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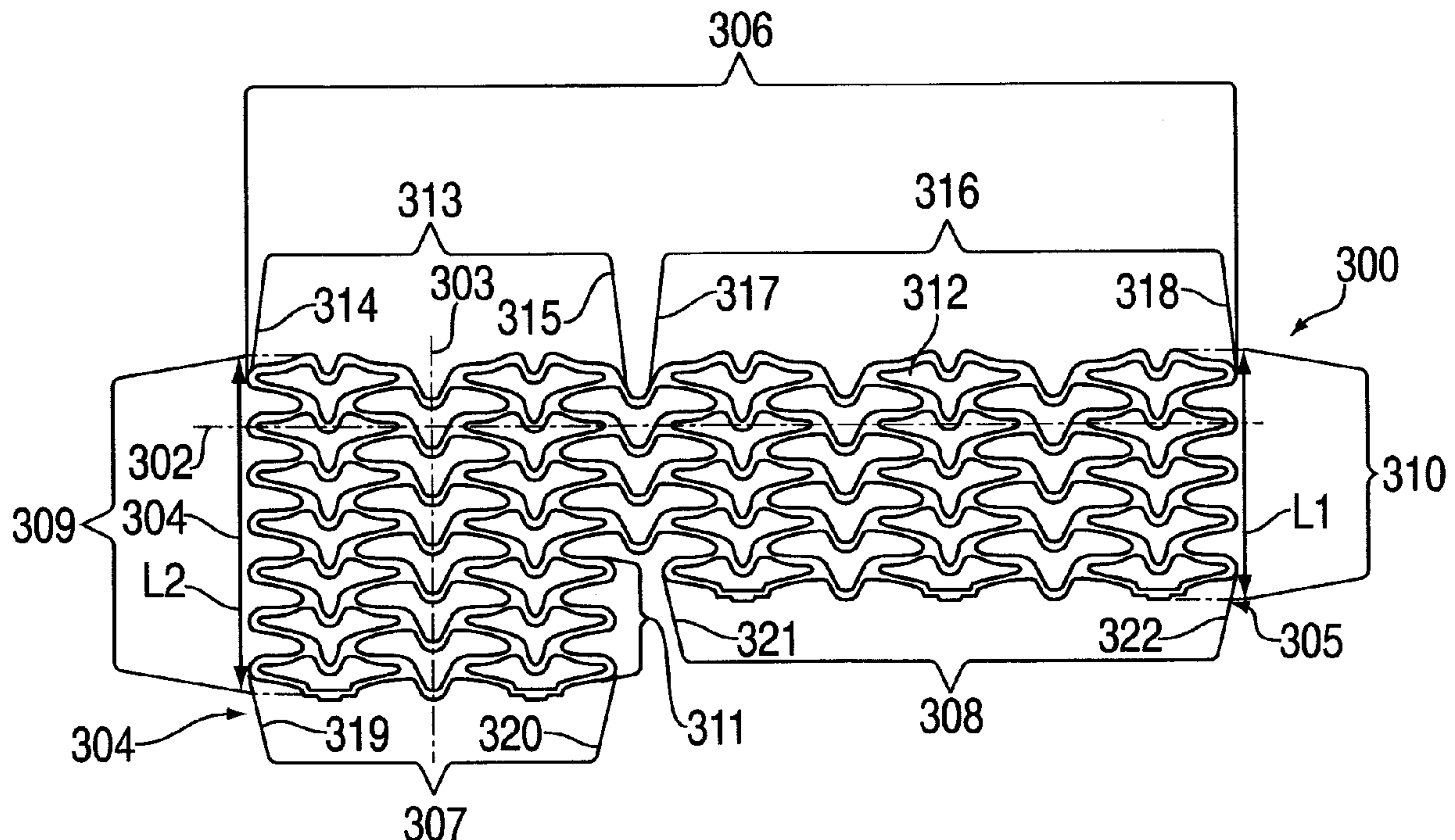
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(54) Titre : TUTEUR BIFURQUE A OUVERTURE DE BRANCHEMENT LATÉRALE AMÉLIORÉE ET SA MÉTHODE DE FABRICATION

(54) Title: BIFURCATED STENT WITH IMPROVED SIDE BRANCH APERTURE AND METHOD OF MAKING SAME



(57) Abrégé/Abstract:

A bifurcated stent for insertion into a bifurcated vessel such as a blood vessel. In one embodiment, a first sheet is formed into a first leg, a second sheet is formed into a second leg, a third sheet is formed into a stem, and the two legs are attached to the stem. In a second embodiment, a first sheet is formed into a member having a first leg and half of a stem, a second sheet is formed into a second member having a second leg and half of a stem, and the two stem halves are combined to form the bifurcated stent. In a third embodiment, the stent comprises two sections that are serially inserted and assembled within the vessel at the site of the bifurcation to be treated.



ABSTRACT

A bifurcated stent for insertion into a bifurcated vessel such as a blood vessel. In one embodiment, a first sheet is formed into a first leg, a second sheet is formed into a second leg, a third sheet is formed into a stem, and the two legs are attached to the stem. In a second embodiment, a first sheet is formed into a member having a first leg and half of a stem, a second sheet is formed into a second member having a second leg and half of a stem, and the two stem halves are combined to form the bifurcated stent. In a third embodiment, the stent comprises two sections that are serially inserted and assembled within the vessel at the site of the bifurcation to be treated.

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5 BIFURCATED STENT WITH IMPROVED SIDE BRANCH APERTURE
 AND METHOD OF MAKING SAME

Field of the Invention

10 The present invention relates to stents, and more
 particularly to bifurcated stents and methods of making
 bifurcated stents for insertion within a branching vessel.

Background of the Invention

15 Stents are well known in the art. They are typically formed
 of a cylindrical metal mesh which can expand when pressure is
 internally applied. Alternatively, they can be formed of wire
 wrapped into a cylindrical shape or sheets of material formed
 into a cylindrical shape.

20 Stents are devices which are usually implanted within bodily
 conduits including the vascular system to reinforce collapsing,
 partially occluded, weakened, or abnormally dilated sections of
 the blood vessel. Stents also have been successfully implanted
 in other areas, e.g., the urinary tract or the bile duct to
 reinforce such bodily conduits.

25 U.S. Patent No. 4,994,071 (MacGregor) discloses an
 expandable, bifurcating stent having a main cylindrical lattice
 formed from interconnected flexible wire. Two additional
 cylindrical lattices, having smaller diameters than the main
 lattice, are similarly constructed. The main lattice includes a
30 flexible wire interconnecting the main lattice to one of the
 additional lattices. A second flexible wire interconnects the

5 main lattice to the other additional lattice. The flexible wires
form backbones that extend axially along the length of the main
lattice and along each of the additional lattices. One
disadvantage of this bifurcating stent is the complex nature of
the interconnection of the flexible wires forming the backbones
10 with the loop structure of each lattice.

Summary of the Invention

The present invention solves these and other disadvantages
of the prior art by providing bifurcated stents and methods of
15 fabricating and deploying bifurcated stents having a stem portion
and two leg portions.

In a first embodiment of the invention, a bifurcated stent
is made by providing three sheets patterned to a desired pattern,
wherein two sheets are substantially the same size and the third
20 sheet is wider than either of the first two sheets. Each of the
sheets is formed into tubes by turning up the longitudinal edges
and forming a joint by welding. The larger sheet forms a tube
that acts as the stem portion of the bifurcated stent and the
other sheets form tubes which act as the leg portions of the
25 bifurcated stent. The two leg portions are then joined to the
stem portion to form the bifurcated stent.

In a second embodiment of the invention, the bifurcated
stent is formed by preparing two stent sheets. For each sheet,
the longitudinal edges of a portion of the sheet are turned up
30 and secured to each other to form one of the two leg portions of

5 the bifurcated stent. The remaining free edges of each of the two sheets are then joined to form the stem portion of the stent.

In a third embodiment, the bifurcated stent comprises first and second tubular portions. The first portion has a proximal end which forms the stem portion and a distal end which forms one
10 of the leg portions of the bifurcated stent. A branch aperture is disposed between the proximal end and the distal end of the first portion. The second portion is introduced into the longitudinal bore of the stem portion of the first portion and is advanced through the branch aperture so that it protrudes beyond
15 the branch aperture to form a second leg. When the second portion is expanded, the proximal end of the second portion engages the material defining the branch aperture so as to secure the second leg in the desired position.

It is an object of this invention to provide a method of
20 making a bifurcated stent, comprising the steps of: a) preparing a first sheet having a first edge, a second edge, a third edge, and a fourth edge; b) preparing a second sheet having a first edge, a second edge, a third edge, and a fourth edge; c)
preparing a third sheet having a first edge, a second edge, a
25 third edge, and a fourth edge; d) attaching the second edge to the third edge of the first sheet to form a tubular first leg portion having a proximal end and a distal end; e) attaching the second edge to the third edge of the second sheet to form a
tubular second leg portion having a proximal end and a distal
30 end; f) attaching the second edge to the third edge of the third

5 sheet to form a tubular stem portion having a proximal end and a distal end; and g) attaching the proximal end of the first leg portion and the proximal end of the second leg portion to the distal end of the stem portion.

10 It is another object of this invention to provide a method of making a bifurcated stent, comprising the steps of a) preparing a first sheet having a proximal end and a distal end; b) deforming the distal end of the first sheet to form a first leg and deforming the proximal end of the first sheet to form a first stem half; c) preparing a second sheet having a proximal
15 end and a distal end; d) deforming the distal end of the second sheet to form a second leg and deforming the proximal end of the second sheet to form a second stem half; and e) joining the first stem half to the second stem half to form a stem.

20 It is yet another object of this invention to provide a method of making a bifurcated stent comprising the steps of a) preparing a first expandable tubular member having a proximal end and a distal end and a longitudinal bore therethrough, the first tubular member provided with a branch aperture disposed between said proximal end and the distal end, the branch aperture
25 communicating with said longitudinal bore and the aperture sized and adapted to receive and secure a second expandable tubular member; b) delivering the first expandable tubular member to a bifurcated vessel having a first lumen and a second lumen so that the first expandable member is disposed within the first lumen
30 and the branch aperture communicates with the second lumen; c)

5 expanding the first expandable member in an amount
sufficient to secure the first expandable member in the first
lumen; d) preparing a second expandable tubular member having a
proximal end and a distal end and having longitudinal bore
therethrough; e) widening the branch aperture; f) delivering the
10 second expandable tubular member into the branch aperture so that
the distal end of the second expandable tubular member is
disposed within the second lumen and the proximal end of the
second expandable tubular member is disposed within the
longitudinal bore of the first longitudinal member; and g)
15 expanding the second expandable tubular member in an amount
sufficient to secure the second expandable tubular member within
the second lumen and within said branch aperture.

It is still another object of this invention to provide a
method of making a bifurcated stent comprising the steps of:

20 a) preparing a sheet having a proximal end, a distal end,
a longitudinal axis, and a circumferential axis, the sheet
provided with:

 a first side having a proximal portion having a
proximal end and a distal end and a distal portion having a
25 proximal end and a distal end;

 a second side having a proximal end and a distal end,
the second side disposed between the proximal end of the sheet
and the distal end of the sheet;

 a third side having a proximal end and a distal end,
30 the third side disposed between the distal end of the second side

5 and the distal end of the sheet;

a fourth side disposed between the proximal end of the proximal portion of the first side and the proximal end of the second side;

10 a fifth side disposed between the distal end of the distal portion of the first side and the distal end of the third side, the fifth side having a length that is shorter than the length of the fourth side; and

a sixth side disposed between the second side and the third side;

15 b) attaching the second side to the proximal portion of the first side and attaching the third side to the distal portion of the first side to form a first expandable tubular member having a longitudinal bore defining a longitudinal axis, the fourth side defining a proximal stent aperture communicating with
20 the longitudinal bore, the fifth side defining a distal stent aperture communicating with the longitudinal bore, and the sixth side and the proximal end of the third side and the proximal end of the distal portion of the first side defining a side branch aperture communicating with the longitudinal bore and sized and
25 adapted to receive and secure a second expandable tubular member;

c) delivering the first expandable tubular member to a bifurcated vessel having a first lumen and a second lumen so that the first expandable tubular member is disposed within the first lumen and the branch aperture communicates with the second lumen;

30 d) expanding the first expandable tubular member in an

5 amount sufficient to secure the first expandable tubular member in the first lumen;

e) preparing a second expandable tubular member having a proximal end and a distal end and having longitudinal bore therethrough;

10 f) delivering the second expandable tubular member into the branch aperture of the first tubular member so that the distal end of the second expandable tubular member is disposed within the second lumen and the proximal end of the second expandable tubular member is disposed within the longitudinal
15 bore of the first tubular member; and

g) expanding the second expandable tubular member in an amount sufficient to secure the second expandable tubular member within the second lumen and within the branch aperture.

20 It is yet another object of this invention to provide a bifurcated stent comprising:

a) a first tubular member having a proximal end and a distal end and a longitudinal bore therethrough defining a longitudinal axis, the first tubular member comprised of a sheet having a proximal end, a distal end, a longitudinal axis, and a
25 circumferential axis, the sheet provided with:

a first side having a proximal portion having a proximal end and a distal end and a distal portion having a proximal end and a distal end;

a second side having a proximal end and a distal end,
30 the second side disposed between the proximal end of the sheet

5 and the distal end of the sheet;

a third side having a proximal end and a distal end,
the third side disposed between the distal end of the second side
and the distal end of the sheet;

10 a fourth side disposed between the proximal end of the
proximal portion of the first side and the proximal end of the
second side;

a fifth side disposed between the distal end of the
distal portion of the first side and the distal end of the third
side, the fifth side having a length that is shorter than the
15 length of the fourth side; and

a sixth side disposed between the second side and the
third side;

b) means for attaching the second side to the proximal
portion of the first side and the third side to the distal
20 portion of the first side so that the fourth side defines a
proximal stent aperture communicating with the longitudinal bore,
the fifth side defines a distal stent aperture communicating with
the longitudinal bore, and the sixth side and the proximal end of
the third side and the proximal end of the distal portion of the
25 first side define a side branch aperture communicating with the
longitudinal bore and sized and adapted to receive and secure a
second tubular member; and

c) a second tubular member having a proximal end and a
distal end and having longitudinal bore therethrough, the second
30 tubular member disposed within the branch aperture so that the

5 proximal end of the second tubular member is disposed within the longitudinal bore of the first tubular member.

It is a further object of this invention to provide a method of making a bifurcated stent comprising the steps of:

10 a) cutting a proximal member from a first expandable tube having a first cross-sectional diameter, the proximal member having a proximal end and a distal end and a longitudinal bore therethrough;

15 b) cutting a distal member from a second expandable tube having a second cross-sectional diameter smaller than the first diameter of the first tube, the distal member having a proximal end and a distal end and a longitudinal bore therethrough;

20 c) attaching a portion of the distal end of the proximal member to a portion of the proximal end of the distal member so that the longitudinal bore of the proximal member is in fluid communication with the longitudinal bore of the distal member to form a first expandable tubular member having a proximal end and a distal end and a longitudinal bore therethrough, the unattached portion of the distal end of the proximal member and the unattached portion of the proximal end of the distal member
25 defining a side branch aperture communicating with the longitudinal bore of the first tubular member and sized and adapted to receive and secure a second expandable tubular member;

30 c) delivering the first expandable tubular member to a bifurcated vessel having a first lumen and a second lumen so that the first expandable tubular member is disposed within the first

5 lumen and the branch aperture communicates with the second lumen;

d) expanding the first expandable tubular member in an amount sufficient to secure the first expandable tubular member in the first lumen;

10 e) preparing a second expandable tubular member having a proximal end and a distal end and having longitudinal bore therethrough;

15 f) delivering the second expandable tubular member into the branch aperture of the first tubular member so that the distal end of the second expandable tubular member is disposed within the second lumen and the proximal end of the second expandable tubular member is disposed within the longitudinal bore of the first tubular member; and

20 g) expanding the second expandable tubular member in an amount sufficient to secure the second tubular member within the second lumen and within the branch aperture.

It is yet a further object of this invention to provide a bifurcated stent comprising:

25 a) a first tubular member having a proximal end and a distal end and a longitudinal bore therethrough, the first tubular member comprised of a proximal member and a distal member, the proximal member having a first cross-sectional diameter, a proximal end and a distal end and a longitudinal bore therethrough, and the distal member having a second cross-sectional diameter smaller than the first diameter, a proximal
30 end and a distal end and a longitudinal bore therethrough;

5 b) means for attaching a portion of the distal end of the proximal member to a portion of the proximal end of the distal member so that the longitudinal bore of the proximal member is in fluid communication with the longitudinal bore of the distal member to form the first tubular member, the unattached portion
10 of the distal end of the proximal member and the unattached portion of the proximal end of the distal member defining a side branch aperture communicating with the longitudinal bore of the first tubular member and sized and adapted to receive and secure a second expandable tubular member; and

15 c) a second tubular member having a proximal end and a distal end and having longitudinal bore therethrough, the second tubular member disposed and secured within the branch aperture so that the proximal end of the second tubular member is disposed within the longitudinal bore of the first tubular member.

20 Brief Description of the Drawings

FIG. 1 shows a bifurcated stent manufactured in accordance with the present invention;

25 FIG. 2 shows sheets used to form the legs and stem of the stent shown in FIG. 1;

FIG. 3 shows the sheets shown in FIG. 2 after they have been rolled into a tubular shape;

FIG. 4 is a perspective view of the tubes shown in FIG. 3 prior to assembly;

30 FIG. 5 is an end view of the tubes shown in FIGS. 3 and 4

5 after they have been assembled to form a stent;

FIG. 6 is a top view of the assembled apparatus shown in FIG. 5;

FIG. 7 shows sheets used to form another embodiment of a bifurcated stent manufactured in accordance with the invention;

10 FIG. 7B shows sheets used to form another embodiment of a bifurcated stent manufactured in accordance with the invention;

FIG. 8 shows the sheets of FIG. 7 with demarcation points;

FIG. 9 shows the sheets of FIG. 8 after they have been rolled into a tubular shape;

15 FIG. 9B shows the sheets of FIG. 7B after they have been rolled into a tubular shape;

FIG. 10 shows the tubes of FIG. 9 just prior to assembly;

FIG. 10B shows the tubes of FIG. 9B just prior to assembly;

20 FIG. 11 is a side view of the tubes shown in FIGS. 9 and 10 after assembly;

FIG. 11B is a side view of the tubes shown in FIGS. 9B and 10B after assembly;

FIG. 12 is an end view of the assembled apparatus shown in FIG. 11;

25 FIG. 12B is an end view of the assembled apparatus shown in FIG. 11B;

FIG. 12C shows an alternative embodiment of a pattern that may be used in place of the patterns shown in FIGS. 7 and 7B;

30 FIG. 13 shows a stem and first leg portion and a second leg portion used to form another embodiment of a bifurcated stent

5 manufactured in accordance with this invention;

FIG. 14 shows guide wires disposed in the trunk lumen and branch lumen to be treated;

FIG. 15 shows the stem and first leg portion shown in FIG. 13 disposed on catheters and guide wires prior to introduction
10 into the lumen to be treated;

FIG. 16 shows the stem and first leg portion shown in FIG. 13 after it has been delivered to the bifurcation to be treated and prior to its expansion;

FIG. 17 shows the second leg portion shown in FIG. 16 after
15 it has been expanded;

FIG. 18 shows expansion of the branch aperture;

FIG. 19 shows the unexpanded second leg portion disposed in the branch aperture;

FIG. 20 shows the expansion of the second leg portion shown
20 in FIG. 19; and

FIG. 21 shows the assembled bifurcated stent disposed in the bifurcated lumen to be treated;

FIG. 22 shows a sheet used to form a first expandable tubular member;

FIG. 23 shows the sheet of FIG. 22 after it has been formed
25 into a first expandable tubular member;

FIG. 24 shows the first expandable tubular member of FIG. 23 with catheters inserted into the longitudinal bore and the side branch aperture;

FIG. 25 shows the first expandable tubular member of FIG. 24
30

5 after expansion with an unexpanded second tubular member being introduced into the side branch aperture;

FIG. 26 shows the first expandable tubular member of FIG. 24 after expansion with an unexpanded second tubular member disposed in the side branch aperture;

10 FIG. 27 shows the second tubular member of FIG. 26 after it has been expanded;

FIG. 28 shows a side view of a proximal member and a distal member used to make an alternative embodiment of the invention;

15 FIG. 29 shows the proximal and distal members of FIG. 28 after they have been connected to form a first expandable tubular member;

FIG. 30 is an end view of FIG. 29;

20 FIG. 30A is an end view of FIG. 29 showing an alternative embodiment in which a portion of the proximal member and a portion of the distal member have been deformed prior to being attached; and

FIG. 31 shows the first expandable tubular member of FIG. 29 with a second expandable tubular member disposed within the side branch aperture.

25

Detailed Description

In the embodiment illustrated in FIG. 1, the bifurcation stent 5 comprises a first leg 10, a second leg 15, and a stem 20.

30 FIG. 2 shows a first sheet 25 which is used to form first leg 10,

5 a second sheet 30 which is used to form second leg 15, and a
third sheet 35 which is used to form stem 20. The first sheet 25
and second sheet 30 are substantially flat and are sized to a
predetermined length and width. For many applications, the first
sheet 25 and second sheet 30 will have substantially the same
10 dimensions so as to produce legs 10 and 15 that are substantially
the same size, however, the legs 10 and 15, and the sheets 25 and
30 used to produce them, may be of varying sizes as specific
applications dictate. The stents of this invention may be sized
so that when assembled they are their final size, however, in a
15 preferred embodiment the stents are expandable and sized and
adapted to assume their final dimensions upon expansion. The
stent sheets 70 and 75 may be patterned or etched with
perforations forming a variety of patterns as specific
applications dictate to achieve the expandable features required
20 as previously discussed. The third sheet 35 is sized so that
when it is rolled into a tube its internal cross-section can be
made to accommodate the cross-sectional external diameters of
first leg 10 and second leg 15. First sheet 25 has a first edge
26, a second edge 27, a third edge 28, and a fourth edge 29.
25 Second sheet 30 has a first edge 31, a second edge 32, a third
edge 33, and a fourth edge 34. Third sheet 35 has a first edge
36, a second edge 37, a third edge 38, and a fourth edge 39.
After the sheet metal has been cut to form sheets 25, 30, and 35,
it is deformed and rolled so as to cause two opposite edges to
30 meet and create a cylinder. In the example shown in FIGS. 2 and

5 3, edge 27 is joined to edge 29 via weld run 14 to form first leg
10. Edge 32 is joined to edge 34 via weld run 19 to form second
leg 15. Edge 37 is joined to edge 39 via weld run 29 to form
stem 20. The edges may be joined in a wide variety of ways well
known to those skilled in the art as suitable for this purpose,
10 e.g., screwing, crimping, soldering, however, in a preferred
embodiment welding is utilized. In an especially preferred
embodiment, spot welding is utilized. As shown in FIG. 3, first
leg 10 has a proximal end 11, a distal end 12, and defines a
longitudinal bore 13. Second leg 15 has a proximal end 16, a
15 distal end 17, and defines a longitudinal bore 18. The stem 20
has a proximal end 26, a distal end 27, and defines a
longitudinal bore 28. FIG. 4 shows the first leg 10, second leg
15, and stem 20 just prior to assembly. To form the bifurcated
stent 5, the proximal end 11 of first leg 10 and the proximal end
20 16 of second leg 15 are joined to the distal end 27 of the stem
portion 20 so that the longitudinal bores 13, 18, and 28 are in
communication with each other. FIG. 5 is an end view and FIG. 6
is a side view of the assembled apparatus.

FIG. 11 shows a second embodiment of a bifurcation stent
25 manufactured in accordance with this invention. The stent 50 is
provided with a first leg 55 and a second leg 60 attached to a
stem portion 65. The bifurcation stent 50 is formed from a first
sheet 70 and a second sheet 75 as shown in FIG. 7. The stent
sheets 70 and 75 may be patterned or etched with perforations
30 forming a variety of patterns as specific applications dictate to

5 achieve the expandable features required as previously discussed.
The sheets 70 and 75 are substantially flat and have a
predetermined length and width. First sheet 70 has a first edge
71, a second edge 72, a third edge 73 and a fourth edge 74. The
second sheet 75 has a first edge 76, a second edge 77, a third
10 edge 78, and a fourth edge 79. To form the legs of the stent a
portion of edge 72 is rolled towards a portion of edge 74 and a
portion of edge 77 is rolled towards a portion of edge 79.
Demarcation points 80, 81, 82, and 83 are selected on sheets 70
and 75 as shown in FIG. 8. These demarcation points 80, 81, 82,
15 and 83 are selected to meet the requirement of specific
applications and may be adjusted depending upon the length
required for legs 55 and 60 and the length required for stem 65.
Demarcation points 80 and 81 that are equidistant from edges 73
and 71 and demarcation points 82 and 83 that are equidistant from
20 edges 76 and 78 will result in a stent in which the legs 55 and
60 have a length that is substantially equal to stem portion 65.
If the demarcation points are selected to be closer to edges 73
and 78 than to edges 71 and 76 the stem will have a length that
is greater than the length of each of the legs. If the
25 demarcation points are selected to be closer to edges 71 and 76
than to edges 73 and 78, each of the legs 60 and 65 will have a
length that is greater than the length of the stem 65. In a
preferred embodiment, however, the demarcation points 80, 81, 82,
and 83, are selected so that proximal edges 72'', 74'', 77'', and
30 79'' are about 1/3 the length of edges 72, 74, 77, and 79. As

5 shown in FIG. 8, demarcation point 80 divides edge 72 at
approximately its midpoint into a distal edge 72' and a proximal
edge 72''. Demarcation point 81 divides edge 74 at approximately
its midpoint into a distal edge 74' and a proximal edge 74''.
Demarcation point 82 divides edge 77 at approximately its
10 midpoint into a distal edge 77' and a proximal edge 77'' and
demarcation point 83 divides edge 79 at approximately its
midpoint into a distal edge 79' and a proximal edge 79''.

To form the stent, edge 72' is connected to edge 74' via
weld run 90 to form first member 95 having a first leg portion 55
15 and a first stem half 65' as shown in FIG. 9. Edge 77' is
connected to edge 79' via weld run 91 to form second member 100
having a second leg portion 60 and a second stem half 65''. As
previously discussed, the edges may be connected in a variety of
ways well known to those skilled in the art. FIG. 10 shows the
20 first member 95 and the second member 100 shown in FIG. 9 in
alignment just prior to assembly. To produce the bifurcated
stent 50 shown in FIGS. 11 and 12, edge 72'' is connected to edge
79'' via weld run 92 and edge 74'' is connected to edge 77'' via
weld run 93 so that first stem half 65' and second stem half 65''
25 form stem 65. FIG. 12 is a cross-sectional end view of the stent
shown in FIG. 11.

In the embodiment shown in FIG. 7, sheets 70 and 75 are
squares or rectangles. The sheets 70 and 75 are not limited to
this configuration, however, as shown in FIG. 7B. FIG. 11B shows
30 a bifurcation stent manufactured using the sheets 270 and 275

5 shown in FIG. 7B. The stent 250 is provided with a first leg
255 and a second leg 260 attached to a stem portion 265. The
bifurcation stent 250 is formed from a first sheet 270 and a
second sheet 275 as shown in FIG. 7B. The stent sheets 270 and
275 may be sized and etched as previously discussed. As shown in
10 FIG. 7B, first sheet 270 has a first edge 271, a second edge 272,
a third edge 273, a fourth edge 274, a fifth edge 275, and a
sixth edge 276, a seventh edge 146, and an eighth edge 147. The
second sheet 275 has a first edge 277, a second edge 278, a third
edge 279, a fourth edge 280, a fifth edge 281, a sixth edge 282,
15 a seventh edge 148, and an eighth edge 149. As shown in FIG. 9B,
edge 274 is connected to edge 276 via weld run 290 to form first
member 295 having a first leg portion 255 and a first stem half
265'. Edge 280 is connected to edge 282 via weld run 291 to form
second member 300 having a second leg portion 260 and a second
20 stem half 265''. As previously discussed, the edges may be
connected in a variety of ways well known to those skilled in the
art. FIG. 10B shows the first member 295 and the second member
300 shown in FIG. 9B in alignment just prior to assembly. To
produce the bifurcated stent 250 shown in FIGS. 11B and 12B, edge
25 272 is connected to edge 149 via weld run 292 and edge 278 is
connected to edge 147 via weld run 293 so that first stem half
265' and second stem half 265'' form stem 265. FIG. 12B is a
cross-sectional end view of the stent shown in FIG. 11B. FIG.
12C shows an alternative pattern that may be used in place of the
30 patterns shown in FIGS. 7 and 7B.

5 A third embodiment of this invention comprises two portions
which are deployed serially in two steps and assembled within the
patient to form a bifurcated stent. FIG. 13 shows stem and first
leg portion 110 provided with a longitudinal bore 131 and having
a proximal end 115 defining a stem portion 125 and a distal end
10 120 defining a first leg portion 130. Second leg portion 140 is
provided with a longitudinal bore 132 and has a proximal end 145
and a distal end 150. Stem and first leg portion 110 and second
leg portion 140 may be sized and patterned or etched as
previously discussed. A branch aperture 135 is disposed between
15 the proximal end 115 and the distal end 120 of stem and first leg
portion 110. The branch aperture 135 is sized to receive second
leg portion 140 and is adapted to engage and secure the second
leg portion 140 when it has been expanded within the branch
aperture 135. Second leg portion 140 is sized and adapted to
20 engage and be secured into branch aperture 135 upon expansion.
FIGS. 14 to 21 show how the bifurcated stent is assembled within
a bifurcated lumen. As shown in FIGS. 14 to 21, the area to be
treated is a bifurcated lumen having a first or trunk lumen 190
and a second or branch lumen 195. As shown in FIG. 14, a first
25 guide wire 155 is introduced into the trunk lumen 190 and a
second guide wire 156 is introduced into the branch lumen 195.
As shown in FIG. 15, a balloon expandable stem and first leg
portion 110 is disposed on the tip of a first balloon catheter
170 so that the balloon 175 is disposed within longitudinal bore
30 131. A second balloon catheter 171 is then introduced into

5 longitudinal bore 131 of stem and first leg portion 110 and is
advanced so that the balloon 176 is disposed within aperture 135.
First catheter 170 is mounted on first guide wire 155 and second
catheter 171 is mounted on second guide wire 156. As shown in
FIG. 16, the unexpanded stem and first leg portion 110 is guided
10 to the area to be treated so that first leg portion 130 is
disposed within trunk lumen 190 and branch aperture 135
communicates with branch lumen 195. Guide wire 156 facilitates
the orientation of the branch aperture 135 with the branch lumen
195. The size of the conventional catheters and balloons is not
15 to scale and details well known to those skilled in the art have
been omitted for clarity. Balloon 175 is inflated which causes
the stem and first leg portion 110 to expand, as shown in FIG.
17, to secure it in the desired position. After expansion, the
external wall of stem and first leg portion 110 would contact the
20 interior walls of trunk lumen 190, however, a gap has been
intentionally left for clarity. The balloon 175 on first
catheter 170 is left inflated and the balloon 176 on second
catheter 171 is then inflated to enlarge the branch aperture 135
as shown in FIG. 18. As the branch aperture 135 is enlarged a
25 portion of the stent defining the branch aperture 135 is pushed
outward to form a branch securing lip 180.

Balloons 175 and 176 are deflated, second catheter 171
is withdrawn, and second guide wire 156 is left in place in the
branch lumen 195. Second leg portion 140 is then applied to
30 second catheter 171 so that balloon 176 is disposed in

5 longitudinal bore 132 and second catheter 171 is then applied to
second guide wire 156. Second leg portion 140 is then guided to,
and introduced into, the longitudinal bore 131 of the stem and
first leg portion 110 and is advanced and passed through branch
aperture 135 so that the distal end 150 of the second leg portion
10 140 protrudes into the branch lumen 195 and the proximal end 145
communicates with longitudinal bore 131, as shown in FIG. 19.
The balloon 176 on second catheter 171 is partially inflated and
the balloon 175 on first catheter 170 is then partially inflated
to a pressure substantially equal to the pressure in balloon 176.
15 Both balloons 175 and 176 are then simultaneously inflated to
substantially equal pressures. As shown in FIG. 20, inflation of
the balloon 176 on second catheter 171 causes second leg member
140 to expand so that its external walls engage and are secured
to the area surrounding aperture 135. Inflation of the balloon
20 175 on the first catheter 170 prevents stem and first leg portion
110 from collapsing when balloon 176 is inflated. After
expansion, the external walls of second leg 140 would contact the
inner wall of lumen 195, however, a gap has been intentionally
left for clarity. The balloons 175 and 176 are deflated,
25 catheters 170 and 171 and guide wires 155 and 156 are withdrawn,
and the assembled bifurcated stent 160 is left in place as shown
in FIG. 21.

FIGS. 22 to 31 show an especially preferred method of making
a bifurcated stent in accordance with the invention. FIG. 22
30 shows a sheet 300 used to form a first expandable tubular member

5 301. The sheet 300 has a longitudinal axis 302, a
circumferential axis 303, a proximal end 304, a distal end 305, a
first side 306, a second side 307, a third side 308, a fourth
side 309, a fifth side 310, and a sixth side 311. The sheet 300
may be provided with a variety of patterns, however, in a
10 preferred embodiment the sheet 300 is provided with a plurality
of expandable cells 312 adapted to be substantially flexible
prior to expansion of the first tubular member 301 and
substantially rigid after expansion of the first tubular member
301. In an especially preferred embodiment the flexible cells
15 312 of the sheet 300 are substantially uniform as shown in FIG.
22.

The first side 306 of the sheet 300 has a proximal portion
313 having a proximal end 314 and a distal end 315. The first
side 306 also has a distal portion 316 having a proximal end 317
20 and a distal end 318.

The second side 307 of the sheet 300 has a proximal end 319
and a distal end 320 and is disposed between the proximal end 304
of the sheet 300 and the distal end 305 of the sheet 300.

25 The third side 308 of the sheet 300 has a proximal end 321
and a distal end 322 and is disposed between the distal end 320
of the second side 307 and the distal end 305 of the sheet 300.

The fourth side 309 of the sheet 300 is disposed between the
proximal end 314 of the proximal portion 313 of the first side
306 and the proximal end 319 of the second side 307.

30 The fifth side 310 of the sheet 300 is disposed between the

5 distal end 318 of the distal portion 316 of the first side 306
and the distal end 322 of the third side 308 and is provided with
a length L1 that is shorter than the length L2 of the fourth side
309. In a preferred embodiment, the length L1 of the fifth side
310 and the length L2 of the fourth side 309 are in a ratio of
10 about 5:7, i.e., the fifth side 310 has a length L1 that is about
70% of the length L2 of the fourth side 309. In an especially
preferred embodiment the sheet 300 is etched with a plurality of
substantially uniform cells 312 as previously discussed and the
number of cells disposed along the circumferential axis 303 of
15 the fifth side 310 and the number of cells disposed along the
circumferential axis 303 of the fourth side 309 are in a ratio of
about 5:7.

A sixth side 311 is disposed between the second side 307 and
the third side 308. In an especially preferred embodiment, the
20 first side 306, second side 307, and third side 308 are
substantially parallel to each other and the fourth side 309,
fifth side 310, and sixth side 311 are substantially parallel to
each other and the first side 306, second side 307, and third
side 308 are substantially perpendicular to the fourth side 309,
25 fifth side 310, and sixth side 311.

To make the first expandable tubular member 301, the second
side 307 of the sheet 300 is attached via attaching means to the
proximal portion 313 of the first side 306 of the sheet 300 and
the third side 308 of the sheet 300 is attached via attaching
30 means to the distal portion 316 of the first side 306 of the

5 sheet 300 to form a first expandable tubular member 301 having a longitudinal bore 323 defining a longitudinal axis 324 as shown in FIG. 23. The attaching step may be carried out utilizing a variety of attaching means well known to those skilled in the art as suitable for this purpose, however, in a preferred embodiment
10 the attaching step is carried out utilizing screwing, crimping, soldering, welding, or spot welding. In the embodiment shown in FIG. 23 spot welding 325 has been utilized. After the sides have been attached as discussed above, the fourth side 309 defines a proximal tubular member aperture or stent aperture 326
15 communicating with the longitudinal bore 323, and the fifth side 310 defines a distal tubular member aperture or stent aperture 327 communicating with the longitudinal bore 323 as shown in FIGS. 23 and 26. The sixth side 311 and the proximal end 321 of the third side 308 and the proximal end 317 of the distal portion
20 316 of the first side 306 define a side branch aperture 328 (as shown in FIGS. 23-26) sized and adapted to receive and secure a second expandable tubular member 329 (shown in FIGS. 26-27). The branch aperture 328 has a diameter D_1 that is larger than the diameter D_2 of the unexpanded stent, i.e., the branch aperture
25 328 is larger than the proximal and distal apertures 326 and 327 of the first tubular member 301 both before and after the tubular member 301 is expanded.

The first expandable tubular member 301 is then delivered to a bifurcated vessel having a first lumen and a second lumen so
30 that the first expandable tubular member is disposed within the

5 first lumen and the branch aperture communicates with the second
lumen. In a preferred embodiment, delivery is via a balloon
catheter as previously discussed. After it has been positioned,
the first expandable tubular member is expanded in an amount
sufficient to secure the first expandable tubular member in the
10 first lumen.

A second expandable tubular member 329 is then prepared
having a proximal end 330 and a distal end 331 and having
longitudinal bore 332 therethrough. The second expandable
tubular member 329 (shown in FIGS. 25, 26, and 27) may be
15 patterned in the same way as the sheet 300 as previously
discussed. In a preferred embodiment the cells 312 of the sheet
300 used to make the first expandable tubular member 301 and the
cells 312' of the second expandable tubular member 329 are
substantially uniform.

20 The second expandable tubular member 329 is delivered into
the longitudinal bore 323 of the first tubular member 301, as
shown in FIG. 25, and is advanced into and beyond the branch
aperture 328, as shown in FIG. 26, so that the distal end 331 of
the second expandable tubular member 329 is disposed within the
25 second lumen and the proximal end 330 of the second expandable
tubular member 329 is disposed within the longitudinal bore 323
of the first tubular member 301. The second expandable tubular
member 329 is then expanded in an amount sufficient to secure the
second expandable tubular member 329 within the second lumen and
30 within the branch aperture 328 of the first tubular member 301 as

5 shown in FIG. 27.

Among the advantages that this embodiment provides is that this stent provides a large branch aperture that facilitates the introduction of the second tubular member into the side branch or second lumen. In addition, this stent is especially suitable for
10 the performance of serial bifurcation stenting and also for stenting around a side branch before it is occluded.

FIGS. 28 to 31 shown an alternative embodiment and alternative method of making the first tubular member shown in FIGS. 23-27. In this embodiment the first tubular member 400
15 (shown in FIG. 29) is comprised of a proximal member 401 having a proximal end 402 and a distal end 403 and a distal member 404 having a proximal end 405 and a distal end 406 as shown in FIG. 28. The proximal member 401 has a longitudinal bore 415 and is cut from a first tube 407 having first cross-sectional diameter
20 D1. The distal member 404 has a longitudinal bore 416 and is cut from a second tube 408 having a second cross-sectional diameter D2. D2 is smaller than D1. The tubes 401 and 404 may be etched or patterned as previously discussed before the proximal member 401 and distal member 404 are cut from the tubes 407 and 408.
25 Alternatively, the proximal and distal members 401 and 404 may be etched or patterned after the proximal and distal members 401 and 404 have been cut from the tubes 407 and 408. To make the first tubular member 400, a portion of the distal end 403 of the proximal member 401 is attached via attaching means 417 to a
30 portion of the proximal end 405 of the distal member 404 to form

5 a first tubular member 400 having a proximal end 409 and a distal
end 410 and a longitudinal bore therethrough 411 as shown in FIG.
29. The members 401 and 404 may be attached utilizing a variety
of attaching means 417 as previously discussed, however, in a
preferred embodiment the attaching means utilized is welding. In
10 an especially preferred embodiment spot welding is utilized.
Because D2 is less than D1 the unattached portion of the distal
end 403 of the proximal portion 401 and the unattached portion of
the proximal end 405 of the distal portion 404 define a branch
aperture 412 as shown in FIG. 29 and FIG. 30 (which is an end
15 view of FIG. 29). In some applications it may be desirable to
have a greater portion of the distal end 403 of the proximal
member 401 and the proximal end 405 of the distal member 404
contact each other before they are attached in order to increase
the strength of the first tubular member 400. This may be
20 accomplished by, e.g., by distorting, aligning, and contacting a
greater surface area of the distal end 403 of the proximal member
401 and a greater surface area of the proximal end 405 of the
distal member 404 prior to attaching the distal end 403 to the
proximal end 405. FIG. 30A is an end view of this embodiment and
25 shows that a greater surface area of the distal end 403 and the
proximal end 405 are attached when compared to the embodiment
shown in FIG. 30. FIG. 30A also shows that in this embodiment
the branch aperture 412' is larger than the branch aperture 412
shown in FIG. 30. A second tubular member 413 may then be
30 introduced into the branch aperture 412 and 412' and as

- 5 previously discussed is expanded and secured so that a portion of the second tubular member 413 communicates with longitudinal bore 411 to form a bifurcated stent 414 (shown in FIG. 31).

What Is Claimed Is:

1. A bifurcated stent comprising:

- a) a first tubular member having a proximal end and a distal end and a longitudinal bore therethrough defining a longitudinal axis, the first tubular member comprised of a sheet having a proximal end, a distal end, a longitudinal axis, and a circumferential axis, the sheet provided with:
 - a first side having a proximal portion having a proximal end and a distal end and a distal portion having a proximal end and a distal end;
 - a second side having a proximal end and a distal end, the second side disposed between the proximal end of the sheet and the distal end of the sheet;
 - a third side having a proximal end and a distal end, the third side disposed between the distal end of the second side and the distal end of the sheet;
 - a fourth side disposed between the proximal end of the proximal portion of the first side and the proximal end of the second side;
 - a fifth side disposed between the distal end of the distal portion of the first side and the distal end of the third side, the fifth side having a length that is shorter than the length of the fourth side; and
 - a sixth side disposed between the second side and the third side;
- b) means for attaching the second side to the proximal portion of the first side and the third side to the distal portion of the first side so that the fourth side defines a proximal stent aperture communicating with the longitudinal bore, the fifth side defines a distal stent aperture communicating with the longitudinal bore, and the sixth side and the proximal end of the third side and the proximal end of the distal portion of the first side define a side branch aperture communicating with the longitudinal bore and sized and adapted to receive and secure a second tubular member; and
- c) a second tubular member having a proximal end and a distal end and having longitudinal bore therethrough, the second tubular member disposed within the branch aperture so

that the proximal end of the second tubular member is disposed within the longitudinal bore of the first tubular member.

2. The stent of claim 1, wherein the attaching means is a screw.
3. The stent of claim 1, wherein the attaching means is a crimp.
4. The stent of claim 1, wherein the attaching means is solder.
5. The stent of claim 1, wherein the attaching means is a weld.
6. The stent of claim 1, wherein the attaching means is a spot weld.
7. The stent of claim 1, wherein the fifth side has a length that is about 70% of the length of the fourth side.
8. The stent of claim 1, wherein the first and second tubular members are provided with a plurality of cells adapted to be substantially flexible prior to expansion and substantially rigid after expansion.
9. The stent of claim 1, wherein the sheet and the second tubular member comprise an etched pattern defining a plurality of cells.
10. The stent of claim 9, wherein the cells are adapted to be substantially flexible prior to the expansion of the first and second tubular members and are adapted to be substantially rigid after the expansion of the first and second tubular members.
11. The stent of claim 10, wherein the cells of the sheet are substantially uniform.
12. The stent of claim 10, wherein the cells of the second tubular member are substantially uniform.
13. The stent of claim 10, wherein the cells of the sheet and the cells of the second tubular member are substantially uniform.

14. The stent of claim 11, wherein the number of cells disposed along the circumferential axis of the fifth side of the sheet and the number of cells disposed along the circumferential axis of the fourth side of the sheet are in a ratio of about 5:7.
15. The stent of claim 1, wherein the branch aperture larger than the proximal and distal apertures of the first tubular member.
16. The stent of claim 1, wherein the first, second, and third sides are substantially parallel to each other and the fourth, fifth, and sixth sides are substantially parallel to each other.
17. The stent of claim 16, wherein the first, second, and third sides are substantially perpendicular to the fourth, fifth, and sixth sides.
18. A kit for forming a bifurcated stent comprising:
 - a) a first expandable tubular member having a proximal end and a distal end and a longitudinal bore therethrough defining a longitudinal axis, the first expandable tubular member comprised of a sheet having a proximal end, a distal end, a longitudinal axis, and a circumferential axis, the sheet provided with:
 - a first side having a proximal portion having a proximal end and a distal end and a distal portion having a proximal end and a distal end;
 - a second side having a proximal end and a distal end, the second side disposed between the proximal end of the sheet and the distal end of the sheet;
 - a third side having a proximal end and a distal end, the third side disposed between the distal end of the second side and the distal end of the sheet;
 - a fourth side disposed between the proximal end of the proximal portion of the first side and the proximal end of the second side;
 - a fifth side disposed between the distal end of the distal portion of the first side and the distal end of the third side, the fifth side having a length that is shorter than the length of the fourth side; and
 - a sixth side disposed between the second side and the third side;

- b) means for attaching the second side to the proximal portion of the first side and for attaching the third side to the distal portion of the first side so that the fourth side defines a proximal stent aperture communicating with the longitudinal bore, the fifth side defines a distal stent aperture communicating with the longitudinal bore, and the sixth side and the proximal end of the third side and the proximal end of the distal portion of the first side define a side branch aperture communicating with the longitudinal bore and sized and adapted to receive and secure a second expandable tubular member;
- c) a second expandable tubular member having a proximal end and a distal end and having longitudinal bore therethrough, the second expandable tubular member sized and adapted to be disposed and secured within the branch aperture so that the proximal end of the second tubular member is disposed within the longitudinal bore of the first tubular member;
- d) a first guide wire;
- e) a second guide wire;
- f) a first balloon catheter; and
- g) a second balloon catheter.

19. A bifurcated stent comprising:

- a) a first tubular member having a proximal end and a distal end and a longitudinal bore therethrough, the first tubular member comprised of a proximal member and a distal member, the proximal member having a first cross-sectional diameter, a proximal end and a distal end and a longitudinal bore therethrough, and the distal member having a second cross-sectional diameter smaller than the first diameter, a proximal end and a distal end and a longitudinal bore therethrough;
- b) means for attaching a portion of the distal end of the proximal member to a portion of the proximal end of the distal member so that the longitudinal bore of the proximal member is in fluid communication with the longitudinal bore of the distal member to form the first tubular member, the unattached portion of the distal end of the proximal member and the unattached portion of the proximal end of the distal member defining

a side branch aperture communicating with the longitudinal bore of the first tubular member and sized and adapted to receive and secure a second expandable tubular member; and

c) a second tubular member having a proximal end and a distal end and having longitudinal bore therethrough, the second tubular member disposed and secured within the branch aperture so that the proximal end of the second tubular member is disposed within the longitudinal bore of the first tubular member.

20. The stent of claim 19, wherein the attaching means is a screw.

21. The stent of claim 19, wherein the attaching means is a crimp.

22. The stent of claim 19, wherein the attaching means is solder.

23. The stent of claim 19, wherein the attaching means is a weld.

24. The stent of claim 23, wherein the weld is a spot weld.

25. The stent of claim 19, wherein the first and second tubular members are comprised of a plurality of cells adapted to be substantially flexible prior to expansion and substantially rigid after expansion.

26. The stent of claim 19, wherein the first tubular member proximal member, the first tubular member distal member, and the second tubular member comprise an etched pattern defining a plurality of cells.

27. The stent of claim 26, wherein the plurality of cells are adapted to be substantially flexible prior to the expansion of the first and second tubular members and are adapted to be substantially rigid after the expansion of the first and second tubular members.

28. The stent of claim 27, wherein the cells of first tubular member and the cells of the second tubular member are substantially uniform.

29. A kit for forming a bifurcated stent comprising:

a) a first expandable tubular member having a proximal end and a distal end and a longitudinal bore therethrough, the first expandable tubular member comprised of an

expandable proximal member and an expandable distal member, the expandable proximal member having a first cross-sectional diameter, a proximal end and a distal end and a longitudinal bore therethrough and the expandable distal member having a second cross-sectional diameter smaller than the first diameter, a proximal end and a distal end and a longitudinal bore therethrough;

- b) means for attaching a portion of the distal end of the expandable proximal member to a portion of the proximal end of the expandable distal member so that the longitudinal bore of the expandable proximal member is in fluid communication with the longitudinal bore of the expandable distal member to form the first expandable tubular member, the unattached portion of the distal end of the expandable proximal member and the unattached portion of the proximal end of the expandable distal member defining a side branch aperture communicating with the longitudinal bore of the first expandable tubular member and sized and adapted to receive and secure a second expandable tubular member;
- c) a second expandable tubular member having a proximal end and a distal end and having longitudinal bore therethrough, the second expandable tubular member sized and adapted to be disposed and secured within the branch aperture so that the proximal end of the second expandable tubular member is disposed within the longitudinal bore of the first tubular member;
- d) a first guide wire;
- e) a second guide wire;
- f) a first balloon catheter; and
- g) a second balloon catheter.

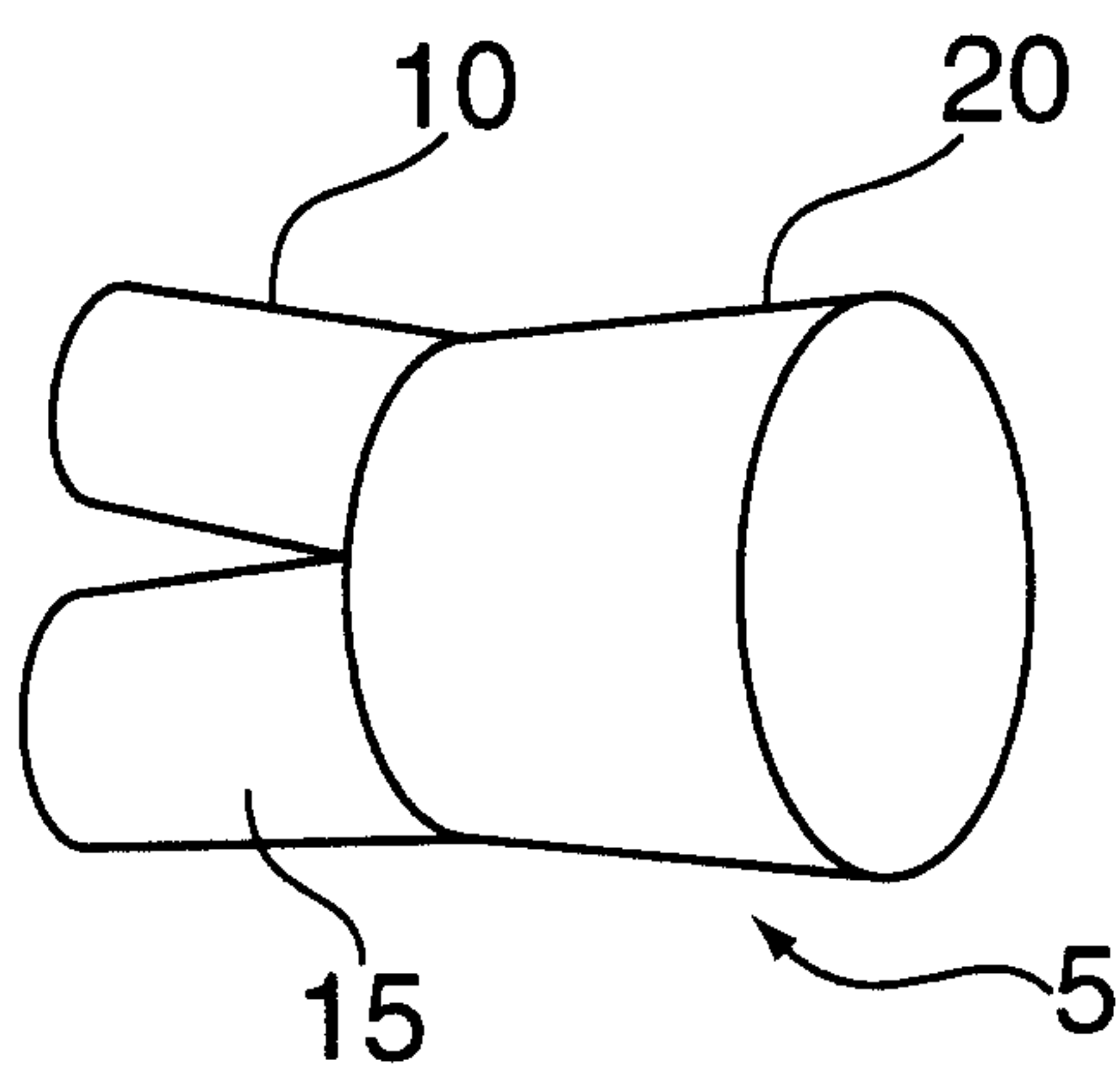


FIG. 1

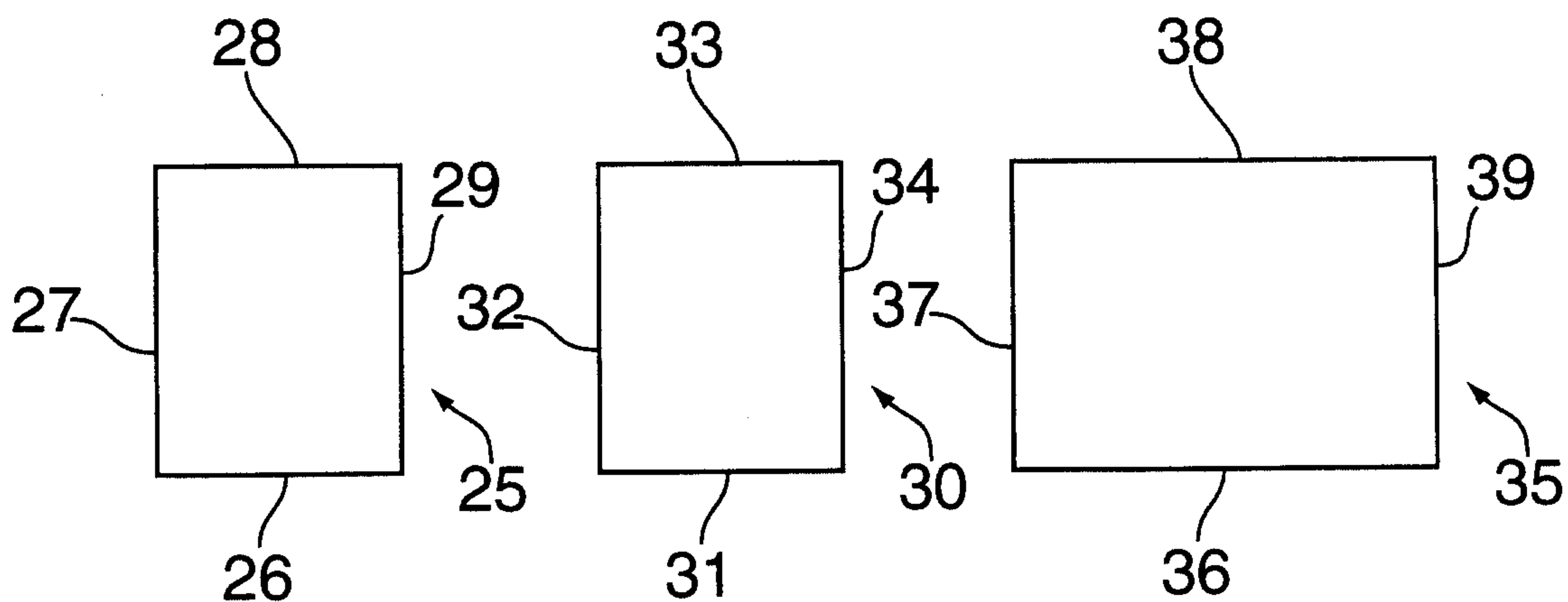


FIG. 2

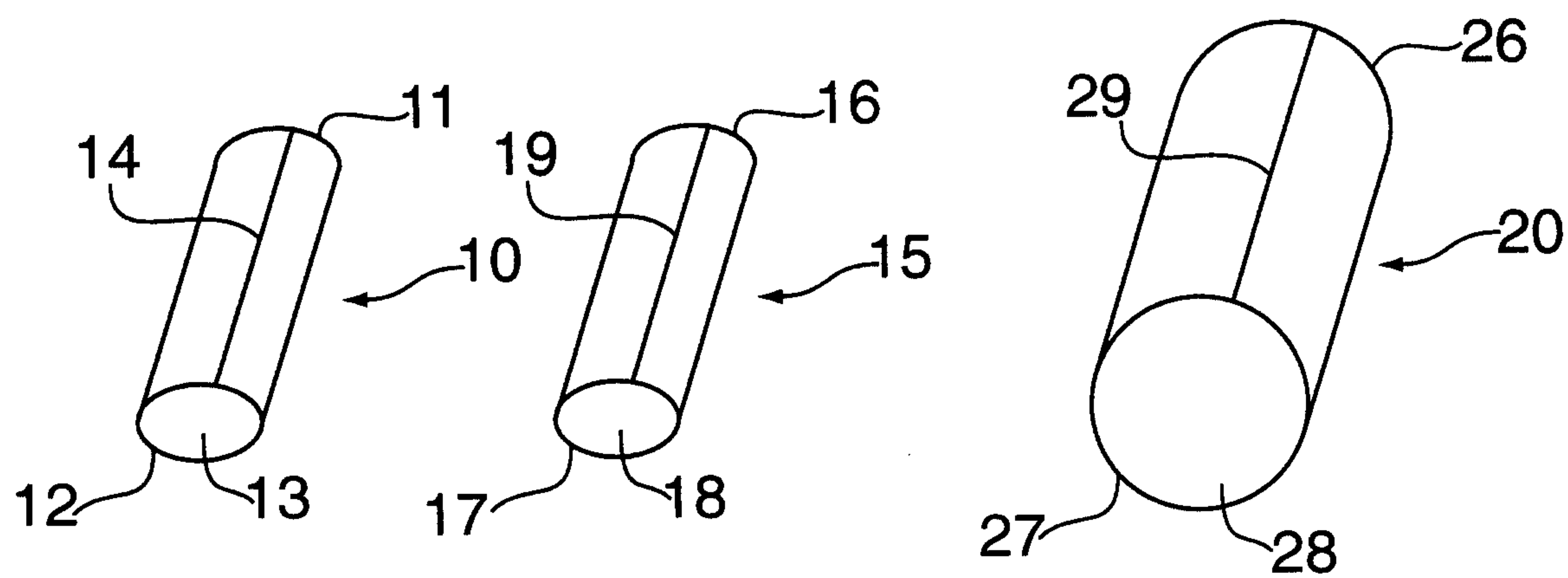


FIG. 3

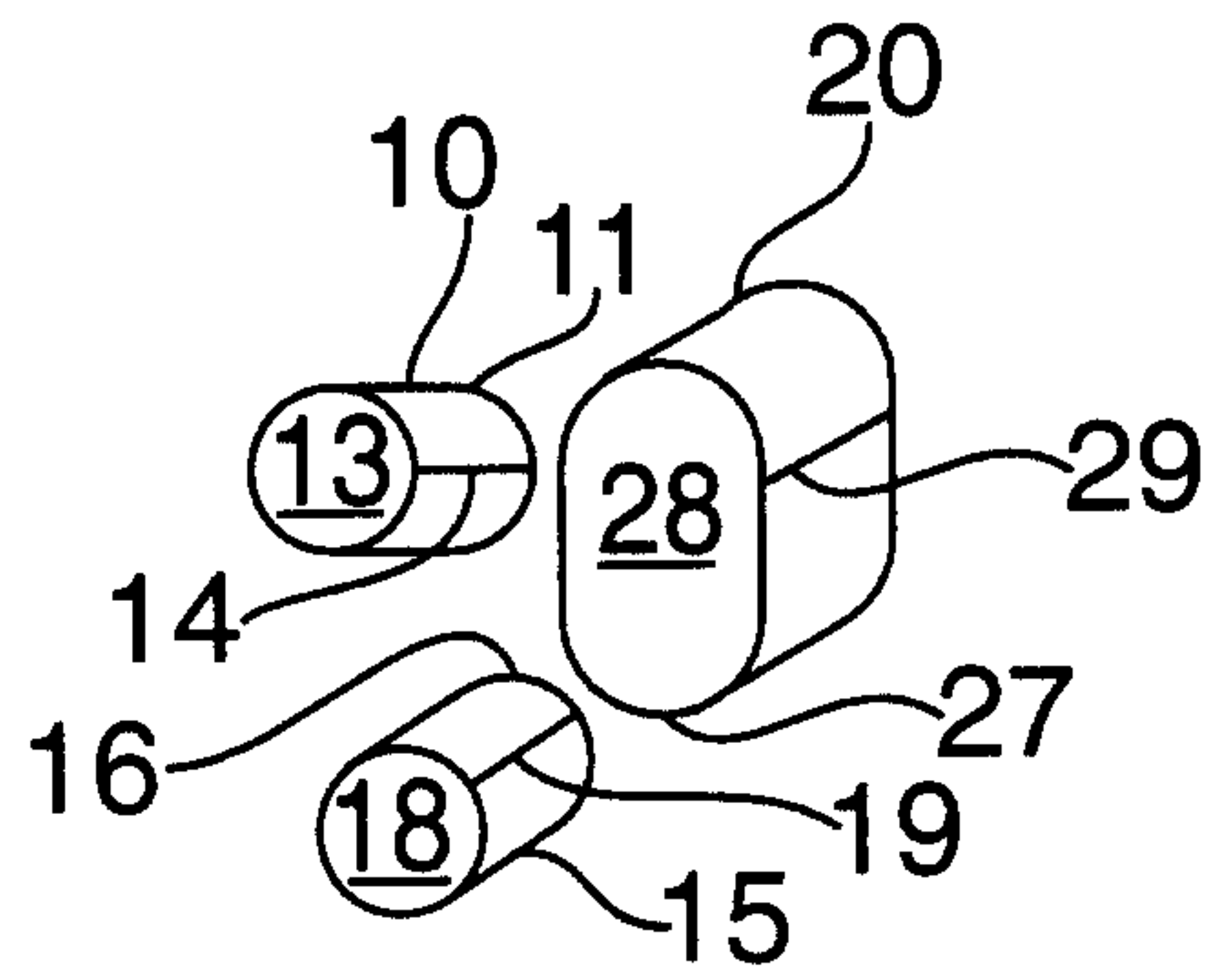


FIG. 4

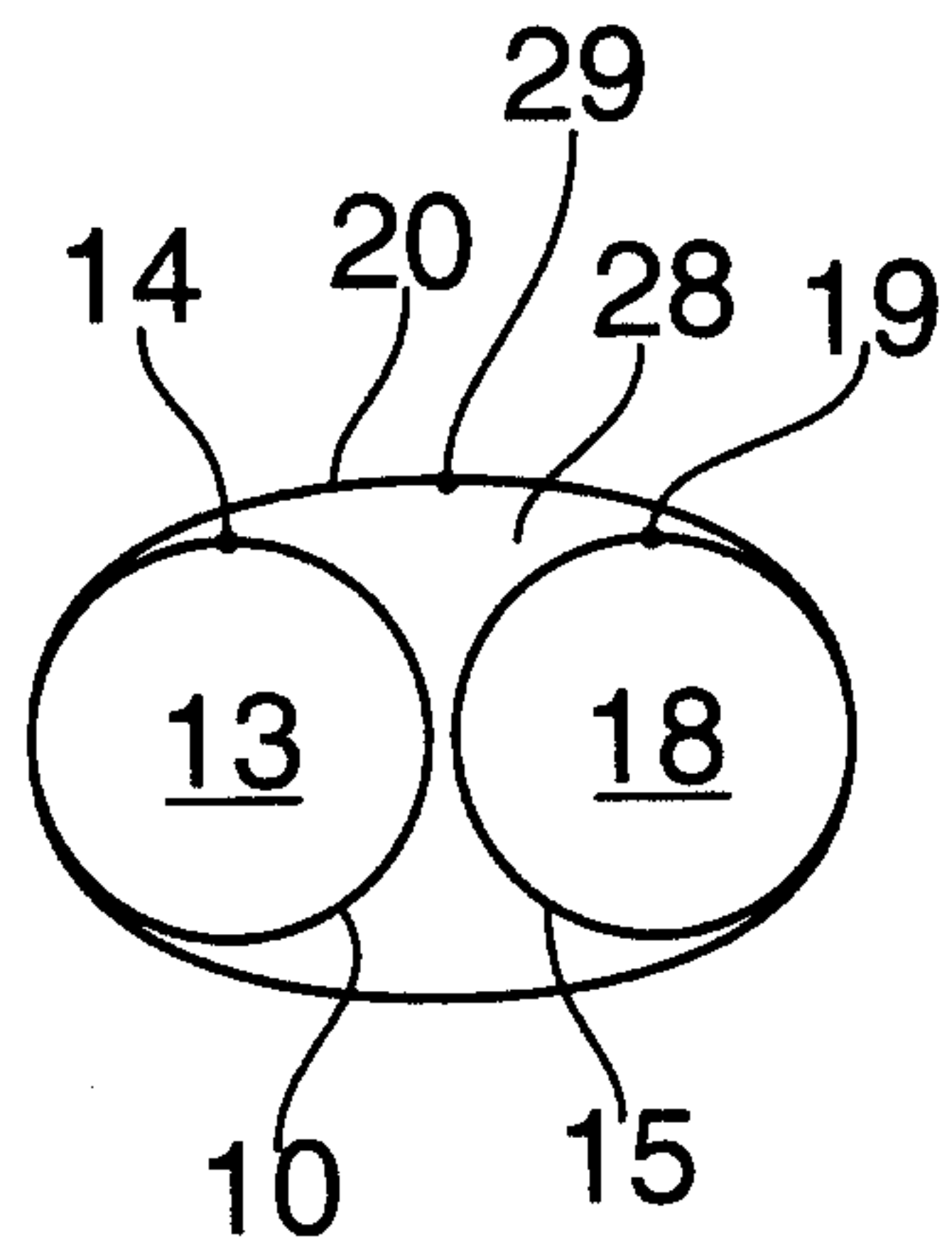


FIG. 5

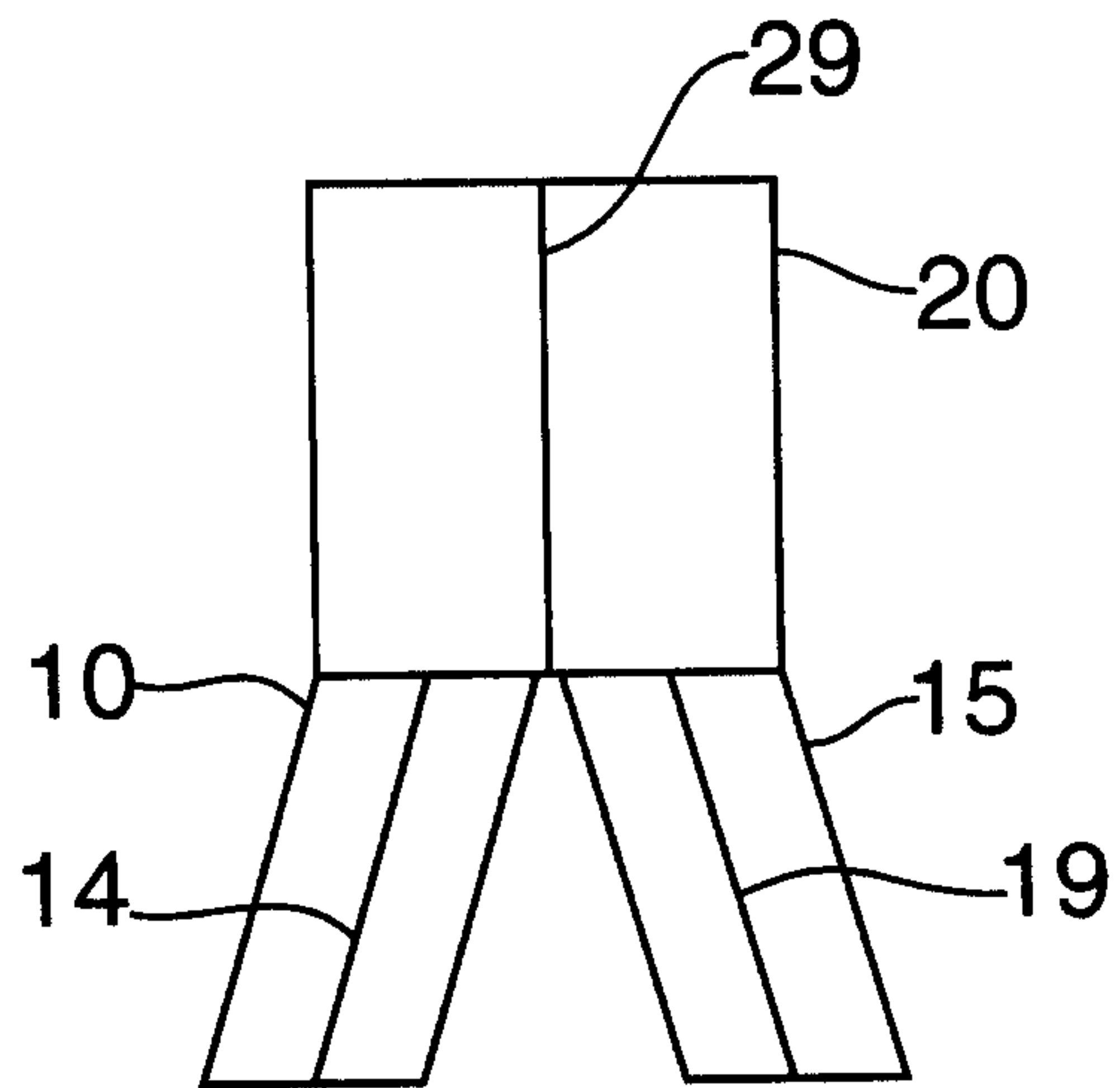


FIG. 6

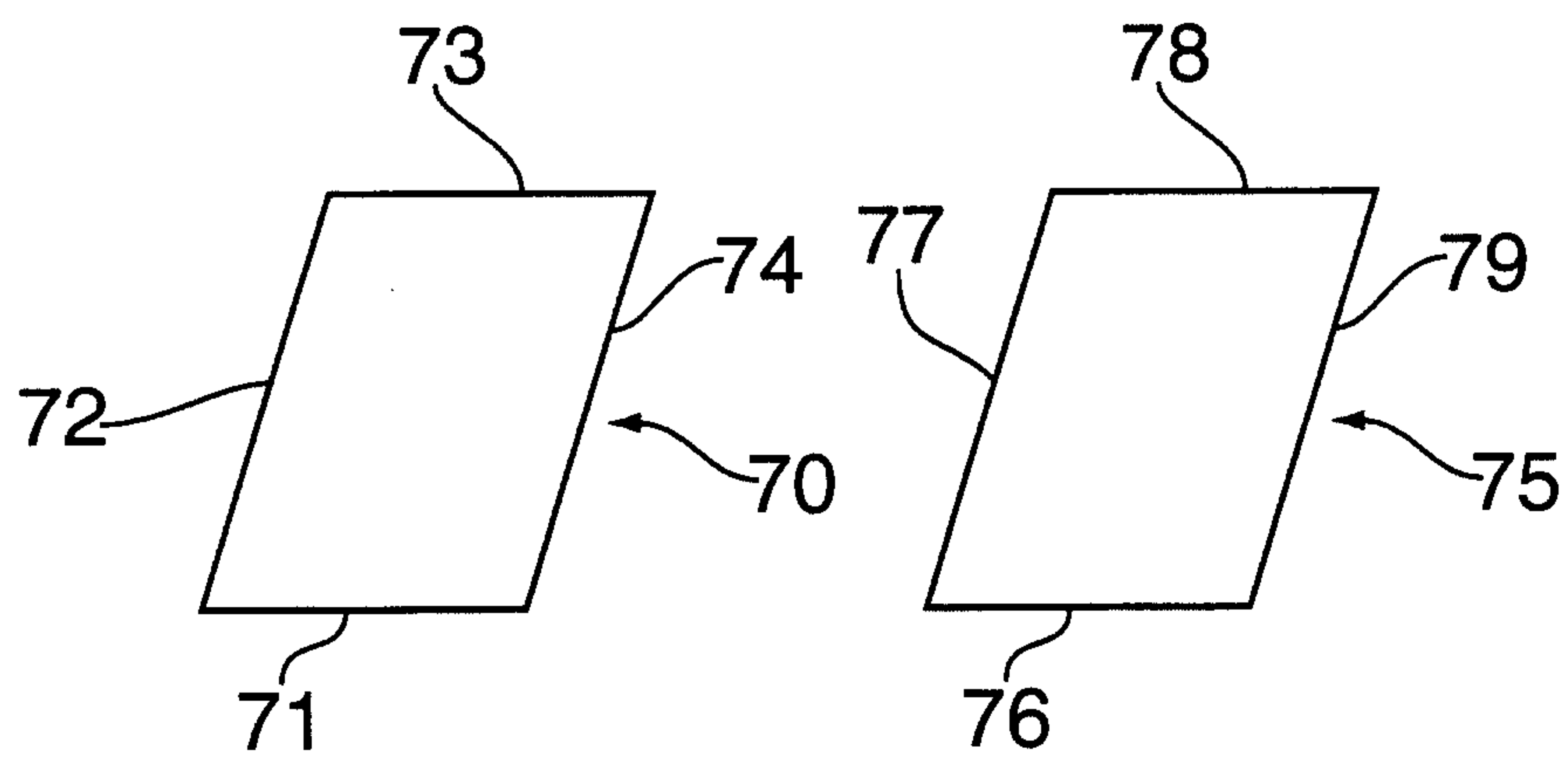


FIG. 7

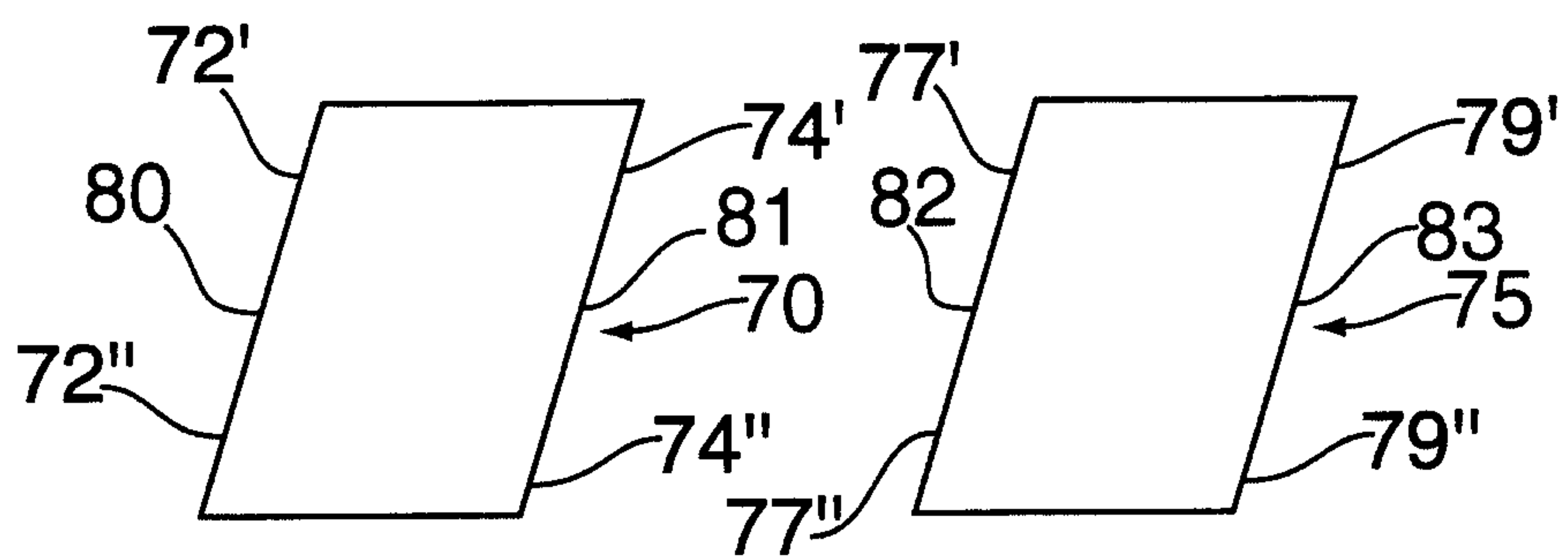


FIG. 8

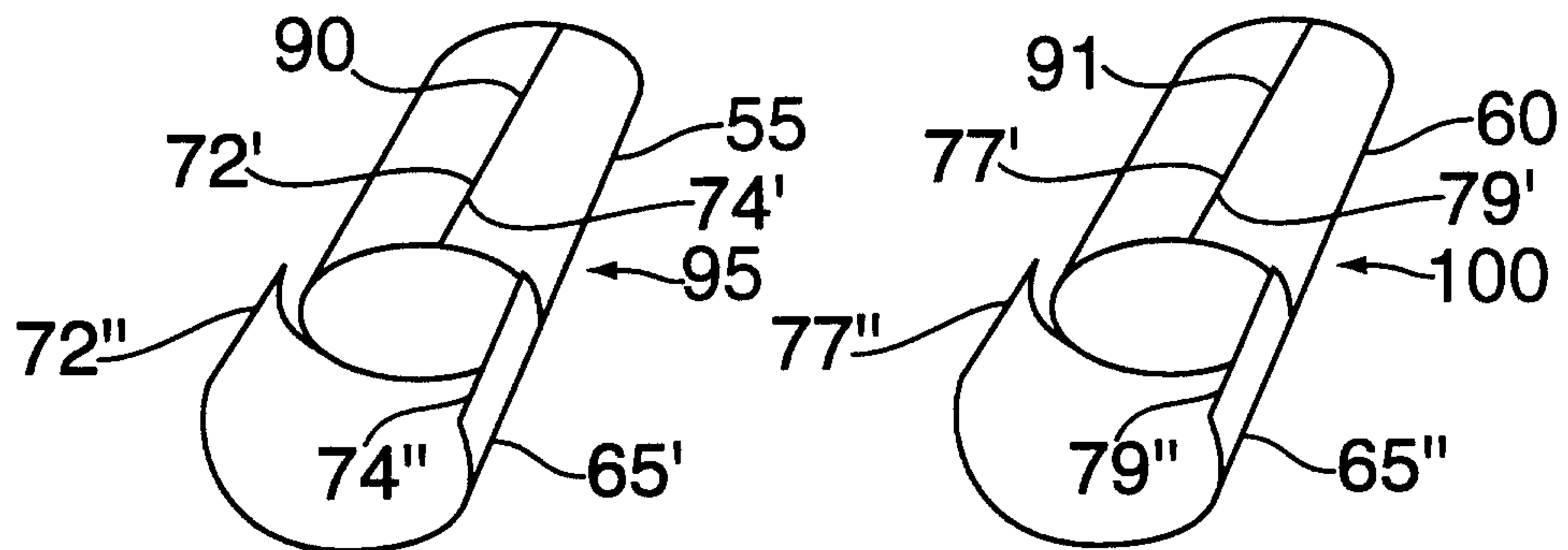


FIG. 9

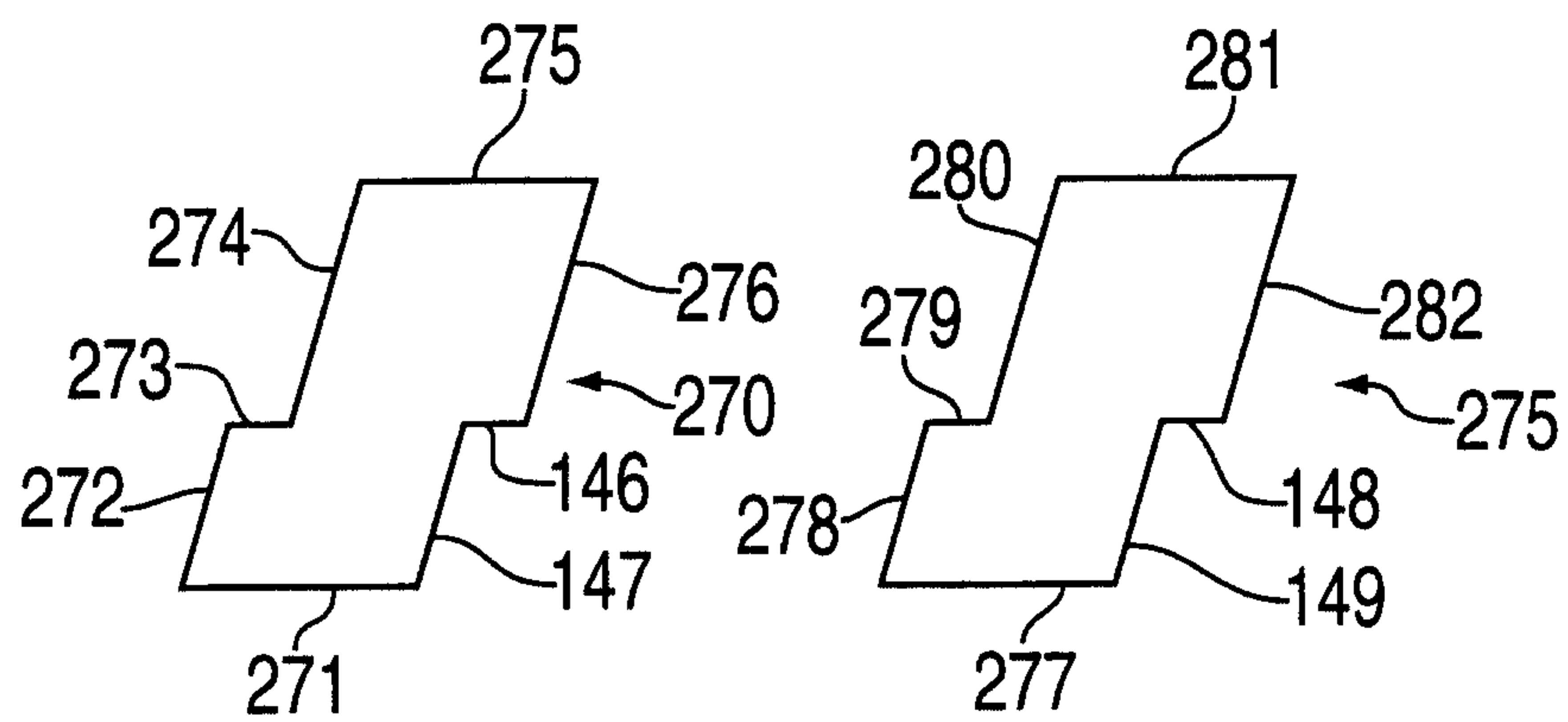


FIG. 7B

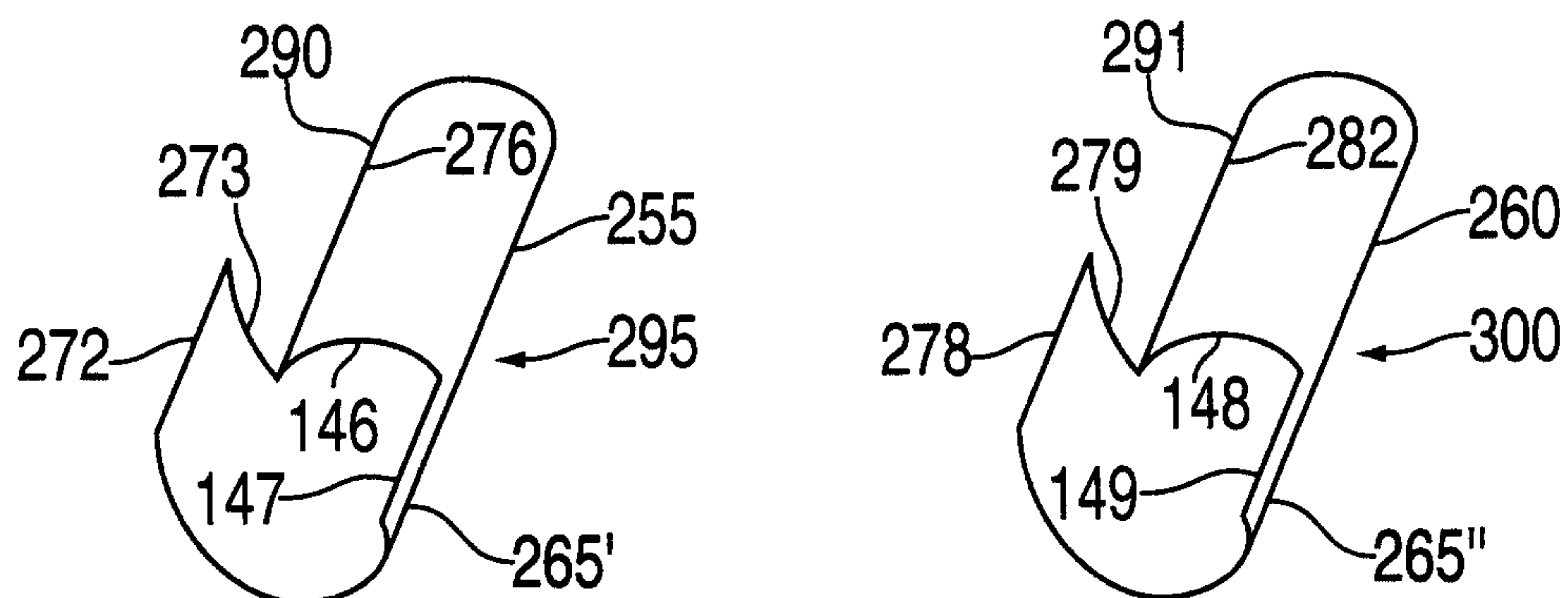


FIG. 9B

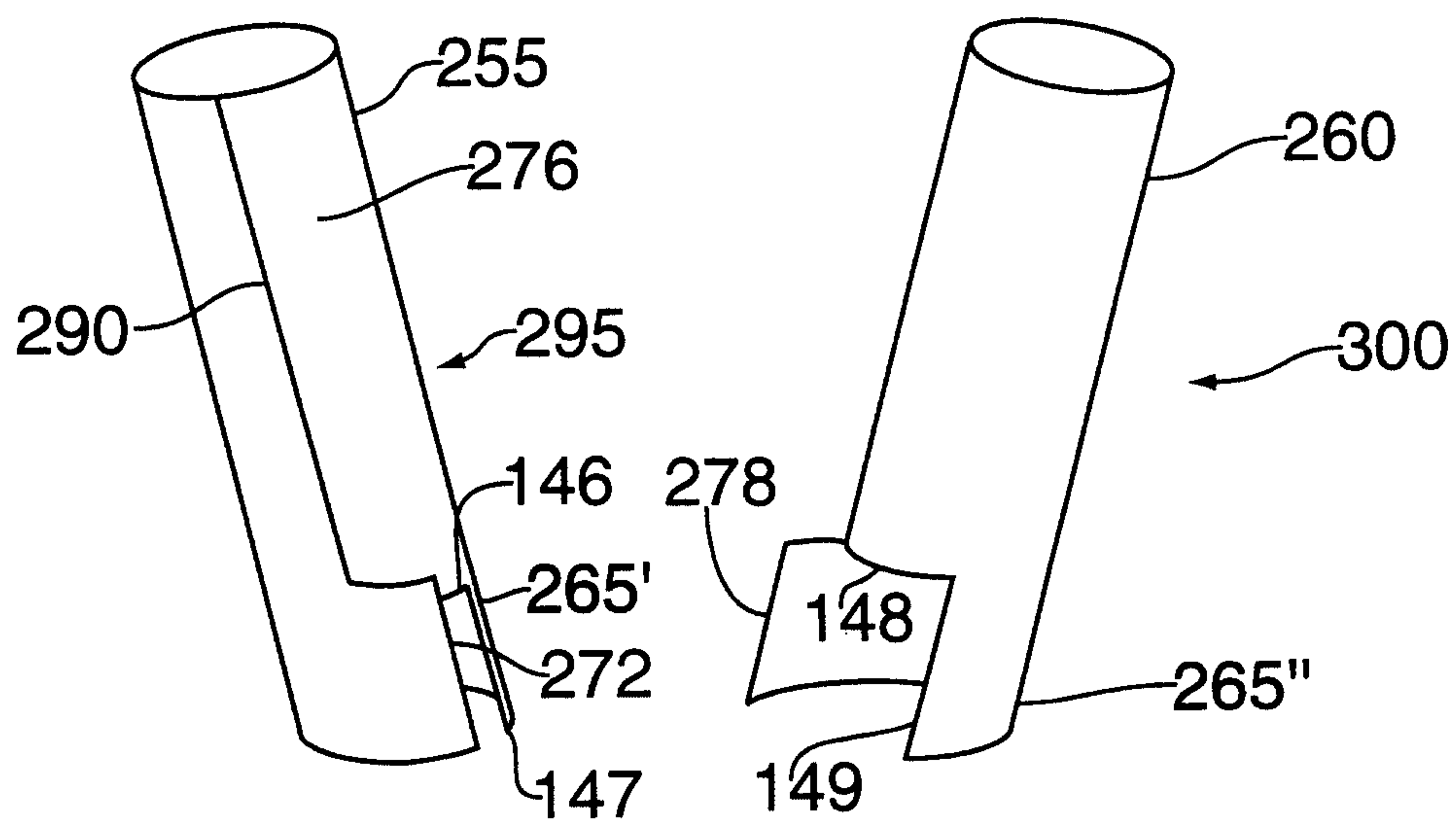


FIG. 10B

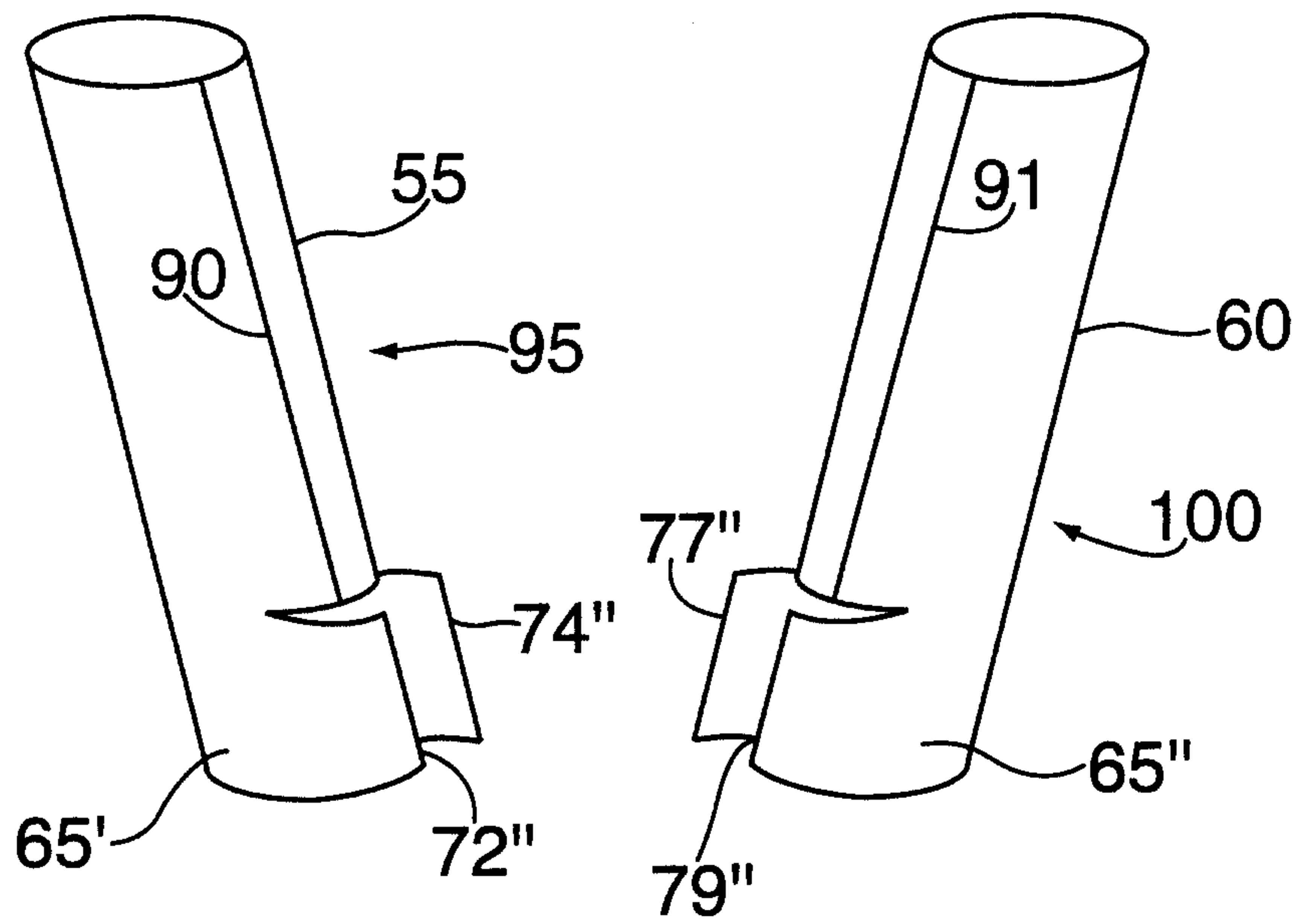


FIG. 10

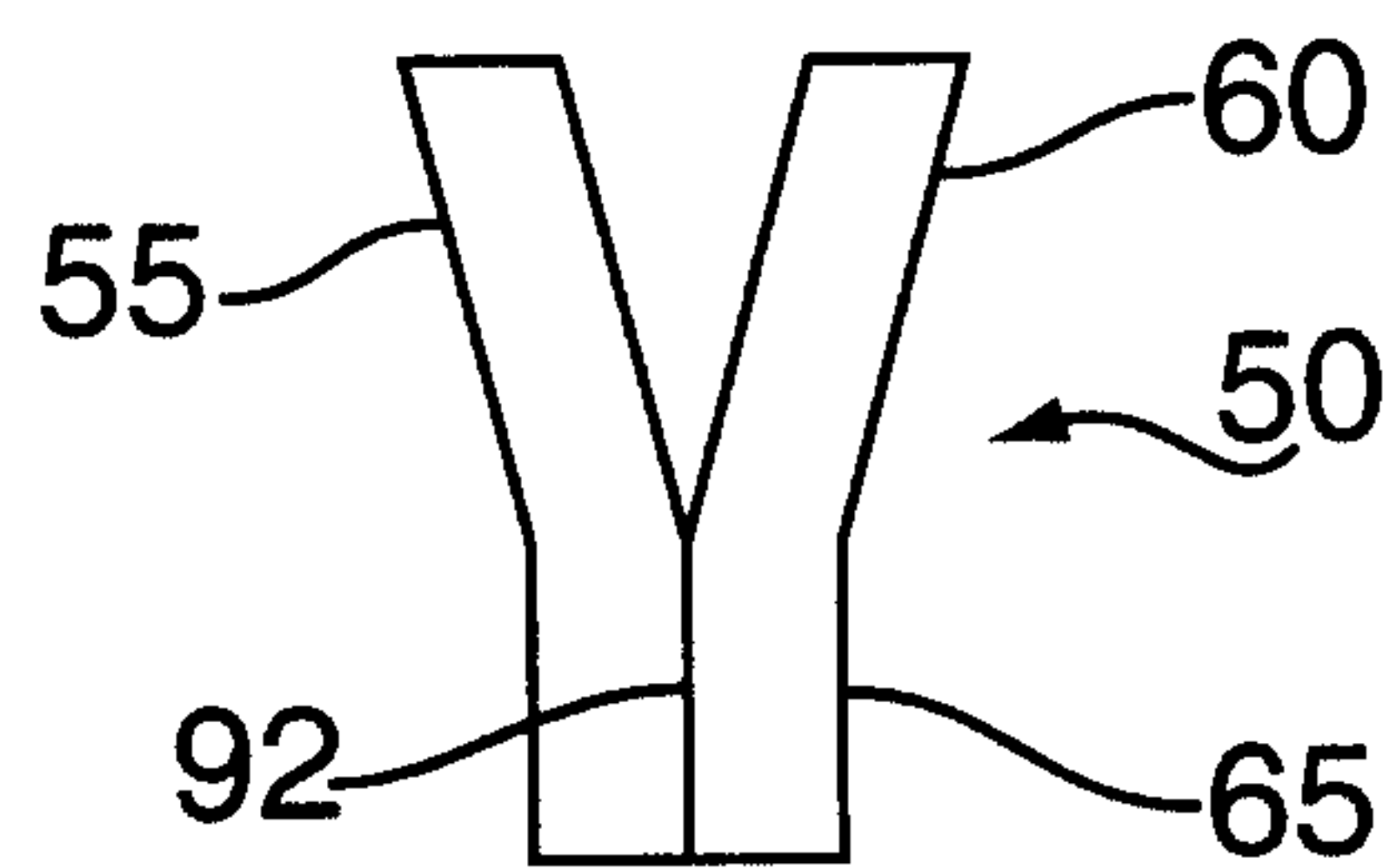


FIG. 11

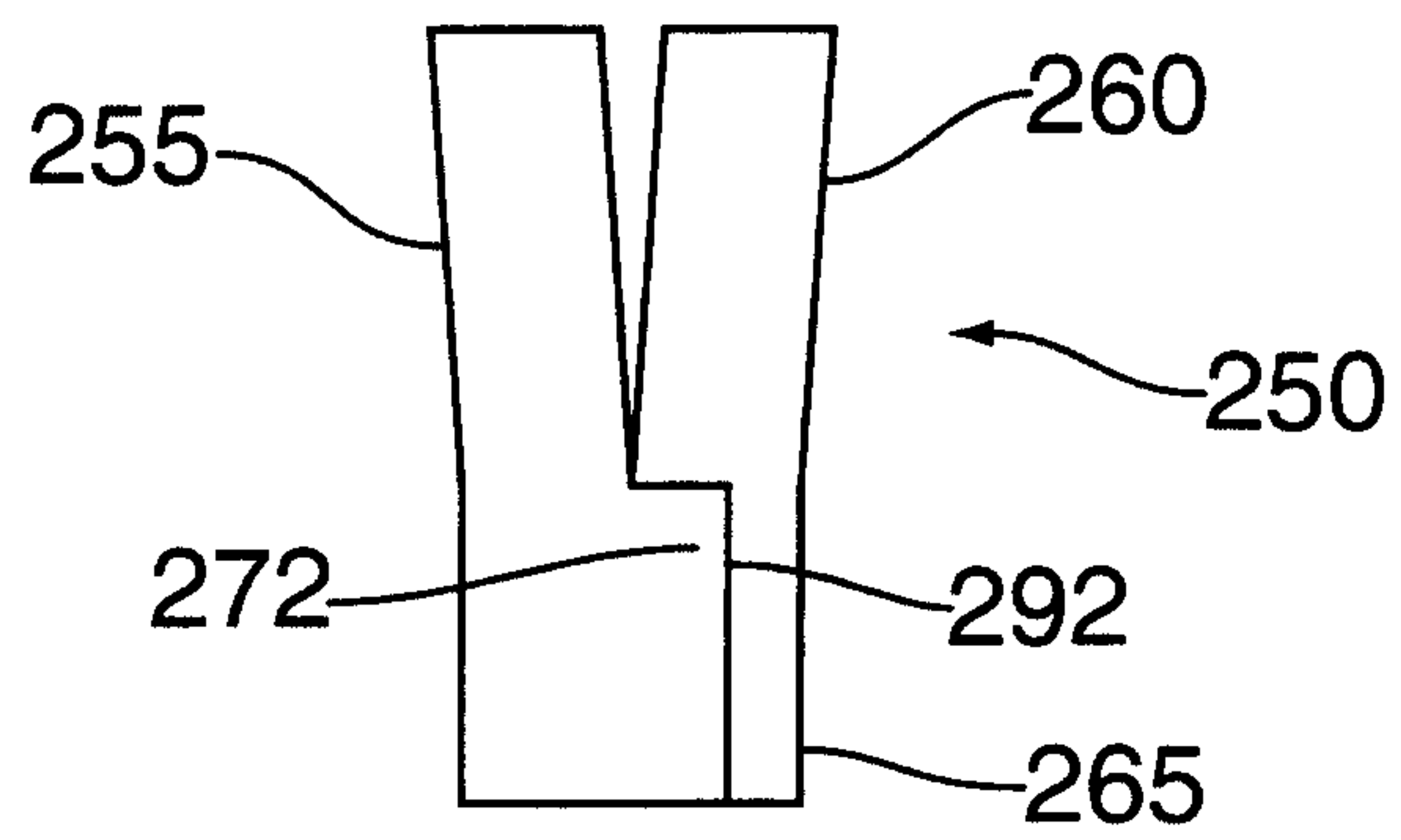


FIG. 11B

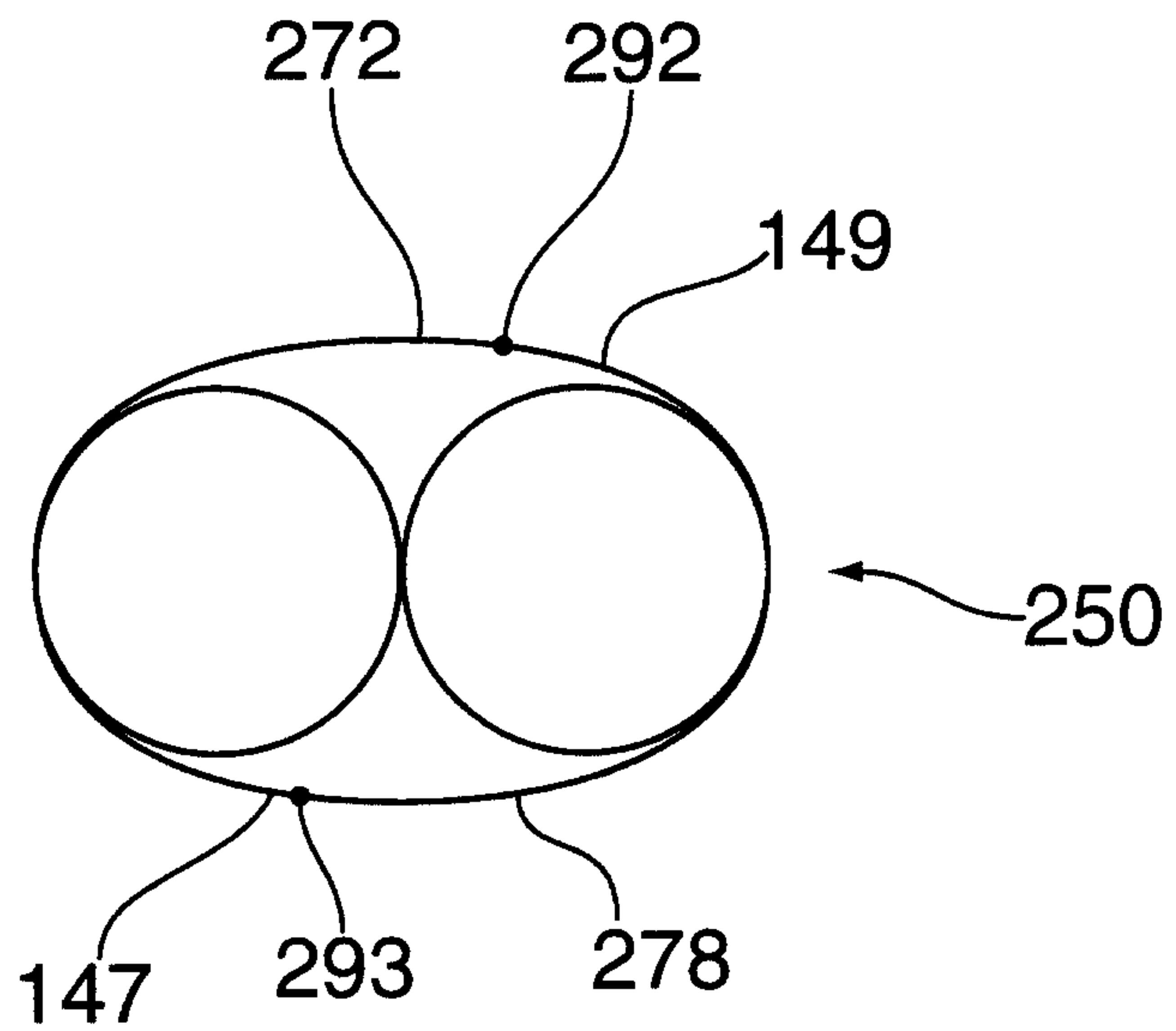


FIG. 12B

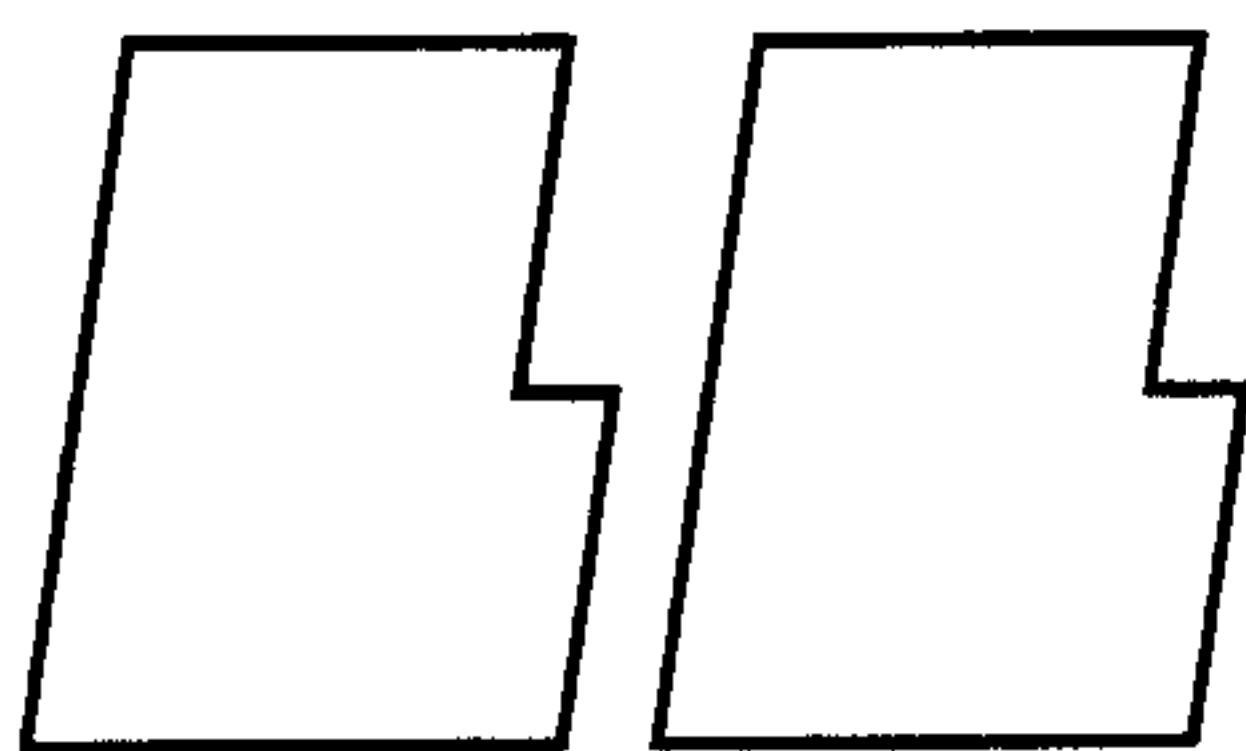


FIG. 12C

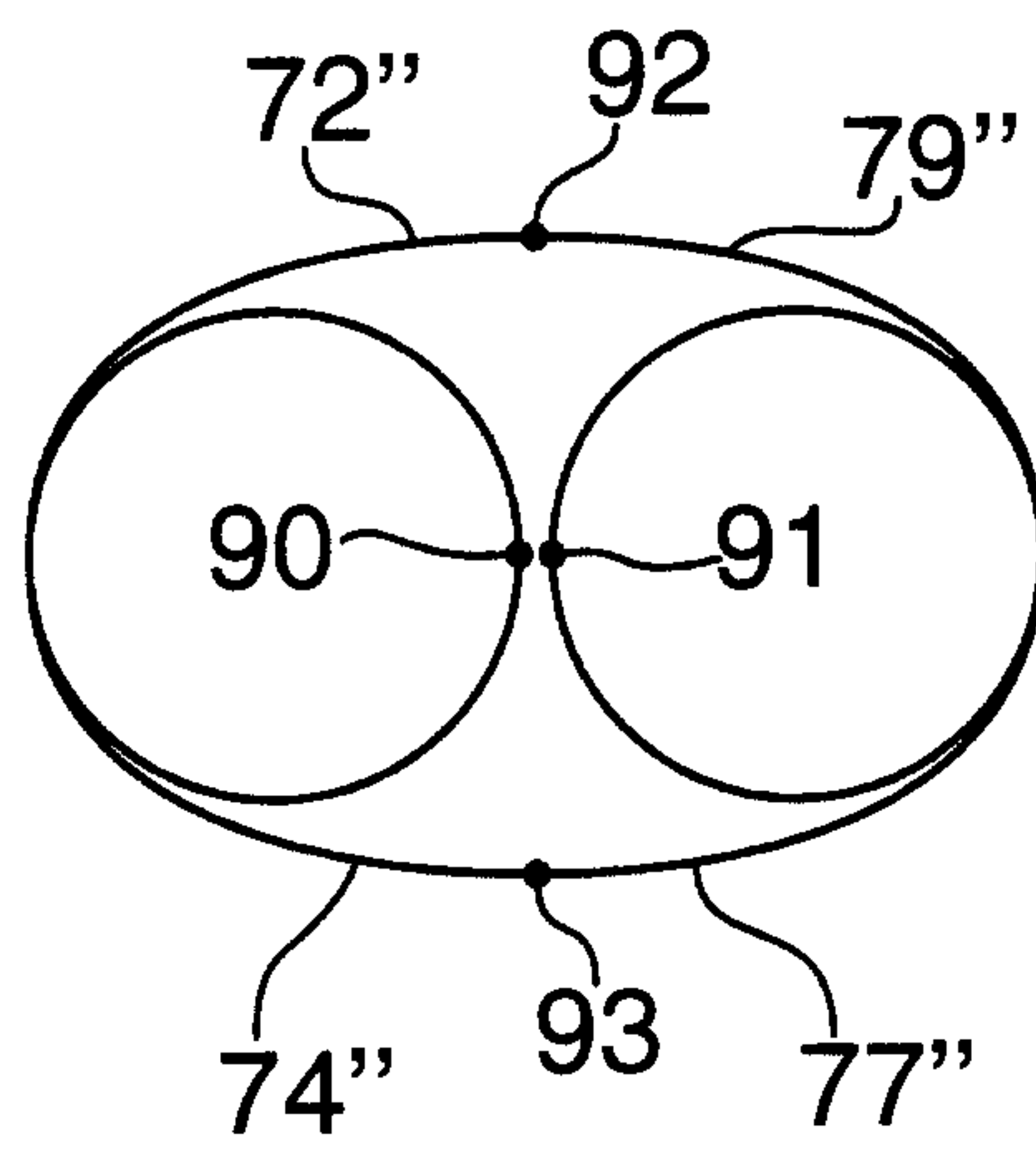


FIG. 12

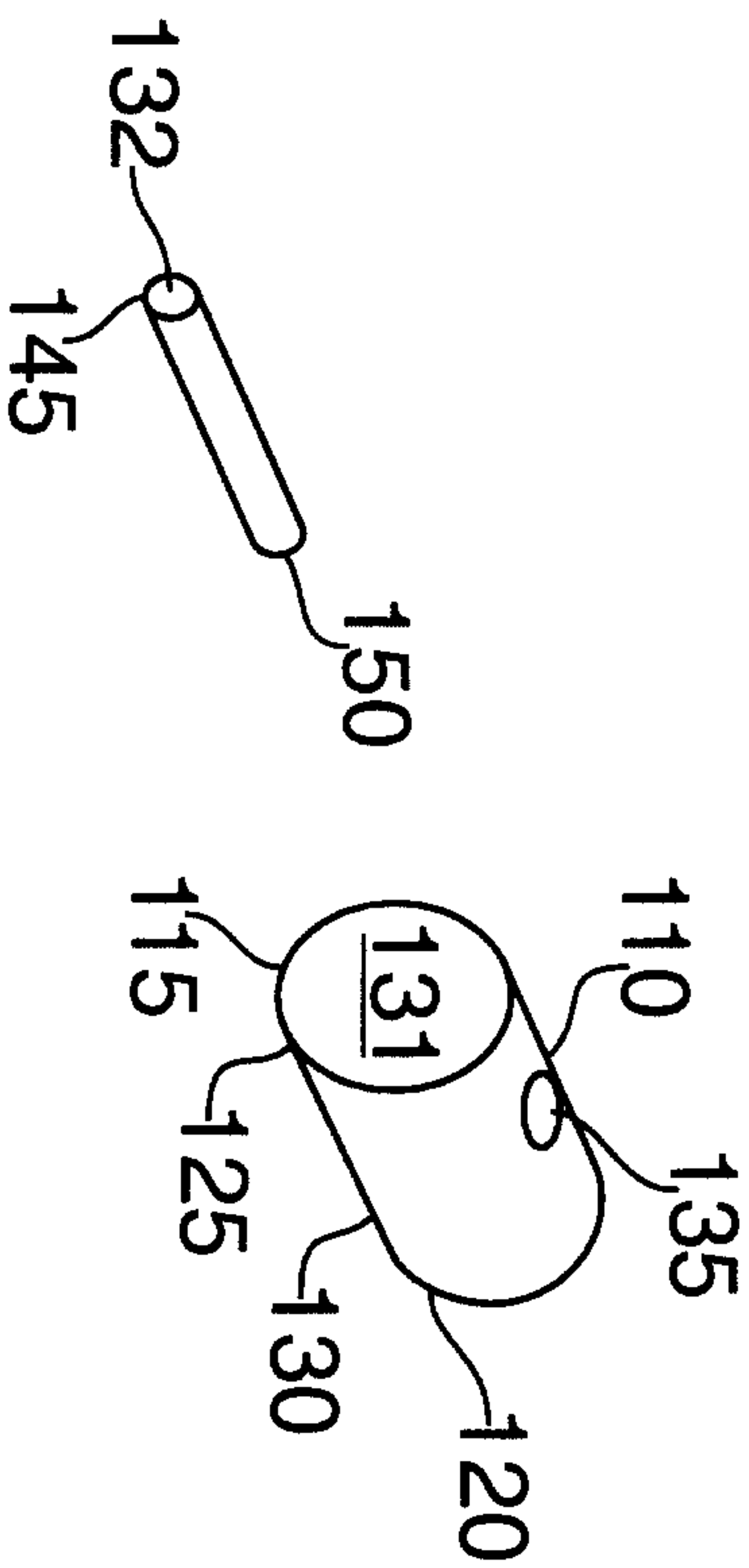


FIG. 13

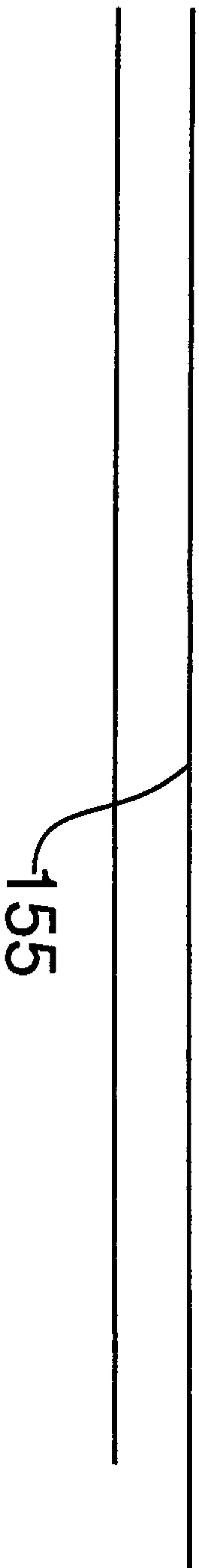
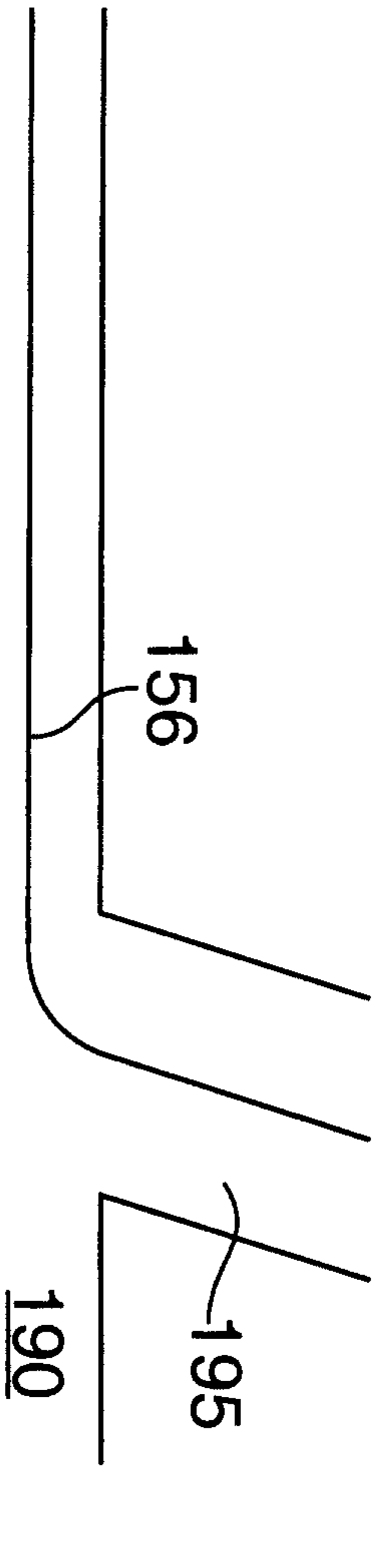


FIG. 14

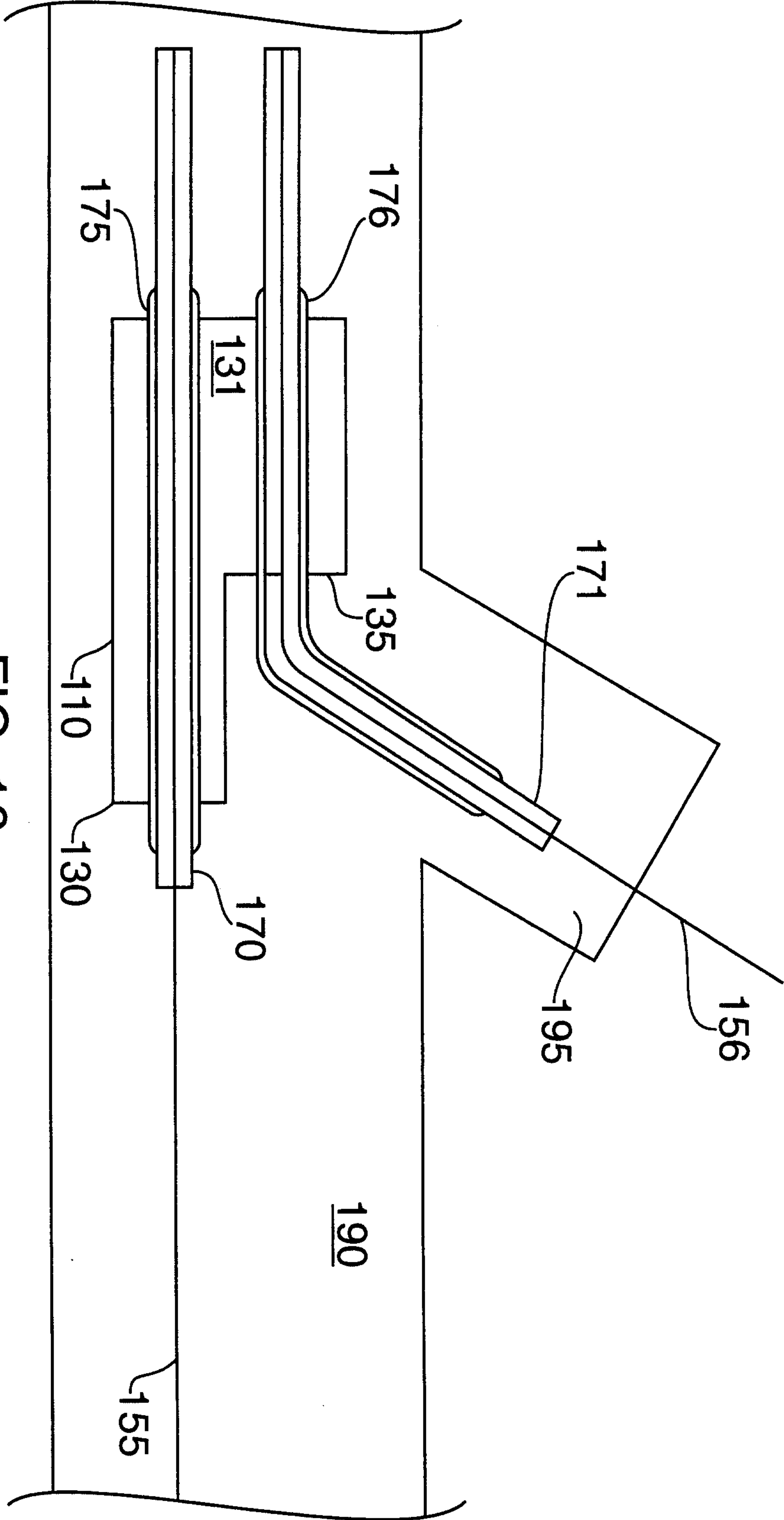


FIG. 16

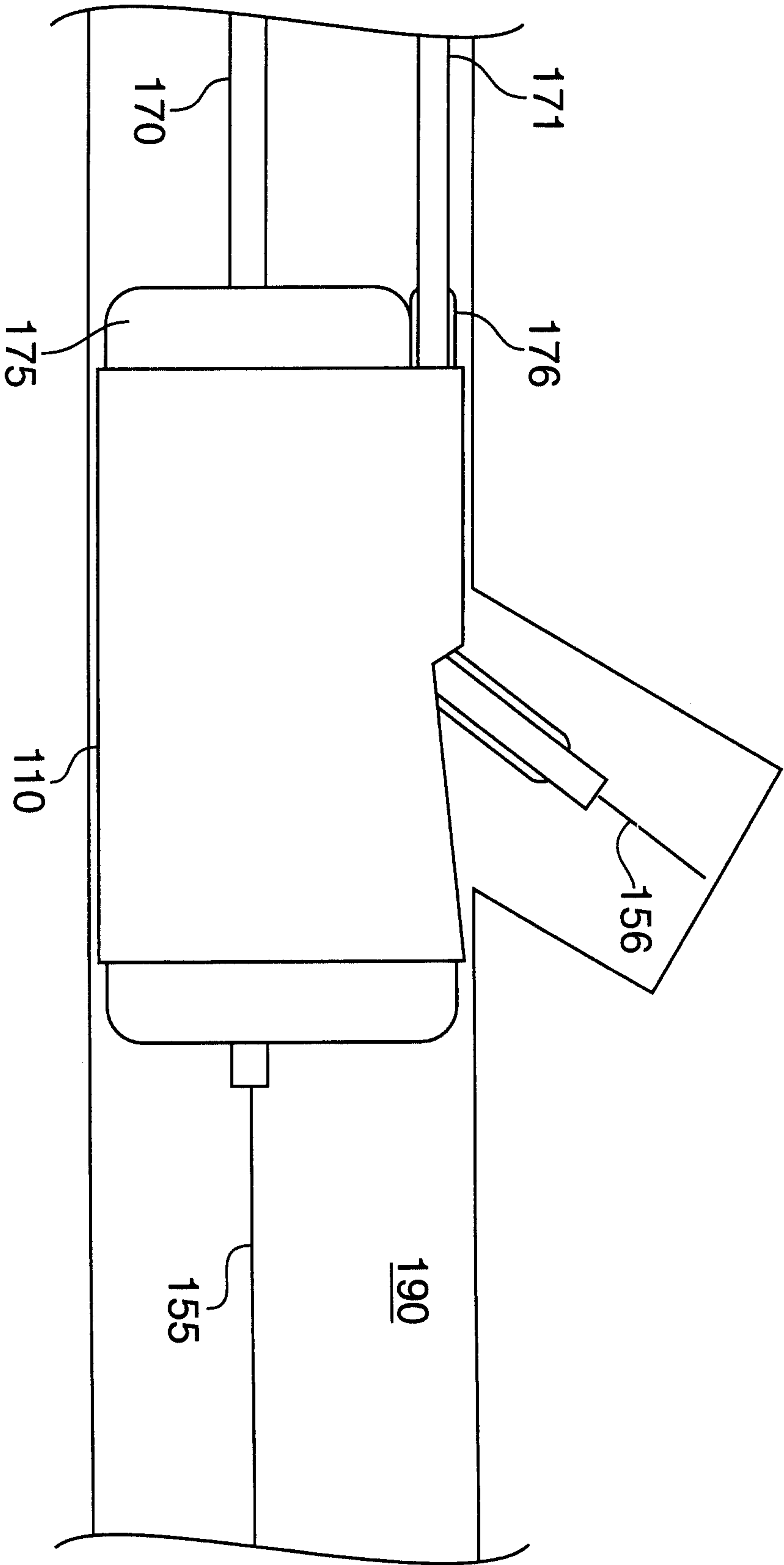


FIG. 17

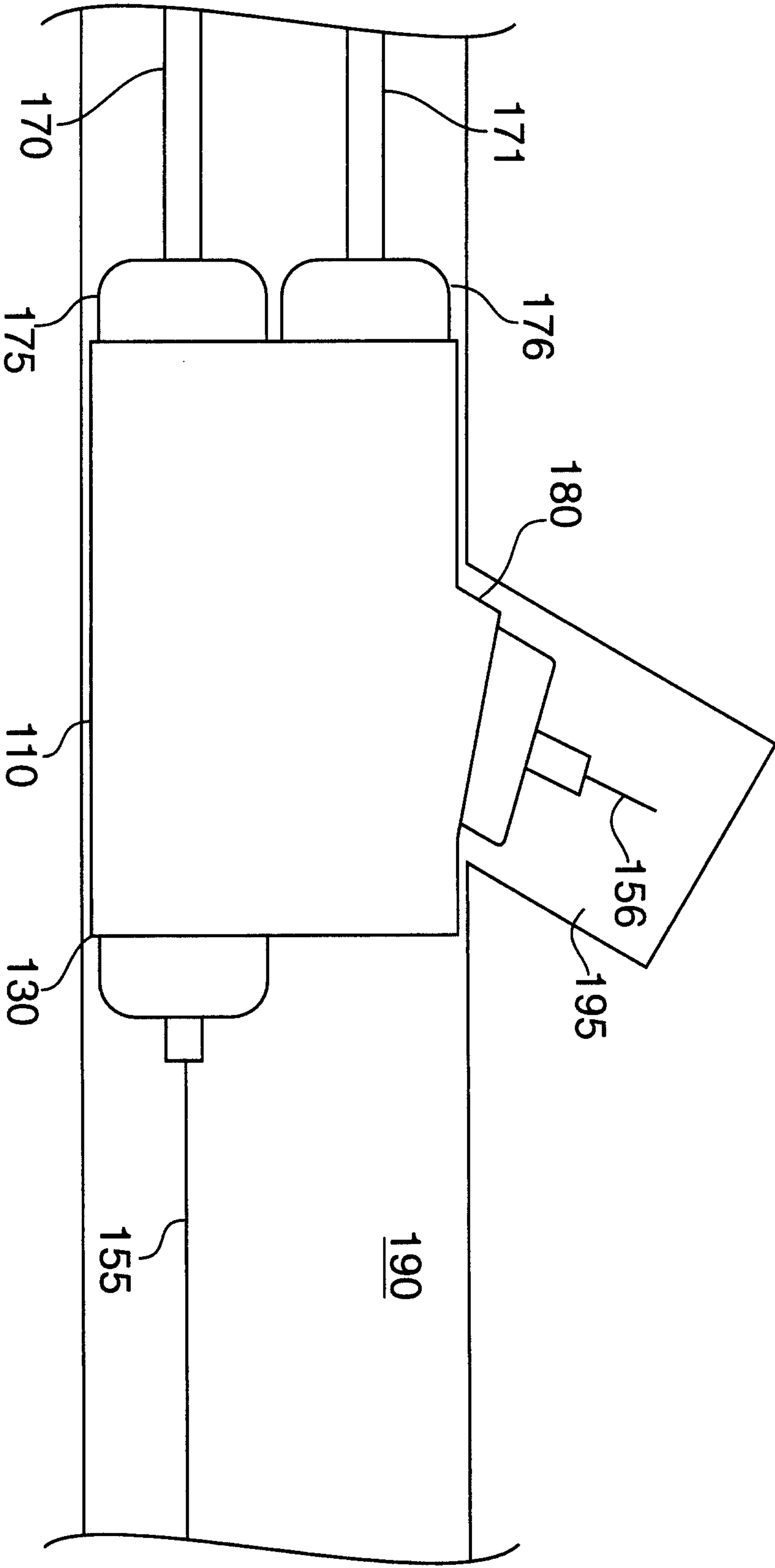


FIG. 18

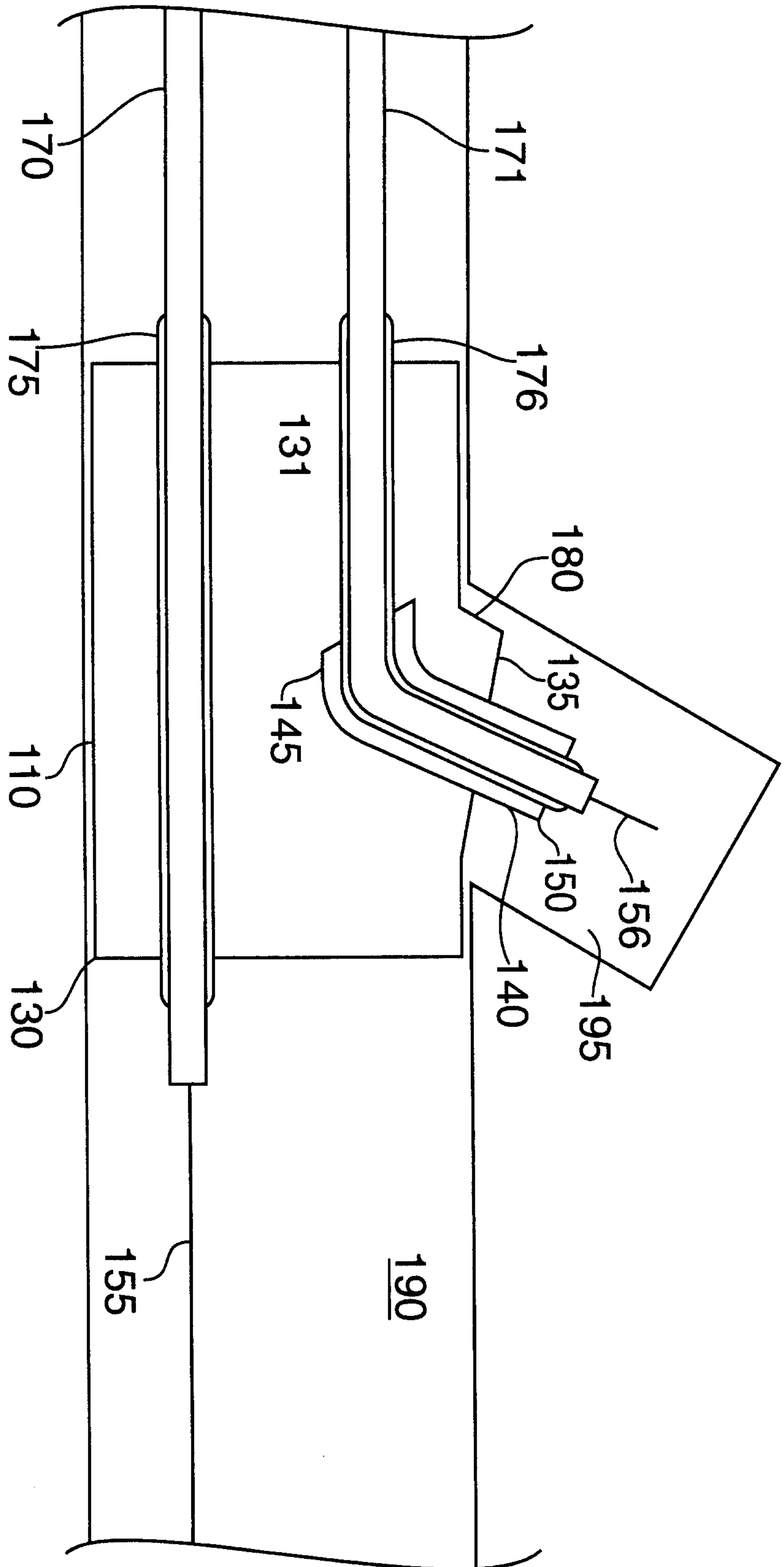


FIG. 19

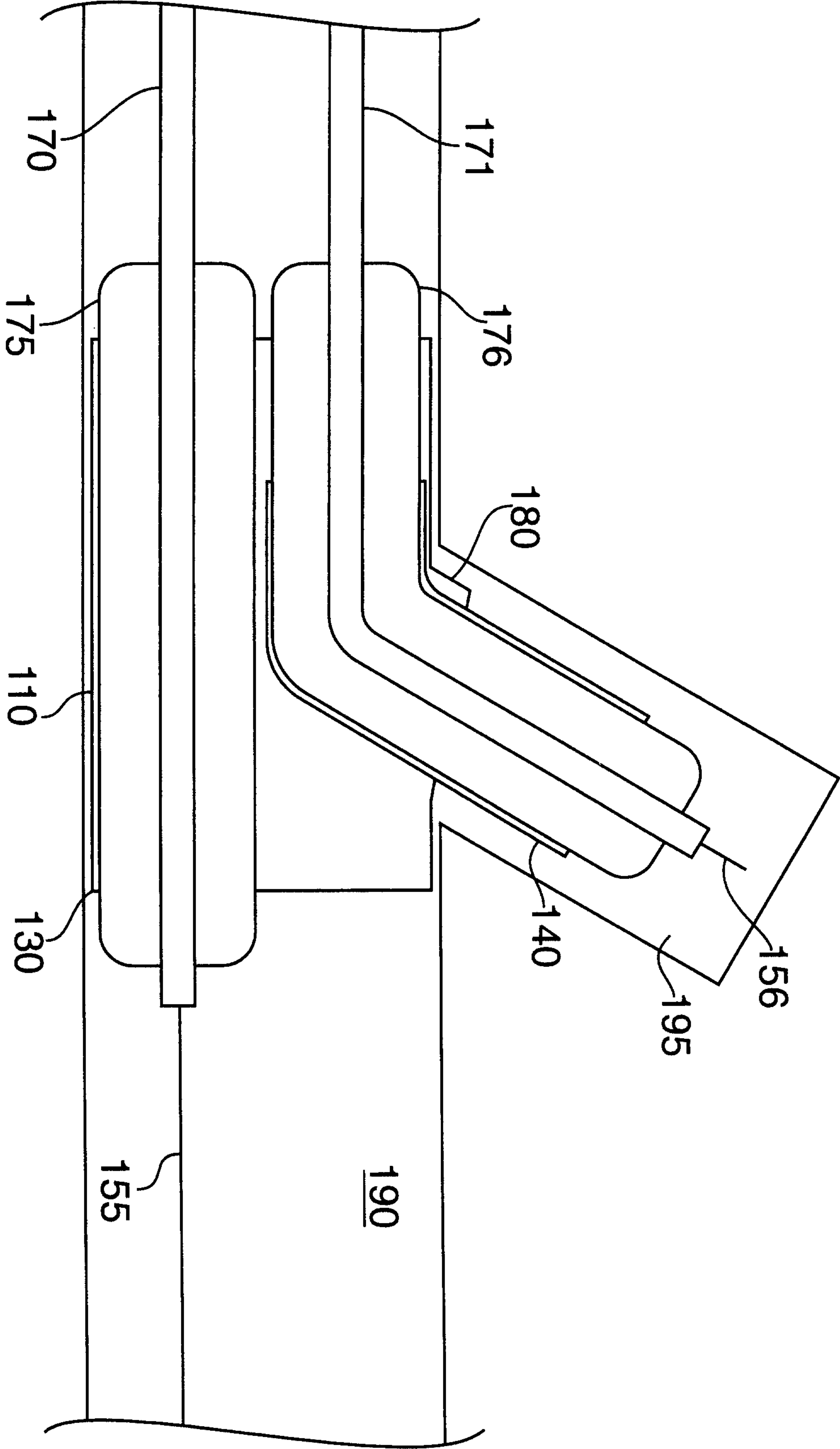
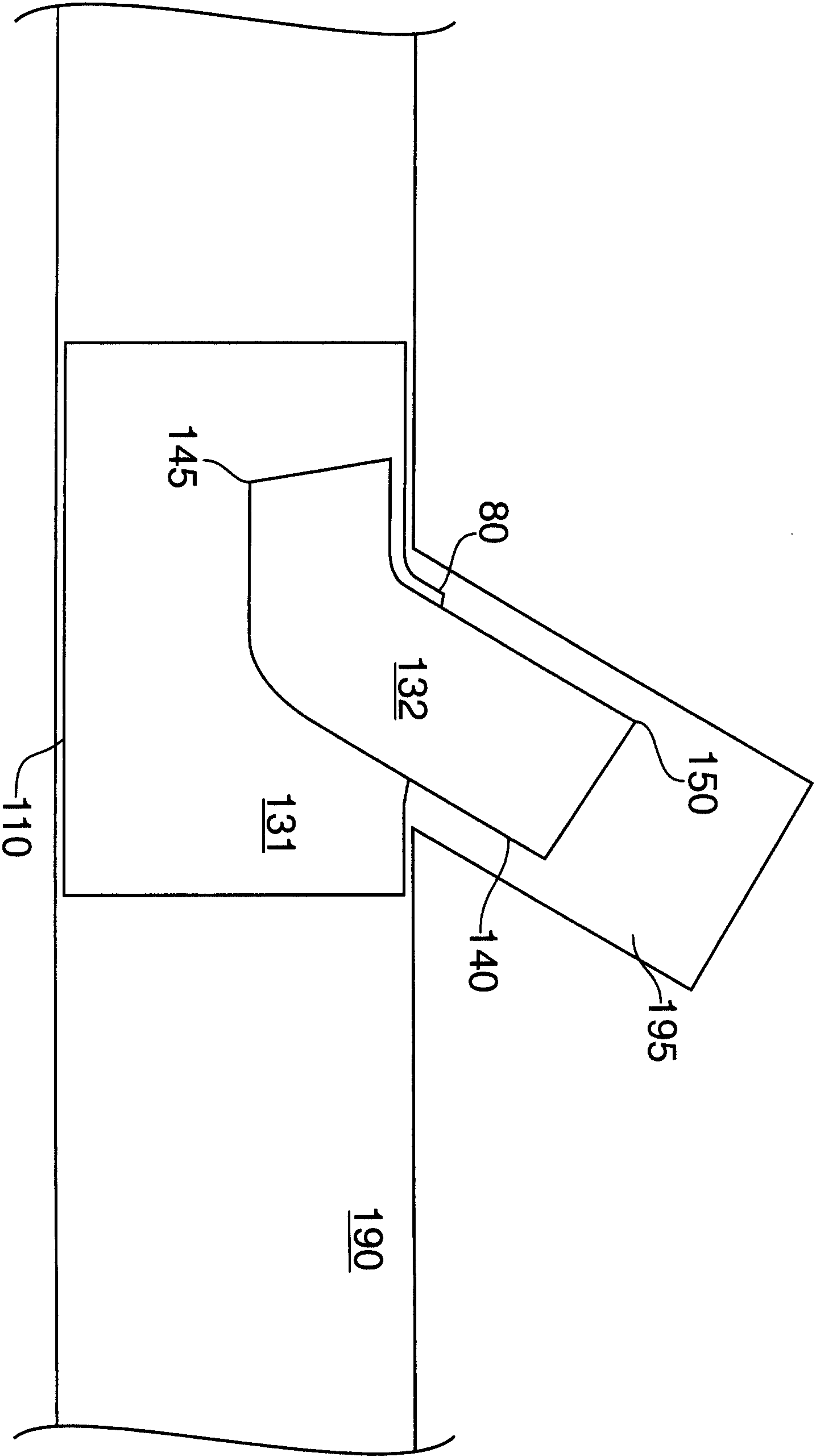
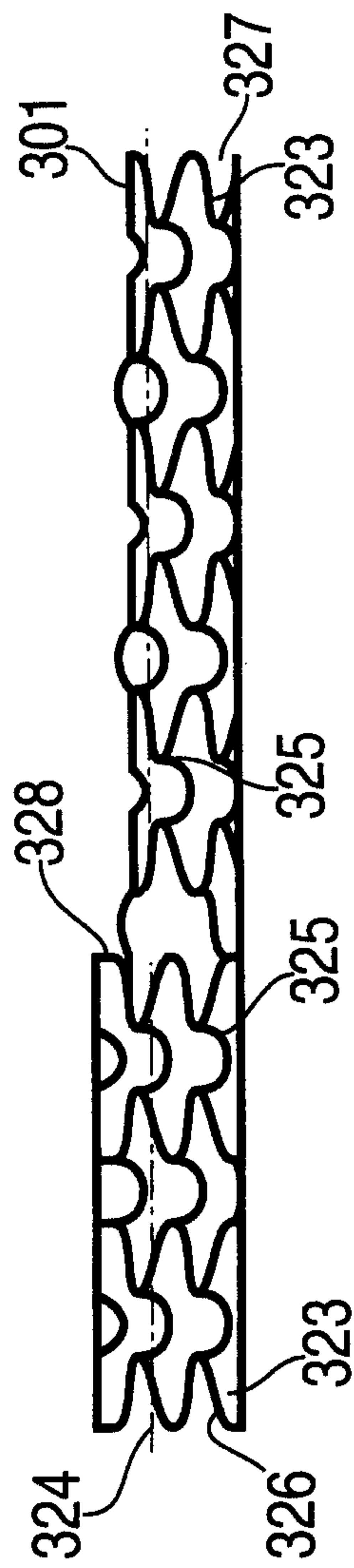
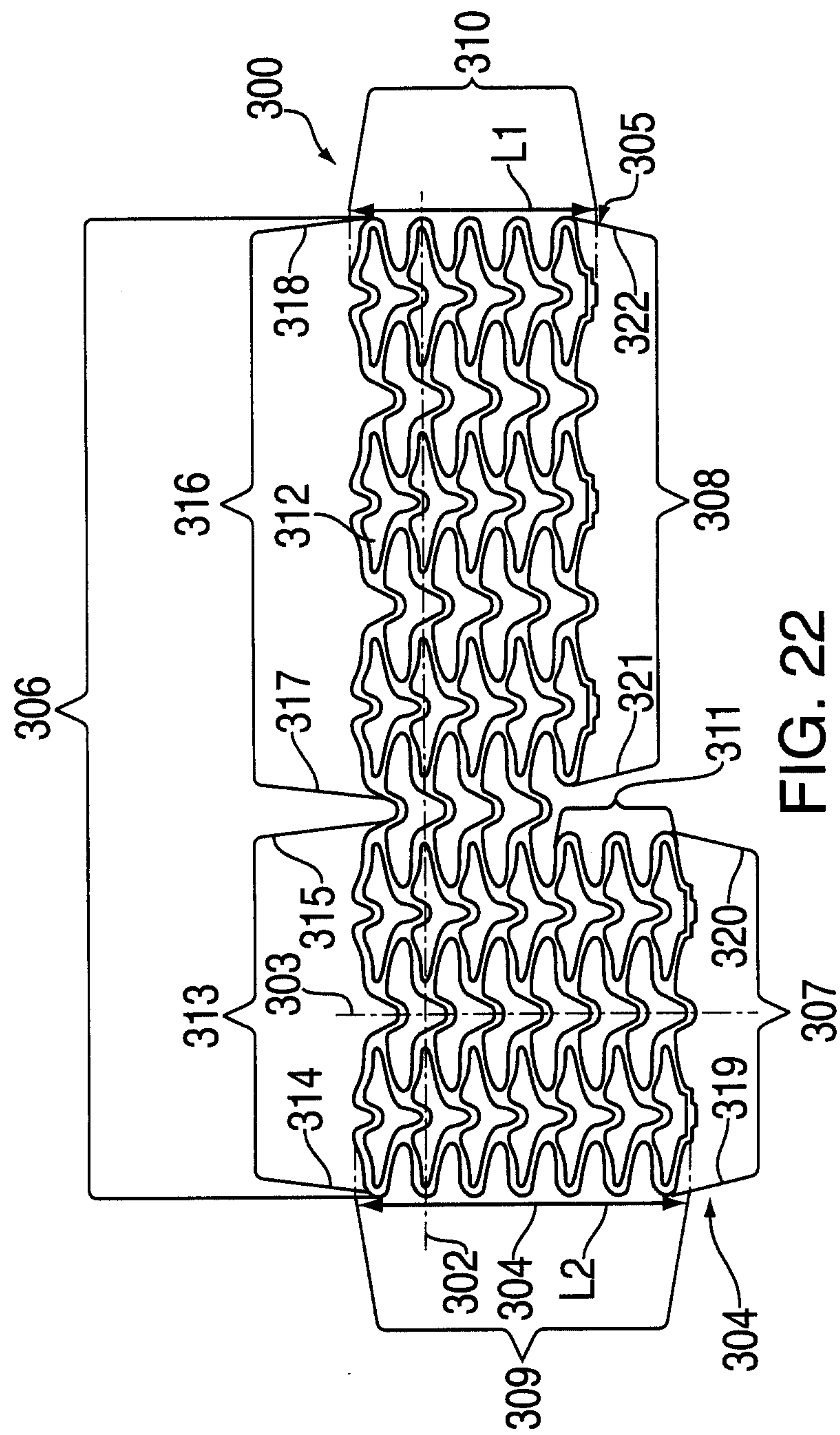


FIG. 20





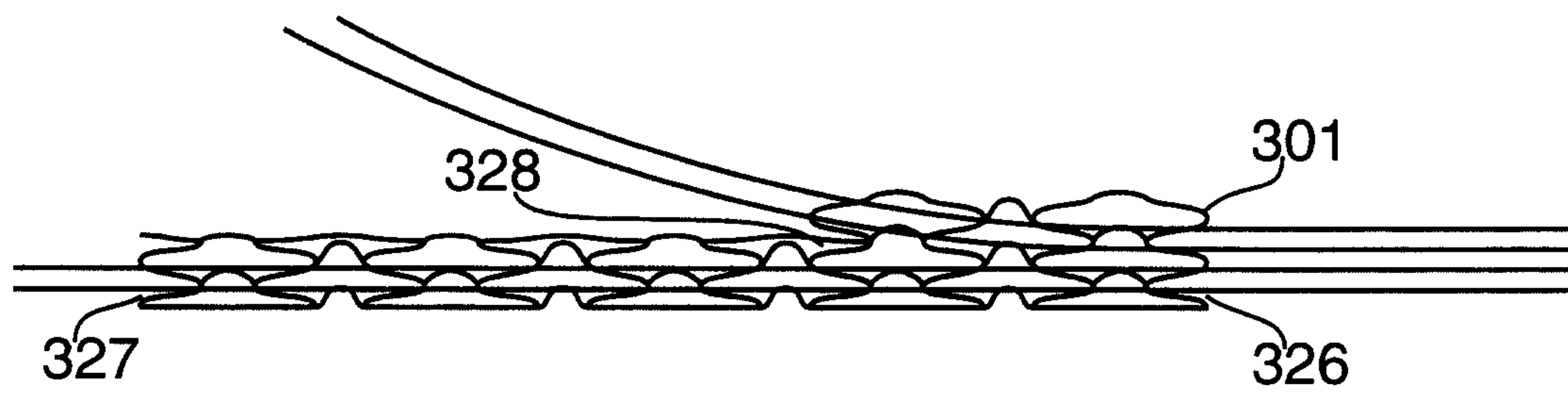


FIG. 24

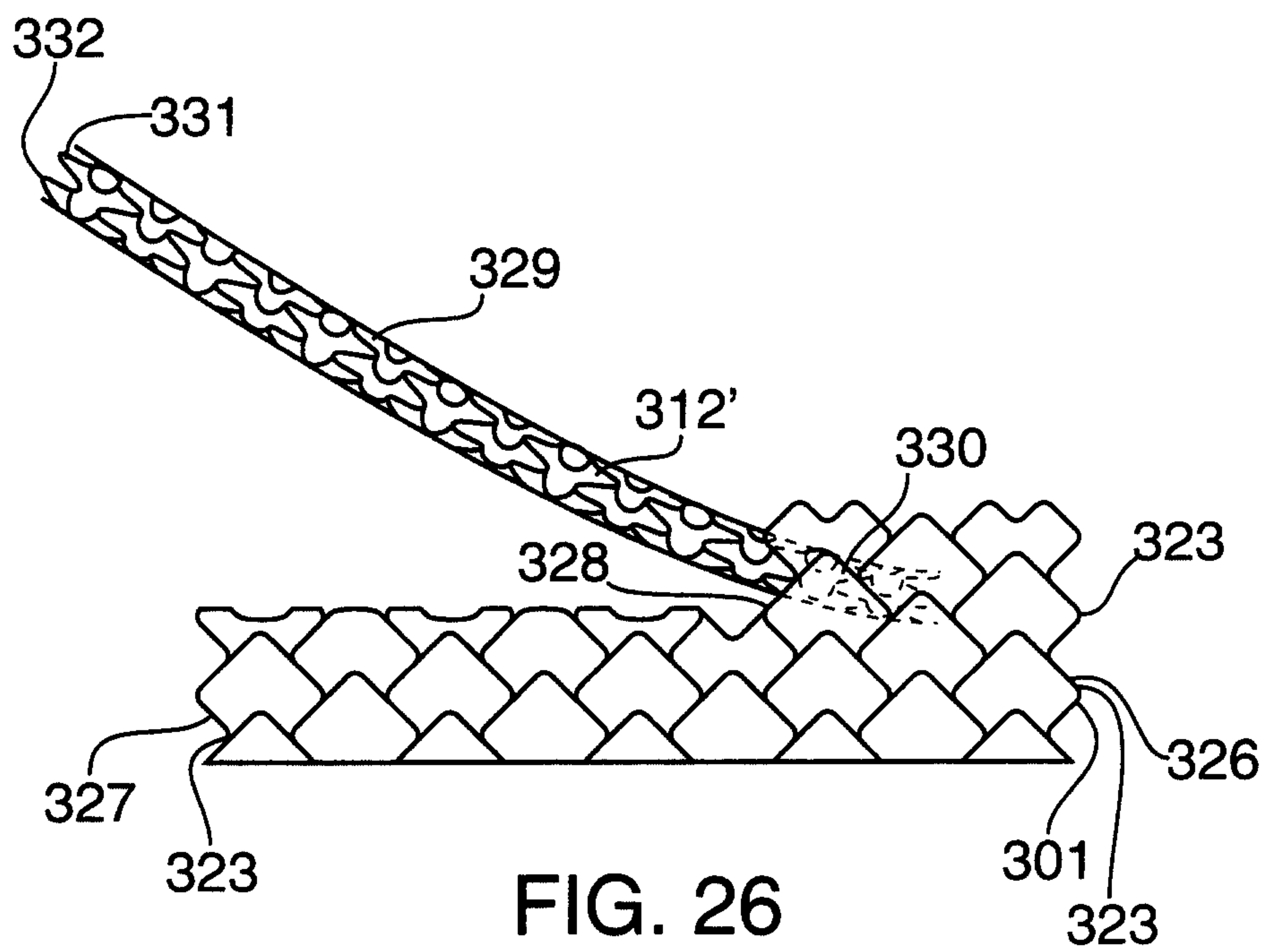


FIG. 26

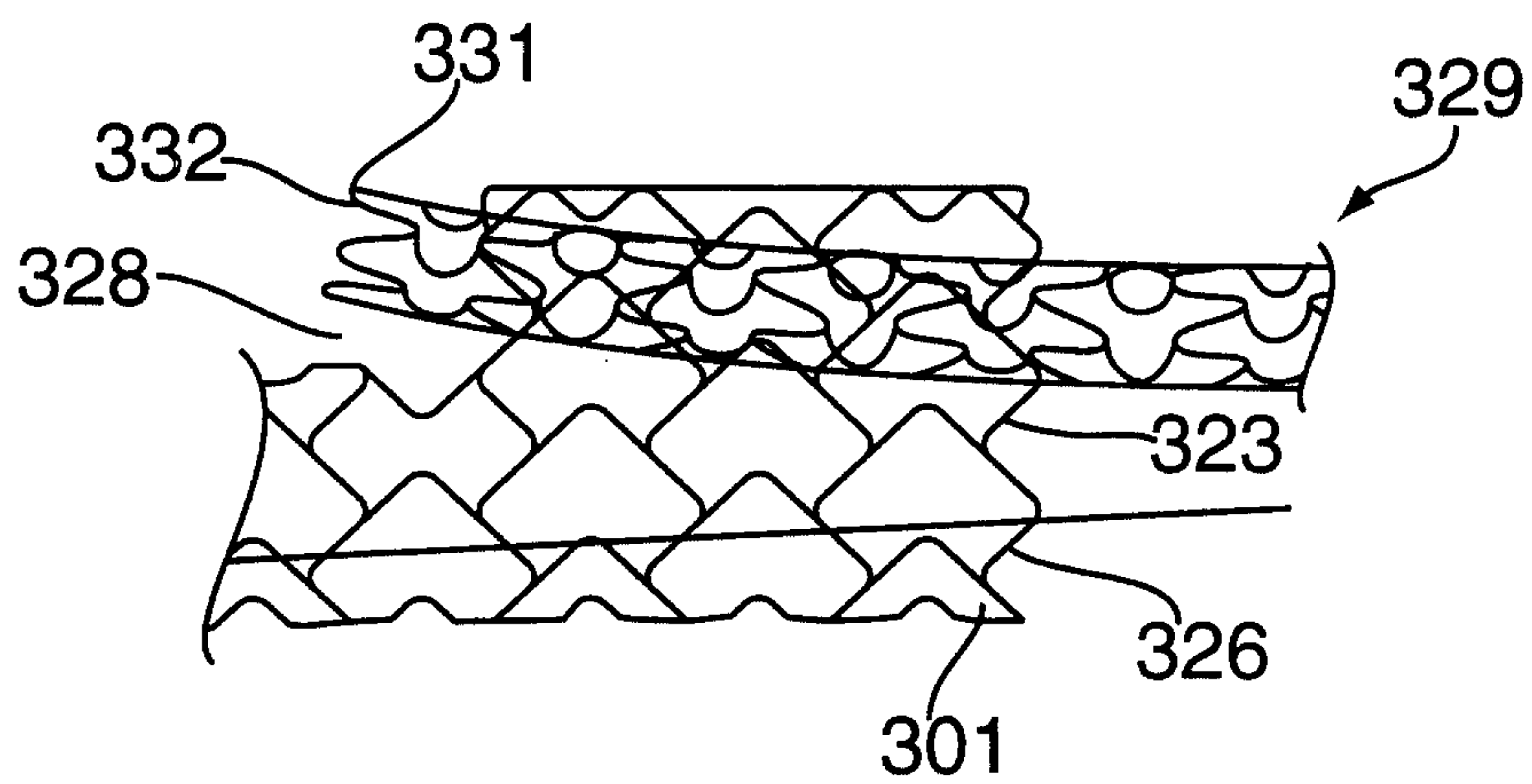


FIG. 25

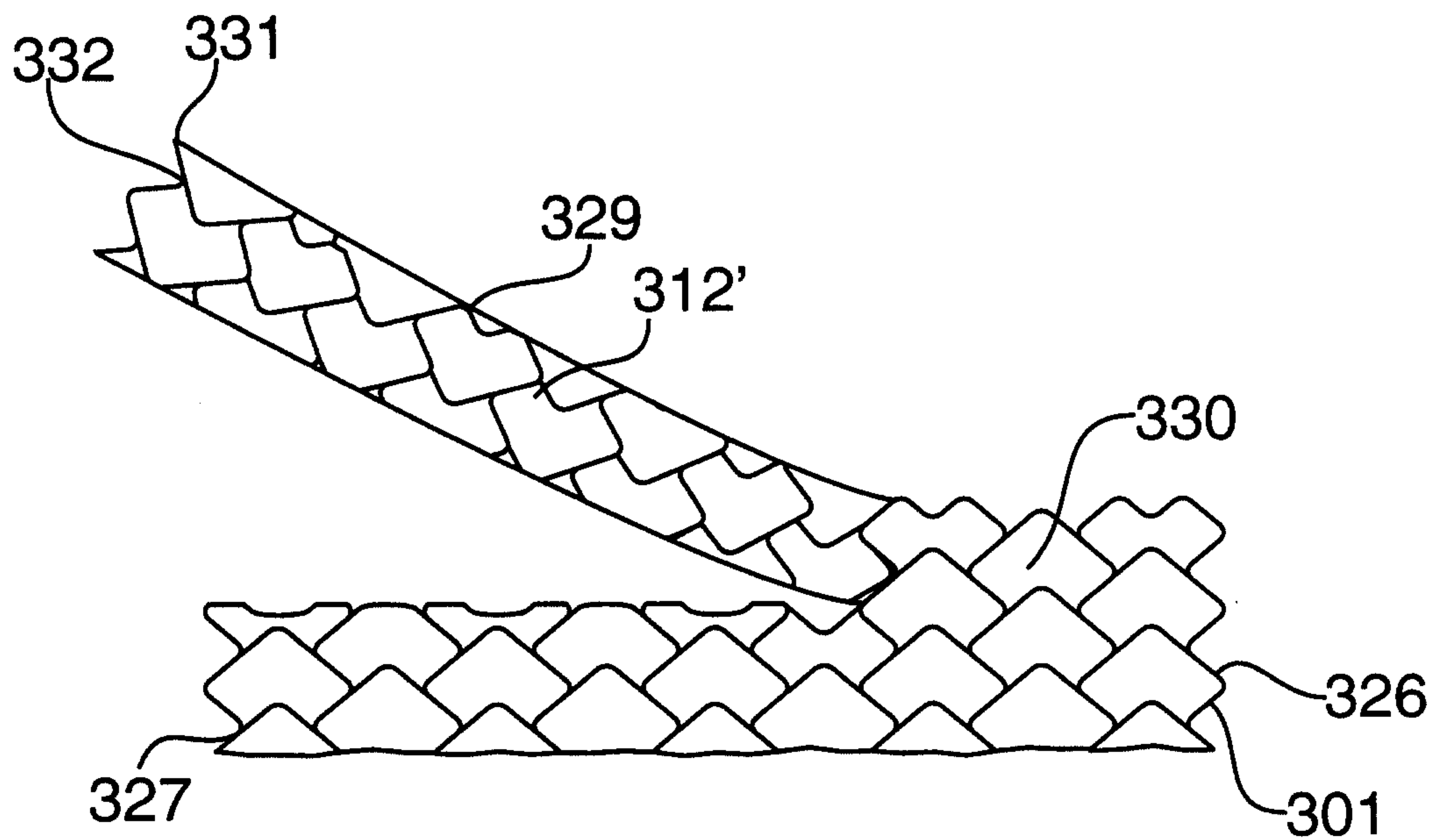


FIG. 27

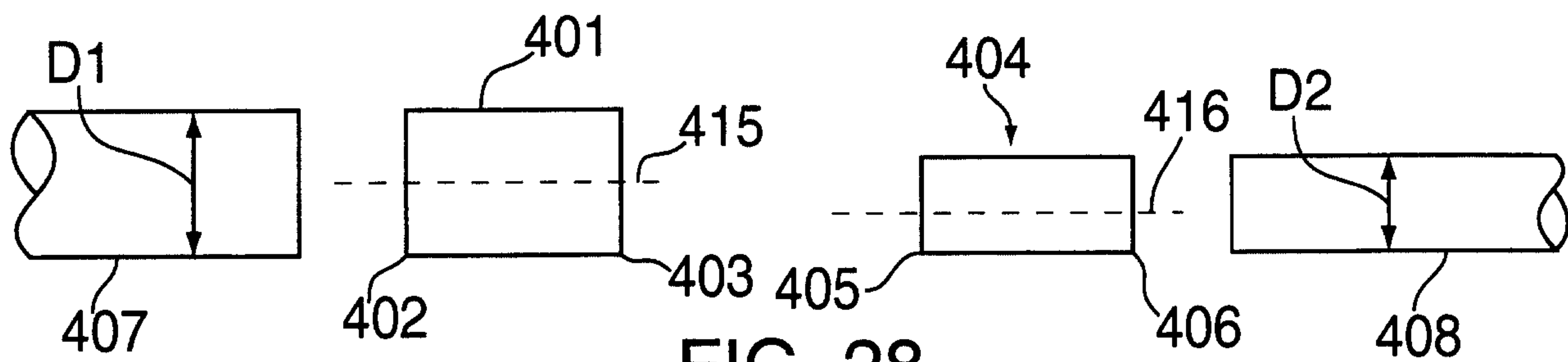


FIG. 28

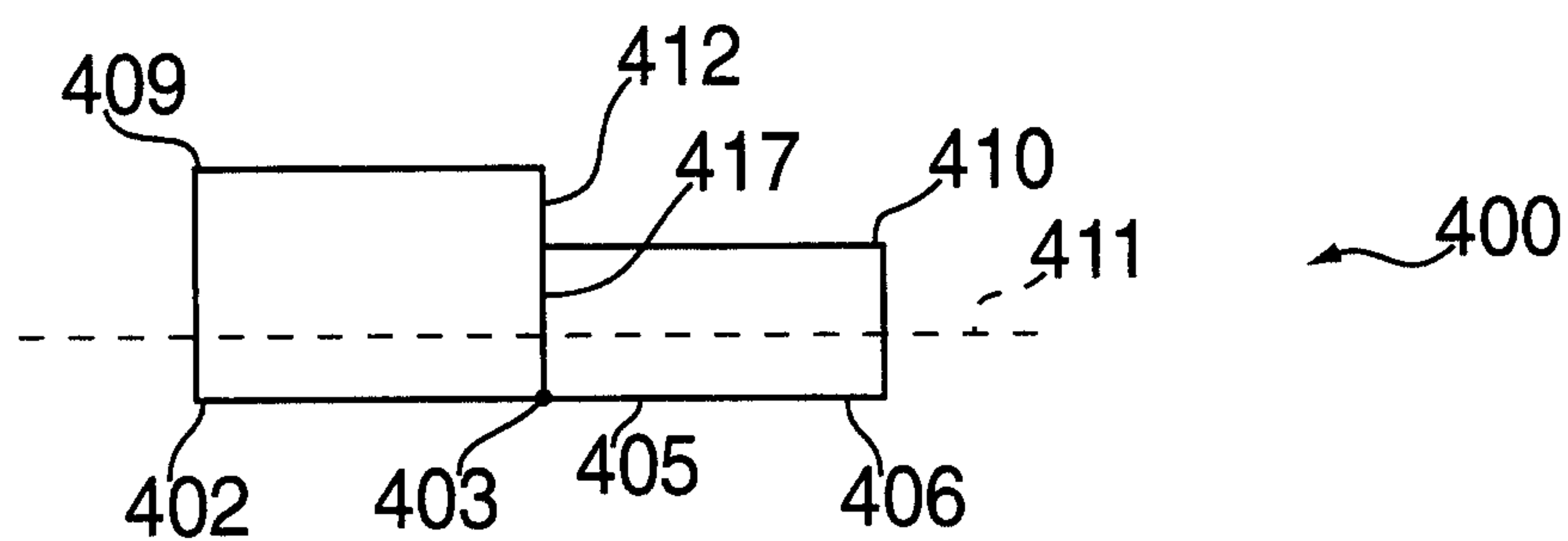


FIG. 29

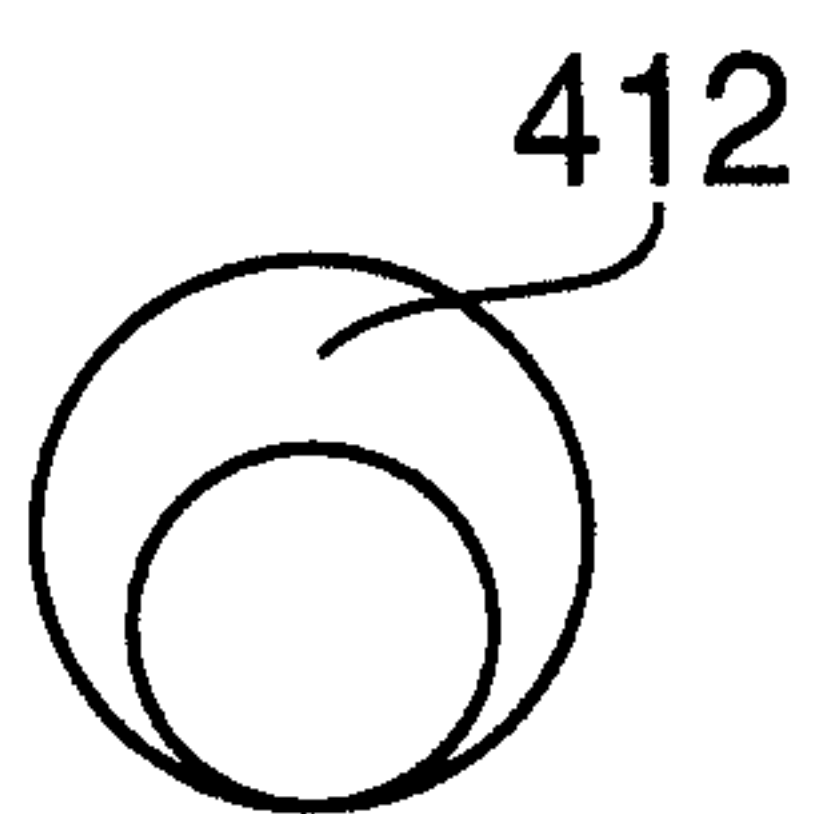


FIG. 30

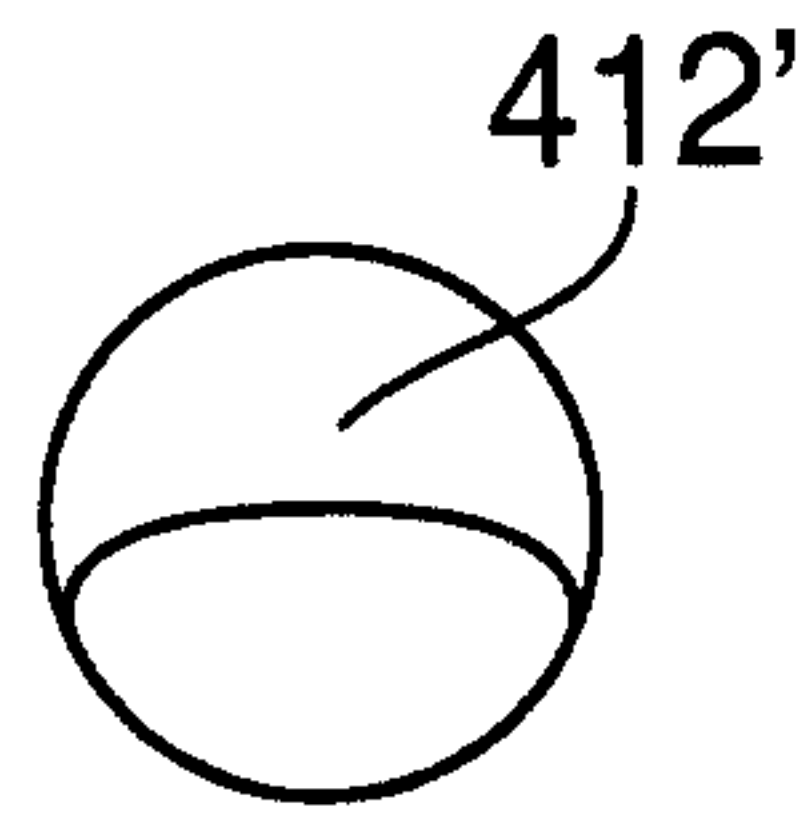


FIG. 30A

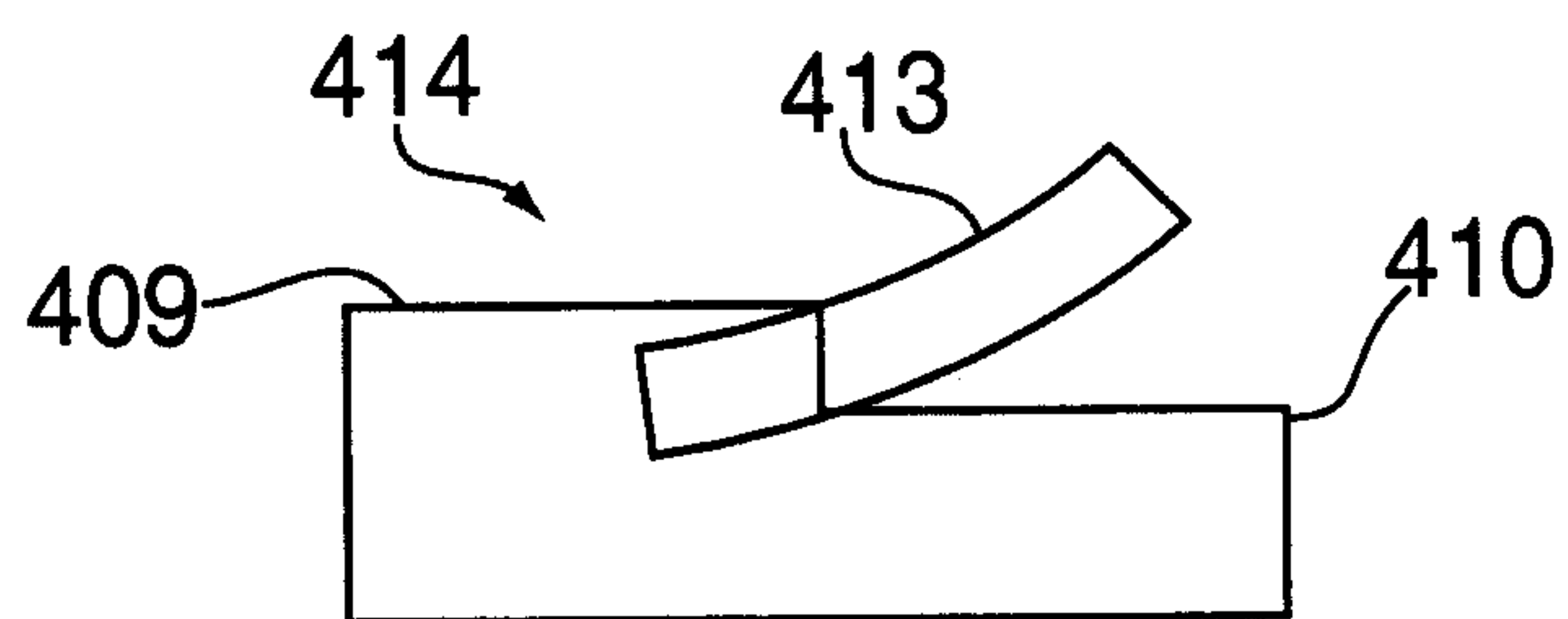


FIG. 31

