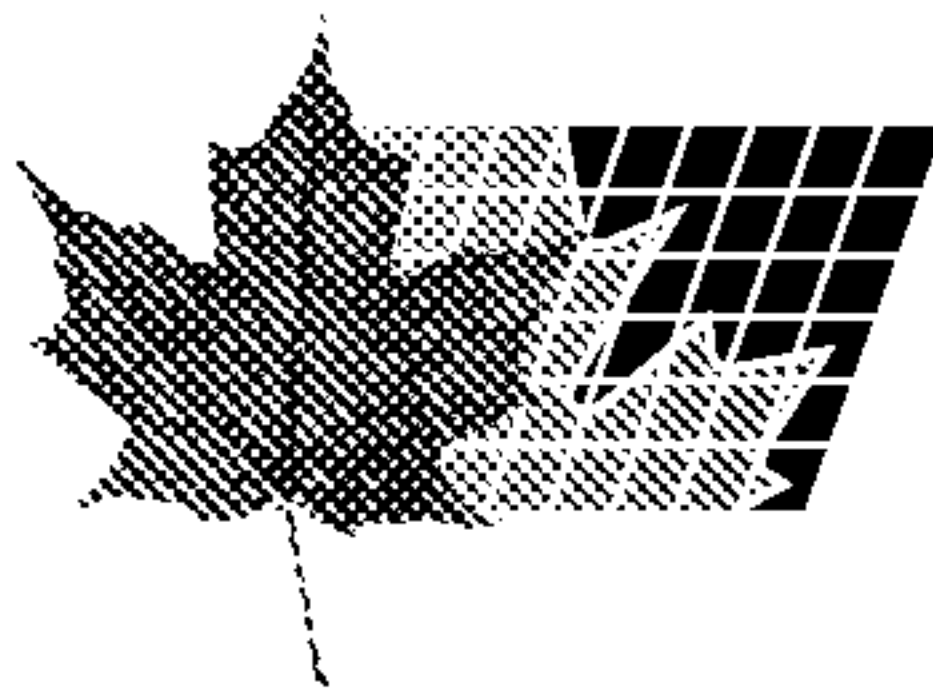




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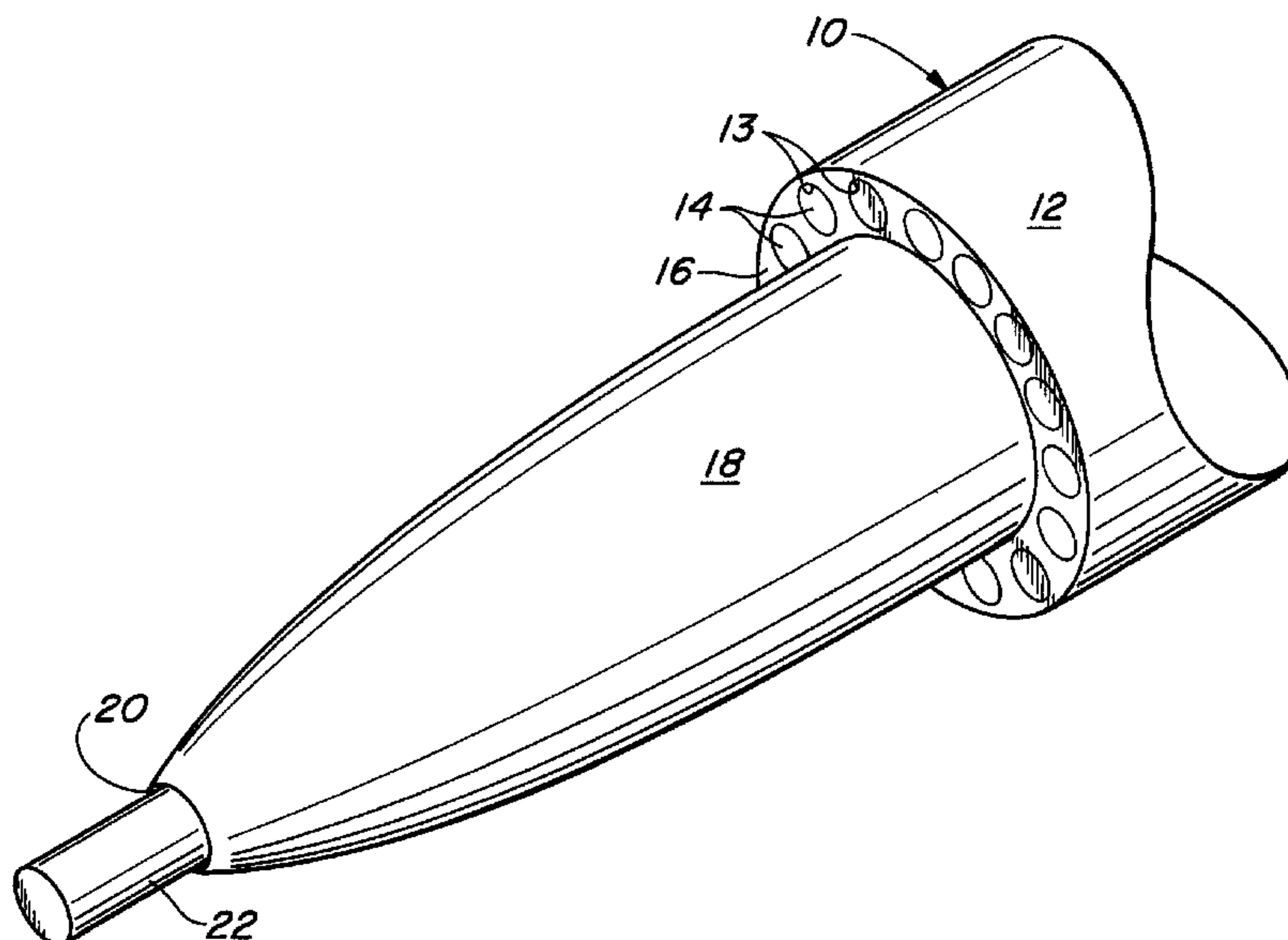
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(54) **METHODE ET APPAREIL POUR ENLEVER LES SUBSTANCES
OBSTRUANTES DANS LES ORIFICES CORPORELS**

(54) **METHOD AND APPARATUS FOR REMOVAL OF
OBSTRUCTIVE SUBSTANCES FROM BODY CHANNELS**



(57) A catheter device and a method for using same to facilitate removal of obstructive material in a human body channel. The catheter comprises an elongated body with a distal end portion adapted to be inserted within the channel and a proximal end portion. A lumen, extending lengthwise through said catheter body, supports a guidewire having a distal end along which the catheter body can be moved within the channel. A series of parallel, closely spaced fiber members extend through the catheter body from its proximal end and terminate near a distal end face of said catheter. Laser energy supplied at the catheter's proximal end is transmitted along the fiber members and is emitted forwardly therefrom at the catheter's distal end face. In one embodiment the catheter has a tapered nose portion for displacing obstructive material in the body channel before the emission of laser energy. In another embodiment, the fiber members are movable longitudinally in unison to sever and trap obstructive material which is removed from the body channel.

1 Abstract of the Disclosure

2

3 A catheter device and a method for using same to

4 facilitate removal of obstructive material in a human body

5 channel. The catheter comprises an elongated body with a

6 distal end portion adapted to be inserted within the

7 channel and a proximal end portion. A lumen, extending

8 lengthwise through said catheter body, supports a guidewire

9 having a distal end along which the catheter body can be

10 moved within the channel. A series of parallel, closely

11 spaced fiber members extend through the catheter body from

12 its proximal end and terminate near a distal end face of

13 said catheter. Laser energy supplied at the catheter's

14 proximal end is transmitted along the fiber members and is

15 emitted forwardly therefrom at the catheter's distal end

16 face. In one embodiment the catheter has a tapered nose

17 portion for displacing obstructive material in the body

18 channel before the emission of laser energy. In another

19 embodiment, the fiber members are movable longitudinally in

20 unison to sever and trap obstructive material which is

21 removed from the body channel.

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Method and Apparatus for Removal of Obstructive
Substance from Body Channels

Specification

This invention relates to methods and apparatus for removing substances or matter which cause obstructions, blockages or occlusions in body passages, channels or ducts such as arteries or veins.

Background of the Invention

Although body channel obstructions such as blocked arteries have been treated heretofore using surgical arteriotomy techniques as well as with medicines for dissolving certain obstructive substances, a substantial effort has been made to perfect so-called minimally invasive techniques using catheter-based systems. In such systems, the artery is entered at a site remote from the obstruction so that elongated devices can be guided through the arterial system to the desired site. Such devices have included a catheter with a tapered tip which was pushed through the area of obstruction using a so-called Dotter technique or a catheter with an inflatable balloon near its distal tip for using the balloon angioplasty technique.

Other mechanical means of opening arteries include the use of rapidly rotating elements, for example the "Auth" technique which is an elongated device with a rotating diamond studded tip which grinds the obstructing material as it advances within the artery, or the "Fischell" technique which slices the blockage as it is

1 withdrawn from the artery, or the "Stack" or Kensey
2 techniques which use elongated catheters with rotating
3 blades to chop the obstructing material, or the "Simpson"
4 technique which is an elongated catheter that slices the
5 obstruction at the side of the distal tip of the device.
6

7
8 Thermal and laser energy have also been used to
9 open obstructed arteries. The "hot tip" technique utilizes
10 thermal energy generated by electrical, chemical or laser
11 to heat the tip of an elongated catheter which then
12 vaporizes or melts the area of obstruction as it is
13 advanced through the artery. Direct laser energy can be
14 transmitted through elongated fiberoptic catheters to the
15 site of obstruction in order to vaporize the obstruction.
16

17 To date, the mechanical means of removing
18 obstructions from arteries are associated with formation of
19 debris which flows downstream and blocks more distal
20 vessels or with high frequency of closure of the artery
21 after the procedure ranging from 25% to 50% in the case of
22 the Auth, Simpson, balloon angioplasty, and related
23 techniques. The cause of the reclosure is thought to be
24 related to the mechanical damage to underlying healthy
25 tissue and to the internal surface characteristics produced
26 by the mechanical procedures. Attempts have been made to
27 use laser energy or thermal energy after the mechanical
28 techniques to improve the damaged surface characteristics
29 and to weld any defects in the artery wall caused by the
30 initial mechanical procedures.
31

32 Attempts have also been made to combine the use
33 of laser energy with an angioplasty catheter to remove
34 arterial obstructions as disclosed by Leckrone in U.S.
35 Patent Nos. 4,685,458 and 4,747,405. In these patents, a
36 catheter having an attached inflatable balloon is provided
37
38

1 with laser transmission filaments for ablating or
2 dissolving obstructive material in an arterial passage.
3

4 One object of the present invention is to provide
5 an improved catheter device for treating obstructions or
6 blockages in body channels which combines the use of
7 mechanical force thereof for displacing or compressing
8 blockage material and manipulations with laser energy for
9 dissolving or severing the blockage material.
10

11 Another object of the invention is to provide a
12 catheter device for removing obstructions in body channels
13 that enables the use of a reduced amount of laser energy
14 directed so as to sever rather than dissolve the
15 obstructing material, thereby reducing the danger of
16 damaging healthy bodily tissue.
17

18 Another object of the invention is to provide a
19 catheter device for removing obstructions in body channels
20 that enables particles of removed obstructive material in
21 body channels such as arteries to be trapped and retrieved,
22 rather than allowed to fall into the fluid stream of the
23 body channel.
24

25 Yet another object of the invention is to provide
26 a catheter device for removing obstructions in body
27 channels that is readily controllable and maneuverable in
28 use to provide for efficient removal of body channel
29 obstructions without damage to healthy tissue and thus with
30 minimum risk to the patient.
31

32 Summary of the Invention

34 In accordance with the principles of the present
35 invention both mechanical and laser elements are combined
36 in a catheter type device to dissolve, breakup and remove
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obstructive material from various body channels. Moreover, the removal process with my device may be accomplished with a minimal risk to healthy body components such as artery walls because the laser energy is directed so as to reduce the force
5 required to remove obstructive material or to stretch the artery under treatment. Lower force requirements in expanding an opening in an arterial channel result in less damage to surrounding healthy tissues, and the laser simultaneously treats the internal arterial surface to achieve a smoother arterial
10 lumen.

The invention provides a catheter device for removing an obstruction in a human body channel, said device comprising: a catheter having an elongated body with a distal end portion
15 adapted to be inserted within a channel and a proximal end portion, said catheter body comprising a forwardly extending tapered nose member at its distal end, said nose member having a large end whose diameter is smaller than the diameter of said catheter body, thereby forming an annular distal end face of
20 said catheter body surrounding said large end of said nose member; a lumen extending lengthwise through said catheter body; a guidewire having a distal end extending through said catheter lumen and longitudinally through said nose member beyond the catheter's distal end; expandable means mounted on said
25 guidewire near its distal end and means for controlling said expandable means at said proximal end portion; a series of fiber members extending through said catheter body, said fiber members being parallel and having distal ends that are closely spaced at said annular distal end face of said catheter and extending to
30 its proximal end: laser means connected to said fiber members near the proximal end of said catheter for delivering laser

energy through said fiber members and forwardly therefrom at said catheter end face.

5 The invention also provides a catheter device for removing an obstruction in a human body channel, said device comprising: a catheter having an elongated body with a distal end portion adapted to be inserted within a channel and a proximal end portion; a lumen extending lengthwise through said catheter body; a guidewire having a distal end extending through
10 said catheter lumen and beyond the catheter's distal end; expandable means mounted on said guidewire near its distal end and means for controlling said expandable means at said proximal end portion; a series of fiber members extending through said catheter body, said fiber members being parallel and closely
15 spaced near a distal end face of said catheter and extending to its proximal end; laser means connected to said fiber members near the proximal end of said catheter for delivering laser energy through said fiber members and forwardly therefrom at said catheter end face; and wherein said catheter body comprises
20 an annular outer portion containing said fiber members and forming a central bore and a tubular lumen within said central bore for said guidewire and a plurality of radial web members interconnecting said annular portion and said lumen.

25 The invention also provides a catheter device for removing an obstruction in a human body channel, said device comprising: a catheter having an elongated body with a distal end portion adapted to be inserted within a channel and a proximal end portion; a lumen extending lengthwise through said
30 catheter body; a guidewire having a distal end extending through said catheter lumen and beyond the catheter's distal end;

expandable means mounted on said guidewire near its distal end and means for controlling said expandable means at said proximal end portion; a series of fiber members extending through said catheter body, said fiber members being parallel and closely spaced near a distal end face of said catheter and extending to its proximal end; laser means connected to said fiber members near the proximal end of said catheter for delivering laser energy through said fiber members and forwardly therefrom at said catheter end face; and wherein said distal end portion of said catheter body has an open compartment on one side defined by an outer transverse face spaced from an inner transverse face, a tapered nose portion on said body extending forwardly from said outer face and a narrowed body portion interconnecting said inner and outer faces, said fiber members terminating at spaced apart location on said inner face and means at said proximal end for moving said fiber members within said catheter body, so that the distal ends of said fiber members can be moved forwardly from said inner face to said outer face as said laser means is activated.

The invention further provides a catheter device for removing an obstruction in a human body channel, said device comprising: a catheter having an elongated body with a distal end adapted to be inserted within a channel and a proximal end, a forwardly extending tapered nose member having a large end attached to said distal end portion of said body and a smaller distal end; a lumen extending lengthwise through said catheter body and said nose member; a guidewire having a distal end extending through said catheter lumen and beyond said nose member; a series of fiber members extending through said catheter body, said fiber members being parallel to the longitudinal axis of said catheter body and terminating at

spaced apart locations on an annular distal end face of said catheter surrounding the inner large end of said nose member, said fiber members extending to the proximal end of said catheter body and;

5 laser means connected to said fiber members near the proximal end of said catheter for delivering laser energy through said fiber members and forwardly therefrom at said circular distal catheter end face, whereby movement of said catheter body through a channel obstruction causes said nose member to
10 mechanically force obstructing material radially outwardly toward the wall of said channel and closer to said annular end face of said catheter body so that laser energy directed through said fibers will impinge directly upon and dissolve said obstructive material.

15

The invention still provides a catheter device for removing an obstruction in a human body channel, said device comprising: a catheter having an elongated body with a distal annular end portion surrounding a central bore and a proximal
20 end portion; a lumen extending lengthwise through said catheter body; a guidewire having a distal end extending through said catheter lumen and beyond the catheter's distal end; an inflatable bladder mounted on said guidewire near its distal end and means for controllably inflation said bladder at said
25 proximal end portion; a series of parallel, closely spaced fiber members extending within said annular end portion of said catheter body from a distal end face thereof to its proximal end; laser means connected to said fiber members near the proximal end of said catheter for delivering laser energy
30 through said fiber members and forwardly therefrom at said catheter end face in a cylindrical pattern, whereby as said laser means is activated to sever said obstructing material near

the wall of said channel, said bladder is moved closer to said distal annular end portion of said body so that separated material is trapped and retained within said central bore.

1
2 Other advantages and features of the invention will
3 become apparent from the following detailed description of the
4 embodiments which is presented in conjunction with the
5 accompanying drawing.
6

7
8 Brief Description of the Drawing

9 Fig. 1 is an enlarged fragmentary view in
10 perspective showing the distal end of one form of catheter
11 device according to the invention
12

13 Fig. 1A is a front end view of the device shown
14 in Fig. 1 and taken along line 1A-1A of Fig. D.
15

16 Figs. 2A-2D are a series of elevation views in
17 section showing the device of Fig. 1 in a typical operation
18 within a body channel.
19

20 Fig. 3 is an enlarged fragmentary view in
21 perspective showing the distal end of another form of
22 catheter device according to the invention.
23

24 Fig. 3A is an enlarged view in section of the
25 embodiment of Fig. 3, taken along the line 3A-3A of Fig.
26 4A.
27

28 Fig. 3B is an enlarged view in section of the
29 embodiment of Fig. 3, having an off-center guidewire lumen.
30

31 Figs. 4A-4E are a series of elevation views in
32 section showing the embodiment of Fig. 3 in a typical
33 operation within a body channel.
34

35 Fig. 5 is an enlarged fragmentary view in
36 perspective showing the distal end of another form of
37
38

1 catheter embodying principles of the present invention.
2

3 Fig. 5A is a view in section of the device of
4 Fig. 5, taken along line 5A-5A of Fig. 6A.
5

6 Figs. 6A-6C are a series of elevation views in
7 section showing the device of Fig. 5 as it appears during
8 a typical operation within a body channel.
9

10 Fig. 7 is an enlarged fragmentary view in
11 perspective showing the distal end of another form of
12 catheter embodying principles of the invention.
13

14 Figs. 8A-8C are a series of elevation views in
15 section showing the catheter of Fig. 7 as it appears during
16 a typical operation within a body channel.
17

18 Fig. 9 is a view in section showing the proximal
19 end for a catheter device according to the invention.
20

21
22 Detailed Description of Embodiments

23 In broad terms, the present invention provides a
24 catheter device adapted to be moved through a body channel
25 while using a combination of mechanical force and laser
26 energy to remove, dissolve and/or retrieve obstructive
27 material in the channel. Such body channels may be
28 arteries, veins, ducts or passages although the following
29 description of embodiments will refer primarily to use of
30 the invention in arteries for the removal of plaque
31 deposits.
32

33 With reference to the drawing, a first catheter
34 device 10, embodying principles of the invention is shown
35 in Figs. 1, 1A and 2A-2D. In general, this embodiment
36 comprises a cylindrical catheter body 12 of a suitable
37
38

1 flexible plastic material (e.g. polyethylene) having a
2 uniform diameter along its length. Circumferentially
3 spaced near its outer surface are a plurality of lumens 13
4 containing laser transmitting elements 14. These laser
5 elements may be glass fibers having a diameter in the range
6 of one to six hundred microns each. At the distal end of
7 catheter 10, the exposed ends of the elements 14 are close
8 together or contiguous and thus terminate at equally spaced
9 apart intervals of less than the diameter of a fiber
10 element around an annular end face 16. The elements thus
11 form an annular ring which encircles the inner end of a
12 conical nose member 18 on the catheter 10. This nose
13 member may be of the same material as the catheter body and
14 for best results, it has a length that is approximately
15 three or four times the maximum diameter at its inner end.
16 The nose member is either attached to or is made as an
17 extended integral part of the catheter 10. Extending
18 through the nose member and the entire length of the
19 catheter is a central lumen 20 within which a conventional,
20 movable guidewire 22 is supported. As shown in Fig. 3A,
21 the catheter body may have an annular configuration with a
22 central guidewire lumen 20 that is concentrically supported
23 within the catheter body by internal transverse web members
24 24, or the catheter body may be essentially a solid member
25 with appropriate lumen passages for the guidewire and the
26 laser transmitting elements 14.

27
28
29 A typical operation using the catheter 10 for
30 removing an obstruction 26 in a lumen body channel 28 is
31 illustrated in Figs. 2A-2D. In many instances, the body
32 channel will be an artery and the obstruction 26 is
33 typically an accumulation of plaque. As a first step in
34 the operative procedure, the guidewire 22 is inserted into
35 the patient's body channel or artery 28 and using
36 conventional fluoroscopic procedures, its distal end is

1 moved through and beyond the obstruction 26. Now, the
2 catheter 10 is installed around the guidewire 22 and is
3 moved along it through the artery until its nose member 18
4 reaches the obstruction, as shown in Fig. 2A. At this
5 point, a somewhat increased axial force is applied to the
6 catheter, if necessary, in order to push well into the
7 obstruction zone so that the ends of the glass fibers 14
8 are relatively close to the obstruction material. As shown
9 in Fig. 2B, the nose member may actually push the
10 obstruction material radially outwardly and compress it
11 slightly so that it is compacted directly in front of the
12 fiber ends 14. The tapered nose member allows this to be
13 done with minimal stretching of the artery wall. Now, with
14 the catheter positioned as shown in Fig. 2B, the laser
15 energy source at the proximal end of the catheter is
16 activated, preferably in a series of pulses, so that laser
17 energy is transmitted from the fiber ends directly into the
18 obstructive material. As the laser energy continues, the
19 obstructive material is dissolved, and the catheter is
20 constantly moved forward at a slow, but sustained rate
21 until the obstruction is substantially fully dissolved.
22 The catheter can then be withdrawn from the patient
23 followed by retraction of the guidewire.
24

25
26 A modified form of catheter 10A embodying
27 principles of the present invention is shown in Fig. 3.
28 This catheter also has an annular body 12A surrounding a
29 central bore 30 with a series of laser transmitting fibers
30 14 circumferentially, closely spaced near its outer
31 surface, all of which terminate around an annular face 16
32 at its distal end. A central lumen 20A as described is
33 provided within the central bore 30 of the catheter body
34 for supporting a guidewire 22A. Here, as shown in Fig. 3A,
35 the guidewire is of the type having an air conduit 32 or
36 some suitable mechanism along its length which may be
37
38

1 connected to either an inflatable balloon 34 or to some
2 mechanically expandable element near the distal end of the
3 guidewire. The balloon, if used, is of a size which is
4 inflatable to a diameter slightly larger than the central
5 bore 30 of the catheter body.
6

7
8 If desired, a lumen 20A for supporting the
9 guidewire 22A may be attached off-center to one side of the
10 catheter body vase 30, as shown in Fig. 3B. This
11 arrangement provides an increased degree of maneuverability
12 for the catheter, particularly where it is desired to move
13 it closer to one side of a body channel.
14

15 At or near the proximal end of the catheter body
16 10 and 10A the glass fibers 14 which are separate, but
17 closely spaced at the distal end of the catheter body, are
18 brought together in one fiber bundle 36. A laser
19 transmission system is then used, as shown in Fig. 9 to
20 transmit laser energy from a suitable generator source 38
21 through a single transmission element 40 and a connector 42
22 into the bundle of fibers and thence through the separate
23 fibers 14 within the catheter body 12. Extending beyond
24 the proximal end of the catheter body is the movable,
25 controllable guidewire 22.
26

27 A typical operation utilizing the catheter 10A in
28 a human artery having a blockage or obstruction 26 is shown
29 in the Figs. 4A-4E. As previously described relative to
30 catheter 10, the guidewire 22A having an expandable element
31 such as a balloon 34 near its distal end is moved through
32 the artery 28 being treated to a point just beyond the
33 obstruction 26. The balloon on the guidewire is now
34 inflated to a diameter somewhat less than the artery
35 diameter but greater than the opening through the arterial
36 obstruction. Now, the catheter is installed around the
37
38

1 guidewire at its proximal end and is moved along it through
2 the artery until its annular end face is directly adjacent
3 the obstruction material (Fig. 4B). As the catheter is
4 continuously forced forwardly at a slow rate the laser
5 energy source at its proximal end is activated. Laser
6 energy thus passes through the fibers 14 and exits from its
7 annular end face 16 directly upon the obstructive material
8 (e.g. plaque), as shown in Fig. 4C. As the distal end of
9 the catheter 10A is moved forwardly through the obstructive
10 material, its end face 16 moves closer to the inflated
11 balloon. Although a portion of the obstructive material is
12 dissolved by the laser energy, the multiple laser beams
13 from the cylindrical pattern of closely spaced fibers 14
14 may actually sever portions of the obstructive material 26
15 from the artery wall. Thus, as the balloon 34 moves closer
16 to the end of the catheter it may force a larger portion of
17 obstructive material directly into the open bore 30 at the
18 end of the catheter body, as in Fig. 4D. Now, when the
19 catheter body 10A and the guidewire 22A are removed
20 together from the artery, the severed portions of
21 obstructive material remain within the catheter and are
22 also removed from the artery, thereby eliminating or
23 greatly reducing any loose obstructive material from the
24 blood flow in the artery.
25

26
27 In another modified form of the invention as
28 shown in Fig. 5, a catheter body 10B is provided with a
29 tapered nose portion 38 spaced from an arcuate end face 40
30 of the catheter and connected by a portion 42 of the
31 catheter body to form an open compartment 44 at its distal
32 end. The compartment is open on one side of the
33 cylindrical catheter body and its length is preferably
34 somewhat larger than the diameter of the catheter. The
35 arcuate end face 40 of the catheter includes the exposed
36 ends of a series of laser transmitting glass fibers 14. At
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38

1 the other end of the compartment and parallel to the end
2 face 40 is an inner face 46 of the nose portion which has
3 an arcuate indented notch 48 (See Fig.6A). Within the
4 catheter body is a lumen 20B for supporting a movable
5 guidewire 22 as in the previous embodiments.
6

7
8 The closely spaced glass fibers 14 in the
9 catheter body 10B are also supported in separate lumens 13
10 and are longitudinally movable within these lumens.
11

12 In the operation of catheter 10B, as shown in
13 Figs. 6A-6C, the guidewire 22 is installed in the
14 conventional manner within the body channel being treated.
15 As shown in Fig. 6A, the guidewire is first moved beyond
16 the channel obstruction that is to be removed. Thereafter,
17 the catheter 10B is installed on the guidewire, is moved
18 along it and through the body channel until the distal end
19 is positioned directly opposite the obstruction. Here the
20 guidewire is offset to one side of the catheter body 12B
21 which helps to maneuver the catheter nose portion 38
22 partially through the obstruction so that the main part of
23 the obstruction material actually extends into the open
24 compartment 44. With the catheter so situated, as shown in
25 Fig. 6A, the fiber members 14 are simultaneously moved
26 forward by an axial force applied to the fiber bundle at
27 the proximal end as a laser energy source at its proximal
28 end provides laser energy to the fibers. As the fibers 14
29 move forward, with pulses of laser energy being emitted
30 from their ends, any obstruction material in their path is
31 dissolved and/or severed as shown in Fig. 6B. When the
32 movable fibers reach the arcuate slot 48 in the inner face
33 of the catheter nose portion 38, the laser energy is turned
34 off, and the severed obstruction material is retained
35 within the compartment 44 which is now closed by the
36 extended series of fibers 14. As shown in Fig. 6C, the
37

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1 catheter 10B with the severed and retained obstruction
2 material and the guidewire 22 are now moved in the reversed
3 direction to withdraw them from the patient's body channel.
4 Again, the body channel obstruction has been removed with
5 a combination of mechanical force and laser energy and a
6 major portion of the severed obstruction material has been
7 removed without allowing it to contaminate the blood or
8 fluid in the body channel.
9

10
11 A somewhat modified catheter 10C similar to the
12 catheter 10B is shown in Fig. 7 wherein a guidewire 22A
13 having an inflatable element such as the balloon 34 is
14 used. As previously described, the distal end of catheter
15 10C includes a tapered nose portion 38 with an open
16 compartment 44 on one side which is closeable by a series
17 of movable, laser transmitting glass fibers 14 in the
18 catheter body 12C. The glass fibers are movable in unison
19 from one inner end face 40 of the catheter compartment to
20 the inner end face 46 of the nose portion 38 which forms
21 the opposite end of the compartment.
22

23 As shown in Figs. 8A-8C, using the catheter 10C,
24 the guidewire 22A is first installed and positioned within
25 a body channel 28 so that the balloon 34 on the guidewire
26 can be inflated just beyond an obstruction 26 located on
27 one side of the body channel, as shown in Fig. 6A. Now,
28 the catheter is moved along the guidewire until the open
29 compartment 44 in the distal end of the catheter is
30 directly opposite the channel obstruction 26. The catheter
31 can be rotated on the guidewire 22A using the known
32 technique so that the catheter is moved laterally closer to
33 the obstruction and the latter projects well into the
34 compartment 44. Now, as with catheter 10B, the fibers 14
35 are moved forwardly in unison at a slow rate as the laser
36 source at the proximal end is energized and laser beams
37
38

1 from the ends of the fibers dissolve and sever the
2 obstruction material. The larger pieces of undissolved
3 obstruction material fall into the compartment 44 and are
4 trapped as the fibers reach the inner face of the nose
5 portion. Thereafter, as shown in Fig. 8C, the balloon 34
6 is deflated, and the entire catheter assembly 10C with its
7 guidewire 22A is carefully removed from the body channel or
8 artery.
9

10
11 From the foregoing it is apparent that the
12 present invention provides a unique catheter system that
13 combines the use of mechanical force, such as dottering,
14 with laser energy to remove obstructions or blockages in
15 body channels with increased efficiency and safety. The
16 combination of mechanical force as described serves to
17 displace the obstructive material directly into the path of
18 the laser beams which are thus highly effective in
19 dissolving and/or severing the obstructive material. The
20 invention also provides for the removal of severed material
21 in lieu of allowing it to be carried away by the channel
22 fluid adds a significant safety feature with respect to the
23 prevention of future blockages in a patient.

24
25 The preferred embodiment described herein is
26 intended to be purely illustrative, and not limiting of the
27 scope of the invention. Other embodiments and variations
28 will be apparent to those skilled in the art and may be
29 made without departing from the essence and scope of the
30 invention as defined in the following claims.

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32 What is claimed is:
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CLAIMS:

1. A catheter device for removing an obstruction in a human body channel, said device comprising:

5 a catheter having an elongated body with a distal end portion adapted to be inserted within a channel and a proximal end portion, said catheter body comprising a forwardly extending tapered nose member at its distal end, said nose member having a large end whose diameter is smaller than the diameter of said
10 catheter body, thereby forming an annular distal end face of said catheter body surrounding said large end of said nose member;

a lumen extending lengthwise through said catheter body;

a guidewire having a distal end extending through said
15 catheter lumen and longitudinally through said nose member beyond the catheter's distal end;

expandable means mounted on said guidewire near its distal end and means for controlling said expandable means at said proximal end portion;

20 a series of fiber members extending through said catheter body, said fiber members being parallel and having distal ends that are closely spaced at said annular distal end face of said catheter and extending to its proximal end:

laser means connected to said fiber members near the
25 proximal end of said catheter for delivering laser energy through said fiber members and forwardly therefrom at said catheter end face.

2. A catheter device for removing an obstruction in a
30 human body channel as described in claim 1 wherein said expandable means is a balloon, said guidewire including an air passage for said balloon to a proximal end.

3. A catheter device for removing an obstruction in a body passage as described in claim 1 or claim 2, wherein said fiber members are spaced apart circumferentially in a circular pattern completely around said catheter body at its distal end face.

4. A catheter device for removing an obstruction in a body passage as described in any one of claims 1 to 3 wherein said fiber members are spaced apart by a distance no greater than one fiber diameter.

5. A catheter device for removing an obstruction in a body passage as described in any one of claims 1 to 4 wherein said conical nose member has a length that is approximately three times its maximum diameter at an inner end.

6. A catheter device for removing an obstruction in a body passage as described in anyone of claims 1 to 5 wherein said fiber members are of glass material having a diameter in the range of 1-600 microns.

7. A catheter device for removing an obstruction in a human body channel, said device comprising:

25 a catheter having an elongated body with a distal end portion adapted to be inserted within a channel and a proximal end portion;

a lumen extending lengthwise through said catheter body;

a guidewire having a distal end extending through said catheter lumen and beyond the catheter's distal end;

expandable means mounted on said guidewire near its distal end and means for controlling said expandable means at said proximal end portion;

a series of fiber members extending through said catheter body, said fiber members being parallel and closely spaced near a distal end face of said catheter and extending to its proximal end;

laser means connected to said fiber members near the proximal end of said catheter for delivering laser energy through said fiber members and forwardly therefrom at said catheter end face; and

wherein said catheter body comprises an annular outer portion containing said fiber members and forming a central bore and a tubular lumen within said central for said guidewire and a plurality of radial web members interconnecting said annular portion and said lumen.

8. The catheter device as described in claim 7 wherein said lumen for said guidewire within said catheter body is fixed within said bore to the inner surface on one inner side of said annular outer portion.

9. The catheter device as described in claim 7 or claim 8 wherein said tubular lumen for said guidewire is concentric with said outer annular portion.

10. A catheter device for removing an obstruction in a human body channel, said device comprising:

a catheter having an elongated body with a distal end portion adapted to be inserted within a channel and a proximal end portion;

a lumen extending lengthwise through said catheter body;

a guidewire having a distal end extending through said catheter lumen and beyond the catheter's distal end;

expandable means mounted on said guidewire near its distal end and means for controlling said expandable means at said
5 proximal end portion;

a series of fiber members extending through said catheter body, said fiber members being parallel and closely spaced near a distal end face of said catheter and extending to its proximal end;

10 laser means connected to said fiber members near the proximal end of said catheter for delivering laser energy through said fiber members and forwardly therefrom at said catheter end face; and

wherein said distal end portion of said catheter body has
15 an open compartment on one side defined by an outer transverse face spaced from an inner transverse face, a tapered nose portion on said body extending forwardly from said outer face and a narrowed body portion interconnecting said inner and outer faces, said fiber members terminating at spaced apart location
20 on said inner face and means at said proximal end for moving said fiber members within said catheter body, so that the distal ends of said fiber members can be moved forwardly from said inner face to said outer face as said laser means is activated.

25 11. A catheter device for removing an obstruction in a body passage as described in claim 10 including an arcuate groove in said outer face of said catheter compartment for receiving the distal ends of said fiber members when they have been moved forwardly from said inner face.

30

12. A catheter device for removing an obstruction in a human body channel, said device comprising:

a catheter having an elongated body with a distal end adapted to be inserted within a channel and a proximal end, a forwardly extending tapered nose member having a large end attached to said distal end portion of said body and a smaller
5 distal end;

a lumen extending lengthwise through said catheter body and said nose member;

a guidewire having a distal end extending through said catheter lumen and beyond said nose member;

10 a series of fiber members extending through said catheter body, said fiber members being parallel to the longitudinal axis of said catheter body and terminating at spaced apart locations on an annular distal end face of said catheter surrounding the inner large end of said nose member, said fiber members
15 extending to the proximal end of said catheter body and;

laser means connected to said fiber members near the proximal end of said catheter for delivering laser energy through said fiber members and forwardly therefrom at said circular distal catheter end face, whereby movement of said
20 catheter body through a channel obstruction causes said nose member to mechanically force obstructing material radially outwardly toward the wall of said channel and closer to said annular end face of said catheter body so that laser energy directed through said fibers will impinge directly upon and
25 dissolve said obstructive material.

13. A catheter device for removing an obstruction in a human body channel, said device comprising:

a catheter having an elongated body with a distal annular
30 end portion surrounding a central bore and a proximal end portion;

a lumen extending lengthwise through said catheter body;

a guidewire having a distal end extending through said catheter lumen and beyond the catheter's distal end;

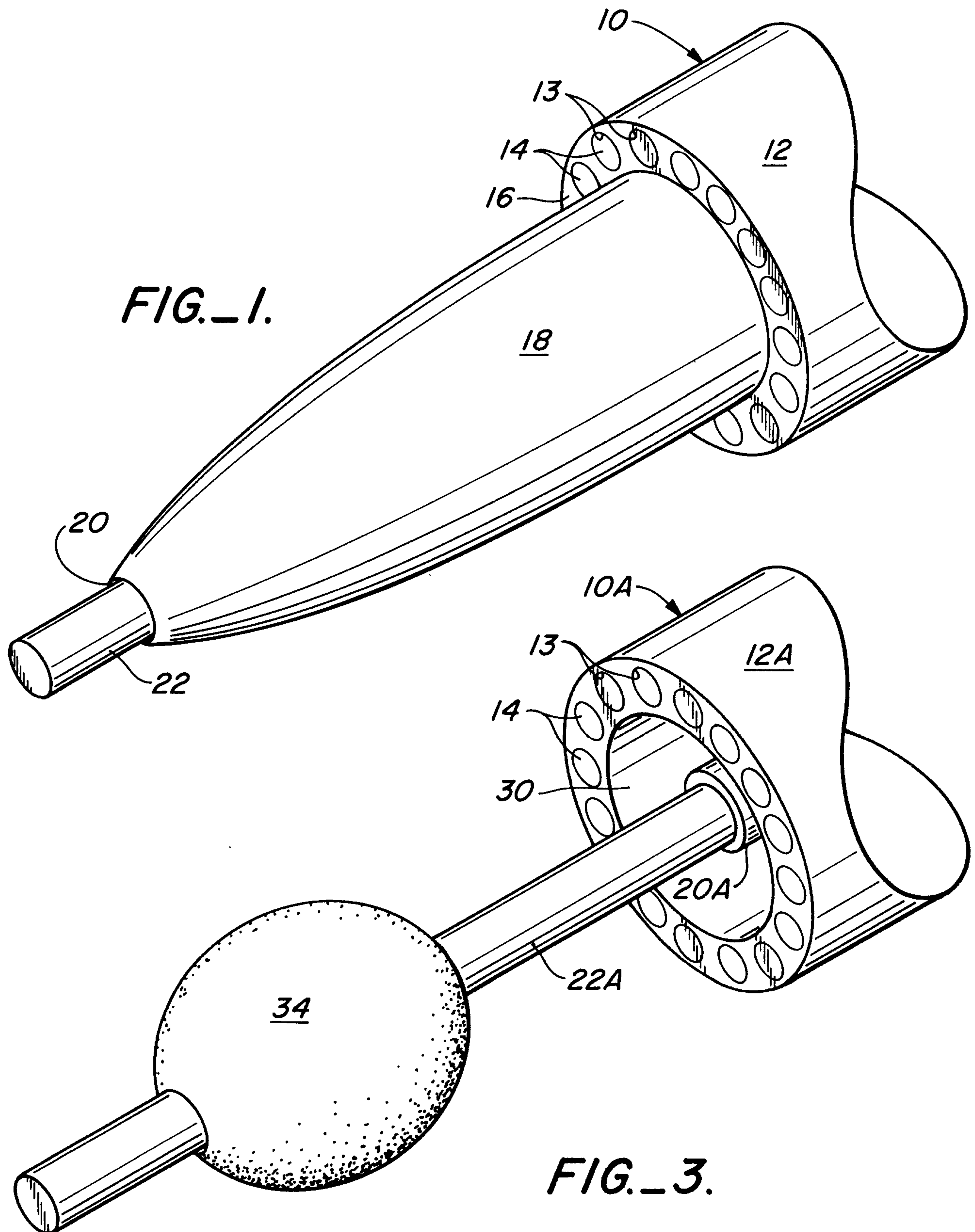
an inflatable bladder mounted on said guidewire near its distal end and means for controllably inflation said bladder at
5 said proximal end portion;

a series of parallel, closely spaced fiber members extending within said annular end portion of said catheter body from a distal end face thereof to its proximal end;

laser means connected to said fiber members near the
10 proximal end of said catheter for delivering laser energy through said fiber members and forwardly therefrom at said catheter end face in a cylindrical pattern, whereby as said laser means is activated to sever said obstructing material near the wall of said channel, said bladder is moved closer to said
15 distal annular end portion of said body so that separated material is trapped and retained within said central bore.

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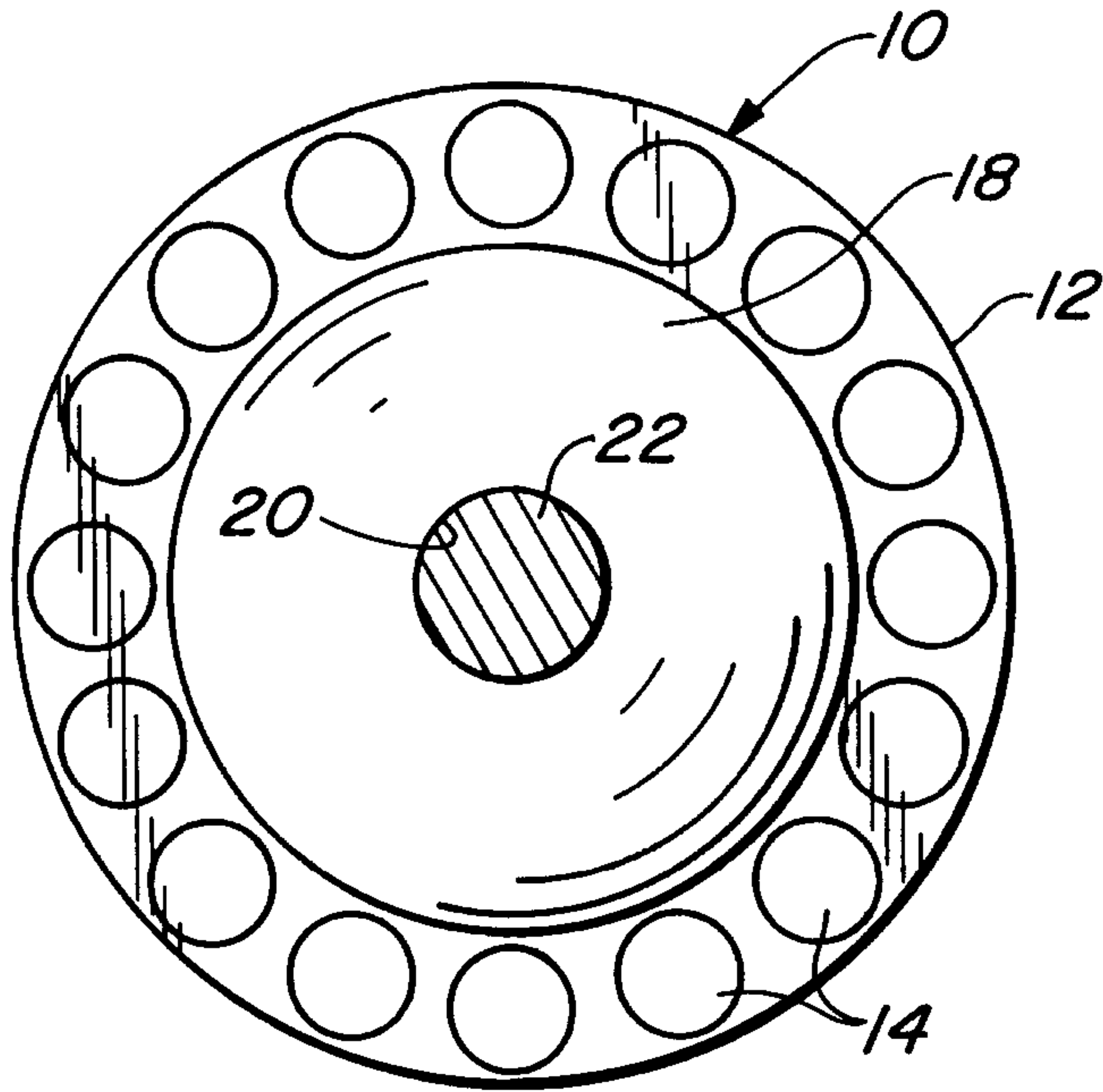


FIG. 1A.

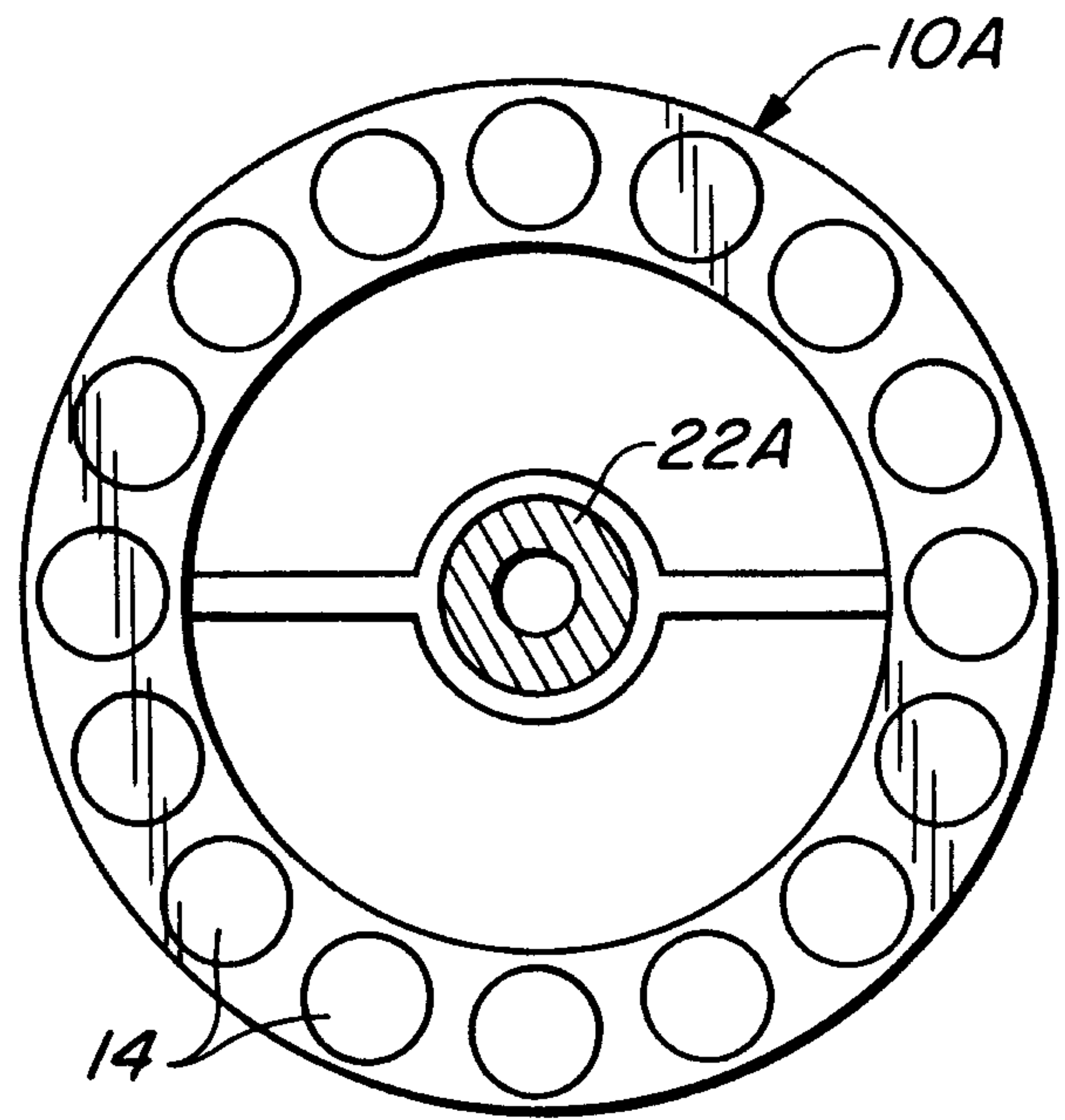


FIG. 3A.

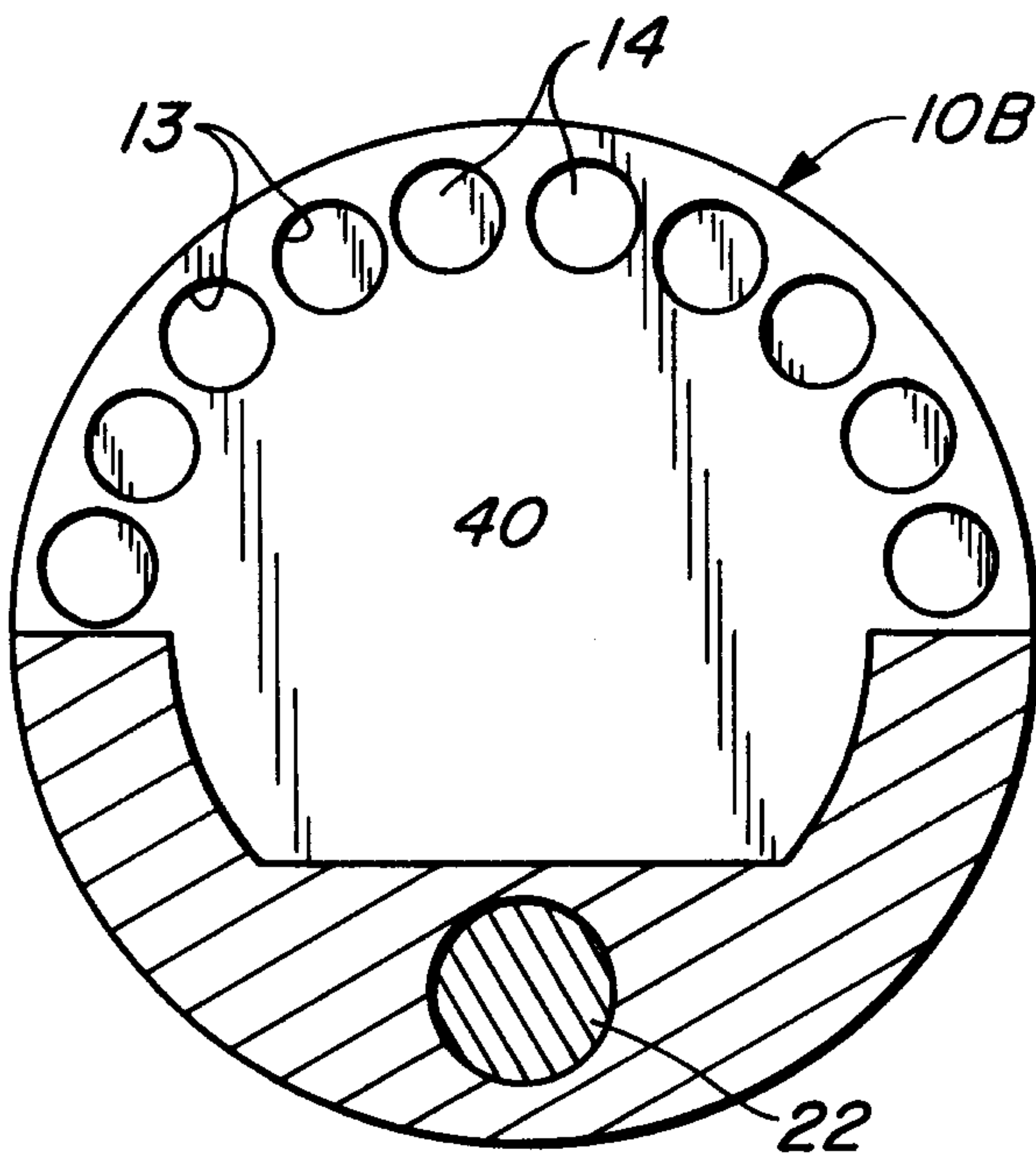


FIG. 5A.

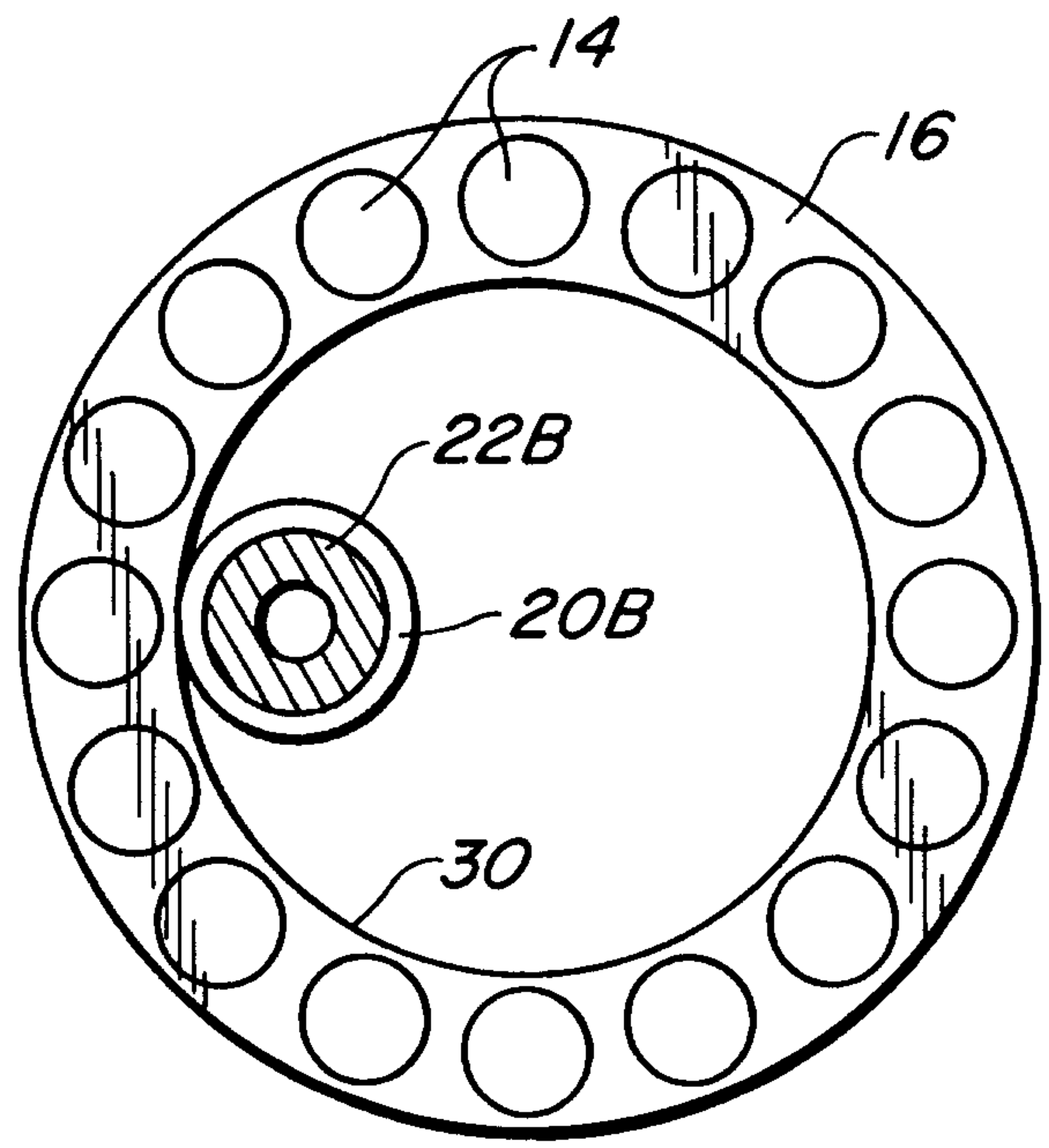


FIG. 3B.

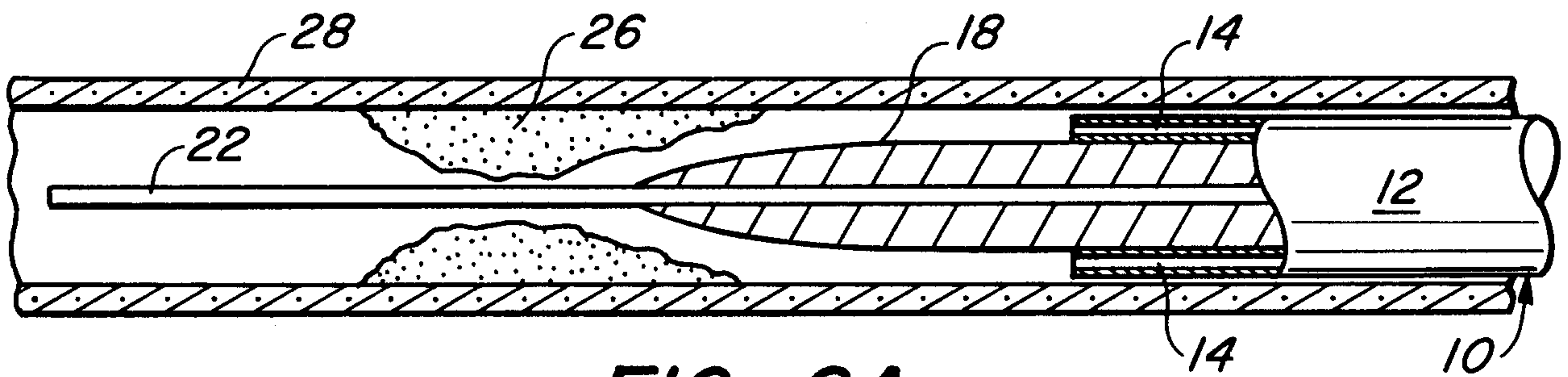


FIG. 2A.

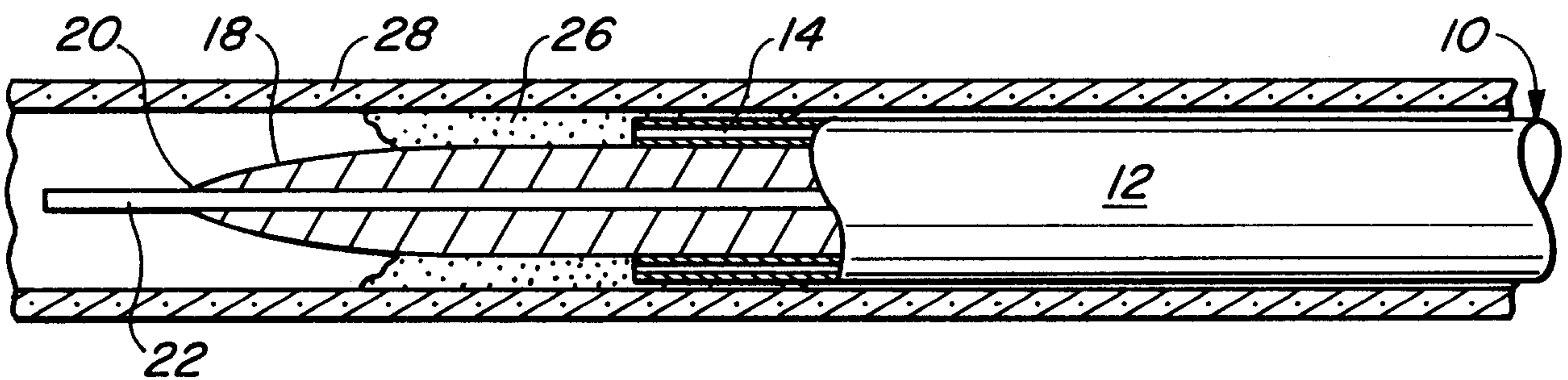


FIG. 2B.

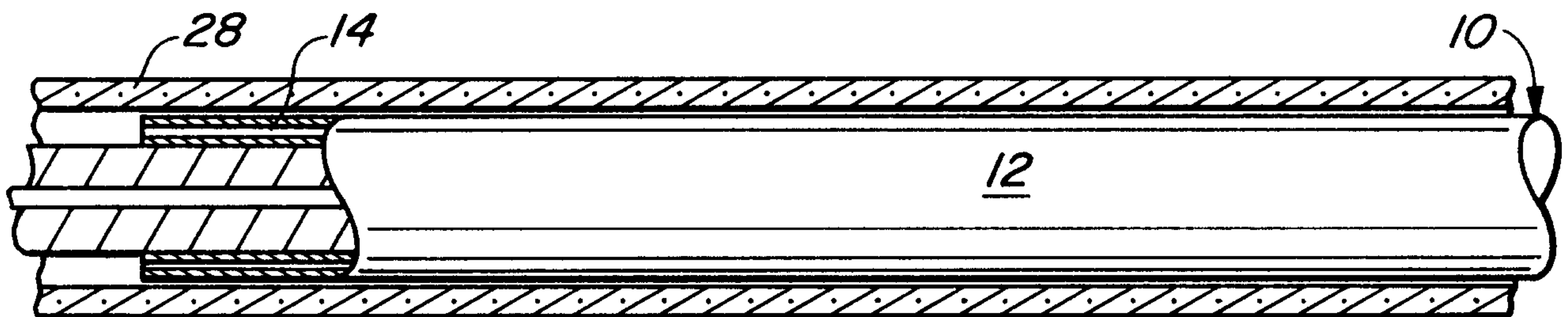


FIG. 2C.

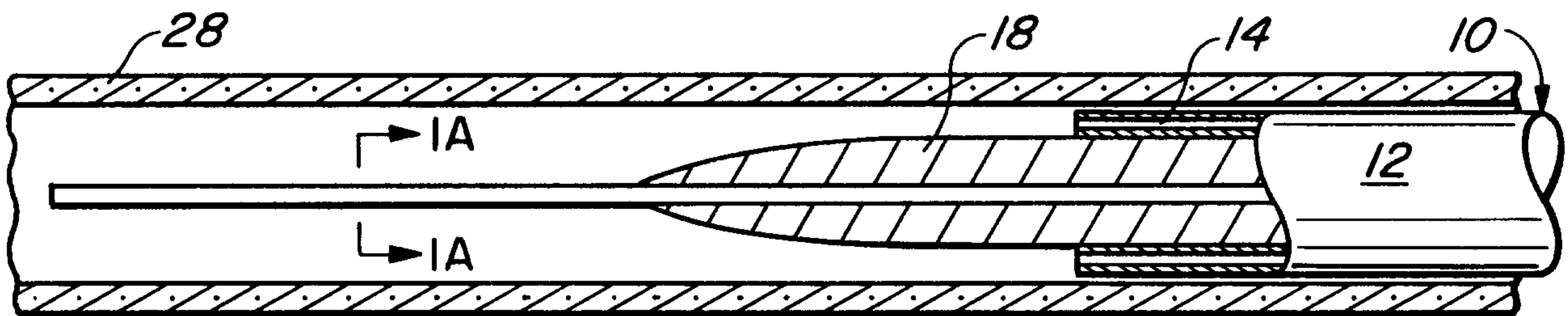


FIG. 2D.

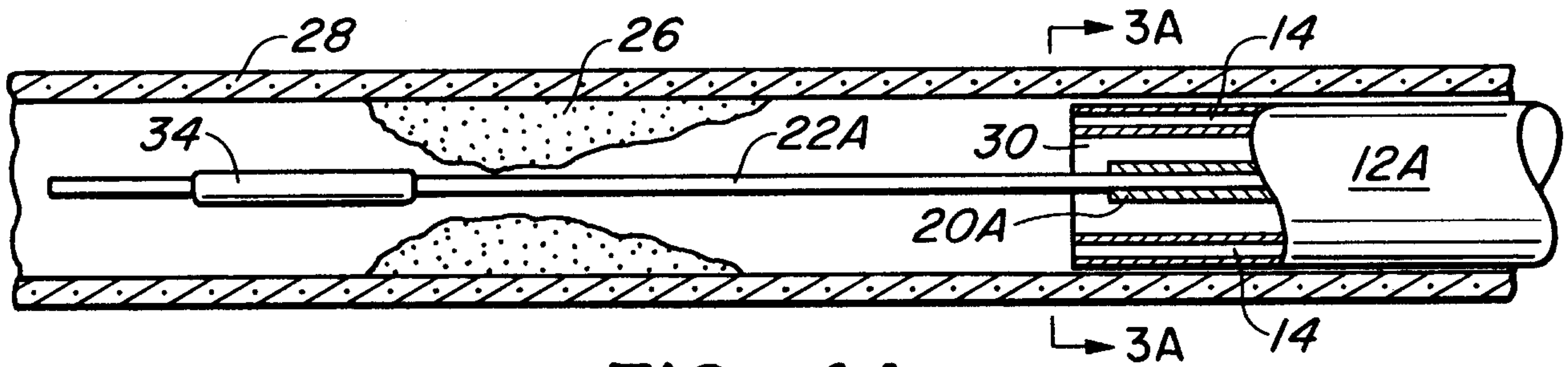


FIG. 4A.

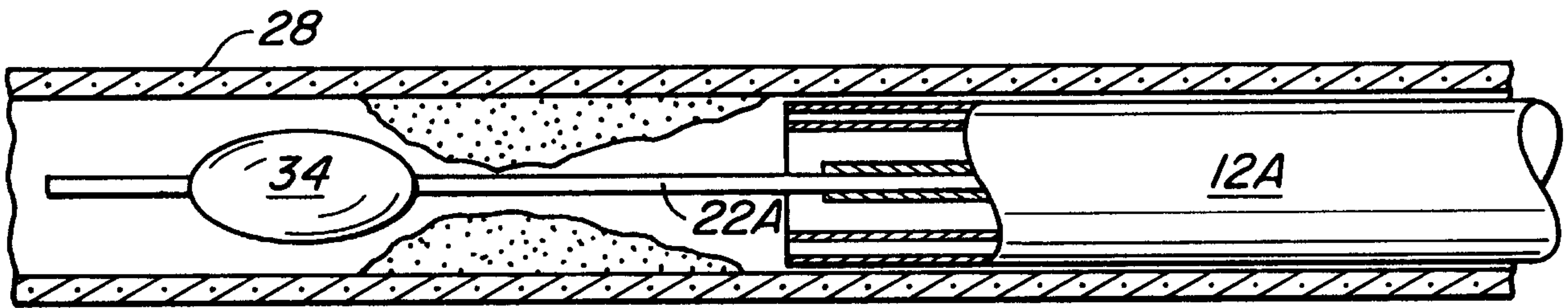


FIG. 4B.

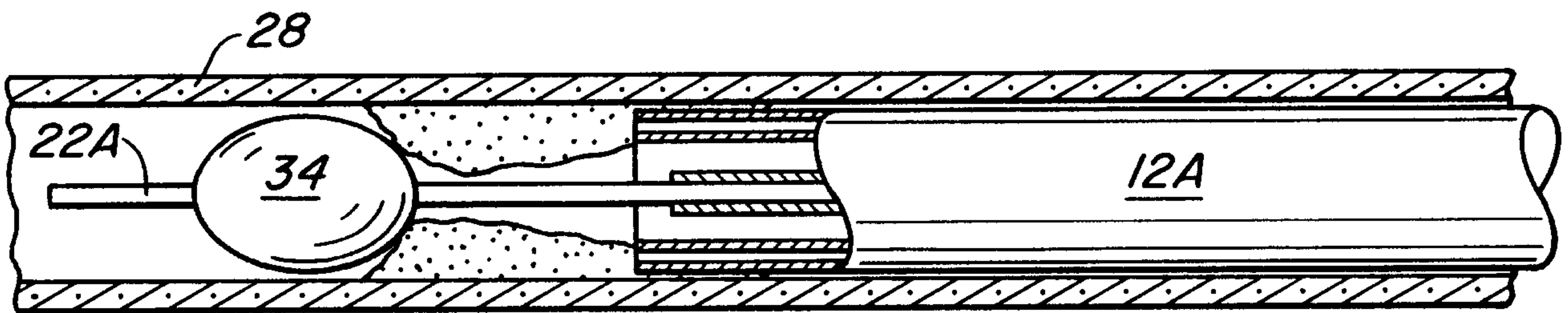


FIG. 4C.

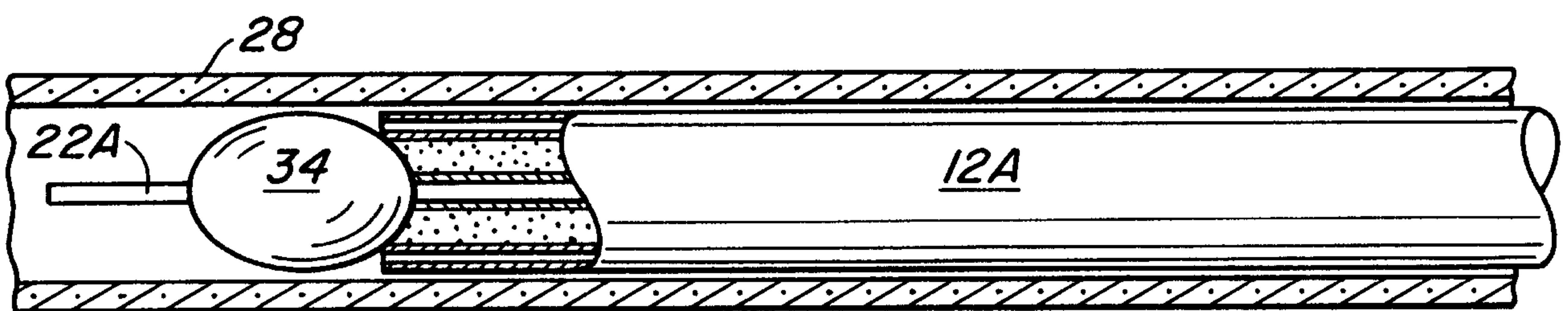


FIG. 4D.

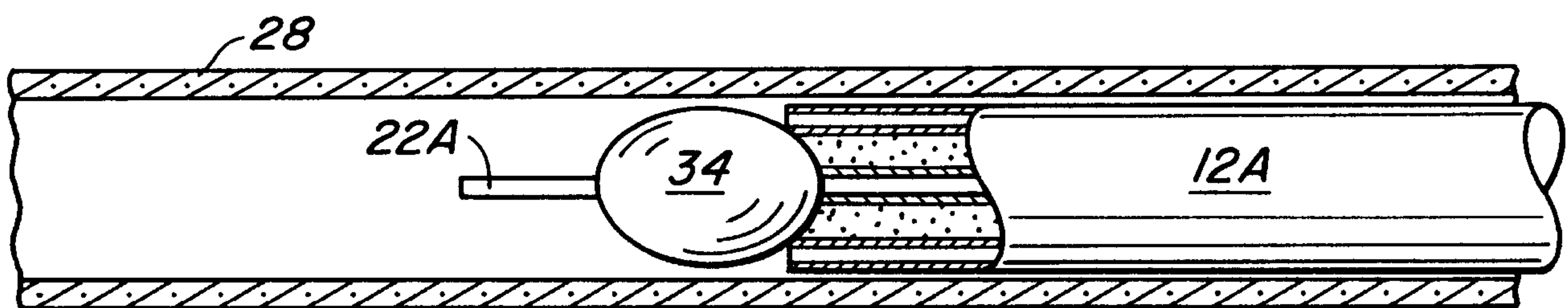
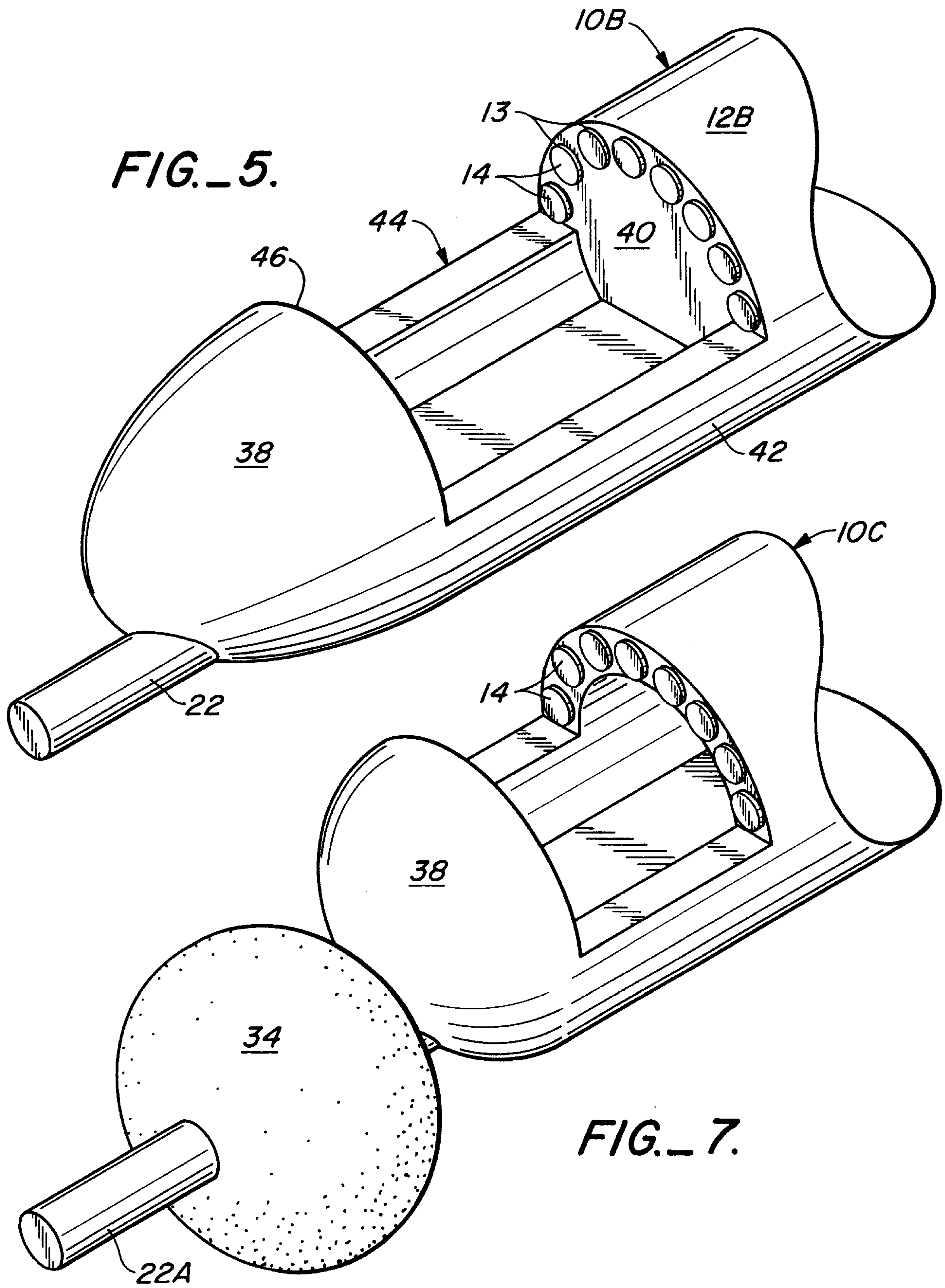


FIG. 4E.



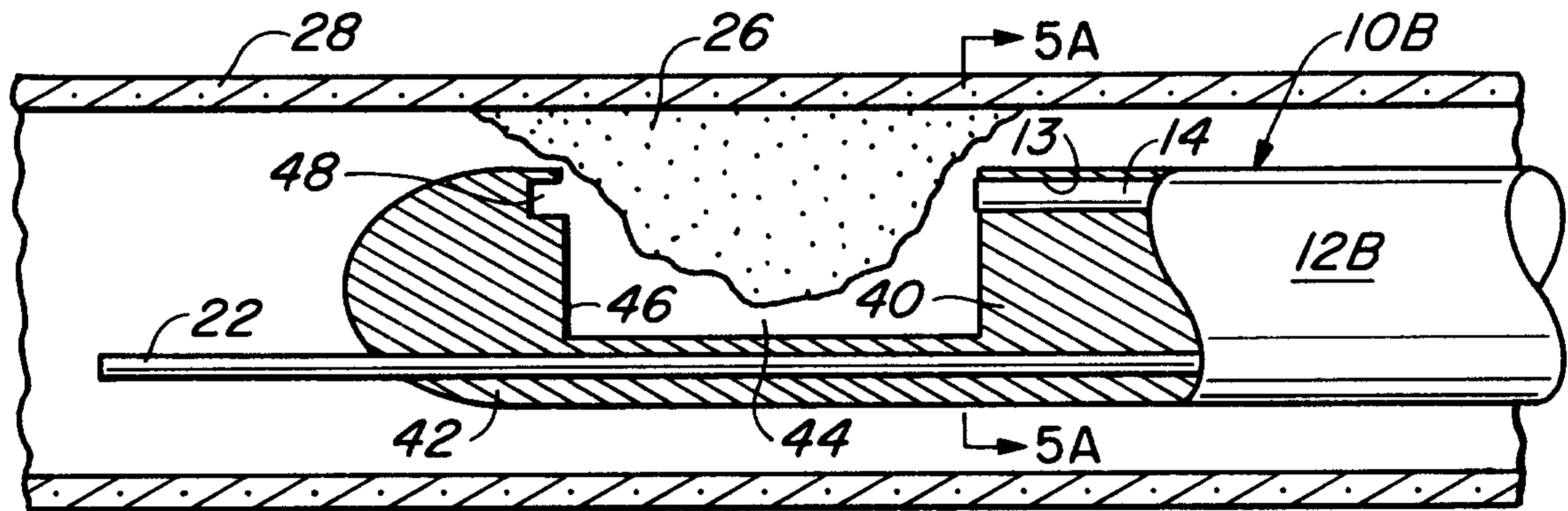


FIG. 6A.

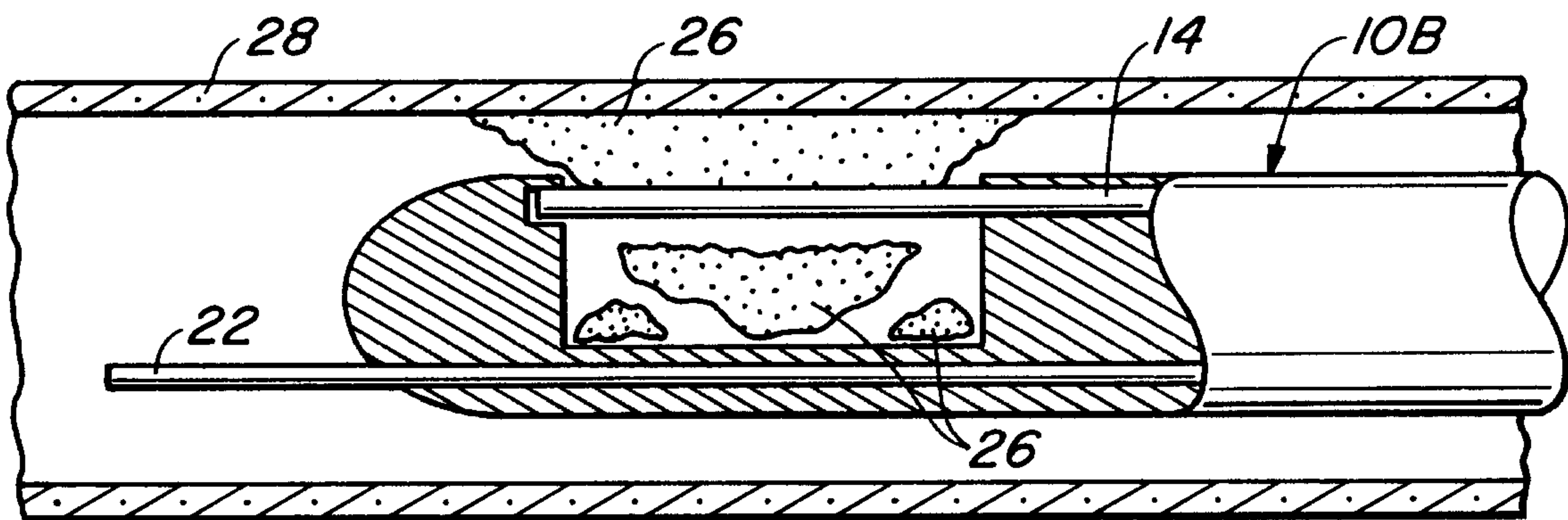


FIG. 6B.

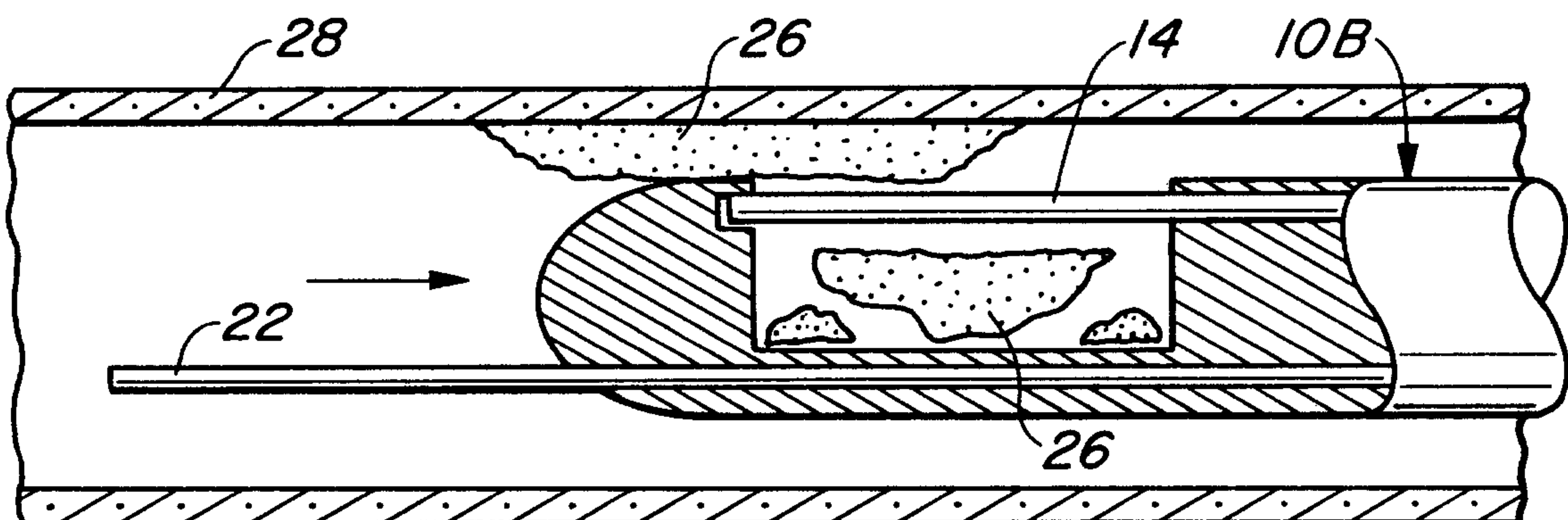


FIG. 6C.

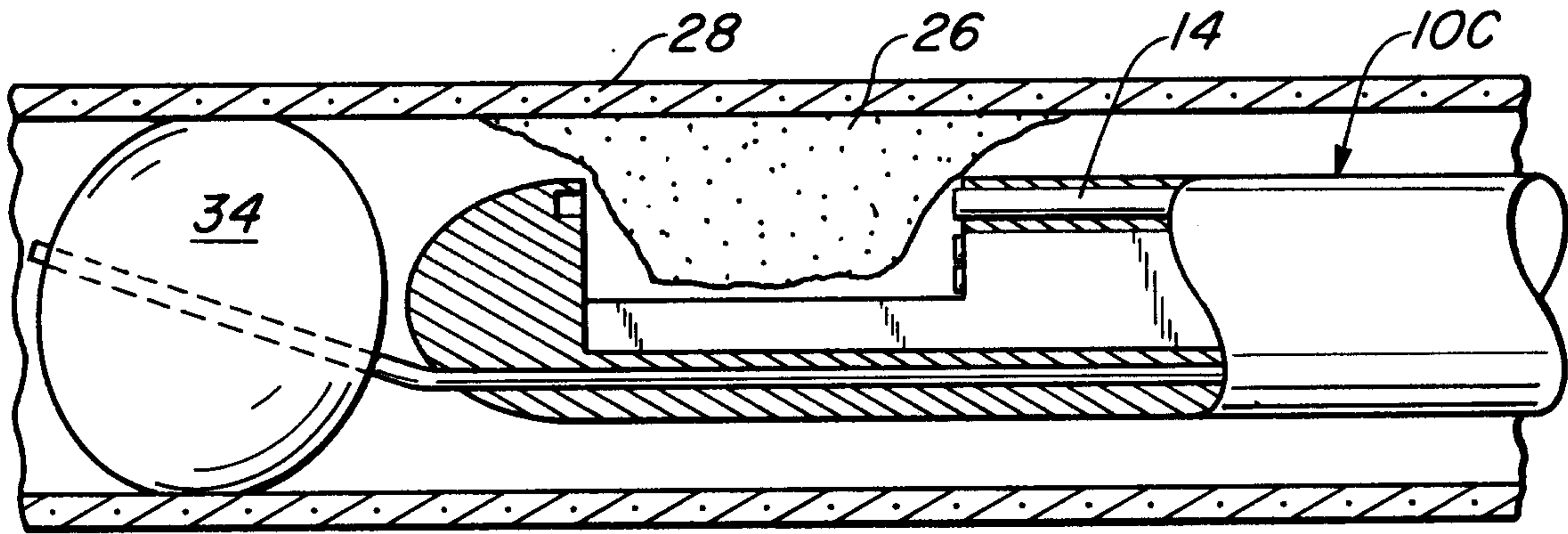


FIG. 8A.

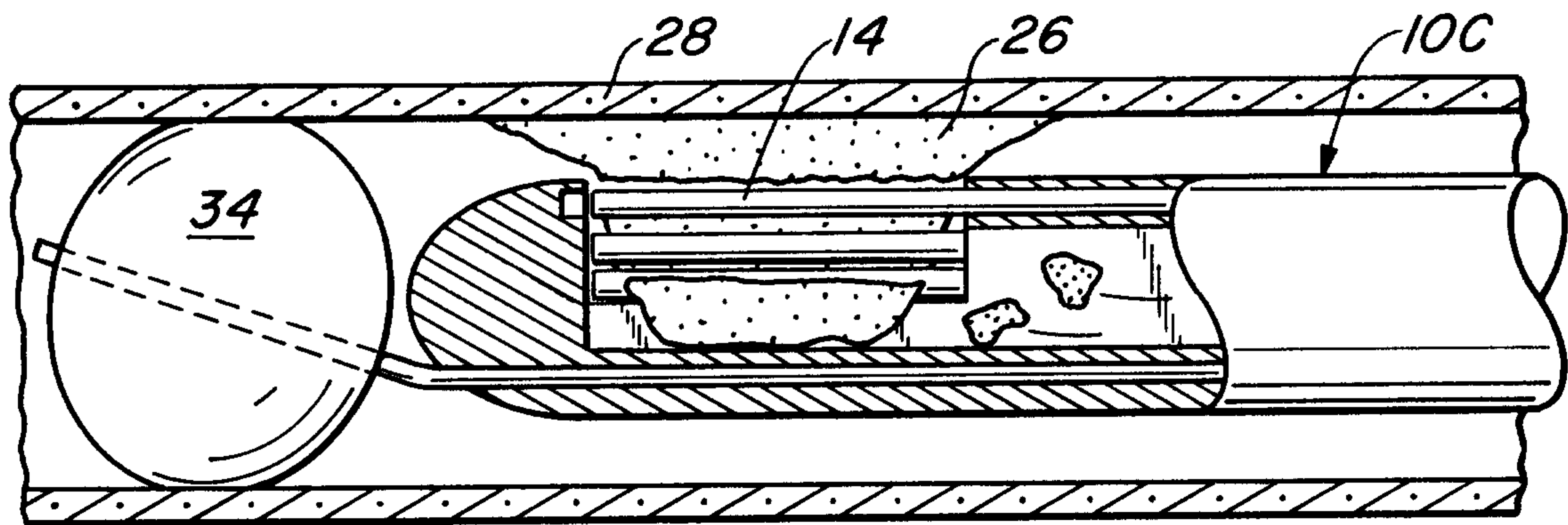


FIG. 8B.

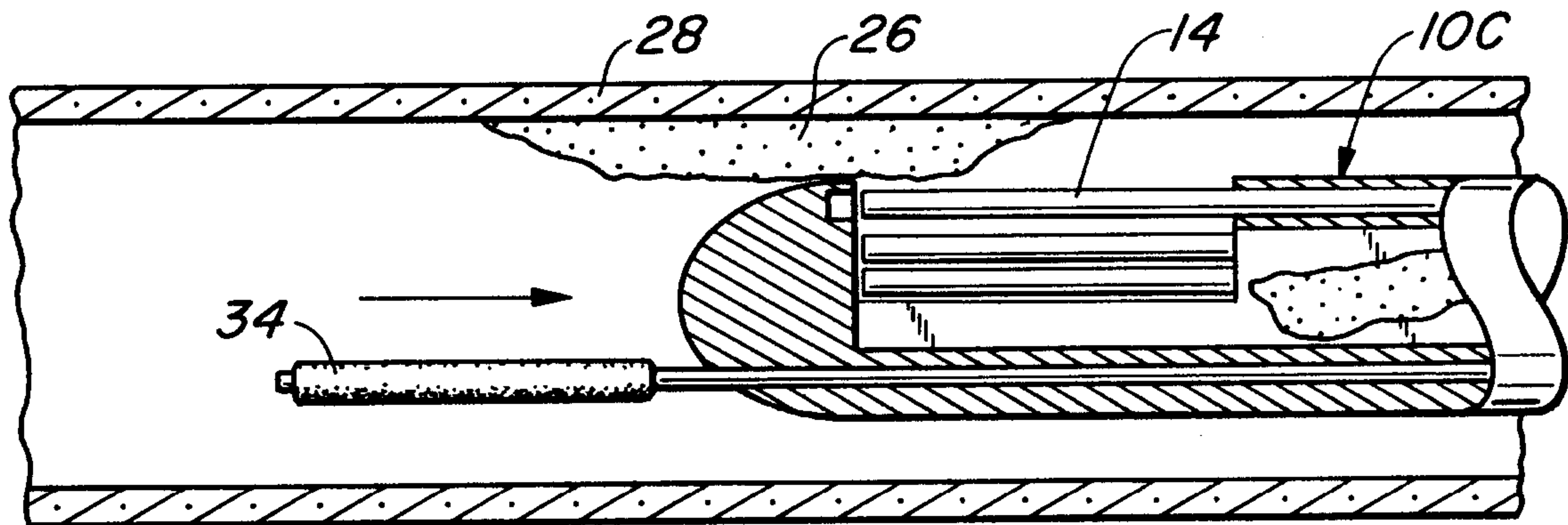


FIG. 8C.

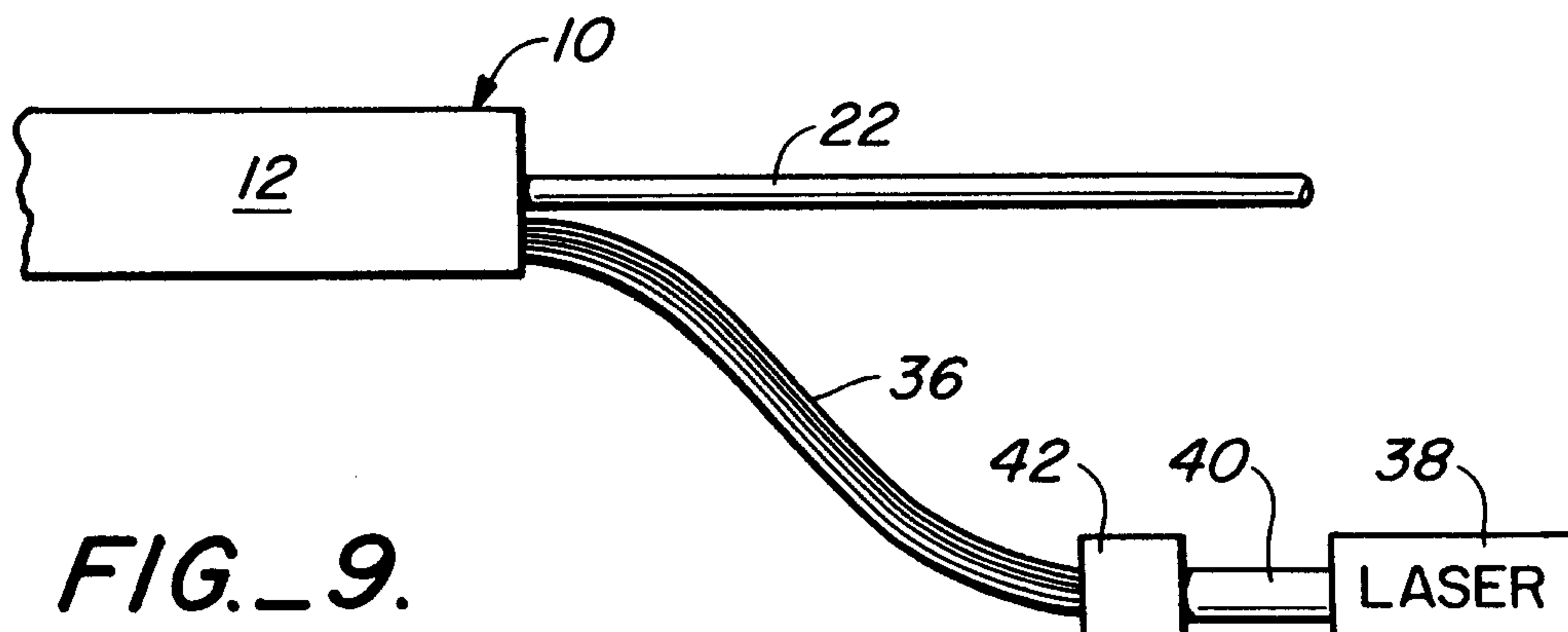


FIG. 9.

