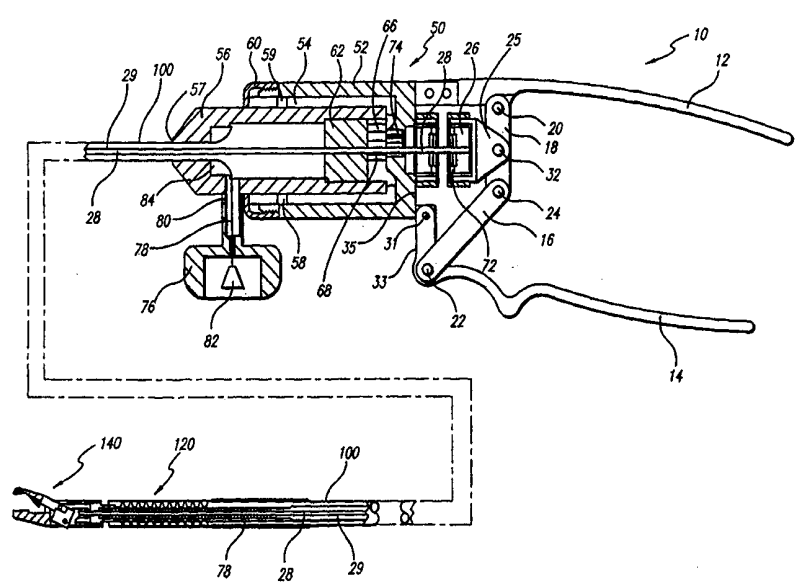




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(54) Title: ENDOSCOPIC SURGICAL INSTRUMENT FOR ROTATIONAL MANIPULATION



(57) Abstract

This invention is an endoscopic surgical instrument suitable for use with a needle grasper (140) having a rotational translation device (50) for creating rotational motion at the distal end of the surgical instrument in a non 1:1 ratio to rotational energy imparted at the handle (10) of the surgical instrument. The shaft (100) of the surgical instrument has an articulated segment (120) capable of remote adjustment to articulate the effector unit (140) at the end of the surgical instrument. The effector unit (140) may be a needle gripper (140) having an upwardly pointed V-shaped notch (146) in a channeled upper jaw (142), and a convex gripping surface (153) on the lower jaw (144) such that grasping a curved suture needle between the upper and lower jaws (142, 144) serves to automatically orient the needle perpendicular to the needle gripper (140) with the curvature pointed down.

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ENDOSCOPIC SURGICAL INSTRUMENT FOR ROTATIONAL MANIPULATION

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to a surgical instrument for remote manipulation and more particularly to an instrument for use in endoscopic surgery, the instrument having an articulated shaft and transmitting rotational motion to the distal end of the instrument.

Minimally invasive surgery (MIS) such as laparoscopic, endoscopic, hysteroscopic, and arthroscopic surgery (referred to hereafter generally as endoscopic surgery), is becoming more widely used because it is less traumatic to the patient, generally involves less hospitalization time, less discomfort and less risk to the patient, and is usually less costly than traditional open surgery.

Such a procedure is typically performed by making a small incision in the patient which provides access to the area to be treated. A trocar sheath may be inserted in the incision and an airtight seal around the trocar established. The area under the skin which is to be treated may be dissected from surrounding tissue by, for example, balloon dissection. With or without dissection, the area may be expanded slightly as by insufflation with CO<sub>2</sub> in order to create a cavity within which to perform the surgical procedure. Access to this cavity may be through by one or more trocar sleeves which may be configured to permit the slidable insertion of endoscopes and surgical instruments without compromising the air tight seal around the trocar sheath. Each such endoscopic surgical instrument is often inserted through a different incision.

The endoscopic surgery is generally preformed using elongate instruments slidably inserted through the trocar sleeves, or if the endoscopic surgery is performed in a naturally occurring body cavity, such as the uterus, the instruments may be inserted through a relatively narrow body orifice such as the cervix. The manipulations being performed by the instruments during endoscopic surgery are generally observed through an endoscope which may be inserted through a separate trocar into the operating cavity.

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10 Alternatively, the endoscope may be contained within a surgical tube which also contains surgical instruments. In any event, the operator must perform the surgical manipulations using an effector unit, such as a scalpel or needle gripper on the end of the surgical instrument remotely located from the operator's hands and confined within a relatively small cavity created for the operation. The manipulation must be performed while observing the procedure with an endoscope. The image from the endoscope is often displayed on a video screen and generally results in an image

15

20 having little or no depth perception.

Of particular interest is suturing or tying knots during endoscopic surgery. Suturing and tying knots using remote effector units while observing the manipulation through an endoscope is very challenging for the surgeon.

25

Traditionally the surgical instruments employed to perform endoscopic suturing may include simple endoscopic needle holders, a variety of specialized needle drivers, and motorized telesurgical systems. The problems associated with remote knot tying have lead to the development of such

30

instruments and devices as pre-tied knots, ultrasonic welded knots, beads swaged in such a way as to facilitate the crimping of sutures together, and, again, motorized systems. Most of the methods described above are limited in use to interrupted rather than continuous suturing. Some, for

example the telesurgical system, require complex instrumentation and may not be available for all endoscopic procedures, especially the simpler procedures. In addition, the motorized systems generally limit or eliminate the  
5 kinesthetic ability of the surgeon to sense and directly manipulate the suture or needle.

One particularly cumbersome technique that is often used to achieve suturing using traditional endoscopic instruments, is the "hand off" of the needle from one instrument to  
10 another. This technique exacerbates the difficulty of remote manipulation in limited space and restricted visualization with the requirement of coordination of two or more instruments. This technique involves insertion of the suturing needle by the operative instrument into the tissue  
15 to be sewn. The needle is then pushed forward, driving the needle through the tissue. A second instrument, may apply counter-pressure to the tissue at the location where the sharp tip of the needle will emerge at the end of the stitch. This entrance drive of the needle through the tissue  
20 generally involves a rotating motion, particularly critical where a sharply curved needle is used.

Once the tip of the needle emerges from the tissue, it is extracted by the assisting instrument grasping the tip of the needle and pulling. The principal needle driver releases  
25 its grip on the needle and may be placed beside the location where the needle is exiting the tissue to act as a counter-pressure instrument in place of the assisting instrument which is now pulling the needle from the tissue, pushing the tissue down while the needle is being pulled out by the  
30 assisting instrument. As with the entrance drive, the extracting motion often involves significant rotation in order to avoid tearing the tissue, particularly with a sharply curved needle.

After the needle is extracted, the trailing suture may be pulled through the tissue, again with the use of two cooperating instruments, each pulling at the suture sequentially until the correct amount of suture has been  
5 pulled through the tissue.

For single stitch technique, the suture is then tied, itself a complex procedure especially where performed with a viewing system having very limited depth perception. When continuous sewing is performed, the needle is grasped by the  
10 principal operative instrument after the suture is pulled through the tissue as desired in preparation to performing the sequence again to form a second stitch. First, the assisting instrument grasps the fully extracted needle and holds it in an optimal position for the principal needle  
15 driver to grasp. The assisting second instrument generally must grasp the needle near the tip so that the principal needle driver can grasp the needle far enough to the rear of the sharp tip to provide adequate length to pass the needle through the tissue layers during the next entrance drive so  
20 that enough of the needle tip will exit to be grasped by the assisting instrument. The assisting instrument must hold the needle at an appropriate orientation so that the principal needle driver will grasp the needle at the proper orientation for making the next entry into the tissue. Since traditional  
25 endoscopic instruments have a limited range of rotation at the distal end relative to the handle, this orientation is critical. Once again, this needle insertion and drive through the tissue, and subsequent extraction of the needle at the end of the stitch, requires significant rotational  
30 motion. It is often desirable during such procedures to hold the forearms of the operator relatively stationary, the rotational motion imparted by the hands of the operator rotating at the wrists may be insufficient to successfully accomplish the stitching.

The efforts required for a successful hand-off and continuous suturing highlights a number of problems with current endoscopic tools. It is a problem to properly orient the needle relative to the needle gripper. For effective  
5 suturing, the curved needle should be grasped by the principal needle driver with the needle extending perpendicular to the grasper and with a sufficient length of the front end of the needle protruding so that the needle may be inserted into the tissue. This is very difficult when the  
10 operator is viewing the procedure with limited or no depth perception.

It is also a problem to provide sufficient rotation after grasping the needle to rotate the needle to insert the tip into the desired location to start the stitch. This is  
15 particularly problematic given the limited rotational motion of the human wrist, or with mechanical devices such as side mounted rotational knobs that are sometimes provided to achieve rotation at the distal end at an endoscopic tool. The requirement for two instruments to carry out this  
20 technique may also create the need for additional incisions, further complicating the procedure and adding additional trauma, risk and expense to the procedure.

Another problem presented by the use of some current endoscopic instruments with needle grabbers is access to a  
25 location that is at an angle to the end of a straight surgical instrument. An endoscopic surgical instrument must generally be straight to be inserted through a trocar sleeve. Although some angle of reach is available by twisting the trocar in the patient's body and thereby pointing the  
30 instrument in slightly different directions, this is obviously limited by such considerations as the need to keep the trocar incision relatively airtight if the operating cavity is insufflated, and the need to avoid traumatizing the patient unnecessarily. Since movement of the instrument and

the twisting and straining of the trocar at the site of the incision can threaten the airtight seal and be traumatic to the patient, it would be preferable to reach locations within the operating area by articulating the end portion of the surgical instrument without having to twist the instrument or the trocar at the site of the incision. Some form of articulation within the instrument shaft, preferably near the distal end of the instrument shaft, with the articulation being controllably adjustable by the operator after insertion of the instrument, is advantageous.

Various endoscopic surgical instruments, such as surgical staplers, and surgical retraction devices for use in endoscopic procedures, are disclosed in the prior art. See, for example, U.S. Patent No. 5,192,288, directed to a surgical clip applier and U.S. Patent No. 5,431,669, directed to a surgical clip applier with distal hook. Also disclosed in the art are endoscopic surgical instruments having knobs for the adjustment of angles of articulation and rotation of a staple applier as disclosed in U.S. Patent No. 5,662,662, directed to a surgical instrument and method, and U.S. Patent No. 5,607,095, directed to an endoscopic surgical instrument with pivotable and rotatable staple cartridge.

Graspers for suture needles are also shown in the prior art. For example, U.S. Patent No. 5,015,250, directed to a medical instrument for driving a suture needle, discloses a needle driver instrument suitable for use with a trocar sheath in operative endoscopic surgical procedures for holding and driving a curved suture needle.

Given the needs of those operating in the environment of endoscopic surgery, it would be desirable to provide a surgical instrument directly responsive to hand and forearm rotation which is capable of imparting rotational motion in a non 1:1 ratio to an effector unit such as a needle gripper. It would also be desirable to provide a needle gripper which



would automatically orient a curved suture needle.  
Additionally, it would be desirable to provide a needle gripper which could be remotely operated by, for example, operating a reciprocating rod at the handle of a surgical  
5 instrument to open and close the jaws of a needle gripper at the distal end of an elongate shaft on the surgical instrument. Moreover, it would also be desirable to provide a surgical instrument such as a needle gripper that could simultaneously be manipulated in multiple ways, such as  
10 opening and closing and simultaneously rotating, by the same hand of the operator, thus providing dynamic control over the manipulation of effector unit such as a needle gripper.

SUMMARY OF THE INVENTION

According to the present invention an improved surgical  
15 instrument for endoscopic surgery is provided for performing surgical manipulations requiring rotational motion of an effector unit a non 1:1 ratio to the rotational movement applied by the hands of the surgeon to the handle. For example, translating the rotational movement applied by  
20 direct rotation of the hands of the surgeon through a planetary gear system may allow the surgeon to rotate a small diameter (e.g., 5mm) tool such as a needle gripper at the distal end of an endoscopic surgical tool sufficiently to perform a surgical manipulation within the relative limited  
25 space generally available in an endoscopic procedure. Moreover, the invention provides a surgical instrument having direct rotational translation without employing a motor, or a knob that must be turned by the fingers, thereby providing surgical manipulation that is kinesthetically similar to the  
30 rotational movement provided by the wrist action of the surgeon but in degree may be greater than or less than the rotational motion available directly from the wrist of the surgeon. In one embodiment, the surgical instrument provides

reciprocating motion which is supplied to the effector unit by squeezing the same handle used to impart the rotational motion through the translation mechanism to the effector unit, thereby allowing the surgeon to simultaneously operate  
5 the effector unit, as in opening and closing the jaws of a needle gripper, while causing rotation. This dynamic control with the same hand adds advantageously to the control by the surgeon.

Because of the possibility for exaggerated rotational  
10 movement, the surgeon is able to keep his forearms very still while rotating only his wrists and thereby achieves adequate rotation at the distal end of the tool in order to perform a manipulation that requires a greater degree of rotation than would normally be available from simply his wrist rotation.  
15 Conversely, he is able to perform very delicate rotational motions at the distal end if the rotational motion at the distal end is less than a ratio of 1:1 to the rotational motion applied to the handle.

The rotational action of the surgeon's wrists provides  
20 rotational motion directly to the effector unit. The familiar kinesthetic control by the surgeon over the effector unit, a situation often desirable in employing the manual skill of the surgeon. This may be particularly critical where the surgeon is performing a dynamic manipulation such  
25 as sewing rather than merely positioning a mechanical device such as a staple cartridge.

The instrument of the preferred embodiment is provided with an articulated section, which provides for angulation of the distal end portion of the instrument inside the patient  
30 so that the working end of the instrument can be directed to a location that is not in a straight line with the upper portion of the shaft of the instrument. This may be particularly important where the shaft of the instrument is inserted through a trocar sleeve and angular motion is

somewhat restricted. The articulated portion is remotely adjustable so that the amount and direction of the curvature can be adjusted by the operator to locate the working end of the instrument with an effector unit such as a needle gripper  
5 within the operating area while observing the instrument in the operating area and thus position the working end as desired in direct relation to the tissue to be treated, for example, sutured.

A means is provided for smooth transmission of  
10 rotational motion around any curve in the articulated section so that rotation applied by the operator can be transmitted to the distal portion to rotate an actuary unit, for example, a surgical needle gripper. The needs for transmitting rotational motion may be a sheathed cable, a jointed hex rod  
15 with pins, other pinned joint linkage, or other similar device for smoothly transmitting rotational motion around a curve.

The invention may be provided with an effector unit, whether permanent, detachable or interchangeable at its  
20 distal end. Such effector units may include cannulas, cameras, staplers, ligation devices, forceps, drills, cutting devices, scalpels, clamps, illumination devices and the like. In the aforescribed surgical effector unit, a surgical instrument of the invention may be employed to provide the  
25 desired rotational movement of the articulatable tip of the surgical instrument shaft.

One novel effector unit that is advantageously usable with the surgical instrument is a novel needle gripper which functions to securely grasp a curved surgical needle while  
30 simultaneously placing the needle in a predetermined orientation for performing stitching by use of the rotational motion of the surgical instrument of the invention. In a preferred embodiment, the needle gripper is configured having two jaws, a first jaw having a U-shaped channel therein,

which first jaw has a V-shaped side face. The second jaw has a gripper surface opposed to the channel in the first jaw, which gripper surface is an elongate linear convex surface. As the jaws close over a curved suture needle having a round cross-section, that needle is oriented so that it is gripped perpendicular to the jaws and is rested in the apex of the V notch in the one jaw and curved pointing downward over the gripper surface so that the needle arc is curved around the convex surface of the gripper surface. The edges of the legs of the U-shaped channel are conically tapered so that, as the curved needle is gripped between the convex gripper surface on the anvil and the conically tapered edges of the upper jaw channel, it assumes the orientation pointing downward as described above.

The invention generally includes a handle portion rotationally attached to a rotational motion translator such as a planetary gear mechanism, an elongate shaft attached to the rotational motion translator, an articulated section at the distal portion of the elongate shaft, and an effector unit such as a suture needle gripping device attached to or integrally incorporated onto the distal end of the shaft beyond the articulated section. A means for smoothly transmitting rotational energy from the rotational translation means, including through the articulated section, even when the articulated section is curved or angled, to the effector unit is provided. That may include a sheathed cable, or multiple jointed hex-rod with pins, and may include the elongate shaft. Alternatively, the elongate shaft may be hollow and contained within it the rotational transmitting means.

A reciprocating motion transmitter is also contained as part of the instrument. It may generally be actuated by motion of a lever or levers at the handle and reciprocates a motion carrier which may be contained within the elongate

shaft to transmit reciprocating motion to the effector unit. This may be used, for example, to open and close the jaws of the needle gripper.

Other features and advantages of the invention will  
5 become apparent from the following detailed description, taking into conjunction with the accompanying drawings, which illustrate, by way of example, the features of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a cross-sectional view of a surgical  
10 instrument embodying the invention.

FIG. 2 is an exploded view of the tension rod and head assemble of the surgical instruction of FIG. 1.

FIG. 3 is an exploded view of an embodiment of the invention.

15 FIG. 4 is an exploded view of an embodiment of a portfolio of the invention.

FIG. 5 is an end cross-sectional view of the planetary gear mechanism of an embodiment of the invention.

FIG. 6 is an enlarged cross-sectional view of a portion  
20 of the shaft and the needle gripper of an embodiment of the invention.

FIG. 7 is a perspective view of a segmented tube of the articulated section of an embodiment of the invention.

FIG. 8 is a top plan view of a segmented tube of the  
25 articulated section of an embodiment of the invention.

FIG. 9 is a top plan view of section C in Fig. 8.

FIG. 10 is a partial cross-section of the segmented tube of an embodiment of the invention.

FIG. 11 is a rear plan view of the needle gripper of an  
30 embodiment of the invention.

FIG. 12 is a cut-away view taken along line A-A in FIG. 11.

FIG. 13 is a perspective view of the lower jaw of a needle gripper of an embodiment of the invention.

5 FIG. 14 is a top perspective drawing of the yoke of the needle gripper of an embodiment of the invention.

FIG. 15 is a top perspective view of the upper jaw of the needle gripper of an embodiment of the invention.

10 FIG. 16 is a front view of the needle gripper of the invention showing a curved suture needle contained therein.

FIG. 17 is a side cut-away view of the articulated section of an embodiment of the invention in curved configuration.

#### DETAILED DESCRIPTION

15 As shown in the drawings for purposes of illustration, the invention is embodied in a surgical instrument of the type having a handle portion 10 for gripping by the hands of a surgeon, a rotational motion translator 50 for translating rotational motion imparted to the handle, into rotational  
20 motion imparted to a torque transmitting tube 29 which serves to transmit rotational motion from the translator through the outer shaft portion 100. The outer shaft portion extends from the rotational motion translator to an effector unit 140 and includes an articulated section 120. The effector unit  
25 140 may be a needle gripper for grasping and driving a curved needle during suturing. Alternatively the effector unit may be any of a variety of tools as listed in exemplary form in the summary section above.

Referring in general to FIG. 1 for purposes of  
30 illustration, the handle portion 10 is comprised of an upper gripping lever 12, and a lower gripping lever 14 connected to the upper gripping lever by means of a lower connector link

16 and an upper connector link 18. The upper connector link is pivotally attached at one end to the upper gripping lever at pivot pin 20 and to the lower connector link at pivot pin 24. The lower connector link is pivotally attached to the  
5 lower gripping lever at pivot pin 22 and to the upper connector link at pivot pin 24. Gripping levers 12, 14 may be biased apart, so that when squeezed they will be compressed toward each other, but when released they will move away from each other. The gripping mechanism may be  
10 provided with a ratchet or other catch mechanism whereby the return travel of the gripping levers may be prevented or restrained until released by the operator. By this means, the effector unit may be maintained in the condition having the tension rod 28 retracted, as with the jaws 142, 144 of  
15 FIG. 11, of the needle gripper 140 closed, without constant manual pressure from the operator, until the operator releases the gripper levers by intentionally releasing the ratchet or catch mechanism. Downward movement of the lower gripping lever is limited when an end surface 33 of the lower  
20 gripping lever contacts on end surface 35 of the carrier.

A holder 25 is pivotally attached to the upper connector link 18 at centrally located pivot pin 32. A thrust bearing nut 26 of a tension rod 28 is contained within the holder. The tension rod is firmly affixed to the nut which, in turn,  
25 is firmly contained within the holder 25 so that compression of the gripper levers towards each other functions to pivot the upper connector link and lower connector link 16 so that the connector links 18, 16 close in scissor like fashion, reciprocating the holder rearward. This in turn functions to  
30 pull the tension rod in a reciprocating motion rearward.

Referring generally to FIG. 2, which is an exploded view of the tension rod 28 and head assembly 31, the tension rod 28 is inserted through thrust bearings 37, 38, orifice 39 and orifice 40, bearing 41 and is firmly attached within the

thrust bearing nut 26 by, for example, screw threads 33. By means of this arrangement it will be seen that compression of the handles functions to reciprocate the tension rod.

Referring again to FIG. 1, the upper handle 12 is  
5 fixedly attached to a carrier 52 which comprises the outer section of rotational motion translator 50. The lower gripper handle 14 is pivotally attached at pivot pin 31 to the carrier. The carrier has a generally cylindrical interior cavity. Contained within the interior cavity is a  
10 bearing 54 which is a generally tubular, contact with the outer surface of bearing 54 in the carrier's cylindrical inner surface, and with inner surface of bearing 54 in contact with the generally tubular outer surface of a nose piece 56. The bearing may be secured to the nose piece by  
15 one or more pins 58, 59. The carrier may be secured longitudinally relative to the bearing 54 and thus to the nosepiece 56 by means of a housing cap 60 which is generally annular in shape and serves to be securely affixed to the forward end of the carrier to be angled over the distal end  
20 of the bearing 54 and to encircle the nose piece. Smooth rotation is thereby facilitated because, as the carrier is rotated, the nose piece is stationary relative to the carrier, the carrier rotates with the inner surface in contact with the outer surface of the bearing 54 while the  
25 gripper angle is rotating around the end surface of the bearing 54.

The nose piece 56 is generally tubular in shape. At its distal end it is attached to the shaft 100. At its proximal end it contains a planetary gear mechanism.

30 Referring generally for purposes of illustration to FIGS. 1 and 15, the planetary gear mechanism comprises a planetary housing 62 configured around the internal circumference of the planetary housing are the teeth of a ring gear 64. Meshed with the ring gear are three planetary



gears 65, 66, 67. The planetary gears rotate around rotation pins 73, 74, 75. The planetary gears are, in turn, meshed with the sun gear 68. It may therefore be seen that rotation of the carrier 52 relative to the nose piece 56 will cause  
5 the ring gear to rotate, transferring rotational motion through the sun gear. In the configuration shown, the rotation is translated at a ratio of 4:1. That is, a 90° rotation of the carrier relative to the nose piece translates into a 360° rotation of the sun gear.

10 Sun gear 68 is attached to torque transmitting tube 29. The torque transmitting tube may be, for example, braided wire or mesh. Rotation of sun gear causes rotational motion in the torque transmitting tube which is transmitted in an essentially 1:1 ratio smoothly to the effector unit 140 at  
15 the distal end of shaft 100.

Contained within the torque transmitting tube 29 is tension bar 28. The tension rod is slidably contained within the torque transmitting tube 29 and is slidably contained within the sun gear 68, and extends through the sun gear to  
20 the thrust bearing nut 26. As previously described, compression of the upper gripping lever 12 and lower gripping lever 14 functions to withdraw the thrust bearing nut rearwardly and slidably move the torsion rod rearward within the torque transmitting tube. Bearing 72 serves to minimize  
25 friction as a result of the reciprocating motion of torsion rod 28.

The nose piece 56 has mounted thereon an articulation adjustment knob 76. The articulation adjustment knob may be rotated to tighten or loosen an adjustment cable 78 by means  
30 of a threaded hollow shaft 80 and wire collet 82. This tightening or loosening of the cable 78 functions to adjust the amount of curvature of the articulating section 120 as described in greater detail below. The movement of the cable into the interior of the shaft 100 through an aperture 57 in

the nose piece 56 is facilitated as the cable runs across friction reducing bearing 84.

The elongate shaft 100 may be in the form of a smooth hollow tube made of, for example, surgical stainless steel.

5 The smooth outer skin of the tube may be particularly advantageous for an instrument to be inserted slidably contained within a trocar cannula in an endoscopic procedure. The tube serves as a conduit for the torsion rod 28, the torque transmitting tube 29 and the articulation adjustment  
10 cable 78.

For purposes of creating rotational motion as the effector unit by rotation applied by the hands of the surgeon, the carrier 52 and thus the ring gear 64 or rotated relative to the nose piece 56 and thus rotated relative to  
15 the sun gear and torque transmitting tube. The nose piece may be held in one hand while the other hand rotates the handle portion. Likewise, the nose piece may be fixed to the trocar cannula as with a spline or keyed slot (not shown). Rotation of the handle 10 may then occur relative to the nose  
20 piece with the surgeon having to grip the nosepiece with his hand. Alternatively, a gimble (not shown) may be provided wherein the nose piece is rotationally restrained relative to the handle. Depending upon the preference of the surgeon, such an arrangement will be provided to allow the surgeon to  
25 create rotational manipulation by rotation of his wrists and to kinesthetically mimic direct rotational manipulation of the effector unit during surgical procedures. In a dynamic situation such as sewing, as opposed to a relatively static situation wherein an effector unit is positioned first and  
30 subsequently functions while stationary, as in a stapler, this permits the surgeon to perform surgical tasks such as sewing and knot tying wherein dynamic motion directly under the control of the surgeon's hands is necessary.

The elongate shaft 100 contains at its distal region the articulated section 120. Referring generally to FIG. 6 through FIG. 10, the articulated section 120 is in the general form of a slotted tube 121. The tube has an  
5 unsegmented proximal length 122. Distal of the unsegmented proximal length are a series of ribs 124 interspersed between cutout sections 126. Along the length of the tube and located 180° apart with respect to each other are spines 128, 129. The width of the spine increases by .001 inches with  
10 each successive cut, beginning with a width of .024 inches at the initial cut 130 and ends with the 12th spine area being .035 inches wide at 132.

Located along the length of the interior of one side of the tube 121 is cable channel 133. The cable channel is  
15 located approximately equal distance from each spine, that is 90° around the tube from each spine. The cable channel 133 contains the articulation adjustment cable 78. That cable is affixed to the distal end of the articulated section. As the wire is withdrawn, it causes the articulated section to  
20 compress on the side containing the wire and curve in that direction.

The cut-out section 126 between ribs is generally angular with the greatest distance between adjacent ribs generally located immediately adjacent the spines and the  
25 narrowest distance located on the circumference midway between the spines. The shape may be formed, for example, by cutting the tube slightly greater than perpendicular to the tube's longitudinal axis until the cut reaches the edge of the spine, continuing the cut for a short distance along the  
30 longitudinal axis of the tube perpendicular to the spine, and then cutting outward at an angle slightly less than perpendicular to the longitudinal axis of the tube. This results in a cut out section, which when viewed directly from

above as in FIG. 8, is roughly triangular in shape with a truncated apex.

The segmented articulated section may be covered on its exterior by an elastomeric smooth membrane 125. Such smooth covering is advantageous for cleanliness and safety. The elastomeric nature of the membrane allows curvature of the articulated section.

In the interior of the tube 121 there may be an elastomeric sleeve 112 of friction reducing plastic, for example Teflon®. Since, as described below, a push/pull wire 108 and a torque transmitting sheath 106, as well as cable 78 may all move within the limited space within tube 121, a friction reducing sleeve is generally helpful. The articulated section 120 may be formed by the segmented tube 121 of a super elastic and flexible metal such as nitinol having shape memory and flexibility. Alternatively, it may be in the form of any number of articulated tube structures as known in the art. In the case of the segmented tube 121, when the cable 78 is relaxed, the tube forming the articulated section naturally reverts to some preselected configuration such as a relatively straight configuration. It may be altered in configuration by tightening the cable which compresses one side of the tube to increase curvature of the articulated section, such curvature is illustrated in FIG. 16, wherein a segmented tube having ribs 232,233,234,235 that are slightly offset with respect to each other, is compressed on one side by the retraction of cable 278. When the cable is relaxed, the tube returns to its prestressed shape (not shown).

The segmented tube may be attached to the elongate shaft 100 by means of a transitional tube 208 encasing the unsegmented length 122 of the articulated segment and the distal end 206 of the elongate shaft 100. Alternatively, the unsegmented portion of the segmented tube may be configured

to fit within the tube of the elongate shaft (not shown), or to fit over the exterior of that tube (not shown) to join the two lengths.

Within the elongate shaft is contained tension rod 28  
5 and torque transmitting tube 29. Referring in general to FIG. 6, the tension rod 28 is attached at its distal end to a shielded cable 104. The torque transmitting tube 29 is attached at its distal end to torque transmitting flexible sheathing 106. The torque transmitting sheathing may be, for  
10 example, braided wire or mesh. When the articulated section is curved, the shielded cable and flexible sheathing function to transmit reciprocating motion from the tension rod 28 and rotational motion from the torque transmitting tube 29 to the effector unit 140 as described hereafter.

15 In the embodiment as illustrated in, for example, FIGS 6 and 11-16, the effector unit 140 is a needle grasper for grasping a curved suture needle and automatically orienting the needle in a predetermined orientation. The needle grasper 140 comprises an upper jaw 142 and a lower jaw 144.  
20 The upper jaw is formed having a V-shaped side notch in its surface 146. Referring generally to FIGS. 11 through 16, the upper jaw has a generally U-shaped cross-section as shown at 148. The channel 152 at the apex of the notch 146 is sufficient to accommodate the curvature of a curved suture  
25 needle. The lower jaw as illustrated in FIG. 12 has a generally convex gripping surface 153. The radius of convexity is generally less than the radius of curvature of a suture needle to be used as illustrated in FIG. 15 at 150. In conjunction with the V-shaped notch in the upper jaw and  
30 the concave channel 152 within the upper jaw, the convex gripping surface 153 of the lower jaw serves to predictably orient a curved needle. A needle grasped generally between the upper and lower jaws of this needle gripper would tend to be forced along upwardly angled edge 154 or 156. At the same

time the round surgical needle would tend to assume an orientation curved over the convex surface of the lower jaw and retained within concave channel 152 of the upper jaw. This results in a predictable orientation of the needle  
5 regardless of the angle at which the needle was initially grasped. This is particularly useful where the surgeon is attempting to orient the needle using endoscopic cameras or the like having little or no depth perception.

The lower edges of the sidewalls of the upper jaw 158,  
10 258 are configured having a taper from the outer edge towards the inner edge. As a curved needle is gripped between the anvil and the upper jaw, it slides towards the apex 146 in the upper jaw. As it is sliding along the edges 158, 258, the taper acts to rotate the needle so that its curvature is  
15 generally pointed down. In conjunction with the convex gripping surface on the lower jaw, these two configurations act in concert to align the curved suture needle.

Referring generally to FIGS. 1, 6 and 11 through 16, the effector unit may be in the form of a needle gripper. The  
20 needle gripper as shown in the embodiment illustrated may be opened and closed by the reciprocating action of tension rod 29 transmitted through the articulated section 120 by cable 104. The means by which the needle gripper acts to orient a curved suture needle in a predetermined orientation is set  
25 forth above. This requires that the upper jaw of the needle gripper 142 be opened relative to the lower jaw of the needle gripper 144, receive a curved suture needle between the jaws, and then have the jaws close relative to each other and pinch the curved needle between them.

30 As stated, the needle gripper has an upper jaw 142, and a lower jaw 144 and further involves a yoke 170. The lower jaw has a generally tubular reward portion 143 which contains a generally cylindrical cavity therein 145. The surface of the lower jaw immediately above the cylindrical cavity

therein has a slot 147. On the lower surface there is located another slot 149. There is a whole 181 formed in the upper portion of the lower jaw, and a complimentary whole in the facing surface (not shown). The forwardly projecting lower portion of the lower jaw has a convex gripping surface 153.

The needle gripper yoke 170, as in FIG. 14, has a rear body portion 176 that has a tubular passage therethrough 174. At the forward portion of the yoke are two support plates 177, 178, each of which has a whole therethrough 171, 172.

Referring specifically to FIG. 15, the upper jaw 142 has a generally U-shaped cross section with side walls 159, 161 and a channel 152 extends therebetween. The side walls 163 of the upper jaw have a generally upwardly pointed V-shape, with a forward driving wedge 154 and a reward driving wedge 156 which are joined at apex 146. Lower edges of the sides 157, 158 are generally conically tapered inwardly. At the rear of the upper jaw are pivot plates 163.

When assembled as shown in FIG. 12, the distal end of push/pull cable 104 is secured within tubular passage 174. The yoke is contained within the cavity 145 in the reward section 143 of the lower jaw 144. The two pivot plates of the upper jaw, 163 and its compliment (not shown) are located within slot 147. The upper jaw is pivotally attached to the lower jaw by placing pivot pin 164 through hole 181 and the complimentary holes in the upper jaw. The yoke is pivotally attached to the upper jaw by a pin through the pivot plates of the upper jaw 163 and the support plates 177, 178 of the yoke. As can be most clearly seen in FIG. 12, the yoke 170 is dimensioned smaller than the cavity 145 in the lower jaw. When push/pull cable 104 is pulled rearwardly, it pulls the yoke which in turn pulls the upper jaw at a pin 162. This serves to rotate the upper jaw around a pin 164 while allowing rotation at the pin 162. This acts to close the

channel in the upper jaw down over the convex gripping surface of the lower jaw. The reverse action of the push/pull cable 104 serves to open the jaws of the needle gripper 140. If the lower rear corner of the pivot plates is  
5 caused by this action to extend below the surface of the interior cavity 145, the slot 149 permits the corner to extend out and thus permits this motion.

Referring generally to FIG. 6, a rotation collar 183 is attached to torque transmitting mesh 106 at the distal end  
10 206 of the tube 100. The rotation collar is affixed around its outer periphery to the internal surface of the cavity 145 in the lower jaw. When the torque transmitting tube 29 is rotated and in turn rotates the torque transmitting mesh, this acts to rotate the rotational collar and thus the  
15 effector unit 140. A bearing 185 may be provided to facilitate rotating at the distal end of the articulated section 120. This bearing may also attach to the distal end of the tension wire 78 so that when the tension wire is tightened, is acts to curve the articulated section.

20 Referring again to FIGS. 1 and 6, in practice, the surgeon may grasp the surgical tool with rotational capability by the gripper levers 12, 14, and may cause rotation of the effector unit by rotating the handle 10. The rotational motion of handle rotates the carrier 52 which, in  
25 turn, rotates the planetary housing 62 which contains ring gear 66. The ring gear's teeth are meshed with the teeth of the planetary gears 65, 66, and 67, which planetary gears are meshed on their other side with the gun gear 68. This turning the handles effects a turning of the sun gear. In  
30 the embodiment shown, the sun gear is attached to and rotates the torque transmitting tube 29 with a ratio of 4:1 to the rotation of the handle. This rotational motion is carried via the torque transmitting tube 29 to the torque transmitting mesh 106 covering the cable shielded cable 104.



The outer mesh of the shielded cable 104 in turn transmits the torque to the effector unit 140 and rotates the effector unit, for example, a needle grasper, in direct response to the rotational action of the surgeon's hands. Although the  
5 ratio of motion is 4:1, the timing of the rotation, the feel of direct contact between hands and effector unit, the coordination of the turning motion with pushing and pulling motion, and other similar kinesthetic effects permit the surgeon to directly and dynamically manipulate the effector  
10 unit to perform various functions, for example, suturing, while at the same time keeping the surgeon's forearms relatively still. Likewise, the surgeon may directly cause reciprocating motion of the tension rod 28 by squeezing the handles 10, 12 which acts to pull the tension rod head  
15 rearwardly, retracting the tension rod through the various bearings and, ultimately, retracting the shielded cable which acts to open and close the jaws of the needle gripper.

As shown in FIGS. 12, 15 and 16, the surgeon may position a curved suture needle 150 between the open jaws  
20 142, 144 of the needle gripper and close those jaws around the needle. The configuration of the needle gripper having an upper jaw with an apex 146 and conically tapered upper jaw edges 158, 258, in combination with a lower jaw having a convex grasping surface 153 acts to grasp the needle, slide  
25 it upward to the apex in the upper jaw, while simultaneously and automatically orienting the needle perpendicular to the needle gripper with the curved needle 150 pointing downward. In conjunction with the rotational motion possible by action of the rotational motion translator 50, a suturing motion is  
30 thereby facilitated. Note that while the directional terms upper, lower, downward and the like, are used, such relative terms are descriptive only and in no way limit the disclosure.

While a particular form of the invention has been illustrated and described, it will be apparent that various modifications can be made without departing from the spirit and scope of the invention.

WHAT IS CLAIMED IS:

1. A surgical instrument for endoscopic procedures comprising:

a handle, said handle rotationally attached to a translation section, said translation section attached to a transmitting means, said translation section receiving rotational motion from said handle and imparting rotational motion to said transmitting means in a non 1:1 ratio;

a shaft extending from said translation section to an effector unit, said shaft having an articulated region, said articulated region intermediate said translation section and said effector unit, said articulated region capable of adjustably assuming an angled configurations, said rotation transmitting means smoothly transmitting rotational motion smoothly through said articulated region.

2. A surgical tool as in Claim 1, further comprising;

a reciprocating motion carrier, said reciprocating motion carrier attached to said handle and said effector unit, said reciprocated in motion carrier receiving reciprocating motion at said handle and transmitting said reciprocating motion to said effector unit.

3. A surgical tool as in Claim 2, said handle having an upper grip and a lower grip, said reciprocating motion generated by squeezing said upper grip and said lower grip toward each other.

4. A surgical tool as in Claim 1 wherein said effector unit is a needle gripper.

5. A surgical tool as in Claim 4, wherein the rotational motion applied to said handle is transmitted to

said effector unit in a ratio sufficiently greater than 1:1 such that a curved surgical needle gripped by said needle gripper may traverse through two adjacent edges of tissue in an arc of approximately 180 degrees upon application of rotational motion to said handle of significantly less than 180 degrees.

6. An effector unit as in Claim 1, wherein said translational means is a planetary gear transmission having a ring gear, a planetary gear, and a sun gear, said sun gear attached to said transmitting means.

7. A surgical tool as in Claim 1, wherein said articulated region is entirely enclosed with a relatively smooth outer skin.

8. A needle gripper for gripping a curved suture needle, said gripper comprising an upper jaw and an anvil. Said upper jaw having a generally U-shaped cross-section, said upper jaw having a sidewall. Said sidewall configured  
5 in an upward pointed V-shape;  
said anvil having a gripper surface, said convexly curved.

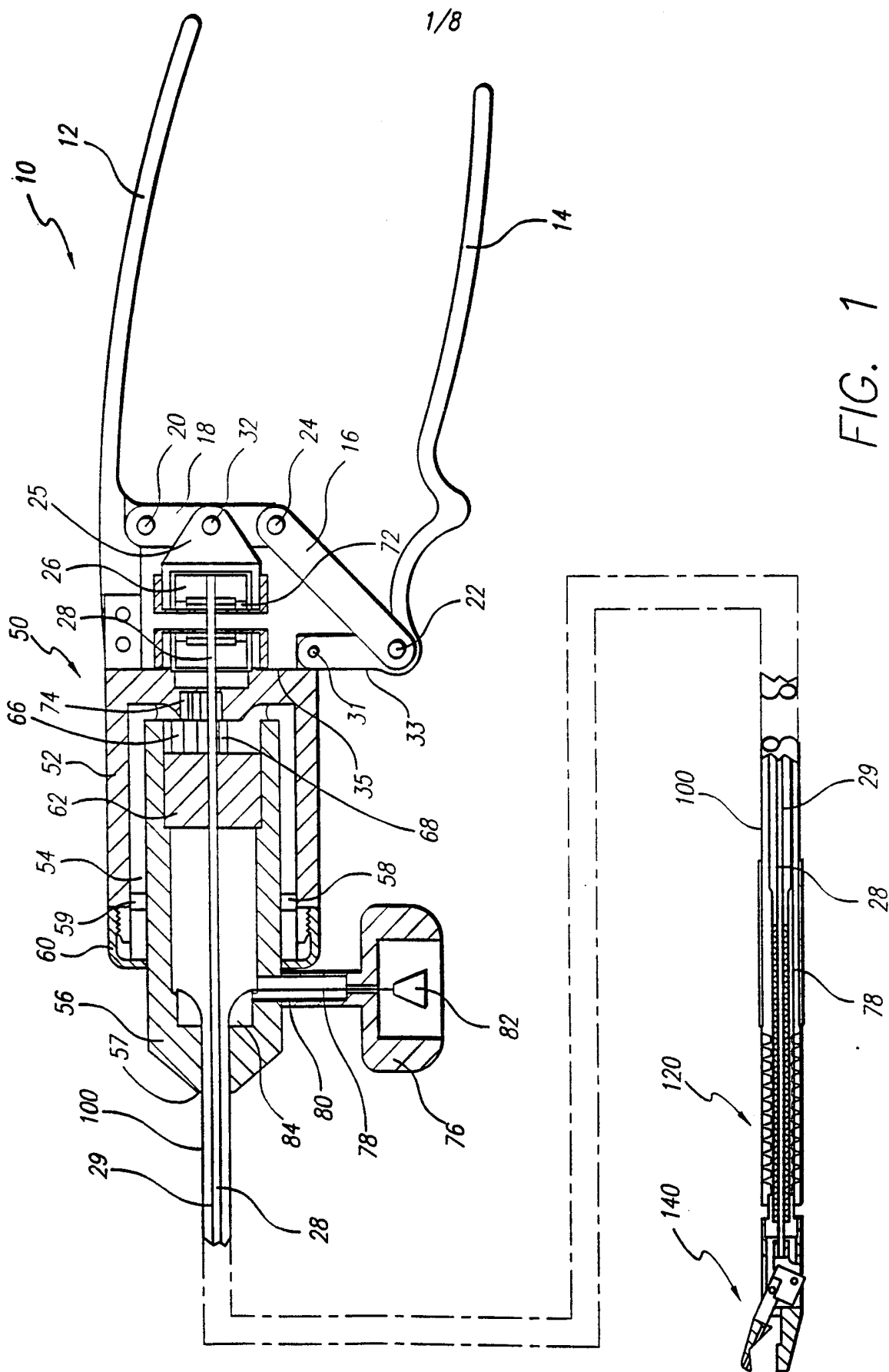
9. A needle gripper as in Claim 7 above, said sidewall having an outer surface, an inner surface, and a lower edge, said lower edge, being conically tapered between said outer surface and said inner surface;

said gripper surface having a radius of curvature less than the radius of curvature of the curved needle.

10. A method of endoscopic surgical tool application, the surgical tool having a handle and an effector unit in which the application of rotational motion to said handle

results in rotational motion of said effector unit in a greater than 1:1 ratio.

11. A method for endoscopic suture placement using a surgical tool having a handle and a needle holder, wherein in rotation of the handle a limited arc of 45 to 90 degrees drives a needle in said needle holder through approximately 180 degrees of arc.



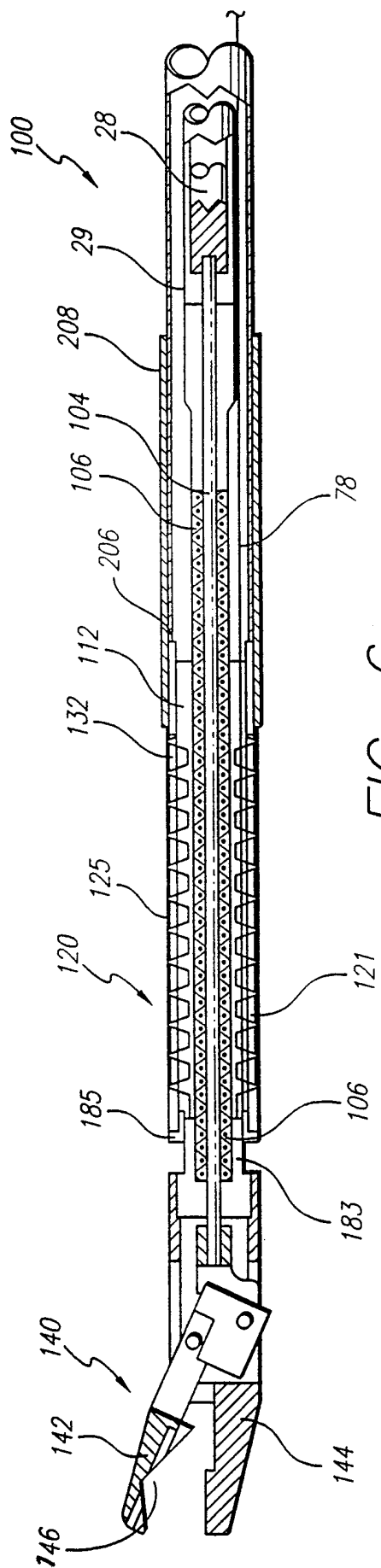


FIG. 6

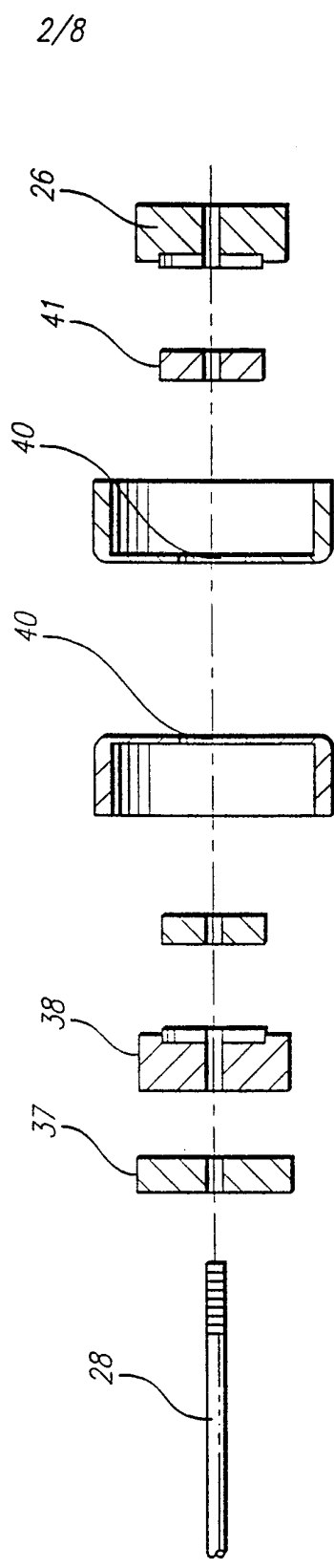


FIG. 2

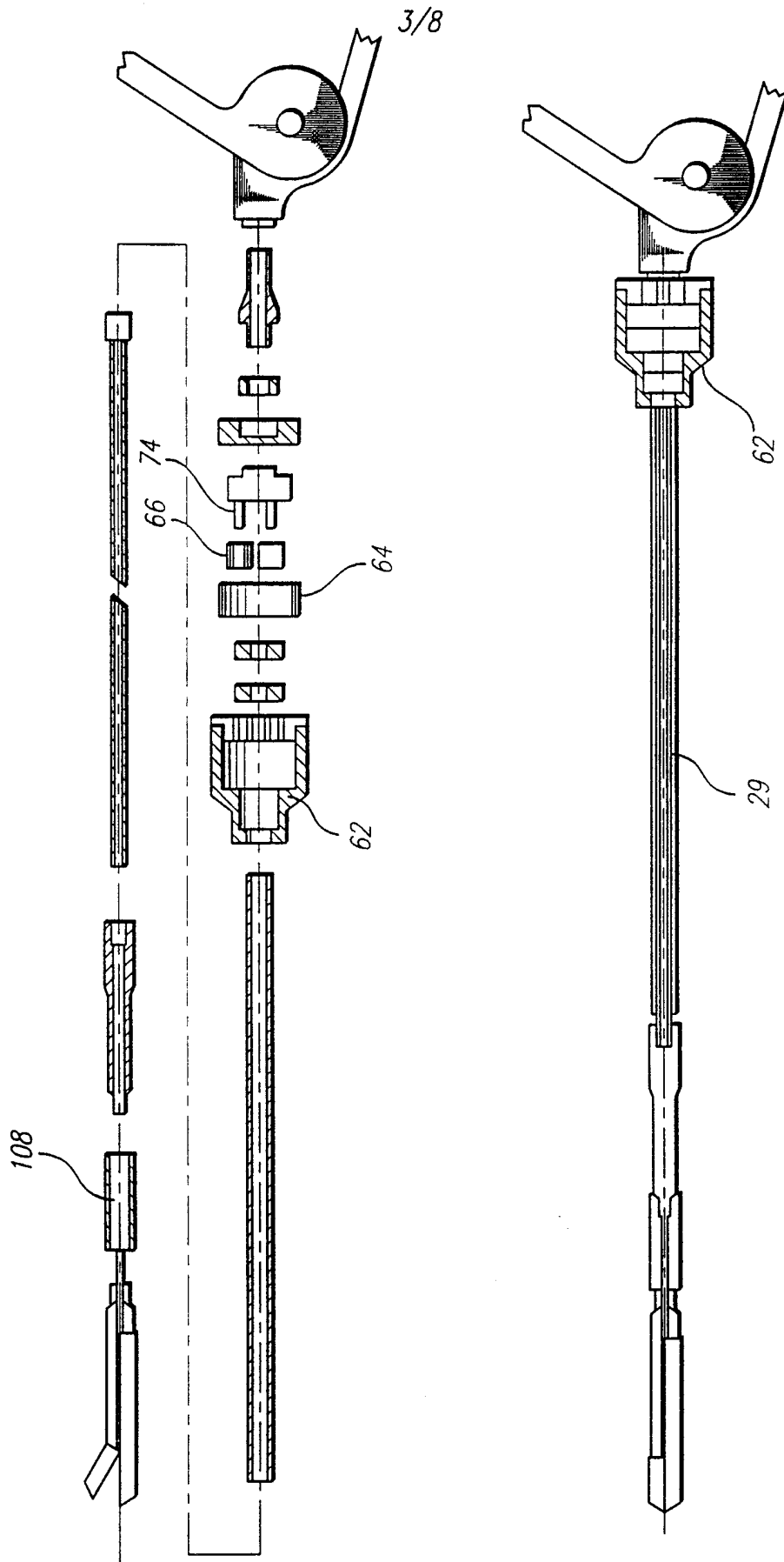


FIG. 3



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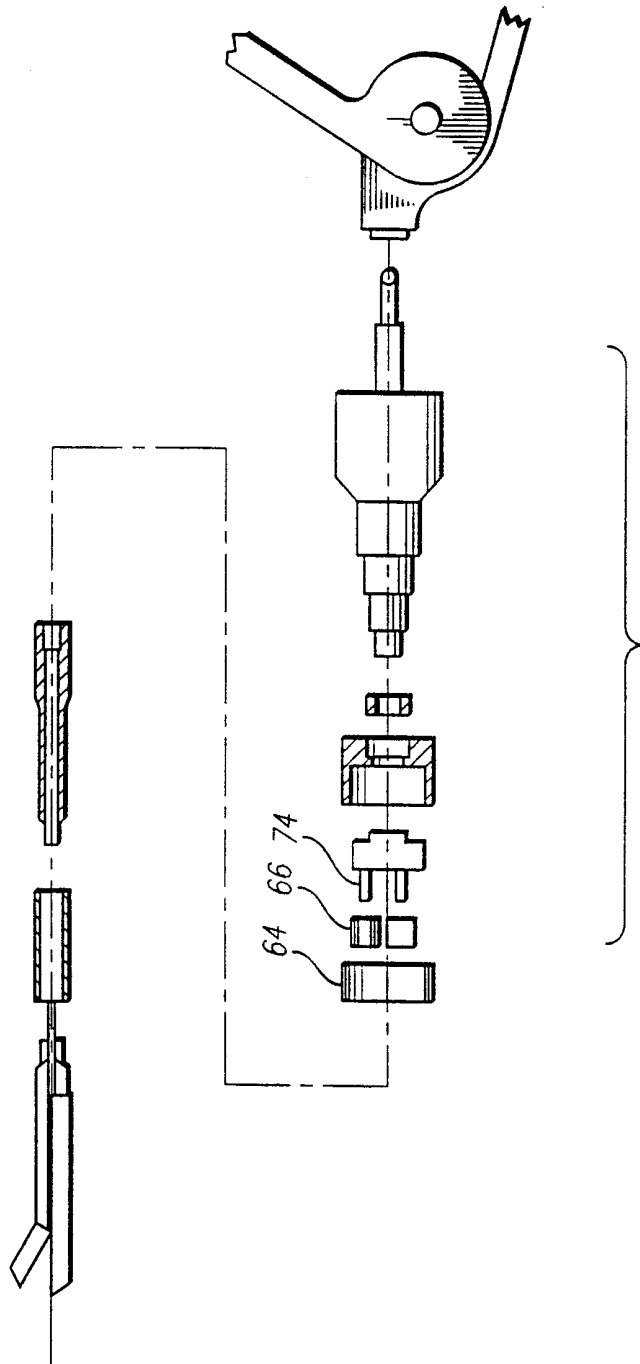


FIG. 4

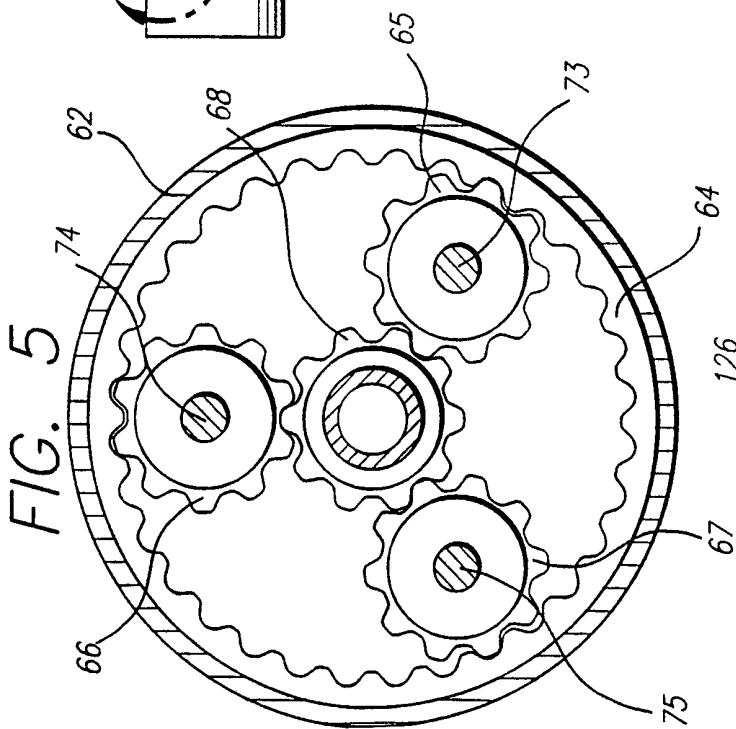


FIG. 9

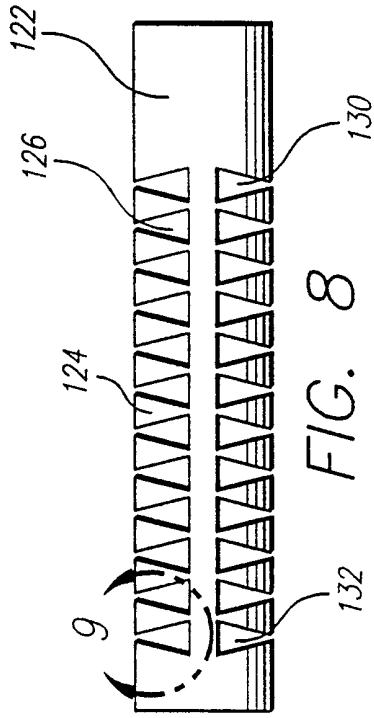
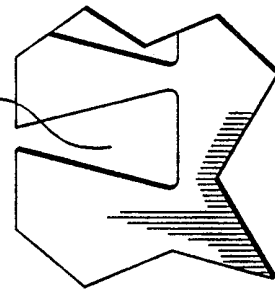


FIG. 8

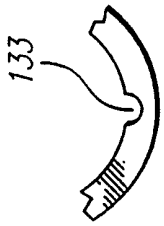


FIG. 10

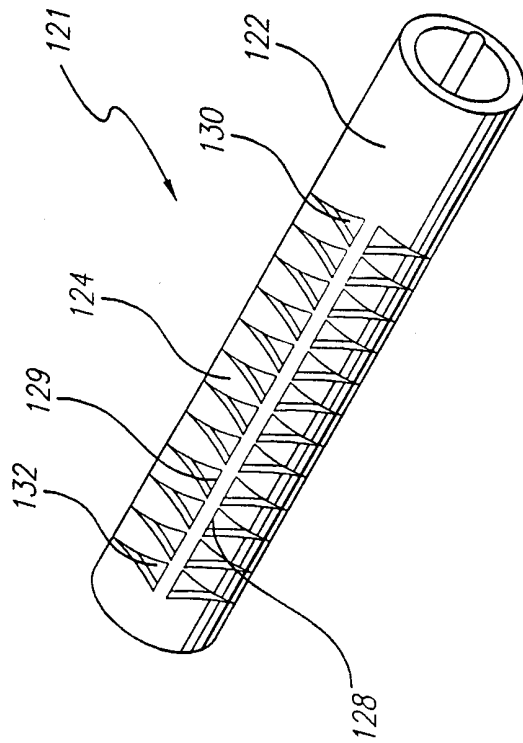


FIG. 7

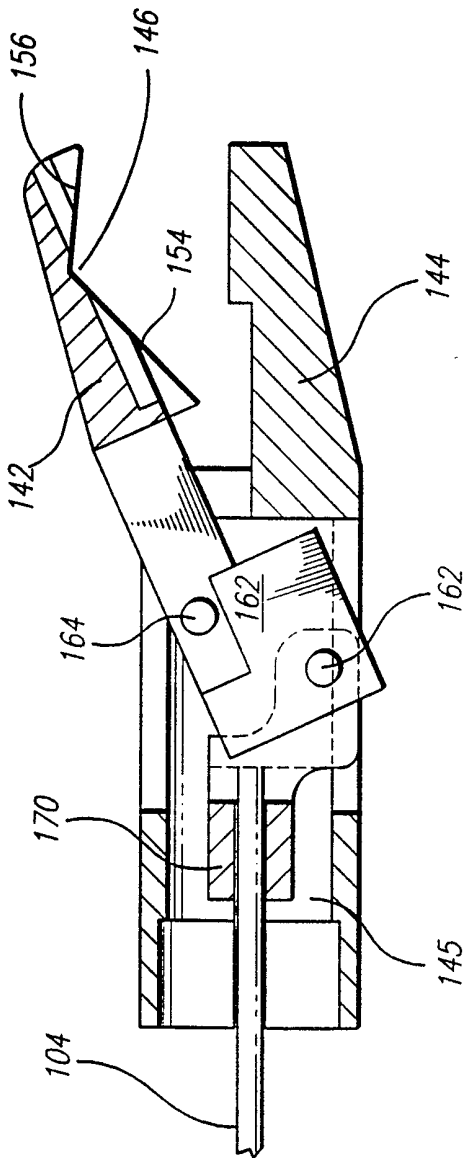


FIG. 12

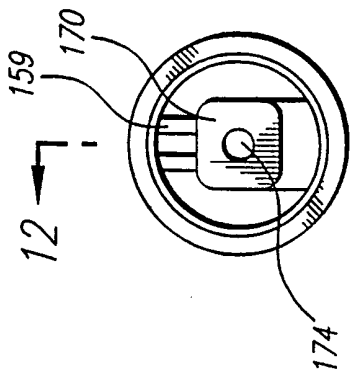


FIG. 11

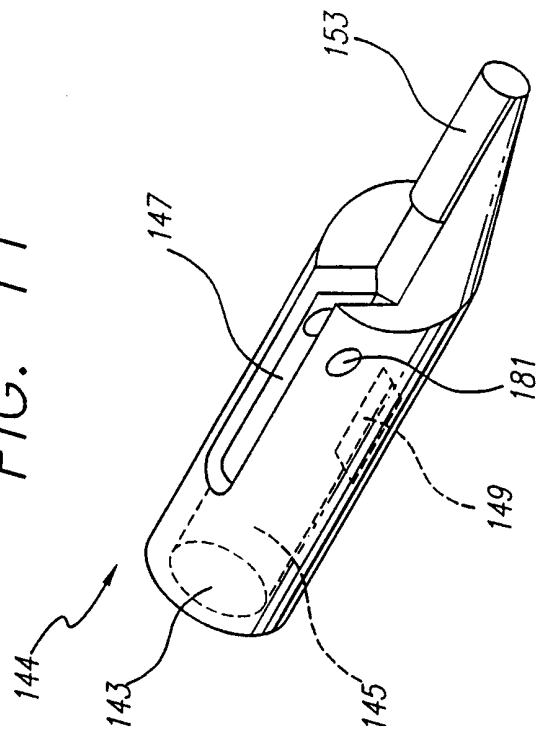


FIG. 13

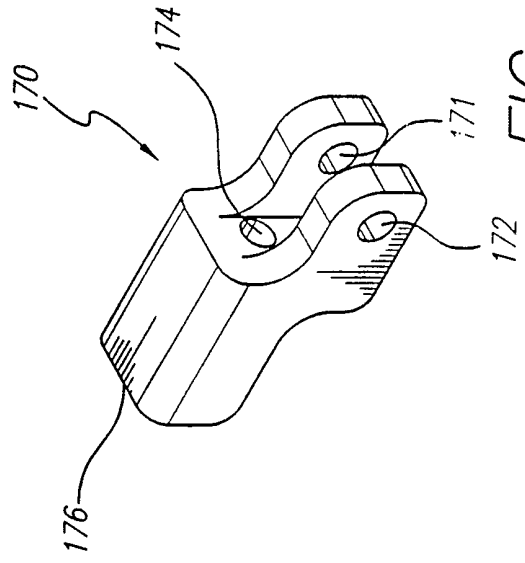


FIG. 14

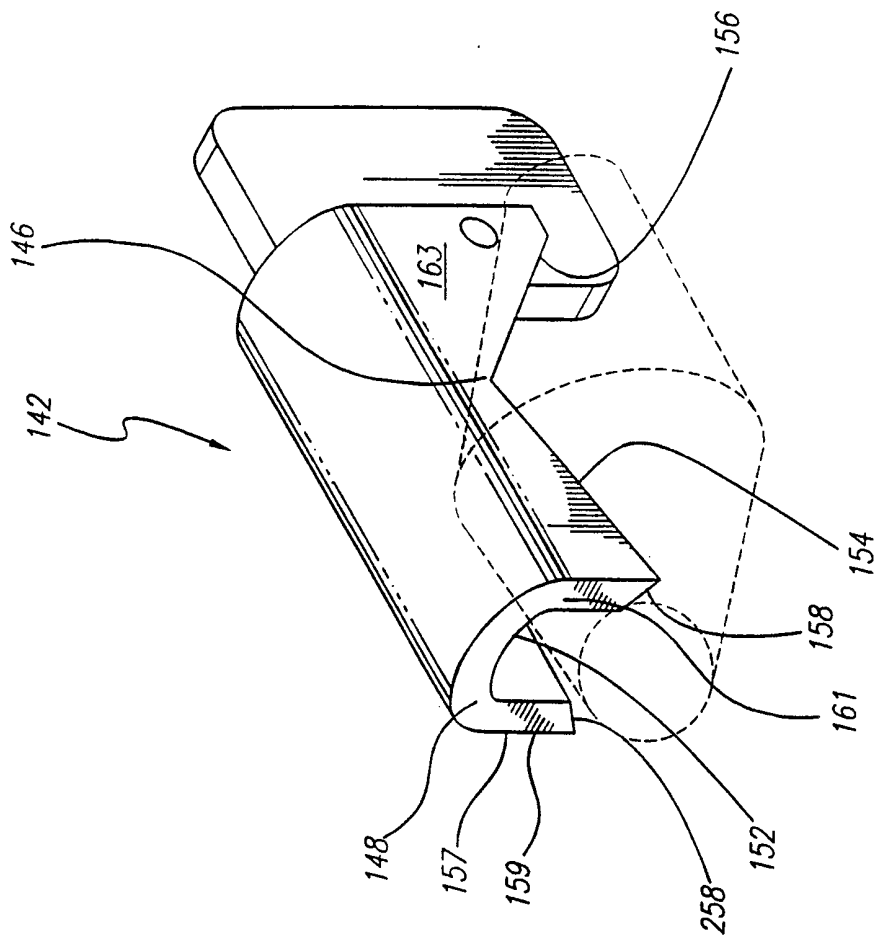


FIG. 15

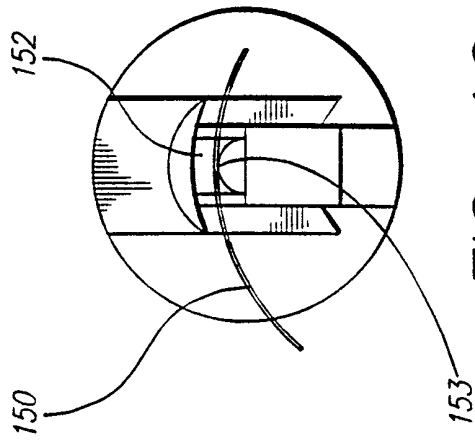


FIG. 16

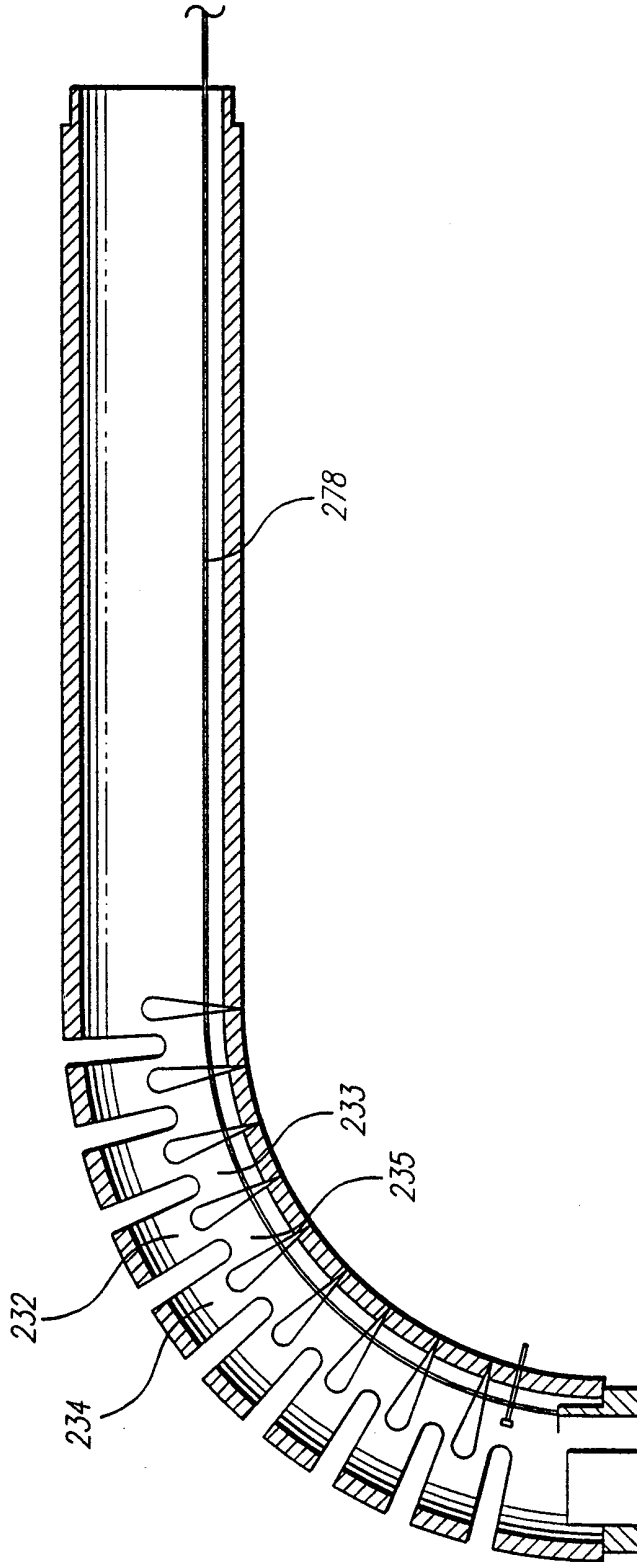


FIG. 17

INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US98/21773

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> IPC(6) :A61B 17/04 US CL :606/144 According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) U.S. : 606/139, 144, 148, 205, 208 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,643,294 A (TOVEY et al.) 01 July 1997, whole document.	1-11
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents:	*T*	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A* document defining the general state of the art which is not considered to be of particular relevance	*X*	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
*E* earlier document published on or after the international filing date	*Y*	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*a*	document member of the same patent family
*O* document referring to an oral disclosure, use, exhibition or other means		
*P* document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search 09 DECEMBER 1998	Date of mailing of the international search report <b>29 DEC 1998</b>	
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer <i>Patricia Mart</i> JULIAN W. WOO Telephone No. (703) 308-0421	