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(54) Title: ROTATIONAL SYSTEMS COMPRISING A POLYMER DRIVESHAFT

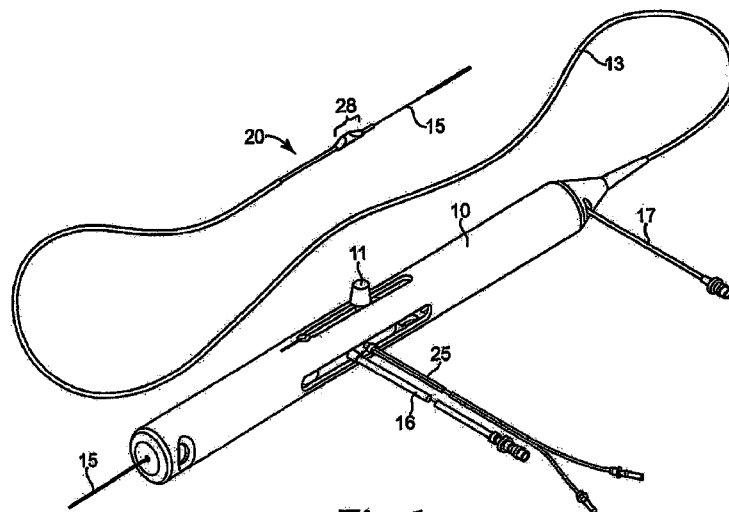


Fig. 1

(57) Abstract: Various embodiments of devices and systems comprising a polymer driveshaft for use in high-speed rotational medical procedures, e.g., atherectomy, are disclosed. Generally, the primary driveshaft for transferring torque and activating rotation of a tool attached thereto, e.g., an abrasive element, is constructed with at least a polymer outer and inner surface. In certain embodiments, the polymer driveshaft may comprise a metallic band for fixed attachment of a structure, e.g., an abrasive element, thereto. Various embodiments may comprise a coupler that connects a drive shaft connected with a prime mover, e.g., a turbine or electric motor, with the polymer drive shaft, the coupler comprising openings through the coupler wall to the inner diameter of the coupler to allow fluid flow to the inner diameter of the coupled polymer drive shaft.

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TITLE OF THE INVENTION**Rotational Systems Comprising a Polymer Driveshaft****INVENTORS****Preston L. Grothe, a citizen of United States of America, resident at Maple Grove, MN****Matthew D. Cambronne, a citizen of United States of America, resident at North Oaks, MN****Joseph P. Higgins, a citizen of United States of America, resident at Minnetonka, MN****William F. Kuester, III, a citizen of United States of America, resident at Maplewood, MN****Benjamin Haselman, a citizen of United States of America, resident at St. Paul, MN****Joshua J. Cranston, a citizen of United States of America, resident at Andover, MN****Ric A. Gould, a citizen of United States of America, resident at Brooklyn Park, MN****CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of U.S. Provisional Application No. 62/169,002, filed June 1, 2015 and entitled POLYMER DRIVESHAFT FOR HIGH-SPEED ROTATIONAL MEDICAL PROCEDURES; U.S. Provisional Application No. 62/184,399, filed June 25, 2015 and entitled DEVICES, SYSTEMS AND METHODS FOR PERFORMING ATHERECTOMY PROCEDURES WITH POLYMER DRIVE SHAFT WITH METALLIC MARKER BAND; U.S. Provisional Application No. 62/184,358, filed June 25, 2015 and entitled DEVICES, SYSTEMS AND METHODS FOR PERFORMING ATHERECTOMY PROCEDURES WITH POLYMER OR NON-POLYMER DRIVE SHAFTS COMPRISING A DRIVE SHAFT COUPLER; and U.S. Provisional Application No. 62/279,379, filed January 15, 2016 and entitled POLYMER DRIVESHAFT FOR USE IN ORBITAL AND ROTATIONAL ATHERECTOMY, the entirety of each of which is hereby incorporated by reference.

[0002] STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0003] Not Applicable

[0004] BACKGROUND OF THE INVENTION**[0005] FIELD OF THE INVENTION**

[0006] The disclosure relates to devices and methods using guidewires, for example intravascular procedures, e.g., removing tissue from body passageways, such as removal of atherosclerotic plaque from arteries with, e.g., a rotational atherectomy device. More specifically, the disclosure provides a guidewire tip that is reformable and, therefore, resistant to damaging deformation.

[0007] DESCRIPTION OF THE RELATED ART

[0008] A variety of techniques and instruments have been developed for use in the removal or repair of tissue in arteries and similar body passageways. A frequent objective of such techniques and instruments is the removal of atherosclerotic plaques in a patient's arteries. Atherosclerosis is characterized by the buildup of fatty deposits (atheromas) in the intimal layer (under the endothelium) of a patient's blood vessels. Very often over time, what initially is deposited as relatively soft, cholesterol-rich atheromatous material hardens into a calcified atherosclerotic plaque. Such atheromas restrict the flow of blood, and therefore often are referred to as stenotic lesions or stenoses, the blocking material being referred to as stenotic material. If left untreated, such stenoses can cause angina, hypertension, myocardial infarction, strokes and the like.

[0009] Rotational atherectomy procedures have become a common technique for removing such stenotic material. Such procedures are used most frequently to initiate the opening of calcified lesions in coronary arteries. Most often the rotational atherectomy procedure is not used alone, but is followed by a balloon angioplasty procedure, which, in turn, is very frequently followed by placement of a stent to assist in maintaining patency of the opened artery. For non-calcified lesions, balloon angioplasty most often is used alone to open the artery, and stents often are placed to maintain patency of the opened artery. Studies have shown, however, that a significant percentage of patients who have undergone balloon angioplasty and had a stent placed in an artery experience stent restenosis, which is blockage of the stent that most frequently develops over a period of time as a result of excessive growth of scar tissue within the stent. In such situations an

atherectomy procedure is the preferred procedure to remove the excessive scar tissue from the stent (balloon angioplasty being not very effective within the stent), thereby restoring the patency of the artery.

[0010] Several kinds of rotational atherectomy devices have been developed for attempting to remove stenotic material. In one type of device, such as that shown in U.S. Pat. No. 4,990,134 (Auth), a burr covered with an abrasive abrading material such as diamond particles is carried at the distal end of a flexible drive shaft. The burr is rotated at high speeds (typically, e.g., in the range of about 150,000-190,000 rpm) while it is advanced across the stenosis. As the burr is removing stenotic tissue, however, it blocks blood flow. Once the burr has been advanced across the stenosis, the artery will have been opened to a diameter equal to or only slightly larger than the maximum outer diameter of the burr. Frequently more than one size burr must be utilized to open an artery to the desired diameter.

[0011] U.S. Pat. No. 5,314,438 (Shturman) discloses another atherectomy device having a drive shaft with a section of the drive shaft having an enlarged diameter, at least a segment of this enlarged surface being covered with an abrasive material to define an abrasive segment of the drive shaft. When rotated at high speeds, the abrasive segment is capable of removing stenotic tissue from an artery. Though this atherectomy device possesses certain advantages over the Auth device due to its flexibility, it also is capable only of opening an artery to a diameter about equal to the diameter of the enlarged abrading surface of the drive shaft since the device is not eccentric in nature.

[0012] U.S. Pat. No. 6,494,890 (Shturman) discloses a known atherectomy device having a drive shaft with an enlarged eccentric section, wherein at least a segment of this enlarged section is covered with an abrasive material. When rotated at high speeds, the abrasive segment is capable of removing stenotic tissue from an artery. The device is capable of opening an artery to a diameter that is larger than the resting diameter of the enlarged eccentric section due, in part, to the orbital rotational motion during high speed operation. Since the enlarged eccentric section comprises drive shaft wires that are not bound together, the enlarged eccentric section of the drive shaft may flex during placement within the stenosis or during high speed operation. This flexion allows for a larger diameter opening during high speed operation, but may also provide less control

than desired over the diameter of the artery actually abraded. In addition, some stenotic tissue may block the passageway so completely that the Shturman device cannot be placed therethrough. Since Shturman requires that the enlarged eccentric section of the drive shaft be placed within the stenotic tissue to achieve abrasion, it will be less effective in cases where the enlarged eccentric section is prevented from moving into the stenosis. The disclosure of U.S. Pat. No. 6,494,890 is hereby incorporated by reference in its entirety.

[0013] Moreover, we provide disclosure of the following patents and applications, each of which are assigned to Cardiovascular Systems, Inc., and incorporated herein in their entirety, each of which may comprise systems, methods and/or devices that may be used with various embodiments of the presently disclosed subject matter:

[0014] U.S. Pat 6,295,712, "ROTATIONAL ATHERECTOMY DEVICE";

[0015] U.S. Pat 6,494,890, "ECCENTRIC ROTATIONAL ATHERECTOMY DEVICE";

[0016] U.S. Pat 6,132,444, "ECCENTRIC DRIVE SHAFT FOR ATHERECTOMY DEVICE AND METHOD FOR MANUFACTURE";

[0017] U.S. Pat 6,638,288, "ECCENTRIC DRIVE SHAFT FOR ATHERECTOMY DEVICE AND METHOD FOR MANUFACTURE";

[0018] U.S. Pat 5,314,438, "ABRASIVE DRIVE SHAFT DEVICE FOR ROTATIONAL ATHERECTOMY";

[0019] U.S. Pat 6,217,595, "ROTATIONAL ATHERECTOMY DEVICE";

[0020] U.S. Pat 5,554,163, "ATHERECTOMY DEVICE";

[0021] U.S. Pat 7,507,245, "ROTATIONAL ANGIOPLASTY DEVICE WITH ABRASIVE CROWN";

[0022] U.S. Pat 6,129,734, "ROTATIONAL ATHERECTOMY DEVICE WITH RADIALLY EXPANDABLE PRIME MOVER COUPLING";

[0023] U.S. Pat Application 11/761,128, "ECCENTRIC ABRADING HEAD FOR HIGH-SPEED ROTATIONAL ATHERECTOMY DEVICES";

[0024] U.S. Pat Application 11/767,725, "SYSTEM, APPARATUS AND METHOD FOR OPENING AN OCCLUDED LESION";

[0025] U.S. Pat Application 12/130,083, "ECCENTRIC ABRADING ELEMENT FOR

HIGH-SPEED ROTATIONAL ATHERECTOMY DEVICES”;

[0026] U.S. Pat Application 12/363,914, “MULTI-MATERIAL ABRADING HEAD FOR ATHERECTOMY DEVICES HAVING LATERALLY DISPLACED CENTER OF MASS”;

[0027] U.S. Pat Application 12/578,222, “ROTATIONAL ATHERECTOMY DEVICE WITH PRE-CURVED DRIVE SHAFT”;

[0028] U.S. Pat Application 12/130,024, “ECCENTRIC ABRADING AND CUTTING HEAD FOR HIGH-SPEED ROTATIONAL ATHERECTOMY DEVICES”;

[0029] U.S. Pat Application 12/580,590, “ECCENTRIC ABRADING AND CUTTING HEAD FOR HIGH-SPEED ROTATIONAL ATHERECTOMY DEVICES”;

[0030] U.S. Pat Application 29/298,320, “ROTATIONAL ATHERECTOMY ABRASIVE CROWN”;

[0031] U.S. Pat Application 29/297,122, “ROTATIONAL ATHERECTOMY ABRASIVE CROWN”;

[0032] U.S. Pat Application 12/466,130, “BIDIRECTIONAL EXPANDABLE HEAD FOR ROTATIONAL ATHERECTOMY DEVICE”;

[0033] U.S. Pat Application 12/388,703, “ROTATIONAL ATHERECTOMY SEGMENTED ABRADING HEAD AND METHOD TO IMPROVE ABRADING EFFICIENCY”; and

[0034] U.S. Pat Application 13/624,313, “ROTATIONAL ATHERECTOMY DEVICE WITH ELECTRIC MOTOR”.

[0035] BRIEF SUMMARY OF THE INVENTION

[0036] Various embodiments of devices and systems comprising a polymer driveshaft for use in high-speed rotational medical procedures, e.g., atherectomy, are disclosed. Generally, the primary driveshaft for transferring torque and activating rotation of a tool attached thereto, e.g., an abrasive element, is constructed with at least a polymer outer and inner surface. In certain embodiments, the polymer driveshaft may comprise a metallic band for fixed attachment of a structure, e.g., an abrasive element, thereto. Various embodiments may comprise a coupler that connects a drive shaft connected with a prime mover, e.g., a turbine or electric motor, with the polymer drive shaft, the coupler comprising openings through the coupler wall to the inner diameter of the coupler to

allow fluid flow to the inner diameter of the coupled polymer drive shaft.

[0037] The figures and the detailed description which follow more particularly exemplify these and other embodiments of the invention.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0038] FIG. 1 is a perspective view of one embodiment of a known rotational atherectomy device and system;

[0039] FIG. 2 is a cross-sectional view of one embodiment of the present invention;

[0040] FIG. 3A is a cross-sectional view of one embodiment of the present invention;

[0041] FIG. 3B is a cross-sectional view of one embodiment of the present invention;

[0042] FIG. 4 is a perspective partial cutaway view of one embodiment of the present invention;

[0043] FIG. 5 is a perspective partial cutaway view of one embodiment of the present invention;

[0044] FIG. 6 is a schematic diagram illustrating the connection of elements for one embodiment of the present invention;

[0045] FIG. 7 is a perspective view of one embodiment of the present invention;

[0046] FIG. 8 is a perspective view of one embodiment of the present invention;

[0047] FIG. 9 is a perspective view of one embodiment of the present invention; and

[0048] FIG. 10 is a perspective view of one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0049] While the invention is amenable to various modifications and alternative forms, specifics thereof are shown by way of example in the drawings and described in detail herein. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention.

[0050] FIG. 1 illustrates one known embodiment of a rotational atherectomy device. The device includes a handle portion 10, an elongated, flexible drive shaft 20 having an eccentric enlarged abrading head 28, and an elongated catheter 13 extending distally from the handle portion 10. The drive shaft 20 is constructed from helically coiled wire as is known in the art and an abrasive element 28 is fixedly attached thereto. Known drive

shafts are manufactured from a multi-filar wound coil. The inherent construction of this known coil allows for spaces between the filars. These spaces allow fluid, e.g., saline and/or water or other fluid, to pass through to the inner diameter of the drive shaft coil in order to provide cooling and/or lubrication effects to the interface of the drive shaft coil and the guide wire 15.

[0051] Generally, in this known construction, a coupler (typically comprising a solid metallic tube) is attached to the proximal end of the coiled drive shaft and to the drive shaft of the handle portion 10, wherein the drive shaft of the handle portion 10 is driven by a prime mover, thereby providing a connection between the prime mover, e.g., a turbine or electric motor, and the drive shaft 20.

[0052] Continuing with reference to Fig. 1, the catheter 13 has a lumen in which most of the length of the drive shaft 20 is disposed, except for the enlarged abrading head 28 and a short section distal to the abrasive element 28. The drive shaft 20 also contains an inner lumen, permitting the drive shaft 20 to be advanced and rotated over the guide wire 15. A fluid supply line 17 may be provided for introducing a cooling and lubricating solution (typically saline or another biocompatible fluid) into the catheter 13.

[0053] The handle 10 desirably contains a turbine (or similar rotational drive mechanism) for rotating the drive shaft 20 at high speeds. The handle 10 typically may be connected to a power source, such as compressed air delivered through a tube 16. A pair of fiber optic cables 25, alternatively a single fiber optic cable may be used, may also be provided for monitoring the speed of rotation of the turbine and drive shaft 20. The handle 10 also desirably includes a control knob 11 for advancing and retracting the turbine and drive shaft 20 with respect to the catheter 13 and the body of the handle.

[0054] Turning now to Figure 2, an embodiment of a layered polymer driveshaft 100 is illustrated. In this embodiment, the outer layer 102 may comprise nylon, PEEK, polyimide or any composite comprising two or more of these materials. The inner layer 104 may comprise PTFE, polyimide, nylon, PEEK, or any composite comprising two or more of these materials and defines a lumen. The middle layer 106 comprises a flat wire coil or braid, a structure that is well known to the skilled artisan.

[0055] Figure 3A illustrates an end view wherein an alternate embodiment of a polymer driveshaft 110 is comprised entirely of non-metallic elements, i.e., without a middle layer

comprising flat wire coil or braid. In this embodiment, the driveshaft may be constructed of a single polymer material layer 112 such as nylon, PEEK, polyimide or any composite of nylon, PEEK and/or polyimide, as illustrated, with lumen defined thereby.

[0056] Another alternative embodiment of a polymer driveshaft 114 as shown in Figure 3B, an outer layer 116 may comprise either polyimide (natural or colored) or a nylon, e.g., nylon TR55LX, and an inner layer 118 may comprise PTFE, polyimide or a composite comprising PTFE and polyimide and defining a lumen. This embodiment may be manufactured as a polymer tube that is extruded or dip coated as will be well understood by the skilled artisan.

[0057] As discussed above, the driveshaft disclosed herein will comprise at least one tool, typically near the distal end of the driveshaft such as an abrasive element 28 as show in Figure 1. An exemplary tool comprises an atherectomy tool such as a burr or abrasive crown and may be concentric or eccentric. Other tools may comprise sensors, transceivers, receivers and the like for, inter alia, obtaining, sending and/or receiving data regarding the biological lumen such as position/distance, elastance, compliance, composition, etc., that the polymer driveshaft is received within and/or the region of interest, e.g., a lesion, within the lumen.

[0058] The various embodiments comprising a polymer driveshaft as disclosed herein provides particular advantages over the known metal coil filar driveshaft.

[0059] 1. The known driveshaft 20 augurs fluid when rotating as the inner and outer diameters of the driveshaft 20 is coiled metal. All of the polymer driveshaft embodiments comprise smooth polymer-coated inner and outer diameters and will, therefore, not auger fluid. The benefit of this difference is that the saline flow from the distal end of a rotating device will not change, or change minimally, when the driveshaft is rotating as compared with when the drive shaft is not rotating.

[0060] 2. The known metal coil drive shaft 20 will eventually weld to the guidewire 15 when rotated without lubrication, a condition that is known to occur on occasion. In contrast, the inner diameter of the disclosed polymer driveshaft embodiments comprises a low friction polymer, e.g., PTFE, that will not weld or otherwise stick to the guide wire 15 when no lubrication is present.

[0061] 3. Particulate or tissue may flow the inner diameter of the known driveshaft 20 and/or auger along the inner or outer diameter of the wire coiled driveshaft 20 and may result in sticking between the driveshaft 20 and the guidewire 15. In contrast, the presently disclosed polymer driveshaft embodiments may comprise a smooth and continuous outer and inner surface that is impermeable to biological material such as plaque particulate or tissue. And, as discussed above, since the inner and outer diameters are both smooth and continuous polymer structures, no fluid augering or tissue or particulate augering will occur. The polymer driveshaft embodiments of the present disclosure, therefore, provide a structure that makes it much less likely for any plaque particulate and/or tissue to flow to the driveshaft's inner diameter and, in turn, much less likely for the polymer driveshaft to stick to the guide wire.

[0062] 4. The known metal coiled driveshaft 20 comprises a wall thickness of .006 inches or greater. In contrast, the polymer driveshaft embodiments of the present invention may comprise a wall thickness that is less than .006 inches. For example, single material polymer construction may have a wall thickness as small as .001 inches, while 3-layer constructions comprising an outer polymer layer, middle metal coil or braid layer and inner polymer layer may comprise wall thickness as small as .003 inches. The primary benefit to the smaller wall thickness of the polymer driveshaft embodiments disclosed herein is that the driveshaft itself comprises a smaller or lower profile, with a smaller outer diameter than the known coiled metal driveshaft 20 while still using the standard .004 inch core guidewire 15.

[0063] 5. The known metal coiled driveshaft 20 comprises coiled wires that store axial tension and/or compression that, when released, may spring forward as a spring unexpectedly and result in unwanted trauma to the vessel. In contrast, the polymer driveshaft embodiments disclosed herein will either not store any axial tension or compression in the case of the single material polymer construction embodiment. In addition, the 3-layer polymer construction, comprising a middle metal coil or braid layer 106 sandwiched between inner and outer polymer layers 104, 102, will store much less axial compression than the known all metal coiled driveshafts 20 and, therefore, much less likely to spring forward and with less force than the known driveshaft 20.

[0064] 6. The known metal coiled driveshaft 20 spins on bare metal guidewires, resulting in wearing of the guidewire coating and, eventually, heat buildup and possible sticking of the driveshaft 20 to the guidewire 15. The polymer inner layer of the present invention comprises a low friction material, e.g., PTFE, that will not wear on guidewire coatings.

[0065] 7. The known metal coiled driveshaft 20 comprises individual filars that are known to catch the guidewire 15 when advancing through the driveshaft lumen. The polymer driveshaft embodiments of the present invention comprise a smooth and continuous inner diameter that cannot catch the guidewire 15 during advancement therethrough. As a result, the guidewire 15 is easier to load through the inner diameter of the inventive driveshaft embodiments and may be easier to remove the inventive driveshaft off the guidewire 15 after completion of the procedure and thereby enabling easier retention of the guidewire's position in the vessel.

[0066] Turning now to Figures 4 and 5, with continued reference to Figs. 1-3, an orbital atherectomy drive shaft comprising at least inner and outer polymer layers is provided. An intermediate layer 106 may be provided between the inner and outer polymer layers 104,102 as illustrated. This intermediate layer may comprise a metallic layer 106, e.g., a metallic braid or a metallic coil, positioned between the inner and outer polymer layers 104,102 as described in connection with Fig. 2. As shown in Figures 4 and 5, a marker band 120 is attached to the metallic layer 106. In one embodiment, the marker band 120 is affixed to the metallic layer 106 by means known to the skilled artisan including, e.g., welding, adhesive, molding and crimping. In another embodiment, the driveshaft comprises only polymer as in Fig. 3A (single polymer material) or as in Fig. 3B (two polymer materials) and the marker band 120 is embedded within the polymer by heating the polymer and allowing the marker band 120 to sink within the polymer.

[0067] As illustrated, the marker band 120 may comprise perforations 122. These perforations 122 may allow additional torsional strength between the inventive polymer driveshaft and the structure, e.g., abrasive element 28, attached to the marker band 120. An alternative embodiment of the marker band 120 may comprise no perforations. The illustrated embodiment of the marker band 120 also comprises a generally cylindrical profile, though other profile shapes, e.g., oval, rectangular, square, etc., are within the scope of the invention. Additionally, for example, a marker band 120 comprising an

incomplete cylinder and, therefore, wrapping incompletely around the metallic layer 106, may be provided.

[0068] Figures 6 – 10 illustrate a coupler for the various embodiments of the polymer drive shaft described herein and for use with a system comprising the polymer driveshaft. The coupler 152 connects the prime mover, via a prime mover drive shaft, with the polymer drive shaft. This relationship is best seen in Figure 6.

[0069] In the known systems, the coiled wire driveshaft 20 is formed with an uncoated multi-filar construction, providing gaps between the filars that allow or enable water and/or saline or other lubricating and/or cooling fluids to access the inner diameter of the coiled wire driveshaft 20.

[0070] Because the polymer driveshaft embodiments described herein are coated generally continuously on the outer and inner surfaces, there are no fluid access points along the driveshaft that will allow fluid to move into the inner diameter of the driveshaft.

[0071] Accordingly, the coupler 150 shown in various embodiments in Figures 7-10 is provided with openings 152 through the wall of the coupler 150 and comprising an axial lumen through the coupler 150. These openings may be located on the center line of the coupler or may be offset from the centerline. The openings 152 may be longitudinally shaped along the center line, or parallel with the centerline or axis of rotation. The openings 152 may alternatively be perpendicular to the center line or at some angle thereto, or some combination of any of these possible configurations as illustrated in the alternate embodiments of Figures 8-10. Further, there may be a single opening 152 or there may be more than one opening 152 in the coupler 150, configured to allow fluid to pass therethrough for subsequent access to the inner diameter of the polymer driveshaft embodiments disclosed herein.

[0072] The descriptions of the embodiments and their applications as set forth herein should be construed as illustrative, and are not intended to limit the scope of the disclosure. Features of various embodiments may be combined with other embodiments and/or features thereof within the metes and bounds of the disclosure. Upon study of this disclosure, variations and modifications of the embodiments disclosed herein are possible, and practical alternatives to and equivalents of the various elements of the embodiments will be understood by and become apparent to those of ordinary skill in the

art. Such variations and modifications of the embodiments disclosed herein may be made without departing from the scope and spirit of the invention. Therefore, all alternatives, variations, modifications, etc., as may become to one of ordinary skill in the art are considered as being within the metes and bounds of the instant disclosure.

CLAIMS**WHAT IS CLAIMED IS:**

1. A rotational atherectomy device comprising:
a prime mover with a prime mover drive shaft operationally connected thereto;
a flexible drive shaft operationally connected with the prime mover drive shaft,
the drive shaft comprising a single polymer layer defining an axial lumen
therethrough and an inner surface that is generally smooth and continuous.
2. The rotational atherectomy device of claim 1, further comprising two polymer
layers consisting of an outer polymer layer and an inner polymer layer, the inner
polymer layer comprising a different polymer than the outer polymer layer and
defining an axial lumen therethrough and an inner surface that is generally smooth
and continuous.
3. The rotational atherectomy device of claim 1, further comprising three layers
consisting of an outer polymer layer, an inner polymer layer, the inner polymer
layer comprising a different polymer than the outer polymer layer and defining an
axial lumen therethrough and an inner surface that is generally smooth and
continuous, and a middle metallic layer disposed between the inner and outer
polymer layers.
4. The rotational atherectomy system of claim 3, further comprising a marker band
comprising a wall and fixedly attached to, and at least partially surrounds, the
middle metallic layer.
5. The rotational atherectomy system of claim 4, further comprising a tool fixedly
attached to the marker band.
6. The rotational atherectomy system of claim 5, wherein the tool comprises an
abrasive element.
7. The rotational atherectomy system of claim 4, the marker band further comprising
at least one perforation through the wall of the marker band.
8. The rotational atherectomy system of claim 2, further comprising a marker band
comprising a wall and wherein the marker band is partially embedded within the
outer polymer layer.
9. The rotational atherectomy system of claim 8, further comprising a tool fixedly

- attached to the marker band
10. The rotational atherectomy system of claim 9, wherein the tool comprises an abrasive element.
 11. The rotational atherectomy system of claim 8, the marker band further comprising at least one perforation through the wall of the marker band.
 12. The rotational atherectomy system of claim 1, further comprising a marker band comprising a wall and wherein the marker band is partially embedded within the single polymer layer.
 13. The rotational atherectomy system of claim 12, further comprising a tool fixedly attached to the marker band
 14. The rotational atherectomy system of claim 13, wherein the tool comprises an abrasive element.
 15. The rotational atherectomy system of claim 12, the marker band further comprising at least one perforation through the wall of the marker band.
 16. The rotational atherectomy system of claim 1, further comprising a coupler in operational attachment with the prime mover drive shaft and the drive shaft comprising a single polymer layer and comprising a wall and an axial lumen.
 17. The rotational atherectomy system of claim 16, the coupler further comprising at least one opening through the coupler wall.
 18. The rotational atherectomy system of claim 2, further comprising a coupler in operational attachment with the prime mover drive shaft and the drive shaft comprising two polymer layers and comprising a wall and an axial lumen.
 19. The rotational atherectomy system of claim 3, further comprising a coupler in operational attachment with the prime mover drive shaft and the drive shaft comprising an inner and an outer polymer layer with a middle metallic layer therebetween and further comprising a wall and an axial lumen.
 20. A drive shaft for a rotational device, comprising:
a single polymer layer defining an axial lumen therethrough and an inner surface that is generally smooth and continuous.
 21. A drive shaft for a rotational device, comprising:
two polymer layers consisting of an outer polymer layer and an inner polymer

layer, the inner polymer layer comprising a different polymer than the outer polymer layer and defining an axial lumen therethrough and an inner surface that is generally smooth and continuous.

22. A drive shaft for a rotational device, comprising:
three layers consisting of an outer polymer layer;
an inner polymer layer, the inner polymer layer comprising a different polymer than the outer polymer layer and defining an axial lumen therethrough and an inner surface that is generally smooth and continuous; and
a middle metallic layer disposed between the inner and outer polymer layers.

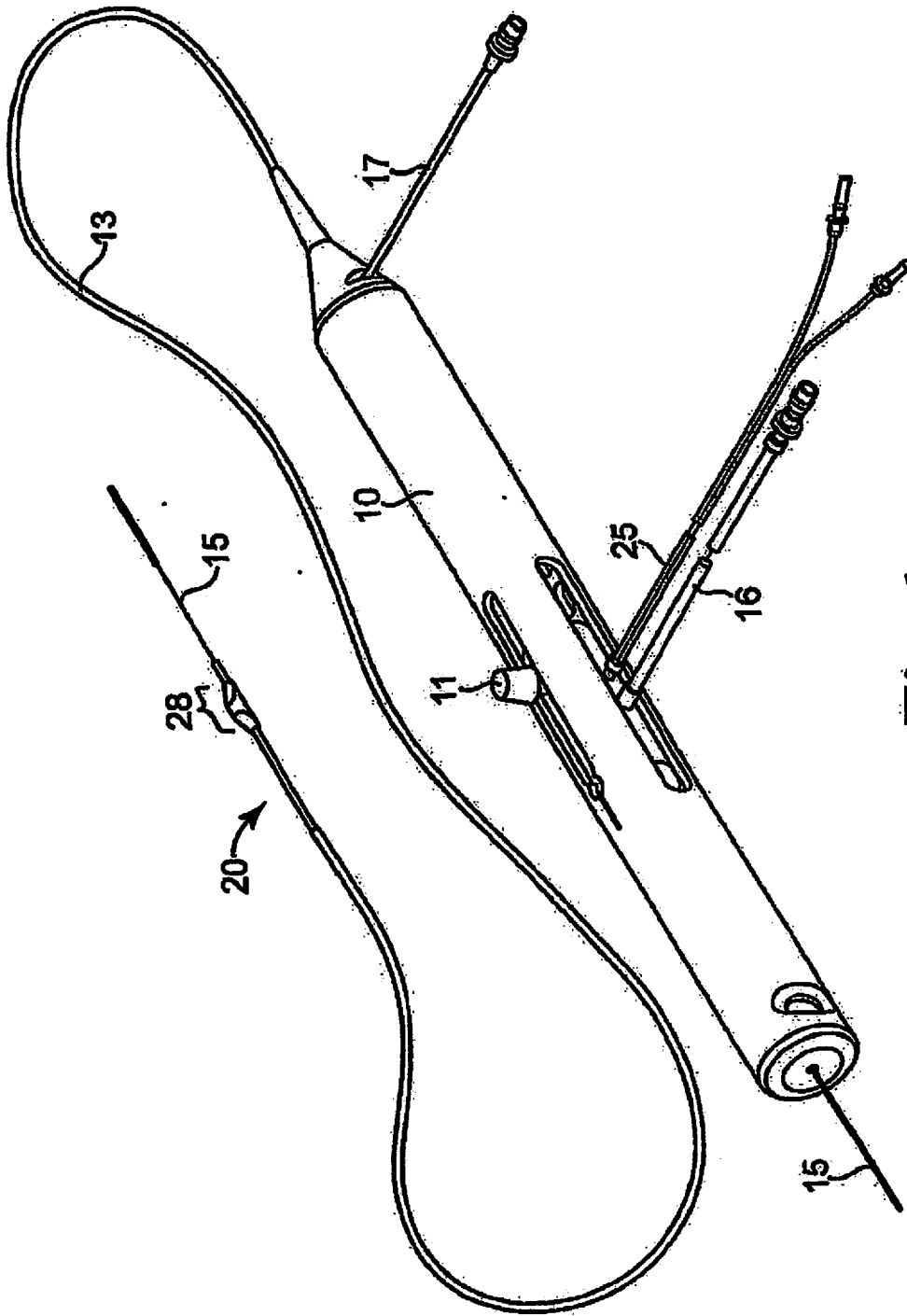


Fig. 1

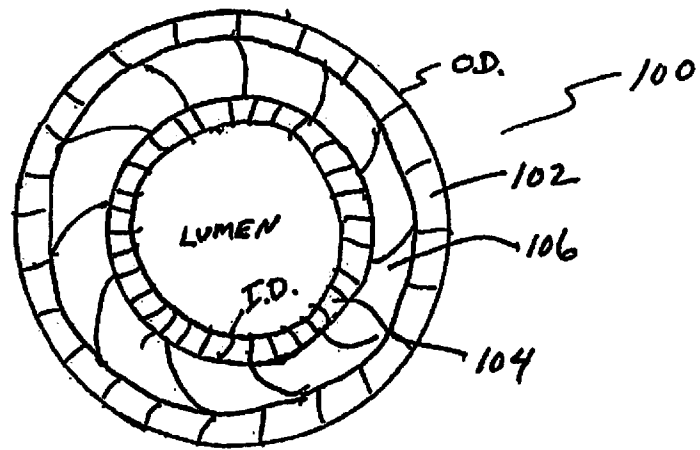


FIG. 2

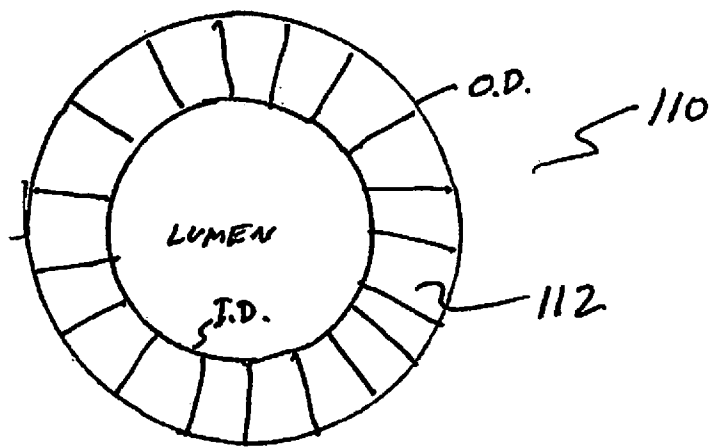


FIG. 3A

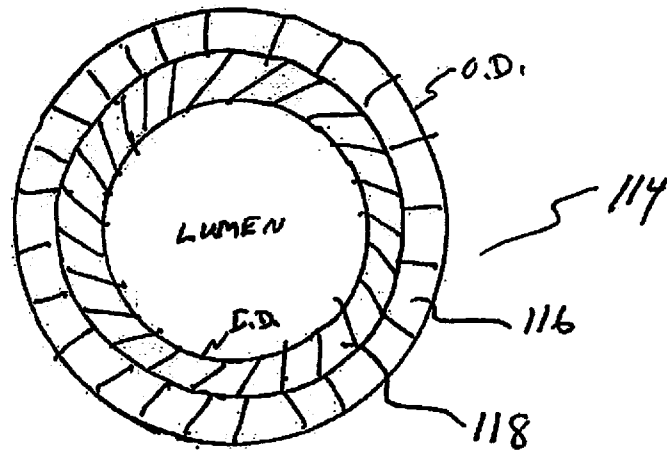
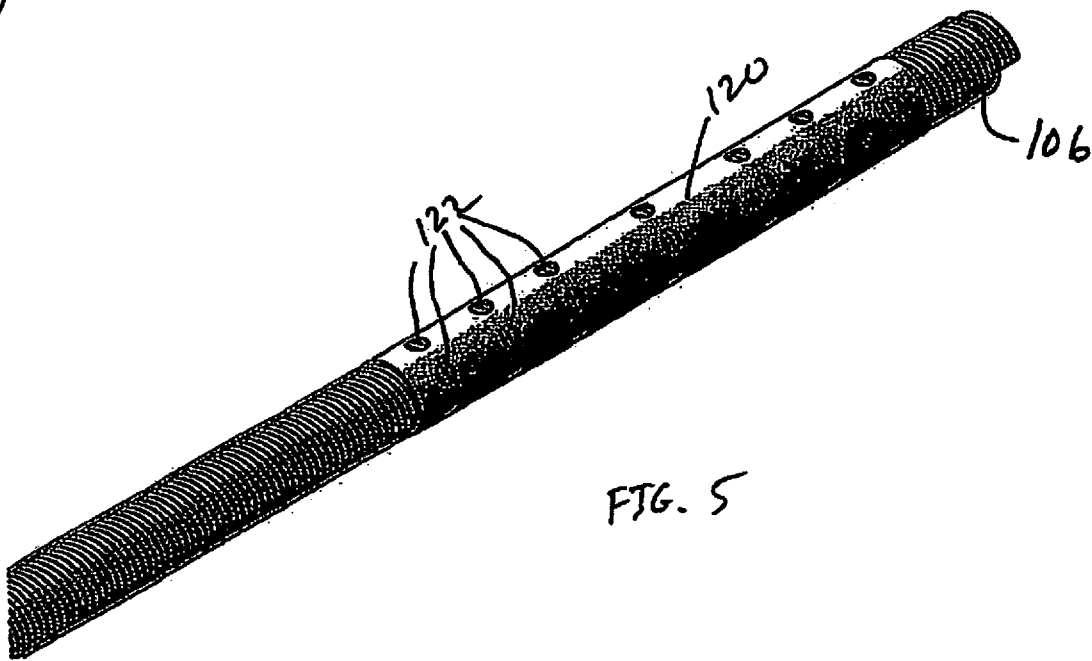
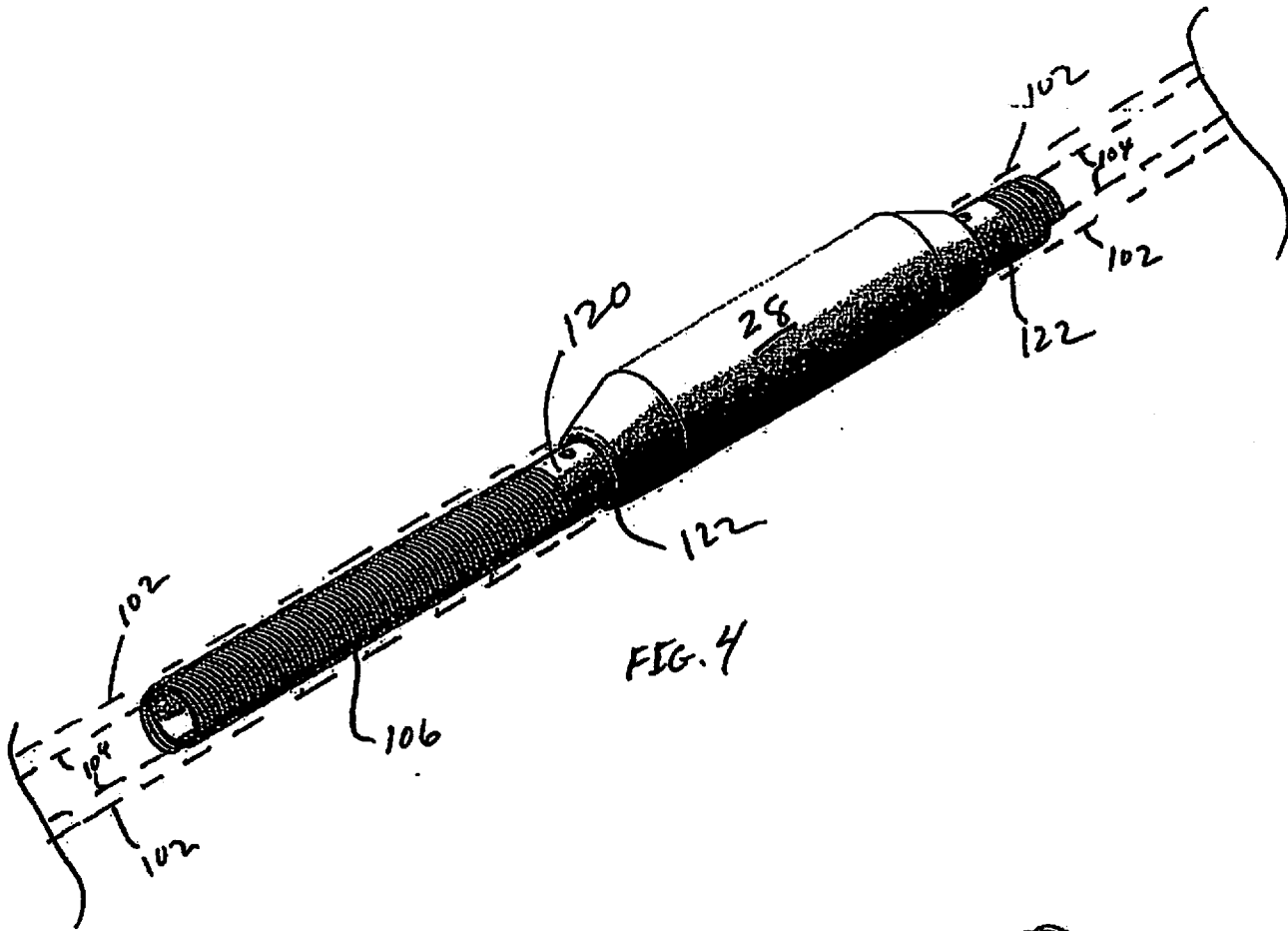


FIG. 3B



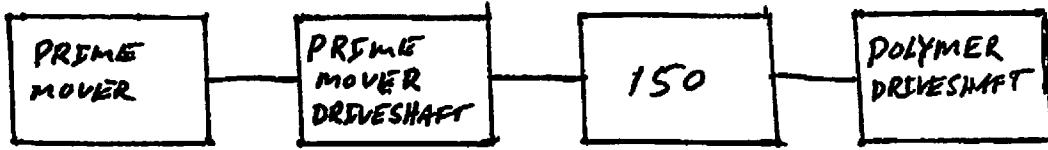


FIG. 6

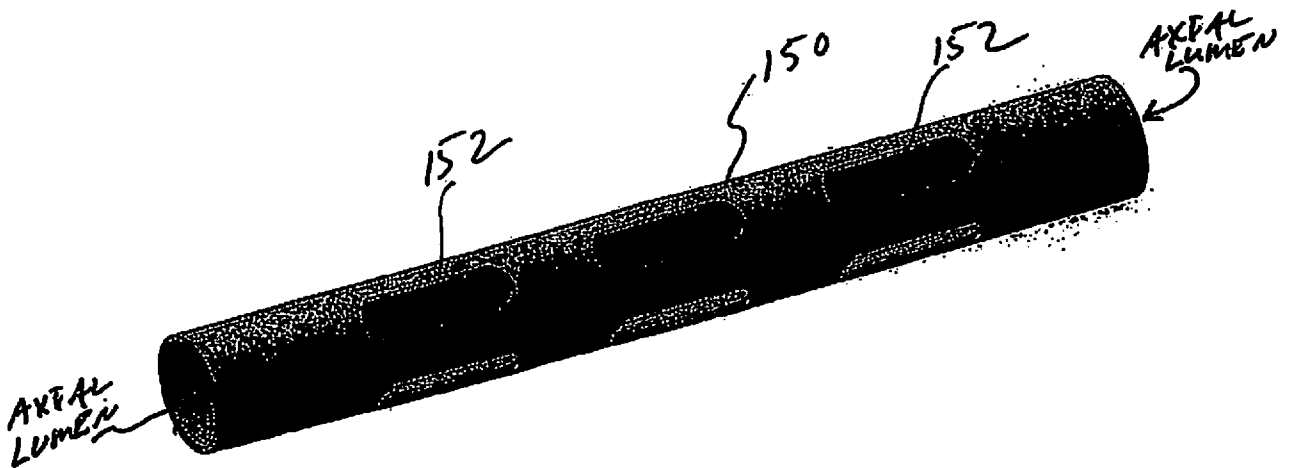
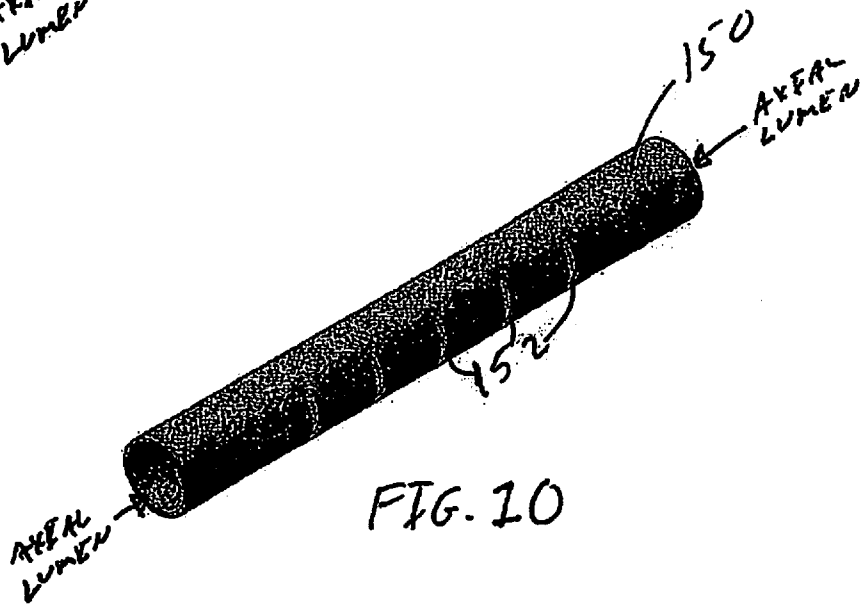
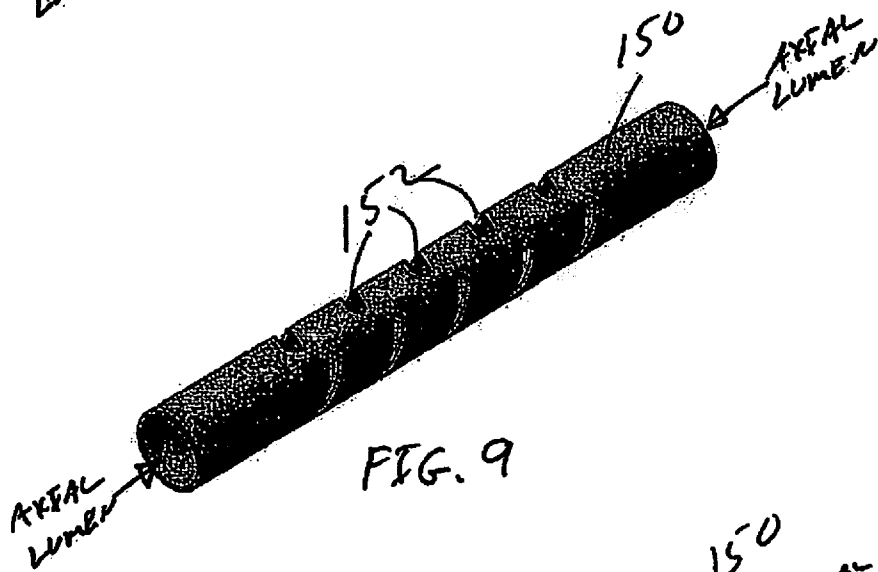
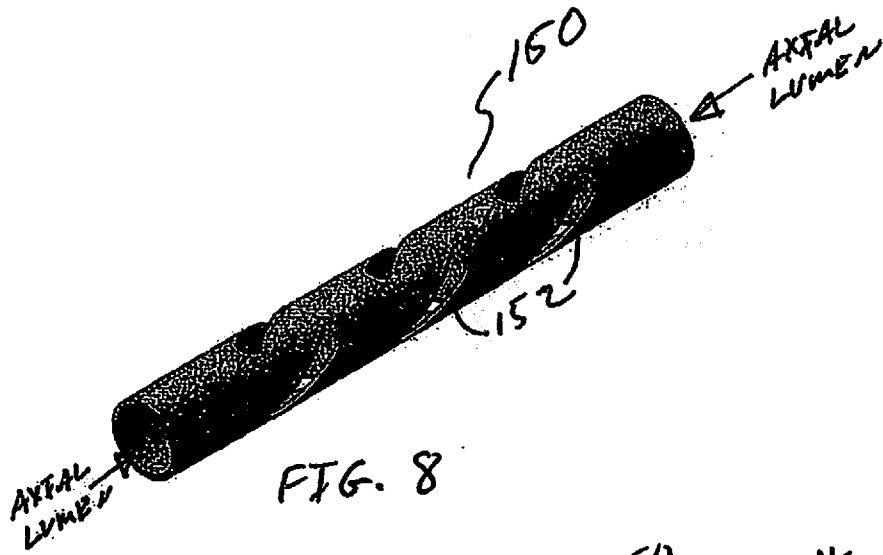


FIG. 7



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 16/35129

<p>A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - A61B 17/22 (2016.01) CPC - A61B 17/320758, A61B 17/3207, A61B 17/22, A61B 17/32 According to International Patent Classification (IPC) or to both national classification and IPC</p>																							
<p>B. FIELDS SEARCHED</p> <p>Minimum documentation searched (classification system followed by classification symbols) IPC (8) A61B 17/22 (2016.01) CPC: A61B 17/320758, A61B 17/3207, A61B 17/22, A61B 17/32</p> <p>Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched IPC (8) A61B 17/32, A61B 17/3207 (2016.01)</p> <p>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) PatBase; Google (Web, Scholar, Patents); Search terms: rotational atherectomy plaque removing driveshaft drive shaft polymer coupler attachment connection join first second layer flexible device apparatus system catheter tool one two more vessel arterial atherosclerosis proximal distal metallic marker band removal motor primary sin</p>																							
<p>C. DOCUMENTS CONSIDERED TO BE RELEVANT</p> <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>X -- Y -- A</td> <td>US 5,669,920 A (CONLEY et al.); 23 September 1997 (23.09.1997); entire document, especially Figs. 1, 5; col. 4, in 19-26; col. 10, in 17-27; col. 10, in 30-35.</td> <td>20-22 ----- 1-3, 16 ----- 4-15, 17-19</td> </tr> <tr> <td>Y -- A</td> <td>US 6,053,907 A (ZIRPS); 25 April 2000 (25.04.2000); entire document, especially Figs. 1, 4; Abstract.</td> <td>1-3, 16 ----- 4-15, 17-19</td> </tr> <tr> <td>A</td> <td>US 7,479,147 B2 (HONEYCUTT et al.); 20 January 2009 (20.01.2009); entire document.</td> <td>1-22</td> </tr> <tr> <td>A</td> <td>US 2012/0109171 A1 (ZERONI et al.); 3 May 2012 (03.05.2012); entire document.</td> <td>1-22</td> </tr> <tr> <td>A</td> <td>US 5,816,923 A (MILO); 6 October 1998 (06.10.1998); entire document.</td> <td>1-22</td> </tr> <tr> <td>A</td> <td>US 2014/0277010 A1 (WEBER et al.); 18 September 2014 (18.09.2014); entire document.</td> <td>1-22</td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X -- Y -- A	US 5,669,920 A (CONLEY et al.); 23 September 1997 (23.09.1997); entire document, especially Figs. 1, 5; col. 4, in 19-26; col. 10, in 17-27; col. 10, in 30-35.	20-22 ----- 1-3, 16 ----- 4-15, 17-19	Y -- A	US 6,053,907 A (ZIRPS); 25 April 2000 (25.04.2000); entire document, especially Figs. 1, 4; Abstract.	1-3, 16 ----- 4-15, 17-19	A	US 7,479,147 B2 (HONEYCUTT et al.); 20 January 2009 (20.01.2009); entire document.	1-22	A	US 2012/0109171 A1 (ZERONI et al.); 3 May 2012 (03.05.2012); entire document.	1-22	A	US 5,816,923 A (MILO); 6 October 1998 (06.10.1998); entire document.	1-22	A	US 2014/0277010 A1 (WEBER et al.); 18 September 2014 (18.09.2014); entire document.	1-22
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<p>Date of the actual completion of the international search 21 July 2016</p>		<p>Date of mailing of the international search report 25 AUG 2016</p>																					
<p>Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300</p>		<p>Authorized officer: Lee W. Young</p> <p>PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774</p>																					