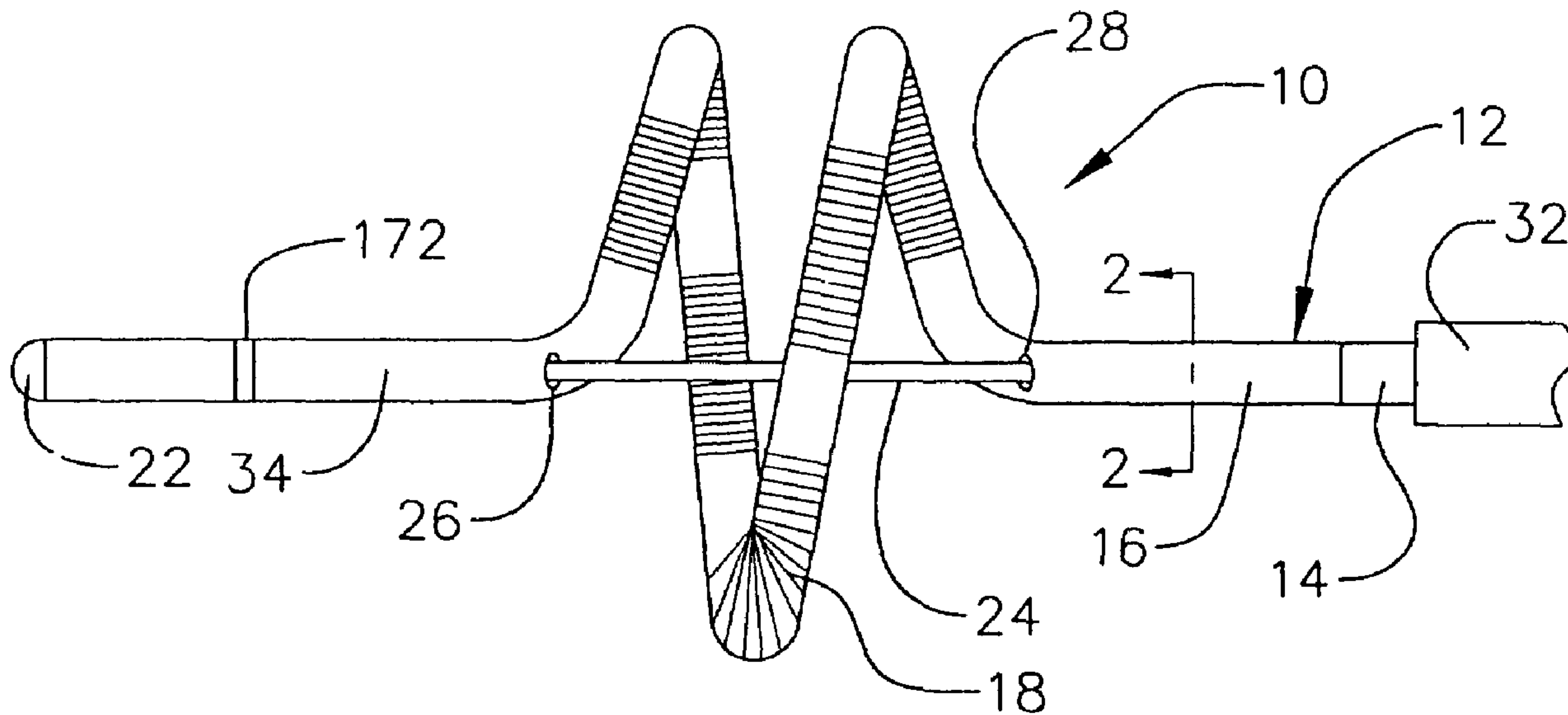




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(57) **Abrégé/Abstract:**

A probe that facilitates the creation of circumferential lesions in body tissue. The probe includes a elongate body and a loop structure, in the form of a helical structure or other loop structure, that supports electrodes or other operative elements against the body tissue.

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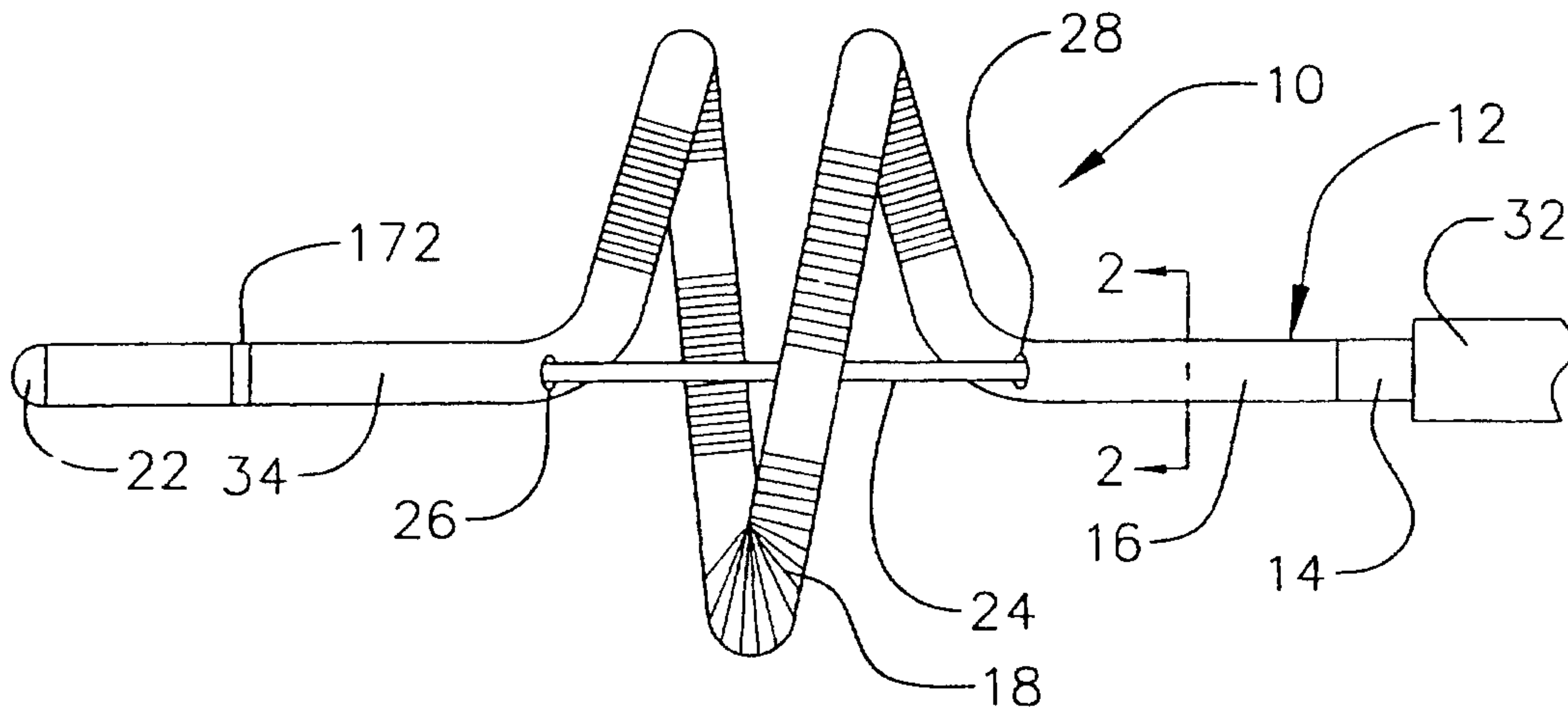
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## LOOP STRUCTURES FOR SUPPORTING DIAGNOSTIC AND THERAPEUTIC ELEMENTS IN CONTACT WITH BODY TISSUE

### BACKGROUND OF THE INVENTIONS

#### 1. Field of Inventions

The present invention relates generally to medical devices that support one or more diagnostic or therapeutic elements in contact with body tissue and, more particularly, to medical devices that support one or more diagnostic or therapeutic elements in contact with bodily orifices or the tissue surrounding such orifices.

#### 2. Description of the Related Art

There are many instances where diagnostic and therapeutic elements must be inserted into the body. One instance involves the treatment of cardiac conditions such as atrial fibrillation and atrial flutter which lead to an unpleasant, irregular heart beat, called arrhythmia.

Normal sinus rhythm of the heart begins with the sinoatrial node (or "SA node") generating an electrical impulse. The impulse usually propagates uniformly across the right and left atria and the atrial septum to the atrioventricular node (or "AV node"). This propagation causes the atria to contract in an organized way to transport blood from the atria to the ventricles, and to provide timed stimulation of the ventricles. The AV node regulates the propagation delay to the atrioventricular bundle (or "HIS" bundle). This coordination of the electrical activity of the heart causes atrial systole during ventricular diastole. This, in turn, improves the mechanical function of the heart. Atrial fibrillation occurs when anatomical obstacles in the heart disrupt the normally uniform propagation of electrical impulses in the atria. These anatomical obstacles (called "conduction blocks") can cause the electrical impulse to degenerate into several circular wavelets that circulate about the obstacles. These wavelets, called "reentry circuits," disrupt the normally uniform activation of the left and right atria.

Because of a loss of atrioventricular synchrony, the people who suffer from atrial fibrillation and flutter also suffer the consequences of impaired



hemodynamics and loss of cardiac efficiency. They are also at greater risk of stroke and other thromboembolic complications because of loss of effective contraction and atrial stasis.

5 One surgical method of treating atrial fibrillation by interrupting pathways for reentry circuits is the so-called "maze procedure" which relies on a prescribed pattern of incisions to anatomically create a convoluted path, or maze, for electrical propagation within the left and right atria. The incisions direct the electrical impulse from the SA node along a specified route through all regions of both atria, causing uniform contraction required for normal atrial transport function. The incisions finally direct the impulse to the AV node to activate the ventricles, restoring normal atrioventricular synchrony. The incisions are also carefully placed to interrupt the conduction routes of the most common reentry circuits. The maze procedure has been found very effective in curing atrial fibrillation. However, the maze procedure is technically difficult to do. It also requires open heart surgery and is very expensive.

15 Maze-like procedures have also been developed utilizing catheters which can form lesions on the endocardium (the lesions being 1 to 15 cm in length and of varying shape) to effectively create a maze for electrical conduction in a predetermined path. The formation of these lesions by soft tissue coagulation (also referred to as "ablation") can provide the same therapeutic benefits that the complex incision patterns that the surgical maze procedure presently provides, but without invasive, open heart surgery.

20 Catheters used to create lesions typically include a relatively long and relatively flexible body portion that has a soft tissue coagulation electrode on its distal end and/or a series of spaced tissue coagulation electrodes near the distal end. The portion of the catheter body portion that is inserted into the patient is typically from 23 to 55 inches (58.4 to 139.7 cm) in length and there may be another 8 to 15 inches (20.3 to 38.1 cm), including a handle, outside the patient. The length and flexibility of the catheter body allow the catheter to be inserted into a main vein or artery (typically the femoral artery), directed into the interior of the heart, and then manipulated such that the coagulation

electrode contacts the tissue that is to be ablated. Fluoroscopic imaging is used to provide the physician with a visual indication of the location of the catheter.

5 In some instances, the proximal end of the catheter body is connected to a handle that includes steering controls. Exemplary catheters of this type are disclosed in U.S. Patent No. 5,582,609. In other instances, the catheter body is inserted into the patient through a sheath and the distal portion of the catheter is bent into loop that extends outwardly from the sheath. This may be accomplished by pivotably securing the distal end of the catheter to the distal  
10 end of the sheath, as is illustrated in U.S. Patent No. 6,071,729. The loop is formed as the catheter is pushed in the distal direction. The loop may also be formed by securing a pull wire to the distal end of the catheter that extends back through the sheath, as is illustrated in U.S. Patent No. 6,048,329. Loop catheters are advantageous in that they tend to conform to different tissue  
15 contours and geometries and provide intimate contact between the spaced tissue coagulation electrodes (or other diagnostic or therapeutic elements) and the tissue.

One lesion that has proven to be difficult to form with conventional devices is the circumferential lesion that is used to isolate the pulmonary vein  
20 and cure ectopic atrial fibrillation. Lesions that isolate the pulmonary vein may be formed within the pulmonary vein itself or in the tissue surrounding the pulmonary vein. Conventional steerable catheters and loop catheters have proven to be less than effective with respect to the formation of such circumferential lesions. Specifically, it is difficult to form an effective  
25 circumferential lesion by forming a pattern of relatively small diameter lesions. More recently, inflatable balloon-like devices that can be expanded within or adjacent to the pulmonary vein have been introduced. Although the balloon-like devices are generally useful for creating circumferential lesions, the inventors herein have determined that these devices have the undesirable  
30 effect of occluding blood flow through the pulmonary vein.

Accordingly, the inventors herein have determined that a need exists generally for structures that can be used to create circumferential lesions

within or around bodily orifices without occluding fluid flow and, in the context of the treatment of atrial fibrillation, within or around the pulmonary vein without occluding blood flow.

#### SUMMARY OF THE INVENTION

Accordingly, the general object of some embodiments of the present inventions is to provide a device that avoids, for practical purposes, the aforementioned problems. In particular, one object of some embodiments of the present inventions is to  
5 provide a device that can be used to create circumferential lesions in or around the pulmonary vein and other bodily orifices in a more efficient manner than conventional apparatus. Another object of some embodiments of the present inventions is to provide a device that can be used to create circumferential lesions in or around the pulmonary vein and other bodily orifices without occluding blood or other bodily fluid flow.

In order to accomplish some of these and other objectives, a probe in  
15 accordance with one embodiment of a present invention includes an elongate body and a helical structure associated with the distal region of the elongate body. In one preferred implementation, a plurality of spaced electrodes are carried by the helical structure. Such a probe provides a number of advantages over conventional apparatus. For example, the helical structure can be readily  
20 positioned with the body such that a ring of electrodes is brought into contact with the tissue in or around the pulmonary or other bodily orifice. The helical structure also defines an opening that allows blood or other bodily fluids to pass therethrough. As a result, the present probe facilitates the formation of a circumferential lesion without the difficulties and occlusion of blood or other  
25 fluids that is associated with conventional apparatus.

In order to accomplish some of these and other objectives, a probe in accordance with one embodiment of a present invention includes an elongate body, a loop structure associated with the distal region of the elongate body, and an anchor member associated with the distal region of the elongate body  
30 and located distally of the loop structure. In one preferred implementation, a plurality of spaced electrodes are carried by the loop structure. Such a probe provides a number of advantages over conventional apparatus. For example,



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the anchor member may be positioned within a bodily orifice, such as the pulmonary vein, thereby centering the loop structure relative to the orifice. This allows a circumferential lesion to be created in or around the pulmonary vein or other orifice without the aforementioned difficulties associated with conventional apparatus.

In order to accomplish some of these and other objectives, a probe in accordance with one embodiment of a present invention includes an elongate body defining a curved portion having a pre-set curvature and a control element defining a distal portion associated with the distal region of the elongate body and extending outwardly therefrom and proximally to the proximal end of the elongate body. In one preferred implementation, a plurality of spaced electrodes are carried by the distal region of the elongate body. Such a probe provides a number of advantages over conventional apparatus. For example, the control element may be used to pull the distal region of the elongate body into a loop in conventional fashion. Unlike conventional apparatus, however, the pre-set curvature of the curved portion may be such that it orients the loop in such a manner that it can be easily positioned in or around the pulmonary vein or other bodily orifice so that a circumferential lesion can be easily formed.

The above described and many other features and attendant advantages of the present inventions will become apparent as the inventions become better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings.

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An aspect of a present invention relates to a probe, comprising: an elongate body defining a distal region, a proximal region and a longitudinal axis; a helical structure, defining a distal end and a proximal end, associated with the distal region of the elongate body, having an external tubular member, an internal member, a substantially straightened state and an expanded state, the internal member being located within the external tubular member and configured to drive the helical structure from the substantially straightened state to the expanded state; at least one operative element supported on the external tubular member; and an anchor member associated with the distal end of the helical structure and extending distally therefrom.

## 10 BRIEF DESCRIPTION OF THE DRAWINGS

Detailed description of preferred embodiments of the inventions will be made with referent to the accompanying drawings.

Figure 1 is a side view of a probe in a relaxed state in accordance with a preferred embodiment of a present invention.

15 Figure 2 is a section view taken along line 2-2 in Figure 1.

Figure 3 is a side view of the probe illustrated in Figure 1 with the stylet extended.



Figure 4 is a side view of the probe illustrated in Figure 1 with the stylet retracted.

Figure 5a is an end view of the probe illustrated in Figure 4.

Figure 5b is a section view taken along line 5b-5b in Figure 5a.

5 Figure 6 is a side view of the probe illustrated in Figure 1 in an expanded state.

Figure 7 is an end view of the probe illustrated in Figure 6.

Figure 8 is a perspective, cutaway view of a probe handle in accordance with a preferred embodiment of a present invention.

10 Figure 9 is a perspective view of a portion of the probe handle illustrated in Figure 8.

Figure 10 is an exploded view of the portion of the probe handle illustrated in Figure 9.

Figure 11 is a partial section view taken along line 11-11 in Figure 9.

15 Figure 12 is a partial section view of the knob and spool arrangement in the probe handle illustrated in Figure 8.

Figure 13 is a perspective view of a probe handle in accordance with a preferred embodiment of a present invention.

20 Figure 14 is an exploded view of the probe handle illustrated in Figure 13.

Figure 15 is a partial section view taken along line 15-15 in Figure 13.

Figure 16 is a side view of a probe in accordance with a preferred embodiment of a present invention.

25 Figure 16a is a side view of a probe in accordance with a preferred embodiment of a present invention.

Figure 16b is a section view taken along line 16b-16b in Figure 16a.

Figure 16c is a perspective view of the probe illustrated in Figure 16a in a helical orientation.

30 Figure 17 is a plan view of a probe in accordance with a preferred embodiment of a present invention.

Figure 18 is a section view of the distal portion of the probe illustrated in Figure 17.

Figure 19 is a side, partial section view showing the probe illustrated in Figure 17 within a sheath.

Figure 20 is a perspective view of the probe illustrated in Figure 17 with the loop reoriented.

5 Figure 21 is a side view of the probe illustrated in Figure 20.

Figure 22 is a perspective view of a probe in accordance with a preferred embodiment of a present invention.

Figure 23 is a side view of the probe illustrated in Figure 22.

Figure 24 is an end view of the probe illustrated in Figure 22.

10 Figure 25 is a side view of the probe illustrated in Figure 22 being used in combination with a sheath and a guidewire.

Figure 26 is an end view of a probe similar to that illustrated in Figures 22-24 with a generally elliptical loop.

15 Figure 27 is a side, partial section view showing a probe in accordance with a preferred embodiment of a present invention.

Figure 28 is a perspective view of the probe illustrated in Figure 27 with the loop reoriented.

#### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

20 The following is a detailed description of the best presently known modes of carrying out the inventions. This description is not to be taken in a limiting sense, but is made merely for the purpose of illustrating the general principles of the inventions.

25 The detailed description of the preferred embodiments is organized as follows:

- I. Introduction
- II. Helical Loop Structures
- III. Other Loop Structures
- IV. Electrodes, Temperature Sensing and Power Control

30 The section titles and overall organization of the present detailed description are for the purpose of convenience only and are not intended to limit the present inventions.

## I. Introduction

The present inventions may be used within body lumens, chambers or cavities for diagnostic or therapeutic purposes in those instances where access to interior bodily regions is obtained through, for example, the vascular system or alimentary canal and without complex invasive surgical procedures. For example, the inventions herein have application in the diagnosis and treatment of arrhythmia conditions within the heart. The inventions herein also have application in the diagnosis or treatment of ailments of the gastrointestinal tract, prostate, brain, gall bladder, uterus, and other regions of the body.

With regard to the treatment of conditions within the heart, the present inventions are designed to produce intimate tissue contact with target substrates associated with various arrhythmias, namely atrial fibrillation, atrial flutter, and ventricular tachycardia. For example, the distal portion of a catheter in accordance with a present invention, which may include diagnostic and/or soft tissue coagulation electrodes, can be used to create lesions within or around the pulmonary vein to treat ectopic atrial fibrillation.

The structures are also adaptable for use with probes other than catheter-based probes. For example, the structures disclosed herein may be used in conjunction with hand held surgical devices (or "surgical probes"). The distal end of a surgical probe may be placed directly in contact with the targeted tissue area by a physician during a surgical procedure, such as open heart surgery. Here, access may be obtained by way of a thoracotomy, median sternotomy, or thoracostomy. Exemplary surgical probes are disclosed in U.S. Patent No. 6,071,281.

Surgical probe devices in accordance with the present inventions preferably include a handle, a relatively short shaft, and one of the distal assemblies described hereafter in the catheter context. Preferably, the length of the shaft is about 4 inches to about 18 inches (10.2 to 45.7 cm). This is relatively short in comparison to the portion of a catheter body that is inserted into the patient (typically from 23 to 55 inches (58.4 to 139.7 cm) in length) and the additional body portion that remains outside the patient. The shaft is



also relatively stiff. In other words, the shaft is either rigid, malleable, or somewhat flexible. A rigid shaft cannot be bent. A malleable shaft is a shaft that can be readily bent by the physician to a desired shape, without springing back when released, so that it will remain in that shape during the surgical procedure.

5 Thus, the stiffness of a malleable shaft must be low enough to allow the shaft to be bent, but high enough to resist bending when the forces associated with a surgical procedure are applied to the shaft. A somewhat flexible shaft will bend and spring back when released. However, the force required to bend the shaft must be substantial.

## 10 II. Helical Loop Structures

As illustrated for example in Figures 1-7, a catheter 10 in accordance with a preferred embodiment of a present invention includes a hollow, flexible catheter body 12 that is preferably formed from two tubular parts, or members. The proximal member 14 is relatively long and is attached to a handle (discussed below with reference to Figures 8-15), while the distal member 16, which is relatively short, carries a plurality of spaced electrodes 18 or other operative elements. The proximal member 14 is typically formed from a biocompatible thermoplastic material, such as a Pebax® material (polyether block emide) and stainless steel braid composite, which has good torque transmission properties. In some implementations, an elongate guide coil (not shown) may also be provided within the proximal member 14. The distal member 16 is typically formed from a softer, more flexible biocompatible thermoplastic material such as unbraided Pebax® material, polyethylene, or polyurethane. The proximal and distal members, which are about 5 French to about 9 French in diameter, are preferably either bonded together with an overlapping thermal bond or adhesively bonded together end to end over a sleeve in what is referred to as a "butt bond."

At least a portion of the distal member 16 has a generally helical shape. The number of revolutions, length, diameter and shape of the helical portion will vary from application to application. The helical portion of the distal member 16 in the embodiment illustrated in Figures 1-7, which may be used to create lesions in or around the pulmonary vein, revolves around the

longitudinal axis of the catheter 10 one and one-half times in its relaxed state. The diameter of the helical portion can be substantially constant over its length. The diameter may, alternatively, vary over the length of the helical portion. For example, the helical portion could have a generally frusto-conical shape where the diameter decreases in the distal direction.

The helical shape of the exemplary distal member 16 may be achieved through the use of a center support 20 (Figure 2) that is positioned inside of and passes within the length of the distal member. The center support 20 is preferably a rectangular wire formed from resilient inert wire, such as Nickel Titanium (commercially available under the trade name Nitinol®) or 17-7 stainless steel wire, with a portion thereof heat set into the desired helical configuration. The thickness of the rectangular center support 20 is preferably between about 0.010 inch and about 0.015 inch (about 0.03 and about 0.04 cm). Resilient injection molded plastic can also be used. Although other cross sectional configurations can be used, such as a round wire, a rectangular cross section arranged such that the longer edge extends in the longitudinal direction is preferred for at least the helical portion. Such an orientation reduces the amount of torsional force, as compared to a round wire, required to unwind the helical portion into an expanded configuration and collapse the helical portion into a circular structure in the manner described below. The preferred orientation of the center support 20 also increases the stiffness of the helical portion in the longitudinal direction, which allows the physician to firmly press the present structure against tissue. The center support 20 is also preferably housed in an insulative tube 21 formed from material such as Teflon™ or polyester.

In the illustrated embodiment, the proximal end of the helical center support 20 is secured to a C-shaped crimp sleeve (not shown) that is located where the proximal and distal members 14 and 16 are bonded to one another and is mounted on a guide coil (not shown) which extends through the proximal member 14 to the distal end thereof. The distal end of the guide coil is located in the area where the proximal and distal members 14 and 16 are bonded to one another. This bond also anchors the proximal end of the center

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support 20 to the distal end of the proximal member 14. The distal end of the center support 20 is secured to a tip member 22 which is in turn secured to the distal end of the distal member 16 with adhesive. Additional details concerning the placement of a center support within the distal member of a catheter can be found in commonly assigned U.S. Patent No. 6,287,301, entitled "Catheter Having Improved Torque Transmission Capability and Method of Making the Same".

The exemplary catheter 10 also includes a stylet 24 that enables the physician to manipulate the helical portion of the distal member 16 and adjust its shape from the at rest shape illustrated in Figure 1. For example, the stylet 24 can be moved distally to deform the helical portion of the distal member 16 in the manner illustrated in Figure 3 or proximally to deform the helical portion in the manner illustrated in Figures 4-5b. The physician can also rotate the stylet 24 in one direction, which will cause the helical portion of the distal member 16 to unwind and so that its diameter increases, as illustrated in Figures 6 and 7, or rotate the stylet in the other direction to cause the distal member to wind up and its diameter to decrease.

In any of these states, the helical portion will define an open area interior to the electrodes 18 through which blood or other bodily fluids can flow. As a result, the helical portion can be used to create a circumferential lesion in or around the pulmonary vein, or other bodily orifice, without occluding fluid flow.

The stylet 24, which is preferably formed from inert wire such as Nitinol® or 17-7 stainless steel wire and should be stiffer than the center support 20, extends through the catheter body 12 from the proximal end of the proximal member 14 to the distal end of the distal member 16. There, it may be secured to either distal end of the center support 20 or to the tip member 22. The stylet 24 is located within the catheter body 12 except in the area of the helical portion of the distal member 16. Here, apertures 26 and 28 are provided for ingress and egress. In order to insure that the stylet 24 moves smoothly through the catheter body 12, the stylet is located within a lubricated guide coil 30 (Figure 2) in the preferred embodiment.



The exemplary catheter 10 illustrated in Figures 1-7 is not a steerable catheter and, accordingly, may be advanced through a conventional steerable guide sheath 32 to the target location. The sheath 32 should be lubricious to reduce friction during movement of the catheter 10. With respect to materials, the proximal portion of the sheath 14 is preferably a Pebax® and stainless steel braid composite and the distal portion is a more flexible material, such as unbraided Pebax®, for steering purposes. The sheath should also be stiffer than the catheter 12. Prior to advancing the catheter 10 into the sheath 32, the stylet 24 will be moved to and held in its distal most position (i.e. beyond the position illustrated in Figure 3) in order to straighten out the helical portion of the distal member 16. The stylet 24 will remain in this position until the helical portion of the distal member 16 is advanced beyond the distal end of the sheath 32. A sheath introducer, such as those used in combination with basket catheters, may be used when introducing the distal member 16 into the sheath 32.

As illustrated for example in Figures 1, 3, 4 and 6, the exemplary catheter 10 may also include an anchor member 34 which allows the catheter to be precisely located relative to the pulmonary vein (or other orifice). More specifically, advancing the anchor member 34 into the pulmonary vein aligns the helical portion of the distal member 16 with the pulmonary vein. The physician can then manipulate the stylet 24 to bring the helical portion of the distal member 16 into the desired configuration and press the distal member (and electrodes 18) firmly against the region of tissue surrounding the pulmonary vein to create a circumferential lesion around the pulmonary vein. Alternatively, the physician can advance the helical portion of the distal member 16 into the pulmonary vein and thereafter manipulate the stylet 24 so that the helical portion expands and brings the electrodes 18 into contact with the interior of the pulmonary vein so that a circumferential lesion can be created within the vein. In the illustrated embodiment, the anchor member 34 is simply the portion of the distal member 16 that is distal to the helical portion. Alternatively, a separate structure may be secured to the distal end of the distal member 16. The exemplary anchor member 34 is approximately 1

to 2 inches (2.5 to 5.1 cm) in length, although other lengths may be used to suit particular applications.

The exemplary catheter 10 illustrated in Figures 1-7 should be used in conjunction with a handle that allows the physician to move the stylet 24 proximally and distally relative to the catheter body 12 and also allows the physician to rotate the stylet relative to the catheter body. One example of such a handle, which is generally represented by reference numeral 38, is illustrated in Figures 8-12. The handle 38 includes distal member 40, a rotatable knob 42 that is connected to the stylet 24 and a rotatable end cap 44 that is connected to the catheter body 12 through the use of a tip member 45. Specifically, the catheter body 12 is bonded to the tip member 45 which is in turn bonded to the rotatable end cap 44. The handle also includes a transition piece 46 that is used to secure the distal member 40 to a proximal member 48 (Figure 11). The proximal end of the proximal member 48 includes a port (not shown) that receives an electrical connector from a power supply and control device. Alternatively, the distal and proximal members 40 and 48 may be combined into a unitary structure having a shape that is either the same as or is different than the illustrated shape of the combined distal and proximal members.

Turning first to the proximal and distal actuation of the stylet 24, the proximal portion of the stylet and lubricated guide coil 30 extend through the catheter body 12 and into the handle 38, as illustrated in Figure 11. The lubricated guide coil 30 is secured to a seat 50 within the distal member 40. A stylet guide 52 that includes a guide slot 54 is secured within the distal member 40. The stylet guide 52 is preferably formed from a lubricious material such as acetal, which is sold under the trade name Delrin®. The stylet 24 passed through the guide slot 54 and is anchored to a threaded spool 56 that is secured to, and is preferably integral with, the rotatable knob 42. The rotatable knob and spool are secured to the proximal member 40 with a cap screw and nut arrangement or the like that extends through aperture 57 (Figure 12). The threads on the spool 56 act as guides to control the manner in which the stylet 24 winds onto and unwinds from the spool. Anchoring is

accomplished in the illustrated embodiment by inserting the stylet 24 into an anchoring aperture 58 and securing the stylet within the aperture with a set screw (not shown) that is inserted into a set screw aperture 60.

5 Proximal rotation of the knob 42 and threaded spool 56, i.e. rotation in the direction of arrow P in Figure 9, will cause the stylet 24 to move proximally and wind onto the threaded spool. As this occurs, the stylet 24 will travel within the guide slot 54 towards the knob 42 in the direction of the arrow in Figure 11. Distal rotation of the knob 42 on the other hand, i.e. rotation in the direction of arrow D in Figure 9, will cause the stylet 24 to move distally,  
10 unwind from the threaded spool 56 and travel away from the knob within the guide slot 54.

In the preferred embodiment illustrated in Figures 8-12, the stylet 24 can be rotated relative to the catheter body 12 because the stylet is anchored with the handle distal member 40, while the catheter body is secured to the  
15 end cap 44 that is free to rotate relative to the distal member. Referring more specifically to Figures 10 and 11, the rotatable end cap 44 is mounted on an end cap support member 66. A set screw (not shown) engages a longitudinally extending slot 68 formed in the support member 66 and holds it in place within the distal member 40. The distal portion of the support member  
20 66 includes a circumferentially extending slot 70. A series of set screws 72, which have a diameter that is substantially equal to the width of the slot 70, pass through the end cap 44 into the slot. This arrangement allows the end cap 44 to rotate relative to the support member 66 and, therefore, rotate relative to the handle distal member 40. The proximal end of the end cap  
25 support member 66 includes a relief surface 74 that prevents unnecessary stress on the stylet 24 as it travels back and forth within the guide slot 54.

To rotate the stylet 24 relative to the catheter body 12, the physician may hold the end cap 44 in place and rotate the handle distal member 40 relative to the end cap. When such rotation occurs, the stylet 24 will rotate  
30 within the catheter body 12. The catheter body 12, on the other hand, will be held in place by virtue of its connection to the end cap 40. As a result, the stylet 24 can be used to apply torsional forces to the helical portion of the



proximal member 16 to move the helical portion between the various states illustrated in Figures 1, 4, and 6.

Another handle that may be used in conjunction with the exemplary catheter 10 is illustrated for example in Figures 13-15. Exemplary handle 76 includes a main body 78 and a stylet control device 80 that can be used to move the stylet 24 proximally and distally and that can also be used to rotate the stylet relative to the catheter body 12. The stylet control device 80 consists essentially of a housing 82, a rotatable threaded spool 84 and knob 86 arrangement, and a housing support member 88 that supports the housing such that the housing may be rotated relative to the main body 78.

The exemplary housing 82 is composed of two housing members 90 and 92 which fit together in the manner illustrated in Figure 14. A stylet guide 94, which includes a guide slot 96, is located within the housing 82. The stylet guide 94 is secured in place and prevented from rotating relative to the housing 82 with a set screw (not shown) that rests within a positioning slot 98 after being inserted through an aperture 100 in the housing. The stylet 24 passes through the guide slot 96 and, in a manner similar to that described above with reference to Figures 8-12, is anchored in an anchoring aperture 102. The stylet 24 is secured within the anchoring aperture 102 with a set screw (not shown) that is inserted into a set screw aperture 104. Here too, proximal rotation of the knob 86 (arrow P in Figure 13) will cause the stylet 24 to wind onto the threaded spool 84, thereby pulling the stylet proximally, while distal rotation (arrow D in Figure 13) will cause the stylet to unwind from the spool and move distally.

In the preferred embodiment illustrated in Figures 13-15, the housing 82 includes a post 106 that may be inserted into the housing support member 88, which is itself fixedly secured to the handle main body 78. A circumferentially extending slot 108 is formed in one end of the post 106. In a manner similar to the end cap 44 illustrated in Figures 8-12, the post 106 may be secured to the housing support member 88 by inserting a series of set screws 110 through a corresponding series of support member apertures and into the slot 108. As described in greater detail below with reference to Figure

15, the catheter body 12 is fixedly secured to the handle main body 78. Thus, rotation of the housing 82 relative to the housing support member 88 and, therefore, the main body 78 will cause the stylet 24 to rotate relative to the catheter body 12. Upon such rotation, the stylet 24 will apply torsional forces  
5 to the helical portion of the proximal member 16, thereby causing it to move between the states illustrated in Figures 1, 4, and 6.

As illustrated for example in Figure 14, the exemplary handle main body 78 is a multi-part assembly consisting of handle members 112 and 114, a base member 116 and a strain relief element 118. Handle member 114  
10 includes a series of fasteners 120a-c which mate with corresponding fasteners (not shown) on the handle member 112. Handle member 114 also includes a wire guide 122 which is used to centralize the electrical wires. A cutout 124 is formed at the proximal end of the handle member 114 and a similar cutout (not shown) is formed in the handle member 112. The cutouts  
15 together form an opening for an electrical connector from a power supply and control device. The base member 116 includes an aperture 126 for seating the housing support member 88 and a cylindrical post 128 on which the strain relief element 118 is fixedly mounted.

The catheter body 12 may be inserted into and bonded to the base  
20 member 116 in the manner illustrated for example in Figure 15. Thus, the catheter body 12 is fixed relative to the handle 76. The guide coil 30 is secured within a guide coil seat 130 and the stylet 24 extends through the guide coil seat and into the housing support member 88 in the manner shown.

Like the catheter illustrated in Figures 1-7, the helical catheter 132  
25 illustrated in Figure 16 includes a catheter body 12 having a proximal member 14 and a distal member 16 with a helical portion, a plurality of electrodes 18, and an anchor member 34. The catheter illustrated in Figure 16 does not, however, include a stylet 24. In order to compensate for the decrease in manipulability associated with the lack of a stylet, the center support may be  
30 formed from material such as actuator-type Nitinol® (discussed in detail below) which has shape memory properties that are activated at a temperature higher than body temperature. The shape memory properties

allow the physician to, for example, cause the helical portion of the distal member 16 to expand from the state illustrated in Figures 4-5b (albeit with respect to catheter 10) to the state illustrated in Figures 6 and 7 by energizing the electrodes 18.

5           The helical portion of the distal member 16 in the catheter 132 should be flexible enough that the helical portion will deflect and straighten out when pushed or pulled into the sheath, yet resilient enough that it will return to its helical shape when removed from the sheath. In addition, the proximal and  
10           distal end of the helical portion should be oriented at an angle relative to the longitudinal axis of the catheter 36 (preferably about 45 degrees) that facilitates a smooth transition as the distal member 16 is pushed or pulled into the sheath 32. Also, because the catheter 132 lacks the stylet 24, it may be used in conjunction with any conventional catheter handle.

          A guidewire may be used in conjunction with the catheters illustrated in  
15           Figures 1-16 to position the sheath 32 in the manner described below with reference to Figure 25.

          Another exemplary catheter that relies on materials which have shape memory properties activated at high temperatures is illustrated in Figures 16a-16c. Exemplary catheter 133, which is a non-steerable catheter that may be  
20           inserted into a patient over a guidewire 135, includes a catheter body 12' having a proximal member 14' and a distal member 16', a plurality of electrodes 18, and an anchor member 34. The catheter 133 also includes a shape memory core wire 137 that is friction fit within the distal member 16' and heat set into a helical configuration. The core wire 137 is relatively flexible  
25           at body temperature. As such, a stylet 24 may be used to maintain the core wire 137 and electrode supporting distal member 16' in the linear state illustrated in Figure 16a.

          The core wire 137 and distal member 16' may be driven to the helical state illustrated in Figure 16c by heating the core wire 137. Resistive heating  
30           is the preferred method of heating the core wire 137. To that end, electrical leads 139 (only one shown) are connected to the ends of the core wire 137 and supply current to the core wire. The stylet 24 and guidewire 135 should



be pulled in the proximal direction beyond the distal member 16' prior to heating the core wire 137.

A suitable material for the core wire 137 is a shape memory alloy such as actuator-type Nitinol®. Such material has a transition temperature above body temperature (typically between about 55°C and 70°C). When the material is heated to the transition temperature, the internal structure of the material dynamically changes, thereby causing the material to contract and assume its heat set shape. Additional information concerning shape memory alloys is provided in T. W. Duerig et al., "Actuator and Work Production Devices," *Engineering Aspects of Shape Memory Alloys*, pp. 181-194 (1990).

The exemplary catheter body 12' is substantially similar to the catheter body 12 described above. However, as illustrated in Figure 16b, the exemplary catheter body 12' includes five lumens – a central lumen 141 and four outer lumens 143. The guidewire 135 passes through the central lumen 141. The core wire 137 and conductor 139 are located within one of the outer lumens 143 and the stylet 24 is located in another outer lumen. The other two outer lumens 143 respectively house electrode wires 168 and temperature sensor wires 174 (discussed in Section IV below). Of course, other catheter body configurations, such as a three outer lumen configuration in which the electrode and temperature sensor wires are located in the same lumen, may be employed.

The exemplary catheter 133 illustrated in Figures 16a-16c also includes a pair of radiopaque markers 145 and 147 that may be used to properly position the helical portion of the catheter. More specifically, because the core wire 137 contracts equally in the distal and proximal directions, the catheter 133 should be positioned such that the target tissue area is located at about the mid-point between the radiopaque markers 145 and 147 prior to actuating the core wire 137. To form a lesion within the pulmonary vein, for example, the anchor member 34 may be inserted into the pulmonary vein to such an extent that the mid-point between the radiopaque markers 145 and 147 is located at the target site within the vein. Actuation of the core wire 137 will cause the electrode supporting distal member 16' to assume the helical

shape illustrated in Figure 16c and press against the vein so as to achieve a suitable level of tissue contact.

Once the lesion has been formed, the core wire 137 may be deactivated and the stylet 24 may be moved back into the distal member 16' to return the distal member to the linear state illustrated in Figure 16a. A diagnostic catheter (not shown) may then be advanced through the central lumen 141 to map the vein and insure that a curative lesion has been formed.

### III. Other Loop Catheters

A loop catheter 134 in accordance with a preferred embodiment of another present invention is illustrated in Figures 17-21. The loop catheter 134 includes a hollow, flexible catheter body 136 that is preferably formed from two tubular parts, or members. The proximal member 138 is relatively long and is attached to a handle, while the distal member 140, which is relatively short, carries a plurality of spaced electrodes 18 or other operative elements. The proximal member 138 is typically formed from a biocompatible thermoplastic material, such as a Pebax® material (polyether block emide) and stainless steel braid composite, which has good torque transmission properties and, in some implementations, an elongate guide coil (not shown) may also be provided within the proximal member. The distal member 140 is typically formed from a softer, more flexible biocompatible thermoplastic material such as unbraided Pebax® material, polyethylene, or polyurethane. The proximal and distal members are preferably either bonded together with an overlapping thermal bond or adhesive bonded together end to end over a sleeve in what is referred to as a "butt bond."

The distal portion of the proximal member 138 includes a pre-shaped curved portion (or elbow) 142. Although other curvatures may be used, the curved portion 142 in the illustrated embodiment is a ninety degree curve with a radius of about 0.5 inch (1.3 cm). The preset curvature may be accomplished in a variety of manners. Preferably, the curved portion 142 is preset through the use of a thermal forming technique (100°C for 1 hour). The preset curved portion 142 in the illustrated embodiment results in a loop that is in plane with the remainder of the catheter 134. However, as discussed

below with reference to Figures 22-24, curvatures that result in an out-of-plane loop may also be employed.

5 The preset curvature may also be accomplished through the use of a pre-shaped spring member (not shown) formed from Nitinol® or 17-7 stainless steel that is positioned within the proximal member 138 and anchored where the proximal and distal members 138 and 140 are bonded to one another. Such a spring member would preferably be rectangular in cross-section and have a nominal radius of about 0.5 inch (1.3 cm). Another alternative would be to adjust the location of the proximal member/distal member bond and use  
10 the center support 150 (discussed below) to provide the preset curvature.

The exemplary catheter 134 illustrated in Figures 17-21 also includes a pull wire 144. The pull wire 144 is preferably a flexible, inert cable constructed from strands of metal wire material, such as Nitinol® or 17-7 stainless steel, that is about 0.012 inch to about 0.025 inch (0.03 to 0.06 cm) in diameter.  
15 Alternatively, the pull wire 144 may be formed from a flexible, inert stranded or molded plastic material. The pull wire 144 is also preferably round in cross-section, although other cross-sectional configurations can be used.

As illustrated for example in Figure 18, the pull wire 144 in the exemplary embodiment extends into an opening 146 in a tip member 148 and  
20 is secured to a center support 150 with a stainless steel crimp tube 152. More specifically, the pull wire 144 passes through a bore 154 in the distal end 156 of the crimp tube 152 and abuts the center support 150. The in-line connection of the center support 150 and pull wire 144 allows for a reduction in the overall diameter of distal portion of the catheter body 136. The tip  
25 member 148 is preferably formed from platinum and is fixedly engaged with, for example, silver solder, adhesive or spot welding, to the distal end 156 of crimp tube 152. The center support may be electrically insulated with a thin walled polyester heat shrink tube 158 that extends beyond the proximal end of the crimp tube 152. The pull wire 144 extends proximally from the tip member  
30 148 and preferably back into the catheter body 136 through an aperture 158 to the proximal end of the catheter body. Alternatively, the pull wire can simply be run proximally within the interior of the sheath 32 along the exterior of the



catheter body 136. Other pull wire configurations, other methods of attaching the pull wire to the catheter body, and methods of reducing stress on the pull wire are disclosed in aforementioned U.S. Patent No. 6,048,329.

5 The center support 150 is similar to the center support 20 illustrated in Figure 2 in that it is positioned inside the distal member 140 and is preferably a rectangular wire formed from resilient inert wire, such as Nitinol® or 17-7 stainless steel wire. The thickness of the rectangular center support 150 is preferably between about 0.010 inch and about 0.020 inch (0.03 to 0.05). Resilient injection molded plastic can also be used. Although other cross  
10 sectional configurations can be used, such as a round wire, a rectangular cross section arranged such that the longer edge extends in the longitudinal direction is preferred. This orientation reduces the amount of force required to pull the distal member 140 into the loop configuration illustrated in Figure 17. The preferred orientation also increases the stiffness of the loop in the  
15 longitudinal direction, which allows the physician to firmly press the present structure against tissue. The center support 150, which may also be heat set into the preset curvature, is secured within the catheter body 136 in the manner described above with reference to Figures 1-7.

20 As illustrated for example in Figure 19, the curved portion 142 of the proximal member 138 will be straightened out when the catheter 134 is within the sheath 32. After the exemplary catheter 134 has been deployed, the curved portion will return to its curved state and the pull wire may be retracted to form the loop illustrated in Figure 17.

25 The loop in the embodiment illustrated in Figures 17-21 is in plane with the remainder of the catheter body 136. A stylet 160 allows the physician to reorient the loop from the orientation illustrated in Figure 17 to, for example, the orientation illustrated in Figures 20 and 21 which is ninety degrees out of plane. The stylet 160 is soldered to the tip member 148 and extends through the sheath 32 to the proximal end thereof. The tip member 148 is, in turn,  
30 bonded to the distal member 140. The stylet 160 is preferably formed from inert wire such as Nitinol® or 17-7 stainless steel wire and should be stiffer than the center support 150.

The combination of the pre-shaped curved portion 142 and the stylet 160 advantageously allows the physician to precisely position the loop relative to the pulmonary vein or other bodily orifice. As a result, the exemplary catheter 134 can be used to create lesions in or around the pulmonary vein or other bodily orifice in an expedient manner without occluding blood or other bodily fluid flow.

Another exemplary loop catheter, which is generally represented by reference numeral 162, is illustrated in Figures 22-24. The loop catheter illustrated in Figures 22-24 is substantially similar to the loop catheter illustrated in Figures 17-21 and common elements are represented by common reference numerals. Here, however, there is no stylet. Loop catheter 162 also includes a pre-shaped curved portion 164 that positions the loop out of plane with respect to the remainder of the catheter. More specifically, the exemplary pre-curved portion 164 positions the loop ninety degrees out of plane with respect to the remainder of the catheter 162 and orients the loop such that the opening 166 defined thereby faces in the distal direction. Other curvatures may be used as applications require.

A sheath 32 and a guidewire 161 (Figure 25), as well as the curvature of the pre-shaped curved portion 164, allows the physician to precisely position the loop relative to the pulmonary vein or other bodily orifice. As a result, the exemplary catheter 162 may be used to expediently create lesions in or around the pulmonary vein or other bodily orifice without the occlusion of blood or other bodily fluids.

The exemplary loop catheter 162 illustrated in Figures 22-24 has a generally circular loop (note Figure 24). However, other loop configurations, such as the elliptical loop configuration on the catheter 167 illustrated in Figure 26, may be employed as applications require.

Still another exemplary loop catheter, which is generally represented by reference numeral 163, is illustrated in Figures 27 and 28. The loop catheter illustrated in Figures 27 and 28 is substantially similar to the loop catheter illustrated in Figures 17-21 and common elements are represented by common reference numerals. Here, however, the pull wire 144 extends

5 along the exterior of the proximal member 138 and the stylet 160 is secured to a collar 165 that is free to slide along the distal member 140 when the distal member is in the substantially linear state illustrated in Figure 27. The collar 165, which has an inner diameter that is slightly larger than the outer diameter of the distal member 140, is preferably formed from a relative soft material, such a soft plastic or silicone rubber. Mechanical interference will cause the collar 165 to become fixed in place when the distal member 140 is bent. As a result, the physician can move the collar 165 to the desired location on the distal member 140 prior to formation of the loop to vary the location at which pushing and pulling forces will be applied by the stylet 160 and, therefore, vary the ultimate shape and orientation of the loop.

10 The exemplary loop catheter 163 illustrated in Figures 27 and 28 has a generally circular loop. However, other loop configurations, such as the elliptical loop configuration on the catheter 167 illustrated in Figure 26, may be employed as applications require.

15 The catheters illustrated in Figures 17-28 may be used in conjunction with conventional catheter handles that provide for the manipulation of one or more control elements, such as a pull wire and a stylet. Suitable handles are disclosed in U.S. Patent Nos. 5,871,523 and 5,928,191.

#### 20 **IV. Electrodes, Temperature Sensing and Power Control**

In each of the preferred embodiments, the operative elements are a plurality of spaced electrodes 18. However, other operative elements, such as lumens for chemical ablation, laser arrays, ultrasonic transducers, microwave electrodes, and ohmically heated hot wires, and such devices may be substituted for the electrodes. Additionally, although electrodes and temperature sensors are discussed below in the context of the exemplary catheter probe illustrated in Figures 1-7, the discussion is applicable to all of the probes disclosed herein.

25 The spaced electrodes 18 are preferably in the form of wound, spiral coils. The coils are made of electrically conducting material, like copper alloy, platinum, or stainless steel, or compositions such as drawn-filled tubing (e.g. a copper core with a platinum jacket). The electrically conducting material of the

30



coils can be further coated with platinum-iridium or gold to improve its conduction properties and biocompatibility. A preferred coil electrode is disclosed in U.S. Patent No. 5,797,905. The electrodes 18 are electrically coupled to individual wires 168 (see, for example, Figure 2) to conduct coagulating energy to them. The wires are passed in conventional fashion through a lumen extending through the associated catheter body into a PC board in the catheter handle, where they are electrically coupled to a connector that is received in a port on the handle. The connector plugs into a source of RF coagulation energy.

As an alternative, the electrodes may be in the form of solid rings of conductive material, like platinum, or can comprise a conductive material, like platinum-iridium or gold, coated upon the device using conventional coating techniques or an ion beam assisted deposition (IBAD) process. For better adherence, an undercoating of nickel or titanium can be applied. The electrodes can also be in the form of helical ribbons. The electrodes can also be formed with a conductive ink compound that is pad printed onto a non-conductive tubular body. A preferred conductive ink compound is a silver-based flexible adhesive conductive ink (polyurethane binder), however other metal-based adhesive conductive inks such as platinum-based, gold-based, copper-based, etc., may also be used to form electrodes. Such inks are more flexible than epoxy-based inks.

The flexible electrodes 18 are preferably about 4 mm to about 20 mm in length. In the preferred embodiment, the electrodes are 12.5 mm in length with 1 mm to 3 mm spacing, which will result in the creation of continuous lesion patterns in tissue when coagulation energy is applied simultaneously to adjacent electrodes. For rigid electrodes, the length of the each electrode can vary from about 2 mm to about 10 mm. Using multiple rigid electrodes longer than about 10 mm each adversely effects the overall flexibility of the device, while electrodes having lengths of less than about 2 mm do not consistently form the desired continuous lesion patterns.

The portion of the electrodes that are not intended to contact tissue (and be exposed to the blood pool) may be masked through a variety of

techniques with a material that is preferably electrically and thermally insulating. This prevents the transmission of coagulation energy directly into the blood pool and directs the energy directly toward and into the tissue. For example, a layer of UV adhesive (or another adhesive) may be painted on  
5 preselected portions of the electrodes to insulate the portions of the electrodes not intended to contact tissue. Deposition techniques may also be implemented to position a conductive surface only on those portions of the assembly intended to contact tissue. Alternatively, a coating may be formed by dipping the electrodes in PTFE material.

10 The electrodes may be operated in a uni-polar mode, in which the soft tissue coagulation energy emitted by the electrodes is returned through an indifferent patch electrode (not shown) externally attached to the skin of the patient. Alternatively, the electrodes may be operated in a bi-polar mode, in which energy emitted by one or more electrodes is returned through other  
15 electrodes. The amount of power required to coagulate tissue ranges from 5 to 150 w.

As illustrated for example in Figures 5a and 5b, a plurality of temperature sensors 170, such as thermocouples or thermistors, may be located on, under, abutting the longitudinal end edges of, or in between, the  
20 electrodes 18. Preferably, the temperature sensors 170 are located at the longitudinal edges of the electrodes 18 on the distally facing side of the helical (or other loop) structure. In some embodiments, a reference thermocouple 172 may also be provided. For temperature control purposes, signals from the temperature sensors are transmitted to the source of coagulation energy by  
25 way of wires 174 (Figure 2) that are also connected to the aforementioned PC board in the catheter handle. Suitable temperature sensors and controllers which control power to electrodes based on a sensed temperature are disclosed in U.S. Patent Nos. 5,456,682, 5,582,609 and 5,755,715.

As illustrated for example in Figures 5a and 5b, the temperature  
30 sensors 170 are preferably located within a linear channel 171 that is formed in the distal member 16. The linear channel 171 insures that the temperature sensors will directly face the tissue and be arranged in linear fashion. The

illustrated arrangement results in more accurate temperature readings which, in turn, results in better temperature control. As such, the actual tissue temperature will more accurately correspond to the temperature set by the physician on the power control device, thereby providing the physician with better control of the lesion creation process and reducing the likelihood that embolic materials will be formed. Such a channel may be employed in conjunction with any of the electrode (or other operative element) supporting structures disclosed herein.

Finally, the electrodes 18 and temperature sensors 172 can include a porous material coating, which transmits coagulation energy through an electrified ionic medium. For example, as disclosed in U.S. Patent No. 5,991,650, electrodes and temperature sensors may be coated with regenerated cellulose, hydrogel or plastic having electrically conductive components. With respect to regenerated cellulose, the coating acts as a mechanical barrier between the surgical device components, such as electrodes, preventing ingress of blood cells, infectious agents, such as viruses and bacteria, and large biological molecules such as proteins, while providing electrical contact to the human body. The regenerated cellulose coating also acts as a biocompatible barrier between the device components and the human body, whereby the components can now be made from materials that are somewhat toxic (such as silver or copper).

Although the present inventions have been described in terms of the preferred embodiments above, numerous modifications and/or additions to the above-described preferred embodiments would be readily apparent to one skilled in the art. It is intended that the scope of the present inventions extend to all such modifications and/or additions and that the scope of the present inventions is limited solely by the claims set forth below.



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CLAIMS:

1. A probe, comprising:
  - an elongate body defining a distal region, a proximal region and a longitudinal axis;
  - 5 a helical structure, defining a distal end and a proximal end, associated with the distal region of the elongate body, having an external tubular member, an internal member, a substantially straightened state and an expanded state, the internal member being located within the external tubular member and configured to drive the helical structure from the substantially straightened state to the expanded  
10 state;
    - at least one operative element supported on the external tubular member; and
    - an anchor member associated with the distal end of the helical structure and extending distally therefrom.
- 15 2. A probe as claimed in claim 1, wherein the elongate body comprises a catheter body.
3. A probe as claimed in claim 1, wherein the helical structure defines a longitudinal axis coincident with the longitudinal axis of the elongate body.
4. A probe as claimed in claim 1, wherein the helical structure defines a  
20 longitudinal axis and completes at least one revolution about the longitudinal axis.
5. A probe as claimed in claim 1, wherein the helical structure defines a longitudinal axis and completes at least two revolutions about the longitudinal axis.
6. A probe as claimed in claim 1, wherein the helical structure defines a  
25 longitudinal axis and the distal and proximal ends are located along the longitudinal axis.

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7. A probe as claimed in claim 1, wherein the at least one operative element comprises a plurality of electrodes.

8. A probe as claimed in claim 1, further comprising:

5 a control element associated with the helical structure and extending to the proximal region of the elongate body.

9. A probe as claimed in claim 8, wherein the helical structure defines a diameter and the control element is associated with the distal end of the helical structure such that rotational movement of the control member results in a change in the diameter of the helical structure.

10 10. A probe as claimed in claim 8, wherein the helical structure defines a length and a diameter and the control element is associated with the distal end of the helical structure such that distal movement of the control member results in a reduction in diameter and an increase in length of the helical structure.

11. A probe as claimed in claim 1, wherein the distance between the  
15 proximal and distal ends is greater when the helical structure is in the straightened state than distance between the proximal and distal ends when the helical structure is in the expanded state.

12. A probe as claimed in claim 1, wherein the internal member is biased to the expanded state.

20 13. A probe as claimed in claim 1, wherein the anchor member is configured to be inserted into a pulmonary vein and align the helical structure with the pulmonary vein.

14. A probe as claimed in claim 13, wherein the anchor member is approximately 2.5 to 5.1 cm in length.

25 15. A probe as claimed in claim 1, wherein at least a portion of the at least one operative element faces distally.

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16. A probe as claimed in claim 1, wherein the at least one operative element comprises an electrode and at least a portion of the electrode faces distally.

17. A probe as claimed in claim 1, wherein the at least one operative element comprises an electrode and at least a portion of the electrode is distal of the  
5 portion of the helical structure on which the electrode is supported.

18. A probe as claimed in claim 1, wherein the internal member comprises a center support.

19. A probe as claimed in claim 1, wherein the internal member comprises a core wire.



FIG. 1

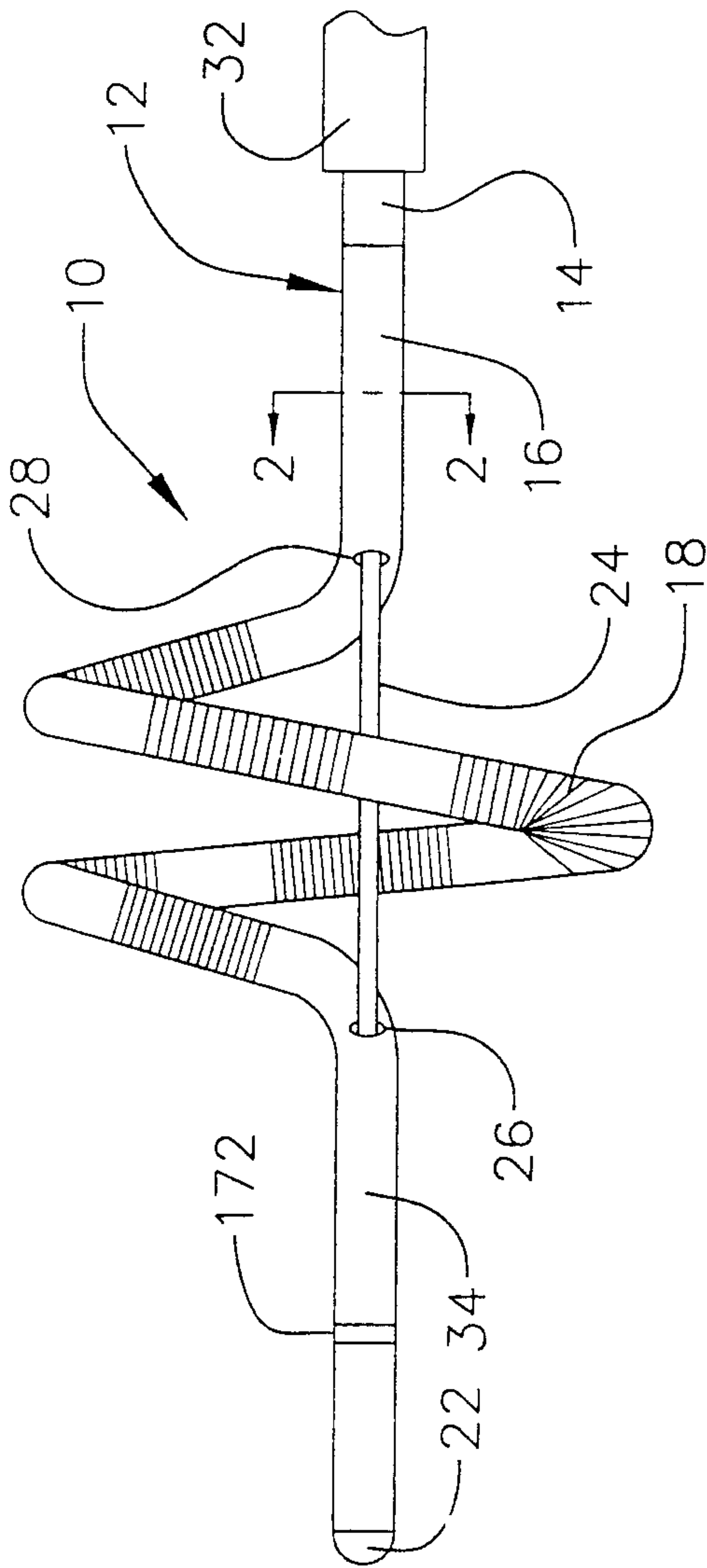


FIG. 2

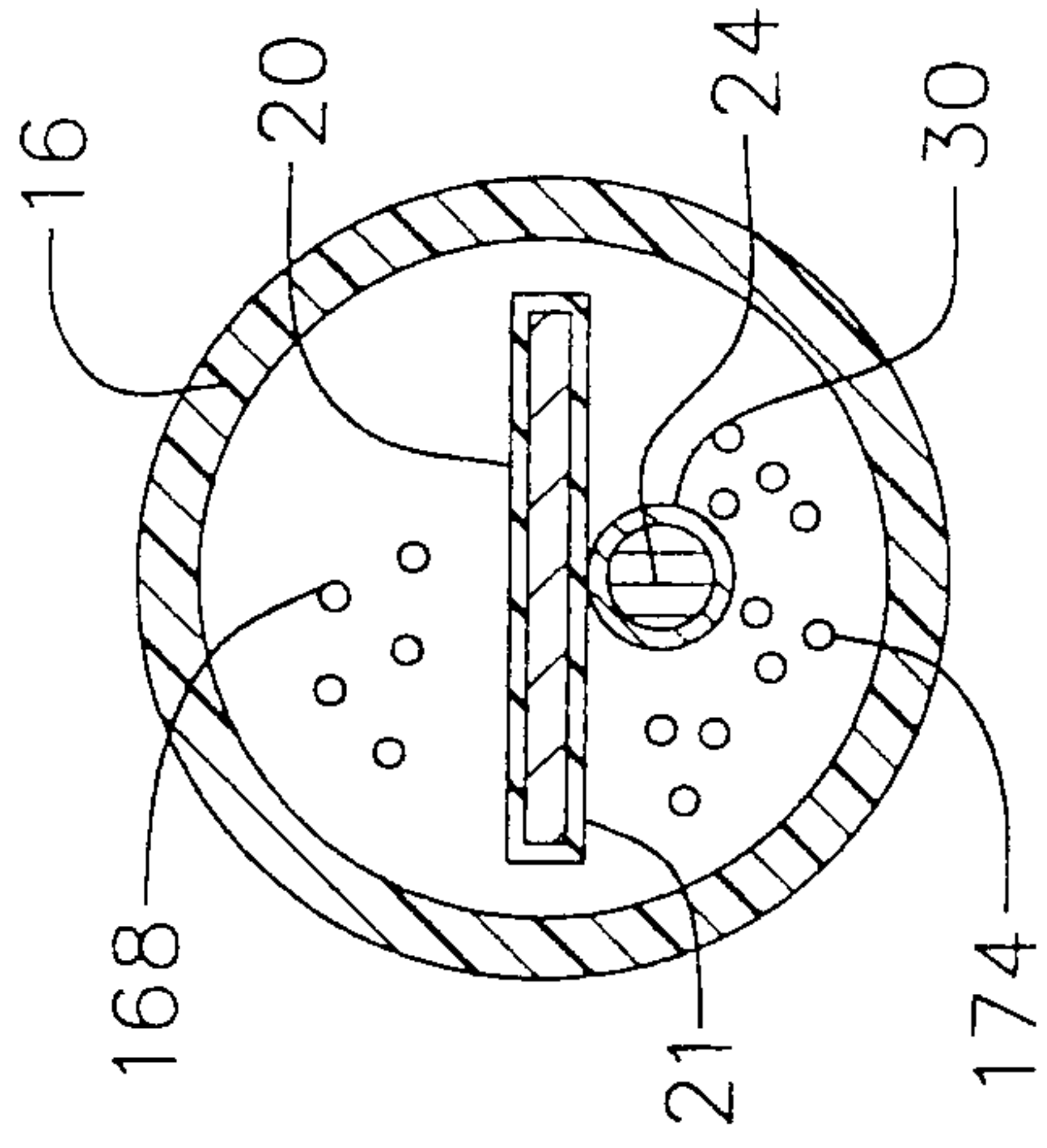
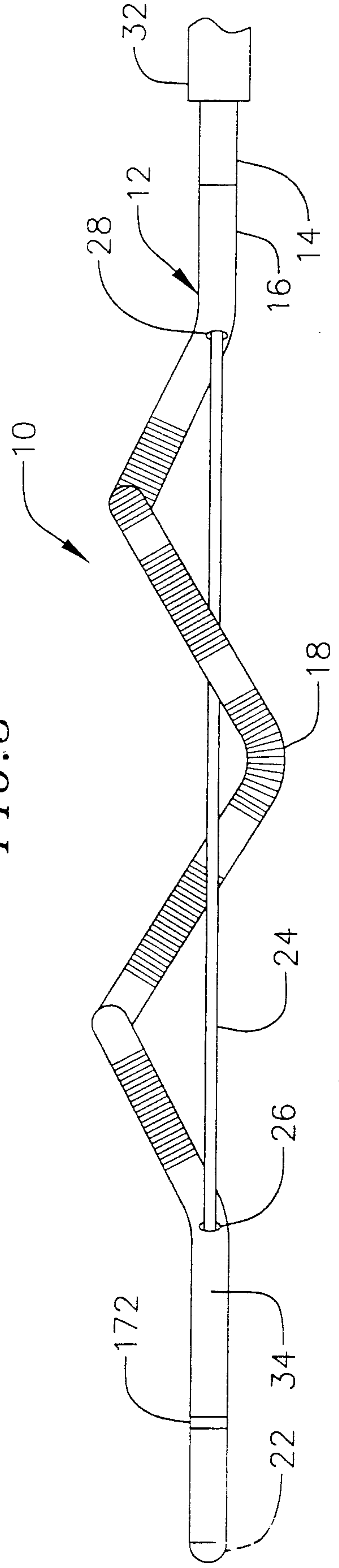
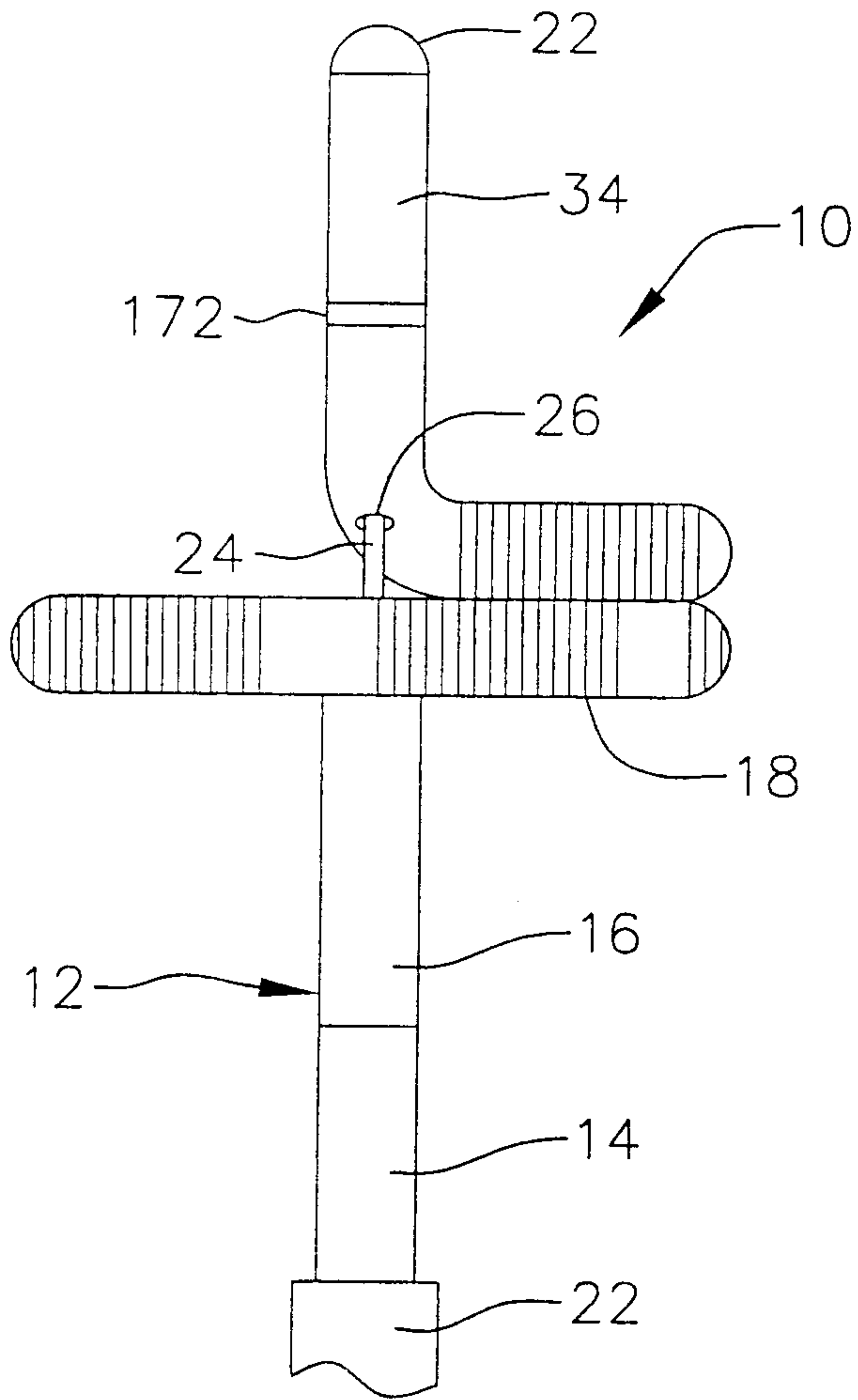


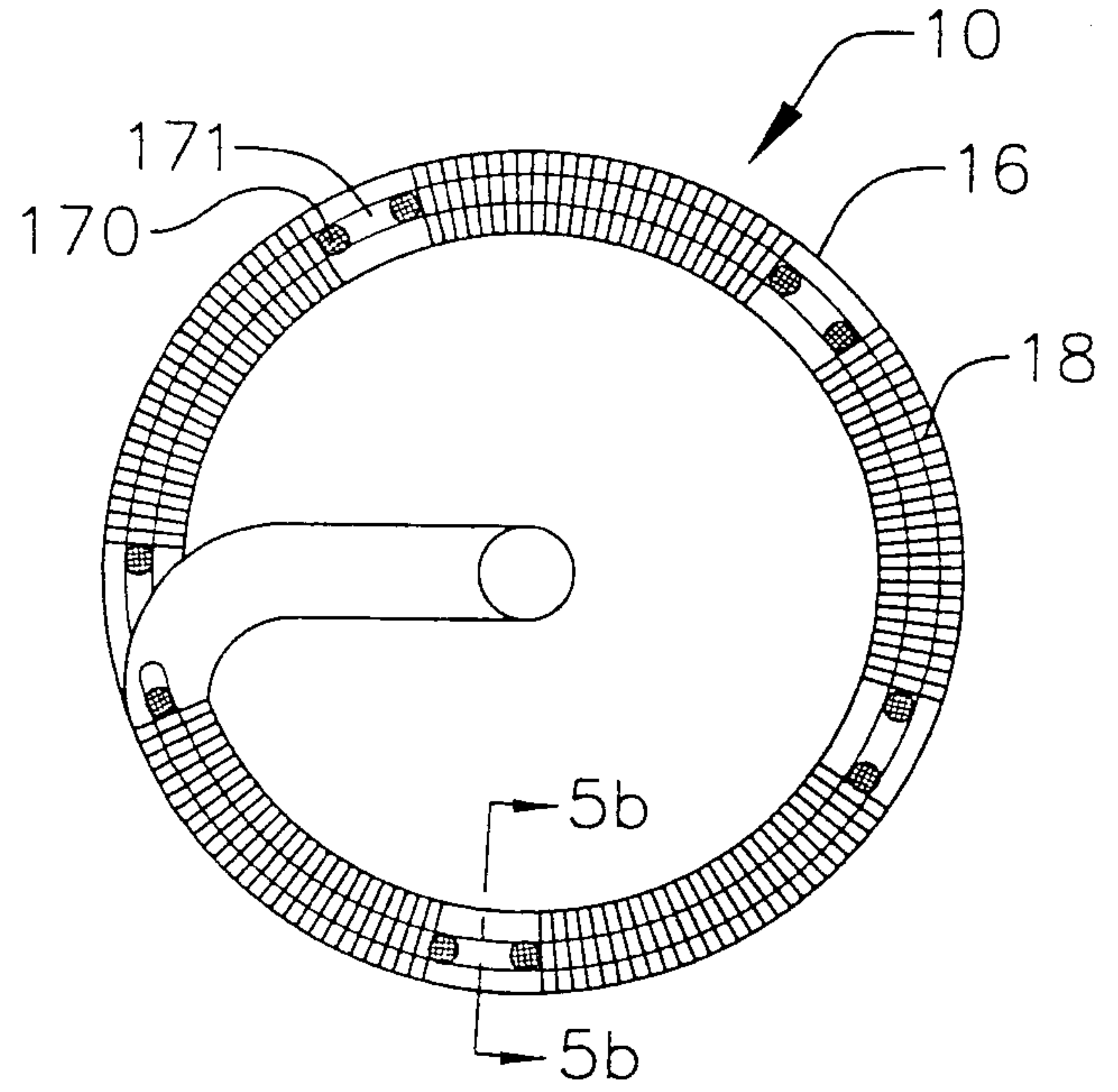
FIG. 3



*FIG. 4*



*FIG. 5a*



*FIG. 5b*

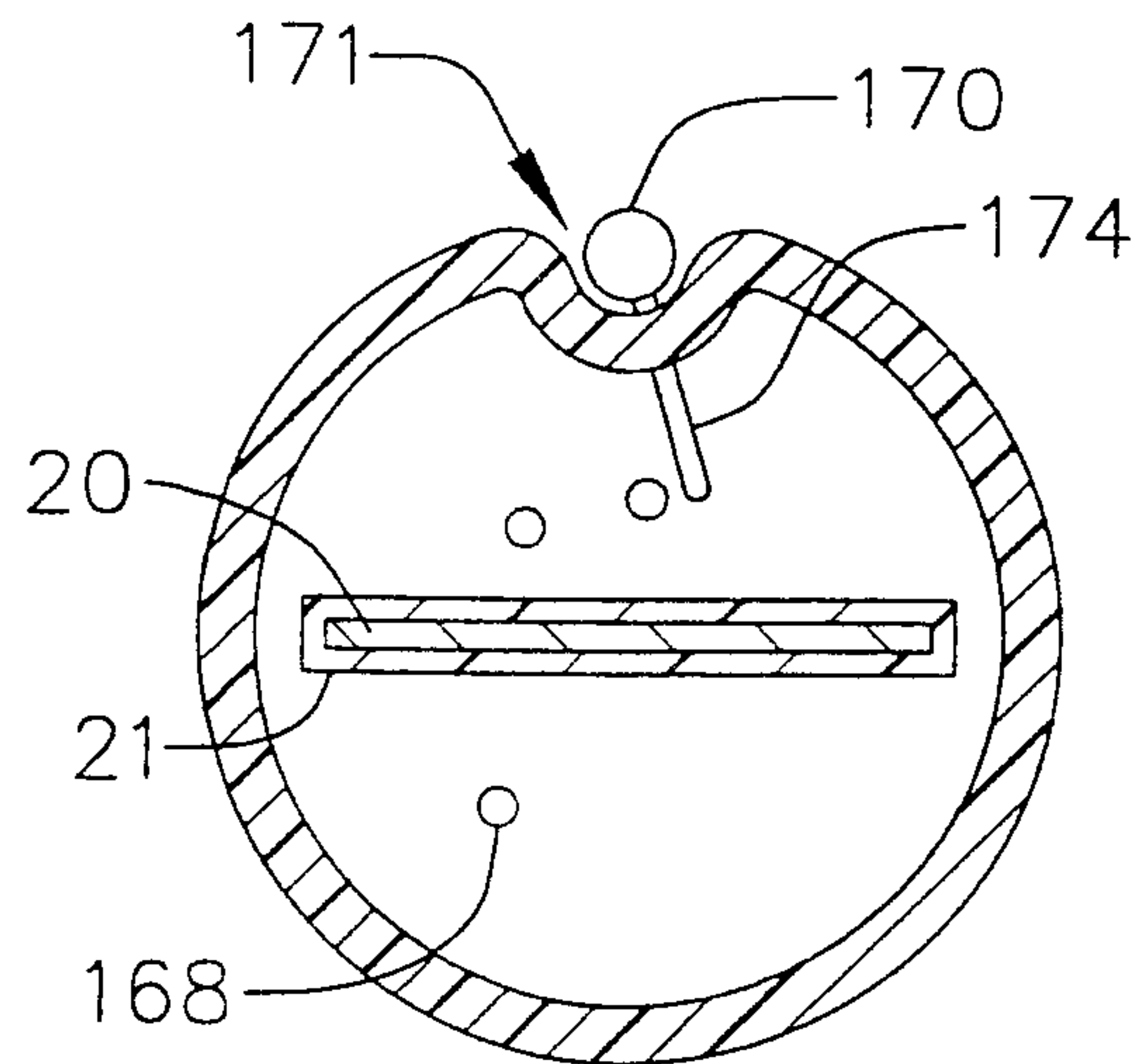


FIG. 6

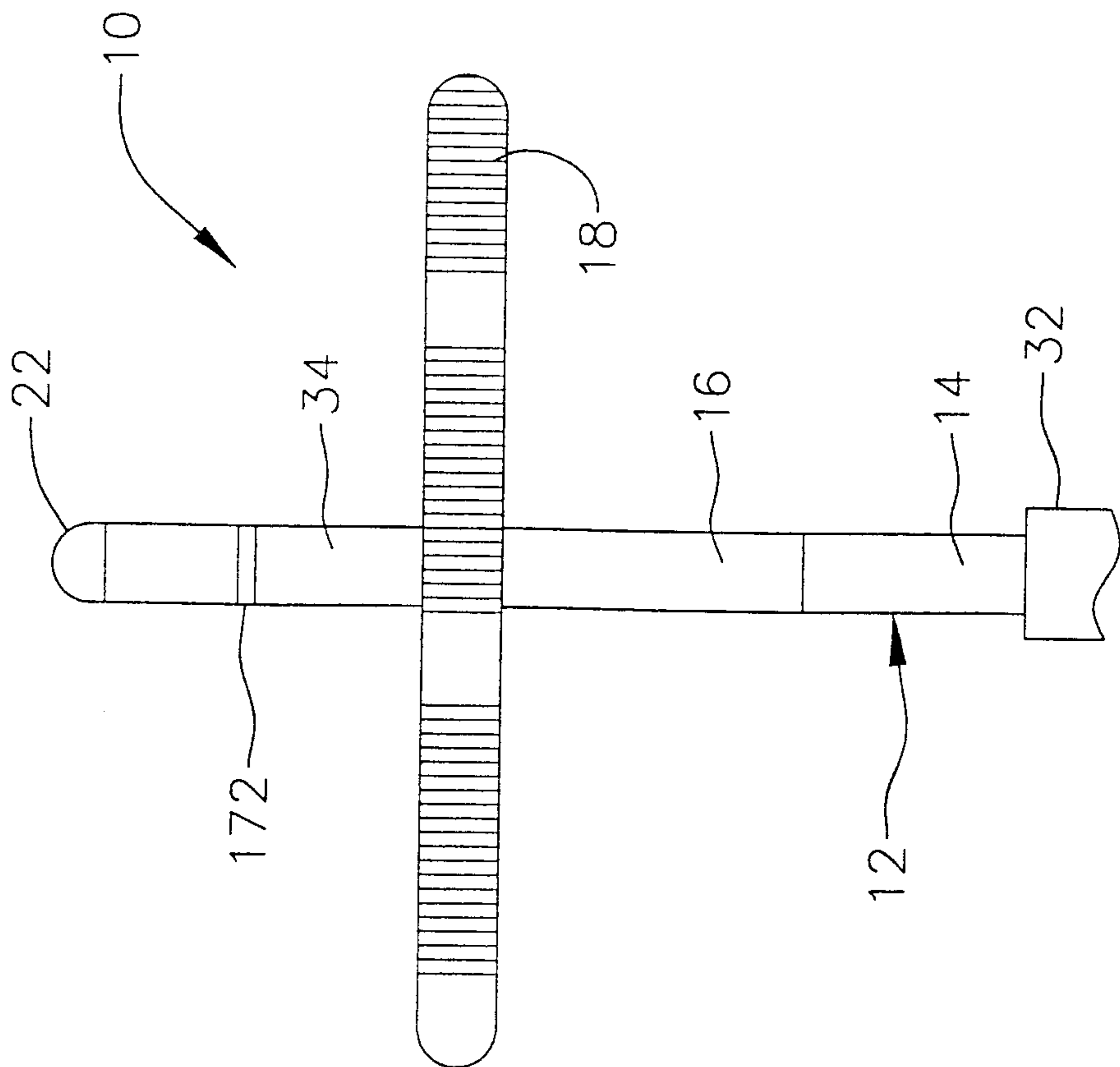
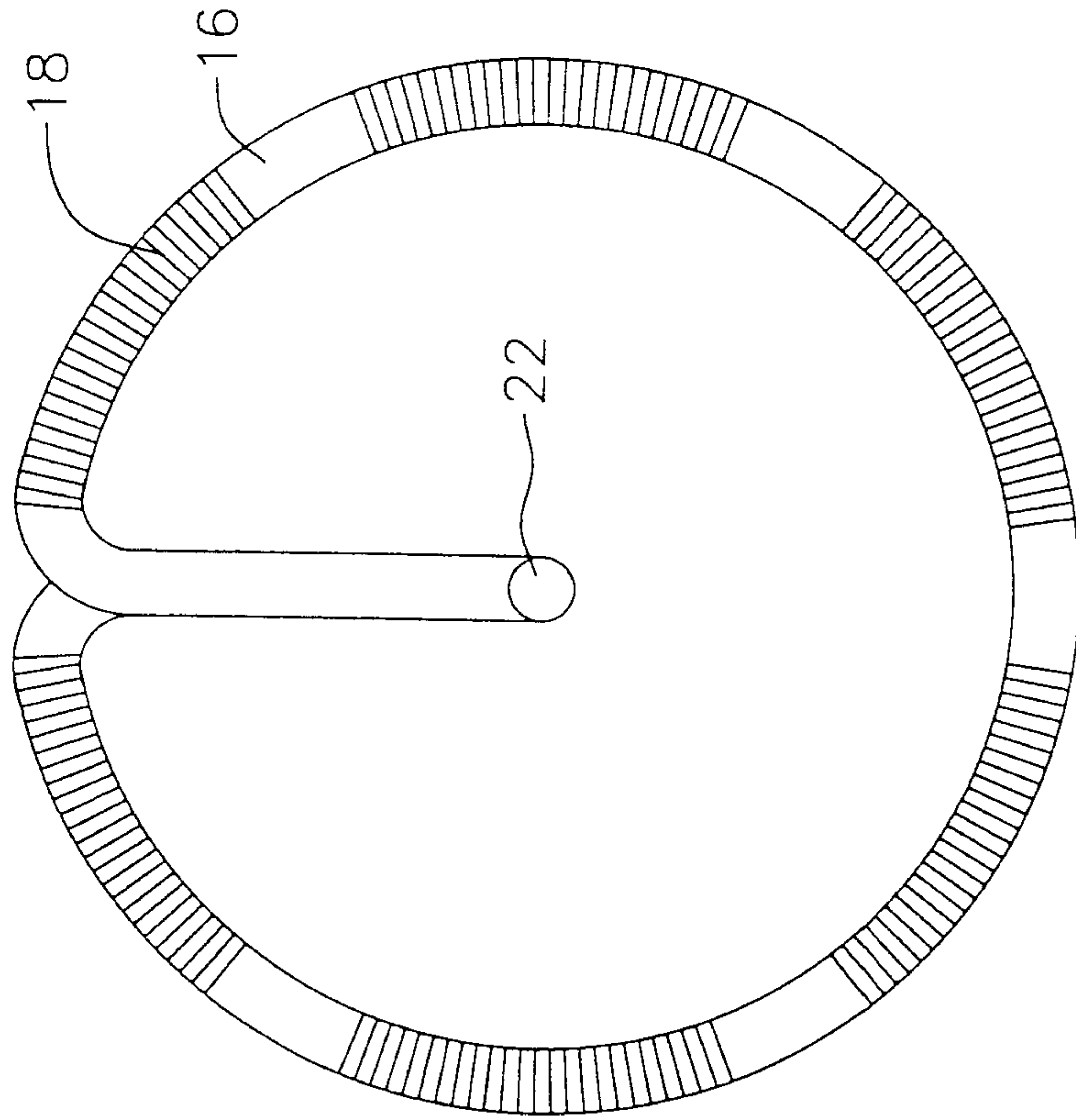


FIG. 7







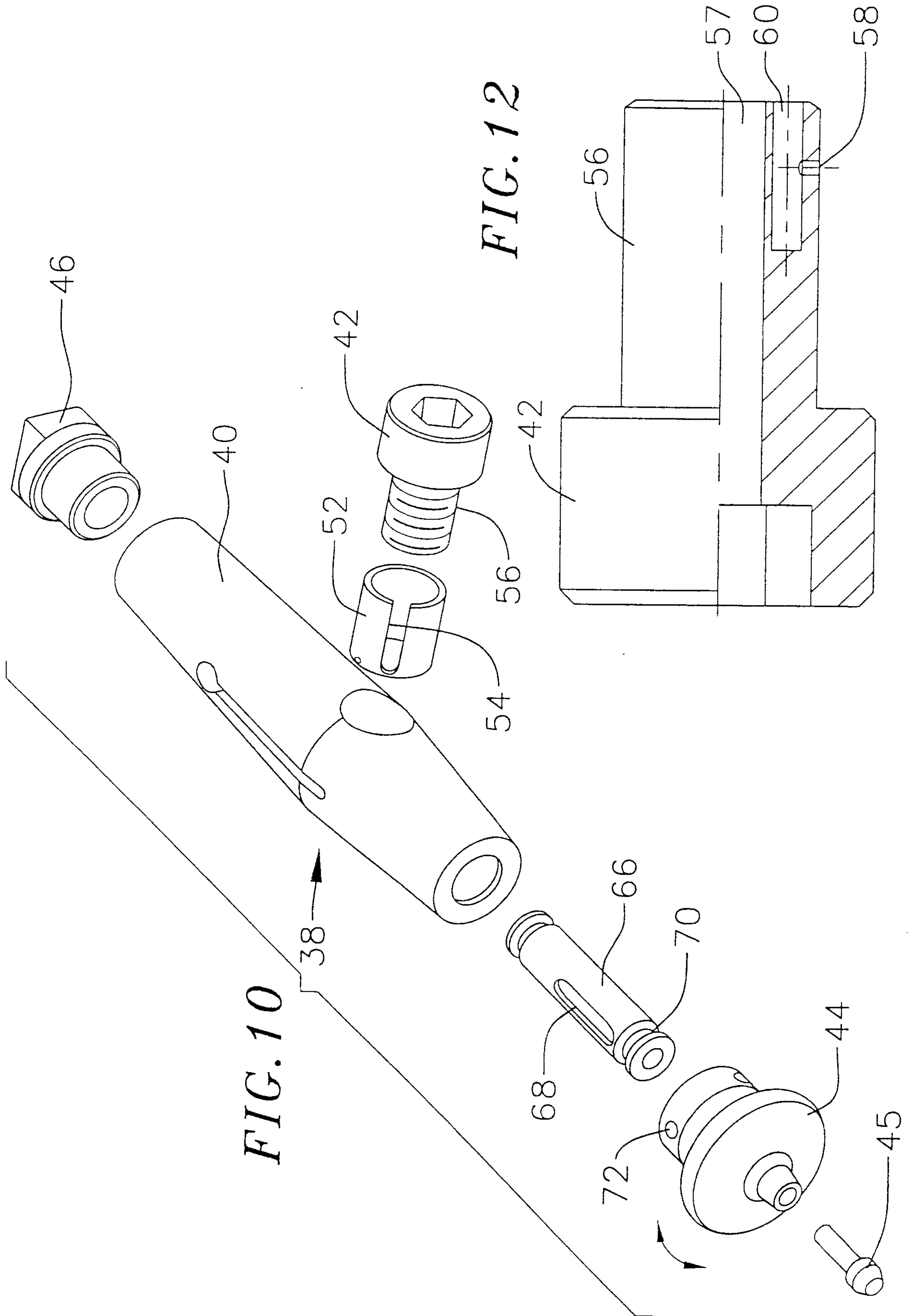
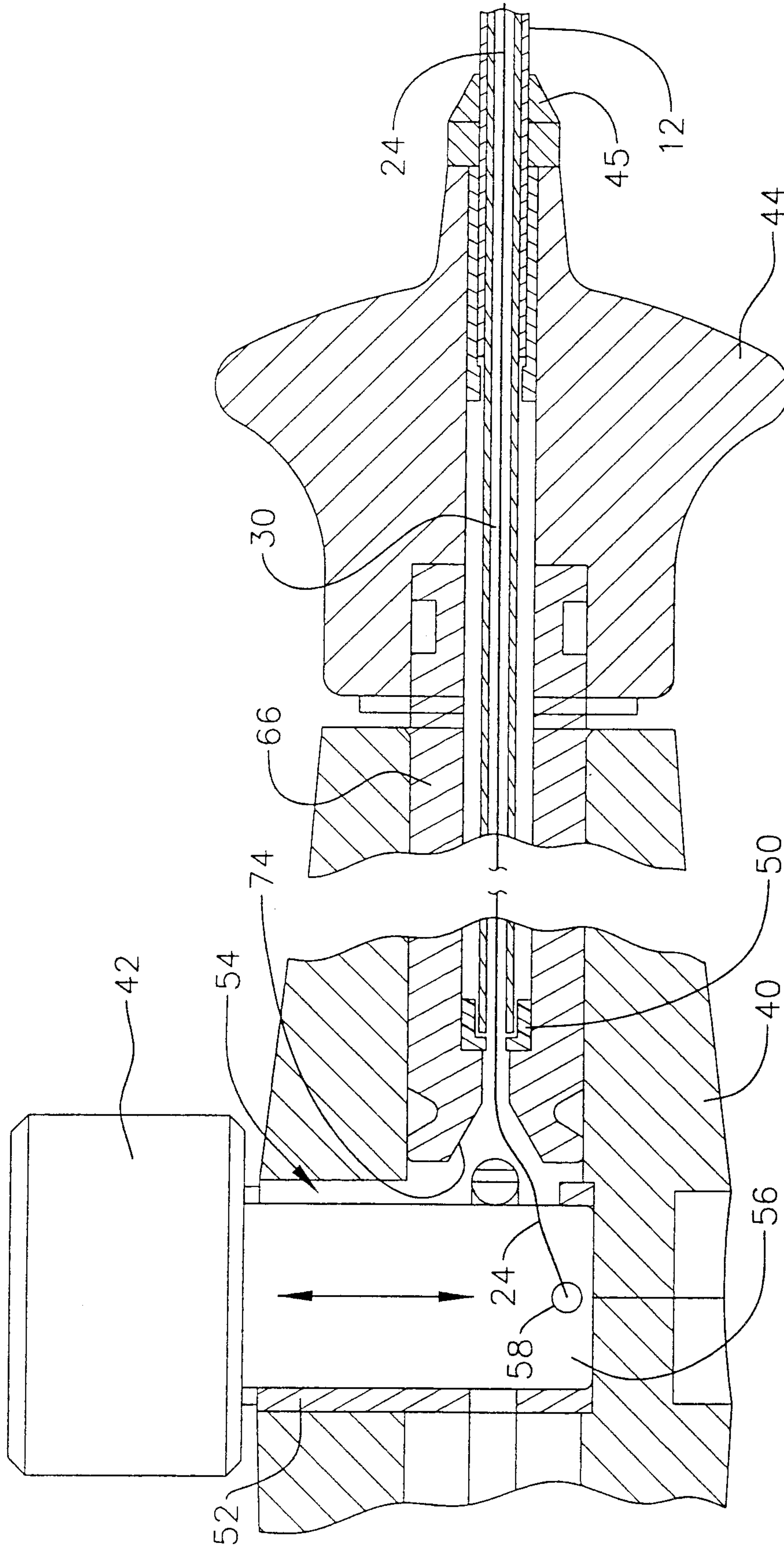


FIG. 11





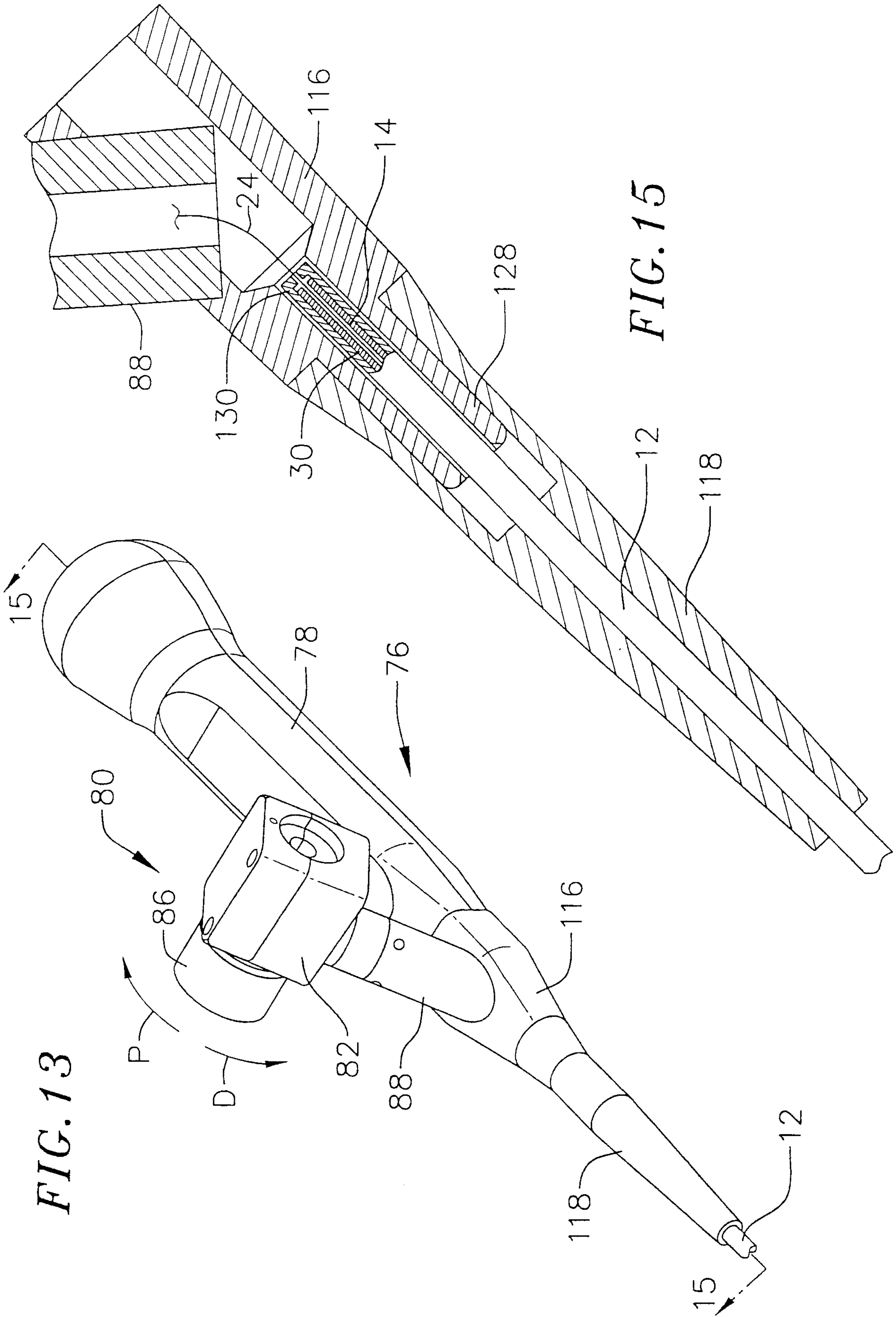


FIG. 13

FIG. 15

FIG. 12

FIG. 14

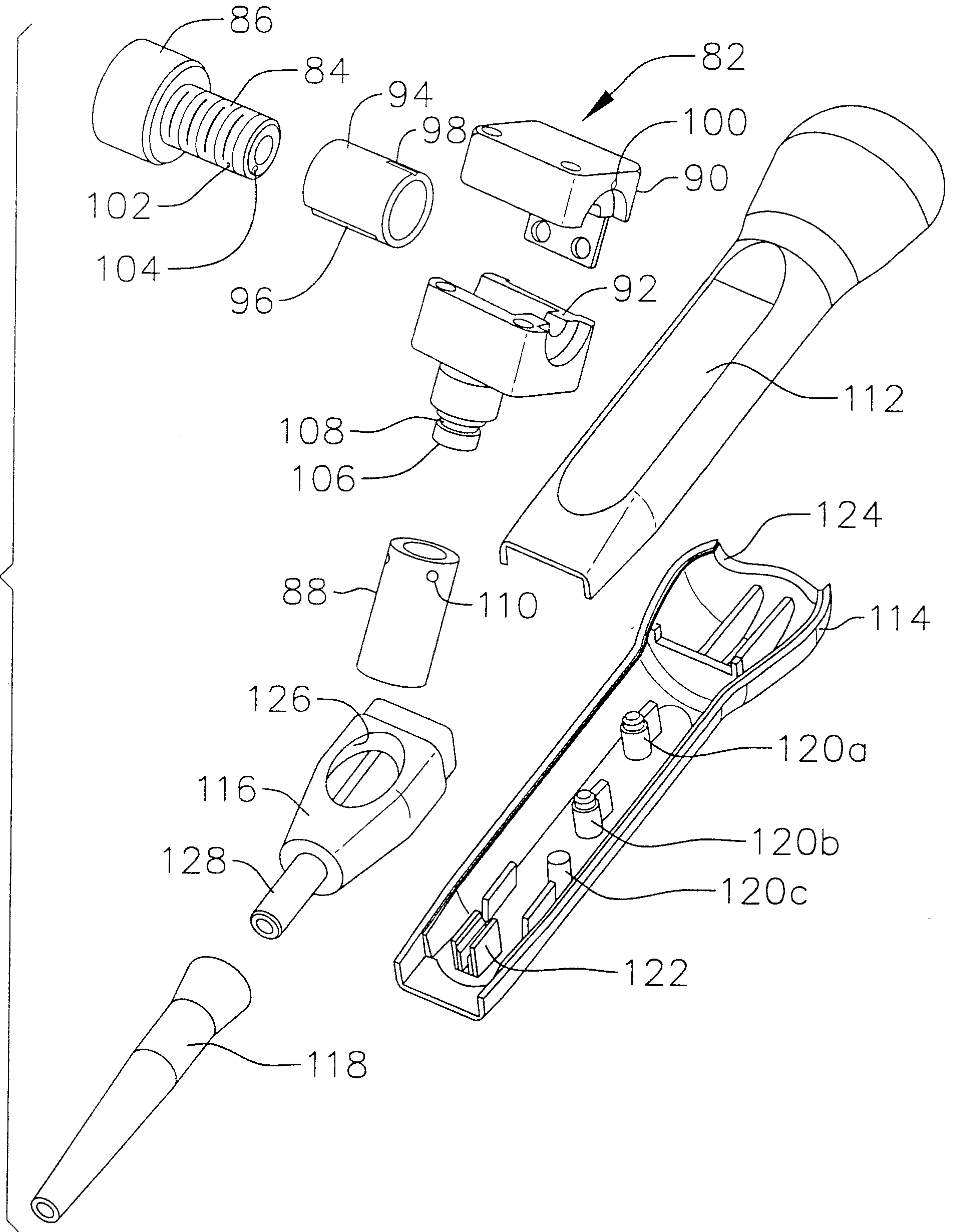
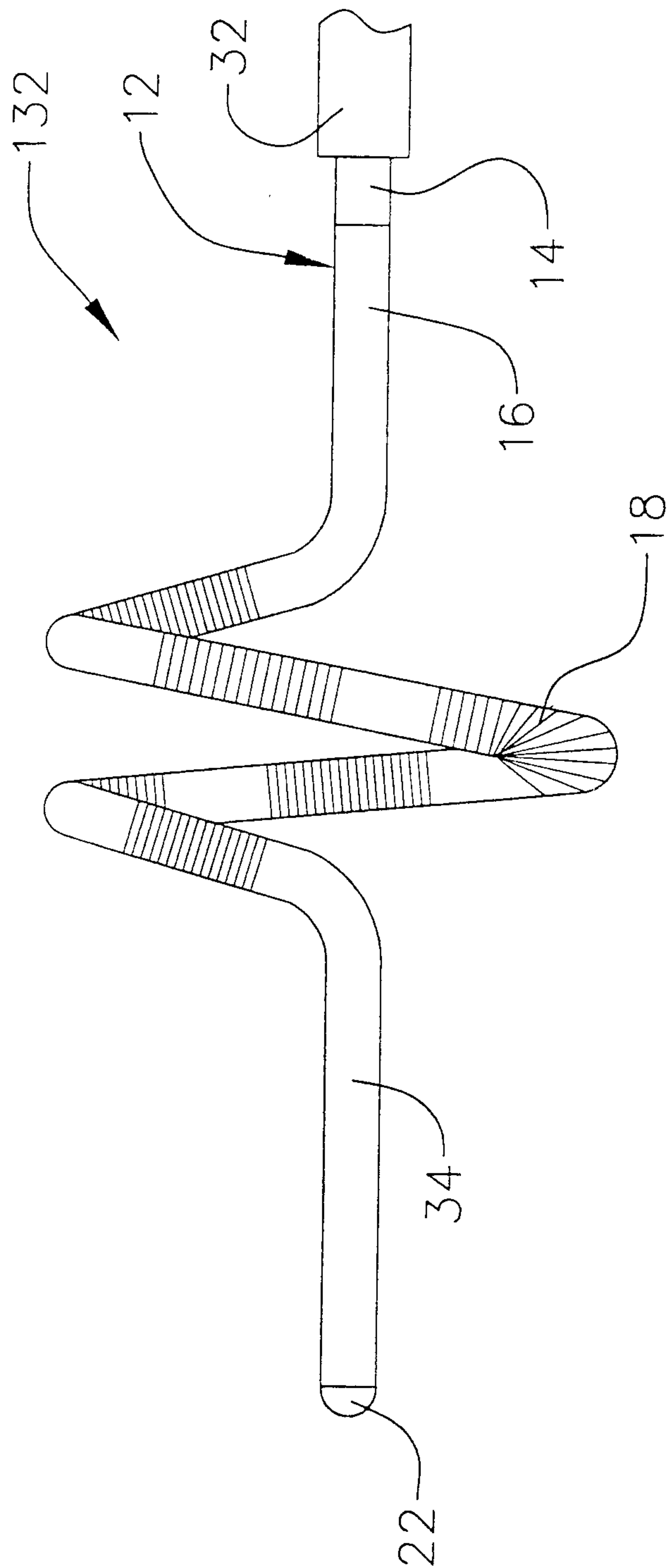


FIG. 16





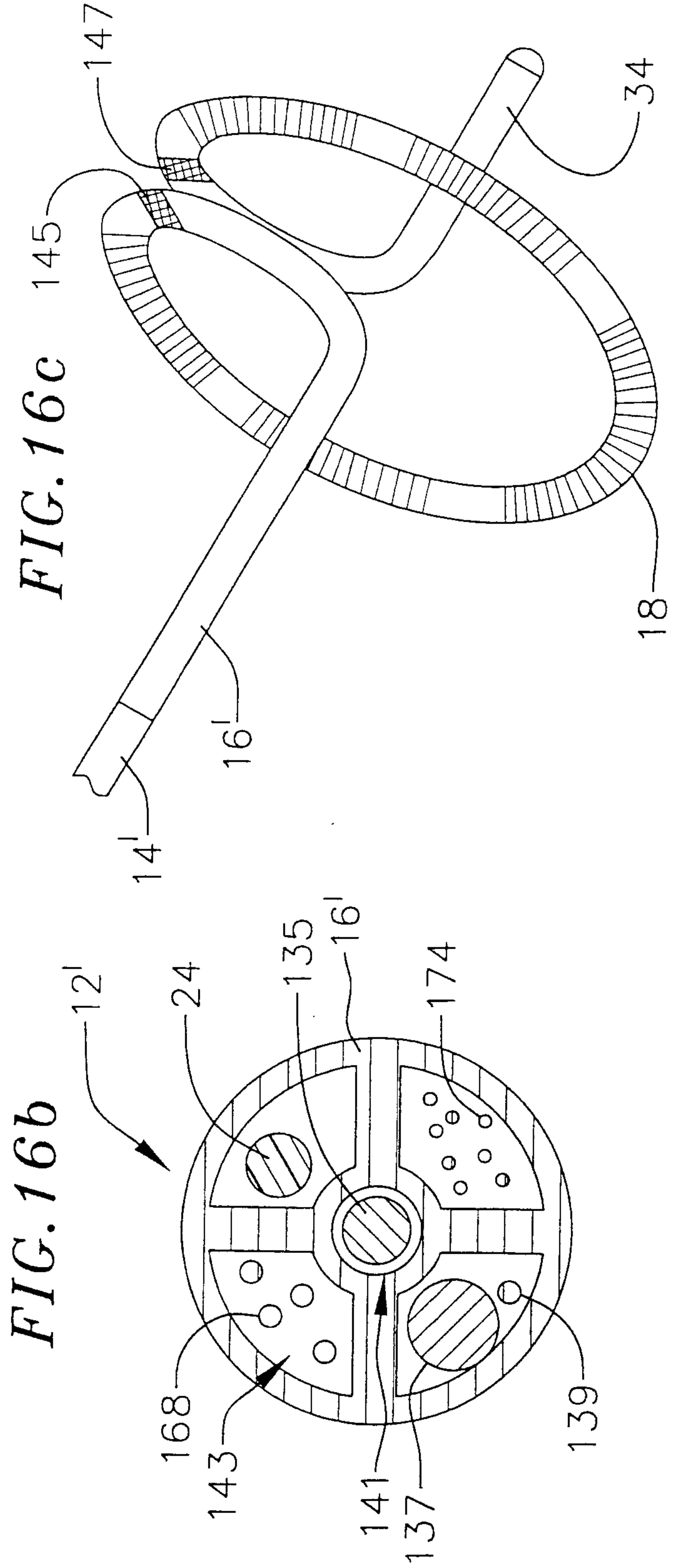
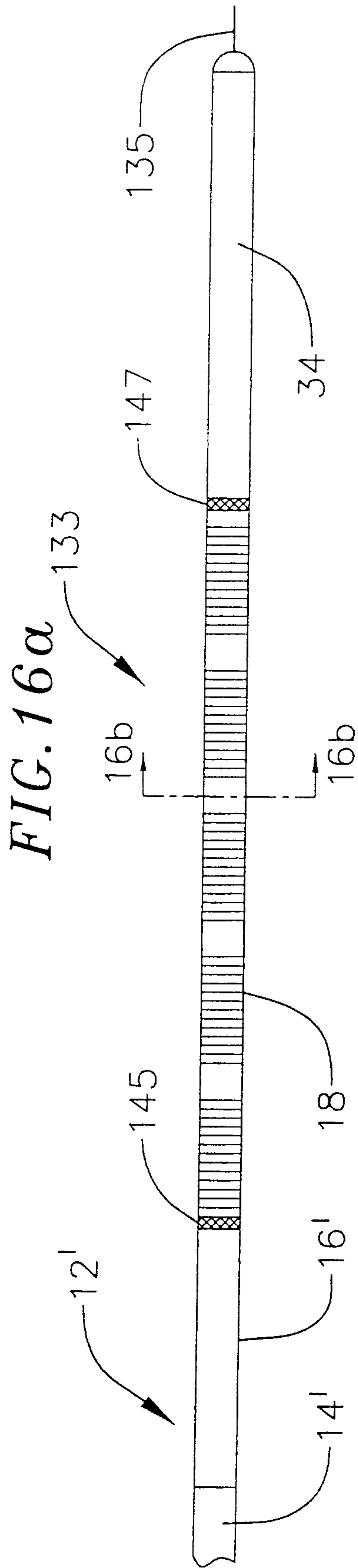


FIG. 17

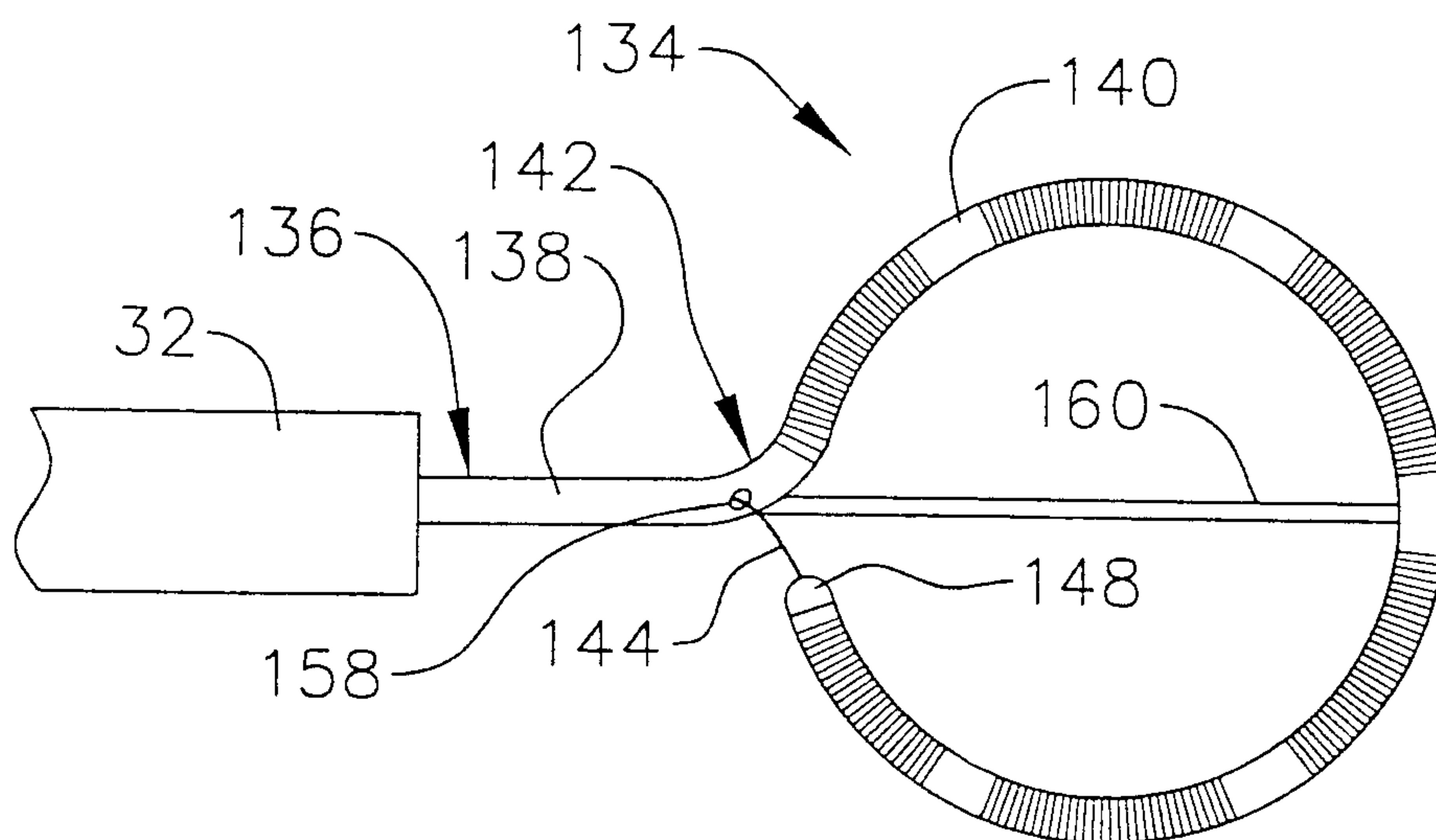


FIG. 18

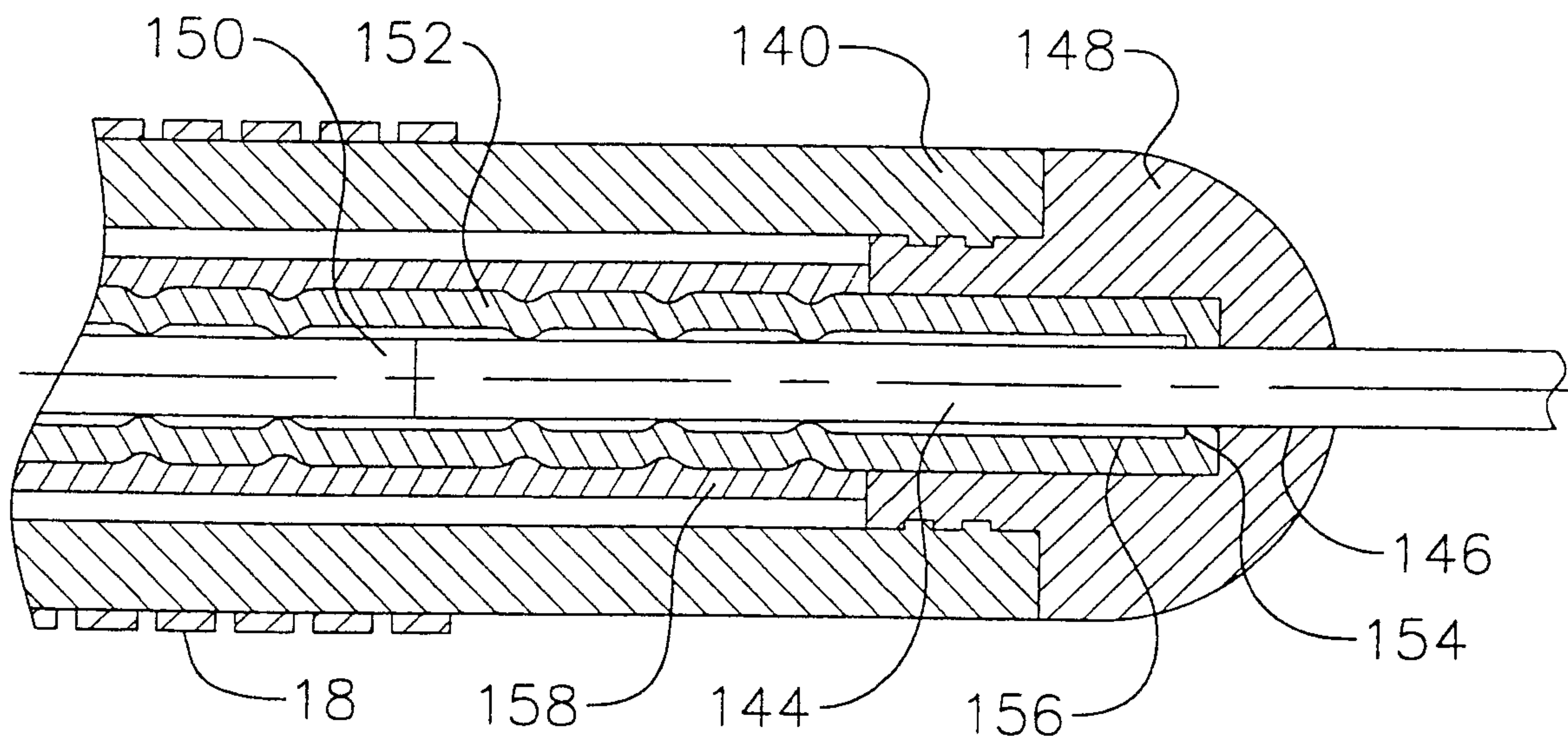


FIG. 19

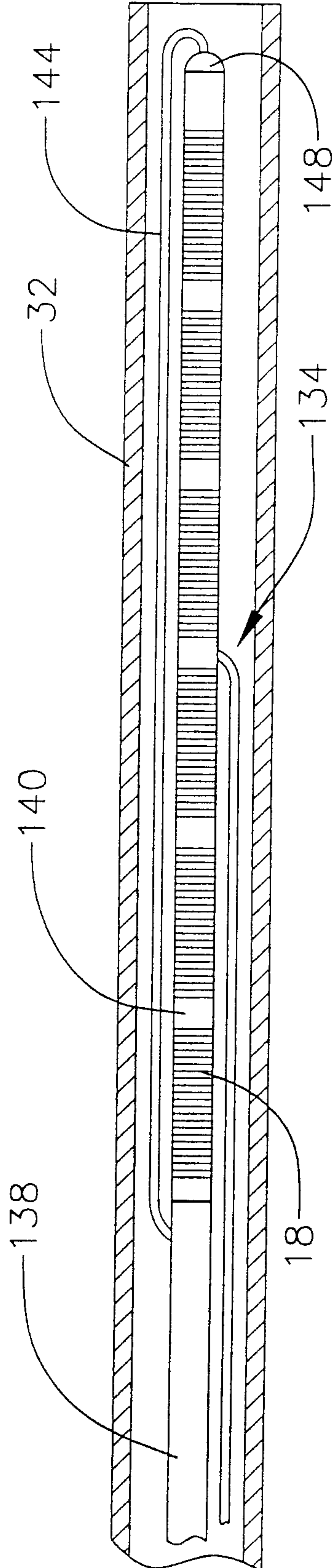


FIG. 20

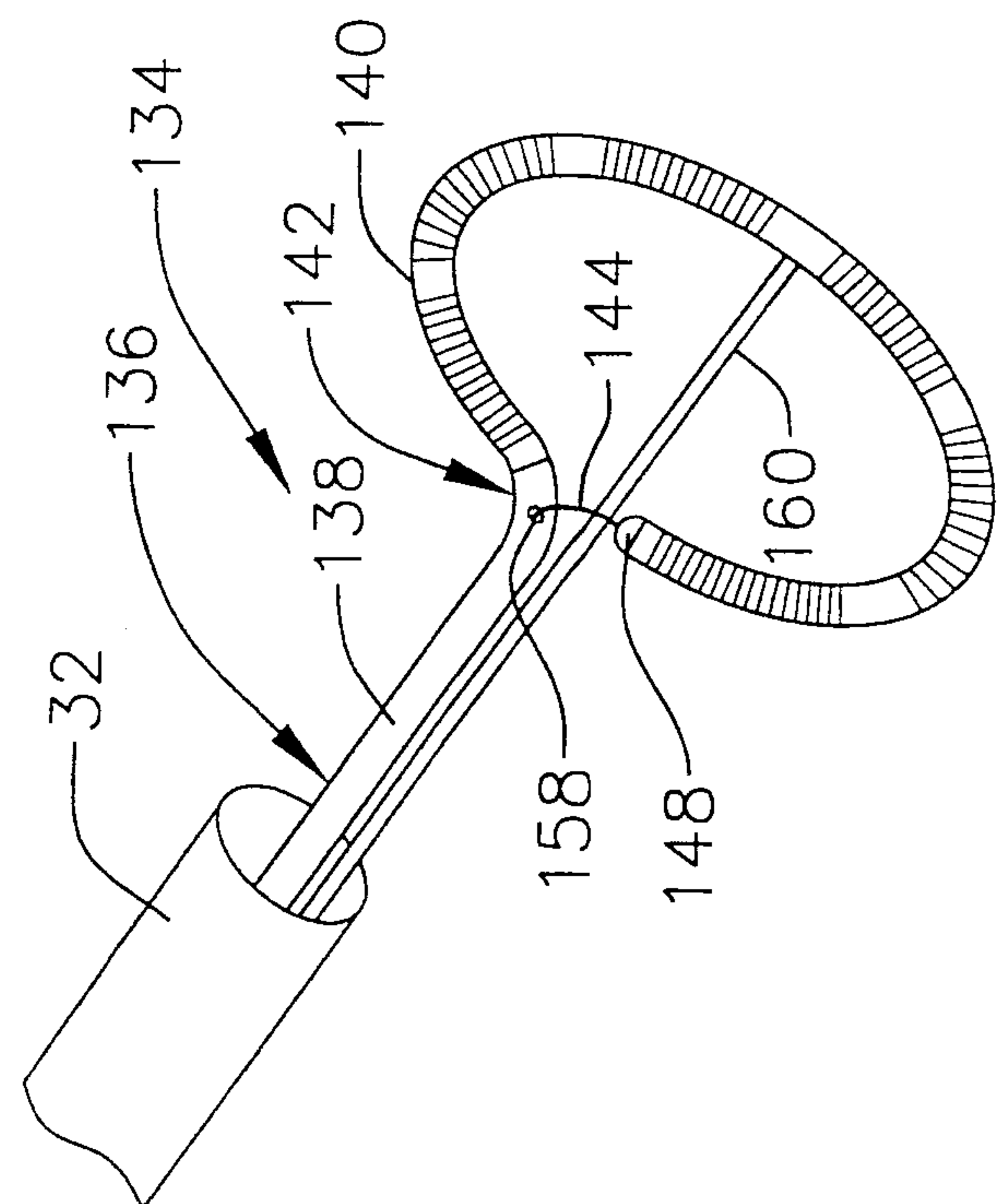
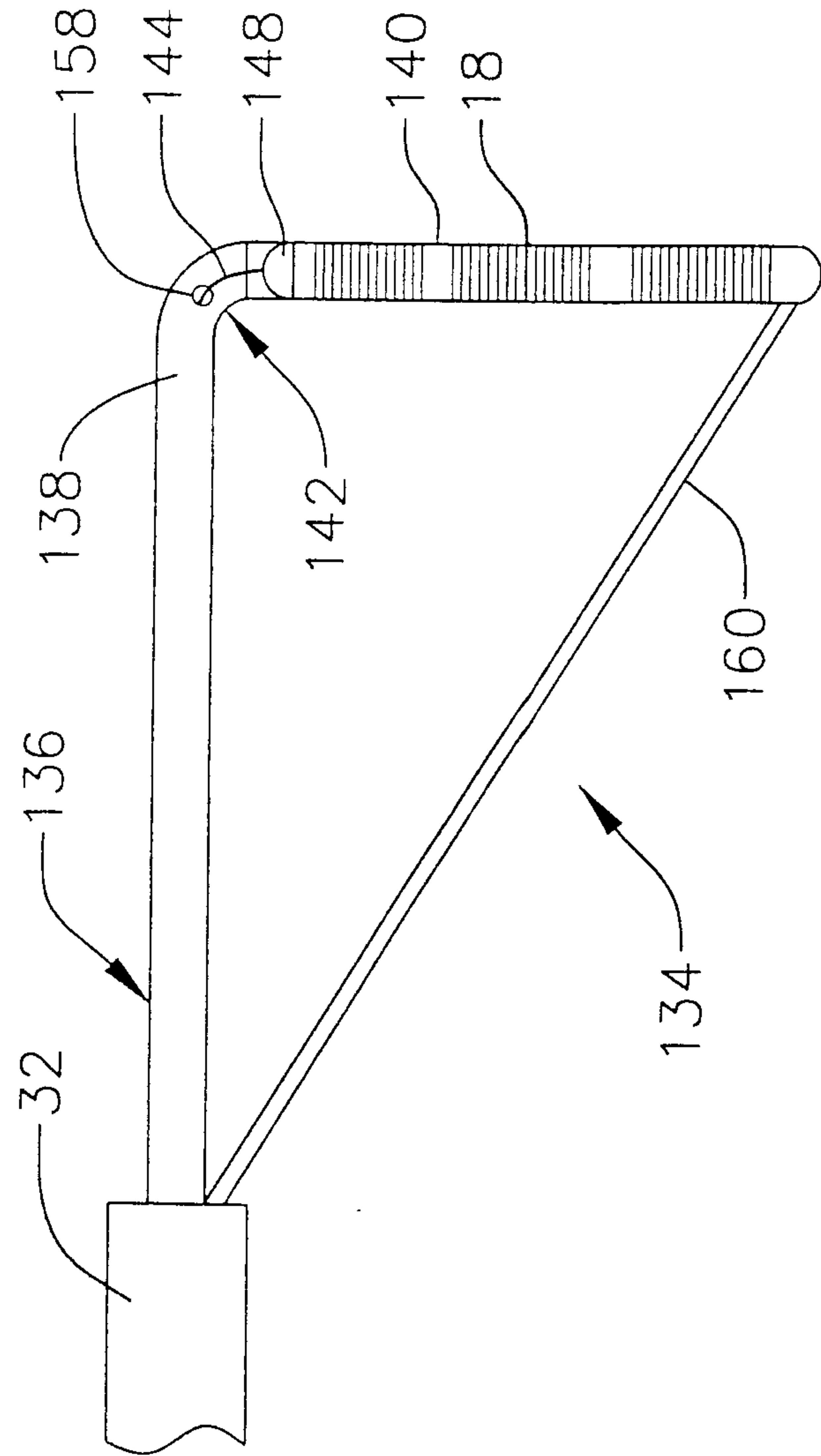


FIG. 21





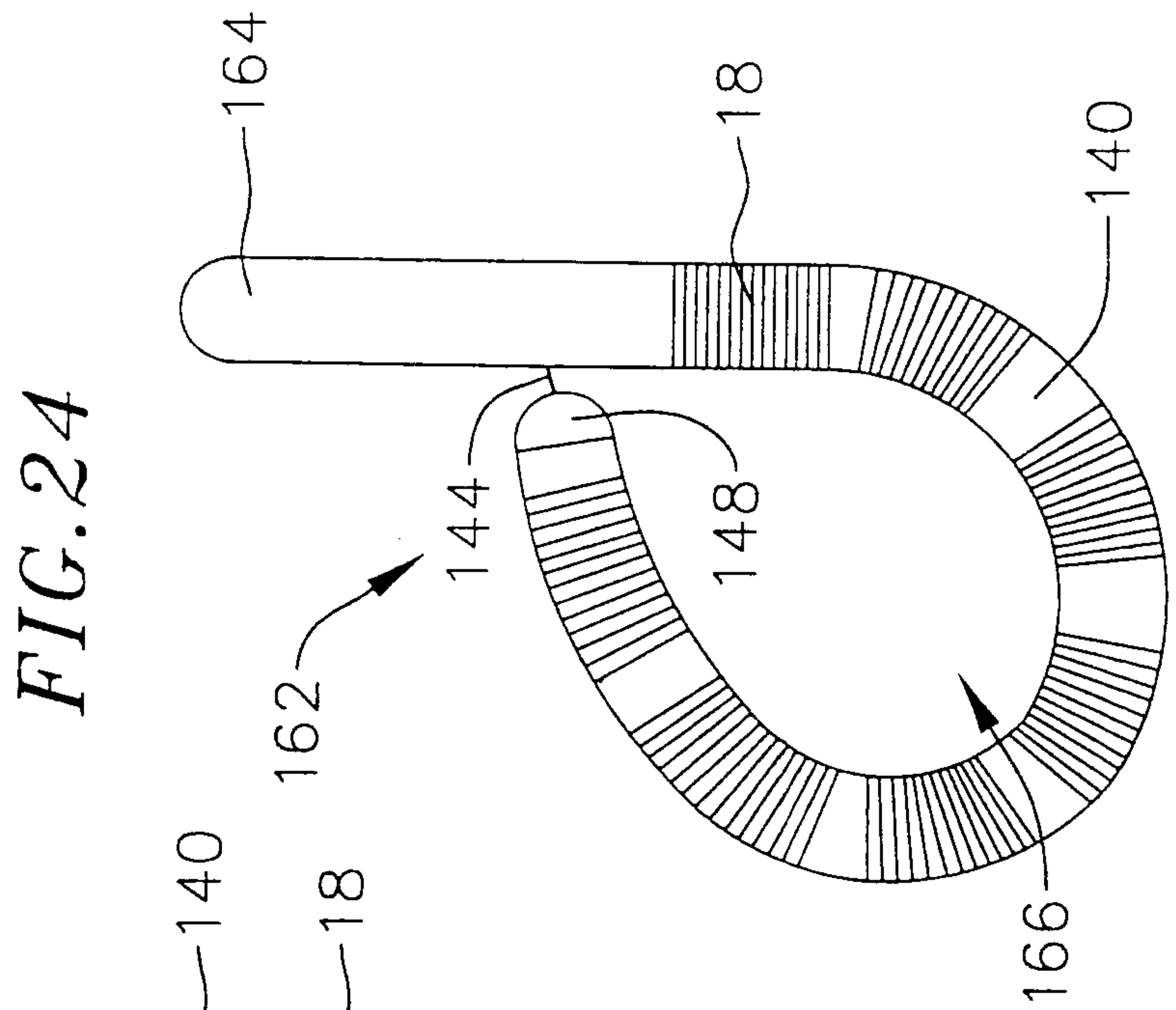
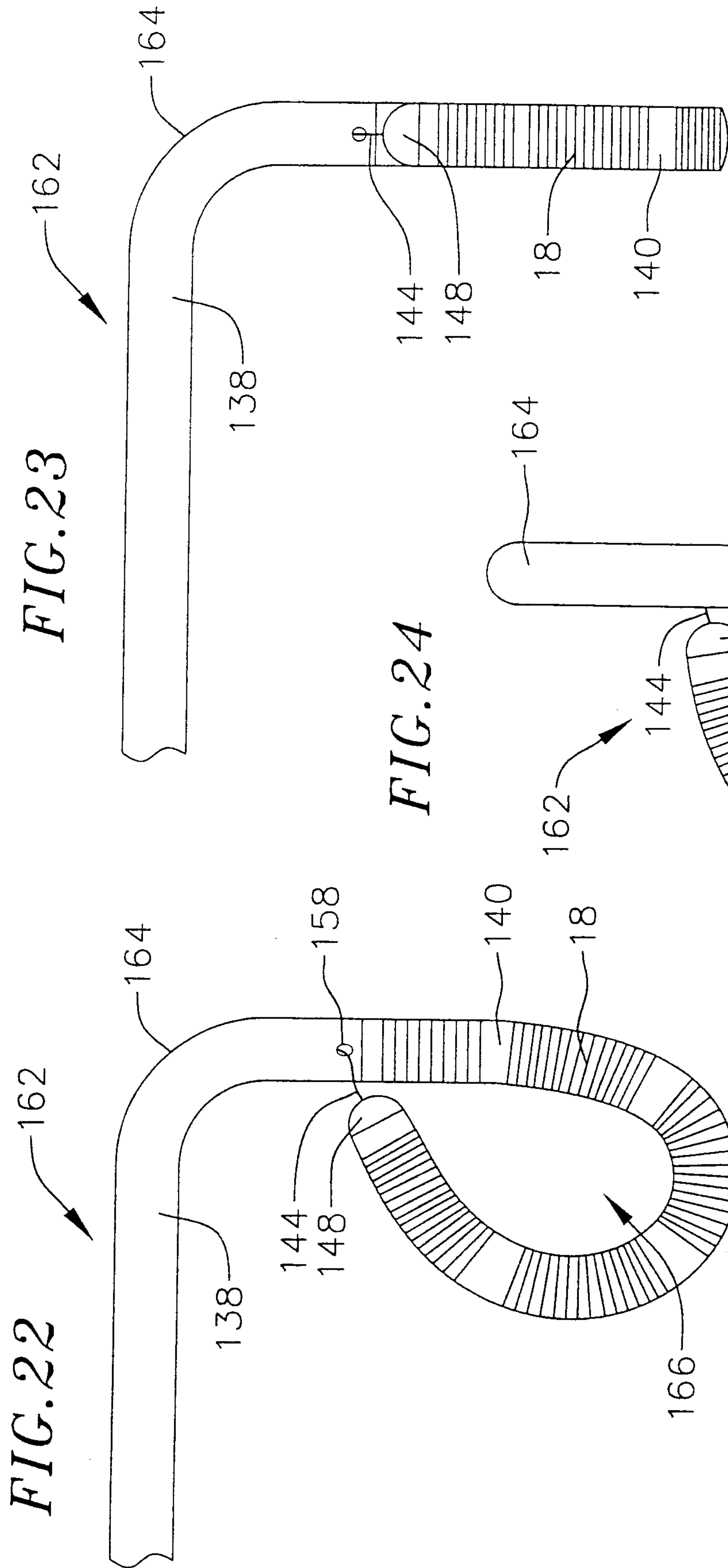


FIG. 25

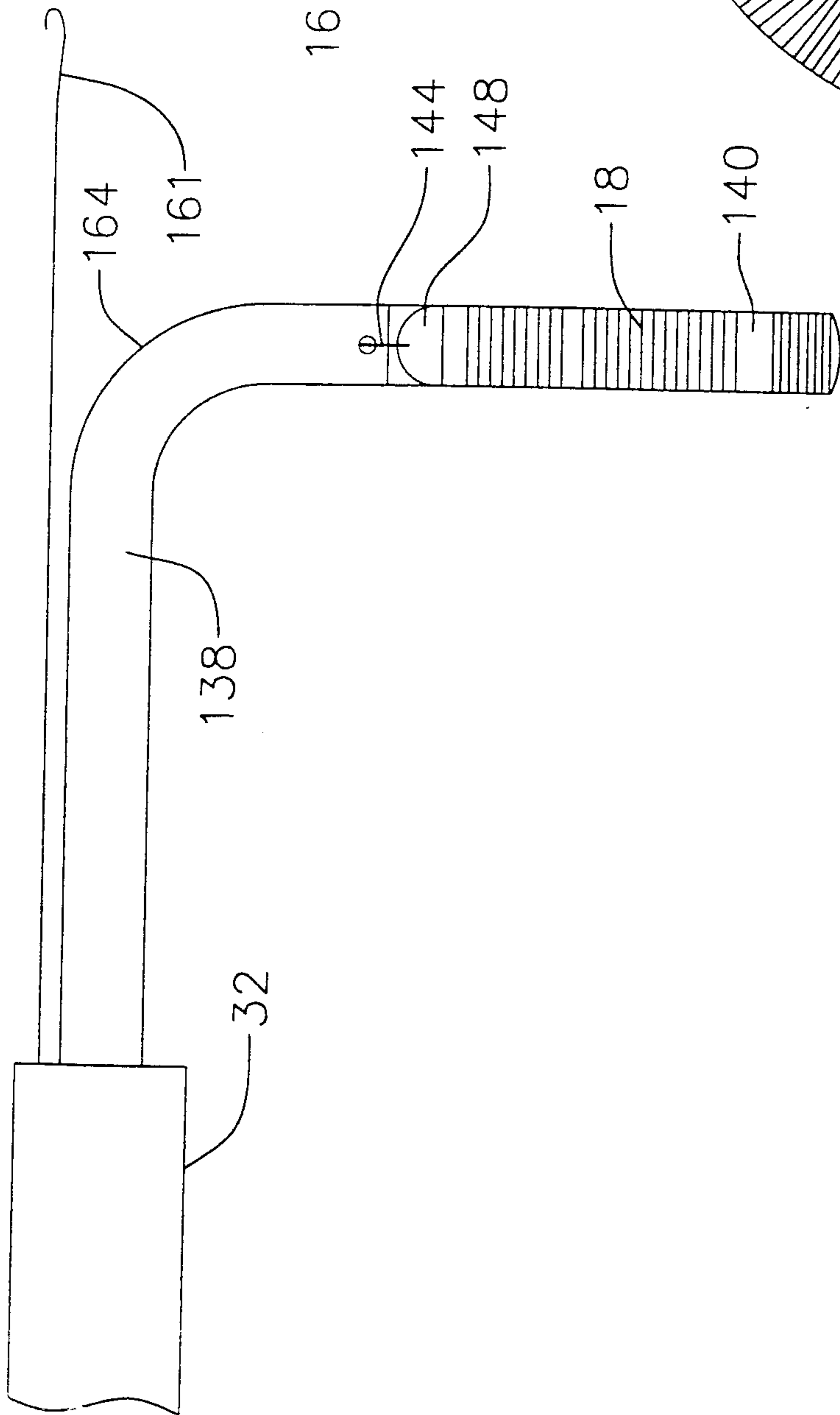


FIG. 26

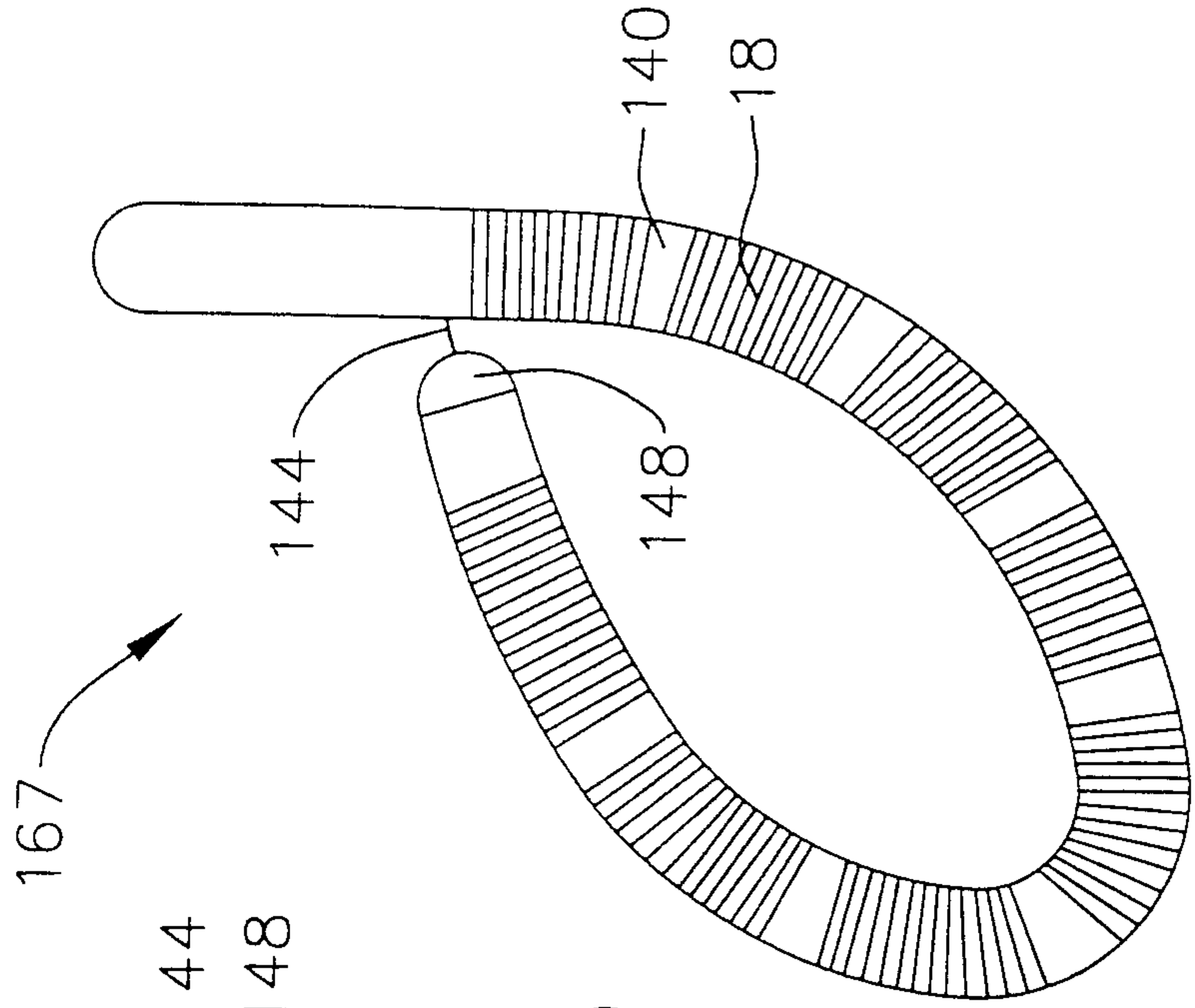


FIG. 27

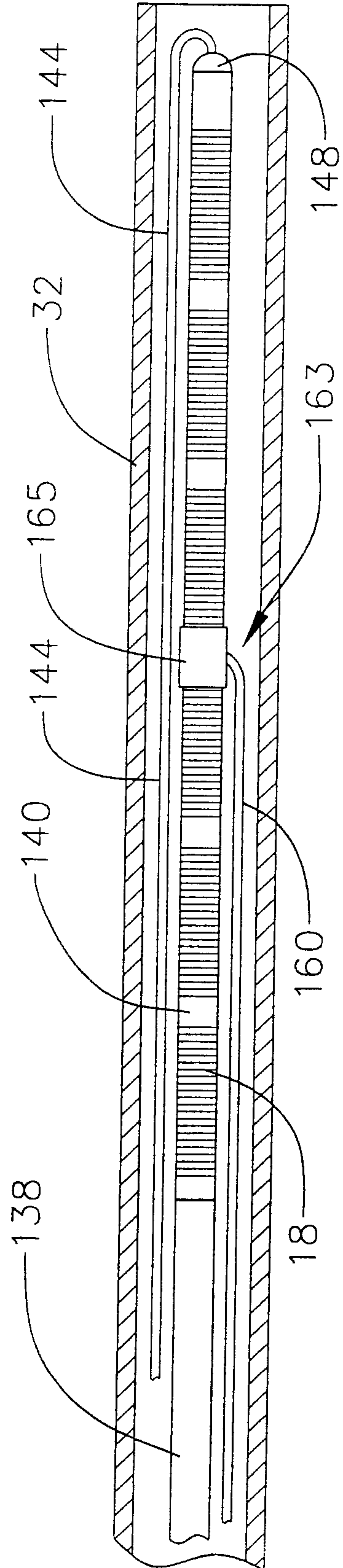


FIG. 28

