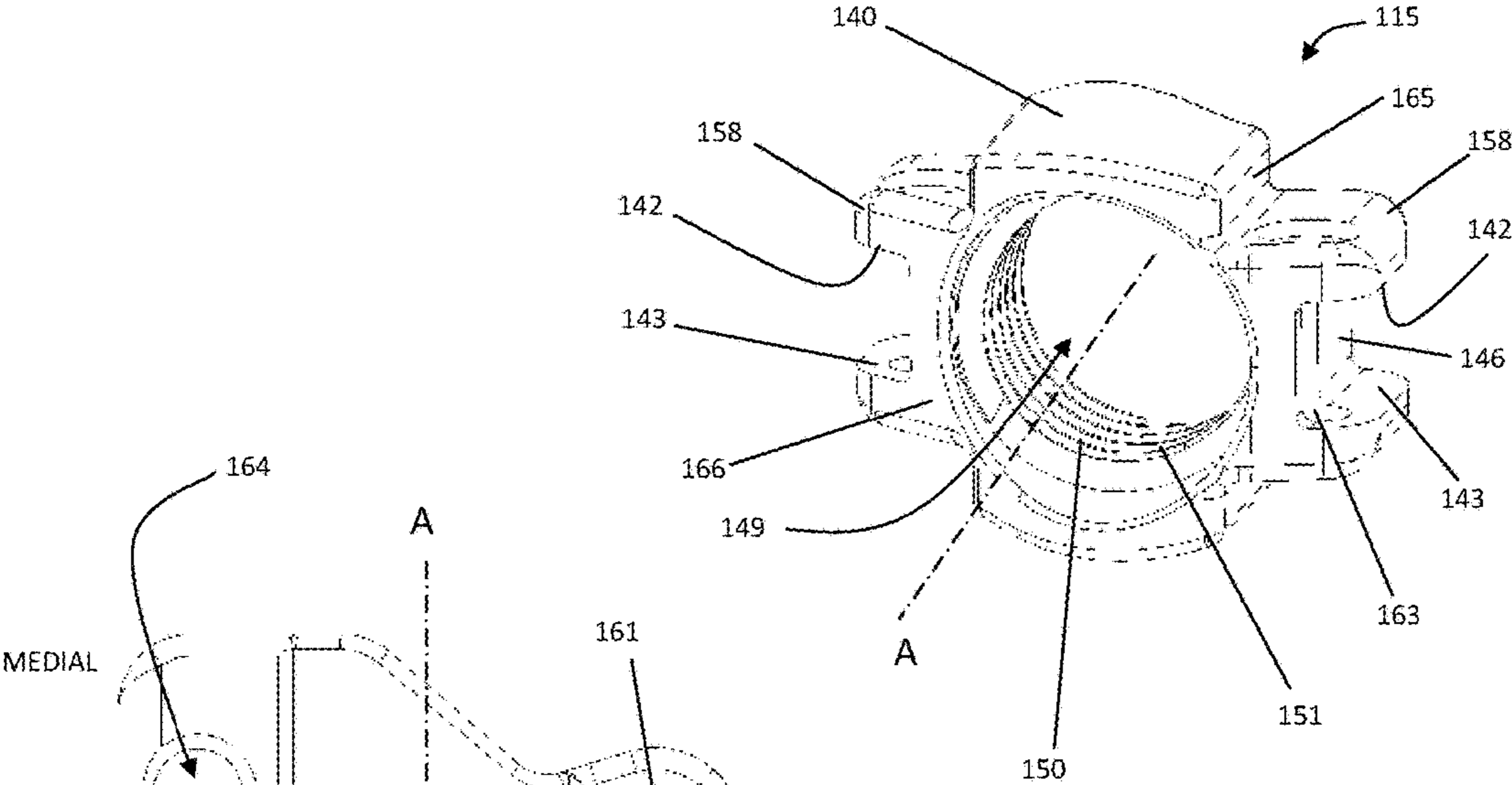
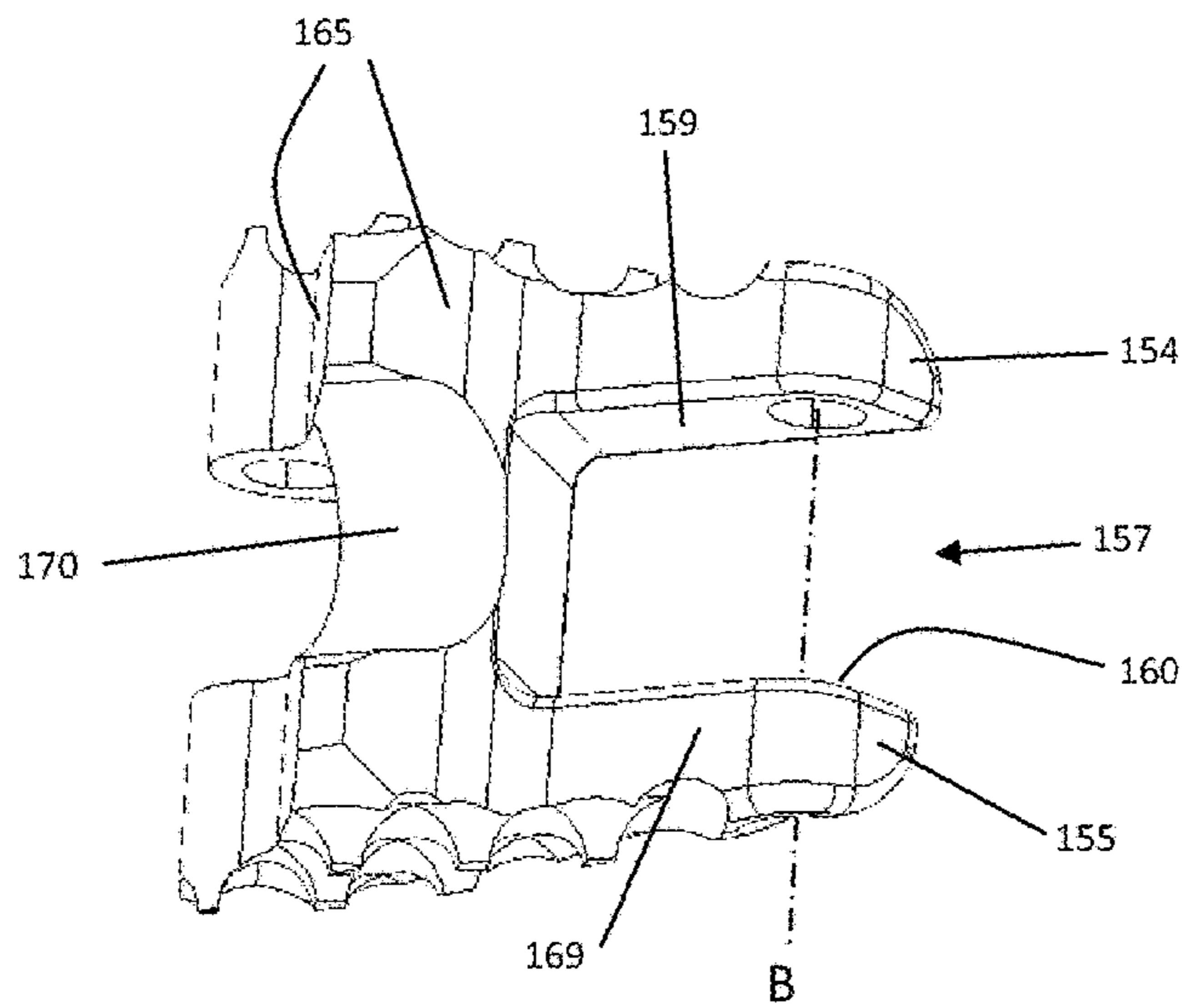
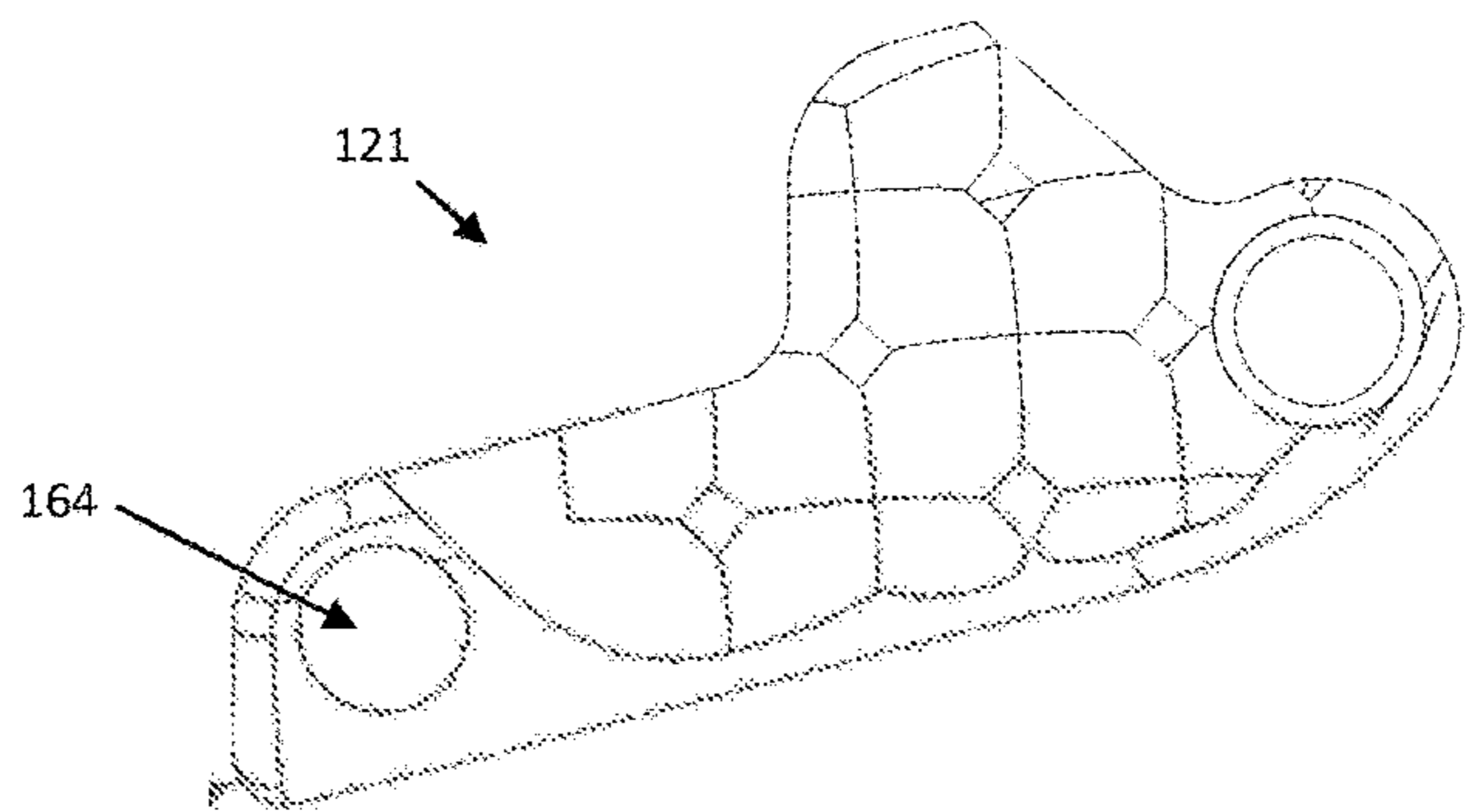
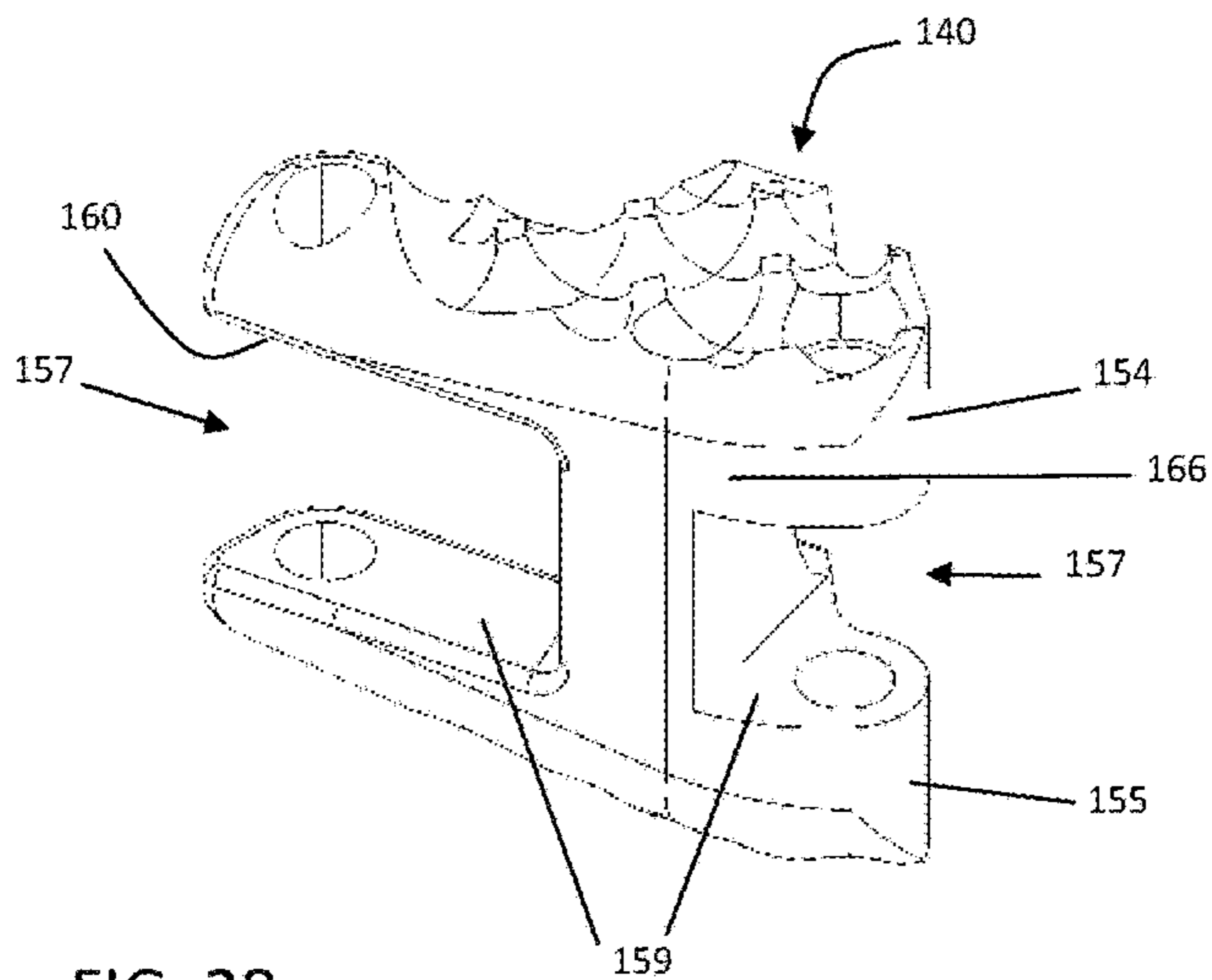
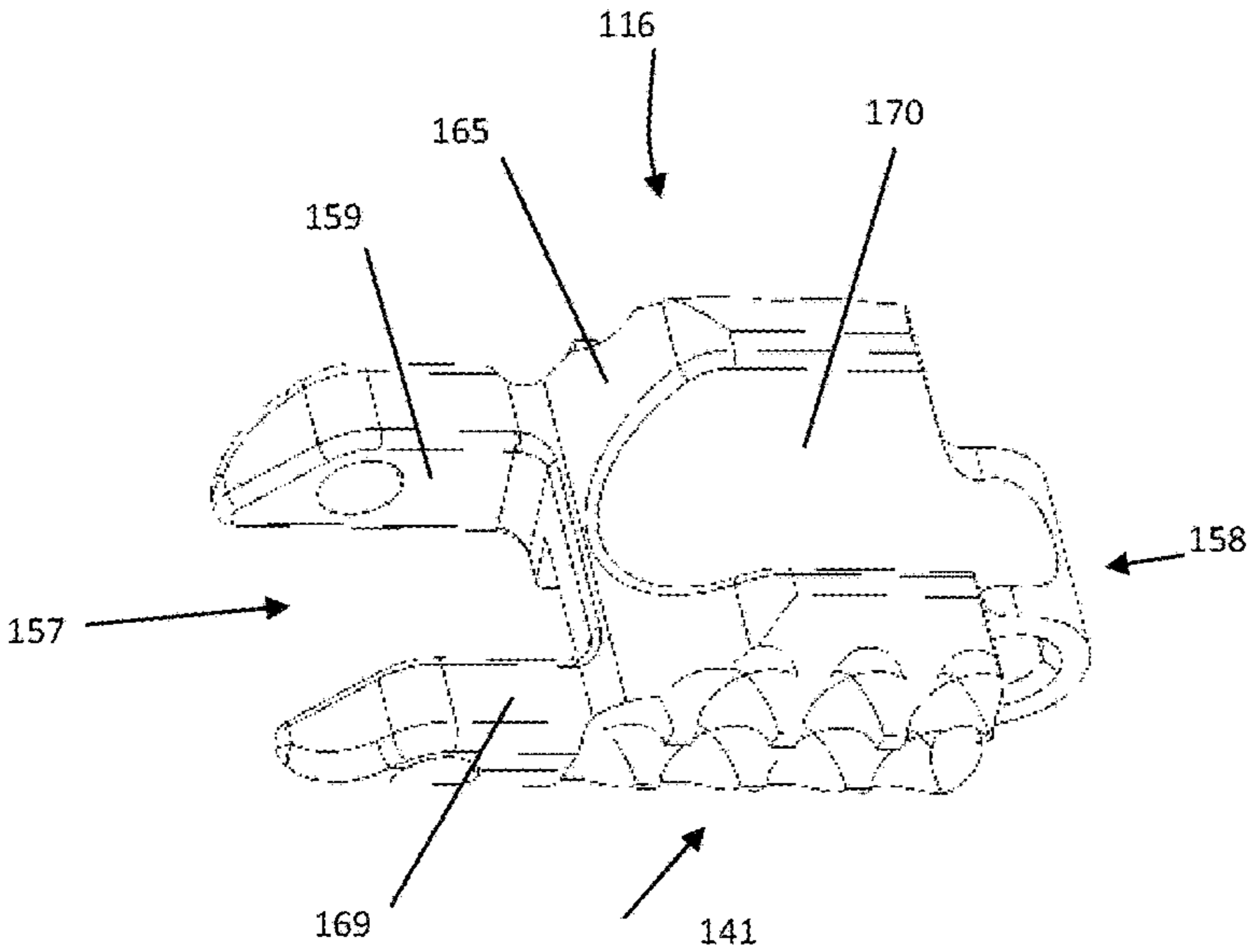
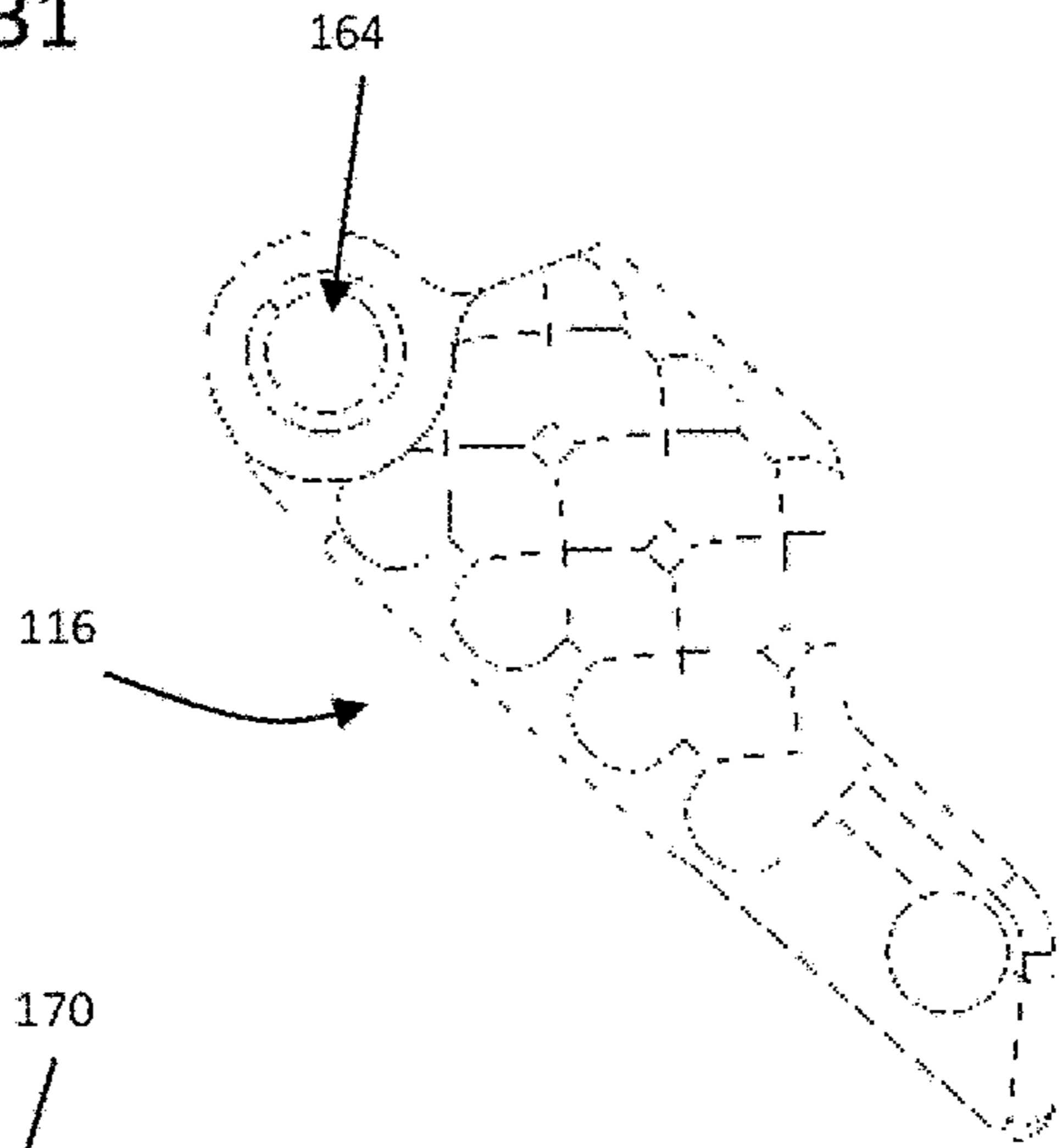
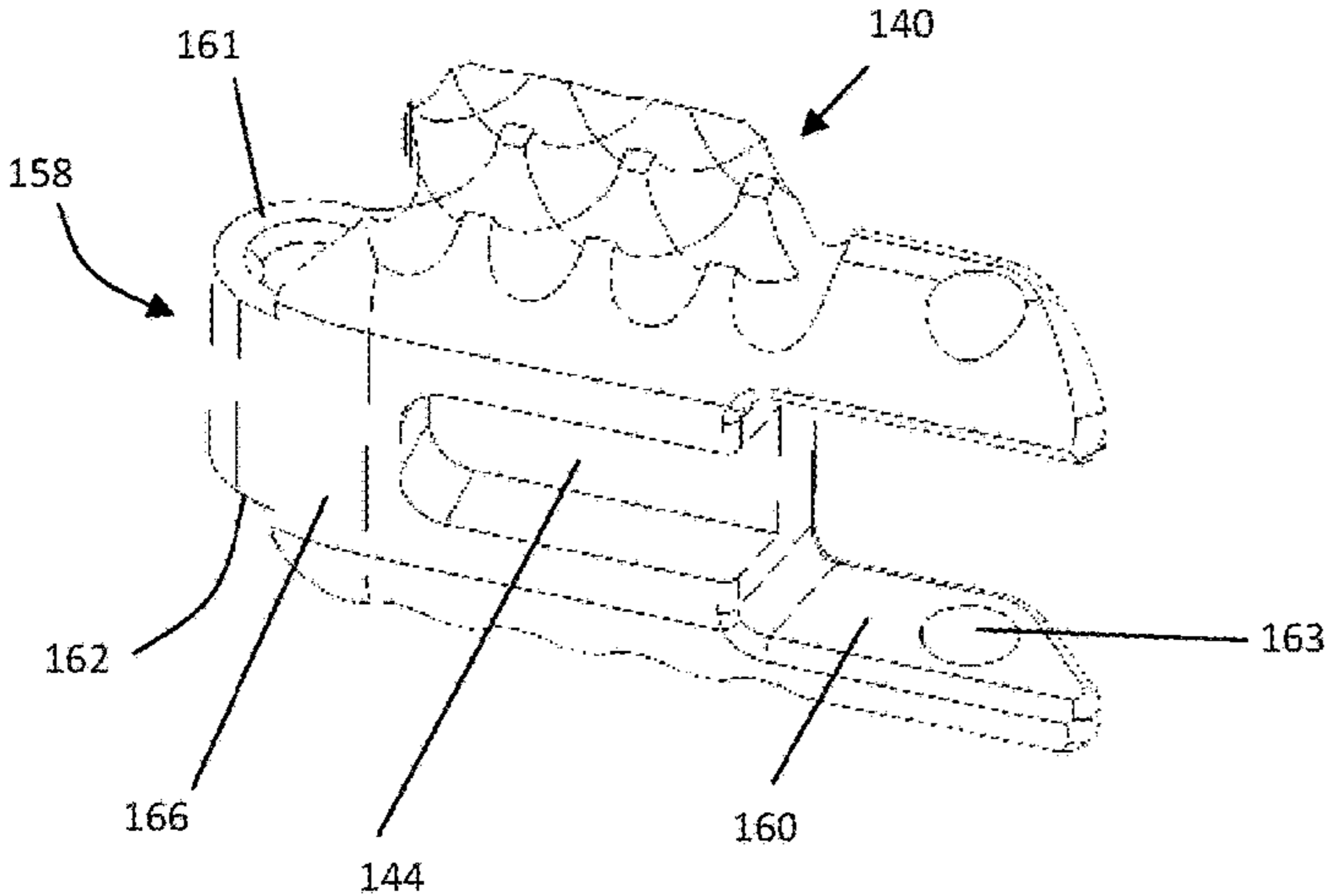


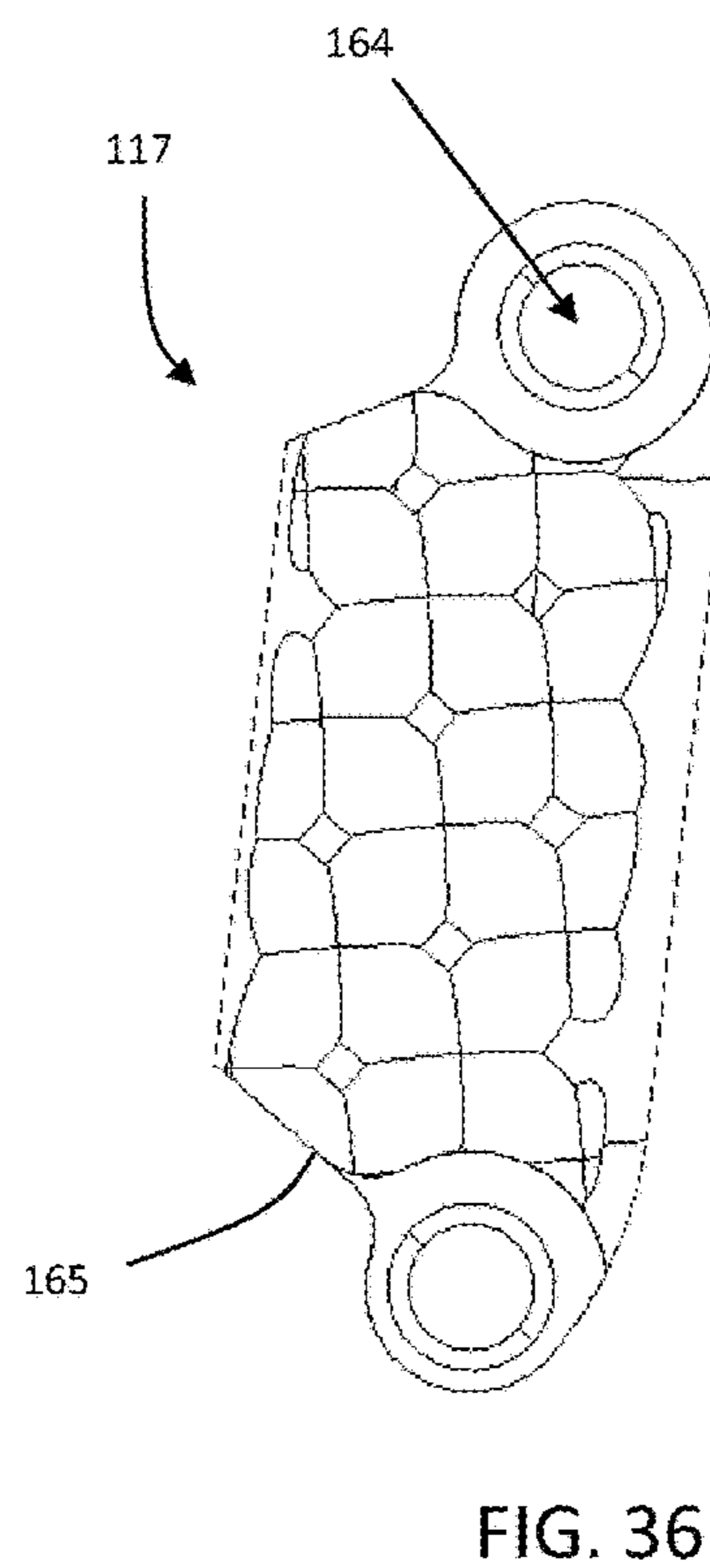
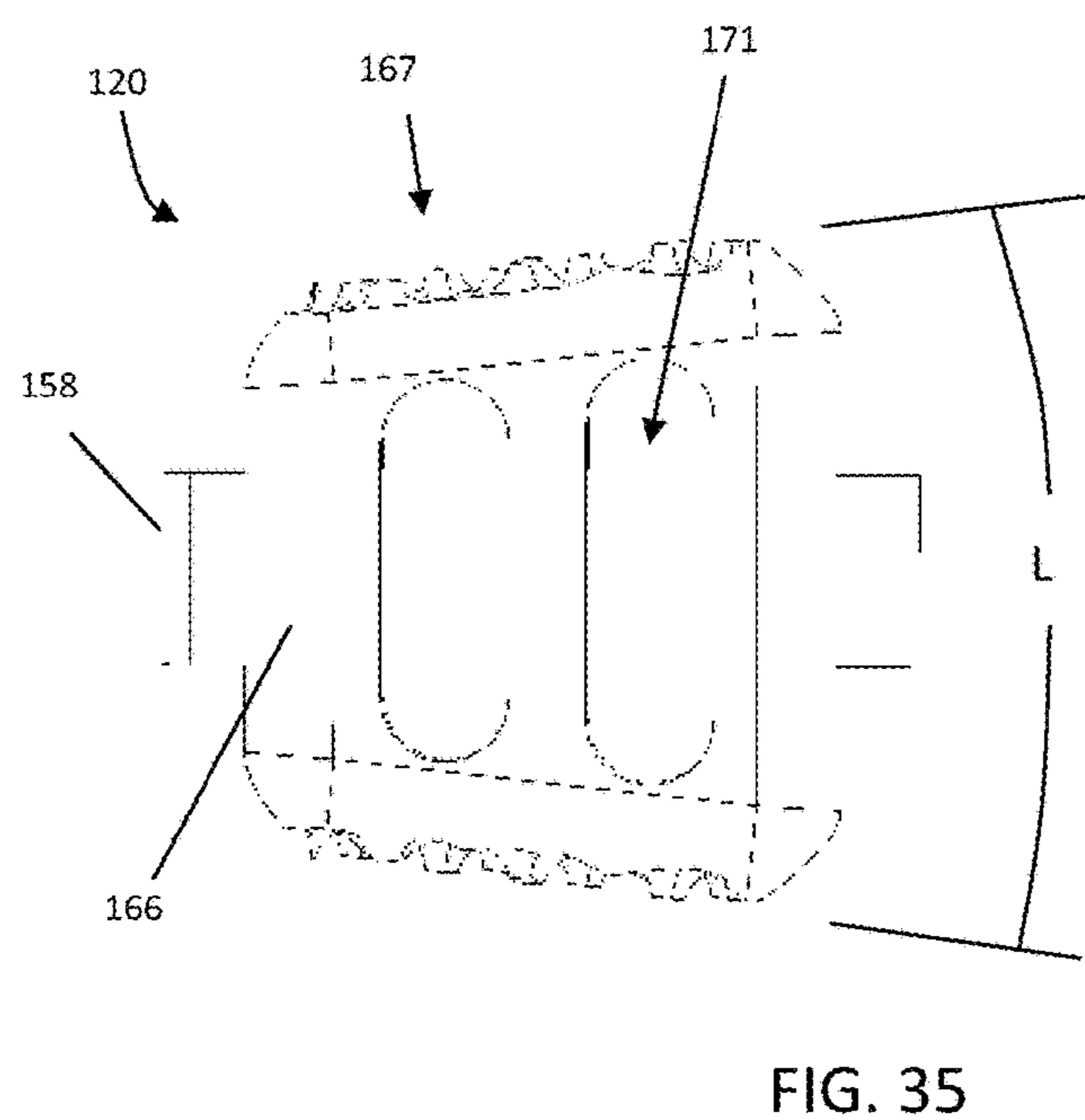
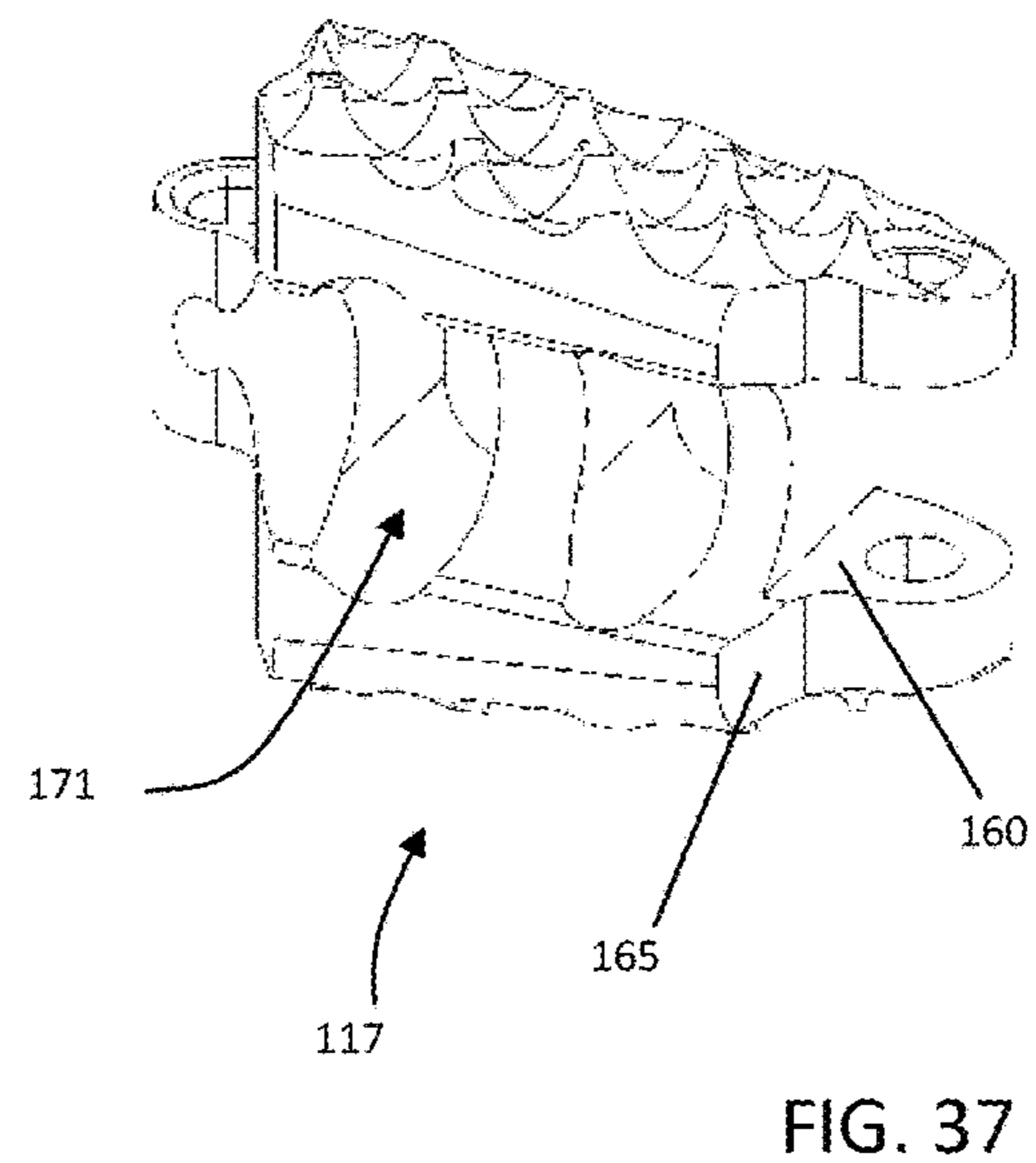
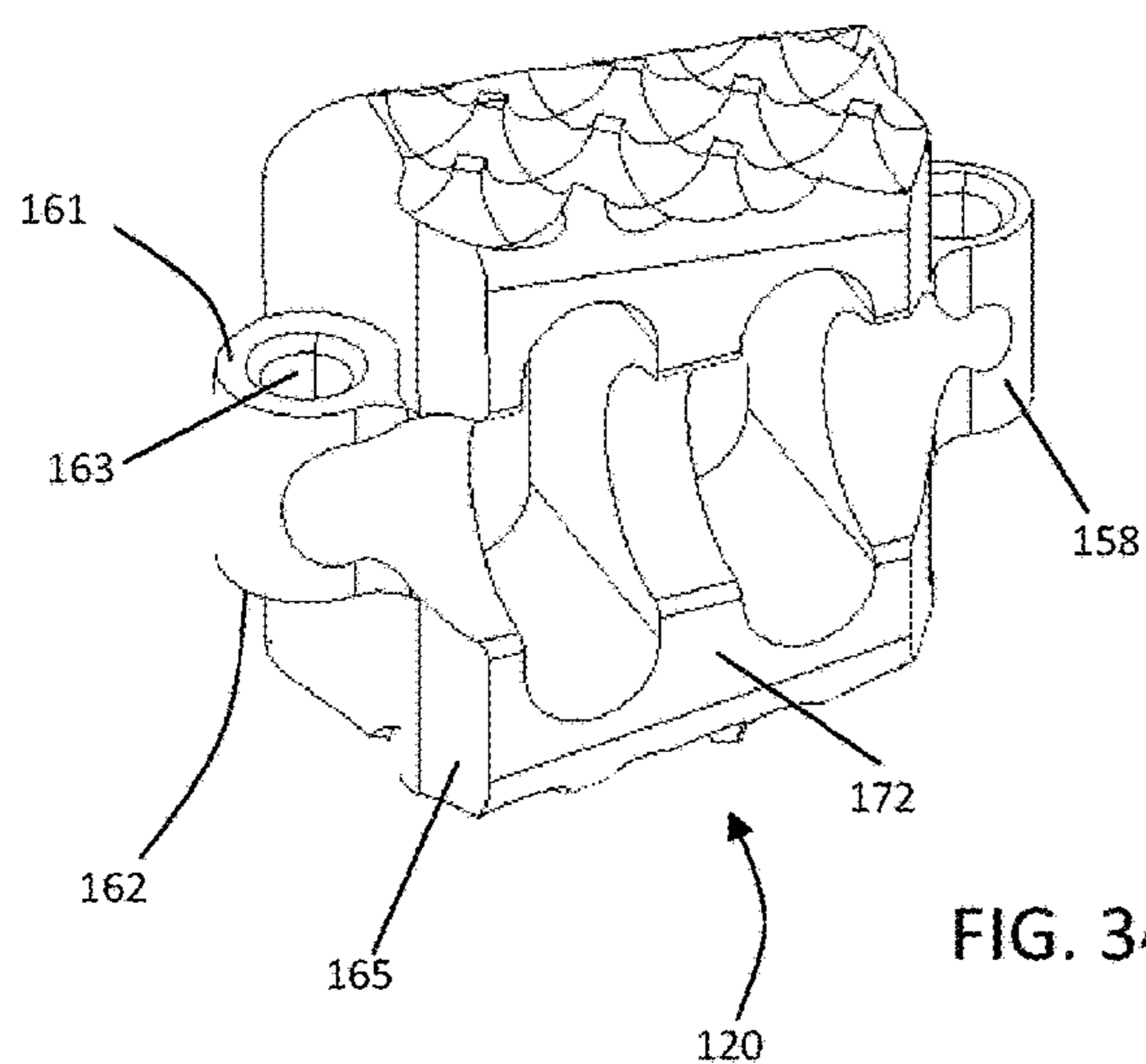
FIG. 21











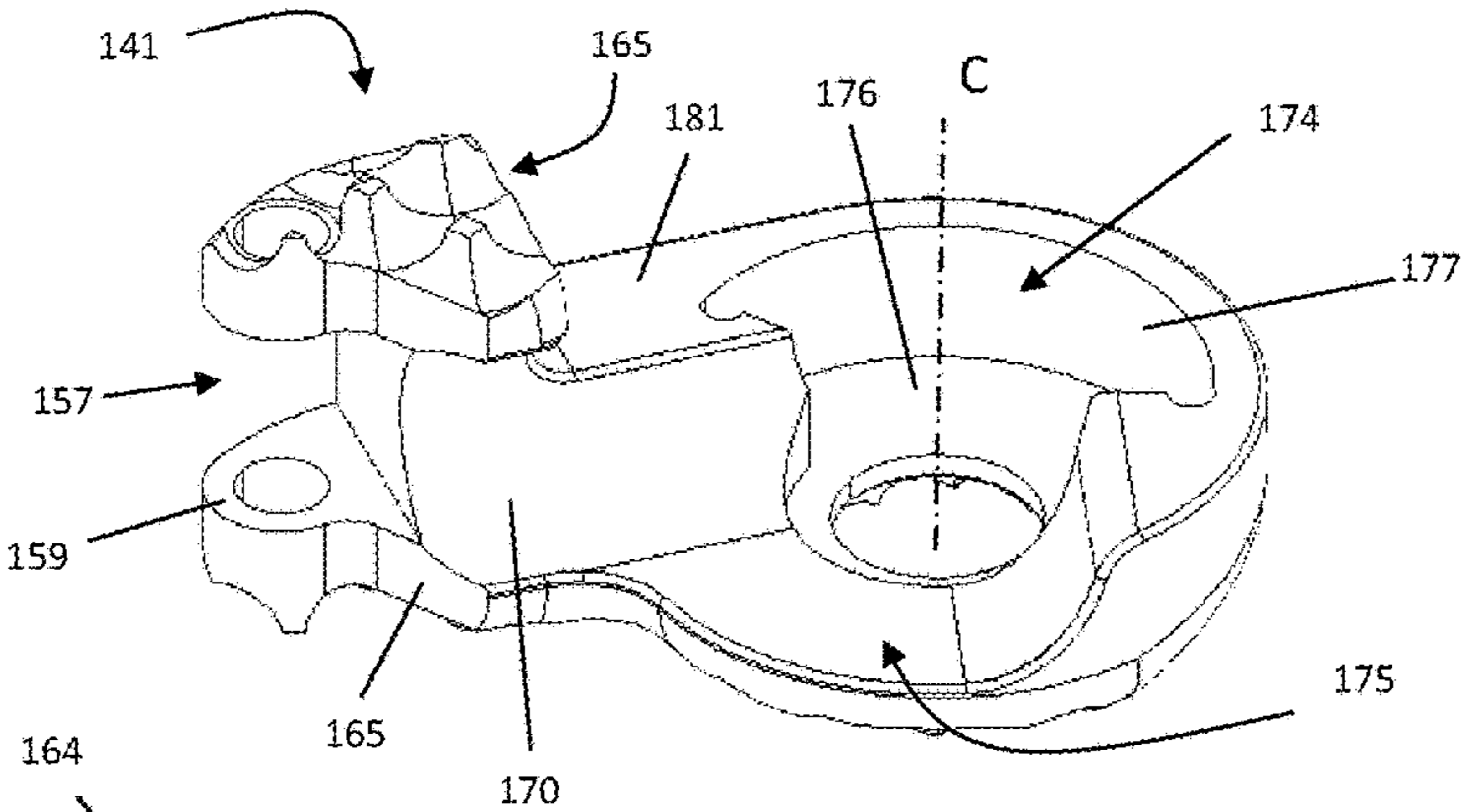


FIG. 38

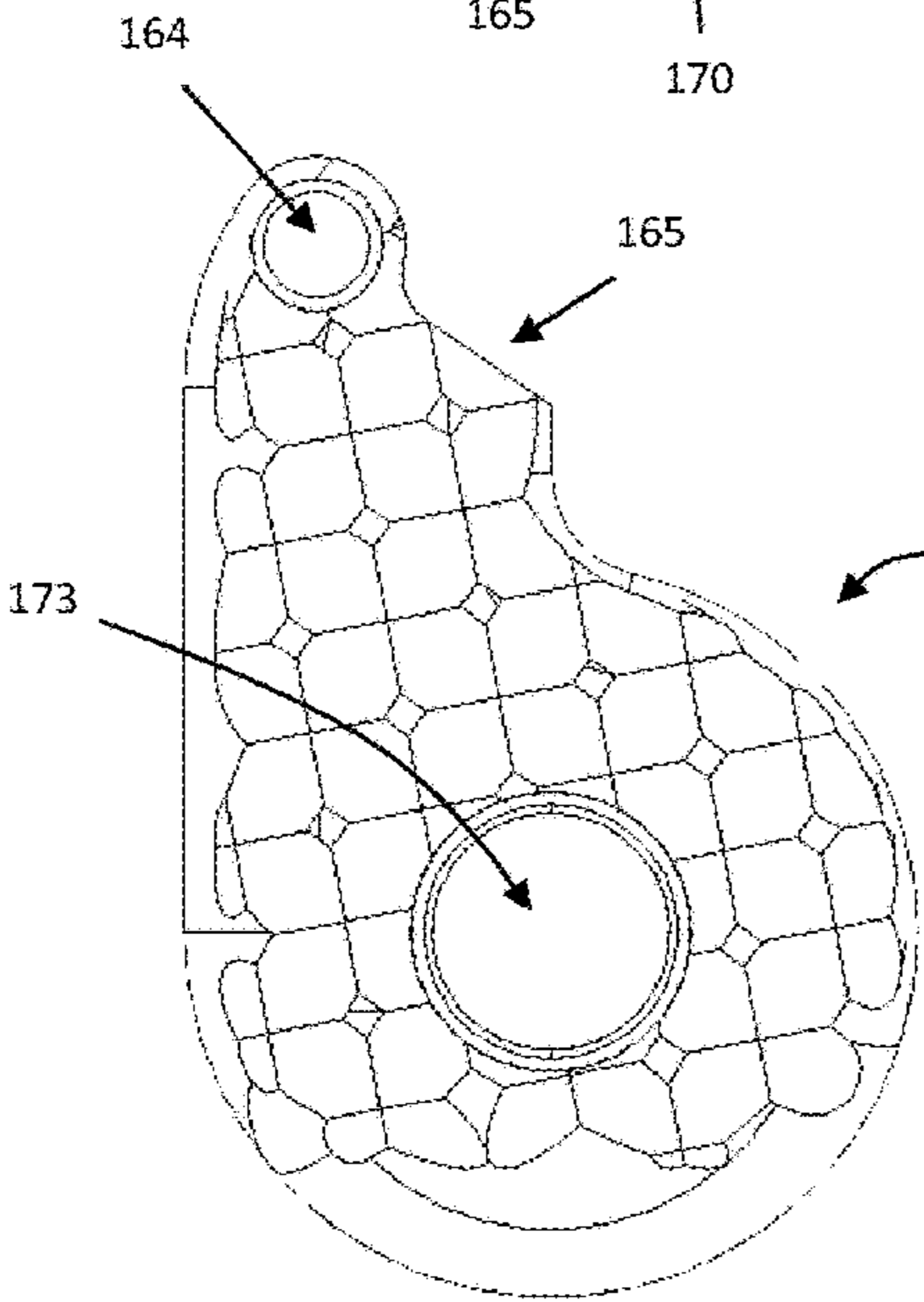


FIG. 39

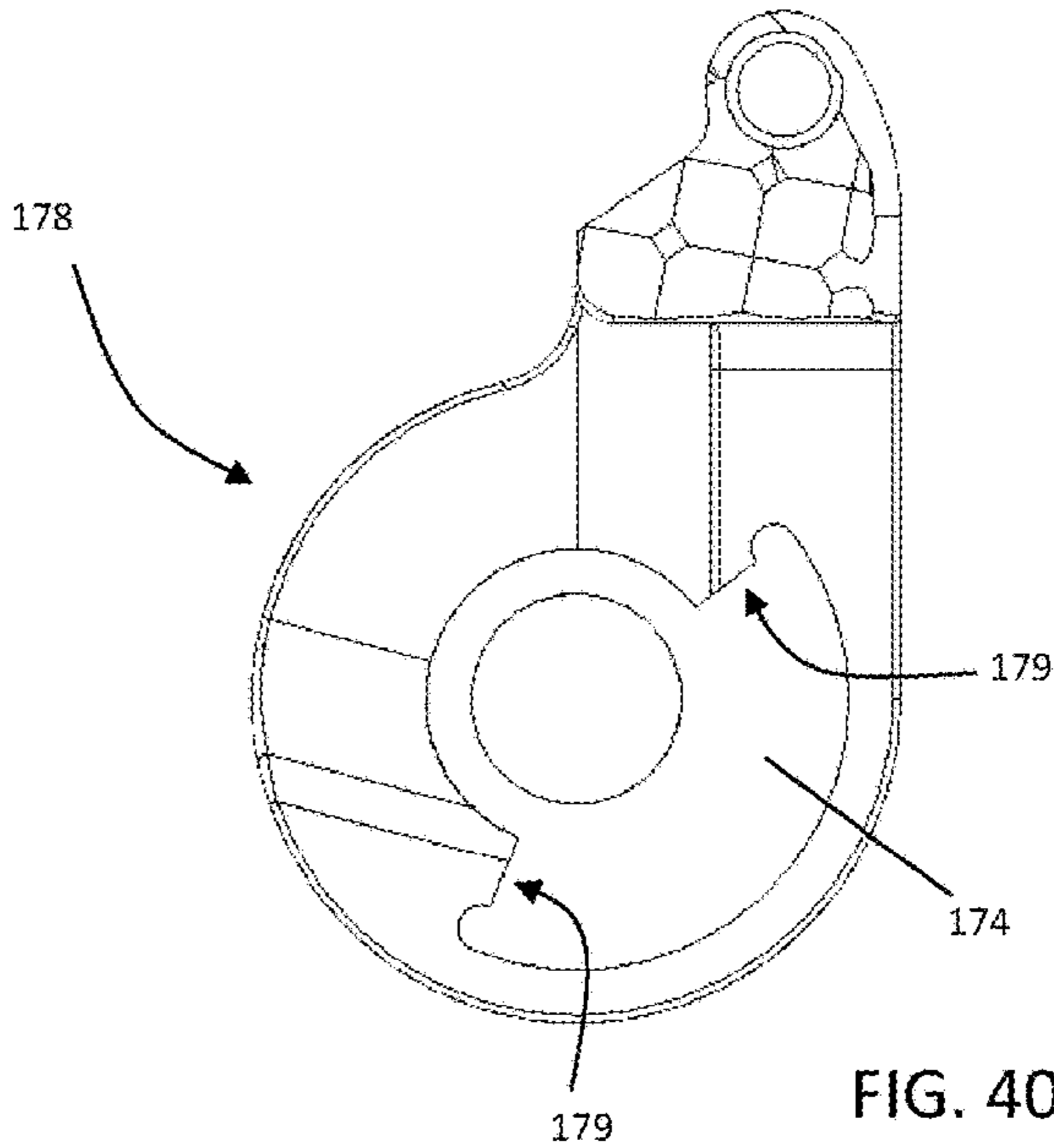


FIG. 40

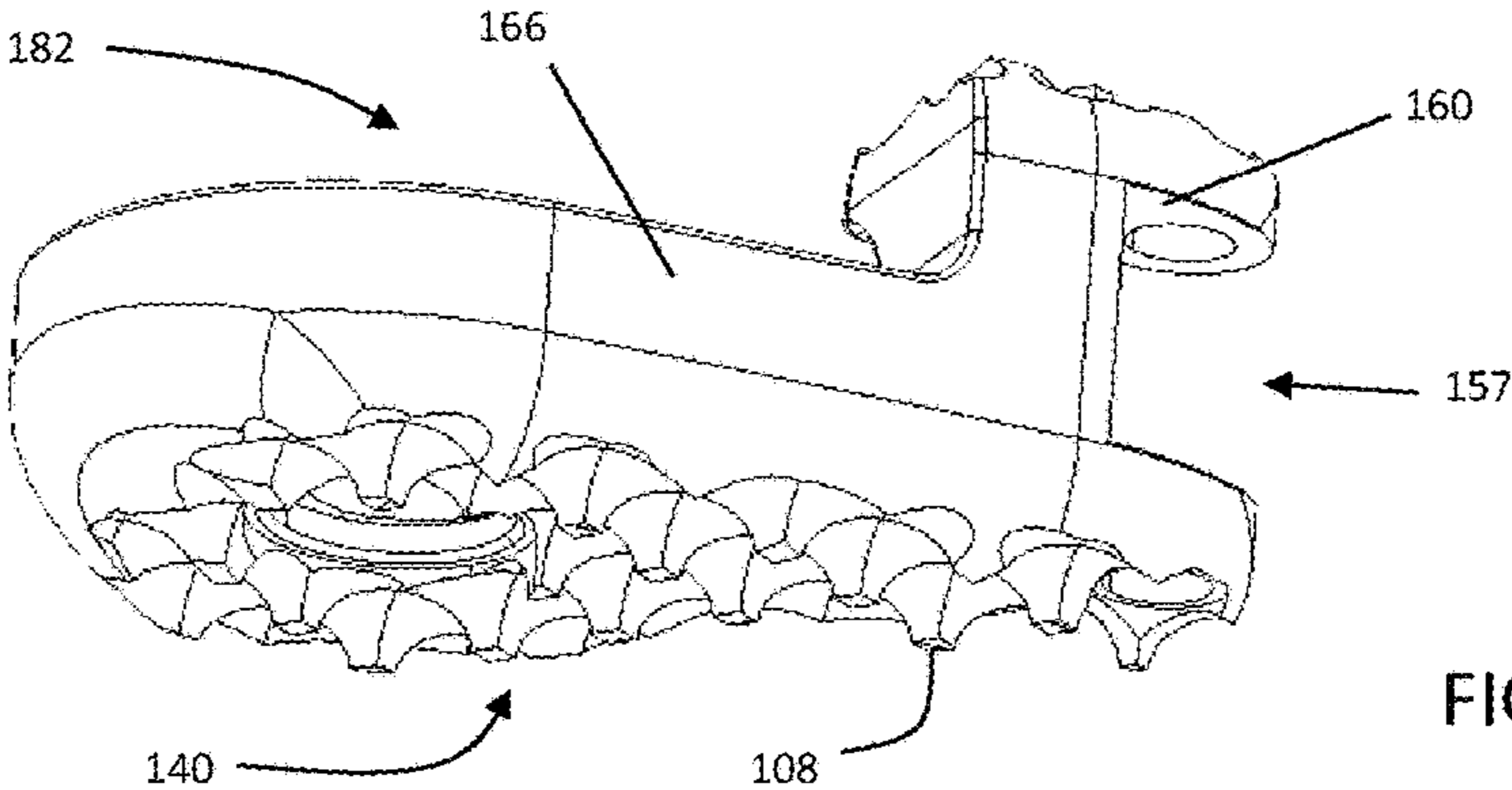
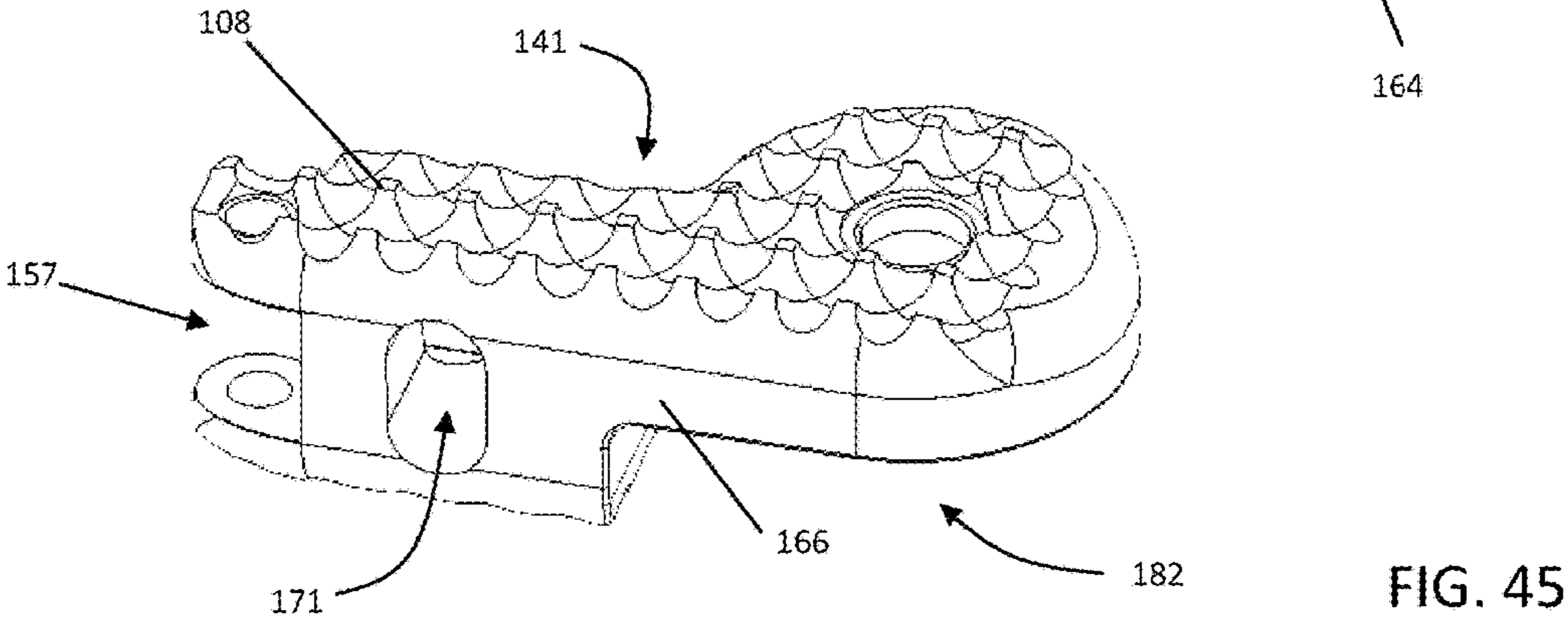
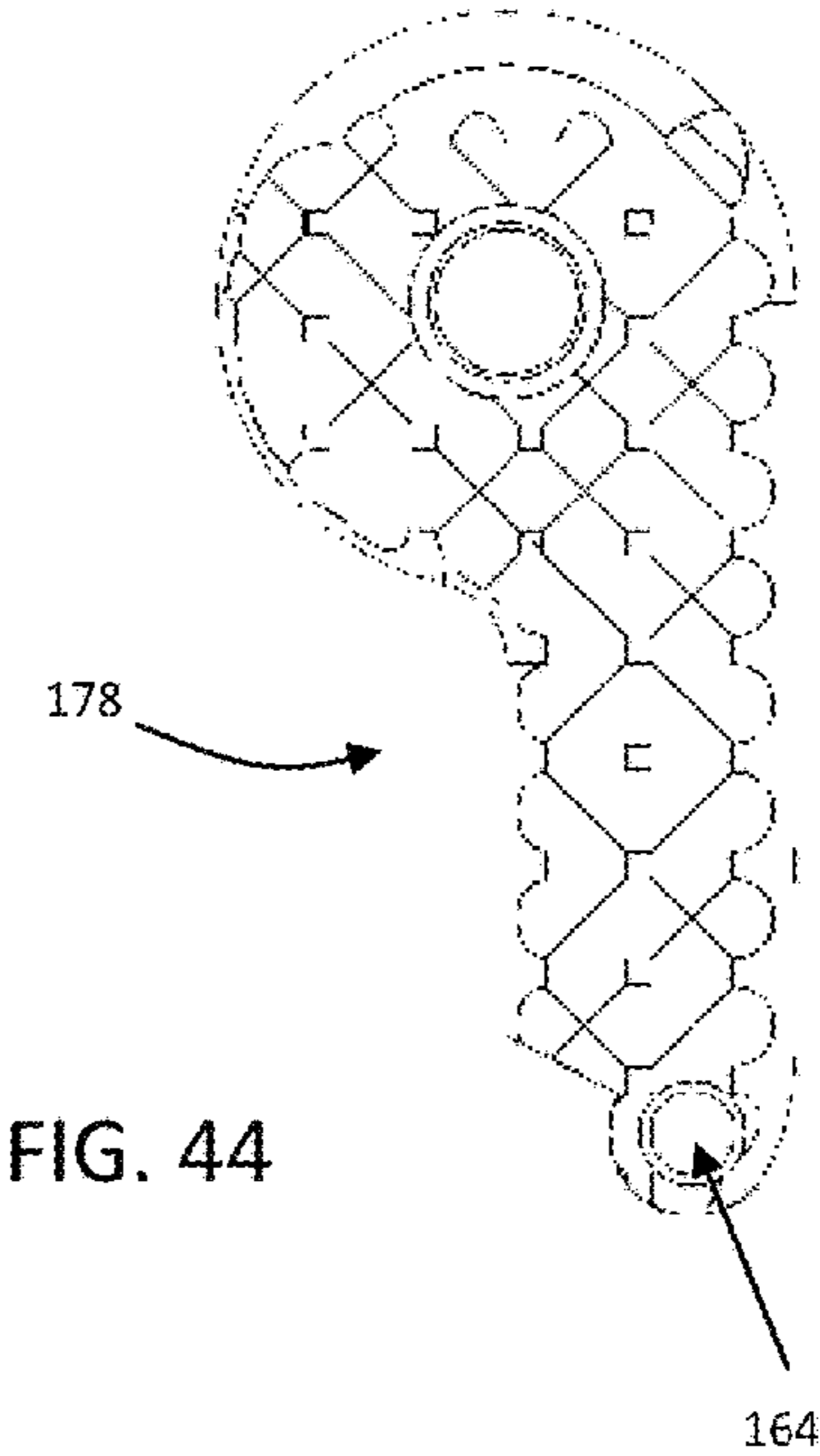
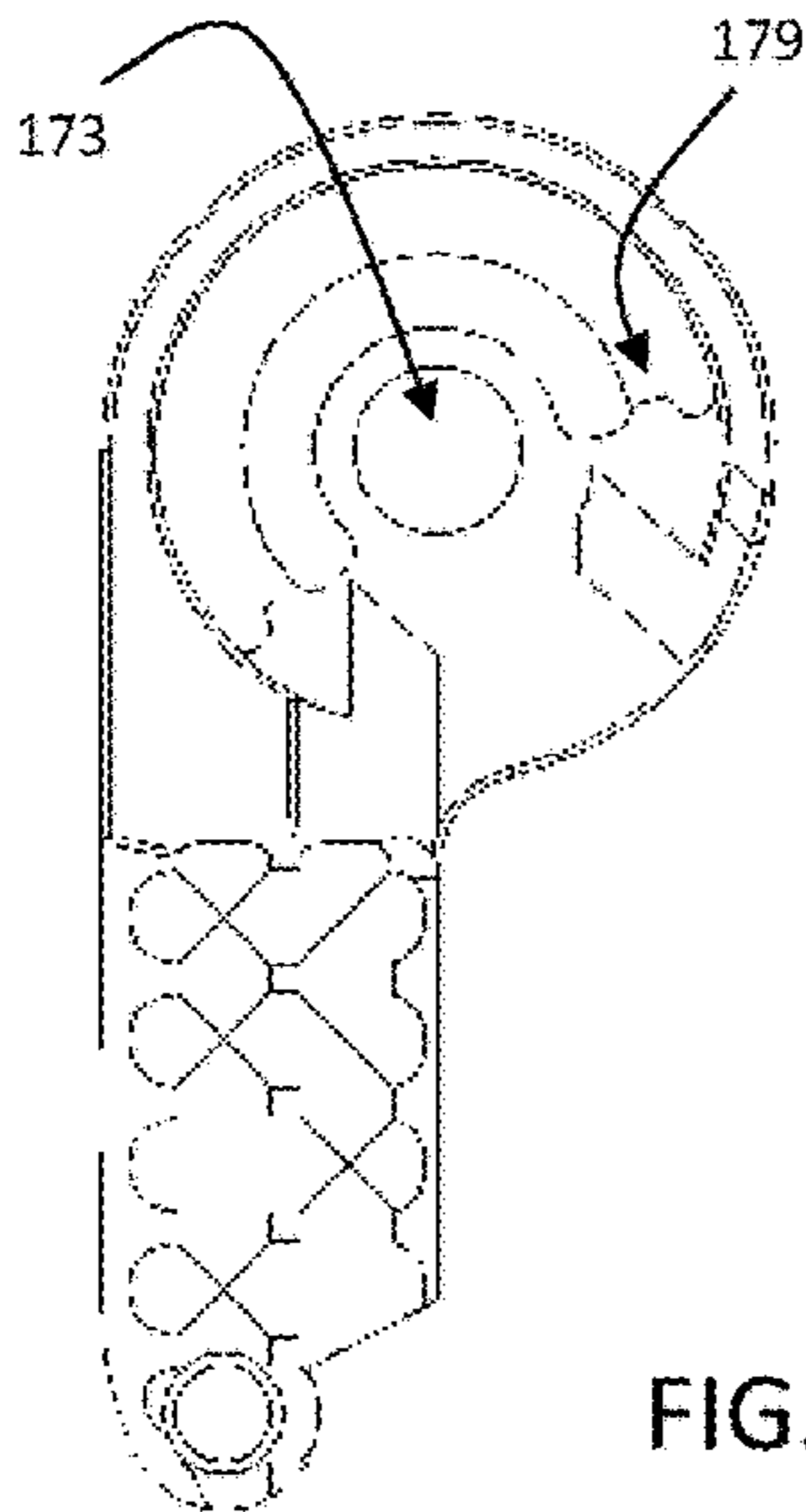
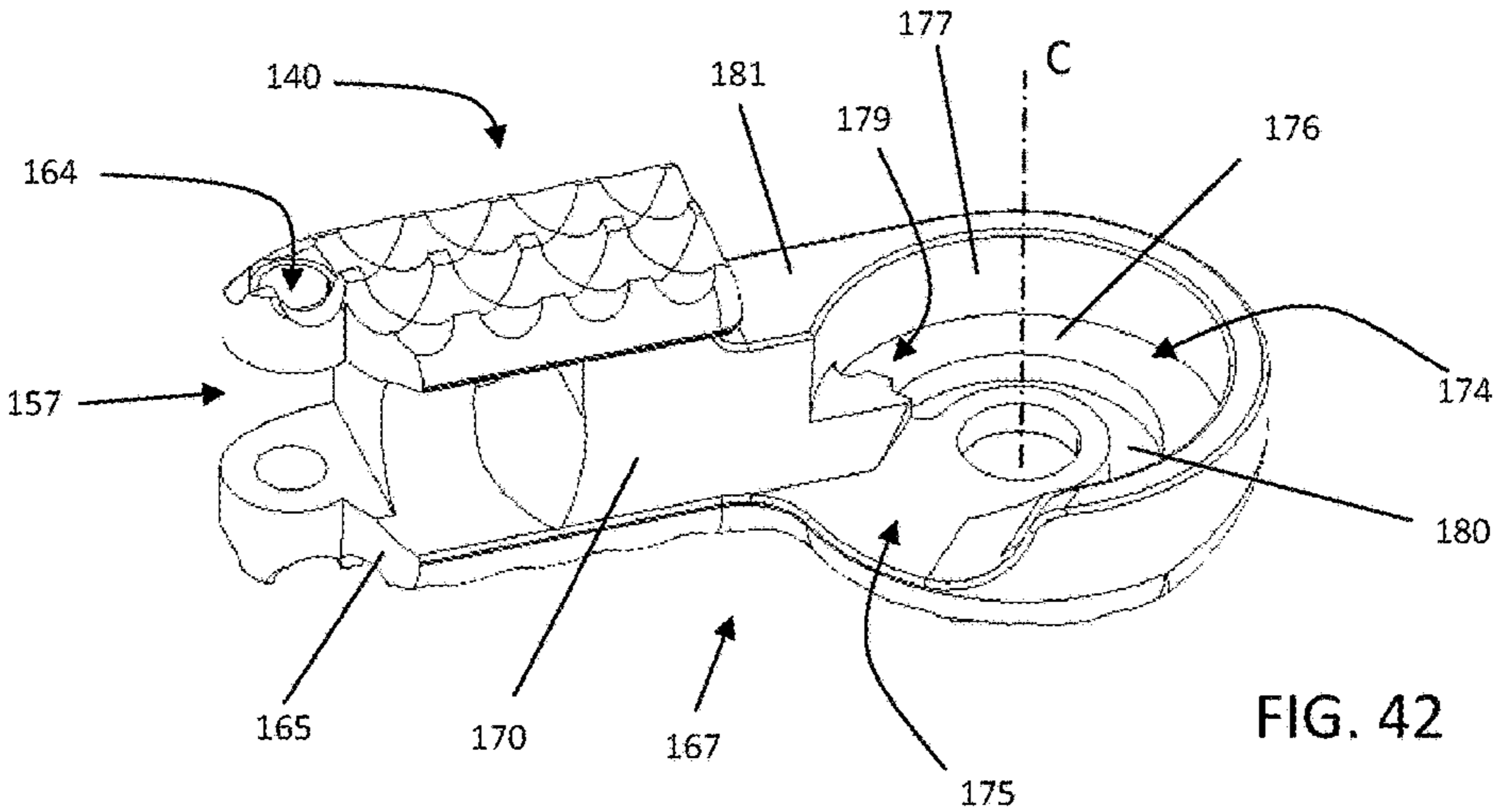
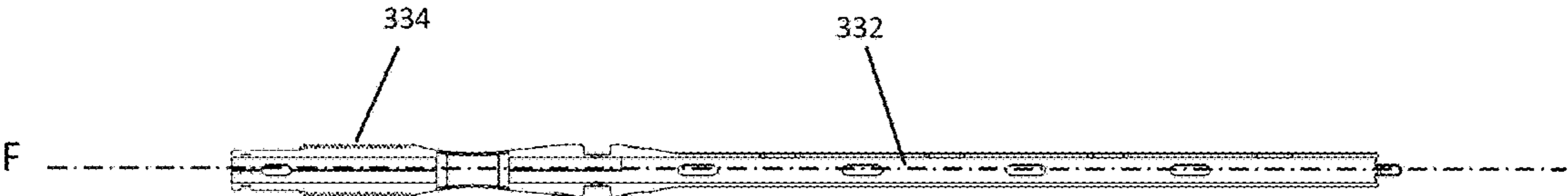
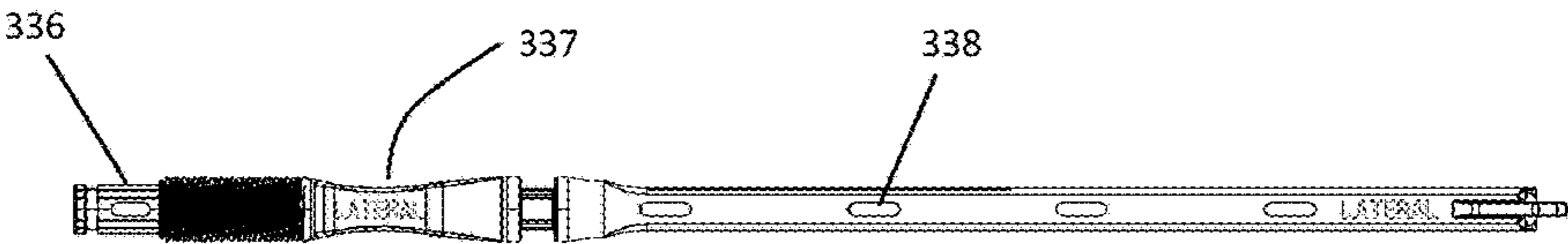
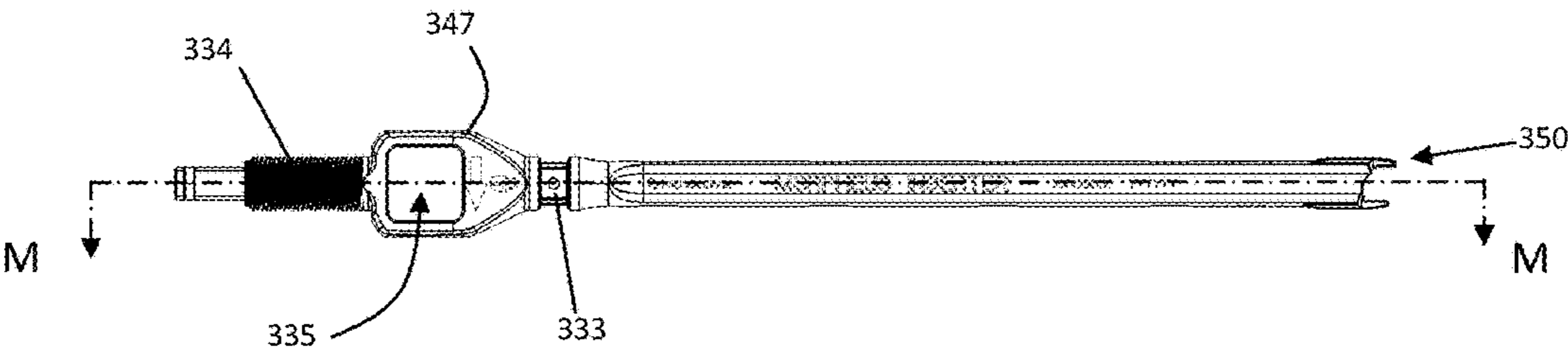
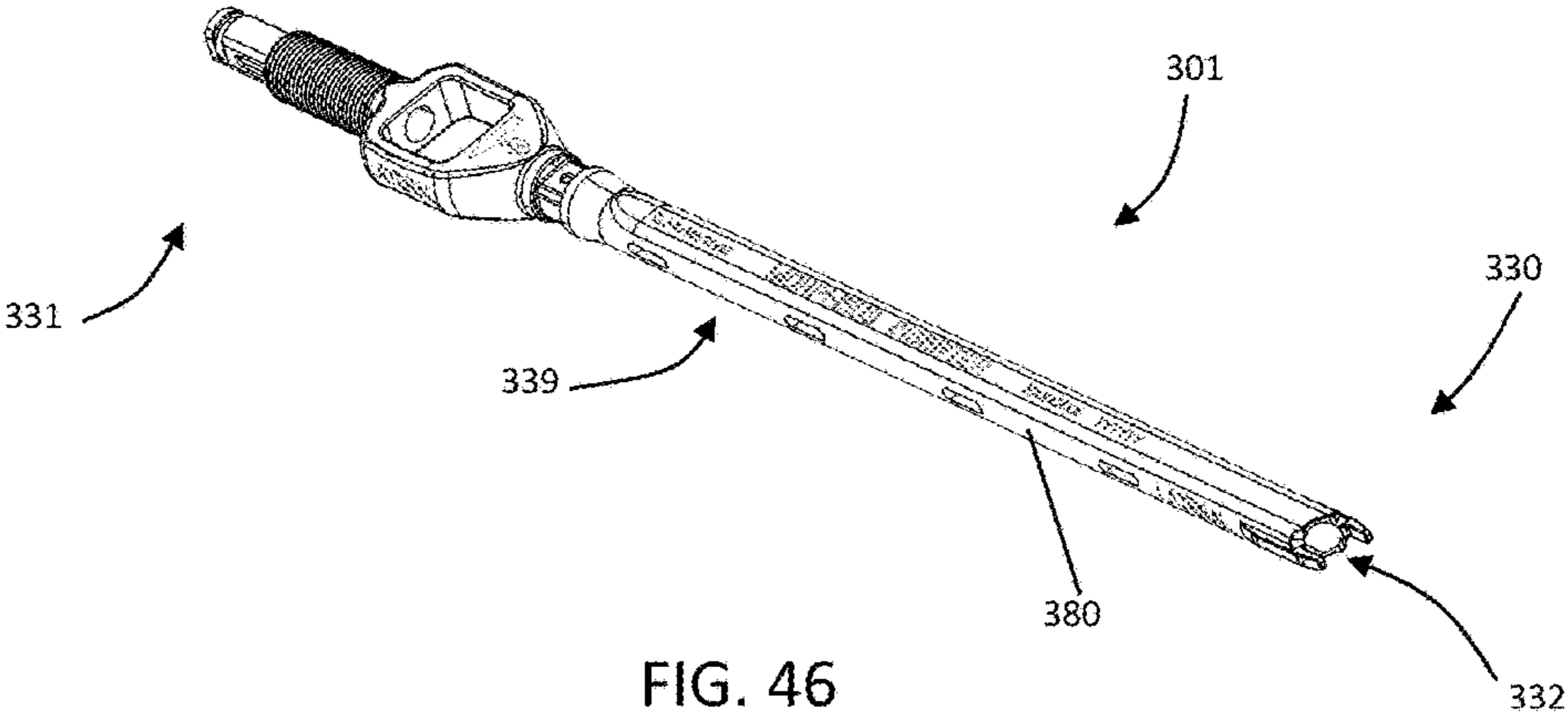


FIG. 41





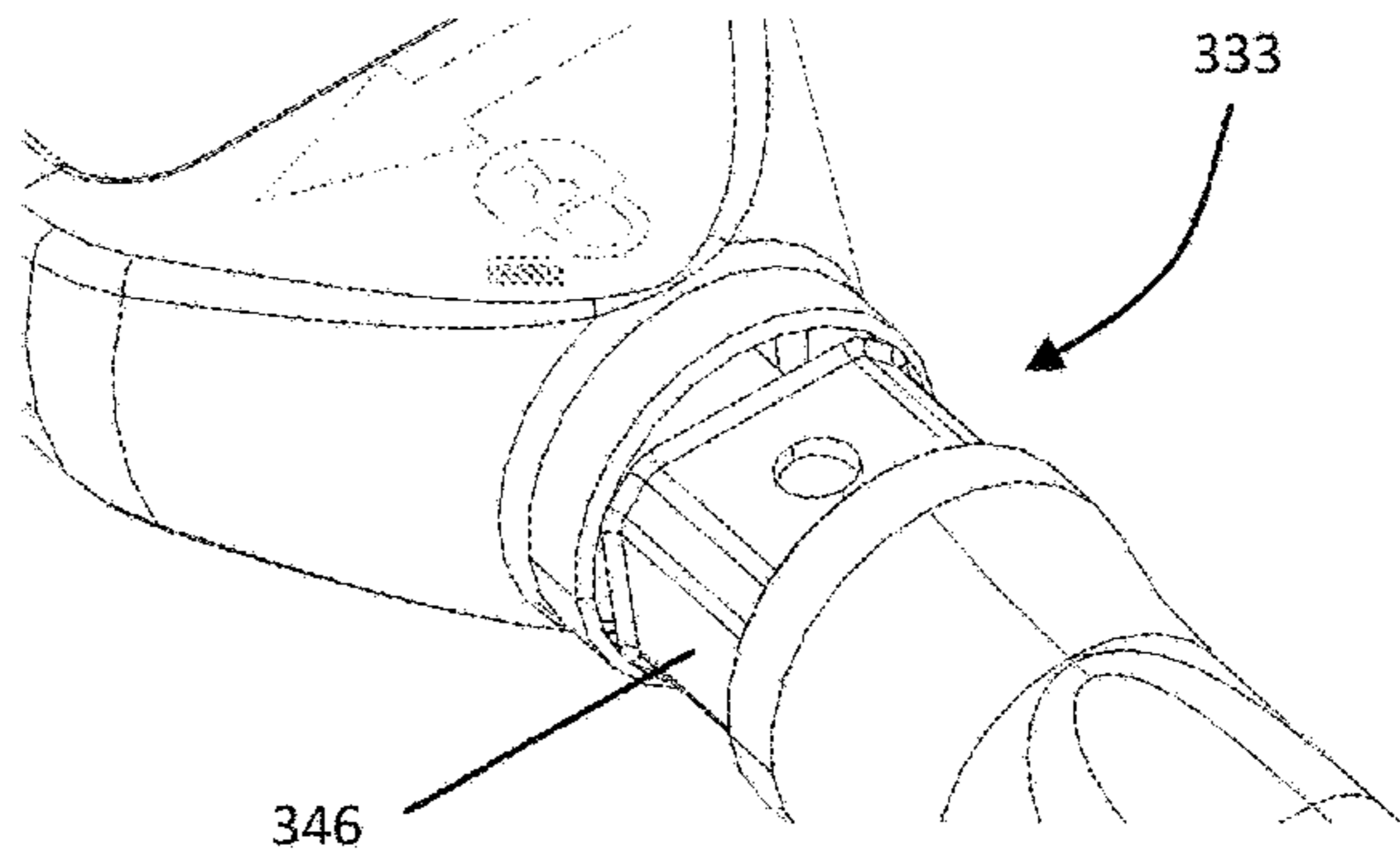


FIG. 50

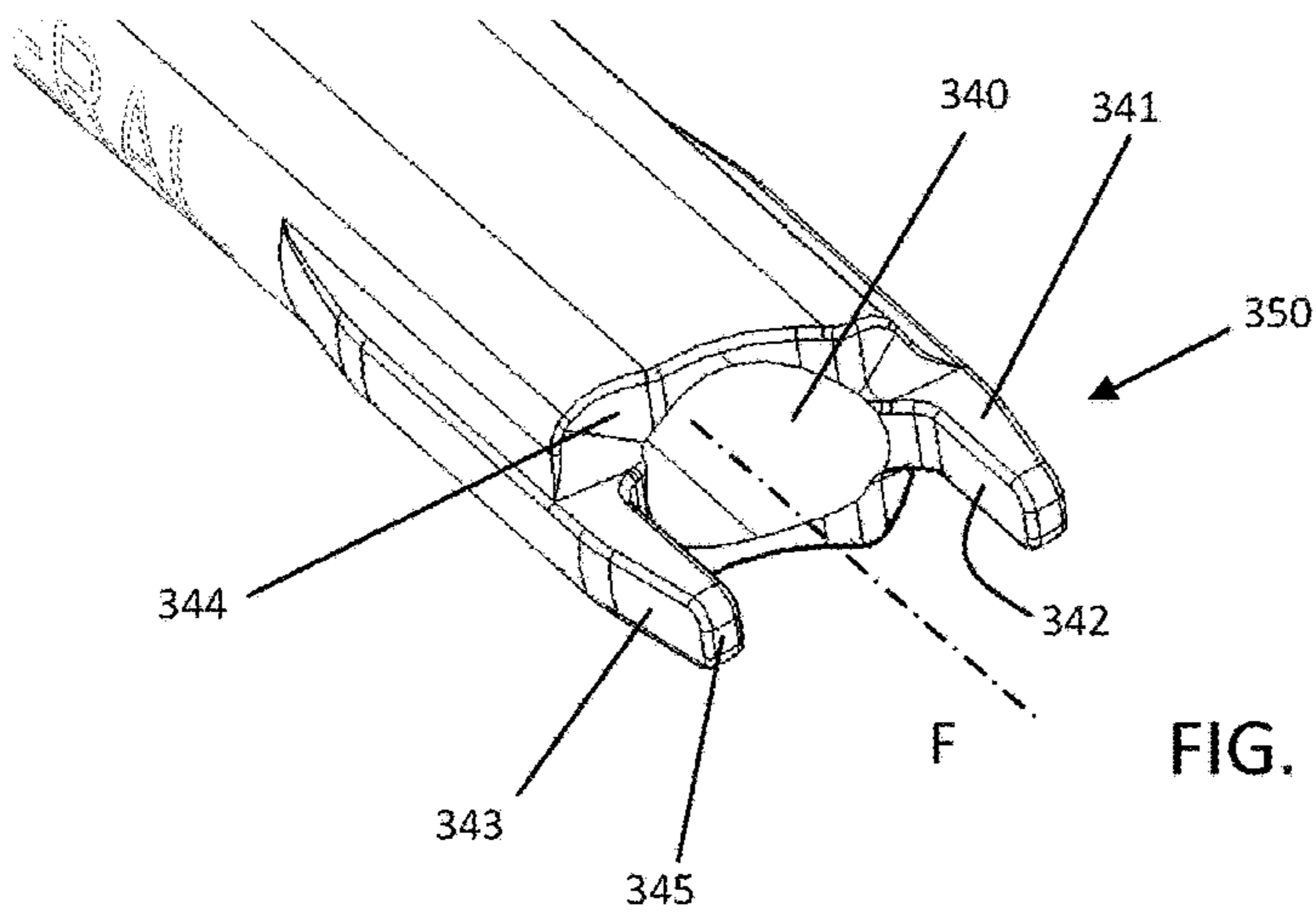


FIG. 51

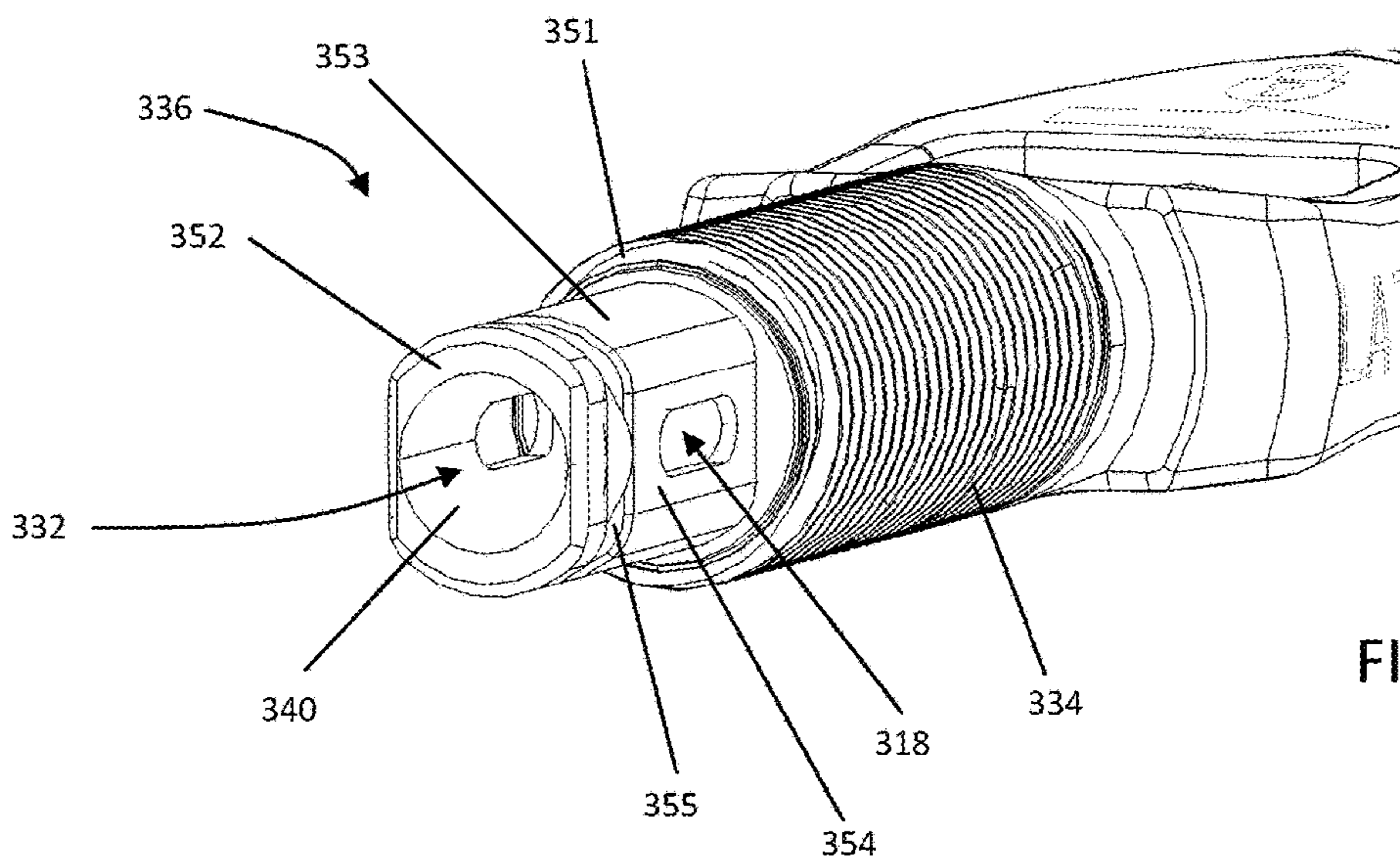


FIG. 52

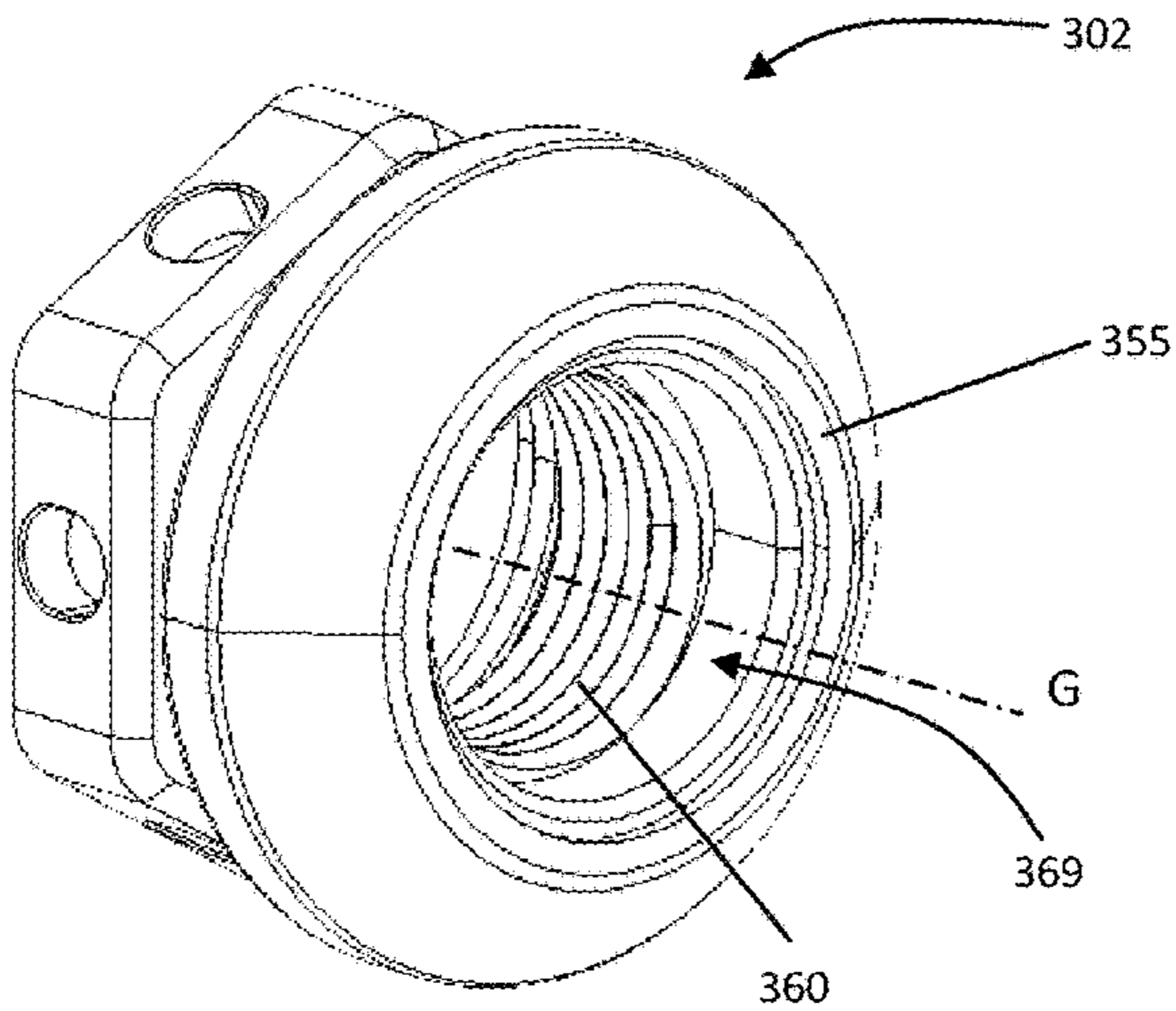


FIG. 53

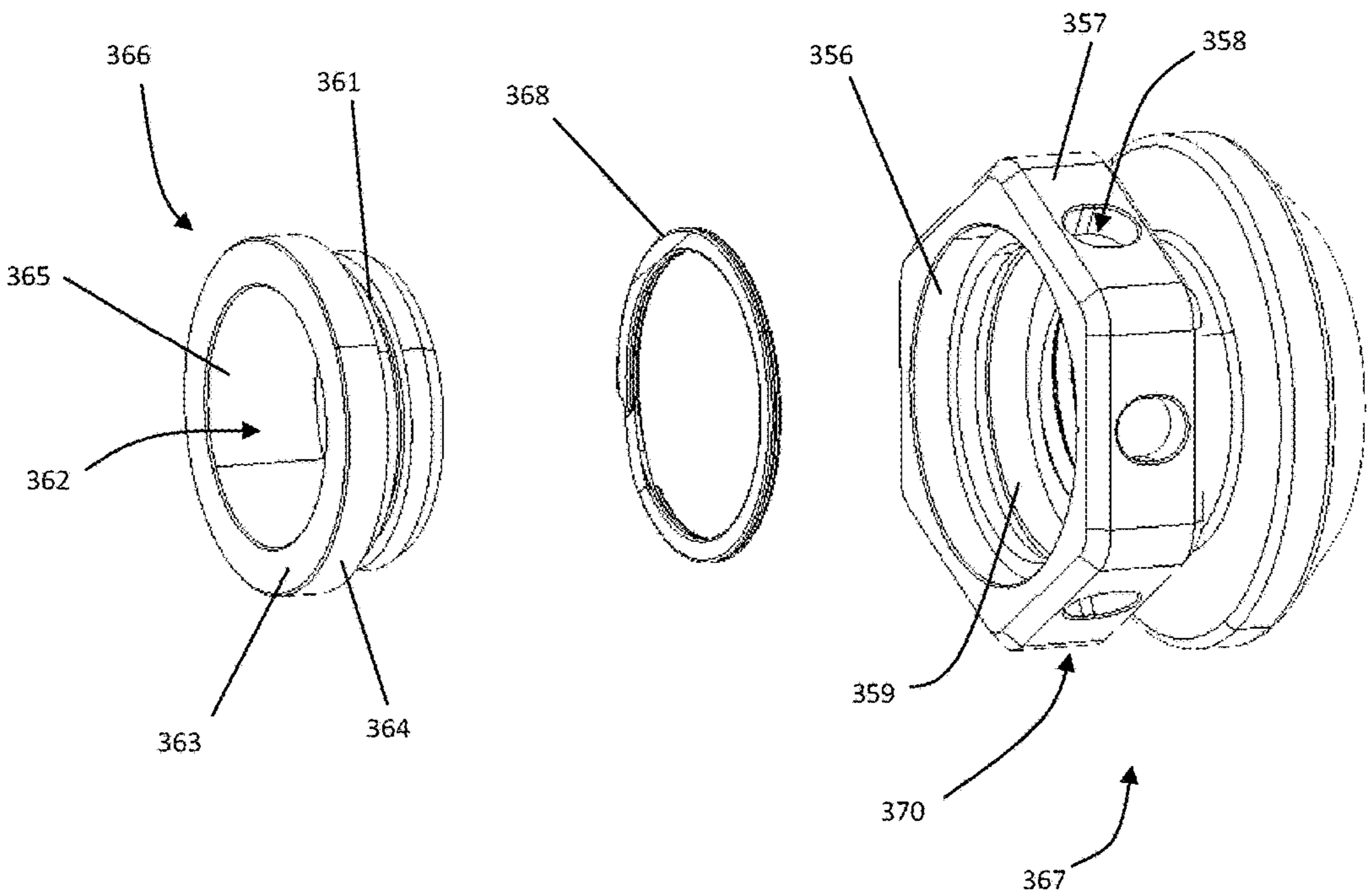


FIG. 54

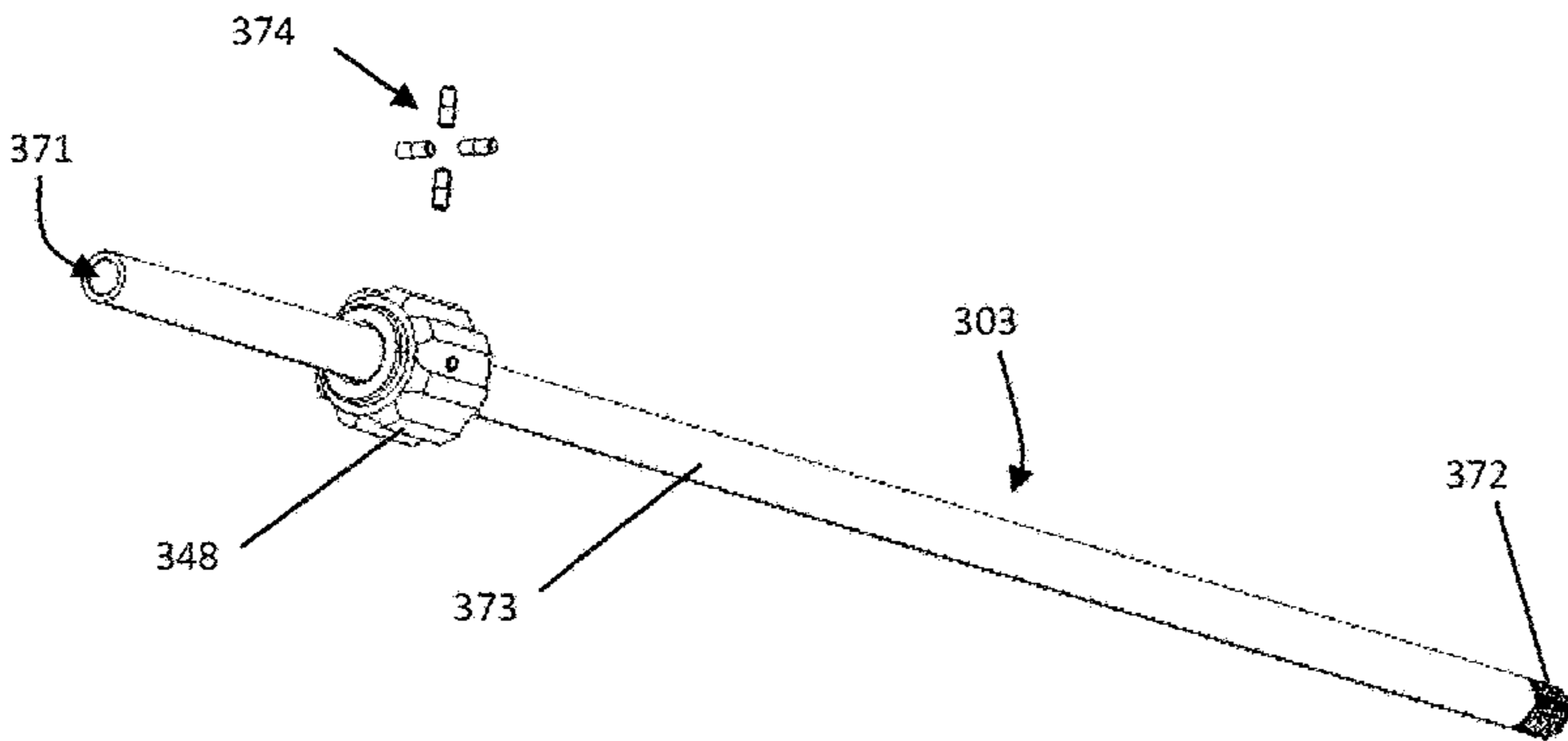


FIG. 55

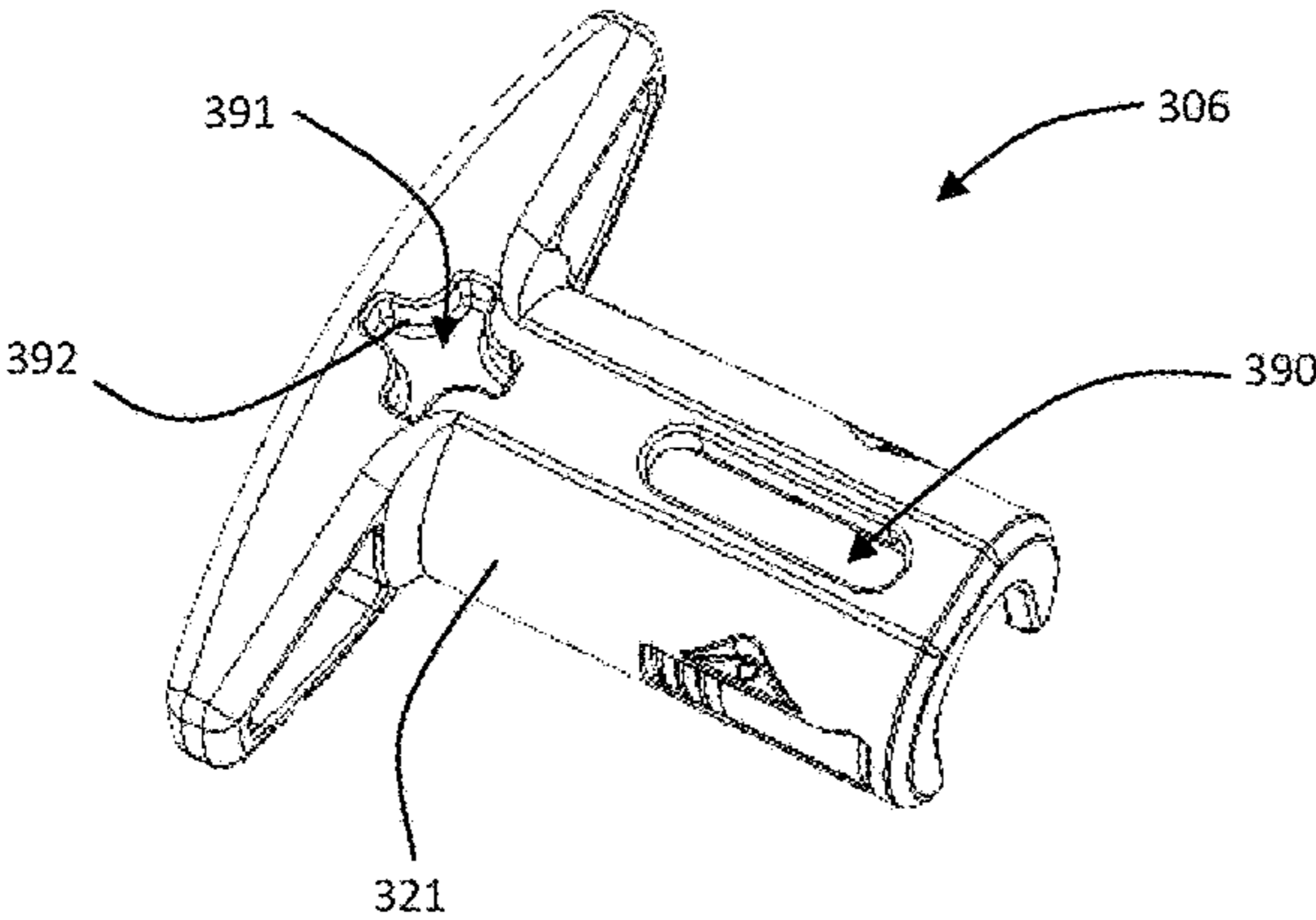


FIG. 56

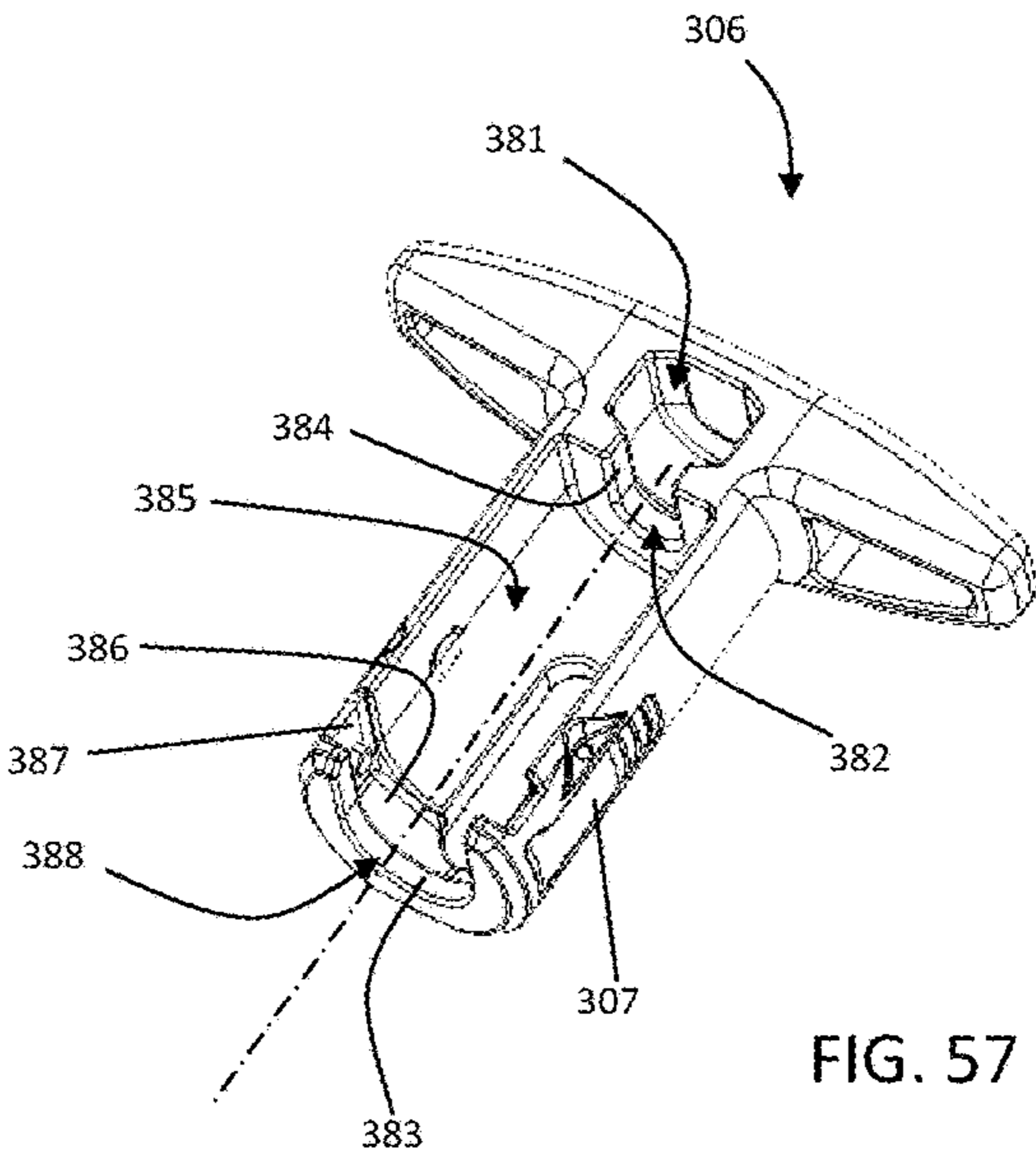


FIG. 57

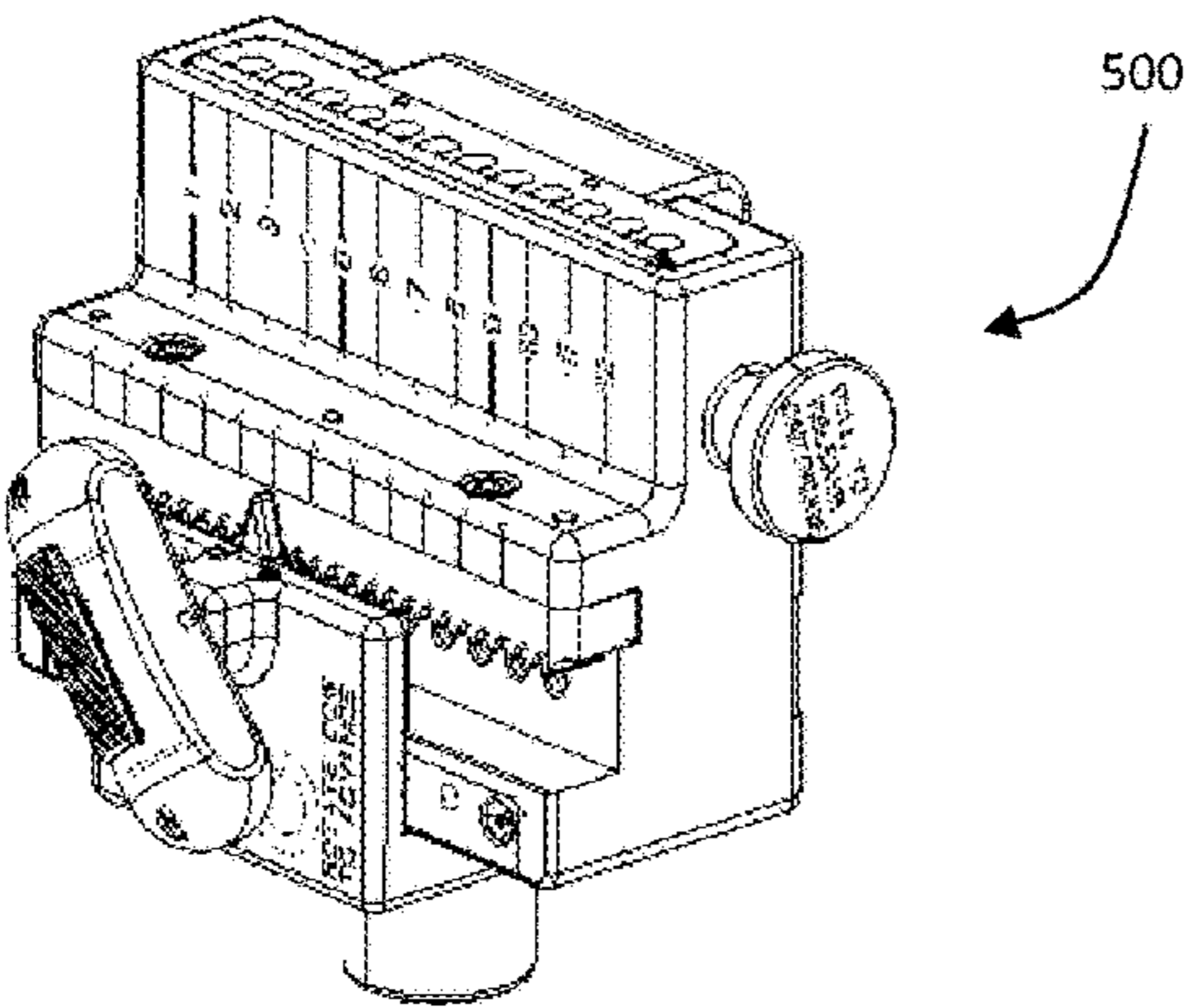


FIG. 58

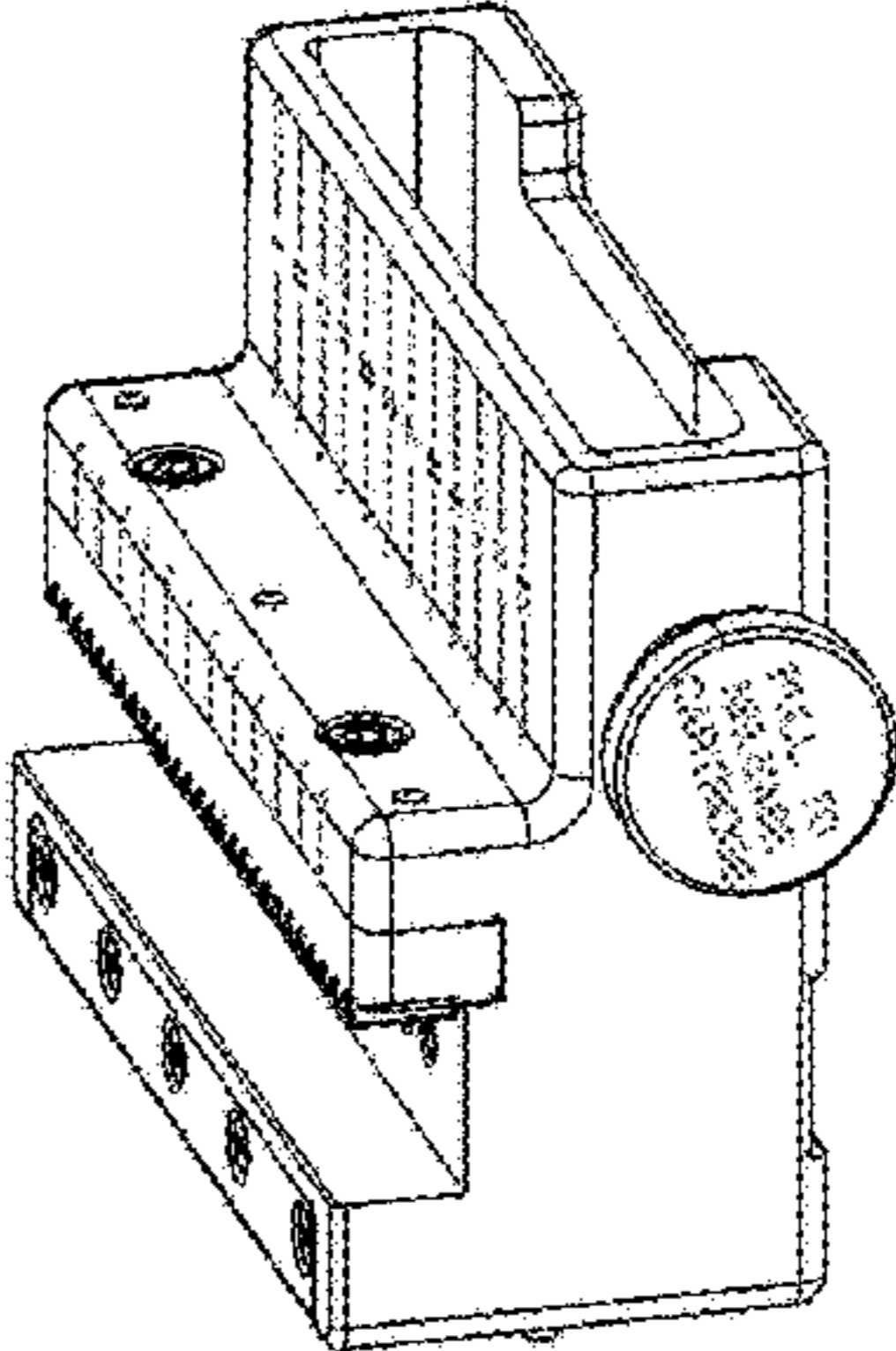
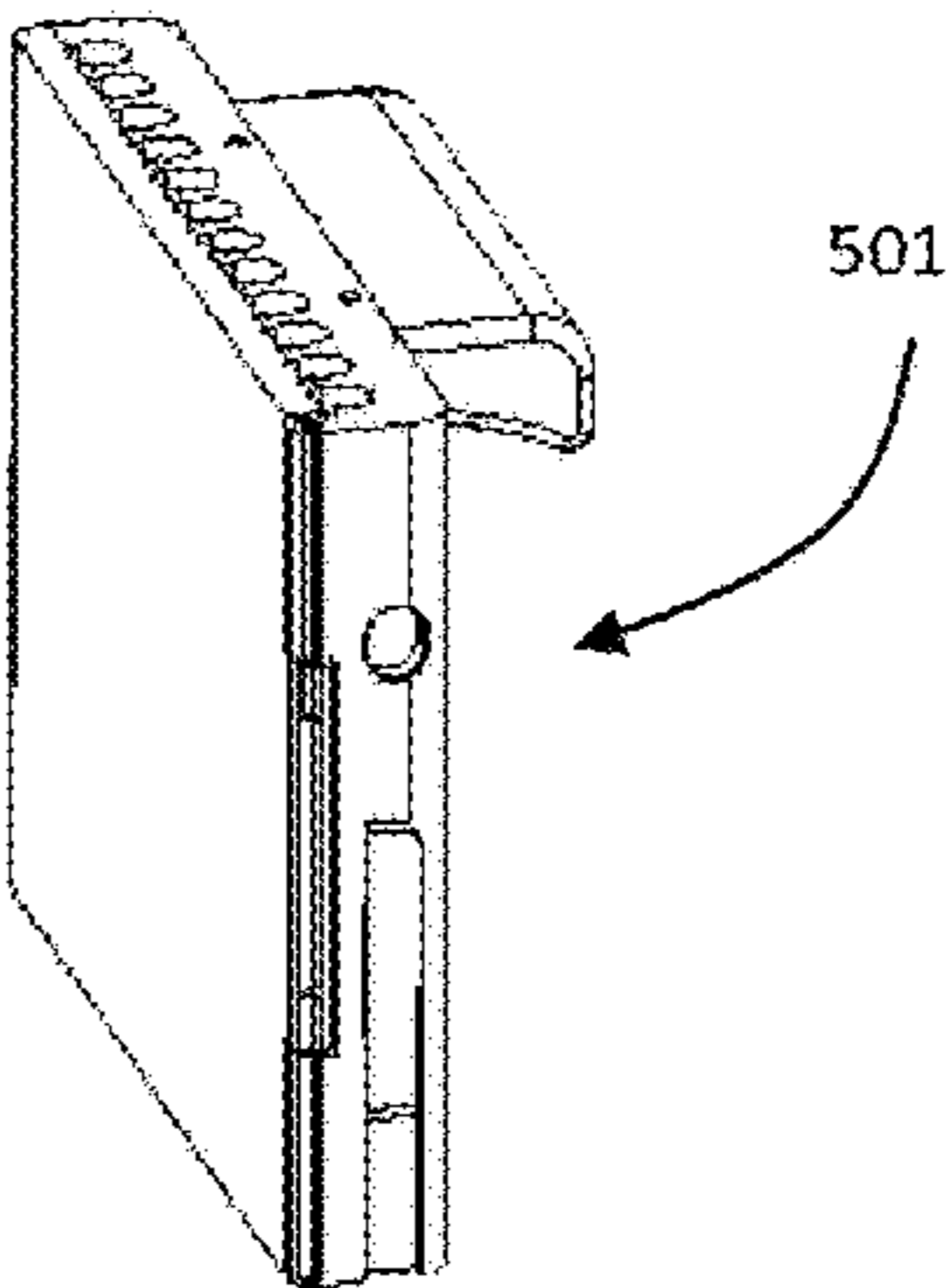


FIG. 59

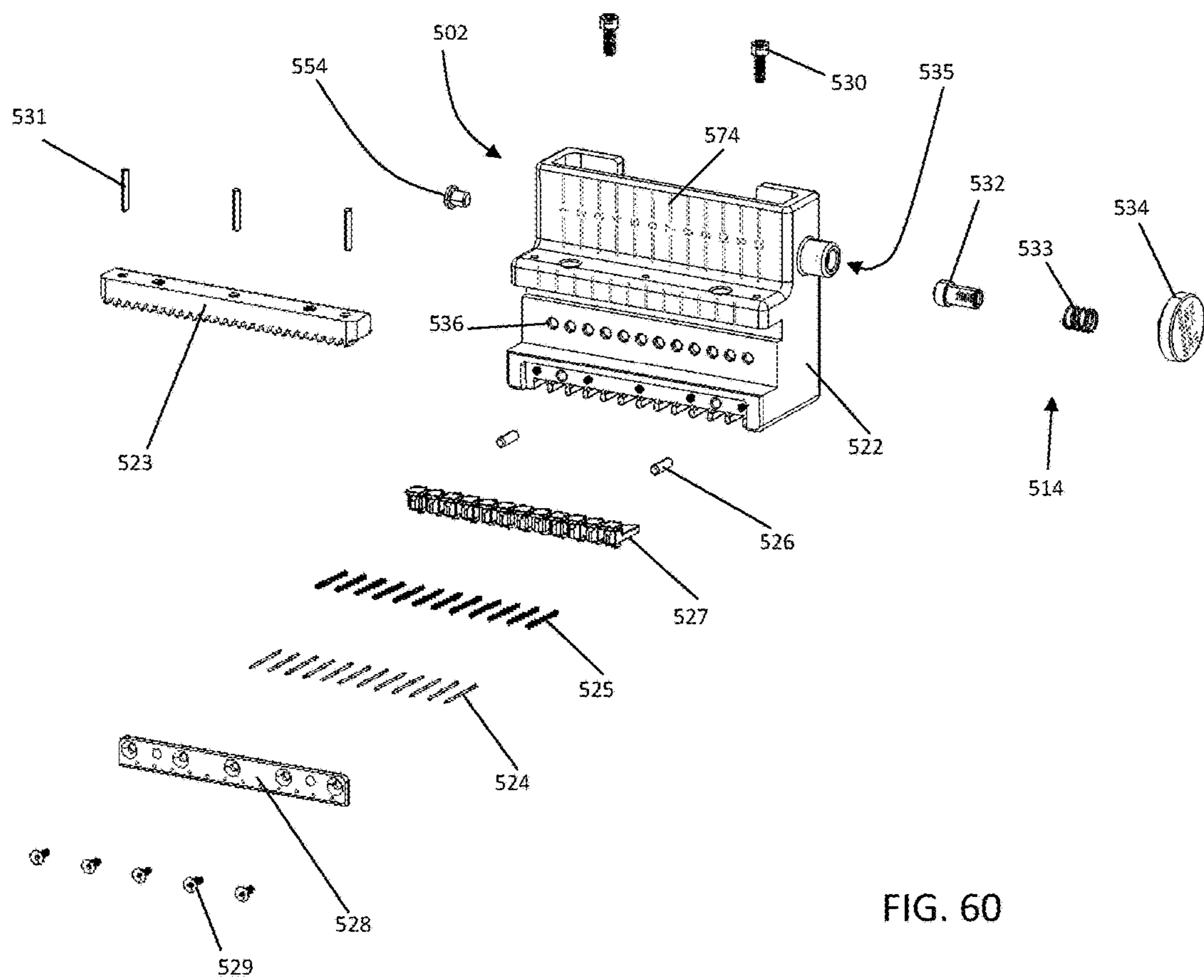


FIG. 60

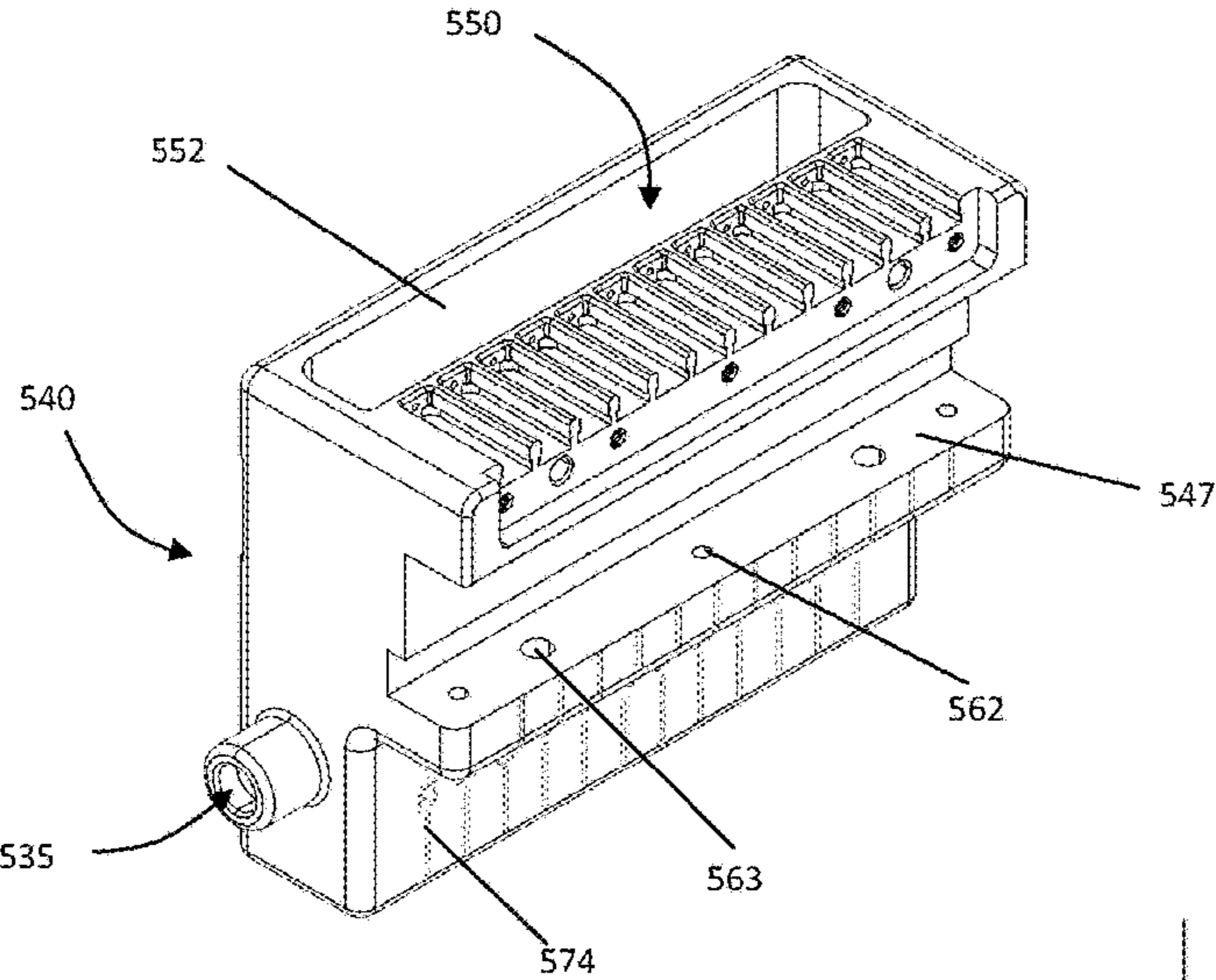


FIG. 61

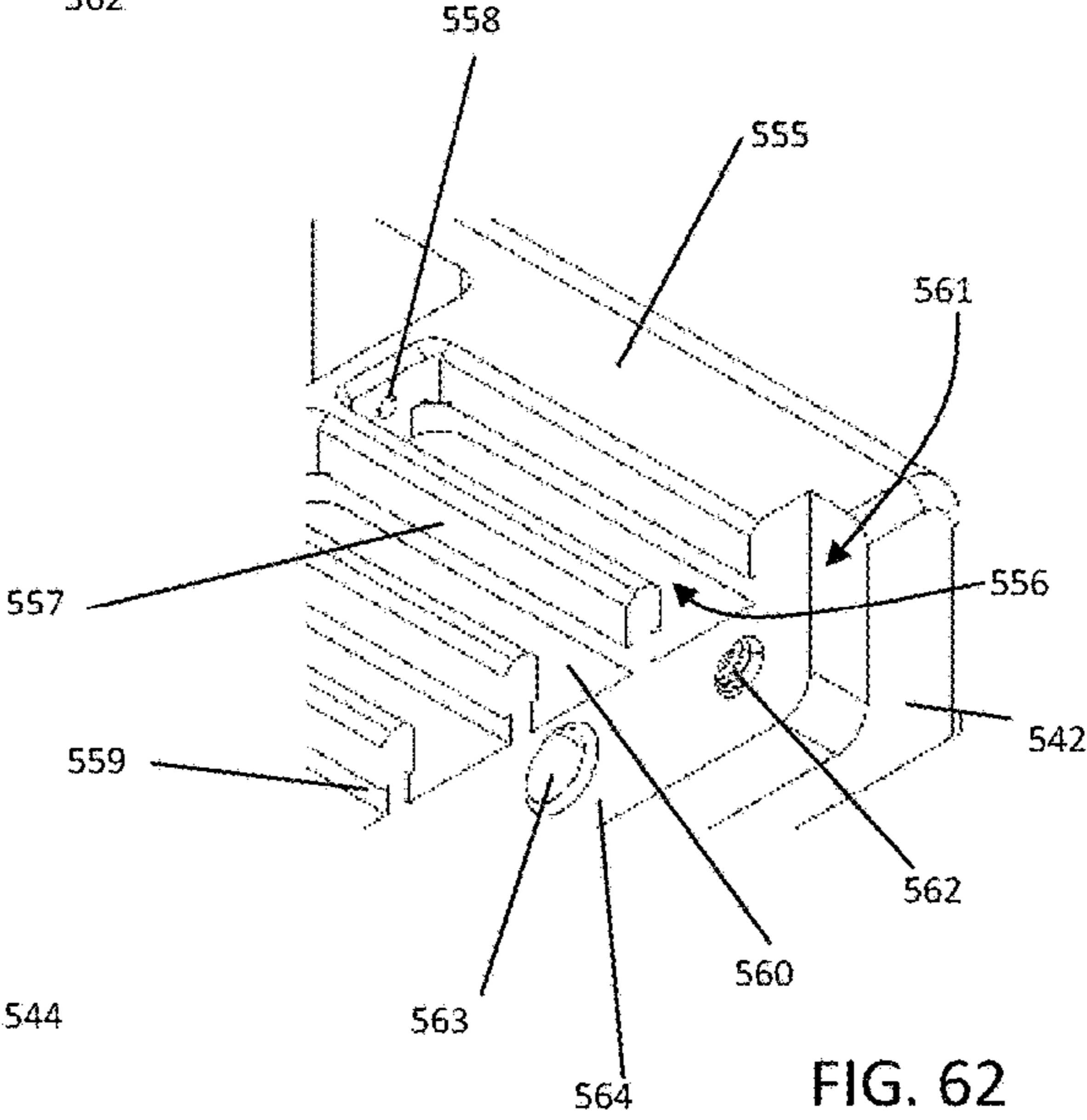


FIG. 62

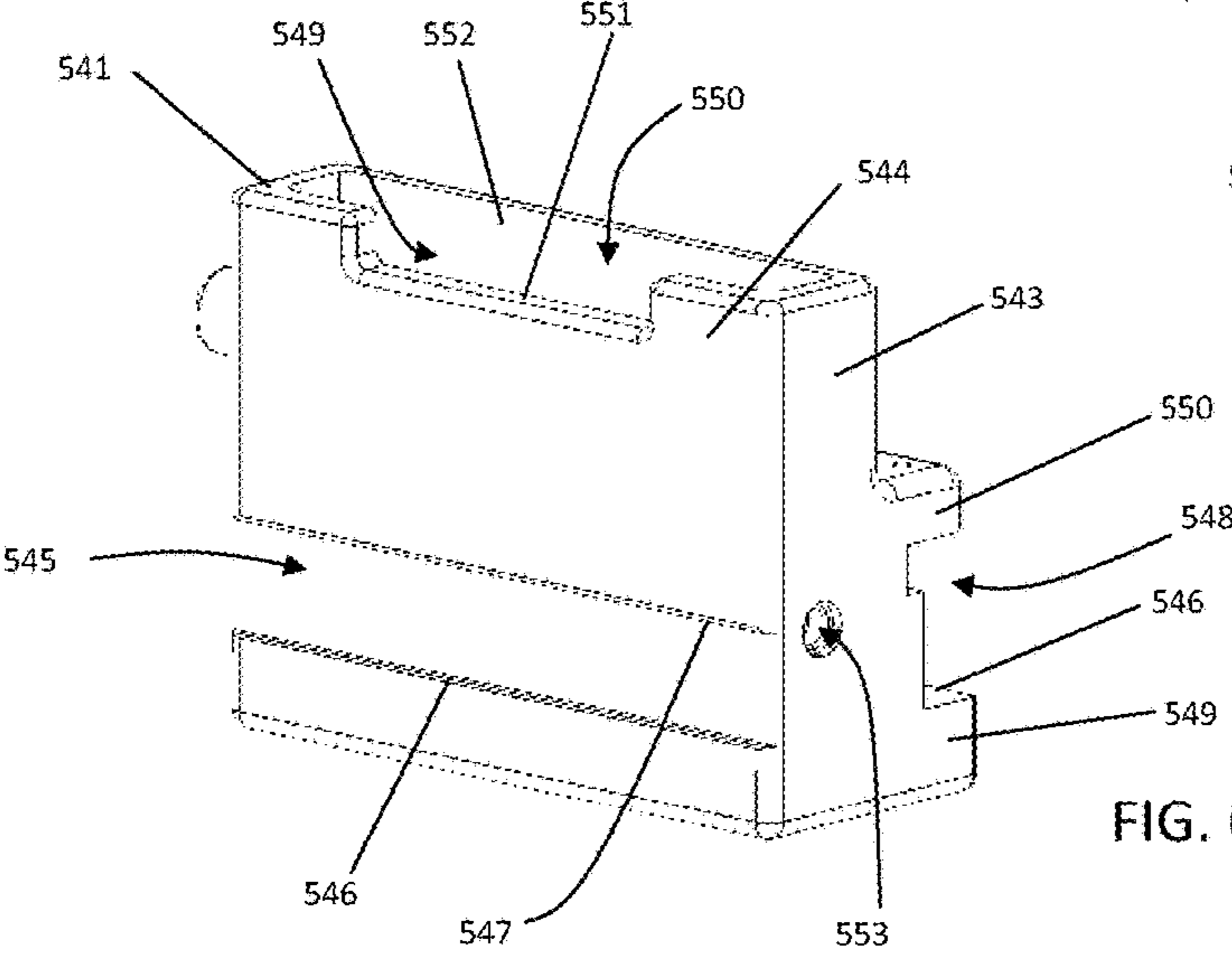


FIG. 63

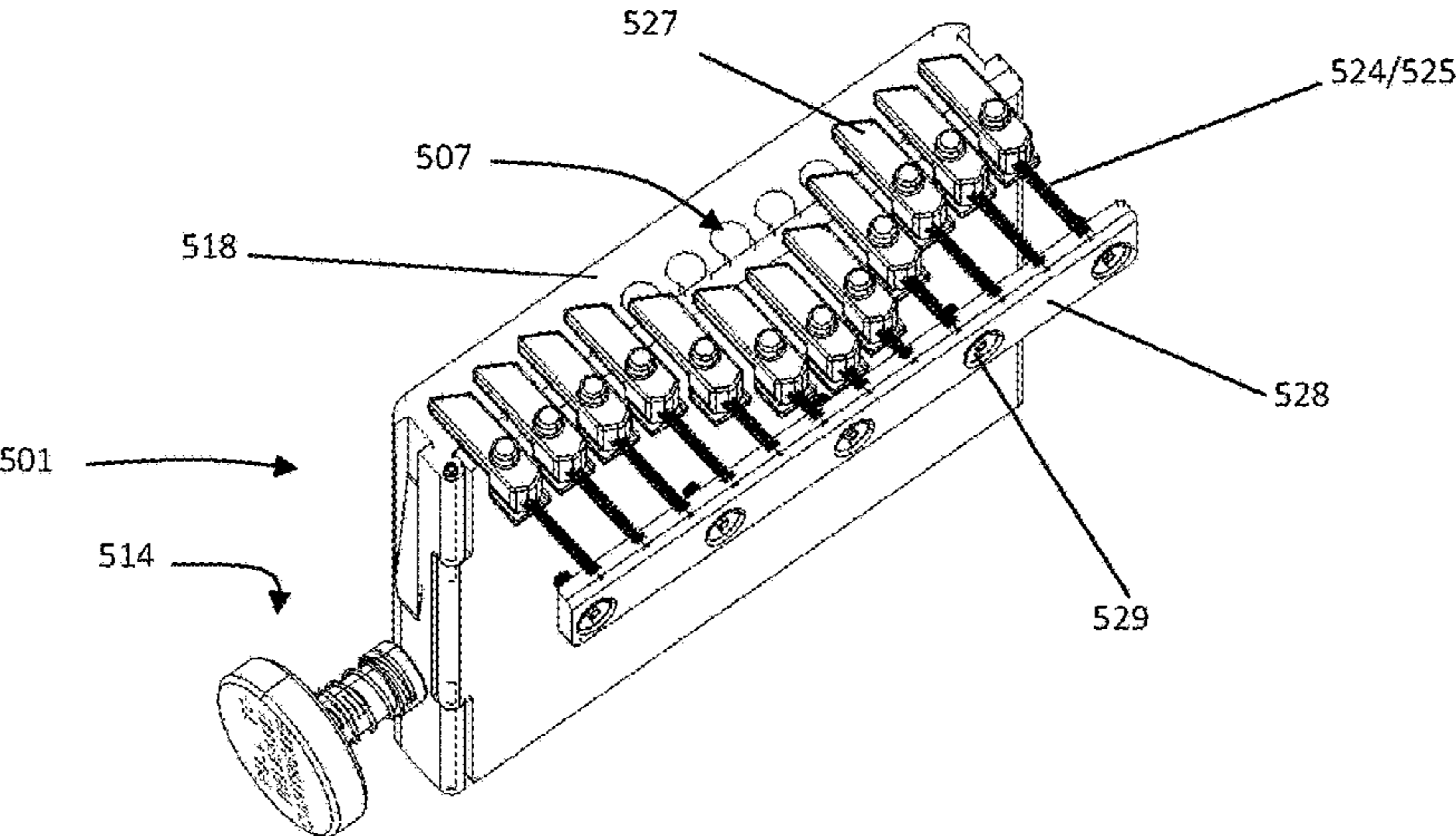


FIG. 64

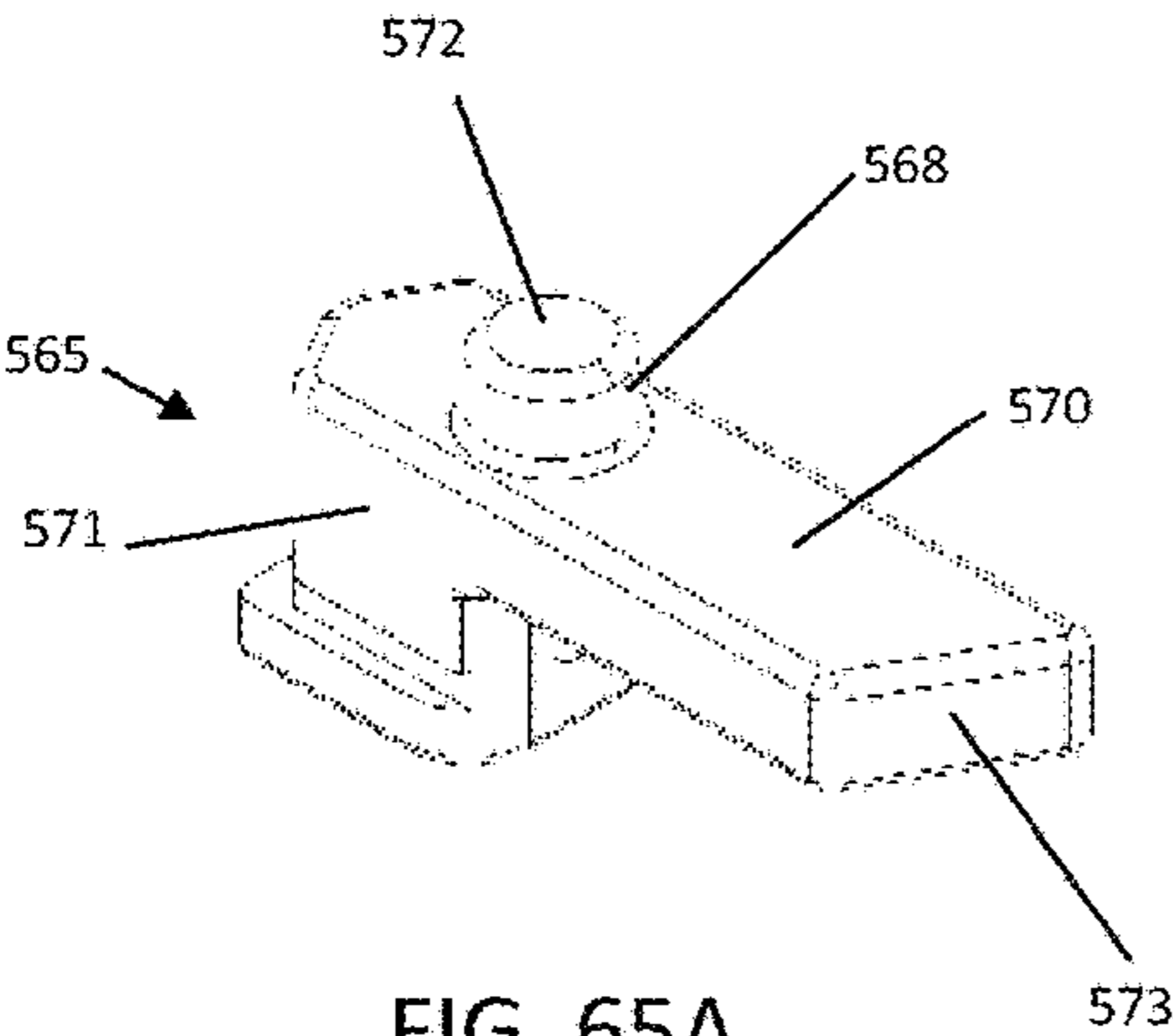


FIG. 65A

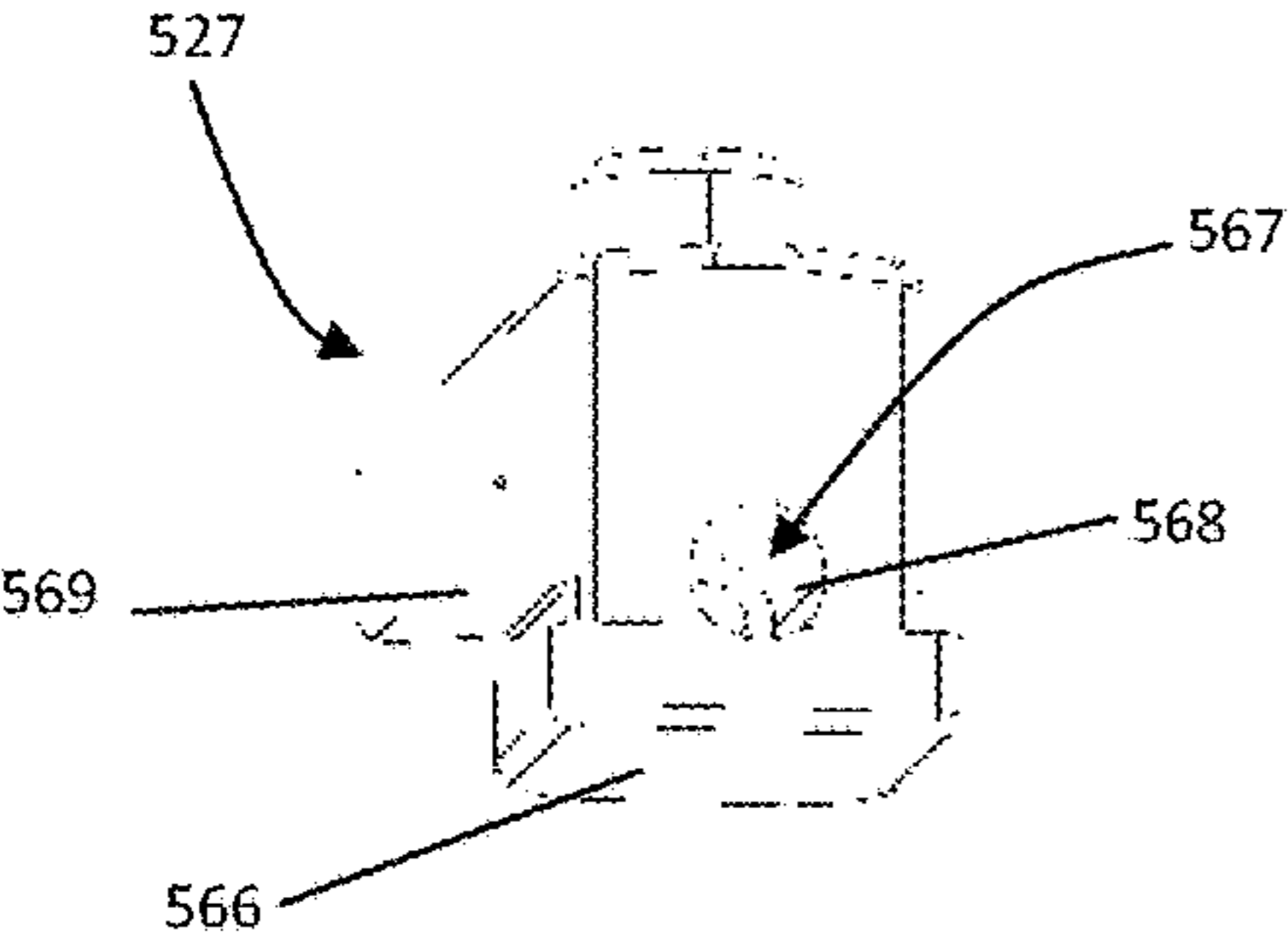


FIG. 65B

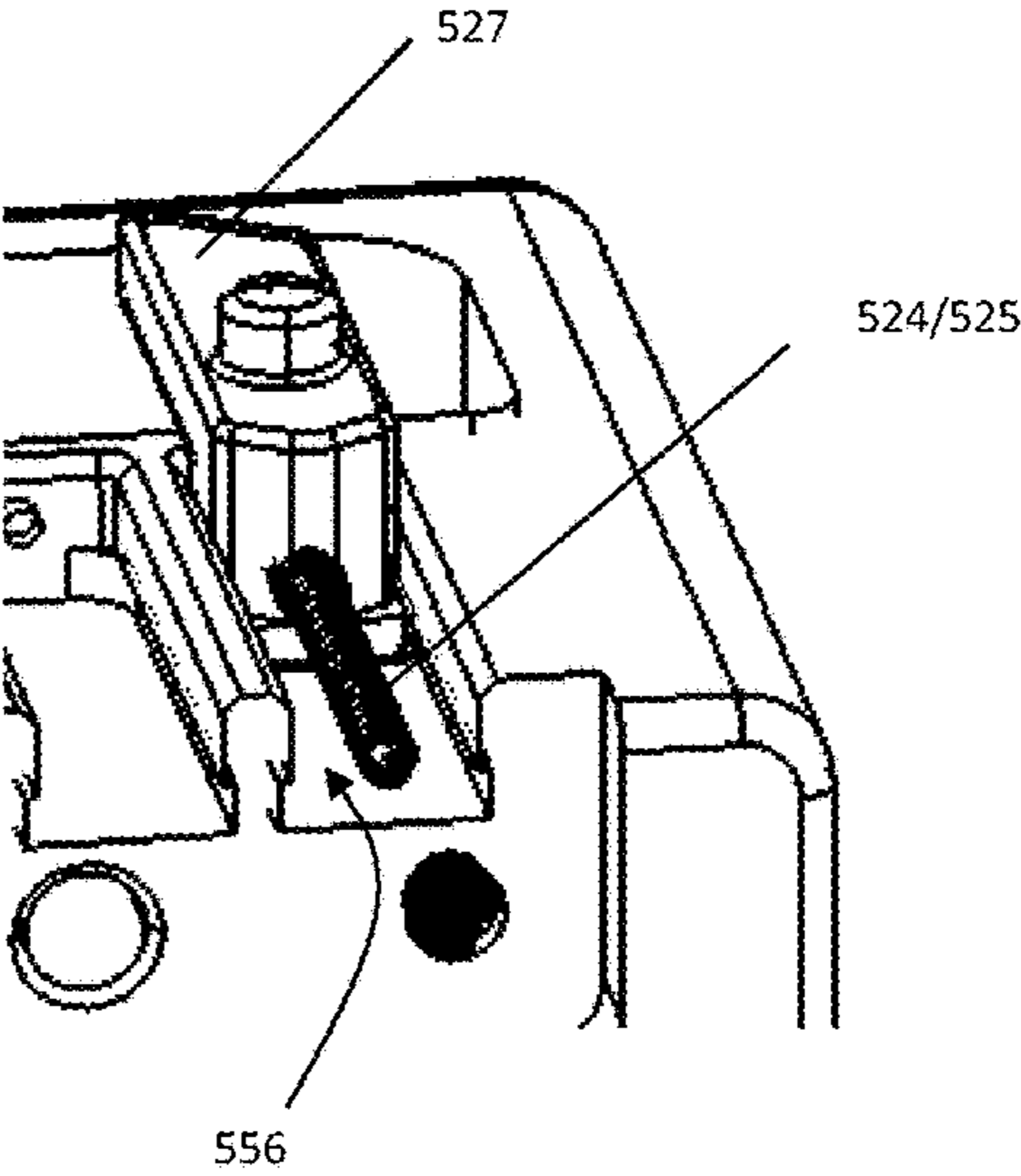


FIG. 65C

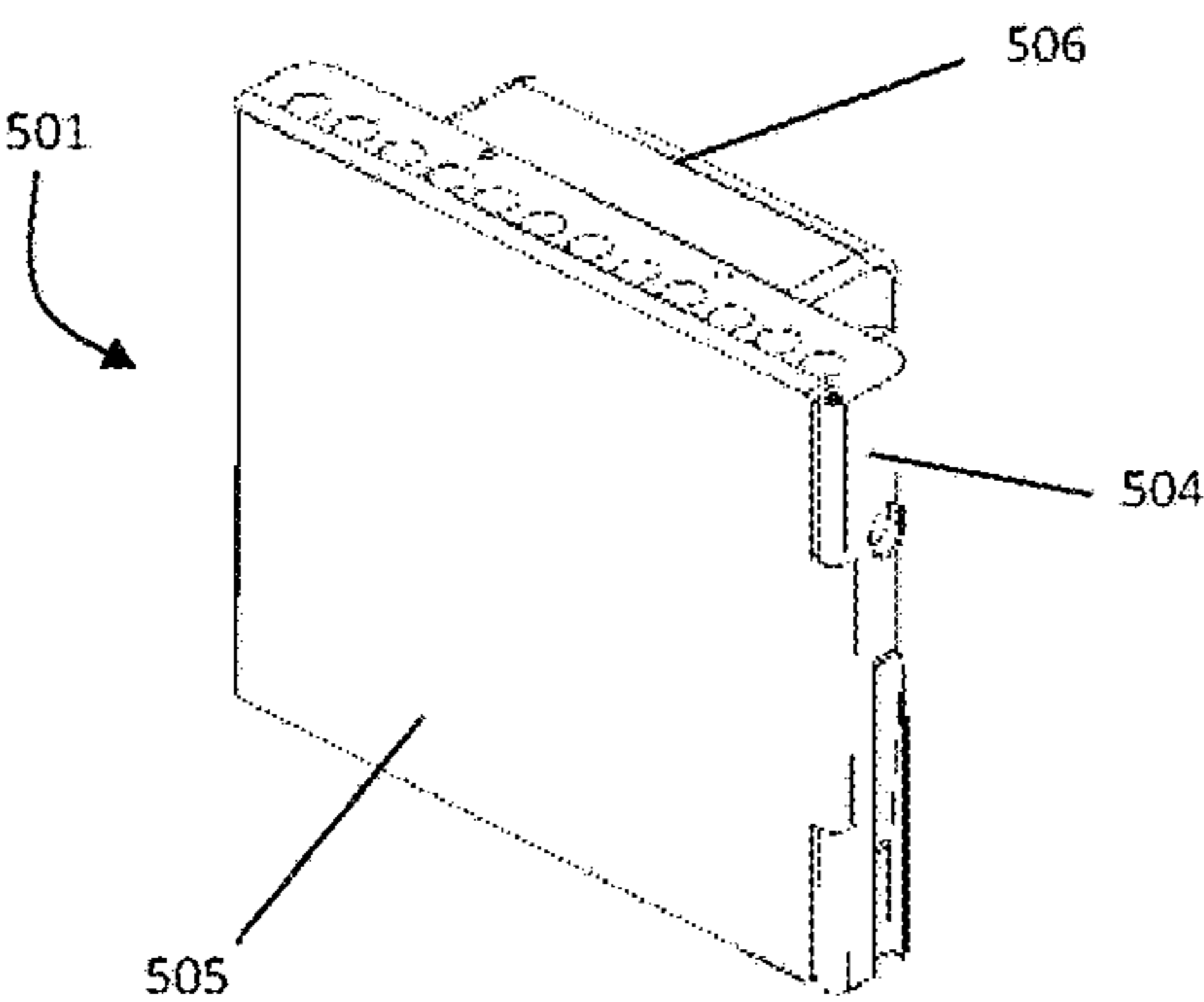


FIG. 66

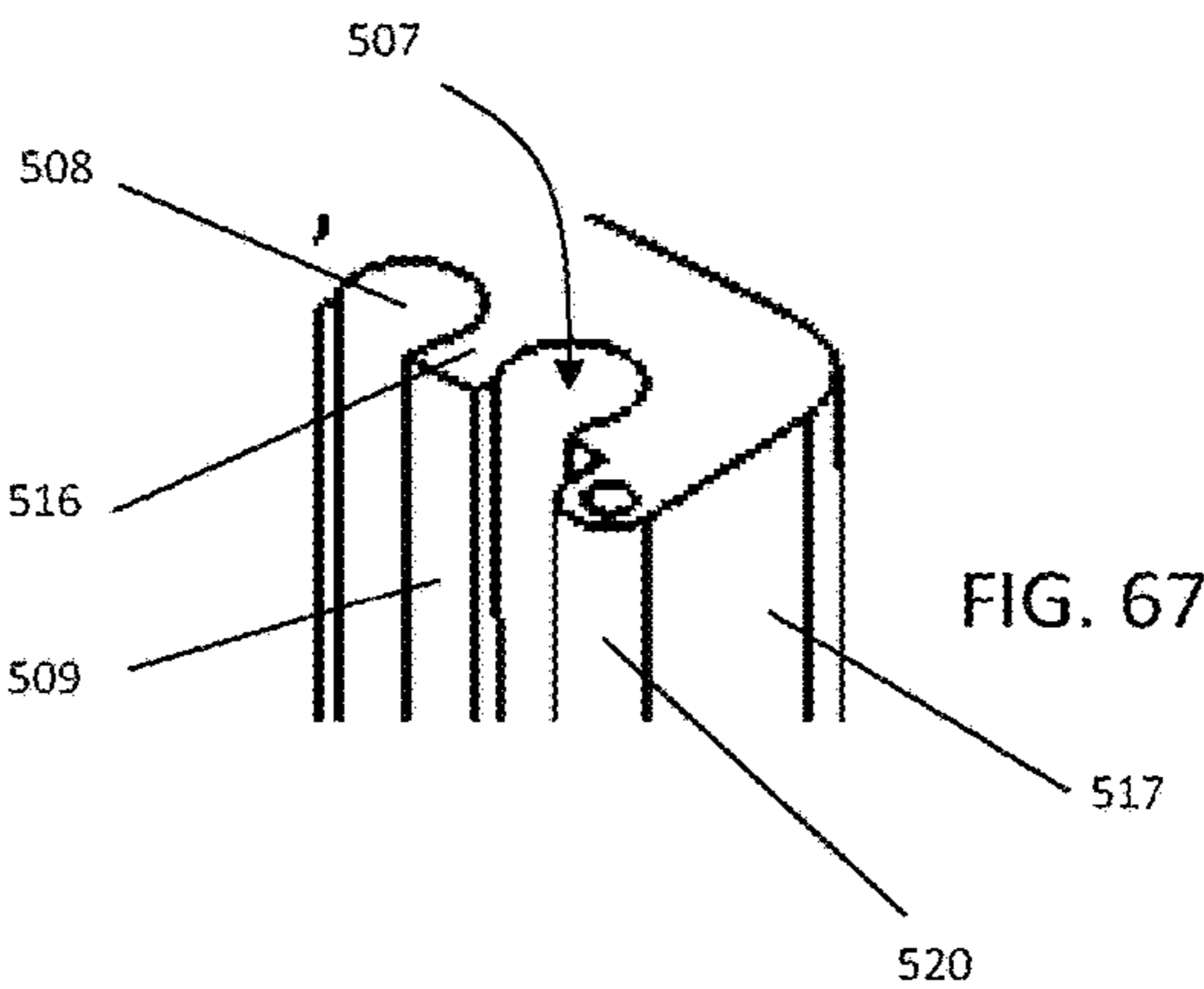


FIG. 67

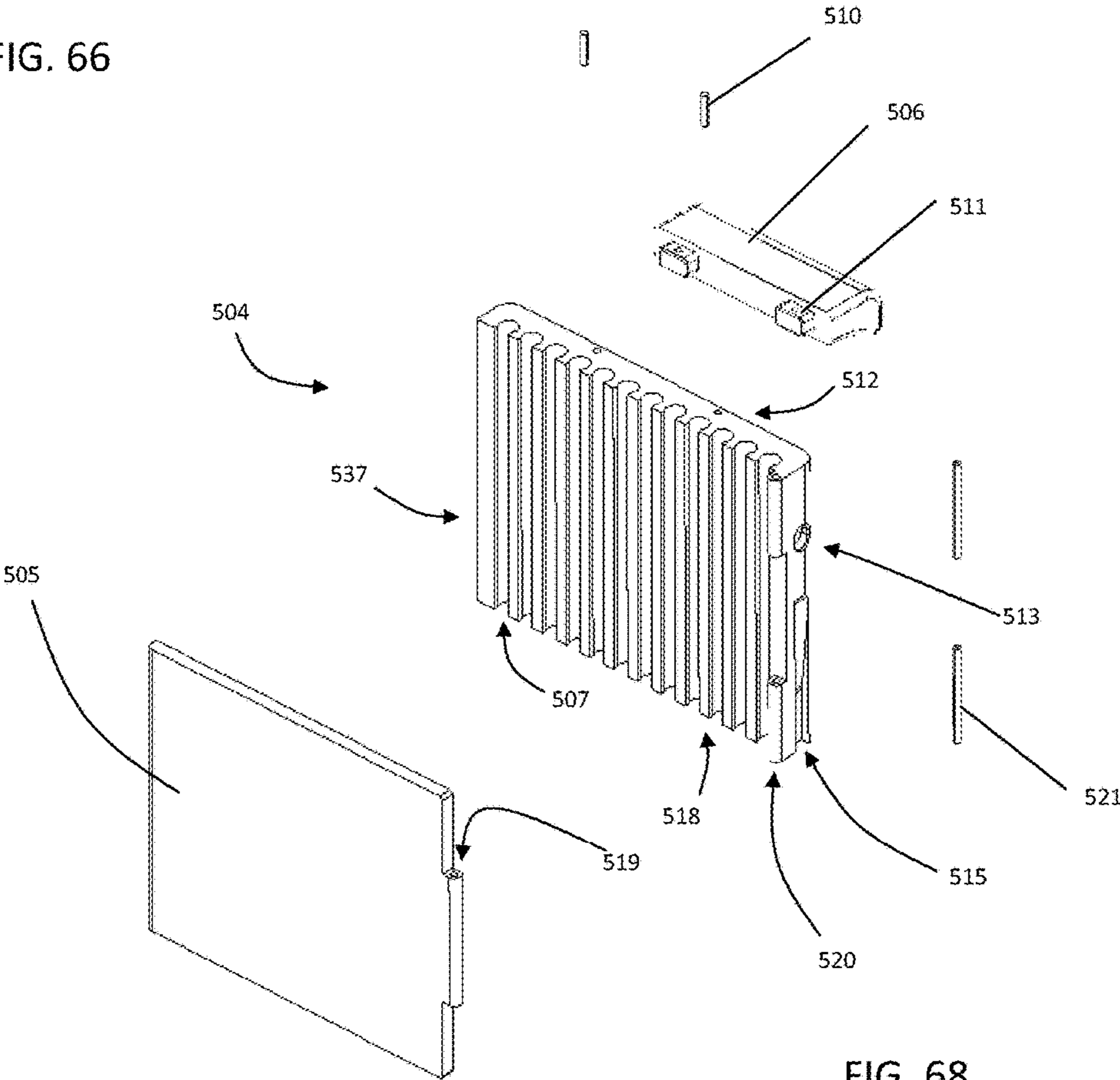
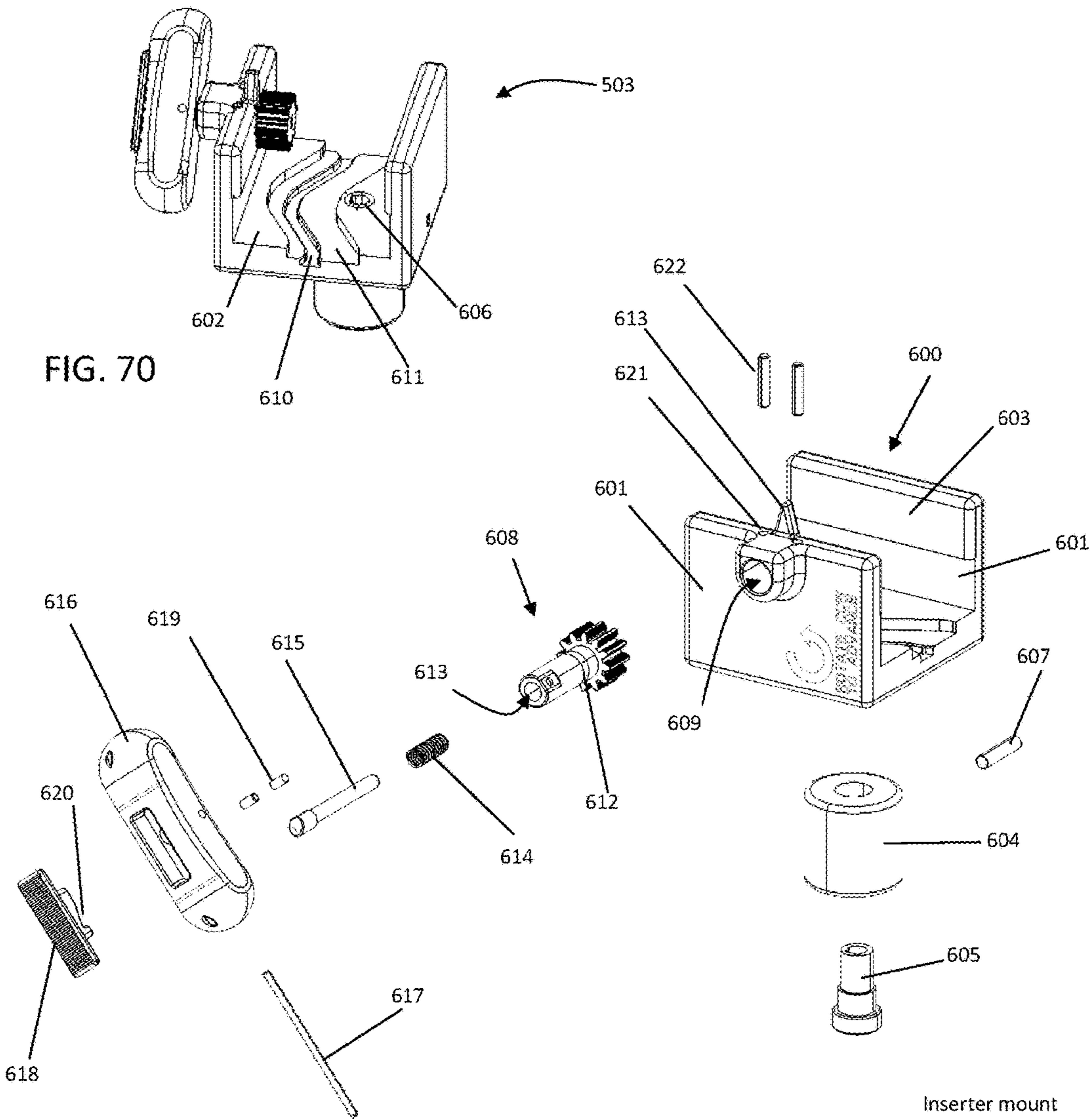


FIG. 68



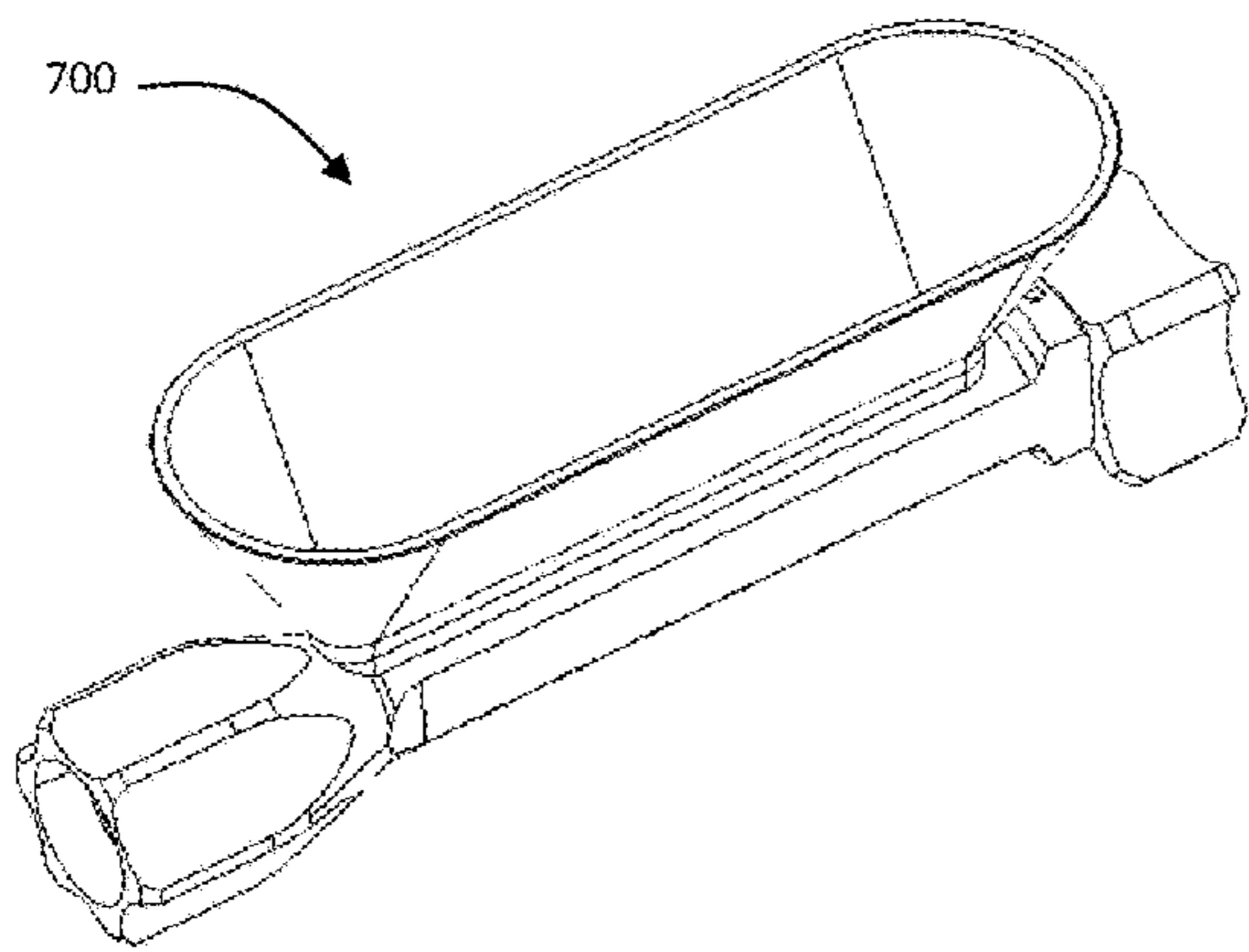


FIG. 72

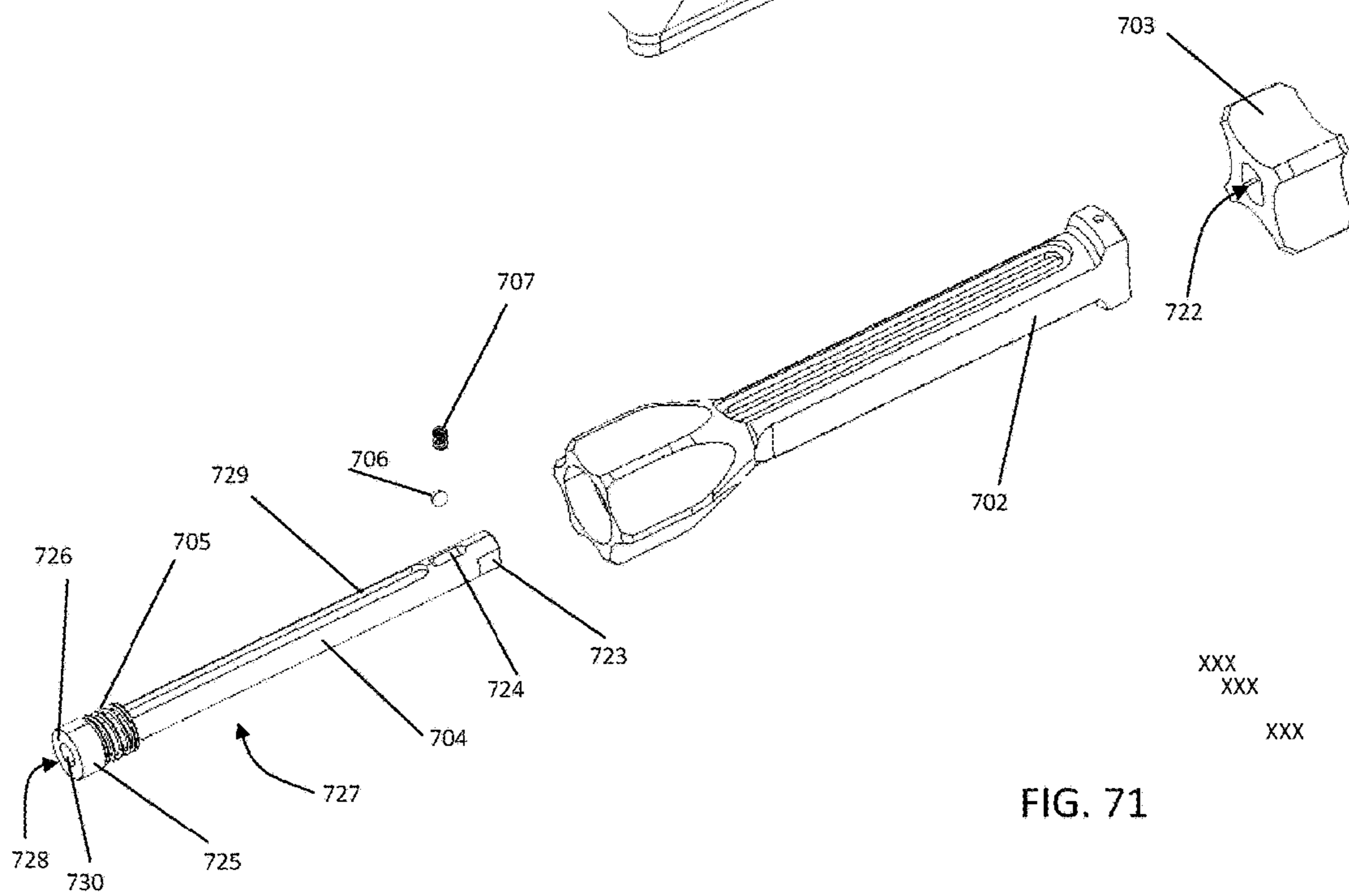
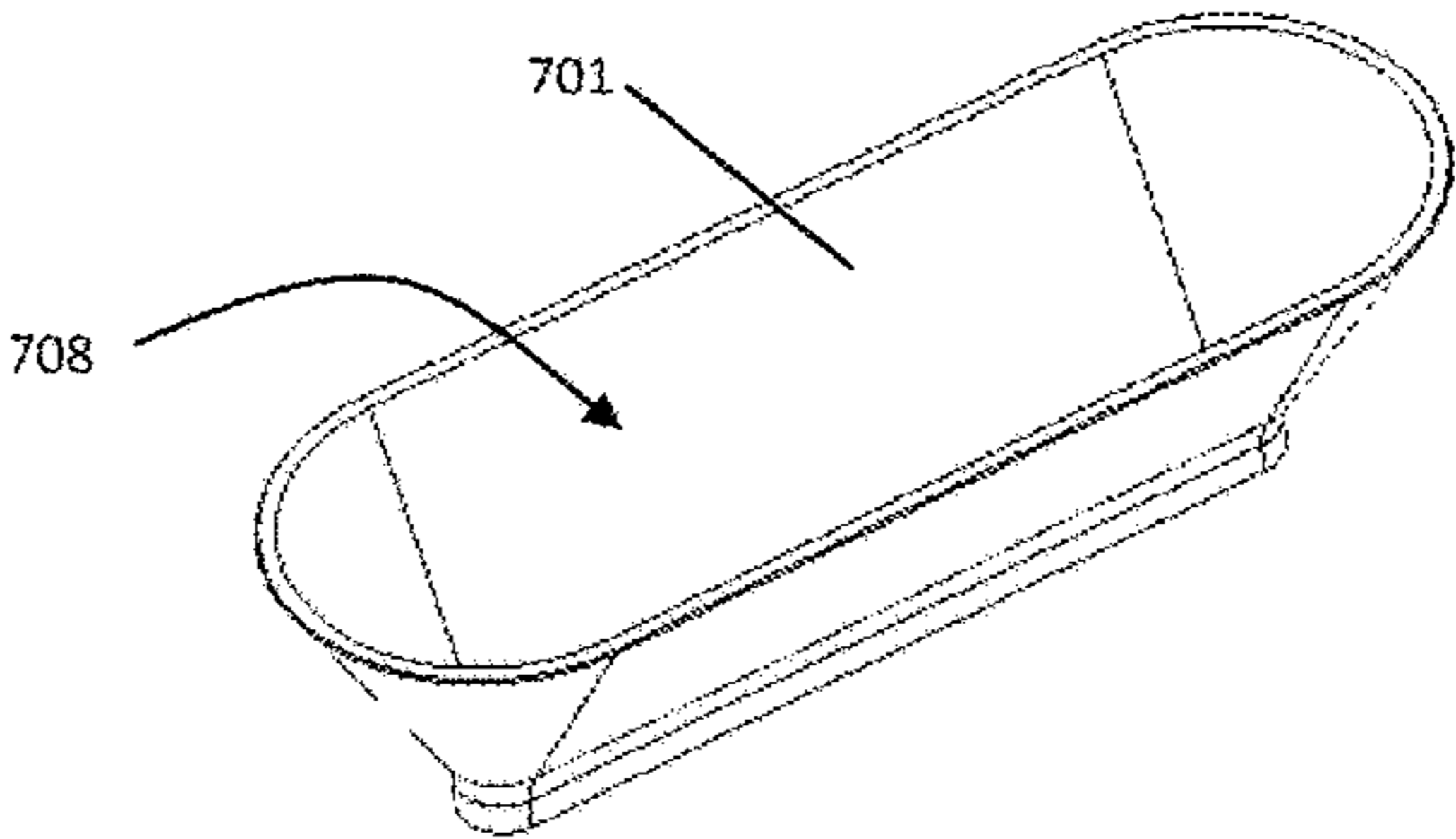
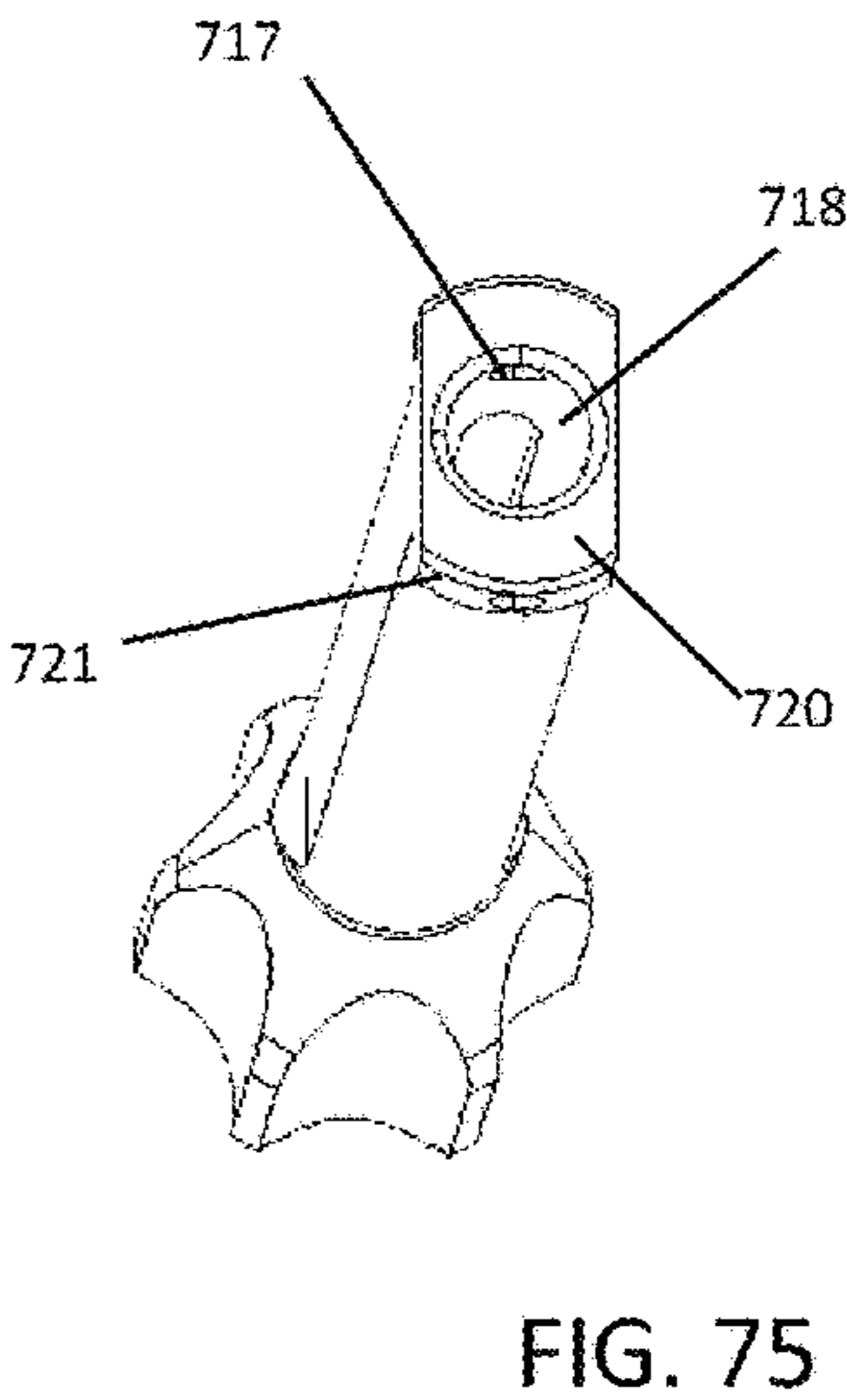
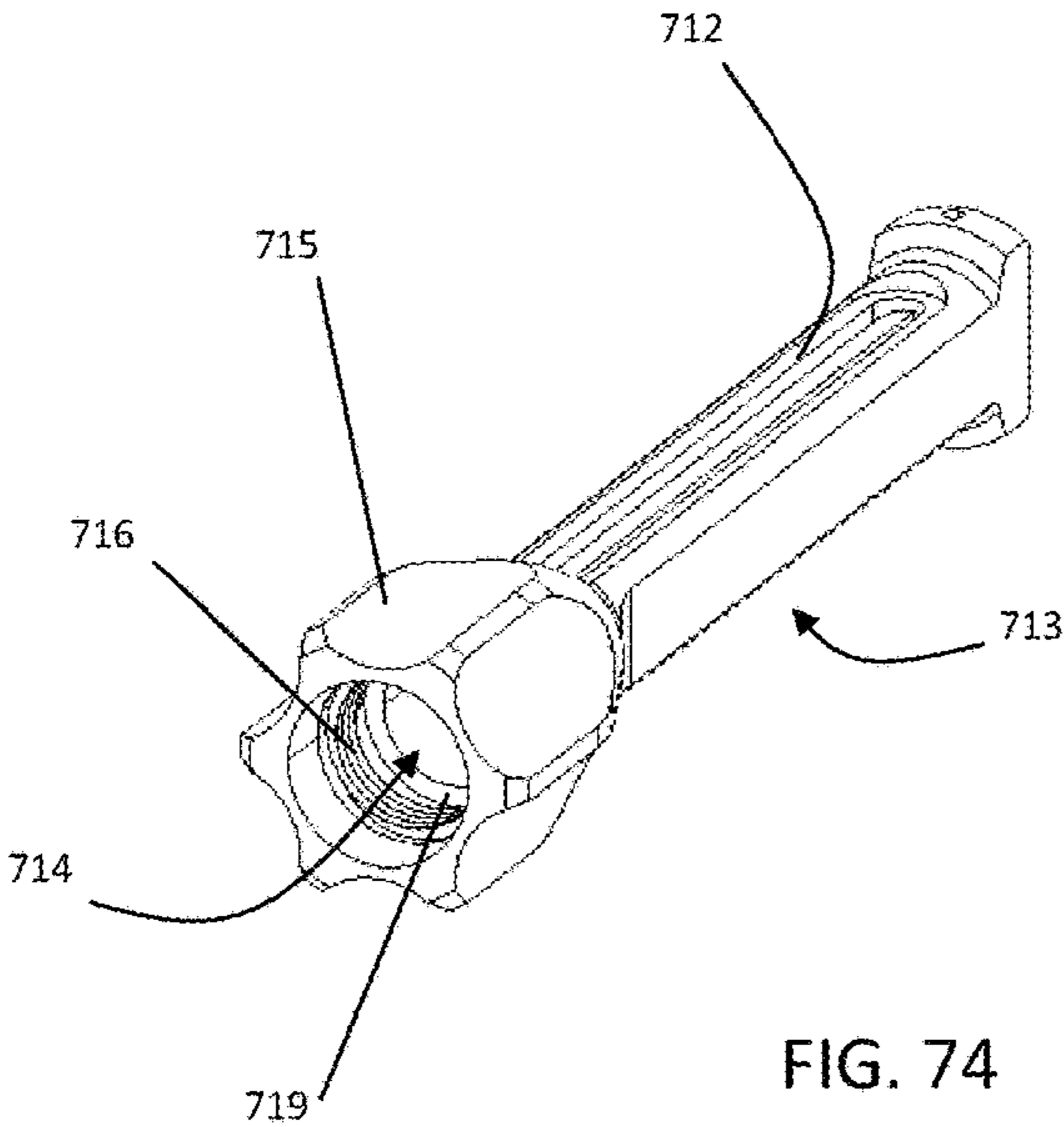
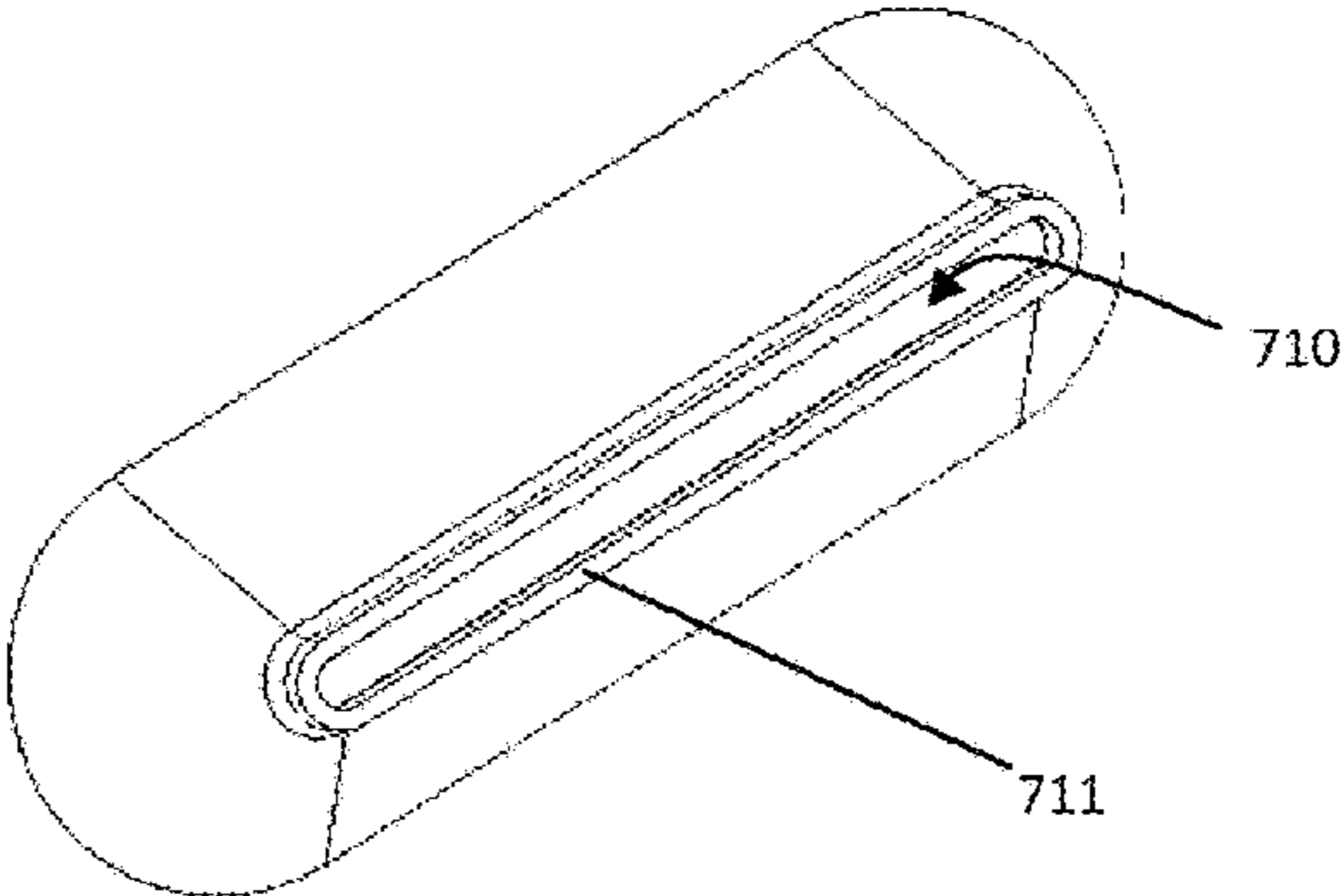
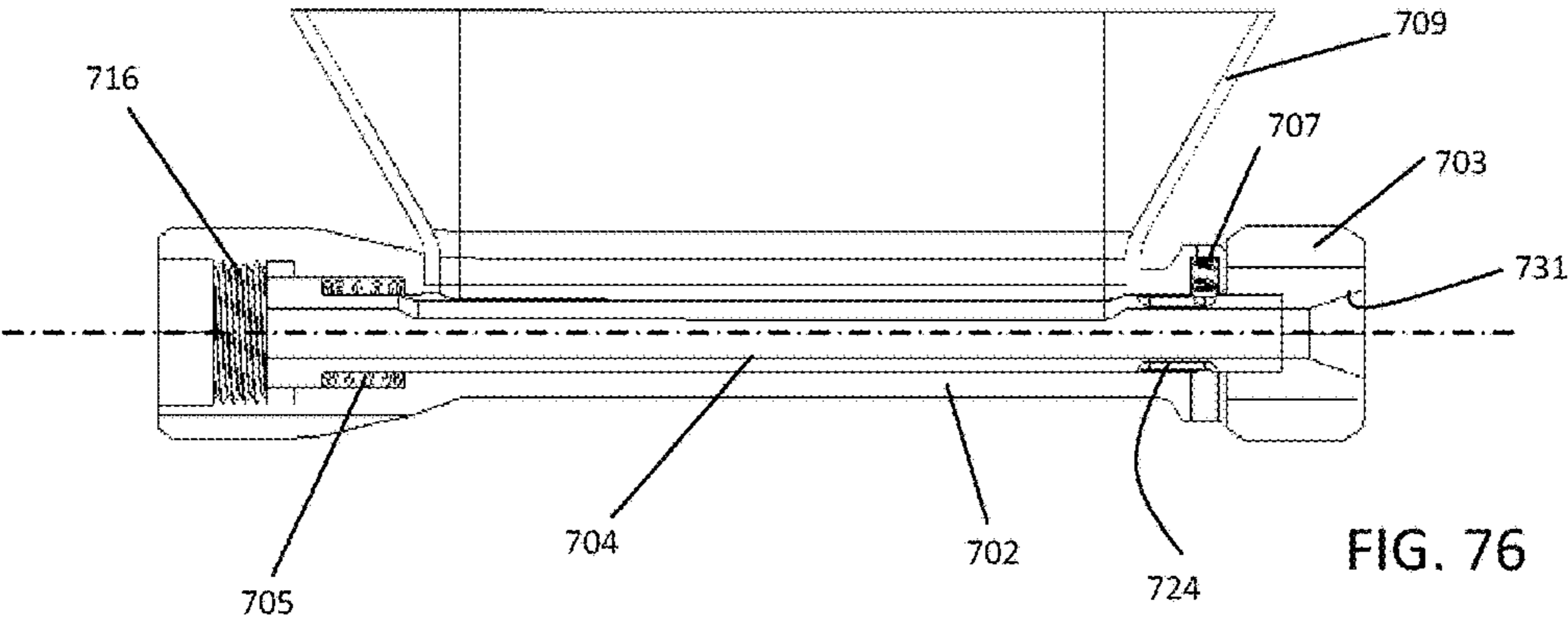
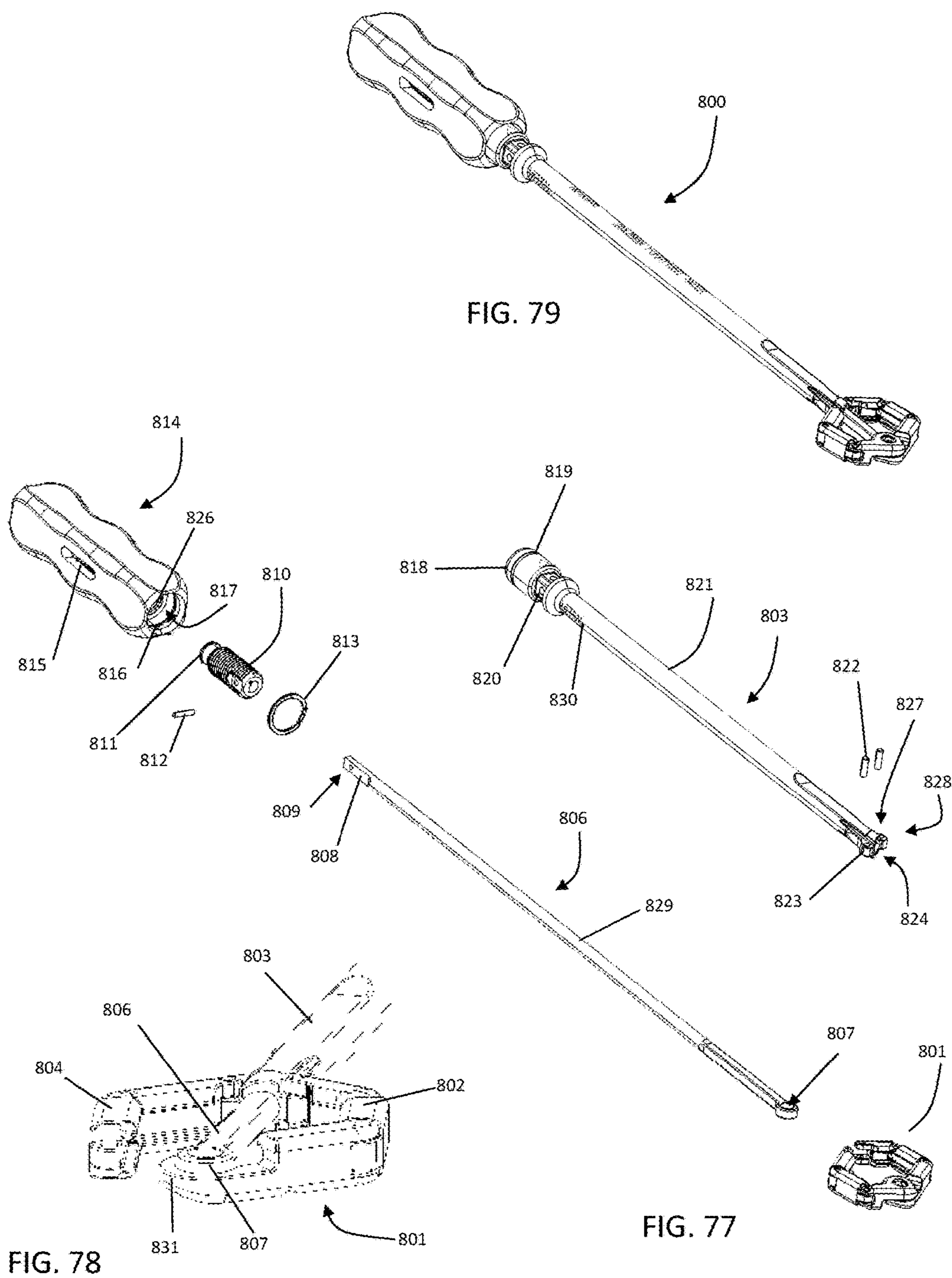


FIG. 71





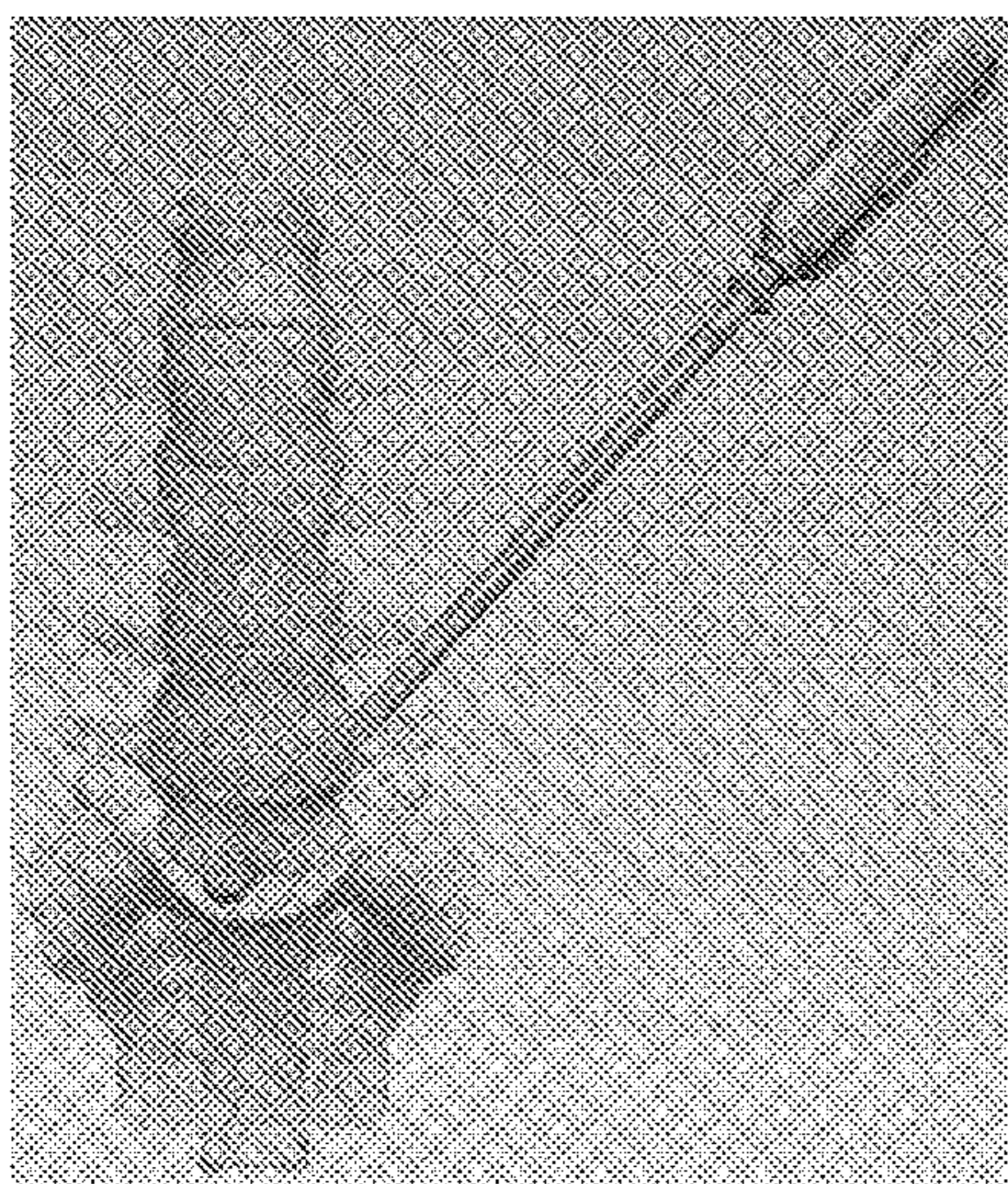


FIG. 80



FIG. 81

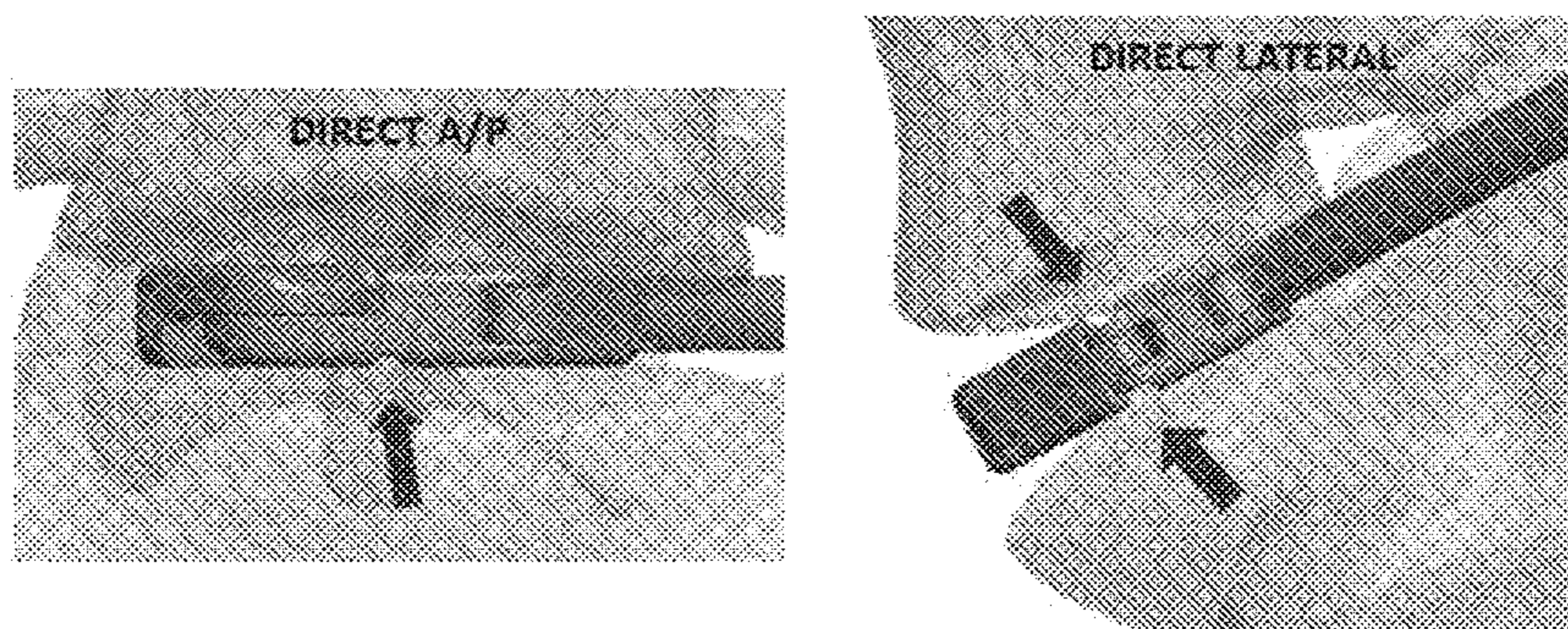


FIG. 82

GREEN INDICATOR IS PROXIMAL TO THE SLOT

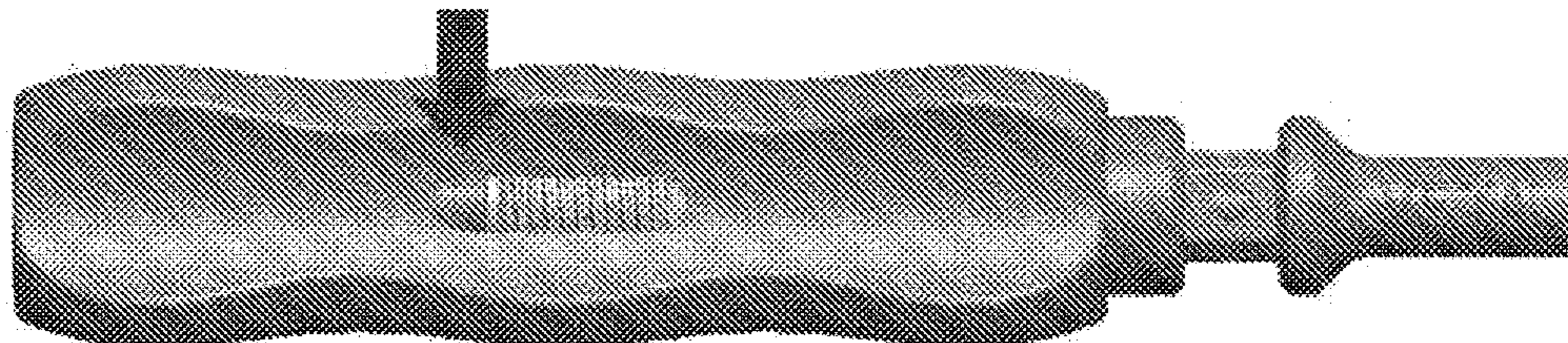


FIG. 83

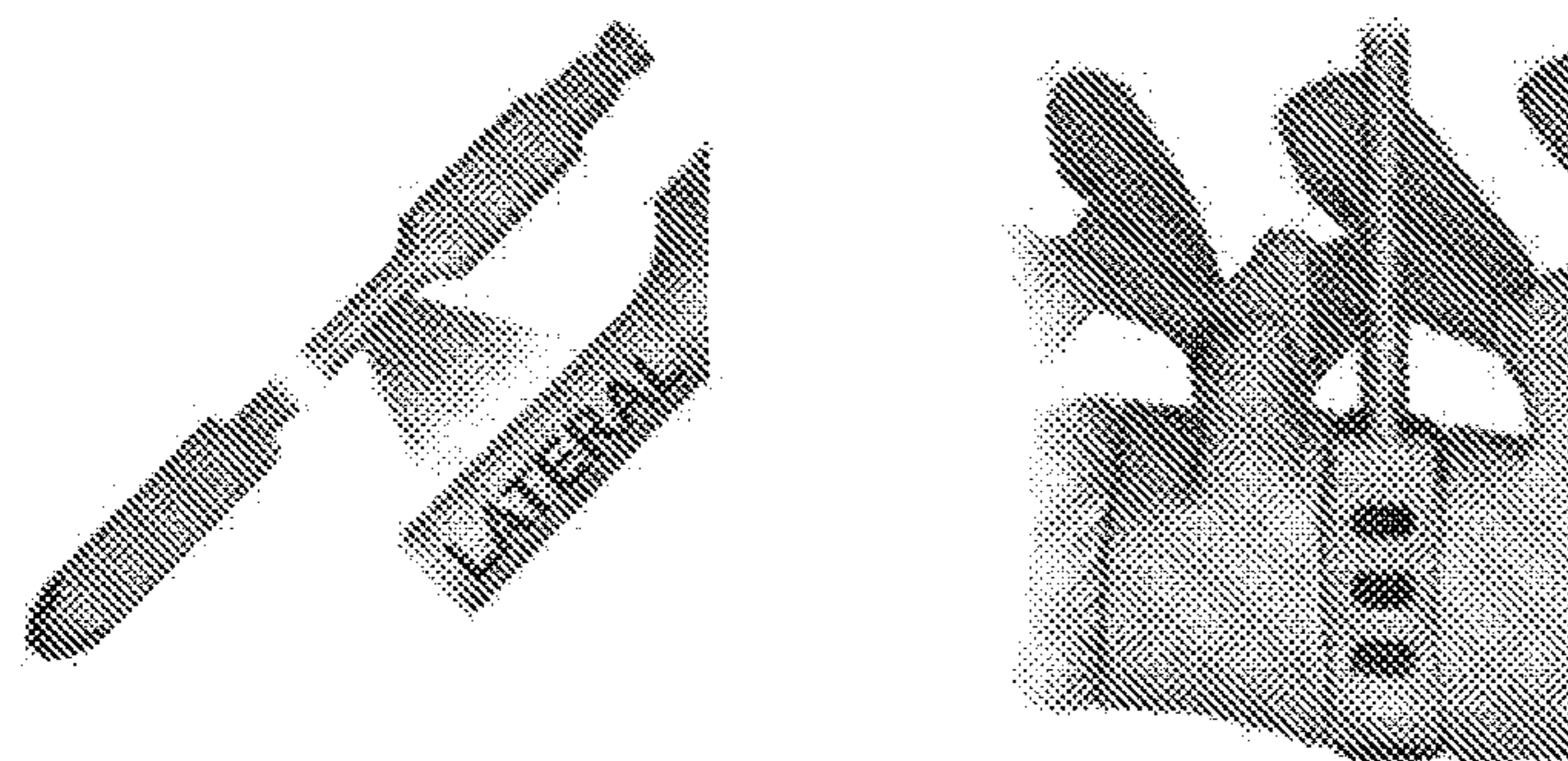


FIG. 84

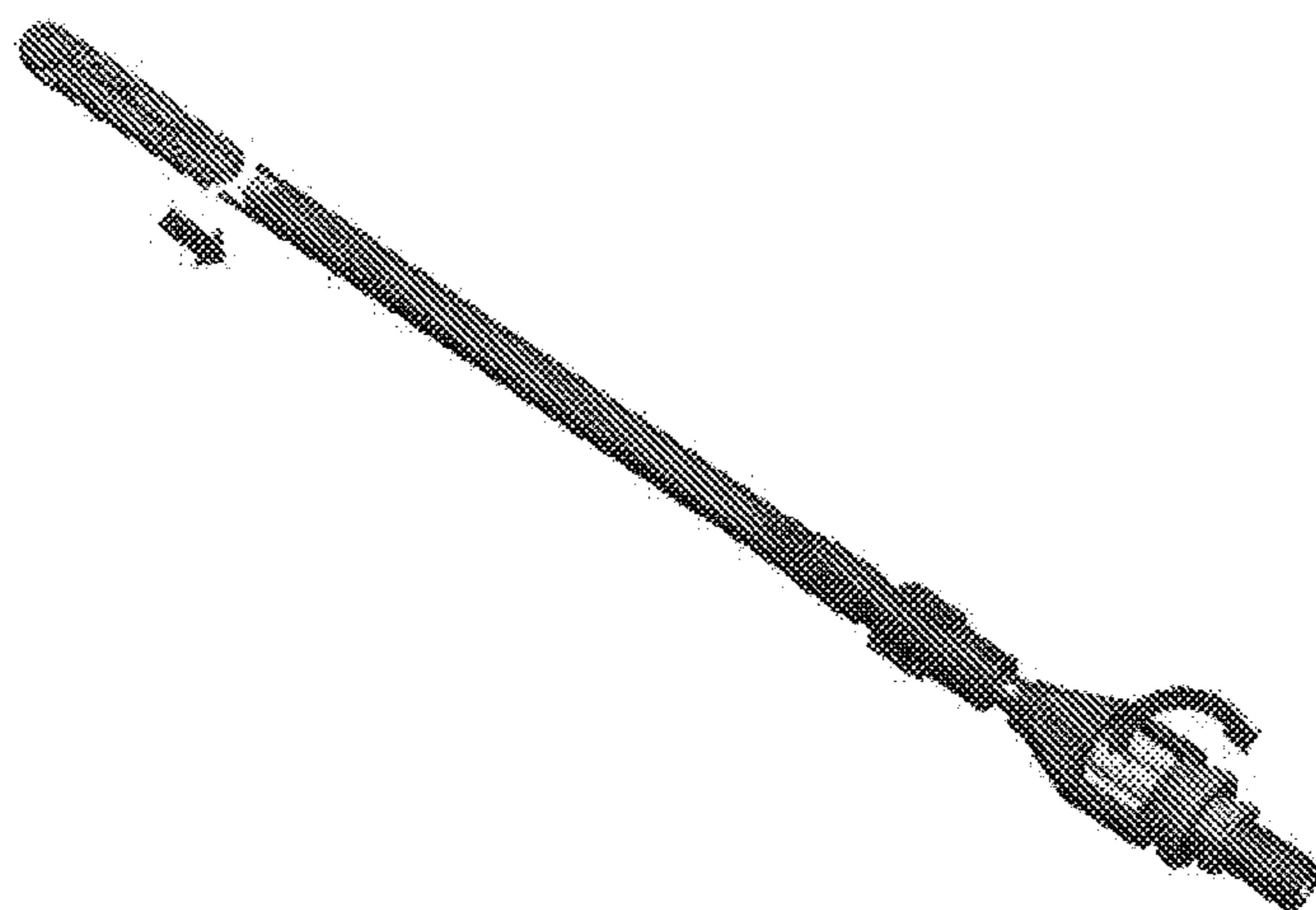


FIG. 85

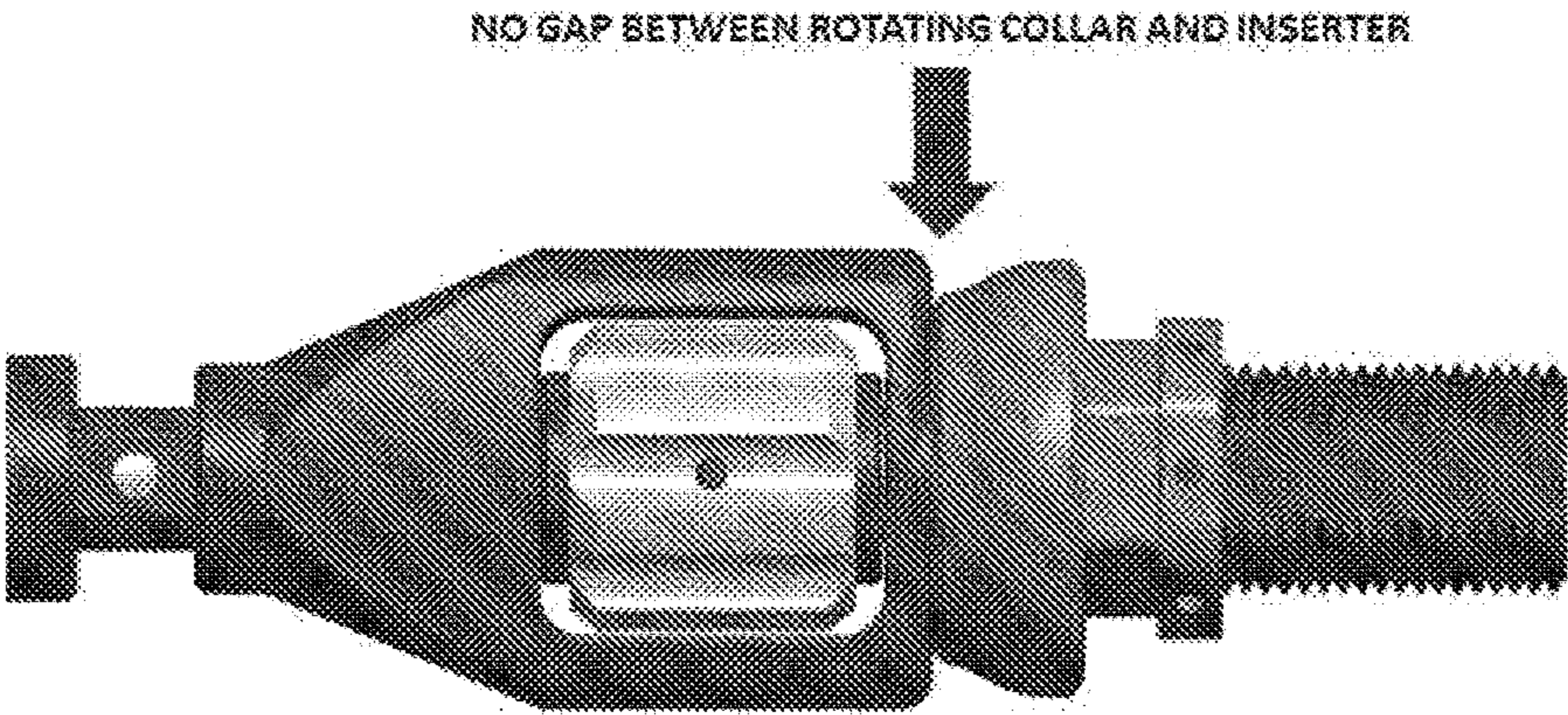


FIG. 86

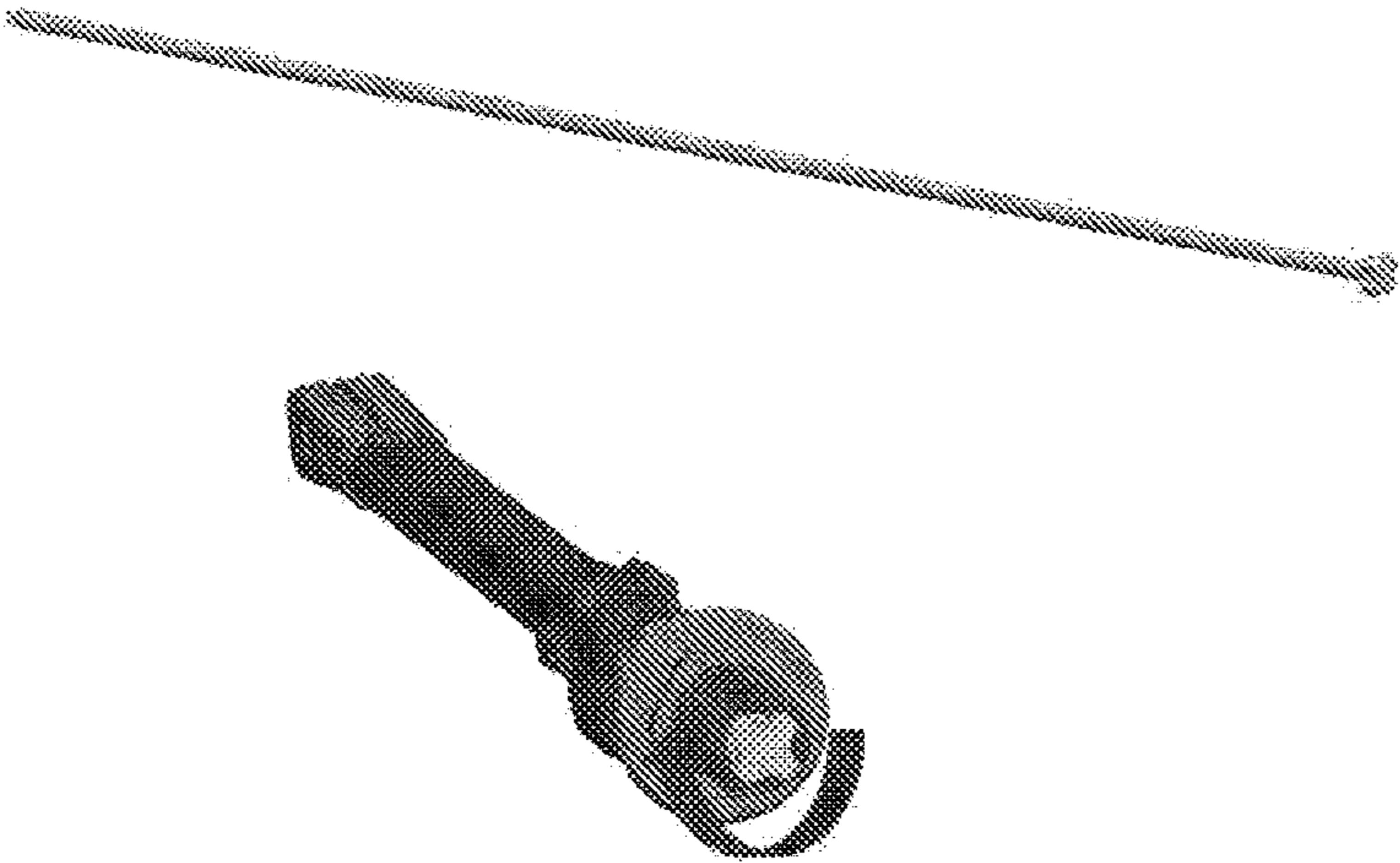


FIG. 87

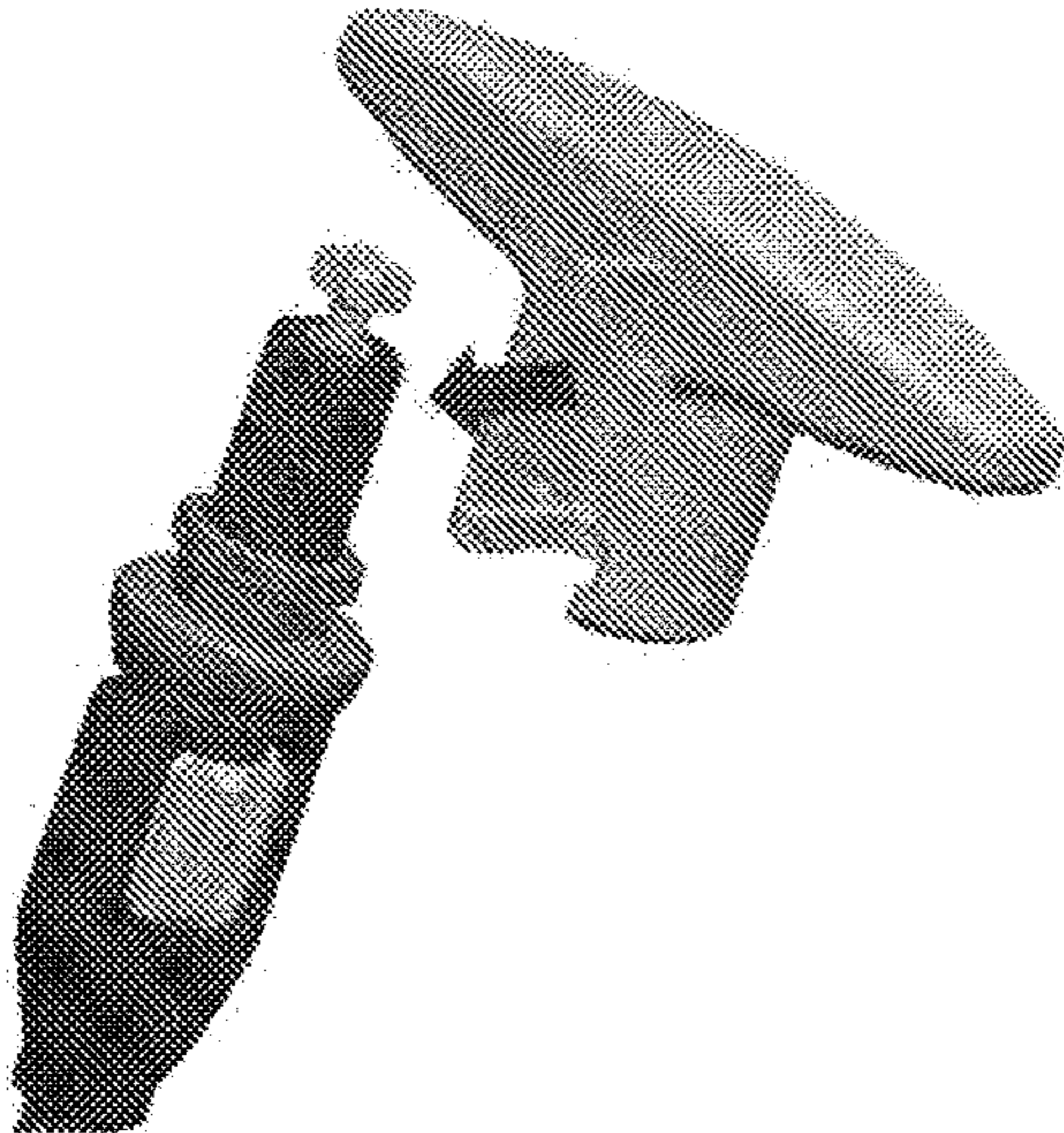


FIG. 88

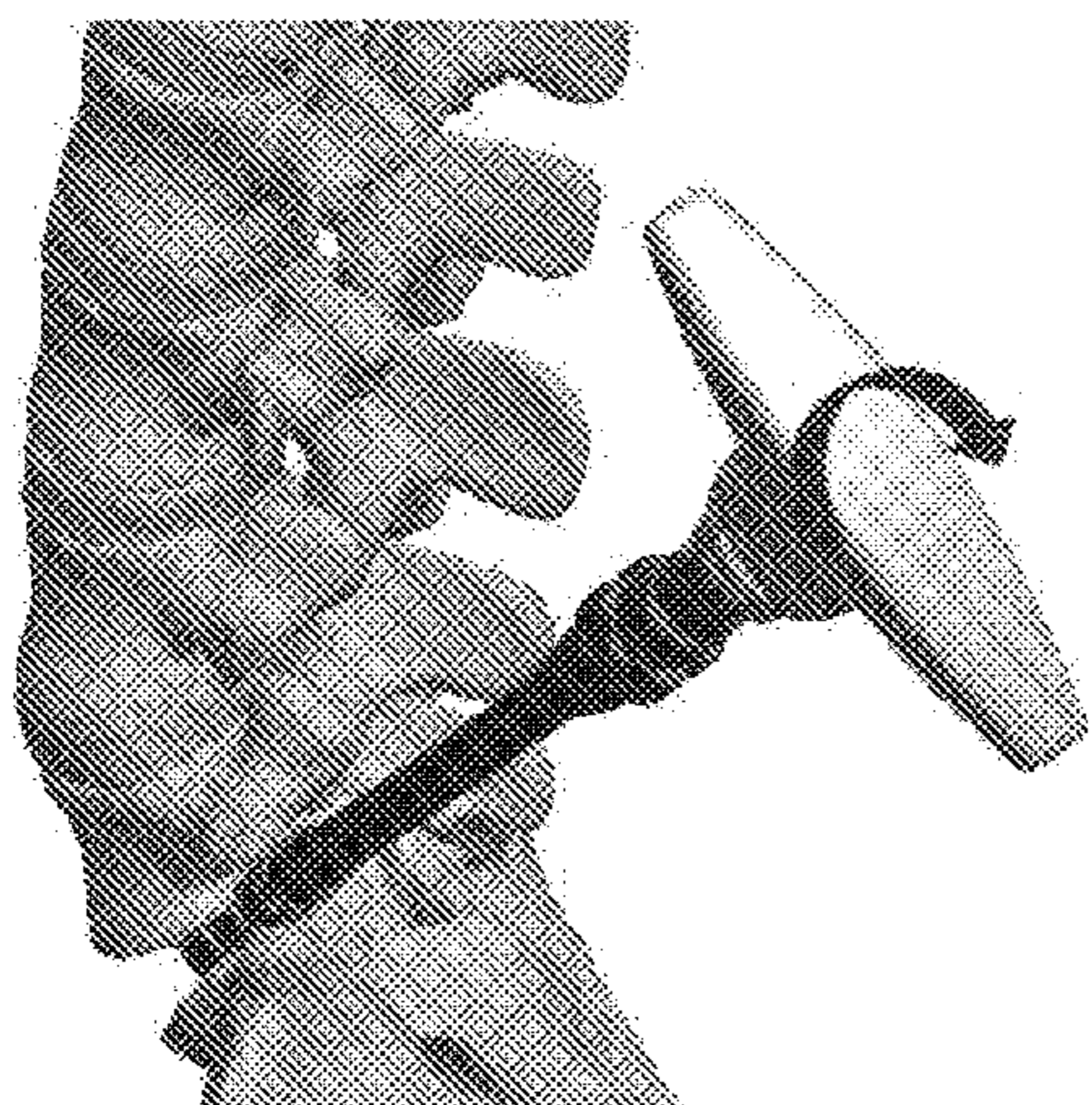


FIG. 89

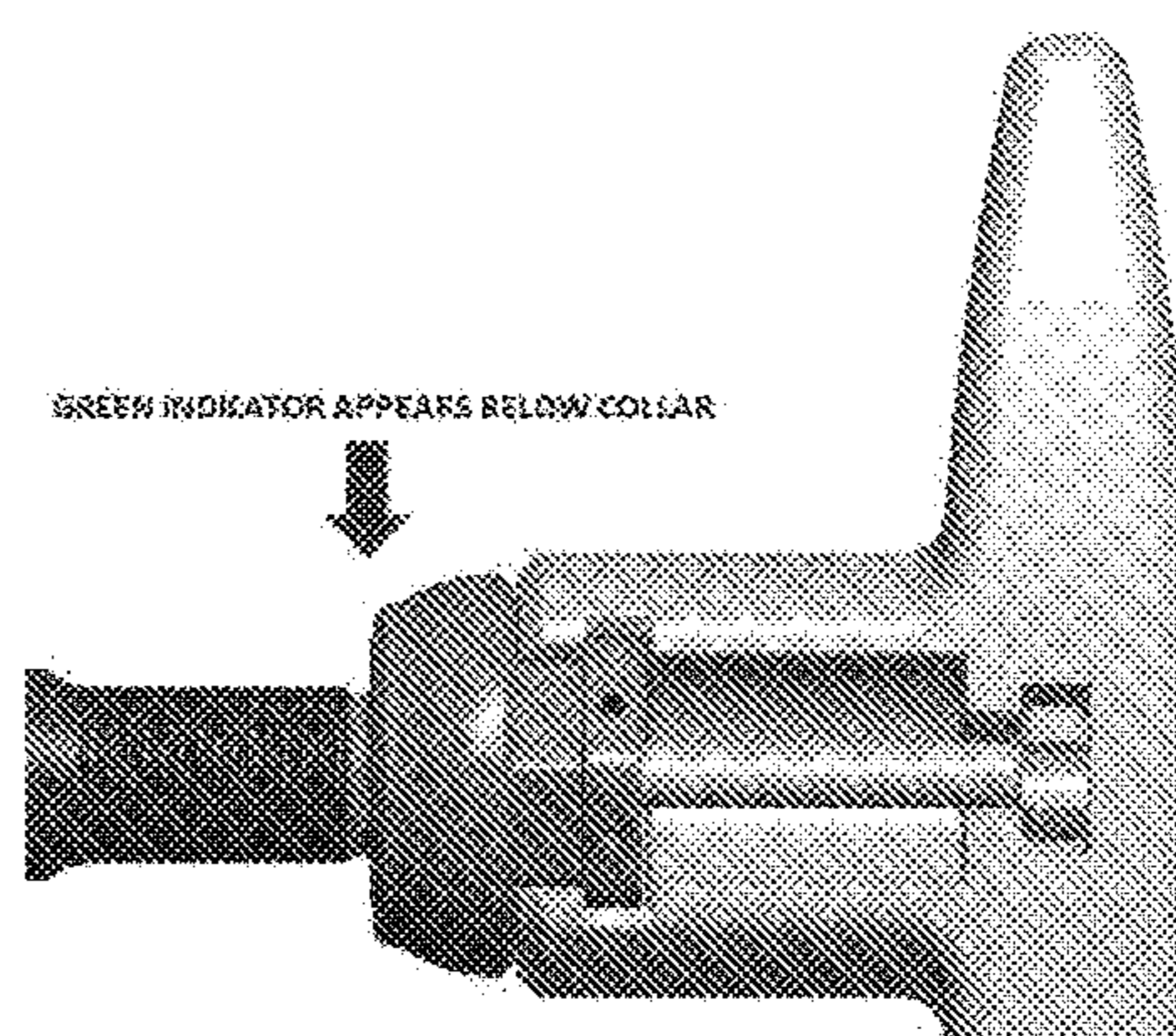


FIG. 90

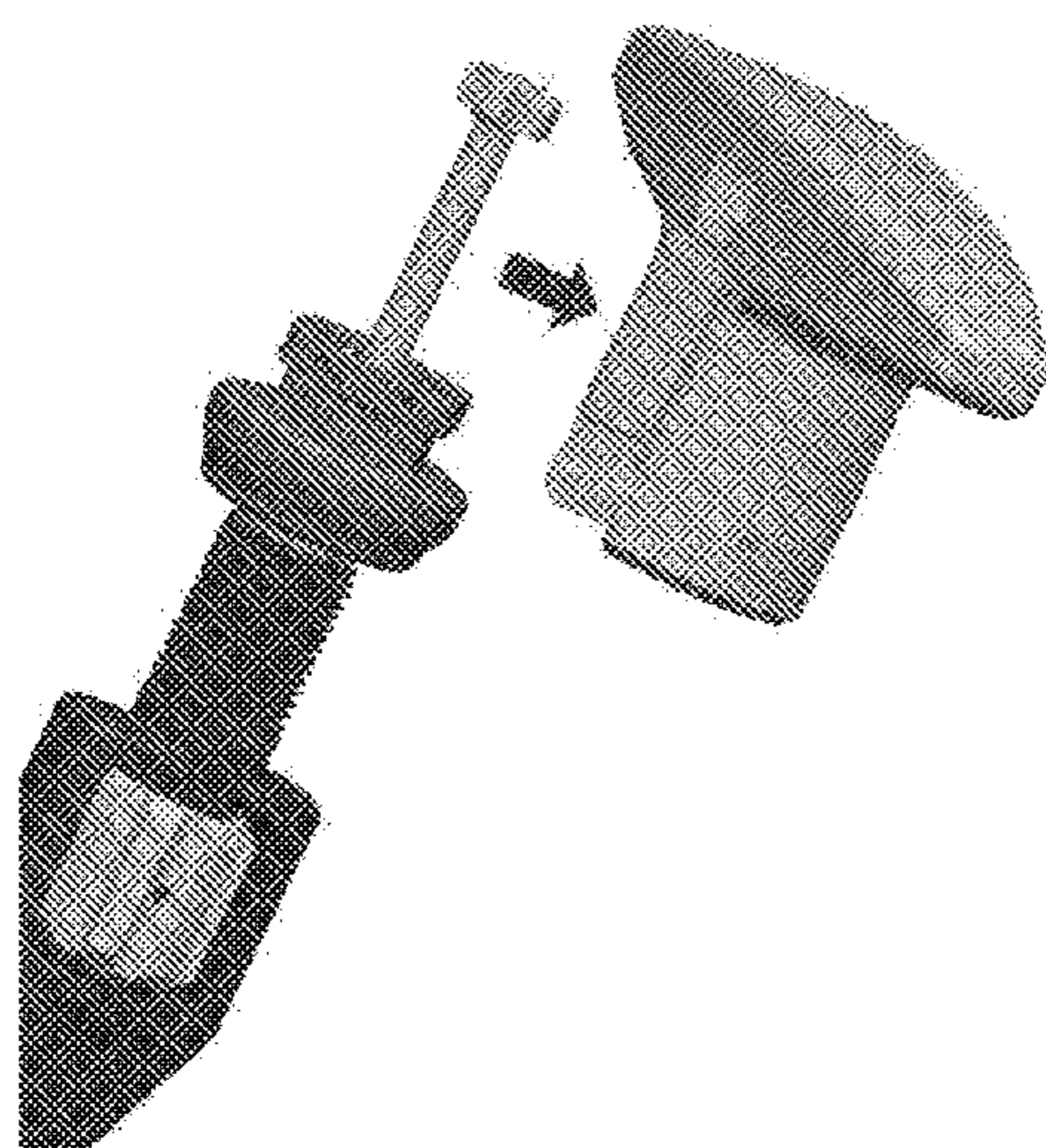


FIG. 91

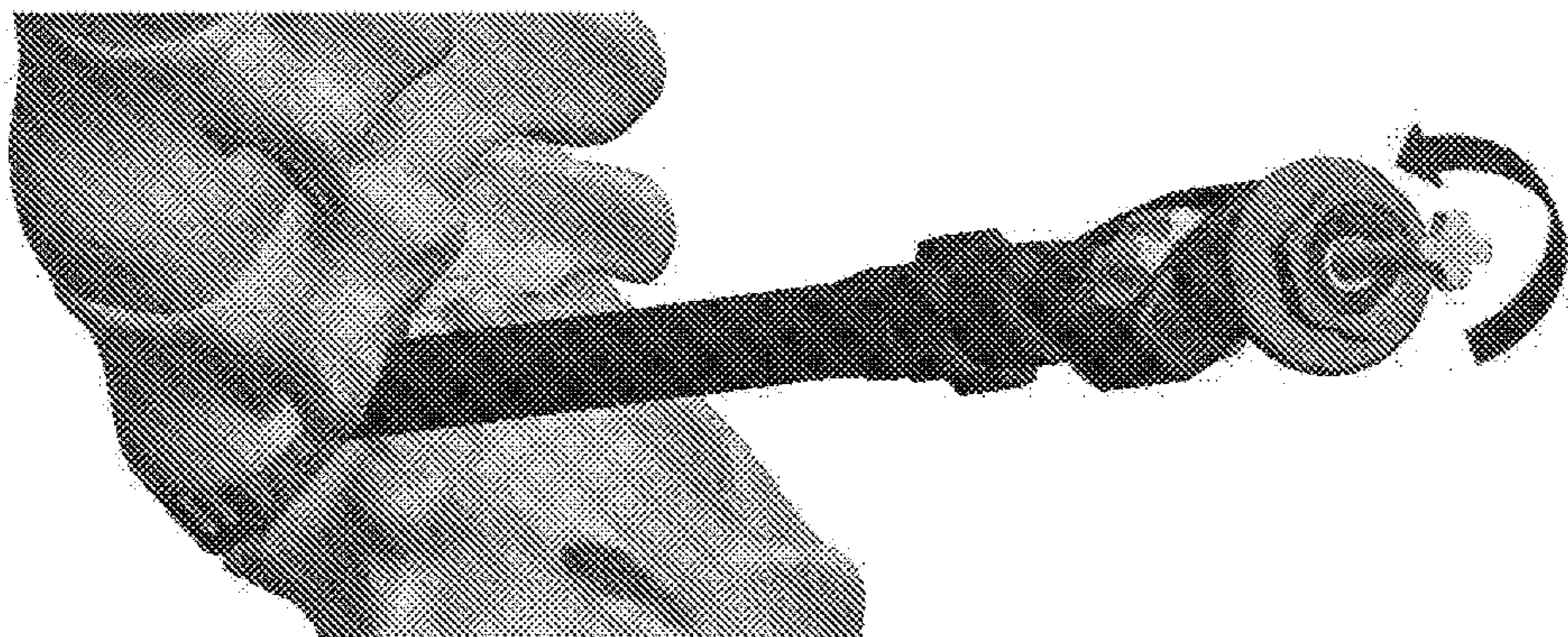


FIG. 92

FIG. 93

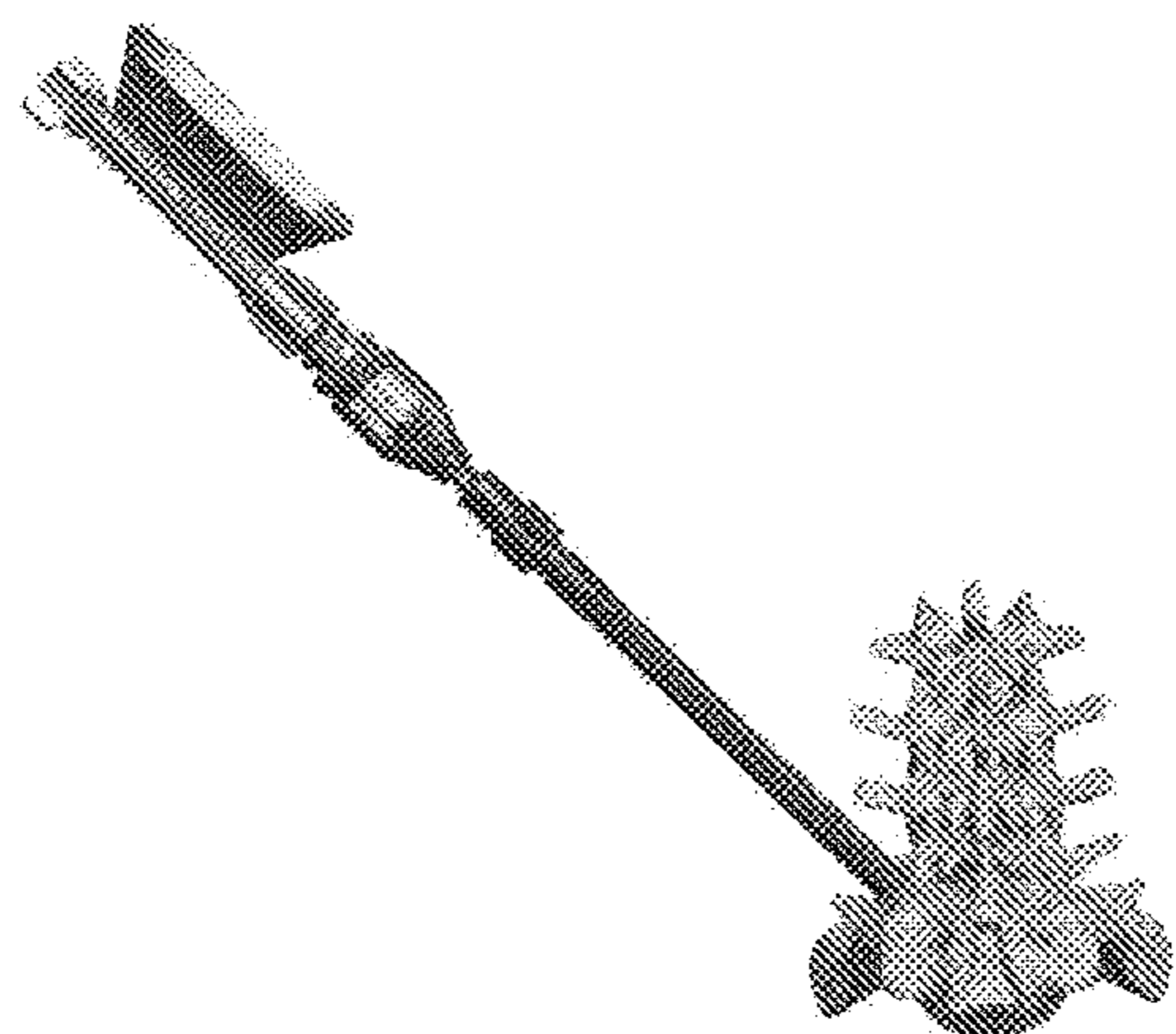
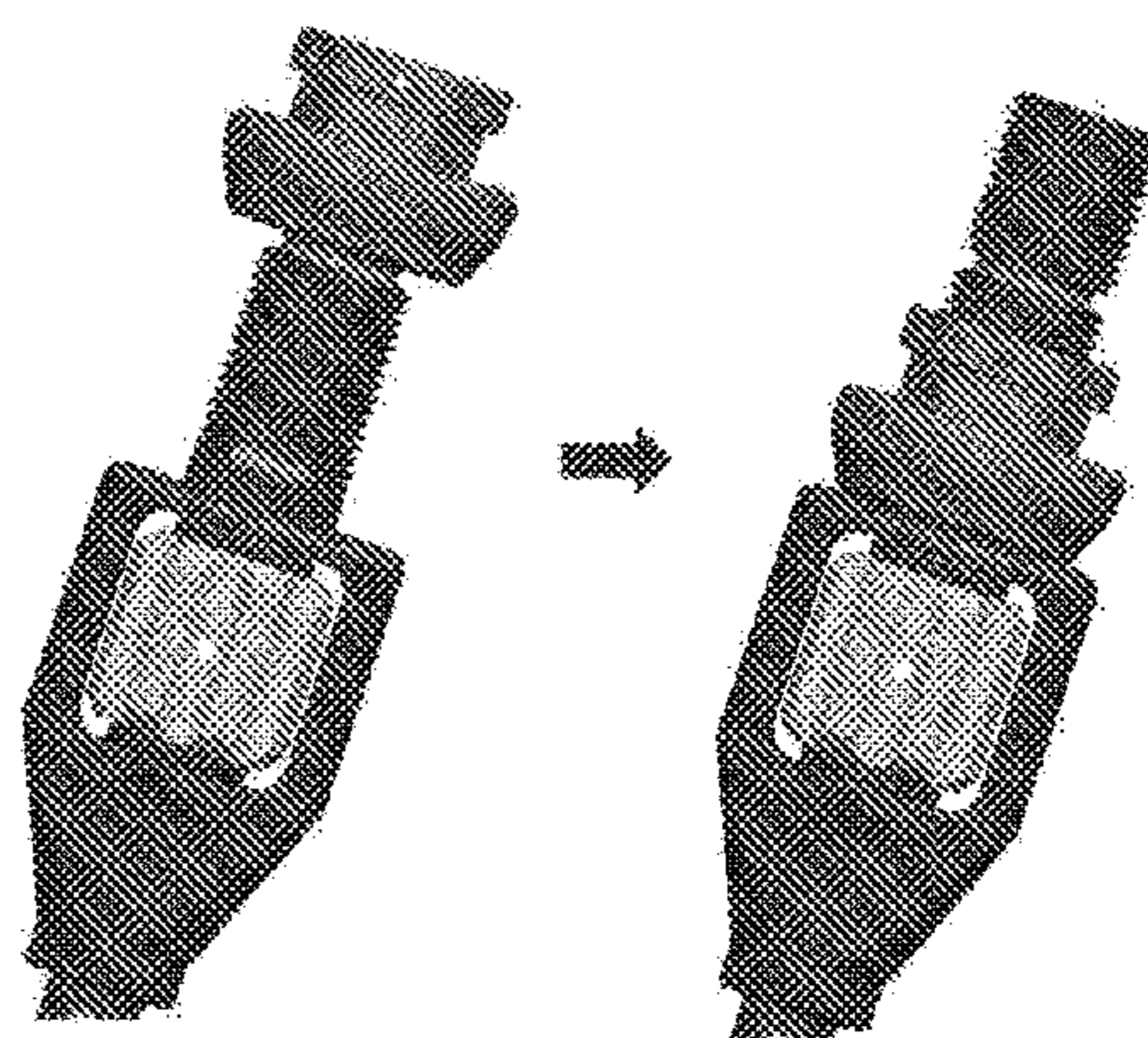


FIG. 94

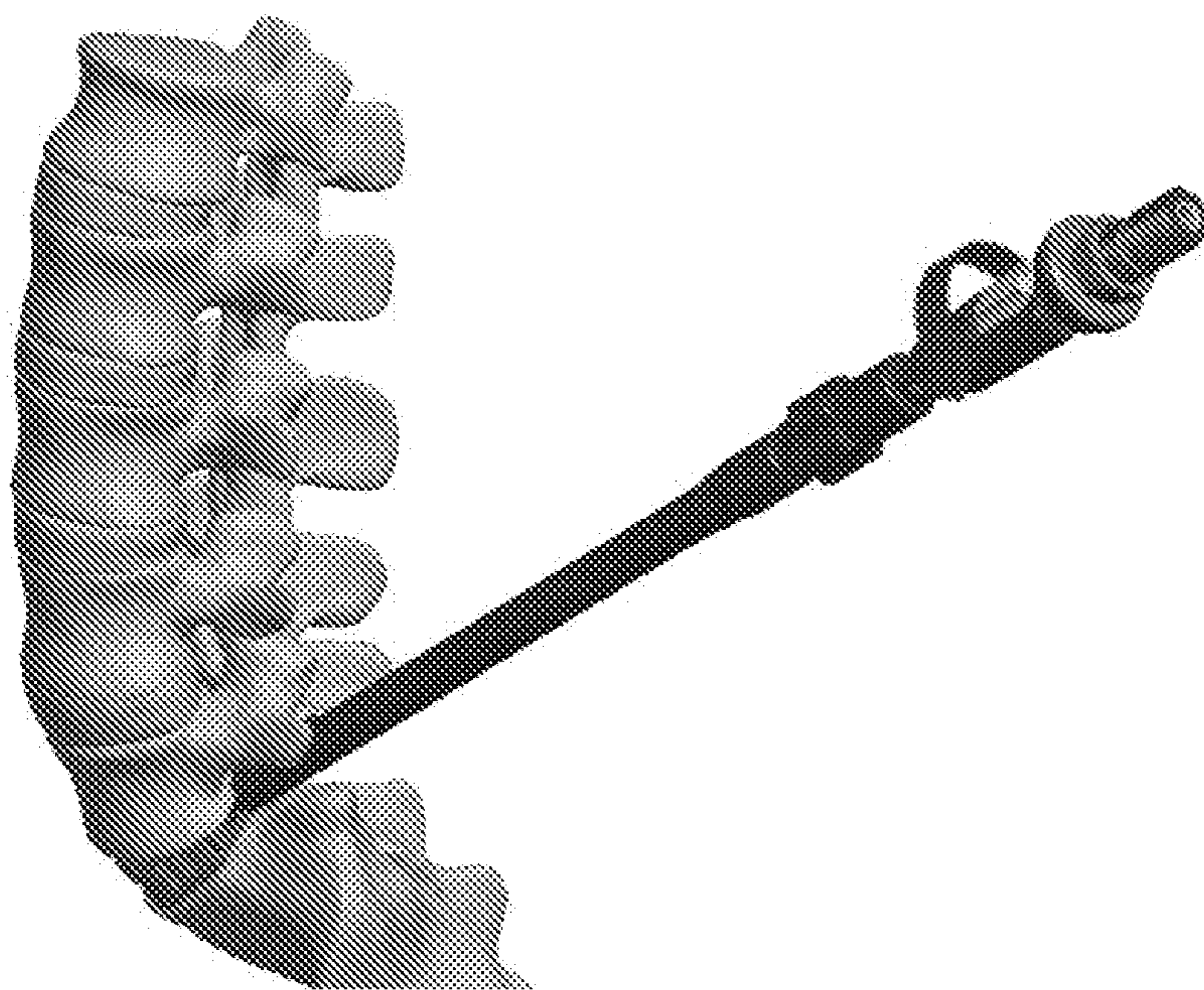


FIG. 95

## EXPANDABLE SPINAL FUSION IMPLANT, RELATED INSTRUMENTS AND METHODS

### CROSS REFERENCE TO RELATED APPLICATIONS

**[0001]** This application is a continuation of and therefore claims the benefit the filing date of pending U.S. application Ser. No. 15/265,300 filed on Sep. 14, 2016 which in turn claimed the benefit of the filing date of U.S. application Ser. No. 14/060,558 filed on Oct. 22, 2013 which in turn claimed the benefit of the filing date of U.S. Provisional Patent Application Nos. 61/717,003, which was filed on Oct. 22, 2012, and 61/793,626 which was filed on Mar. 15, 2013. The entire contents of all of which are hereby incorporated by reference as part of this application.

### FIELD

**[0002]** This application relates generally to an intervertebral spacer and specialized instruments for choosing the correct size of implant, implanting the device within the intervertebral space, and for delivery of bone graft or bone substitute to the interior of the implant.

### SUMMARY

**[0003]** The implant utilizes a plurality of joints between links of interbody spacer segments which in an insertion configuration assumes a collapsed elongate form for minimally invasive insertion down a narrow surgical corridor. The device expands to a larger footprint size in an implanted or expanded configuration at the predetermined site. In the implanted configuration, the implant is roughly the profile of the removed intervertebral disc and therein provides spacer support near the periphery of the endplate where the vertebral bone is most dense. In addition, in the implanted configuration, the spacer links define a large central aperture for packing of graft material.

**[0004]** A spacer template is disclosed to assist the surgeon is choosing the correct implant size but also to help validate that the disc space has been properly prepared through removal of soft tissue that may impede the final spacer from transitioning to the expanded configuration. The implant and instruments include a system and method for the insertion of the device and for the controlled transition from the insertion configuration to the implanted configuration once the device is presented in its predetermined location between the vertebral bodies. This includes mechanisms for controlling the profile of the links to prevent formation into undesired profiles in the intervertebral space and mechanisms to maintain a preferred shape once the device reaches a fully implanted configuration.

**[0005]** The insertion instrument also shares a minimally invasive elongated profile for use down a narrow surgical path. This instrument not only serves to attach, control and steer the implant into its predetermined location, it also controls the device's transition from the insertion configuration to the expanded implanted configuration and comprises features to prevent over expansion of the device. In addition, the instrument comprises features for attachment of a bone graft administration device and for directing the bone graft down a cannula in the instrument into the bone graft aperture defined by the expanded spacer links between the endplates. In cases in which the surgeon desires to remove the device after implantation, the instrument is also

configured for reattachment and for transitioning the implant device from an implanted configuration back to an insertion configuration. Methods for implant size selection, implant insertion, transition to an implanted configuration, bone graft administration, and removal are disclosed in detail in later paragraphs.

**[0006]** In a preferred form, the implant device is well suited for minimally invasive insertion into the intervertebral space through a transforaminal surgical approach.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0007]** FIG. 1 is a front perspective view of an exemplary embodiment of an inserter attached to an expandable implant in its insertion configuration.

**[0008]** FIG. 2 is a partially exploded perspective view of the implant and inserter illustrated in FIG. 1.

**[0009]** FIG. 3 is a distal end perspective view of the implant and inserter illustrated in FIG. 1.

**[0010]** FIG. 4 is a partially exploded perspective view of the proximal end of the inserter illustrated in FIG. 1.

**[0011]** FIG. 5 is a proximal end perspective view of an exemplary embodiment of an expandable interbody implant in its insertion configuration.

**[0012]** FIG. 6 is a lead end view of the expandable implant illustrated in FIG. 5.

**[0013]** FIG. 7 is a side view of the expandable implant illustrated in FIG. 5.

**[0014]** FIG. 8A is a proximal end perspective view of the bottom of an exemplary embodiment of an expandable spacer in its implanted configuration.

**[0015]** FIG. 8B is a superior view illustrating an expanded spacer resting on a vertebral endplate.

**[0016]** FIG. 9 is a posterior view of an expandable spacer adjusted for lordotic angle illustrating a decreasing height from anterior to posterior.

**[0017]** FIG. 10 is a top view of the implant illustrated in FIG. 8.

**[0018]** FIG. 11 is an exploded perspective view of the implant illustrated in FIG. 8.

**[0019]** FIG. 12 is a front perspective view of an exemplary embodiment of a fastener pivot assembly.

**[0020]** FIG. 13 is a cross-sectional view of the fastener pivot assembly illustrated in FIG. 12.

**[0021]** FIG. 14 is a front perspective view of an alternative coupling device.

**[0022]** FIG. 15 is a top close up perspective view of teeth utilized on the endplate facing surface of the spacer.

**[0023]** FIG. 16 is a front perspective view of an exemplary embodiment of a coupling device.

**[0024]** FIG. 17 is a top view of the coupling device illustrated in FIG. 16.

**[0025]** FIG. 18 is a front perspective view of an exemplary embodiment of a pivot coupler assembly.

**[0026]** FIG. 19 is a top perspective view of an exemplary embodiment of a positioner gear.

**[0027]** FIG. 20 is a bottom perspective view of the positioner gear illustrated in FIG. 19.

**[0028]** FIG. 21 is a rear perspective view of an exemplary embodiment of a positioner gear with integrated spring.

**[0029]** FIG. 22 is a front perspective view of an exemplary embodiment of a positioner gear assembly.

**[0030]** FIG. 23 is a rear perspective view of a positioner coupling assembly.

[0031] FIG. 24 is a rear perspective view of an alternative embodiment of a positioner gear with integrated spring.

[0032] FIG. 25 is a proximal perspective view of an exemplary embodiment of an insertion link

[0033] FIG. 26 is a top view of the inserter link of FIG. 25.

[0034] FIG. 27 is a proximal view of the inserter link of FIG. 25.

[0035] FIG. 28 is a front perspective view of an exemplary embodiment of a lateral proximal link of the implant.

[0036] FIG. 29 is a top view of the link of FIG. 28.

[0037] FIG. 30 is a rear perspective view of the link of FIG. 28.

[0038] FIG. 31 is a front perspective view of a medial proximal link of the implant.

[0039] FIG. 32 is a top perspective view of the implant illustrated in FIG. 31.

[0040] FIG. 33 is a rear perspective view of the implant illustrated in FIG. 31.

[0041] FIG. 34 is an inside perspective view of a lateral intermediate link of the implant.

[0042] FIG. 35 is an outside view of the link illustrated in FIG. 34 and illustrating lumbar angle L.

[0043] FIG. 36 is a top view of the link illustrated in FIG. 34.

[0044] FIG. 37 is an inside perspective view of an exemplary embodiment of a medial intermediate link of the implant.

[0045] FIG. 38 is an inside perspective view of an exemplary embodiment of a medial distal link of the implant.

[0046] FIG. 39 is a bottom view of the medial distal link illustrated in FIG. 38.

[0047] FIG. 40 is a top view of the medial distal link illustrated in FIG. 38.

[0048] FIG. 41 is an outside perspective view of the medial distal link illustrated in FIG. 38.

[0049] FIG. 42 is an inside perspective view of an exemplary embodiment of a lateral distal link of the implant.

[0050] FIG. 43 is a top view of the lateral distal link illustrated in FIG. 42.

[0051] FIG. 44 is a bottom view of the lateral distal link illustrated in FIG. 42.

[0052] FIG. 45 is an outside perspective view of the lateral distal link illustrated in FIG. 42.

[0053] FIG. 46 is a front perspective view of an exemplary embodiment of the inserter's control frame.

[0054] FIG. 47 is a top view of the control frame illustrated in FIG. 46.

[0055] FIG. 48 is a side view of the control frame illustrated in FIG. 46.

[0056] FIG. 49 is a cross-sectional view of the control frame illustrated in FIG. 46 along axis M-M.

[0057] FIG. 50 is a top perspective close-up view of the neck portion of the control frame.

[0058] FIG. 51 is a distal end close up view of the control arms of the control frame.

[0059] FIG. 52 is a proximal end close up view of the expansion limiter mount.

[0060] FIG. 53 is front perspective view of an exemplary embodiment of the handle collar assembly.

[0061] FIG. 54 is an exploded view of the handle collar assembly illustrated in FIG. 53.

[0062] FIG. 55 is a front perspective view of an exemplary embodiment of a fixation tube with lockwheel and fixators.

[0063] FIG. 56 is a rear perspective view of an exemplary embodiment of an expansion handle.

[0064] FIG. 57 is a front perspective view of the expansion handle illustrated in FIG. 56.

[0065] FIG. 58 is a front perspective view of an exemplary embodiment of a graft inserter assembly.

[0066] FIG. 59 is an exploded view of 3 components of the graft inserter assembly illustrated in FIG. 58.

[0067] FIG. 60 is an exploded view of a cartridge retainer portion of graft inserter assembly of FIG. 58.

[0068] FIG. 61 is a bottom perspective view of a cartridge retainer housing body.

[0069] FIG. 62 is a bottom perspective close up view of chute door recesses of cartridge retainer housing body.

[0070] FIG. 63 is a rear perspective view of a cartridge retainer housing body.

[0071] FIG. 64 is a bottom perspective view of the graft inserter assembly with selected portions removed to illustrate the functional interaction between the chutes and chute doors.

[0072] FIG. 65A is a bottom perspective view of a chute door.

[0073] FIG. 65B is a rear perspective view of a chute door.

[0074] FIG. 65C is a close-up perspective view of a chute door residing in a chute door recess.

[0075] FIG. 66 is a front perspective view of a graft cartridge portion of graft inserter assembly of FIG. 58.

[0076] FIG. 67 is a front perspective closeup view of the chutes of the graft cartridge portion.

[0077] FIG. 68 is an exploded view of a graft cartridge portion.

[0078] FIG. 69 is an exploded view of a graft delivery guide portion of the graft inserter assembly illustrated in FIG. 58.

[0079] FIG. 70 is a top perspective view of a graft delivery guide portion of the graft inserter assembly.

[0080] FIG. 71 is an exploded view of a graft funnel.

[0081] FIG. 72 is a top perspective view of a graft funnel.

[0082] FIG. 73 is a bottom perspective view of a funnel portion of a graft funnel.

[0083] FIG. 74 is distal perspective view of a collector tube portion of the graft funnel illustrated in FIG. 72.

[0084] FIG. 75 is a proximal perspective view of a plunger tube of the graft funnel illustrated in FIG. 72.

[0085] FIG. 76 is a cross-sectional view of the graft funnel illustrated in FIG. 72.

[0086] FIG. 77 is an exploded perspective view of an exemplary embodiment of the spacer template instrument illustrated in FIG. 79.

[0087] FIG. 78 is a close-up view of template spacer portion of the spacer template instrument illustrated in FIG. 79 with a link removed for viewing of expansion rod coupler.

[0088] FIG. 79 is a front perspective view of an exemplary embodiment of a spacer template instrument.

[0089] FIG. 80 is an anterior view of the spacer template inserted in the disc space.

[0090] FIG. 81 is a lateral view illustrating expansion of the spacer template.

[0091] FIG. 82A illustrates from an anterior and a lateral view notch alignment indicating full expansion of the spacer template.

[0092] FIG. 82B illustrates from a lateral view notch alignment indicating full expansion of the spacer template.

[0093] FIG. 83 illustrates full expansion of a spacer template as indicated on the handle by the arrow pointing to green indicator is proximal to the slot.

[0094] FIG. 84A illustrates a paddle sizer.

[0095] FIG. 84B illustrates use of a paddle sizer inserted in the disc space.

[0096] FIG. 85 illustrates sliding spacer on to the control arms of the insertion instrument and advancing fixation tube threads to secure spacer to the insertion instrument.

[0097] FIG. 86 illustrates pre-setting of the handle collar assembly on the control frame by the arrow pointing to no gap between rotating collar and inserter.

[0098] FIG. 87A illustrates an expansion rod.

[0099] FIG. 87B illustrates threading of the expansion rod through inserter and into coupler link

[0100] FIG. 88 illustrates mounting expansion handle over the handle collar.

[0101] FIG. 89 illustrates rotation of the expansion handle to transition spacer to expanded configuration.

[0102] FIG. 90 illustrates confirmation of full spacer expansion as indicated by indicia on control frame by the arrow pointing to green indicator appears below collar.

[0103] FIG. 91 illustrates removal of expansion handle from handle collar.

[0104] FIG. 92 illustrates derotation of expansion rod to release it from the coupler for removal.

[0105] FIG. 93A and FIG. 93B illustrate re-setting the handle collar assembly.

[0106] FIG. 94 illustrates the graft funnel inserted on the inserter.

[0107] FIG. 95 illustrates derotation of the lockwheel for removal of the instruments from the spacer.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0108] FIG. 1 illustrates an exemplary embodiment of an expandable spacer and insertion assembly 101 with the spacer 100 in its insertion configuration and mounted to spacer inserter 300. FIG. 2 illustrates a partially exploded view of each portion of assembly 101 including spacer 100, control frame 301, handle collar 302, fixation tube 303, expansion rod 304, expansion limiter 305, and expansion handle 306. FIG. 3 is a distal end view of assembly 101 illustrating the small diameter profile when assembly 101 is in its insertion configuration.

[0109] A closer view of spacer 100 in its insertion configuration is illustrated in FIG. 5-7. The spacer 100 comprises a proximal end 102, a distal end 103, a lateral side 104, a medial side 105, and support face 107 with opposing support face 106. Teeth 108 are inscribed on support face 106 and support face 107 and are configured to embed in the superior and inferior vertebral endplates to prevent migration of spacer 100 once the spacer is placed in its predetermined location between the vertebral bodies.

[0110] FIG. 15 illustrates teeth 108 which comprise a penetrating face 112 that is sufficiently narrow or pointed to penetrate the bone of the endplate, and positional faces 113 that upon penetration abut the bone and prevent migration across the endplate. In this embodiment, the penetrating faces 112 have a small square footprint and the positional faces 113 have a sloped rounded pyramid profile. Positional faces 113 of teeth 108 broaden as they move away from the penetrating face 112 therein increasing anti-migration strength as spacer 100 settles into the endplate. A valley face

114 seats against the bone as a limit to subsidence of the spacer 100 into the bone. Teeth 108 in this embodiment are manufactured using a rounded cutter spaced 90 degrees apart.

[0111] Leading the distal end 103 of spacer 100 is nose 109. The nose is configured for eased entry into the intervertebral space and may include tapered 110 and/or rounded 111 surfaces to ease the spacer 100 between the vertebral bodies and by pass soft tissue during entry. In the insertion configuration, spacer 100 assumes a narrow, compact, elongated form in order to minimize the size of the incision required for entry into the intervertebral space. From a lead end view (FIG. 6), the spacer 100 in this embodiment has a generally rectangular profile with support faces 106, 107 longer in length than the lateral 104 and medial 105 sides. In some embodiments, the support faces 106, 107 are sloped to fit a predetermined lumbar angle between the patient's vertebrae as can be seen in FIG. 9 wherein the anterior links of spacer 100 slope to greater heights moving towards the posterior links

[0112] The vertebral body is strongest near the periphery of the endplate while the endplate profile is often described as oval, lima bean, or 'race track' shaped. Better fusions and overall better results are achieved when the interbody spacer is configured to rest on this dense bone near the endplate periphery while providing a large central graft aperture for the packing of bone graft. Therefore, in its expanded configuration, it is preferred that the outer perimeter of spacer 100 approximate the profile of the vertebral endplate as illustrated in FIG. 8A. Spacer 100 is illustrated in its expanded configuration in FIGS. 8-10. In this preferred embodiment, the spacer comprises seven links and forms an irregular hexagon to generally assume the outer endplate 'racetrack' profile. In other embodiments, the number of links utilized in the spacer may vary.

[0113] FIG. 11 illustrates an exploded view of spacer 100 which is comprised of a plurality of links joined by joints 130. The links comprise insertion link 115 with central axis 'A' located at proximal end 102 of spacer 100 which serves as the site of attachment for inserter 300. Central axis 'A' is configured to be generally collinear with the surgical access path. For example, if spacer 100 was configured for a lateral surgical approach, insertion link 115 would preferably be placed lateral with central axis 'A' directed along a lateral direction. In this preferred embodiment, spacer 100 is configured for surgical insertion into the intervertebral space along a transforaminal surgical path indicated as 'P' in FIG. 8B. Insertion link 115 is therefore positioned posterior laterally and axis-A is directed in a posterior lateral direction. The spacer 100 in this embodiment is configured for use from either the left or right side of the spine wherein a support face 140 or 141 that faces superior when inserted from one side will face inferior when inserted from the other. Consistent with the transforaminal surgical approach, spacer 100 is inserted with a definitive medial and lateral side therein assuring alignment of the inserter link with the surgical path regardless of left or right side entry.

[0114] Joints 130 provide movement between each link portion 115-121 in a plane generally parallel to the intervertebral space. The joints may assume any variety of forms such as ball and socket, snap, hinge, or a pin or knuckle joint. Pin joints are utilized in the preferred embodiment and each link portion 115-121 comprises one or more capture tongue 158 configured to reside within a complementary capture

groove **157** (FIG. **31,33**) on an adjacent link portion **115-121** to form an endless chain. In the expanded configuration, this chain of links defines a graft aperture **122** available for packing with bone graft or other bone substitute.

[0115] Each link portion **115-121** of spacer **100** may share a plurality of common features not necessarily labeled on each link. For example, each link is formed from a body **167**, each link except for the inserter link has teeth **108**, and link support faces **140**, **141** are common to each link and abut the endplates therein maintaining the predetermined intervertebral space. Adjacent links **115-121** comprise a capture groove **157** and a capture tongue **158** aligned within said groove to form a joint **130**. Two capture walls **154** & **155** define capture groove **157**. The interior of capture groove **157** comprises one or more capture surfaces **159-160** (FIG. **28,30**). Capture tongue **158** (FIG. **34**) comprises opposing guide surfaces **161** and **162**. Pin wall **163** extends vertical through capture tongue **158** and capture walls **154** & **155** therein defining pin aperture **164** with central axis-B.

[0116] Joints **130** are formed by configuring a capture tongue **158** within capture groove **157** and aligning axis-B. Pivot pins **129** are then pressed into pin apertures **164** except with insertion link **115** wherein shortened pivot pins **128** are utilized within pin apertures **164** (FIG. **26**). Each link **115-121** in this embodiment is configured with a predetermined profile suitable to performing in the insertion configuration, the expanded configuration, and transitional configurations therebetween. For example, FIG. **26** illustrates a generally S-shaped profile of the insertion link **115** from a top view.

[0117] At each joint **130**, a plurality of positional stops **165** interfering with each other are configured to limit motion at each joint when spacer **100** moves from an insertion configuration to an expanded configuration. These positional stops **165** determine the final shape of the expanded implant. In the preferred embodiment for example, the positional stops **165** help guide the implant into the open generally hexagonal profile of FIG. **10**.

[0118] The insertion link **115**, FIGS. **25-27**, comprises a pair of opposing capture tongues **158**. A control guide **144** is situated on insertion link **115** and in this embodiment is in the form of a pair of opposing grooves **145** cut parallel to axis-A through each control tongue **158**. The grooves are configured to accept control arms **350** of inserter instrument **300** when mounted to insertion link **115**. The grooves **145** comprise surfaces **146**, **143**, and **142** upon which surfaces on control arms **350** act to impart forces and direction on the insertion link **115**.

[0119] An inner wall **151** extending along axis-A defines inserter aperture **149**. Inner wall **151** may be threaded **150** for threaded attachment of insertion instrument **300**. At the proximal end of insertion link **115** is instrument stop surface **156** which abuts instrument **300** when attached to insertion link **115**.

[0120] The lateral-proximal (LP) link **121** is illustrated in FIGS. **28-30**. This link is connected by pin joint to the lateral side of inserter link **151**. LP link **168** comprises two capture grooves **157**. The deeper capture groove **157** is configured to house the elongated capture tongue **158** of insertion link **115** when elongated wall **169** of LP link abuts positional stop **165** in the insertion configuration. Situated on the inside of link **168** is instrument channel **170**. This channel accommodates portions of instrument **300** when spacer **100** is in the collapsed insertion configuration.

[0121] FIGS. **31-33** illustrate an embodiment of a medial proximal (MP) link. Unlike LP link **121**, the MP link **116** comprises both a capture groove **157** and a capture tongue **158**. Some embodiments of the MP or LP links include an extension of control guide **144** in the outer surface of the link to accommodate control arms **350** of inserter instrument **300**.

[0122] Various embodiments of the lateral intermediate (LI) link **120** is illustrated in FIGS. **34** & **35**, and of the medial intermediate link (MI) **117** in FIGS. **36** & **37**. The embodiments shown illustrate an angulation between support face **140** and **141** to replicate the lumbar angle 'L' typically encountered between the endplates. This angulation between support faces may be adjusted on any of the spacer links according to the anticipated final position within the intervertebral space. For example, if a link resides obliquely within the intervertebral space, then support faces may be angled accordingly to match the intervertebral space at this orientation.

[0123] LI link **120** utilizes a capture tongue **158** on each side of the link whereas the MI link **117** utilizes one capture tongue **158** and one capture groove **157**. One or more windows **171** may be cut through the body **167** of link **117,120** between the inner **172** and outer **166** surface of the link.

[0124] FIGS. **38-41** illustrate various aspects of an exemplary embodiment of medial distal (MD) link **118** of spacer **100**. Like the other links, the MD link comprises a body **167** formed in the general shape of the number six. At one end, is a capture groove **157** utilized for creating a joint with adjacent MI link **117**. On one side of MD link **118** is an extensive support face **140** with teeth **108** inscribed thereon. On an opposing side is a smaller support face **141**. Located centrally within the base of the 'six', is coupling aperture **173** sized to house shaft **201** of coupling screw assembly **200**.

[0125] Situated between outer surface **166** and aperture **173** is positioner pocket **174**. Pocket **174** is configured with a support floor **176**, containing wall **177**, and stop wall **179**. Situated between inner surface **178** and aperture **173** is coupler window **175**. Cut into body **167** is instrument channel **170** to accommodate portions of instrument **300** when spacer **100** is in its insertion configuration. The body **167** of MD link **118** and LD link include a mating cutaway **182** defining mating surface **181**. MD link **118** and LD link **119** are aligned on axis-C with mating surface **181** of each link in facing opposition.

[0126] FIGS. **42-45** illustrate various aspects of an exemplary embodiment of lateral distal (LD) link **119** of spacer **100**. Again, the LD link comprises a body **167** formed in the general shape of the number six. At one end, is a capture groove **157** utilized for creating a joint with adjacent LI link **120**. One side of LD link **119** comprises an extensive support face **140** with teeth **108** inscribed thereon. On an opposing side is a smaller support face **141**. Located centrally within the base of the 'six', is coupling aperture **173** sized to house shaft **201** of coupling screw assembly **200**.

[0127] Situated between outer surface **166** and aperture **173** is positioner pocket **174**. Pocket **174** is configured with a support floor **176**, containing wall **177**, and stop wall **179**. Inscribed into support floor **176** is a C-shaped groove **180**. Situated between inner surface **178** and aperture **173** is coupler window **175**. Cut into body **167** is instrument channel **170** to accommodate portions of instrument **300**.

when spacer 100 is in its insertion configuration. The body 167 of MD link 118 and LD link 119 include a mating cutaway 182 defining mating surface 181. MD link 118 and LD link 119 are aligned on axis-C with mating surface 181 of each link in facing opposition.

[0128] FIG. 23 illustrates positioner coupling assembly 204 which is comprised of; fastener pivot assembly 200 illustrated in FIGS. 12 and 13, positioner gear assembly 205 illustrated in FIG. 22, and coupler 206 illustrated in FIG. 16.

[0129] Fastener pivot assembly 200 secures MD link 118 and LD link 119 together and in this embodiment is in the form of a shoulder bolt 232 releasably attached to shoulder nut 233 through threaded interengagement 231. However, fastener pivot assembly 200 may be in other forms such as a rivet or a bolt threaded into the aperture of the opposing link Bolt 232 and nut 233 comprise opposing restraining faces 234 that secure links 118 and 119 together when nut 233 is advanced. The shoulders 230 on nut 233 and bolt 232 center links 118 and 119 along axis C. Coupler 206 comprises a rounded body 240 with pivot aperture 241 extending through body along axis D. A coupling aperture 242 extends along axis-E and is generally perpendicular to axis-D. The wall defining the coupling aperture 242 is threaded for engagement with expansion rod 304. Stop surface 243 abuts an opposing surface on expansion rod 304 indicating the rod is fully engaged in coupling aperture 242. Centering surface 244 encircles the outer body 240 about axis D. In an assembled configuration, end surfaces 245 position coupler 206 between the MD and LD links 118 & 119.

[0130] Positioner gear assembly 205 is configured to hold spacer 100 in a predetermined expanded or collapsed configuration. Assembly 205 comprises an arc shaped integral spring positioner gear 209 mated with a complementing positioner gear 207 as illustrated in FIG. 22. Illustrated in FIG. 21, spring positioner gear 209 comprises a biasing element here in the form of an integrated undulating spring 208 or equivalent biasing member. Providing the space required to compress is compression gap 223 and limit face 224 abuts and stops further compression at support floor 176 to prevent plastic deformation of spring 208. A foot 210 of spring 208 resides against support floor 176 of MD link 118. In an alternate form, spring 208 may be in the form of a 'Y' as seen in FIG. 24 wherein the foot 210 is at the tip of arms of the Y, or other forms such a separate compression spring or leaf spring.

[0131] The positioner gears 209 and 207 comprise an arc shaped body 211 with radially cut teeth 212 cut into face wall 222. A convex outer wall 213 opposes a concave inner wall 214 sized to fit around centering surface 244 of coupler 206. At the ends of each arc are position faces 215. As illustrated in FIG. 19-21, positioner gear 207 comprises a seat face 216 opposite teeth 212. Stepping below the seat face 216 is inner rim 217 comprising an outer position face 219, an inner position face 220, bottom face 218, and top face 221.

[0132] In an assembled configuration, inner rim 217 of positioner gear 207 resides in C-shaped groove 180 of LD link 119 with seat face 216 directly adjacent support floor 176. End surface 245 of coupler 206 abuts against top face 221 to keep positioner gear 207 captured in positioner pocket 174. Position faces 215 of positioner gears are bound by stop walls 179 therein causing positioner gear 207 or 209 to rotate about axis C only as part of rotational movement of MD and LD links 118 and 119. Axis-E and coupling aperture

242 of coupler 206 reside within the coupler windows 175 of the MD and LD links with room to pivotably adjust as spacer 100 moves from an insertion configuration to an expanded configuration.

[0133] To create transition from insertion to expanded configuration, instrument 300 creates a tension force on coupler 206 drawing it near insertion link 115. During this motion, MD link 118 with captured spring positioner gear 209 housed within positioner pocket 174 and LD link 119 with positioner gear 207 captured within its own positioner pocket 174, rotate about axis-C in opposite directions. This rotational motion causes the opposing radial cut teeth 212 to move from a tip 225 to valley 227 orientation, to a tip 225 to tip 225 orientation therein imparting a translational motion of spring positioner gear 209 against spring 208. Continued rotation will cause tip 225 to seat in a new valley 227. This mechanical arrangement provides the surgeon a means to selectively expand or contract spacer 100 to predetermined positions once the instrument 300 imparts a sufficient tension or compression force on coupler 206. Similarly, spacer 100 will remain in the predetermined expanded configuration once instrument 300 is removed as the patient's anatomy will be unable under normal circumstances to create forces on spacer 100 sufficient to overcome biasing force of spring 208.

[0134] In an alternative embodiment, a nitinol leaf spring is configured about centering surface 244 of coupler with each leg of the leaf spring extending into the body of MD link 118 and LD link 119. Said spring biases link 118 and 119 towards an expanded configuration with inserter 300 configured to work against bias force to keep spacer 100 in insertion configuration during insertion.

[0135] The spacer inserter 300 and its components are now described in greater detail. The inserter 300 comprises a control frame 301 with proximal end 331 and distal end 330 and is illustrated in FIGS. 46-57. The frame 301 comprises an elongated body 339 with an interior wall 340 defining a central working aperture 332 sized for gliding passage of fixation tube 303 and expansion rod 304 (FIG. 2). The outer wall 380 extends from the distal end 330 with a rectangular profile similar to spacer 100 in the insertion configuration. Extending from the distal end 330 of body 339 are one or more control arms 350 sized to be received within the opposing grooves 145 of control guide 144 of insertion link 115. The control arms 350 comprise a plurality of torque walls 341 facing surfaces 142 and 143 on insertion link 115 and are configured to transmit a torsional force to the insertion link 115. Surfaces 146 of the inserter link are captured between opposing walls 342 therein aligning axis-A of inserter link with axis-F of control frame 301. Outer surfaces 343 of the control arms are sloped to minimize resistance against soft tissue during insertion and tip 345 is rounded for the same purpose. Link face 344 is secured against stop surface 156 when spacer 100 is attached to spacer inserter 300. In this embodiment, link face 344 and stop surface 156 comprise complementary non-planar surfaces assuring proper alignment of spacer and inserter (i.e. lateral side 104 of spacer and side marked 'lateral' on inserter 300 are co-aligned).

[0136] Proximal to control arms 350 are one or more windows 338 cut into body 339 to enhance cleaning after use. At an area along body 339 positioned to reside above the skin when spacer 100 is fully inserted is a counter-torque neck 333 for attachment of a counter torque instrument. The

counter-torque neck 333 is in the form of a plurality opposing torque faces 346 wherein an instrument as simple as an open ended wrench may attach and limit torsional forces transmitted to the implant through inserter 300.

[0137] Also at proximal end 331 of control frame 301 is a bulb portion 347 of body 339. Cut into bulb portion 347 is lock aperture 335 configured to house lock wheel 348. Two sides of bulb 347 are substantially flattened into opposing finger faces 337 to provide access by the user's fingers to lock wheel 348. Proximal along axis-F of body 339 from bulb portion 347 is collar neck 334 comprising threads 349 thereon configured for engagement with handle collar 302. At the proximal end of threads 349 is indicator 351 here illustrated in the form of a groove. The groove may be painted or otherwise highlighted. Located proximal to collar neck 334 of body 339 is limiter neck 336. The limiter neck comprises a proximal wall 352, a centering wall 353, a locator wall 354, and a limiter groove 355. In some embodiments limiter neck 336 is absent.

[0138] Handle collar 302 assembly is illustrated in FIGS. 53 and 54 and comprises an outer drive collar 367 and inner spin collar 366. The outer drive collar 367 comprises a central aperture 369 with threaded walls 360 configured for threaded engagement over threads of collar neck 334. At the proximal end of outer drive collar 367, aperture 369 is enlarged to house inner spin collar 366. Within this enlargement is collar groove 359 for seating expansion ring 368. Ring 368 also encircles inner spin collar 366 within ring groove 361 therein securing inner spin collar 366 within outer drive collar 367 but providing for free rotation of one collar about the other.

[0139] Outer collar 367 also comprises a distal stop surface 355 which when abutted against bulb portion 347 is configured as the starting point for collar 367 prior to transitioning spacer 100 from insertion configuration to expanded configuration. Distally on outer collar 367 is drive 370 configured for moving collar by attachment of expansion handle 306. Drive 370 in this embodiment is in the form of several flat drive surfaces 357 formed in a hexagon encircling central aperture 369. Cut into each drive surface 357 is lock aperture 358. Proximal to inner threaded walls 360 is inner surface 356 sized to house outer surface 364 of inner spin collar 366. Inner spin collar 366 further comprises a spin aperture 362 defining an inner surface 365 enlarged to ride slightly above collar neck 334 threads. At proximal end of spin collar 366 is limiter surface 363.

[0140] Fixation tube 303 is further illustrated in FIG. 55. The tube 303 comprises a linear elongated body with inner cannula 371 extending the length of the tube and cannula sized to house fixation rod 304 to slide therein. The outer surface 373 of tube 303 at the distal end is configured with threads 372 for threaded engagement with threads 150 of insertion link 115. Nearing the proximal end, tube 303 is perforated with pin apertures. Fixators 374 in the form of fixation pins extend through lockwheel 348 and are housed within said pin apertures to fix lockwheel 348 in a predetermined location on tube 303 wherein when tube 303 is housed within control frame 301, lockwheel 348 freely spins within lock aperture 335.

[0141] FIGS. 2 and 4 further illustrates expansion rod 304. Protruding from the distal end of rod 304 is a threaded boss 375 configured for threaded engagement within coupling aperture 242. Stop surface 376 abuts stop surface 243 of

coupler 206 when rod 304 is fully engaged within aperture 242. At step 320, rod 304 decreases in diameter.

[0142] The expansion limiter 305 prevents over expansion of spacer 100 when transitioning to the expanded configuration by limiting travel of expansion rod 304. The limiter 305 comprises a housing 315 with non-circular inner aperture 377 complementing profile of limiter neck 336 for sliding translational movement but not rotary. Cut into side of housing 315 is clip slot 378 configured for sliding entry of clip 318 therein securing housing 315 to expansion rod 304 proximal to step 320. Lock button 316 is housed in a button aperture 394 on side of housing (not viewable). Lock button 316 comprises elongated slot 317 wherein a rib (not viewable) within slot 317 releasably engages limiter groove 355 of control frame 301. Biasing member 379 keeps rib engaged in groove 355 until lock button 316 is depressed by user providing for release of limiter 305 from limiter neck 336.

[0143] Expansion handle 306 comprises a T-shaped body 321 as illustrated in FIGS. 56-57 and FIG. 4. Cut into the front side of body 306 is head recess 381 sized to house enlarged head 310 of expansion rod 304. At the base of the head recess 381 is head shelf 384 to capture head 310 in head recess 381. Cut into head shelf 384 is a narrowed neck slot 382 to provide passage of the elongated rod body of expansion rod 304. Distal to head shelf 384 is limiter recess 385 configured to house expansion limiter 305. Collar recess 386 is situated distal to limiter recess 385, and is configured to fit over handle collar assembly 302. The collar recess 386 is bounded by two opposing collar drive surfaces 387 and a collar shelf 383. Cut through collar shelf 383 is control aperture 388 sized to pass collar neck 334 of control frame 301 while simultaneously capturing outer drive collar 367. This open configuration of head recess 381, neck slot 386, limiter recess 385, collar recess 386, and control aperture 388 provide the means for rapid sideways removal of expansion handle 306 from the inserter 300. With handle 306 connected to inserter 300, torsional force applied by user to handle is transmitted through collar drive surfaces 387 to drive surface 357 of outer drive collar 367 therein causing handle collar assembly 302 to advance proximal or distally along with expansion rod 304 further causing spacer to transition between insertion and expanded configuration.

[0144] One or more handle locks 307 releasably secure expansion handle 306 to handle collar 302. Each lock 307 comprises a lock lever 389 and bias member 312 in the form of a coiled spring. The lock lever 389 in this embodiment is in the shape of a teeter-totter comprising a pivot member 313 in the form of a pin, and a plunger 314. Lock lever 389 resides in lever recess 311 within body 321 of handle 306. The lever 389 is pinned into recess 311 by pivot member 313 extending between pivot apertures 309 and through body of lever 389. Spring force produced by bias member 312 causes plunger 314 to occupy plunger hole 310 and extend into collar recess 386 while simultaneously filling lock aperture 358 of outer drive collar. The handle is removed by the user by placing finger force on lever release surfaces 308 therein causing plungers 314 to retract and sliding handle 306 away.

[0145] On the rear side of expansion handle 306 is viewing window 390 cut between the outer wall of body 321 into limiter recess 385. Although expansion limiter 305 is viewable from the opposing side of the handle 306, window 390 provides a more intuitive method for viewing progress of spacer 100 transition from one configuration to another by

noting position of limiter within window 390. For convenience, head drive pocket 391 is integral to expansion handle 306. This pocket 391 is configured with drive faces 392 complementing enlarged head 310 of expansion rod 304 wherein when handle 306 is removed from collar 302, it can be used to apply greater torque to head 310 when necessary.

[0146] There are several different approaches to filling spacer 100 with graft material once inserted into the pre-determined location within the intervertebral space and transitioned to the expanded configuration. The insertion instrument may be removed and a graft filling instrument may be attached to insertion link 115. This instrument may be the form of an upright funnel with an elongated plunger at the proximal end, wherein the plunger pushes graft material down an elongated tube extending to the insertion link and into graft aperture 122. In an exemplary embodiment, a graft inserter assembly 500 is illustrated in FIG. 58. The graft inserter is configured to cooperate with the spacer & insertion assembly 101 to introduce bone graft into graft aperture 122 of spacer 100. The inserter 500 comprises a graft cartridge portion 501, a cartridge retainer portion 502, and a graft delivery guide portion 503.

[0147] The graft cartridge portion 501 in this embodiment is further illustrated in FIGS. 66-68. It comprises a chute housing 504, a cartridge door 505, and cartridge handle 506. The housing 504 is formed of a flat rectangular body 537 with a plurality of chutes 507, in this case partially opened, traveling from a proximal end top surface 516 to a distal end bottom surface 518 of chute housing 504. The chutes 507 have a chute wall 508 defining a cylindrical aperture configured for storage of graft and passage of a plunger to push the graft material in the chutes 507 from a proximal end to a distal end of the chute. The plunger for example, may be in the form of the expansion rod 304 described earlier but with a blunt tip and length sufficient to push bone graft from the chutes 507 into graft aperture 122 of spacer 100. The chutes 507 may be open on one side along their length and separated by chute divider surface 509.

[0148] A handle 506 is fixed to chute housing 504, here by means of fixing pins 510 holding posts 511 in bores 512 located on the opposing side of chute housing 504. Handle 506 provides eased insertion and removal of chute housing 504 from cartridge retainer portion 502. A lock recess 513 cooperates with a releasable lock 514, here in the form of a spring pin on the cartridge retainer 502 to secure chute housing 504 within retainer 502. A pair of opposed channels 515, one of them wedged, are situated within side wall 517. The channels 515 cooperate with bosses (not shown) within the cartridge retainer 502 to assure the chutes are properly centered within the retainer for the transfer of graft material therethrough.

[0149] A cartridge door 505, here in the shape of a flat square, comprises a hinge channel 519 for cooperation with hinge channel 520 and hinge pins 521. When removed from cartridge retainer portion 502, the graft cartridge 501 may be placed on a table laying on handle 506 with the graft door 505 opened therein exposing the open chutes 507. Graft is then spread across the chute divider surfaces 509 and massaged into the open chutes until they are full. Excess graft is wiped from surface 509 and the graft door 505 is closed. The graft cartridge 501 can then be inserted into the retainer portion 502.

[0150] FIG. 60 illustrates an exploded view of a cartridge retainer 502 illustrated in FIG. 59. The retainer 502 com-

prises a cartridge retainer housing 522 with a rack gear 523 fixed to the housing with locator pins 531 and fasteners 530. Releasable lock 514 is mounted to housing 522 within lock port 535 and comprises a lock plunger 532, plunger biasing member 533 here in the form of a spring, and a release knob 534. The spring biases the plunger towards interfering with lock recess 513 of chute housing 504 to secure it within retainer housing 522 until surgeon desires to remove it.

[0151] The cartridge retainer housing 522 is further illustrated in FIG. 61-63. The housing comprises a body 540 with top face 541, front face 542, opposed side faces 543, rear face 544, and bottom face 555. Linearly cut into the rear face 544 is rear guide recess 545 bounded by a lower guide wall 546 and an upper guide wall 547. Similarly, cut into the front face 542 is front guide recess 548 defining an upper foot 550 and lower foot 549. The front guide recess 548 is bounded by a lower guide wall 546 and an upper guide wall 547. A cartridge aperture 550, bounded by boundary walls 552, extends from the top face 541 through the body 540 and bottom face 555 and is configured in size and profile to house graft cartridge 501. A handle recess 549 is cut through the rear face 544 and top face 541. It is here cartridge handle 506 resides and stop surface 551 abuts handle 506 when cartridge 501 is fully seated within the cartridge aperture 550. On side face 543 is auxiliary port 553 with plug 554.

[0152] Cut into front face 542 and bottom face 555 are chute door recesses 556 to provide housing of chute doors 527. Base wall 560 and containment walls 557 guide the chute doors 527 down a linear path and hold the doors within the recesses 556. At the end of the recesses 556 is pin aperture 558 to hold one end of door pin 524. Each chute door recess 556 is separated by a chute wall 559. Also cut into front face 542 and bottom face 555 is chute plate recess 561 for housing of chute plate 528. Located on base wall 564 of recess 561 is locator pin aperture 563 and threaded hole 562. Similarly, located on upper guide wall 547 are pin apertures 563 and threaded hole 562 for placement of rack gear 523 and securement with fasteners 529.

[0153] As illustrated in FIG. 65C, chute doors 527 reside within the chute door recesses 556. The chute door 527 in this embodiment comprises an L-shaped body 565 with enlarged head 566 (FIG. 65A & 65B). The chute door 527 is configured to slide along door pins 524 and resides between base wall 560, chute wall 559, and containment wall 557. The door 527 comprises a pin aperture 567 for passage of door pin 524 and a counter bore 568 to house end of biasing member 525. Chute door 527 further comprises a pair of opposing side walls 571, and bottom wall 570. Graft face 569 of chute door 527 seals chutes 507 during operation until the chute door is retracted for graft removal. Retraction of individual chute door is controlled by retraction face 573 which is sloped and rides in high door groove 611 of graft delivery guide 503 (FIG. 70) and boss face 568 of boss 572 rides in low door groove 611. Portions of this mechanism are illustrated in FIG. 64 wherein a portion of the chute doors 527 are retracted therein permitting release of graft (may be assisted by a chute plunger), and others are fully covering of chutes 507.

[0154] FIG. 69 illustrates an exploded view of an exemplary embodiment of a graft delivery guide portion 503 of graft inserter 500. The guide portion 503 comprises a coupler 600 with a U-shaped body configured to hold cartridge retainer 502 on a base wall 602 and two opposing upright walls 601. Projecting inward from each upright wall

**601** is capture wall **603**. One capture wall **603** is configured to be received within the rear guide recess **545**, and the other within the front guide recess **548** wherein cartridge retainer **502** is captured within coupler **600**.

[0155] At the bottom of the U-shaped body is inserter tube **604** with cannulated fastener **605** configured to fix tube **604** to coupler **600** by threads on fastener **605** (not shown) threading into coupler aperture **606**. Fixing pin **607** prevents release of inserter tube **604** from coupler **600**. Pinion gear **608** resides in pinion aperture **609** and is secured in place by pins **622** about pinion shaft groove **612** when pins are pressed into pin holes **621**. Pinion gear **608** comprises a locking aperture **613** extending therethrough for housing locking pin **615**. Pinned to the end of the shaft of pinion gear **608** is handle **616** using pins **619**.

[0156] The handle **616** comprises a sliding lock button **618** pinned to handle **616** utilizing pin **617**. Sliding lock button **618** comprises a sloped activation surface **620** configured to engage locking pin **615** wherein when button **618** is slid in one direction, activation surface **620** will cause locking pin **615** to travel towards cartridge retainer **502** and held within one selector hole **536** of cartridge retainer housing **522** therein locking it in position. When button **618** is slid in the opposite direction, a gap is created between activation surface **620** and locking pin **615** wherein spring **614** will cause locking pin **615** to be removed from selector hole **536**. In this 'unlocked' position, the cartridge retainer housing **522** is free to translate parallel to upright walls **601**. Indicator **613** aligns with indicia **574** to indicate the specific chute **507** aligned with graft port **623** of cannulated fastener **605**.

[0157] As an alternative the graft inserter assembly **500**, a graft funnel **700** is illustrated in FIGS. **71-76**. FIG. **71** illustrates an exploded view of graft funnel **700**. It comprises funnel **701**, collector tube **702**, plunger tube **704**, sealing spring **705**, ball **706**, detent spring **707**, and rotation knob **703**. Graft funnel **700** comprises a broad open mouth **708** with inclined funnel walls **709** leading to an elongated funnel outlet **710**. Outlet fitting **711** is configured for fit and secured in funnel inlet **712** of collector tube **702**. The collector tube **702** comprises a tubular elongated body **713** with central aperture **714** along entire length of body **713** defining inner surface **718**. Proximal to threads **716** is spring wall **719** serving as a fixation surface for spring **705**. On outer surface of the collector tube at the distal end is grip **715** configured with ribs, knurling or other feature to ease user insertion of funnel **700** on the inserter. At the proximal end are opposing ears **721** with a blind hole **717** drilled from one side of the ear to house a ball detent mechanism **706,707** cooperating with plunger tube **704**. Proximal face **720** faces rotation knob **703**.

[0158] Plunger tube **704** comprises an elongated body **727** with central aperture **728** defining inner collector wall **730**. Aperture **728** is sized to pass plunger type expansion rod for pushing graft toward spacer **100**. At the distal end is enlarged head **725** terminating with inserter face **726**. Graft inlet window **729** provides for passage of graft material from funnel **701** into central aperture **728**. Proximal to graft inlet window **729** is an elongated detent groove **724** for cupping ball **706** that provides a small amount of translation of plunger tube **704** within collector tube **702**. An opposing detent groove **724** is mirrored on opposing side of plunger tube **704**. This ball detent system with elongated not only holds plunger tube **704** within collector tube **702**, it also

provides the users a means to quickly align the graft inlet window **729** with funnel outlet **710** to provide for graft placed into funnel **701** to flow into and fill central aperture **728** of plunger tube **704**. Knob **703** comprises central aperture **722** having aperture walls configured to act on torsion faces **723** of plunger tube **704**. A 180 degree turn of knob **703** by the user will in turn rotate plunger tube **704** to opposing ball detent groove **724** therein sealing off the central aperture **728** of plunger tube **704**. Knob **703** further comprises a widened aperture **731** at its proximal end through which expansion rod style plunger, as described earlier, is utilized to push the graft housed in the plunger tube **704**, through the fixation tube **303** and into graft aperture **122**.

[0159] FIGS. **77-79** illustrate spacer template **800**. Individual template instruments **800** correspond to specific spacer **100** sizes and are used as a quick method of validating the fit of a spacer **100** prior to implantation in the intervertebral space. Template **800** comprises a template spacer **801** further comprised of a series of pinned template links **802** generally replicating links **116-121** of spacer **100** with a few differences. One difference is teeth **108** on spacer **100** are absent and replaced with a smooth surface **804** to provide eased insertion and removal of template **800** in and out of the intervertebral space. Windows **171** extending through inner surface **172** of select links may be removed. In addition, the functional components of coupler **206** are now integrated into expansion rod **806** and positioner gears **207** and **209** are removed. The functionally equivalent MD and LD links **118, 110** in the template spacer have been modified accordingly to house coupler **807** of expansion rod **806**.

[0160] Expansion rod **806** comprises an elongated body **829**. The distal end of the rod **806** flattens into coupler **807** generally comprising a round disc with central aperture sized to house a fastener similar to fastener pivot assembly **200** used to secure links and coupler together. Located on the proximal end of expansion rod **806** are torsion features, here in the form of a male flat **808**, to inter-attach rod **806** within corresponding female flat **825** within expansion drum **810**. Pin **812** secures drum **810** to rod **806** through pinhole **809**. Located on the outerbody of expansion drum **810**, preferably at the proximal end is indicator **811** that is viewable through window **815** of handle **814** to monitor expansion progress of template spacer **801**. The outerbody of expansion drum **810** comprises threads complementing threads **826** within drum aperture **817**. At the distal end of drum aperture **817** is retainer groove **816** sized to house a portion of spring retainer ring **813**.

[0161] Control tube **803** comprises an elongated body **821** with central rod aperture **824** extending therethrough and sized to house sliding expansion rod **806** therein. At the proximal end of control tube **803** is retainer groove **819** formed within control tube head **818**. The retainer groove **819** is also configured to house a portion of spring retainer ring **813** wherein the ring holds handle **814** to control tube head **818** yet provides for rotational movement therebetween. Just below head **818** are torsional flats **820** for attachment of a counter torque device such as an open end wrench or similar device. At the distal end of control tube **803** is link control head **828**. The head comprises one or more bosses **823** each having an integrated pin aperture **827**. The control head **828** is held with pins **822** to the corresponding template spacer links **802**. The corresponding

insertion link **115** is integrated into control tube **803** of spacer template **800** since the template links are not required to be released from the template instrument. However, in alternative embodiments, it is contemplated that control tube **803** may be configured to be releasable from various spacer templates **800**. The outer surface of the control tube may include indicia **830** to indicate instrument orientation (i.e. medial or lateral). By rotation of handle **814**, spacer template **800** is capable of transforming template spacer **801** between insertion and expanded configurations.

[0162] In an exemplary embodiment, the spacer **100** and method are configured for a transforaminal surgical approach. The patient is placed on a radiolucent surgical table in the prone position. A retractor is positioned over the pre-determined operative level. Anatomic landmarks are identified followed by initial incisions localized at the disc space using fluoroscopy in the anterior/posterior (A/P) and lateral views. A radiograph is taken and additional radiographs are taken at any time at the surgeon's discretion.

[0163] The patient's pedicles are targeted above and below the affected level and the location of each is marked. A skin incision is made between the pedicle markings with sizing appropriate for the retractor used. Using finger dissection, a Cobb, or curette, tissue is released from the facet joint at the affected level. Fascia or tissue at the pedicles preventing placement of the retractor is removed. The retractor is inserted over the facet joint and positioned and secured to be parallel to the disc space for the proper medial exposure trajectory.

[0164] The surgeon then performs a conventional facetectomy and decompression followed by annulotomy and discectomy. Using any combination of pituitary rongeurs, disc cutters, endplate scrapers, curettes, and rasps, the surgeon removes as much disc material from the disc space as possible. A variety of angled instruments are then used to prepare the contralateral/posterior and ipsilateral/anterior regions of the disc. The endplates are prepared to remove cartilage and expose bleeding subchondral bone.

[0165] An appropriately sized spacer template **800**, with template spacer **801** in the collapsed configuration is selected and inserted down the surgical path at an oblique angle with the "MEDIAL" and "LATERAL" markings **830** on the instrument in the correct orientation relative to the patient's spine. The template is inserted until the distal tip **831** of spacer **801** abuts the annulus at the anterior/contralateral region of the disc space (FIG. **80**). Using lateral fluoroscopy, the distal tip **831** is confirmed to be abutting the anterior annulus. Using anterior-posterior (A/P) fluoroscopy, the distal tip is checked to assure it abuts the projected medial border of the contralateral pedicle. If necessary, a surgical mallet is used to impact the proximal end of handle **814** until it reaches the desired location.

[0166] Under A/P and lateral fluoroscopy, the handle **814** of template **800** is advanced by clockwise rotation to expand the template (FIG. **81**). Full expansion can be confirmed via fluoroscopy as the notches on the expanded template will be coincident in the direct A/P and direct lateral views as indicated in FIG. **82**. Full expansion can be confirmed via visual indicator on the footprint template handle as illustrated in FIG. **83**.

[0167] The spacer template **800** is transitioned prior to removal by rotating the template handle counter-clockwise until it returns to a collapsed insertion configuration. The surgeon will choose an alternate sized spacer template if

necessary until the proper spacer template size has been determined using tactile feel and fluoroscopy. Additional disc tissue may be removed as needed to facilitate full expansion.

[0168] An appropriately sized paddle sizer is then chosen as illustrated in FIG. **84**. A T-handle is attached to the end of the sizer and inserted into the disc space using an oblique trajectory. Appropriate "MEDIAL" and "LATERAL" instrument markings are followed if the sizer is rotated to height relative to the patient. The sizing iterations are continued until the proper height and lordosis have been determined using tactile feel and lateral fluoroscopy.

[0169] An appropriately sized spacer **100** is then chosen and attached to the spacer inserter **300** by aligning the control arms **350** with control guide **144** on insertion link **115** and advancing together. Lockwheel **348** is rotated (clockwise) until fixation tube **303** threads **372** advance into aperture **149** and instrument stop surface **156** on insertion link **115** is tight against link face **344** on control frame **301** as illustrated in FIG. **85**.

[0170] Handle collar assembly **302** is advanced on collar neck **334** of control frame **301** until distal stop face **355** abuts bulb portion **347** of control frame **301** as illustrated in FIG. **86**. An optional expansion limiter **305** may be attached to limiter neck **336**. An appropriately sized expansion rod **304** corresponding to the spacer **100** size is selected. Using enlarged head **310**, and leading with threaded boss **375**, the expansion rod **375** is advanced through working aperture **332** of control frame **301** and threaded (clockwise) into coupler aperture **242** of coupler **206** until stop surface **243** abuts stop surface **376** on expansion rod **304** as illustrated in FIG. **87**. Expansion handle **306** is then mounted over outer drive collar **367** while spacer **100** remains in the insertion configuration as illustrated in FIG. **88**.

[0171] Spacer **100** is then inserted down the surgical path into the disc space using an oblique trajectory while ensuring that the "MEDIAL" and "LATERAL" indicia **393** are in the correct orientation relative to the patient. Under fluoroscopy, the implant is expanded through rotation of the expansion handle as illustrated in FIG. **89**, while a distal directed force is maintained during expansion and the anterior aspect of the implant is monitored via fluoroscopy to assure it remains in the desired location. Tactile resistance may be felt when the implant is in its fully-expanded state. Full expansion can be confirmed via fluoroscopy as well as by visual indicator **351** on the implant inserter as seen in FIG. **90**. Radiographs may be taken to confirm correct placement of spacer **100** in the intervertebral space. If desired, handle **306** may be derotated to return to the insertion configuration for spacer **100** removal or readjustment. When fully collapsed, the rotating collar on the inserter will be fully seated distally. Once proper placement is achieved, expansion handle **306** is removed from spacer inserter **300** by releasing handle lock **307** (if so equipped) and sliding handle **306** off as seen in FIG. **91**.

[0172] The expansion rod **304** is released from coupler **206** through derotation of enlarged head **310** as illustrated in FIG. **92**. The handle collar assembly **302** is rotated until distal stop face **355** abuts bulb portion **347** of control frame **301** as illustrated in FIG. **93**. Graft funnel **700** as illustrated in FIG. **94**, or graft inserter assembly **500** may now be attached to collar neck **334** (limiter neck **336** may be absent in some embodiments).

[0173] The graft funnel 700 is attached by advancing threaded 716 aperture of collector tube 702 over collar neck 334 until snug. The funnel 701 is filled with autograft guided into the central aperture 728 of plunger tube 704 until full. Using knob 703, the plunger tube 704 is rotated until ball detent engages at 180 degrees. An expansion rod style plunger is advanced down widened aperture 731 pushing graft into graft aperture 122 of spacer 100. This action is repeated until graft aperture is filled to the desired level.

[0174] The funnel 700 is then removed from the implant inserter followed by removal of the implant inserter by rerotation of lockwheel 348 therein releasing spacer inserter 300 from spacer 100 as illustrated in FIG. 95.

[0175] The retractor and all instruments are then removed from the patient. The surgeon may choose to take an A/P fluoroscopy image of the operative site with the C-Arm at 0 degrees and a lateral image with the C-Arm at 90 degrees. The applicable steps from above are utilized if additional implants are desired at an additional operative level as chosen by the surgeon.

[0176] In an alternative method to using graft funnel 700, graft delivery guide 503 is attached by advancing inserter tube 604 over collar neck 334 and tightening until snug. The cartridge retainer is set on a flat sterile surface against cartridge handle 506 with door 505 facing up. Door 505 is opened and bone graft is spread across chutes 507. Door 505 is closed once chutes 507 are filled with desired amount of bone graft. Lock 514 is withdrawn and cartridge retainer 501 is inserted into cartridge aperture 550 of the cartridge retainer housing 502 and secured by releasing lock 514.

[0177] The cartridge retainer housing 502 with cartridge retainer is then loaded into the right side of graft delivery guide wherein rear guide recess 545 and front guide recess 548 are captured between capture walls 603. With sliding lock button 618 unlocked, handle 616 is rotated counter clockwise causing pinion gear 608 to advance rack gear and cartridge retainer 502 across coupler 600 until a selected chute aligns with indicator 613. Sliding lock button 618 may be engaged to secure cartridge retainer in place. The chute door 527 aligned with indicator 613 at center of coupler 600 is opened by walls of curved low door groove 610 and high door groove 611 acting on retraction face 573 and boss face 568 against biasing member 525.

[0178] A fixation rod style plunger is used to push the bone graft for said open chute through graft port 623 and fixation tube 303 into graft aperture 122. The cartridge retainer 502 is advanced by the pinion gear 608 to the next chute and the plunger process is repeated until a desired amount of graft is pushed into graft aperture 122. The graft inserter assembly and spacer inserter may then be removed.

[0179] While the present invention has been shown and described in terms of preferred embodiments thereof, it should be understood that this invention is not limited to any particular embodiment and that changes and modifications may be made without departing from the true spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. An intervertebral spacer, comprising:

- a first side having a proximal end and a distal end and comprising a first plurality of links joined by a first plurality of joints;
- a second side having a proximal end and a distal end and comprising a second plurality of links joined by a second plurality of joints;

- a proximal end including an insertion link having an aperture dimensioned to receive an insertion tool, said insertion link joined to proximal ends of the first side and the second side;
  - a distal end including a coupling assembly for receiving a portion of the insertion tool and a gear assembly configured to maintain the intervertebral spacer in an expanded configuration;
  - a first support face configured to contact a first vertebral body; and
  - a second support face opposite said first support face configured to contact a second vertebral body;
- wherein said intervertebral spacer has an insertion configuration in which the spacer is elongated and the first side and second side are linear and an axis of insertion is parallel to a longitudinal axis of the intervertebral spacer, and a fully expanded configuration in which the first side and second side are displaced to define a graft aperture therebetween, and the intervertebral spacer has a hexagonal perimeter that is asymmetrical about the axis of insertion.

2. The intervertebral spacer of claim 1, wherein the intervertebral spacer is bisected by a first axis parallel to a sagittal plane when the spacer is in the fully expanded configuration within an intervertebral disc space.

3. The intervertebral spacer of claim 2, wherein the perimeter of the intervertebral spacer is symmetrical about the first axis.

4. The intervertebral spacer of claim 1, wherein at least one of the plurality of links of the first side includes a window.

5. The intervertebral spacer of claim 1, wherein at least one of the plurality of links of the second side includes a window.

6. The intervertebral spacer of claim 1, wherein the first side has a first height at the distal end and a second height at the proximal end and wherein the first height is greater than the second height.

7. The intervertebral spacer of claim 6, wherein the second side has a first height at the distal end and a second height at the proximal end and wherein the first height is greater than the second height.

8. The intervertebral spacer of claim 1, the first support face including a sloped surface.

9. The intervertebral spacer of claim 1, the second support face including a sloped surface.

10. An intervertebral spacer, comprising:

- a first side having a proximal end and a distal end and comprising a first plurality of links joined by a first plurality of joints;
- a second side having a proximal end and a distal end and comprising a second plurality of links joined by a second plurality of joints;
- a proximal end including an insertion link having an aperture dimensioned to receive an insertion tool, said insertion link joined to proximal ends of the first side and the second side;
- a distal end including a coupling assembly for receiving a portion of the insertion tool and a gear assembly configured to maintain the intervertebral spacer in an expanded configuration;
- a first support face configured to contact a first vertebral body; and

a second support face opposite said first support face configured to contact a second vertebral body;  
 wherein said intervertebral spacer has an insertion configuration in which the spacer is elongated and the first side and second side are linear and an axis of insertion is parallel to a longitudinal axis of the intervertebral spacer, and a fully expanded configuration in which the first side and second side are displaced to define a graft aperture therebetween, and the intervertebral spacer has a hexagonal perimeter that is asymmetrical about the axis of insertion.

**11.** The intervertebral spacer of claim **10**, wherein the intervertebral spacer is bisected by a first axis parallel to a sagittal plane when the spacer is in the fully expanded configuration within an intervertebral disc space.

**12.** The intervertebral spacer of claim **11**, wherein the perimeter of the intervertebral spacer is symmetrical about the first axis.

**13.** The intervertebral spacer of claim **10**, wherein at least one of the plurality of links of the first side includes a window.

**14.** The intervertebral spacer of claim **10**, wherein at least one of the plurality of links of the second side includes a window.

**15.** The intervertebral spacer of claim **10**, wherein the first side has a first height at the distal end and a second height at the proximal end and wherein the first height is greater than the second height.

**16.** The intervertebral spacer of claim **15**, wherein the second side has a first height at the distal end and a second height at the proximal end and wherein the first height is greater than the second height.

**17.** The intervertebral spacer of claim **10**, the first support face including a slopped surface.

**18.** The intervertebral spacer of claim **10**, the second support face including a slopped surface.

**19.** An intervertebral spacer, comprising:

a first side having a proximal end and a distal end and comprising a second vertebral body;

wherein said intervertebral spacer has an insertion configuration in which the spacer is elongated and the first side and second side are linear and an axis of insertion is parallel to a longitudinal axis of the intervertebral spacer, and a fully expanded configuration in which the first side and second side are displaced to define a graft aperture therebetween, and the intervertebral spacer has a hexagonal perimeter that is asymmetrical about the axis of insertion.

**20.** The intervertebral spacer of claim **10**, at least one of the first support face and the second support face including a slopped surface.

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