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(54) **ULTRASONIC SURGICAL BLADE WITH IMPROVED CUTTING AND COAGULATION FEATURES**

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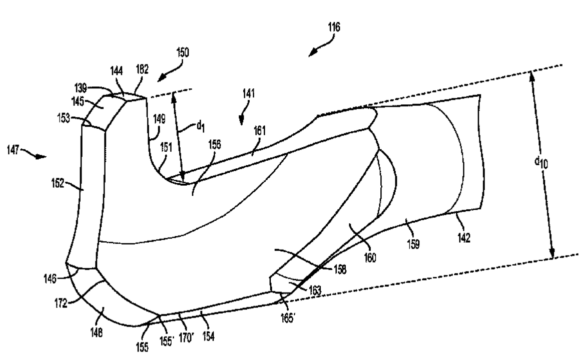
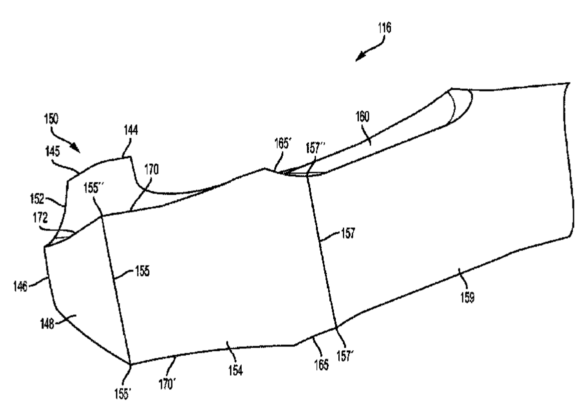
(57) **ABSTRACT**

An ultrasonic surgical blade with improved cutting and coagulation features is disclosed. The blade includes a solid body, a longitudinal portion having a proximal end configured to couple to an ultrasonic transmission waveguide and a transverse portion extending crosswise from the distal end of the longitudinal portion. At least one dissection edge and at least one hemostasis surface is provided on the blade. The transverse portion defines a hook having a free end configured to pull and dissect tissue. Also disclosed is an ultrasonic surgical blade that also includes a sharp central ridge and an end mass for acoustic balance.

14 Claims, 48 Drawing Sheets





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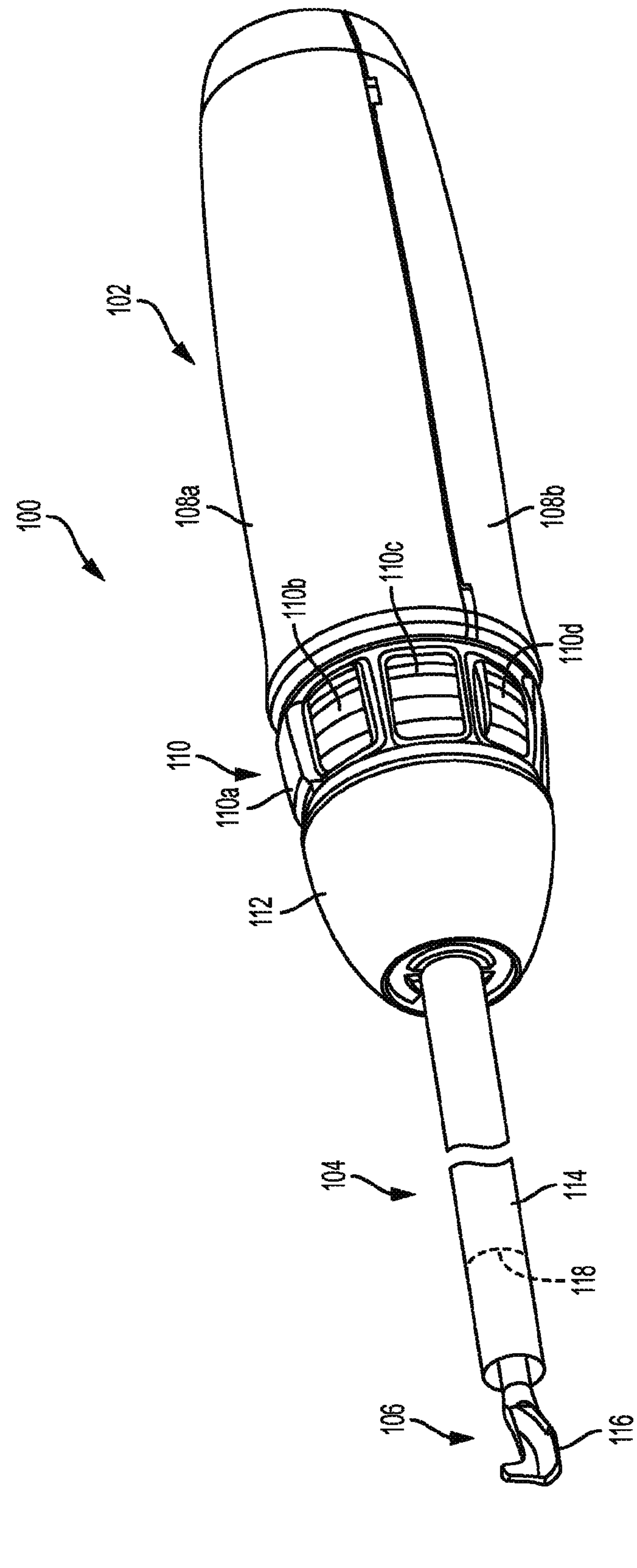
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108a
108b
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110a
112
104
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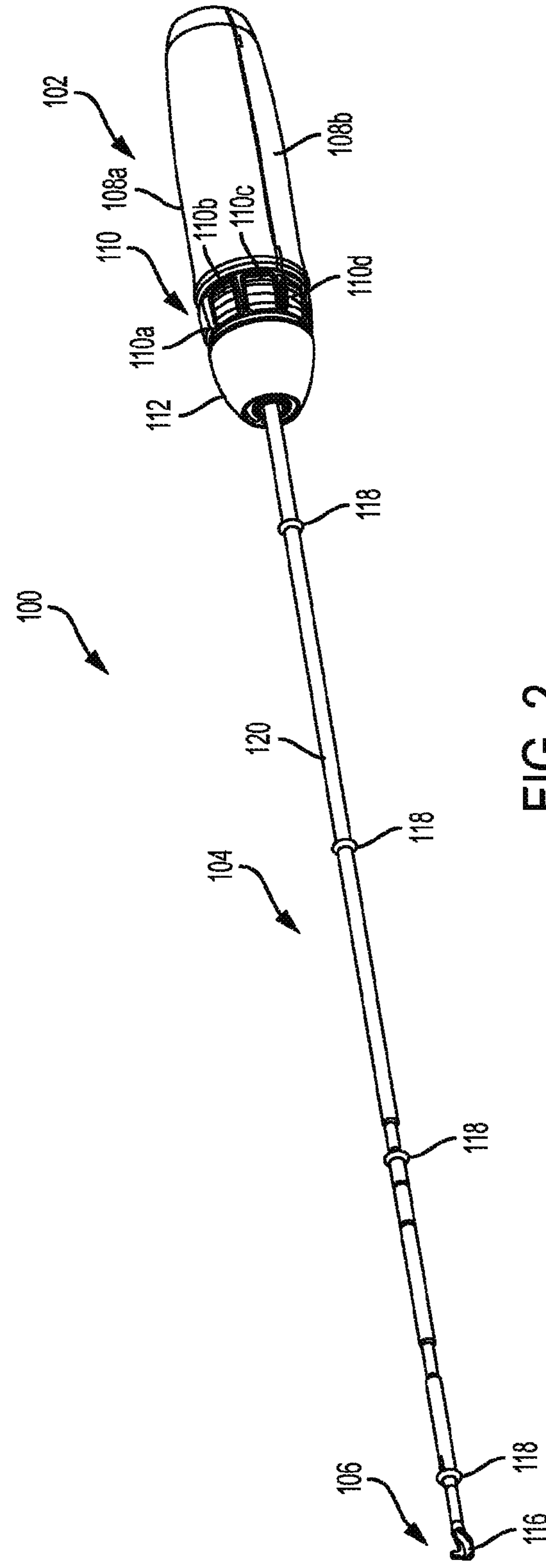
118
106
116

FIG. 1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116

FIG. 2

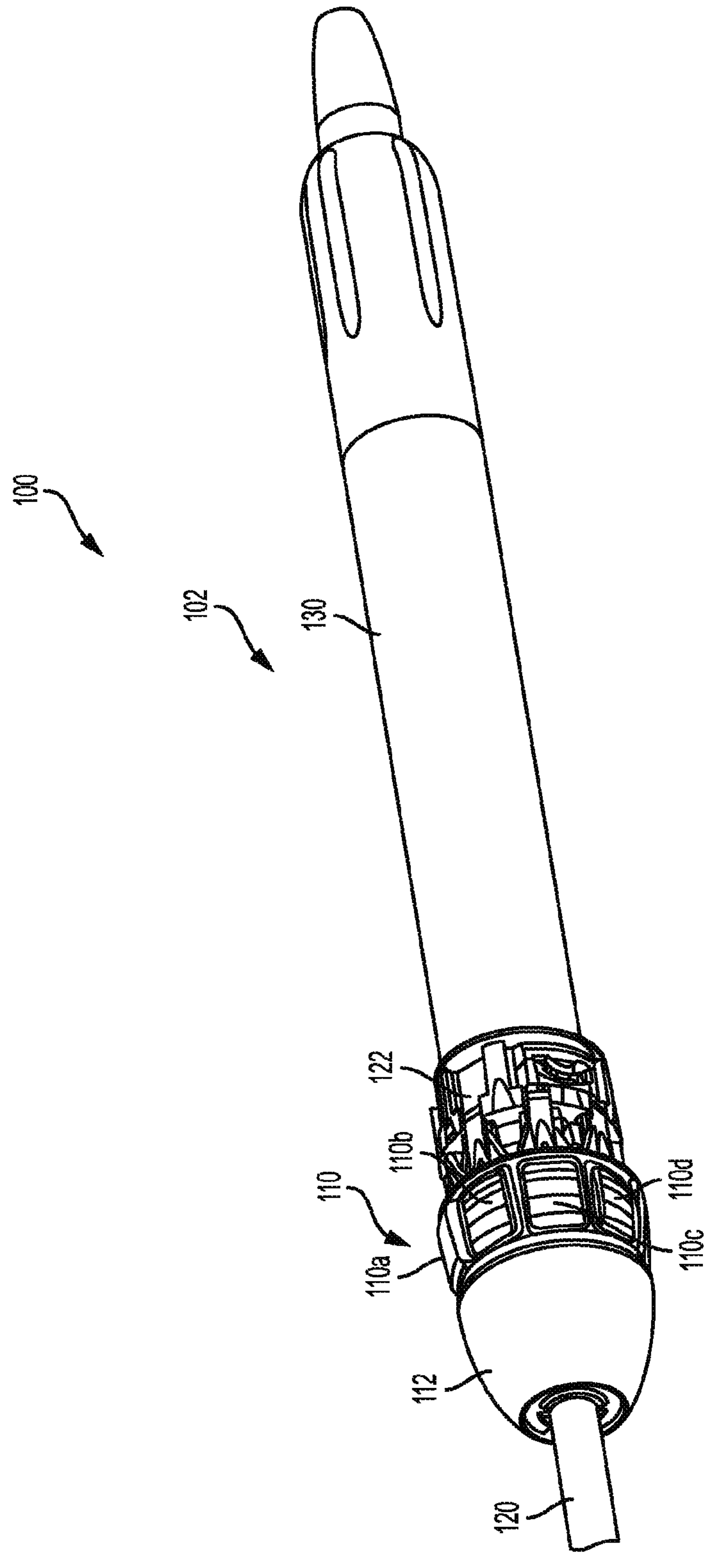


FIG. 3

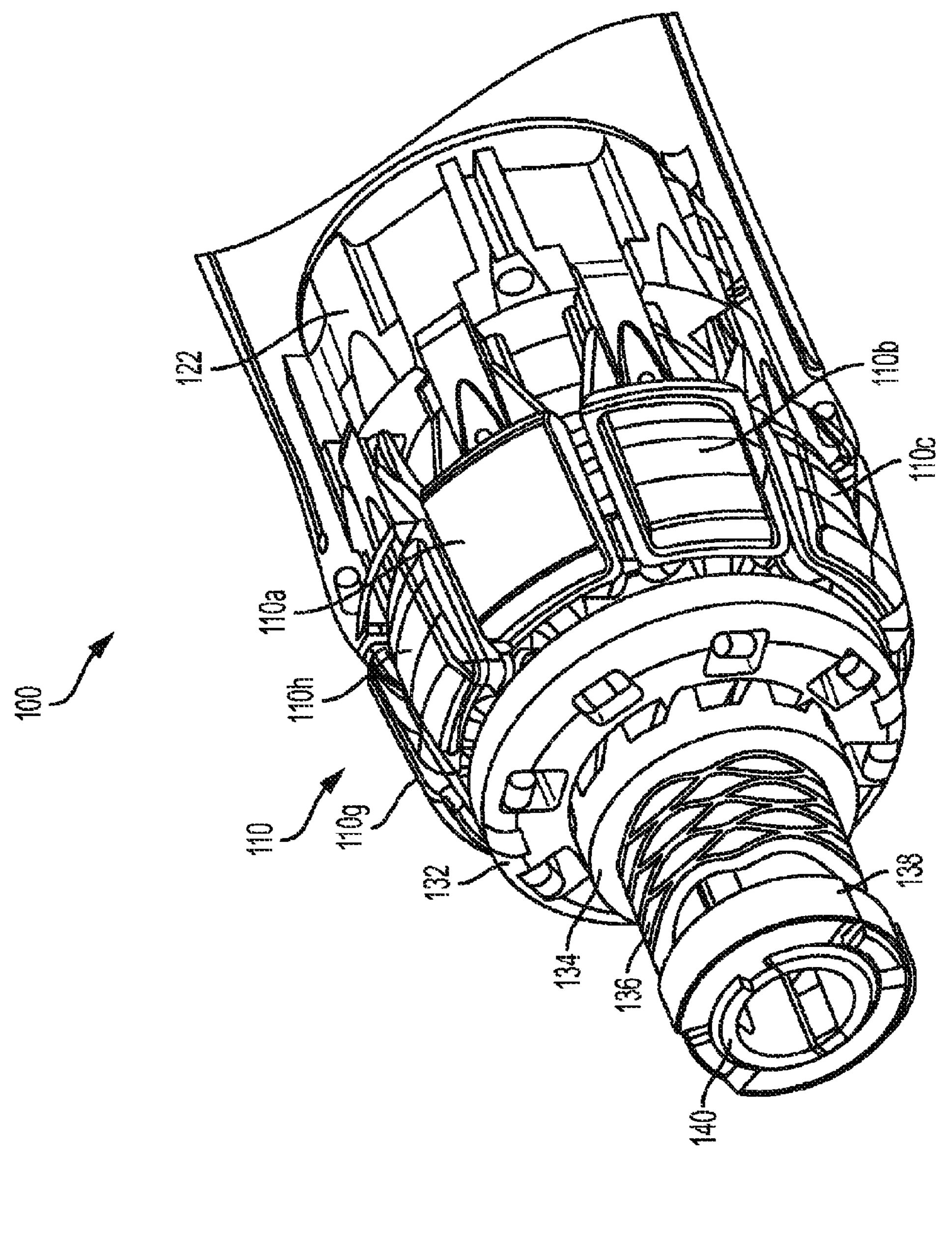


FIG. 4

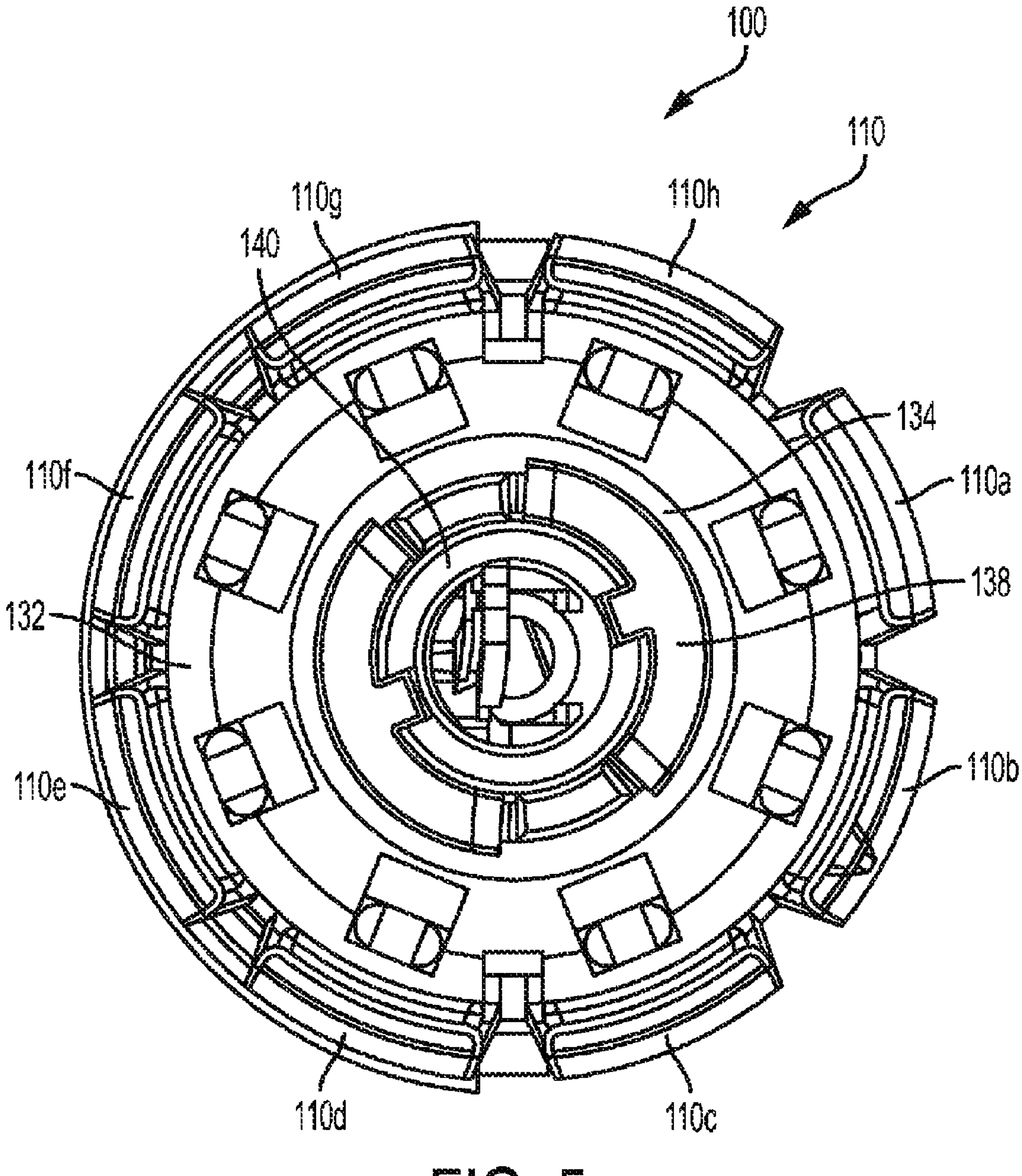

100
110
110g
110h
140
134
110f
110a
138
132
110e
110b
110d
110c

FIG. 5

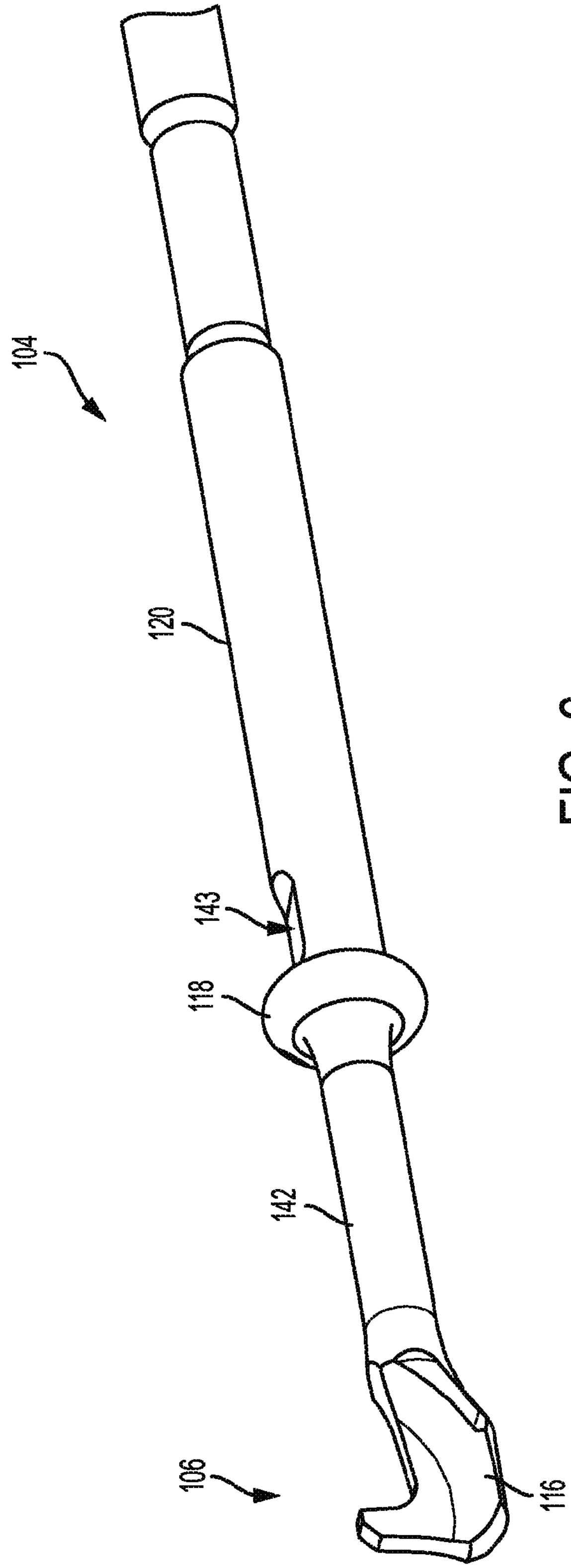
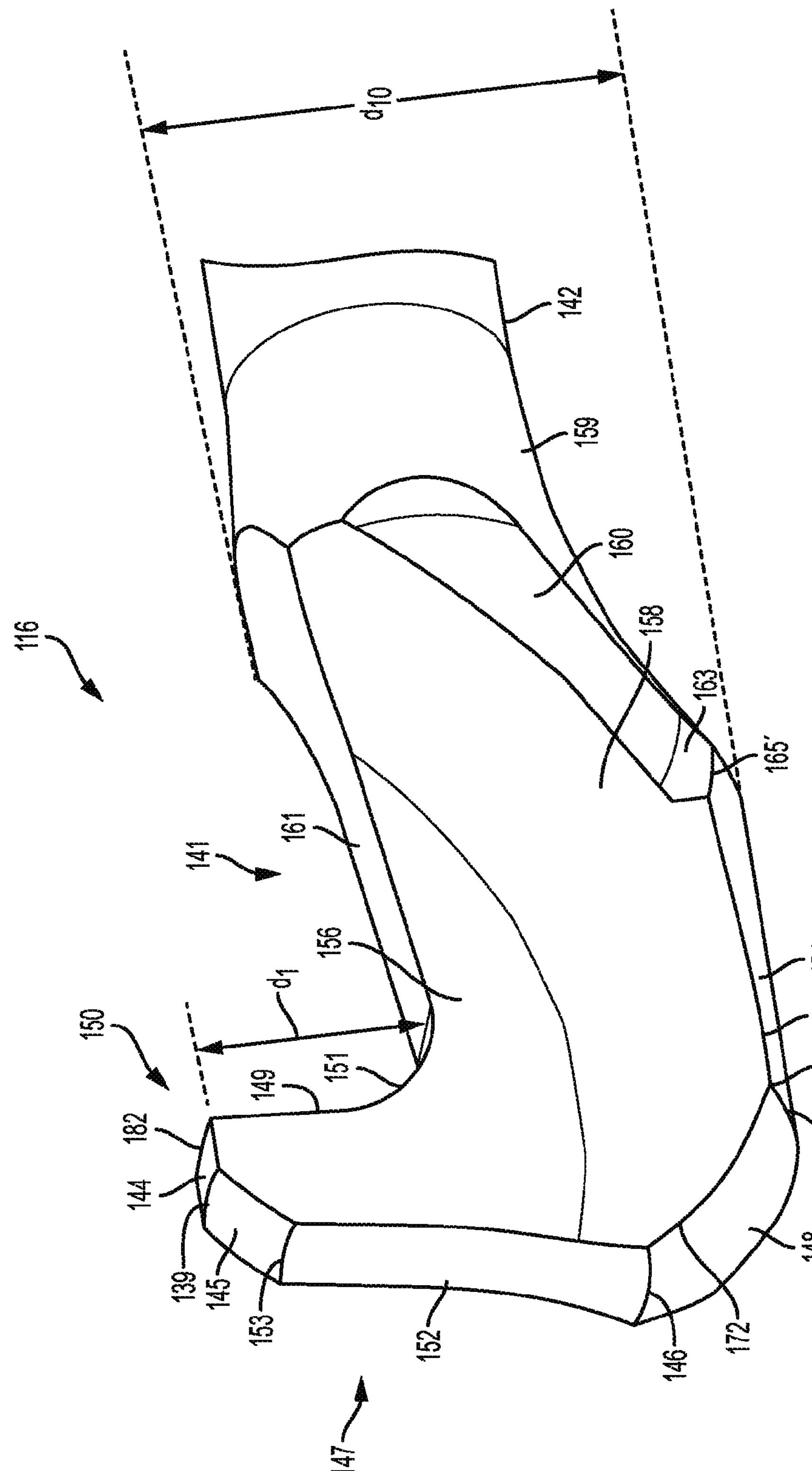


FIG. 6



d10
142
159
160
158
163
165'
116
161
141
156
d1
150
149
151
182
144
139
145
153
152
146
172
148
155
155'
170'
154
147

FIG. 7

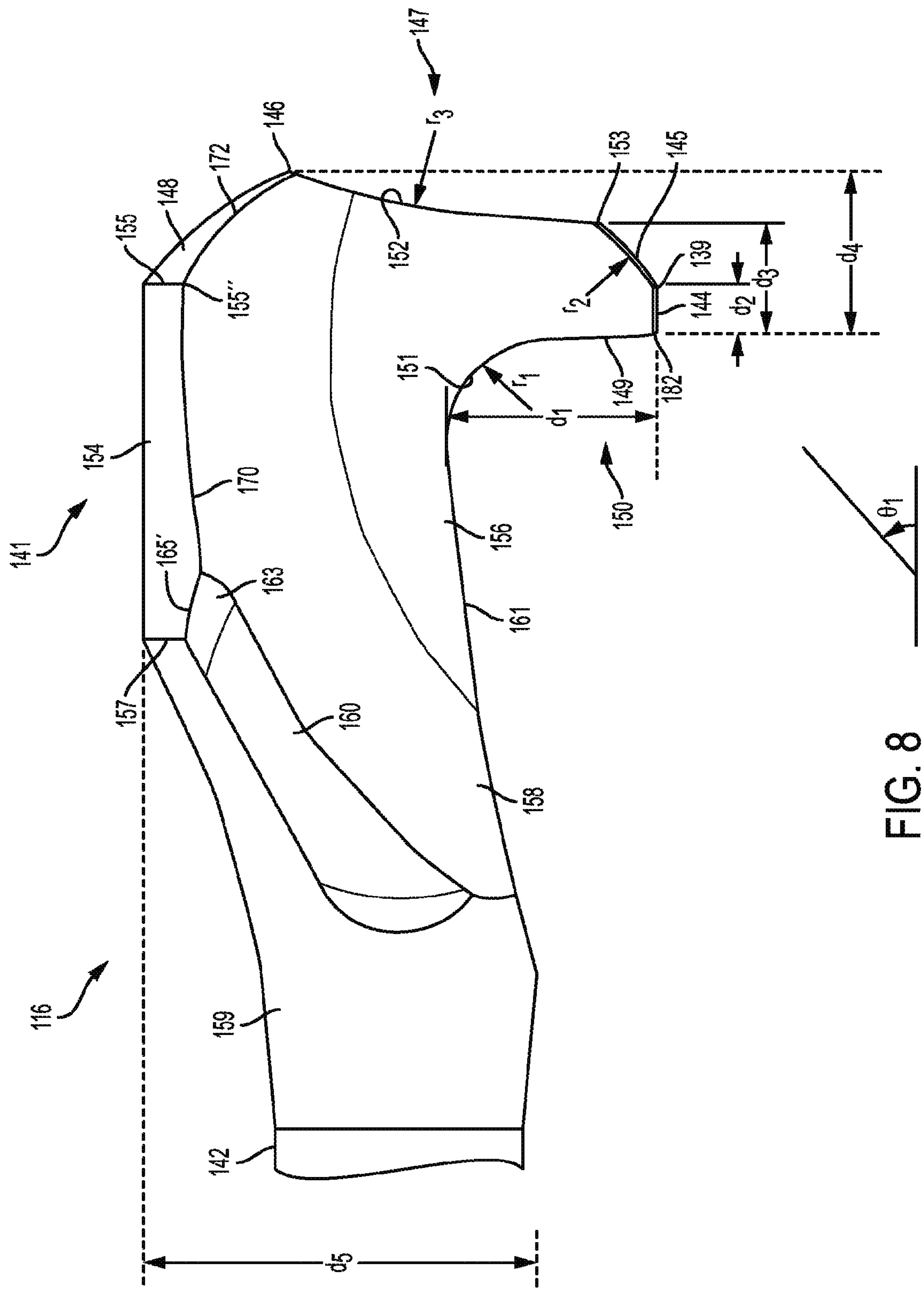

147
146
r_3
172
148
155
153
145
139
152
d_4
d_3
d_2
r_2
155''
144
151
r_1
149
182
154
d_1
170
150
141
165'
163
156
θ_1
161
157
160
158
116
159
142
d_5

FIG. 8

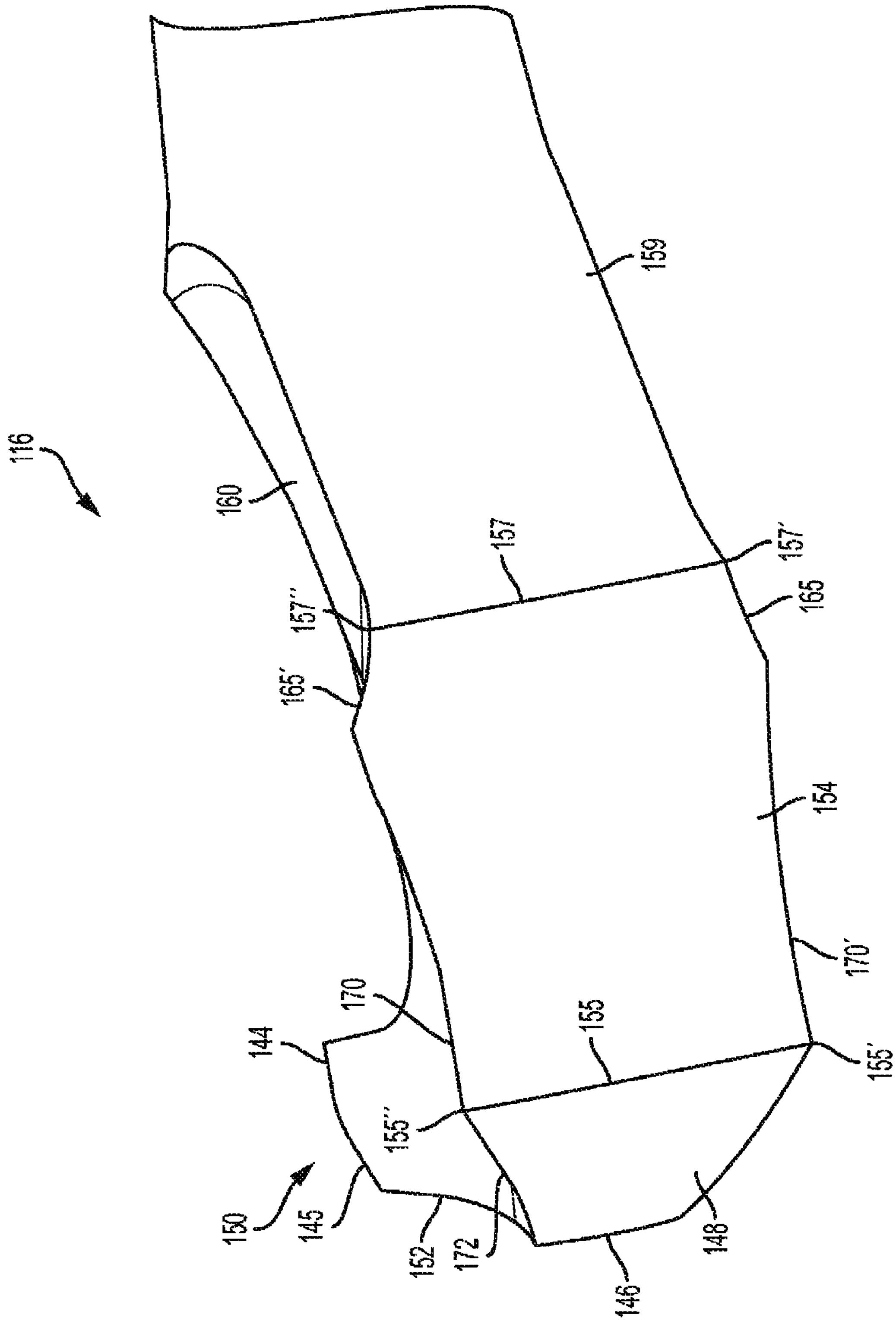

116
160
159
157
157'
157''
165
165'
154
170
170'
155
155'
155''
144
145
150
152
172
146
148

FIG. 9

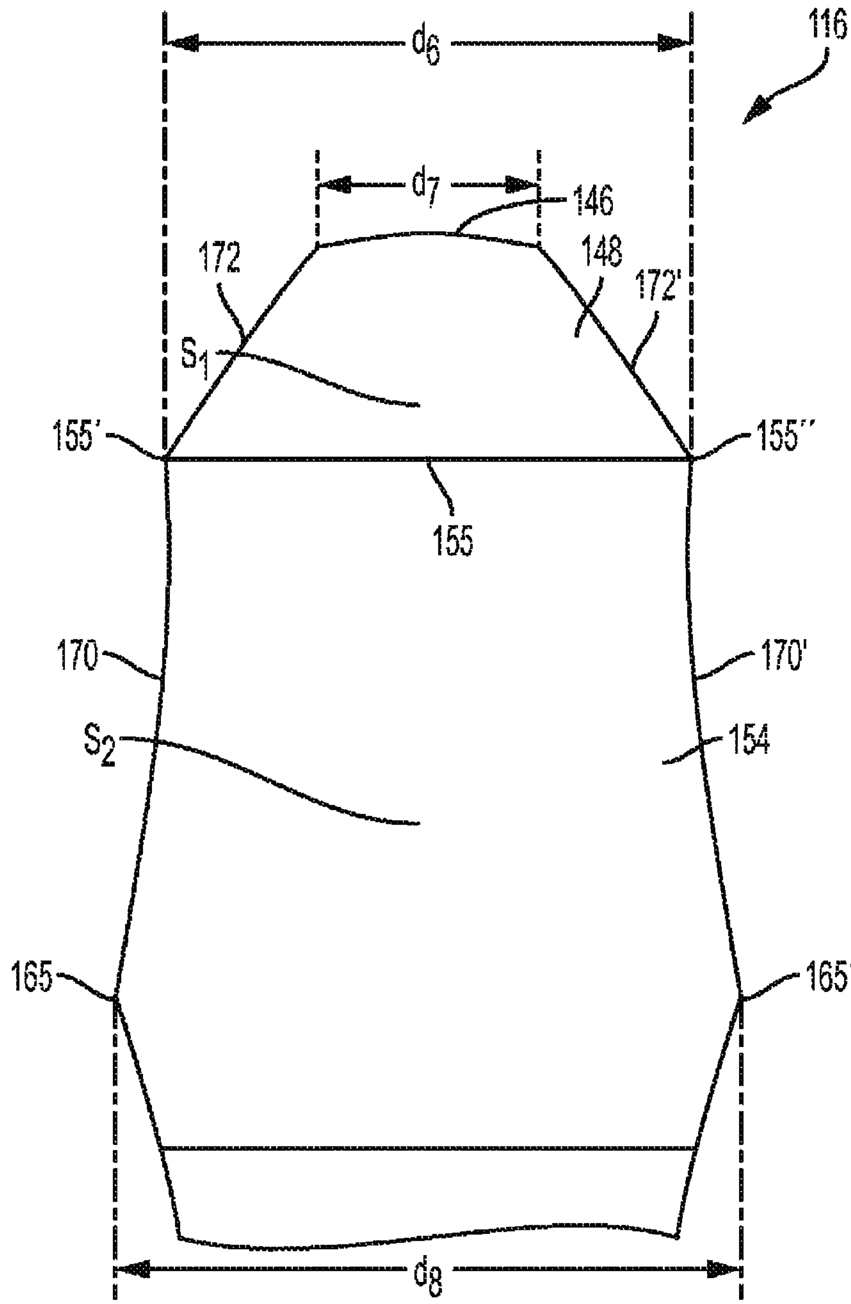


FIG. 10

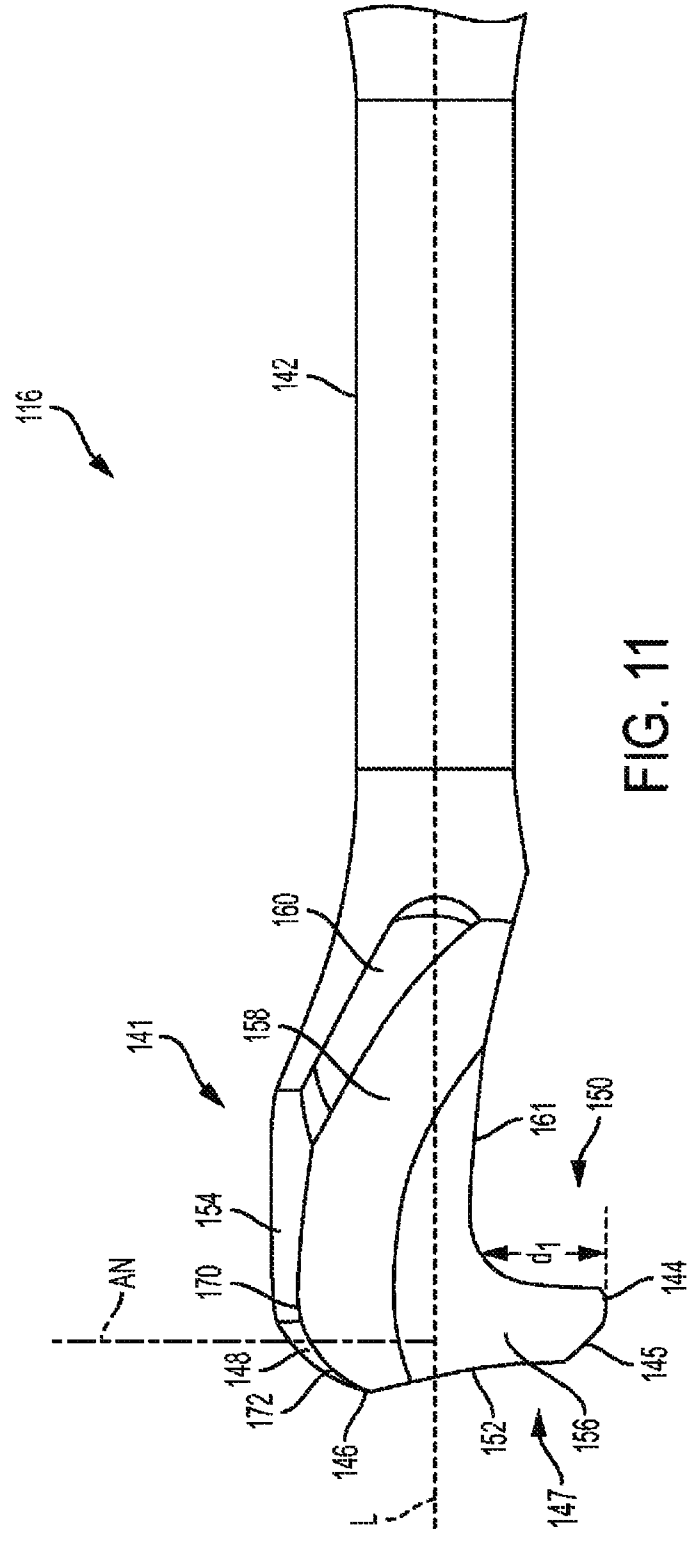

116
142
141
160
158
161
150
154
AN
170
148
172
146
152
156
147
144
145
d_1
L

FIG. 11

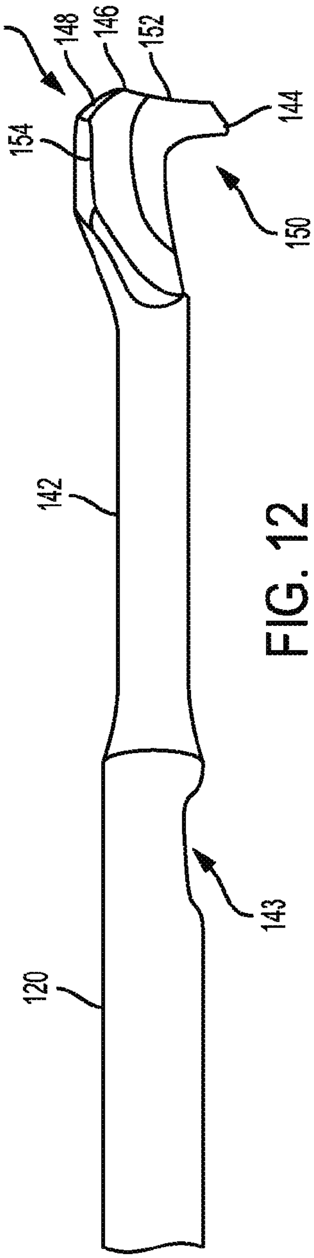


FIG. 12

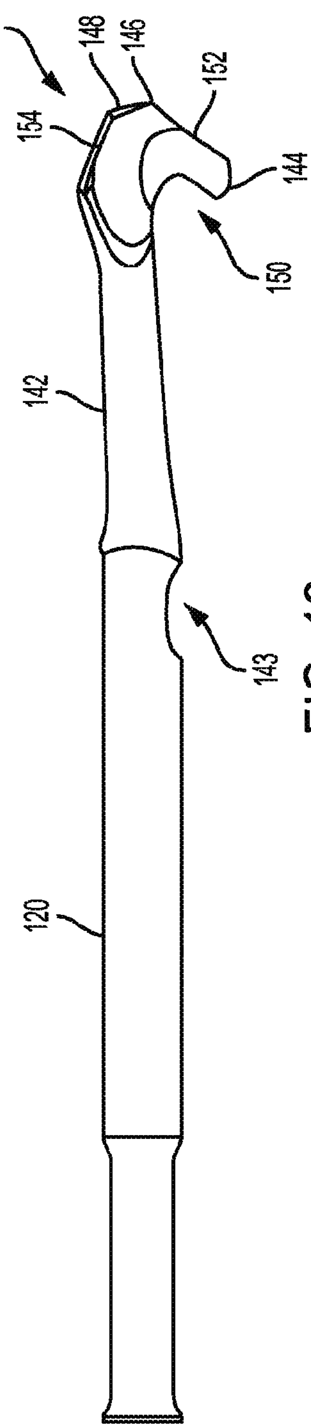


FIG. 13

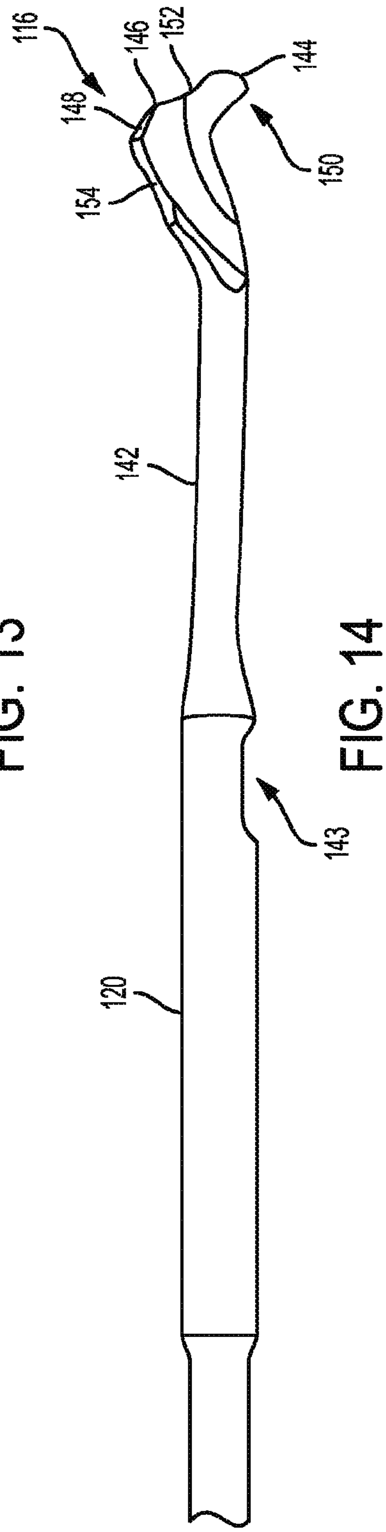


FIG. 14

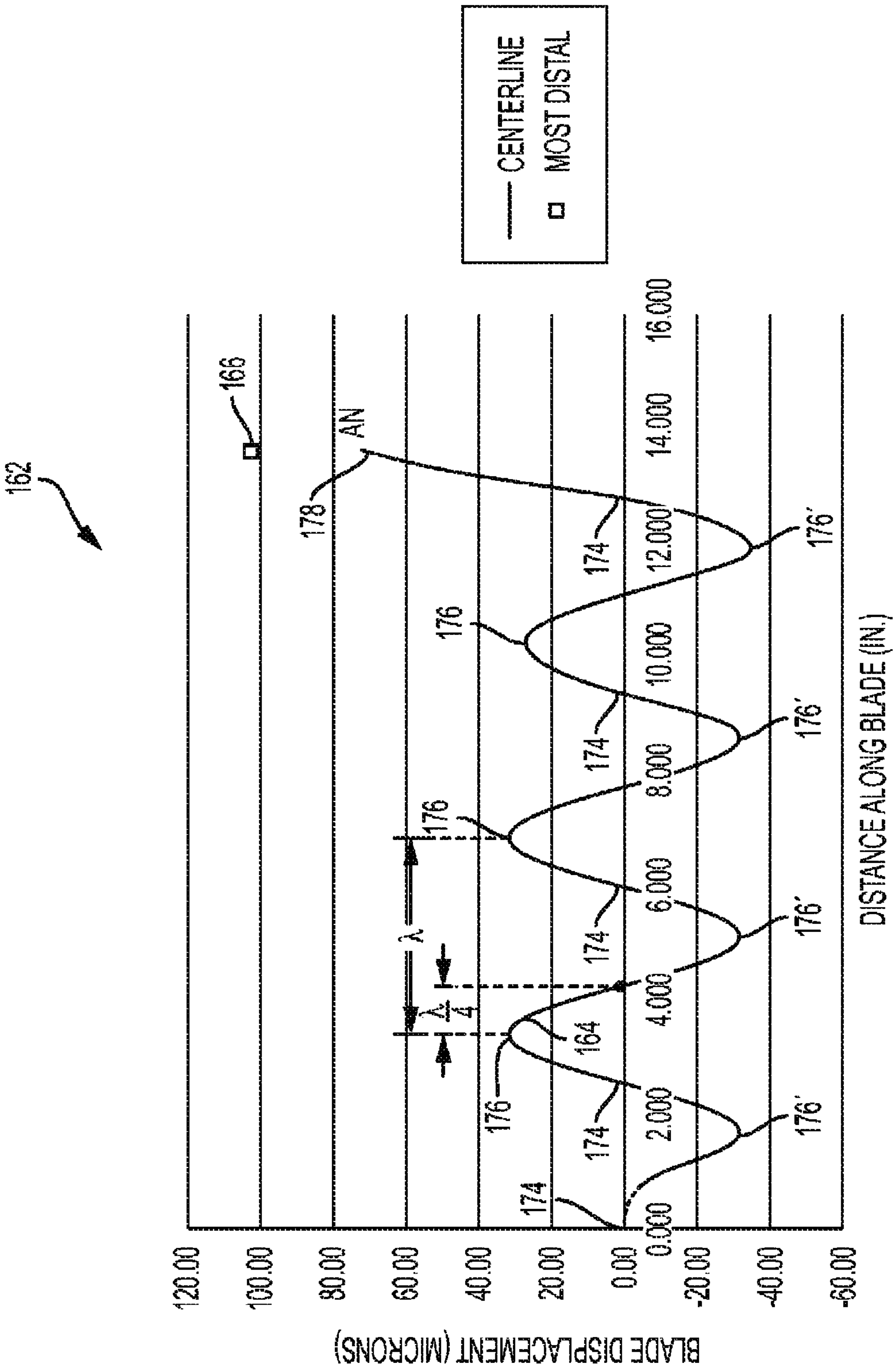

162
CENTERLINE
MOST DISTAL
166
AN
178
174
176
176'
164
λ
λ/4
120.00
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
-60.00
0.000
2.000
4.000
6.000
8.000
10.000
12.000
14.000
16.000
BLADE DISPLACEMENT (MICRONS)
DISTANCE ALONG BLADE (IN.)

FIG. 15

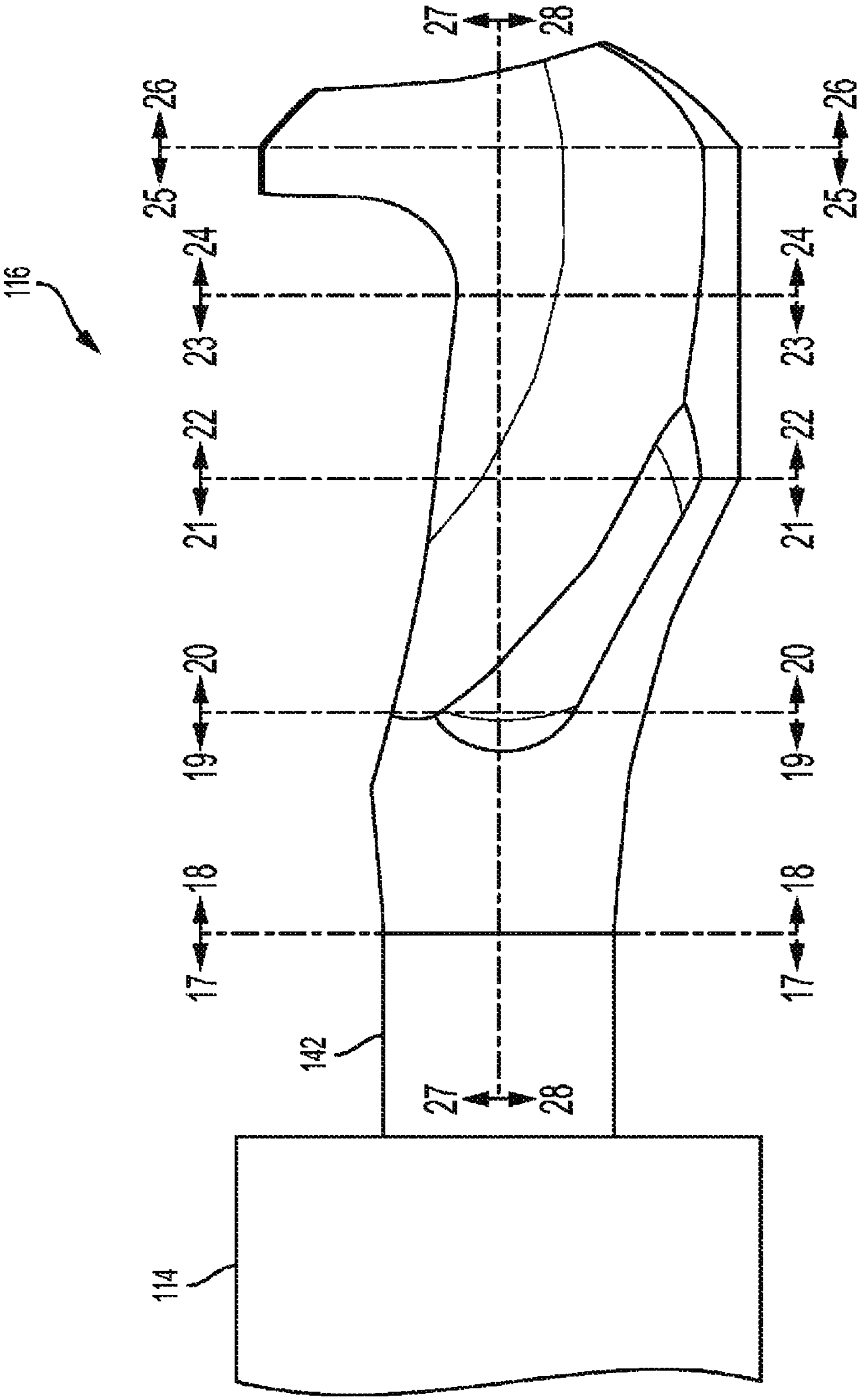


FIG. 16

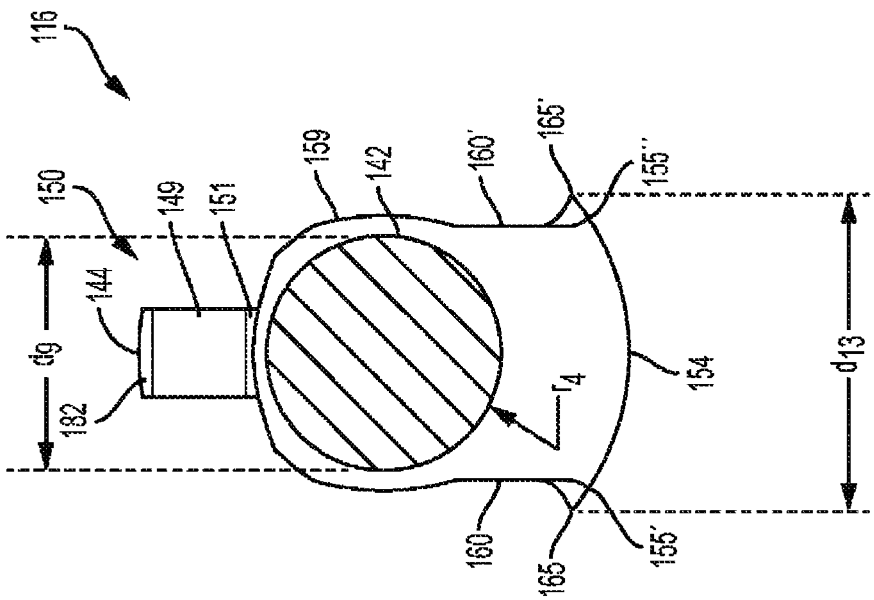

116
150
149
151
159
142
160'
165'
155''
144
d_9
182
r_4
154
d_{13}
160
165
155'

FIG. 18

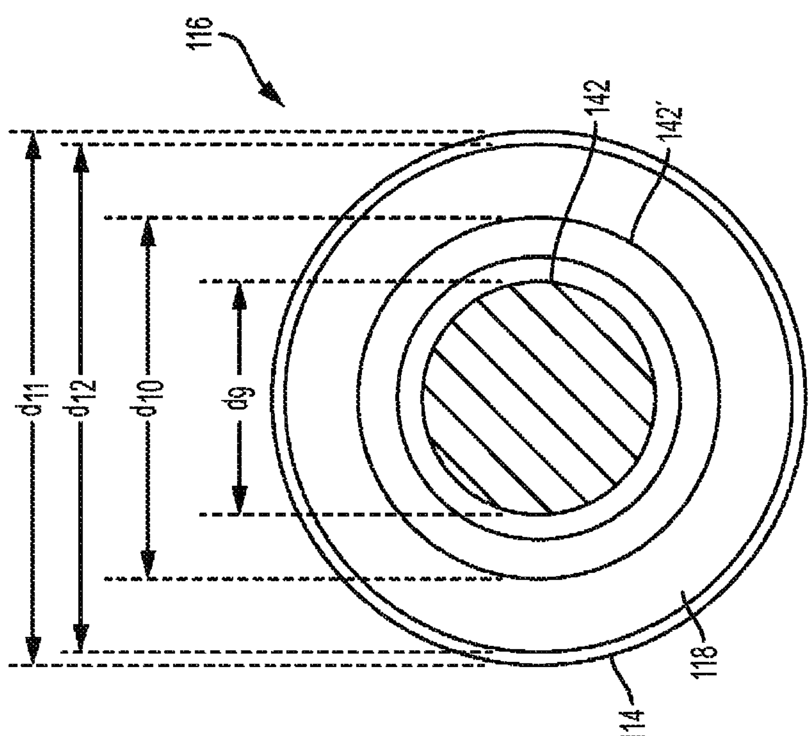

116
142
142'
d_{11}
d_{12}
d_{10}
d_9
114
118

FIG. 17

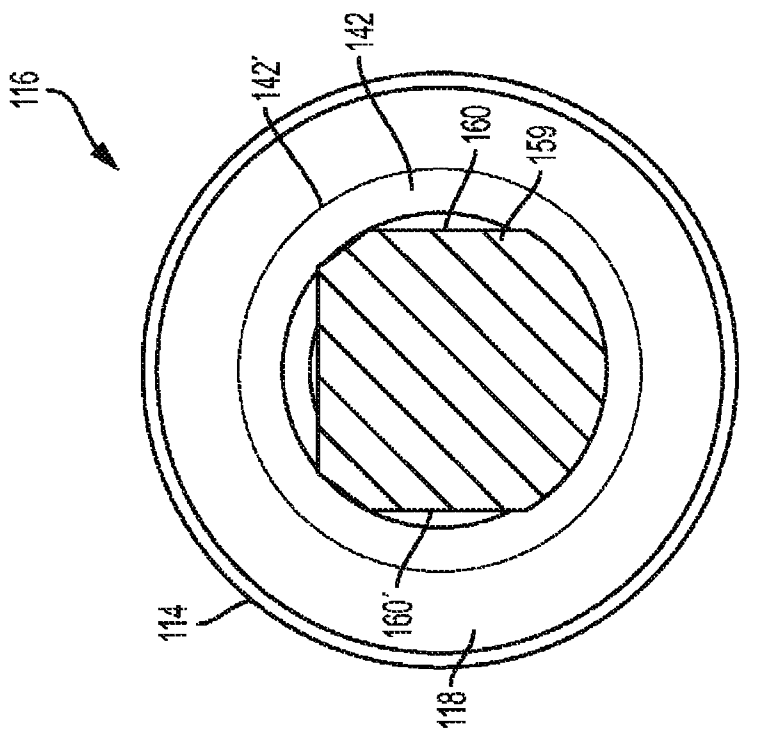

116
142'
142
160
159
160'
114
118

FIG. 19

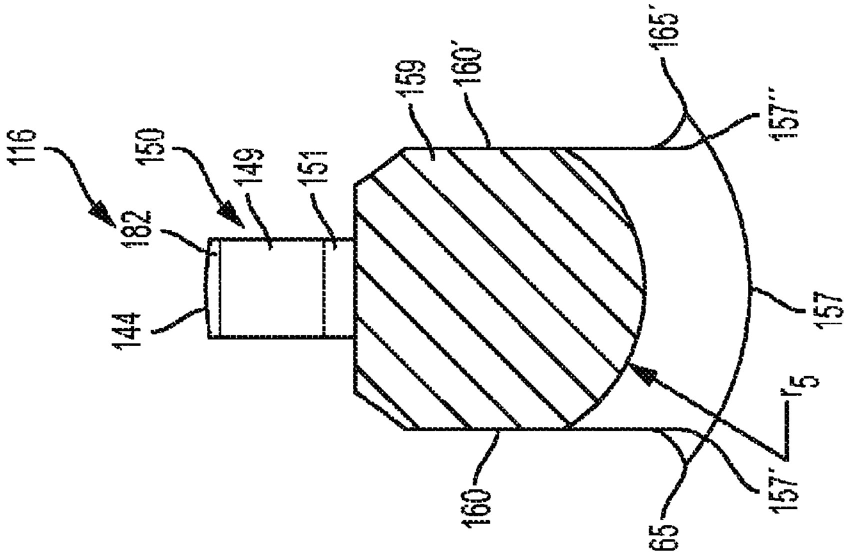

116
150
149
151
182
144
159
160'
165'
157''
157
r_5
160
157'
165

FIG. 20

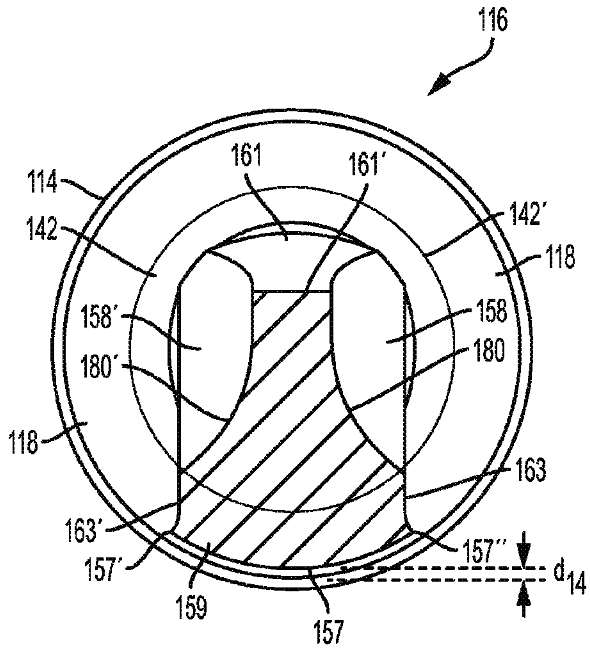

116
114
161
161′
142
142′
118
158′
158
180′
180
118
163
163′
157′
157″
d_{14}
159
157

FIG. 21

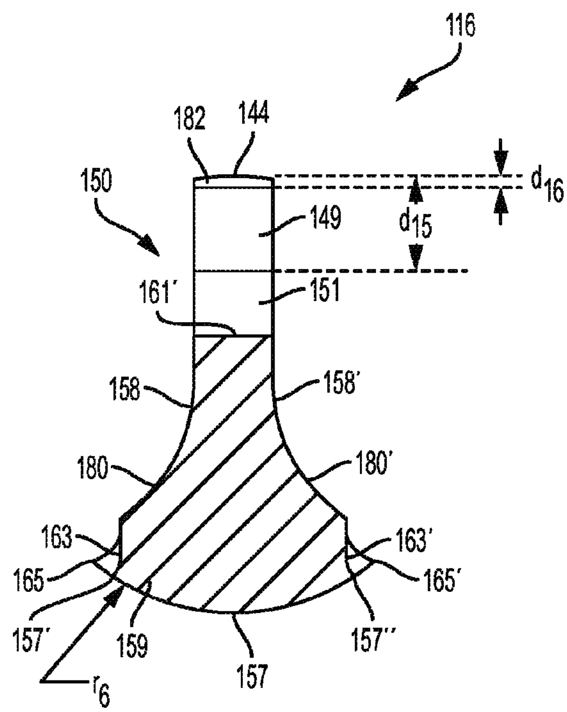

116
182
144
150
d_{16}
149
d_{15}
161′
151
158
158′
180
180′
163
163′
165
165′
157′
159
157″
157
r_6

FIG. 22

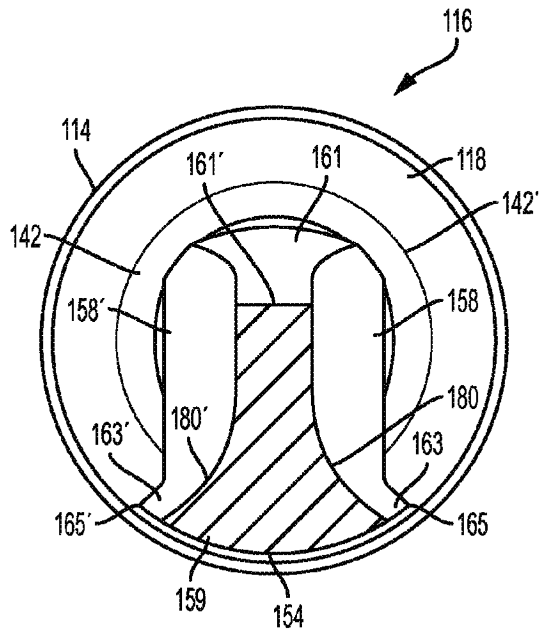

116
114
161′
161
118
142
142′
158′
158
180′
180
163′
163
165′
165
159
154

FIG. 23

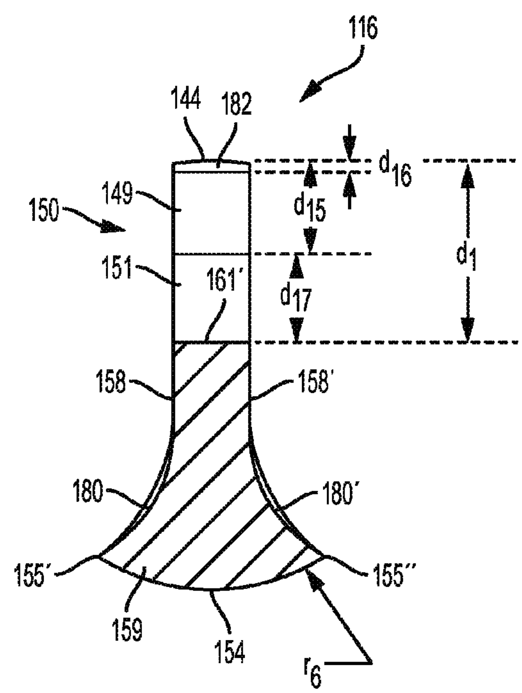

116
144
182
d_{16}
149
d_{15}
150
d_1
151
161′
d_{17}
158
158′
180
180′
155′
155″
159
154
r_6

FIG. 24

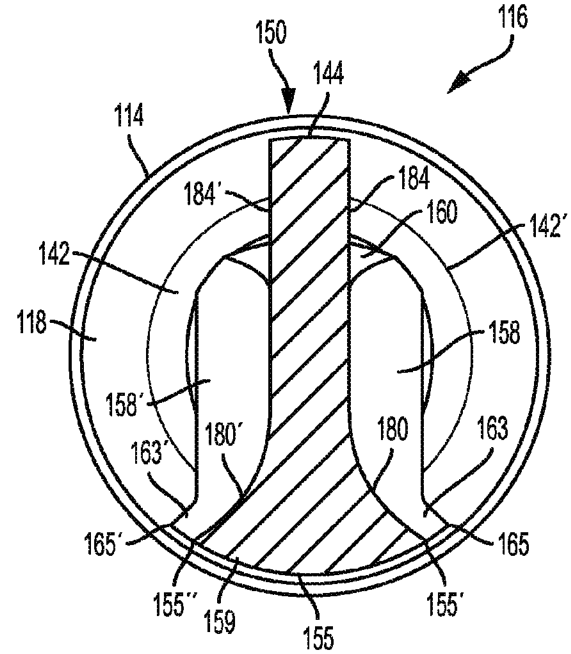

116
150
144
114
184′
184
160
142
142′
118
158
158′
180′
180
163′
163
165′
165
155″
155′
159
155

FIG. 25

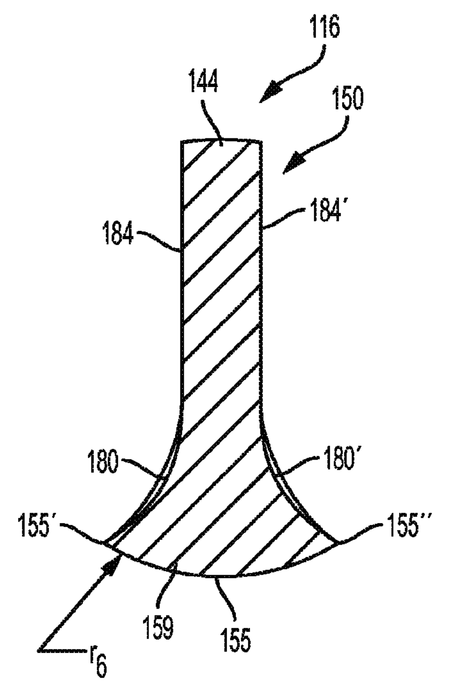

116
144
150
184
184′
180
180′
155′
155″
159
155
r_6

FIG. 26

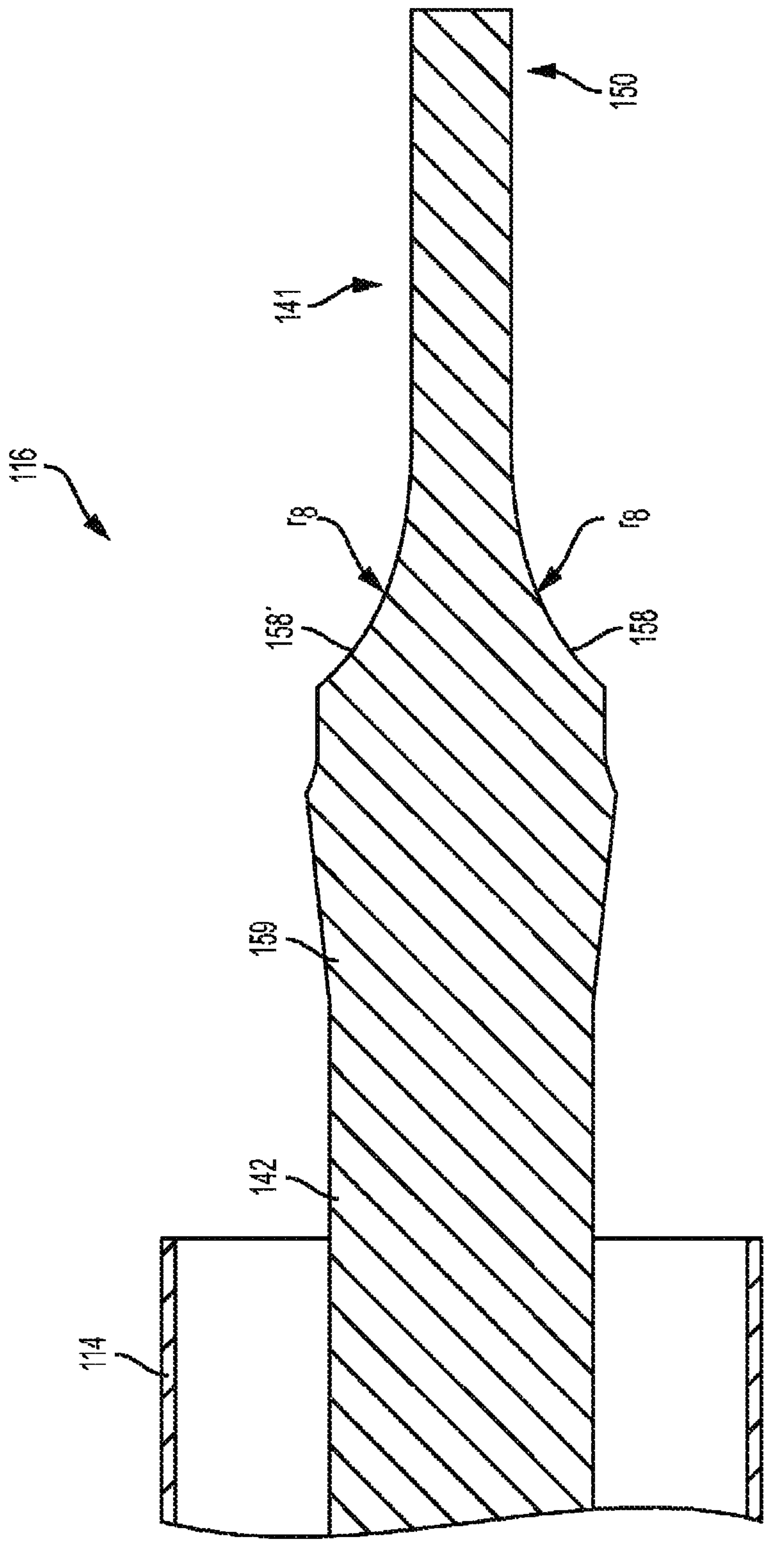


FIG. 27

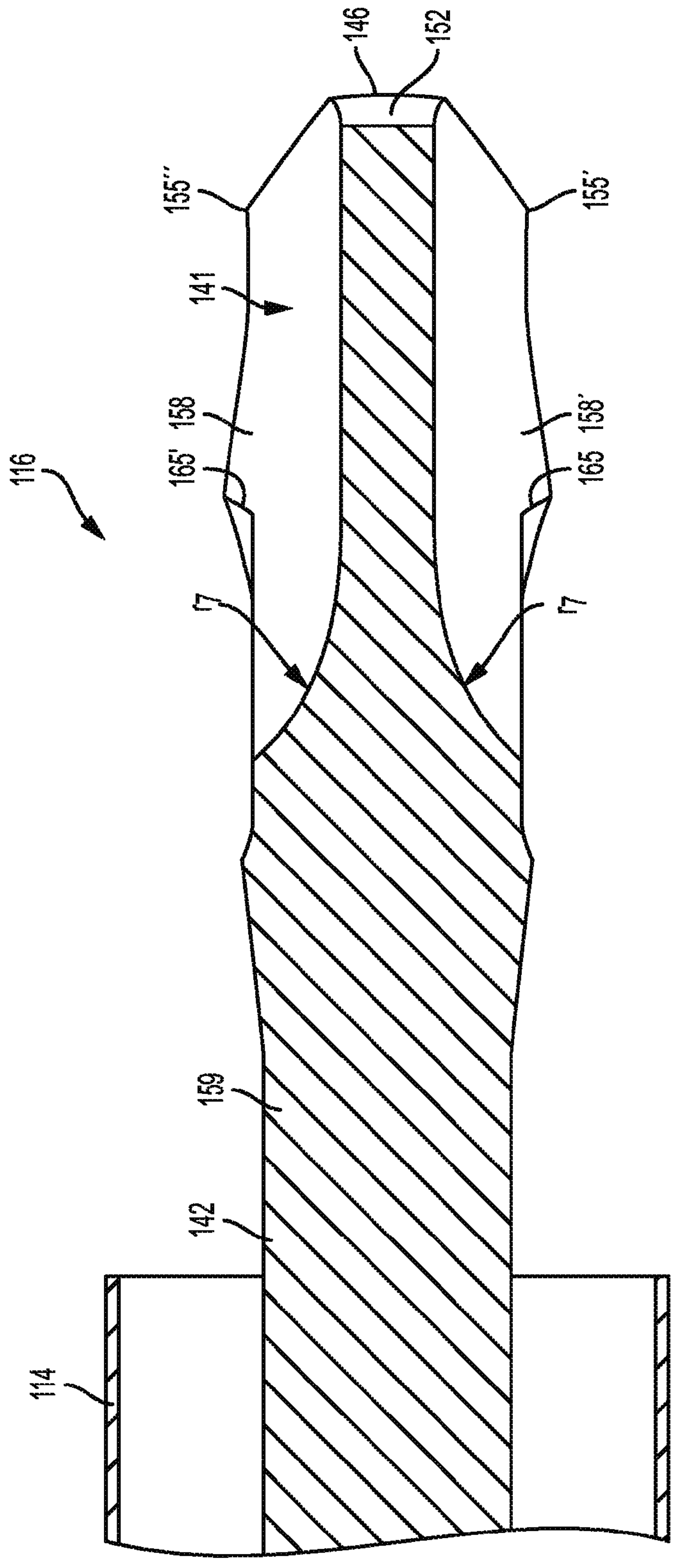


FIG. 28

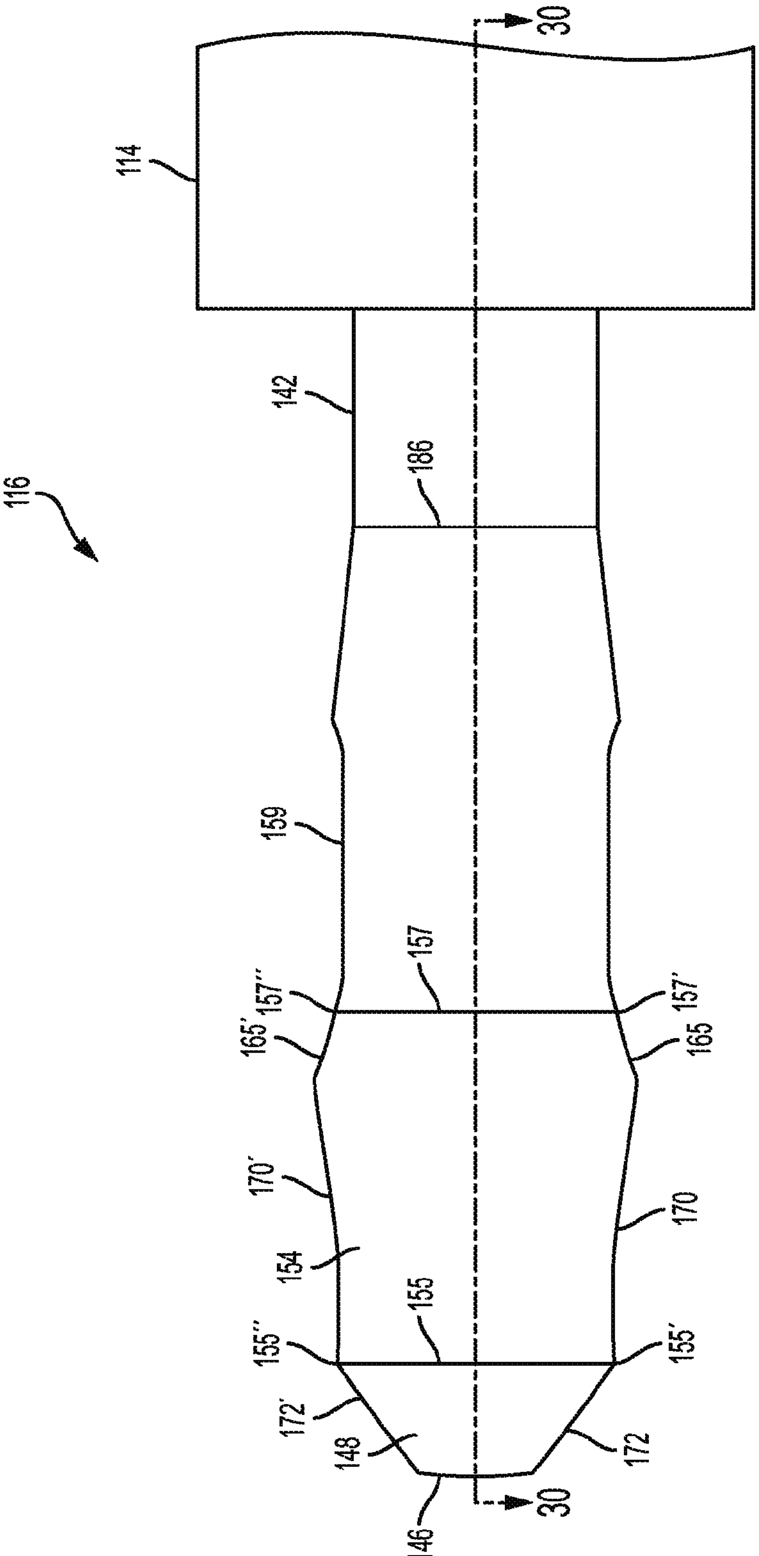

30
114
142
186
116
159
157
157''
157'
165'
165
170'
170
154
155
155''
155'
172'
148
172
30
146

FIG. 29

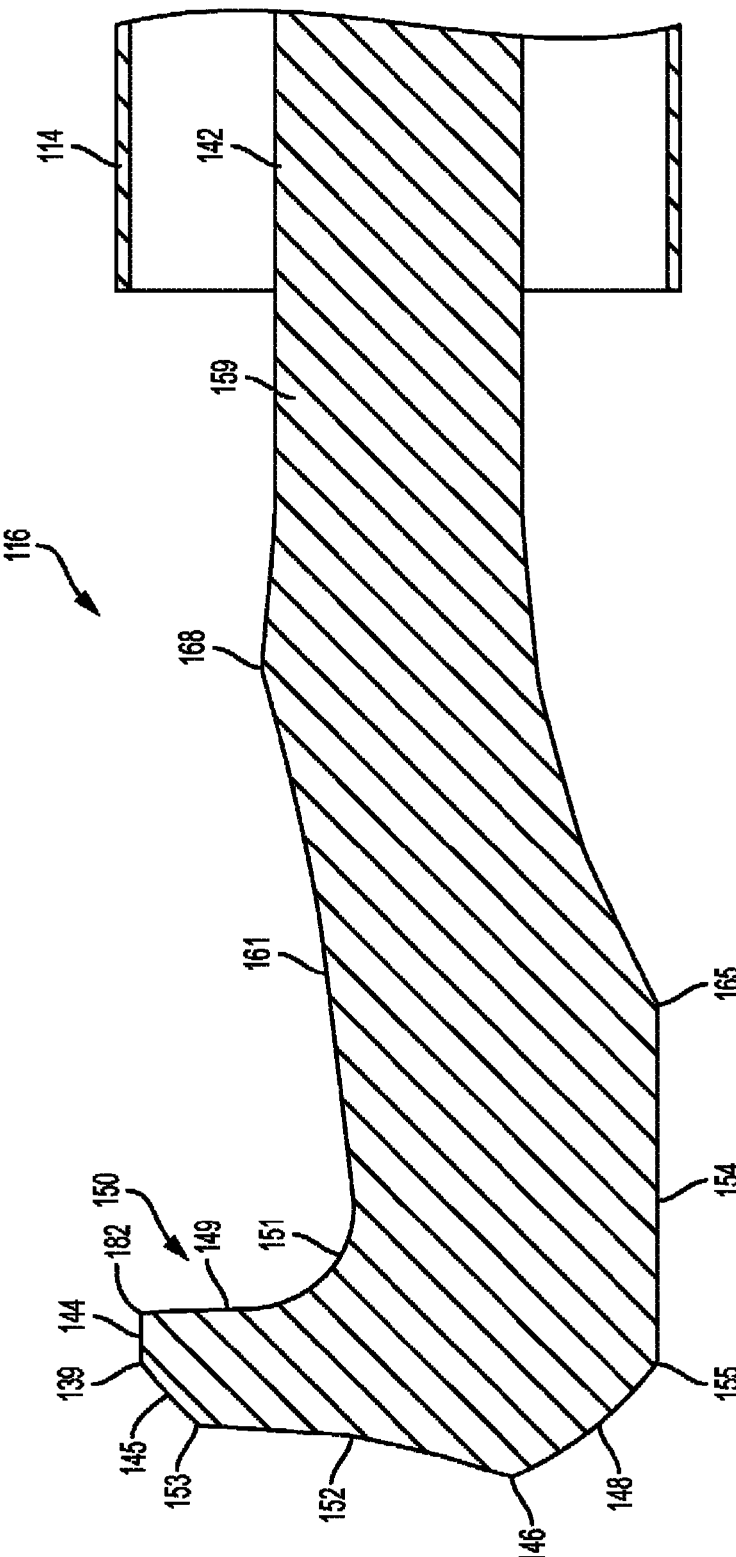

114
142
159
116
168
161
165
154
150
182
149
151
144
139
145
153
152
146
148
155

FIG. 30

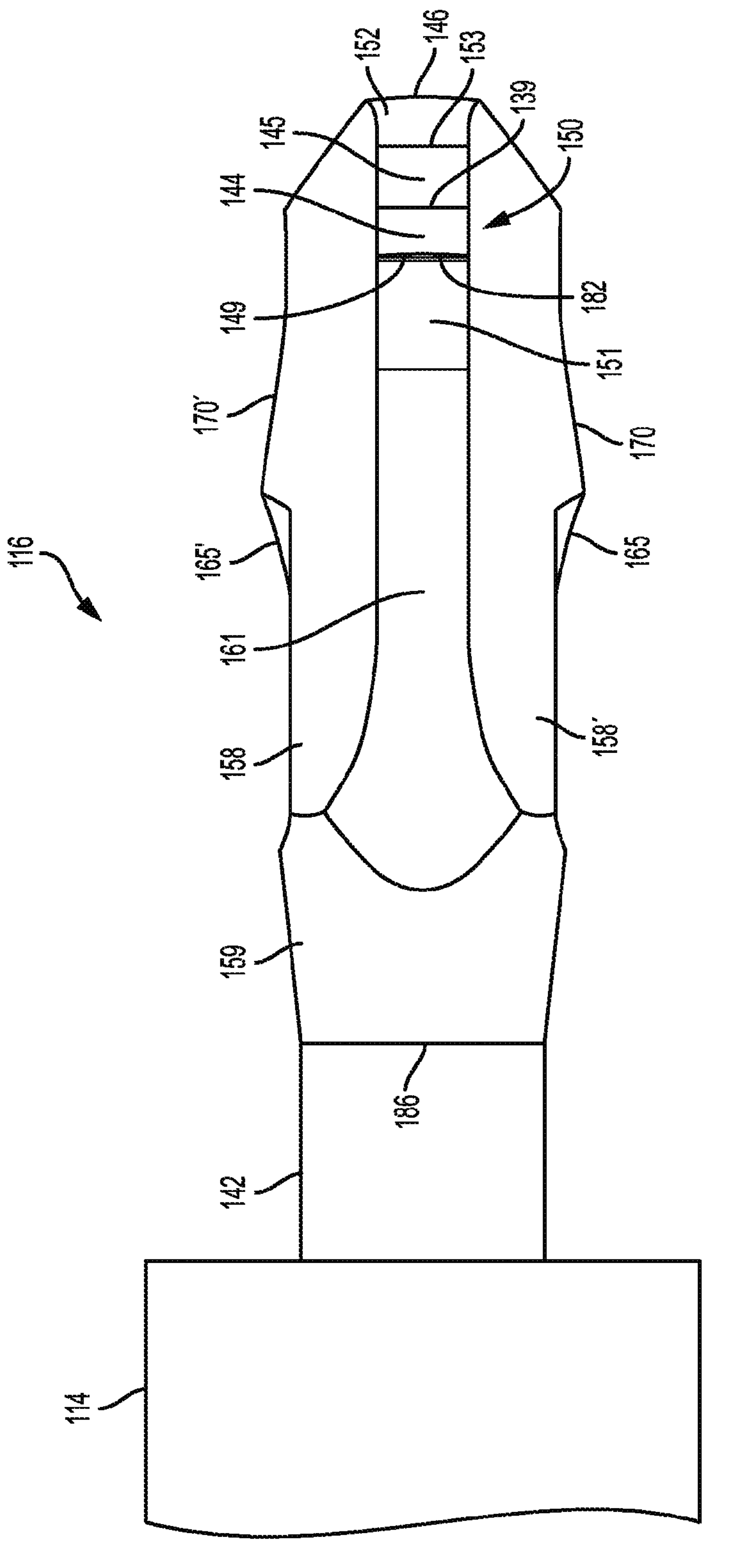

152
146
153
139
145
150
144
149
182
151
170'
170
165'
165
116
161
158
158'
159
186
142
114

FIG. 31

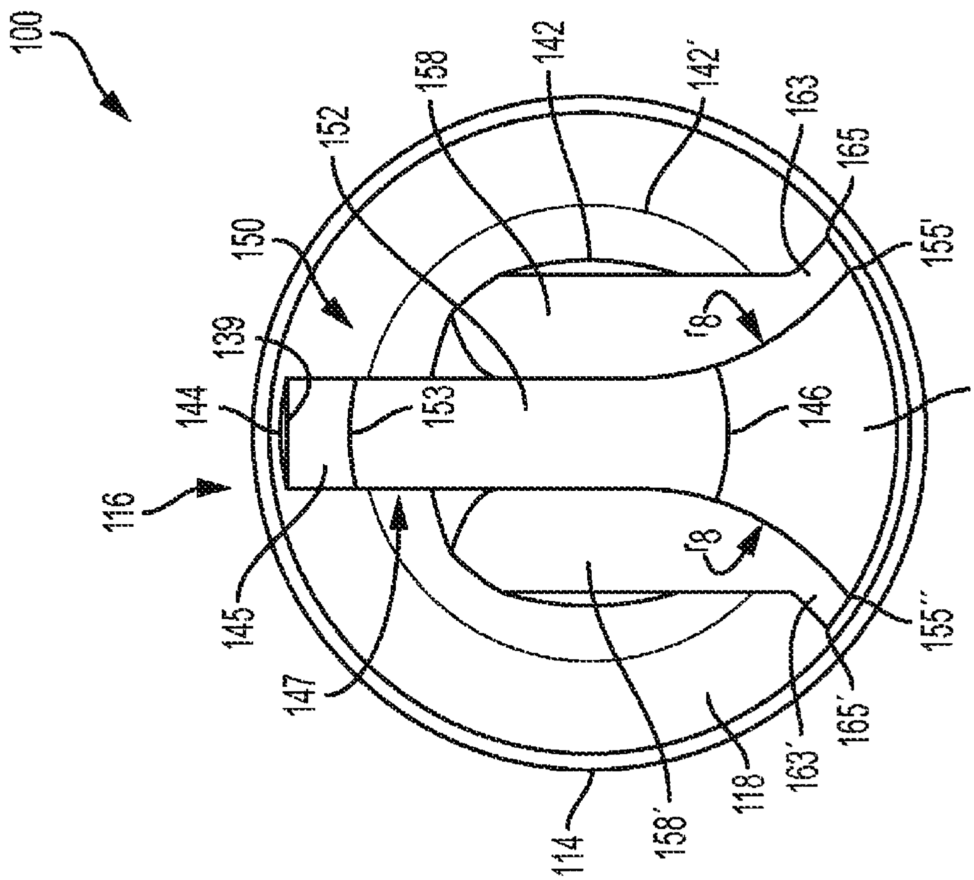

100
150
152
158
142
142'
163
165
155'
139
144
153
146
154
116
145
147
158'
114
118
163'
165'
155''

FIG. 32

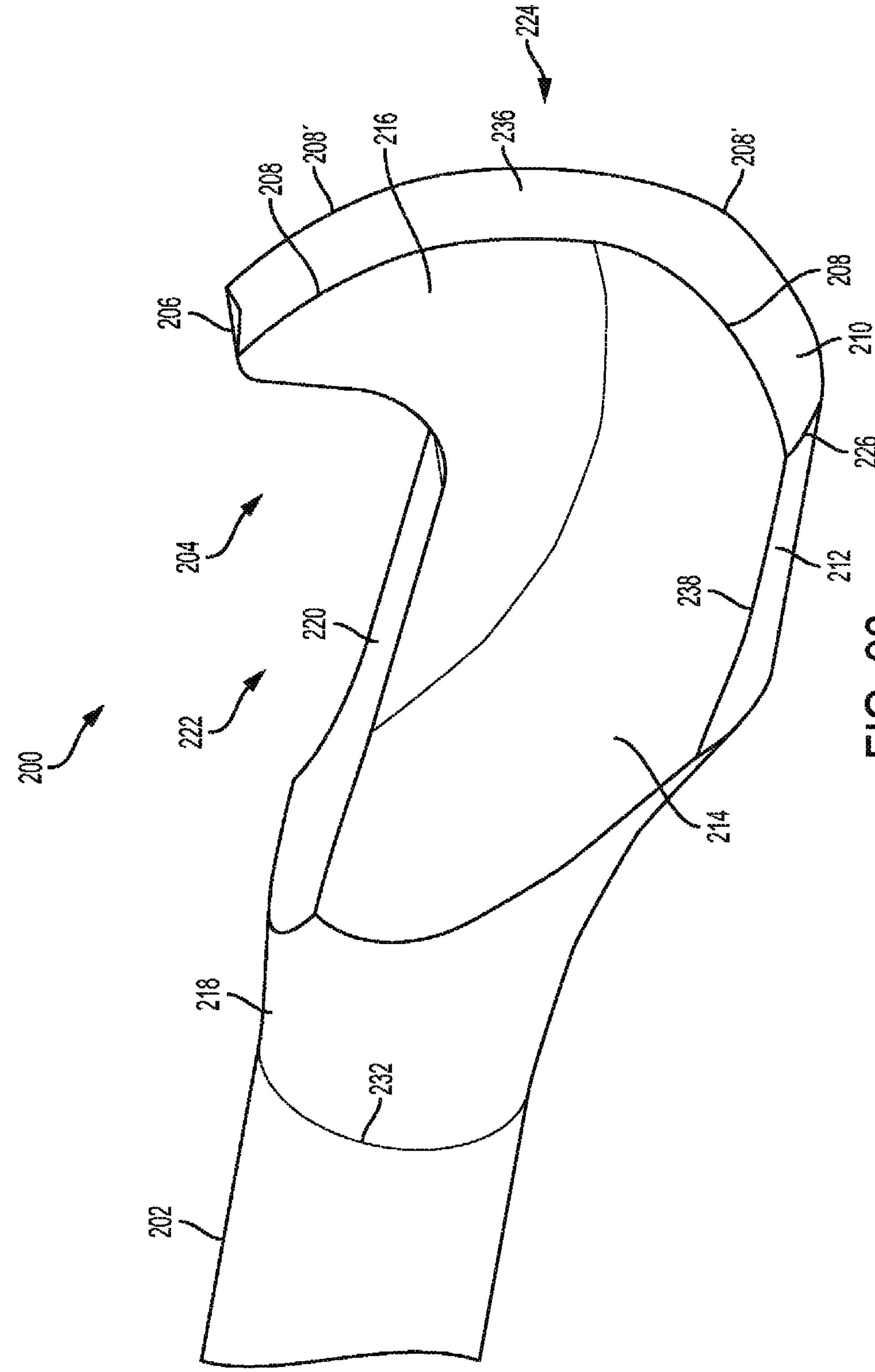

224
208'
216
236
208'
208
206
208
210
226
204
212
238
220
222
200
214
218
232
202

FIG. 33

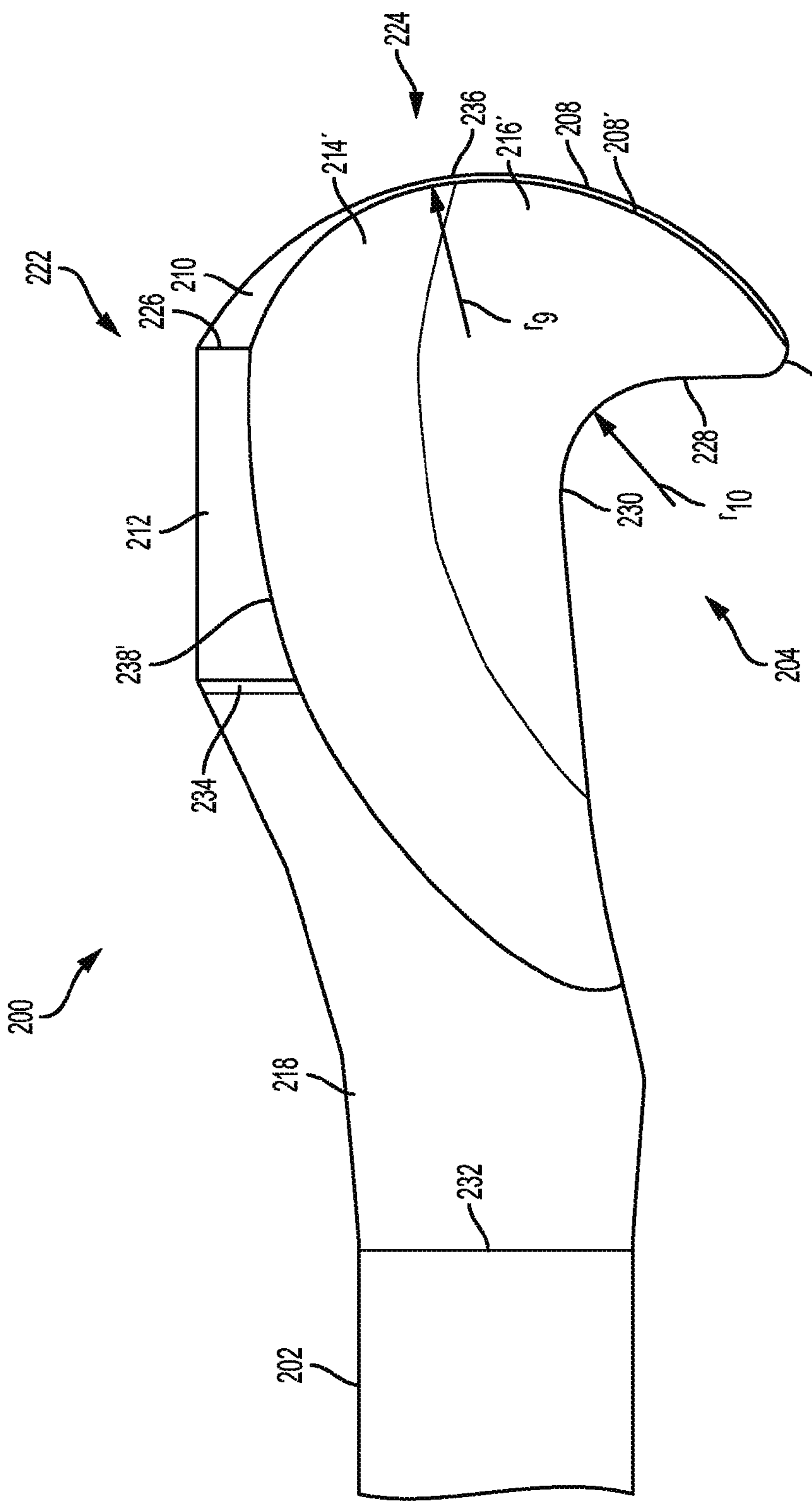

224
236
216'
208
208'
214'
222
226
210
r_9
206
228
212
230
r_{10}
204
238'
234
200
218
232
202

FIG. 34

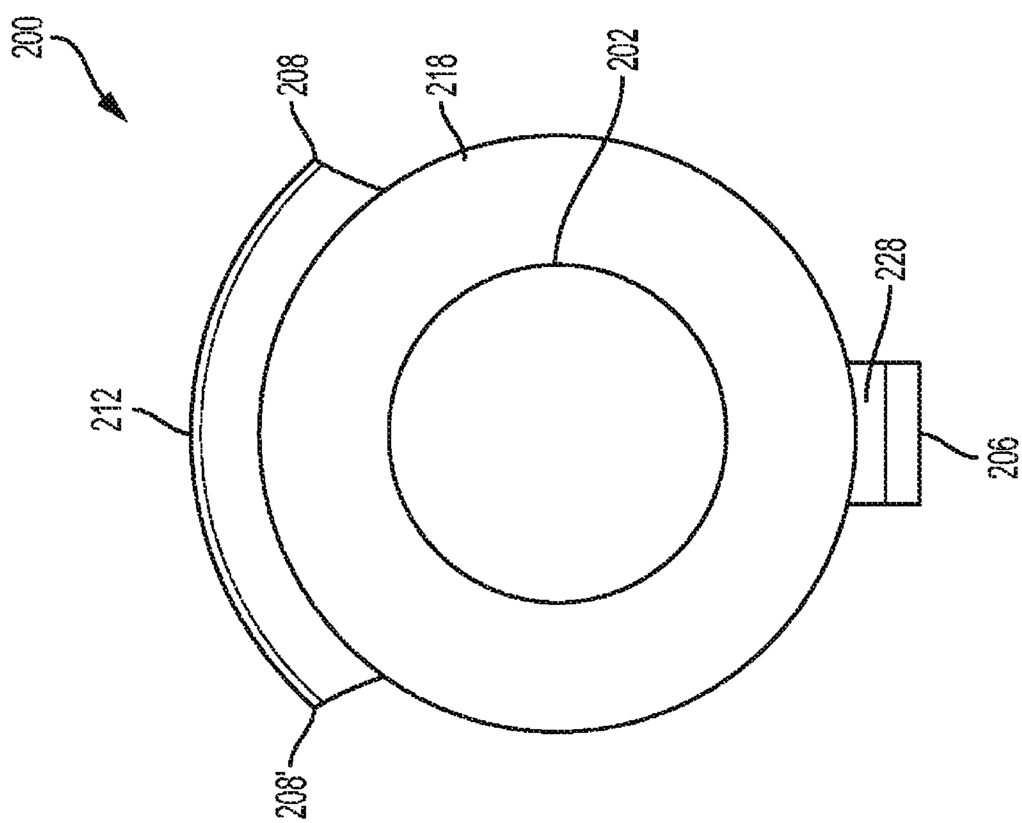


FIG. 35

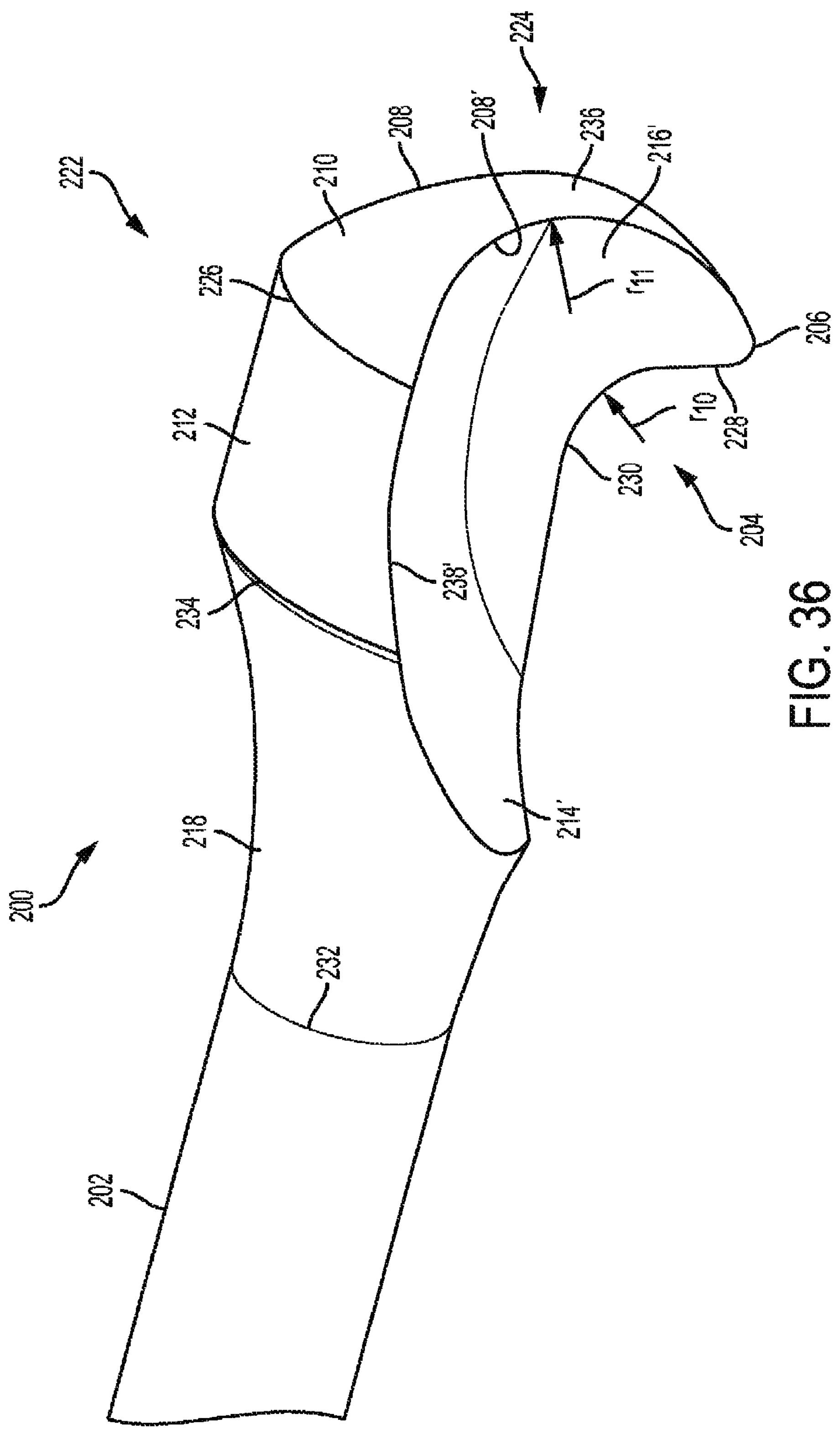

222
224
208
208'
236
216'
210
226
r_{11}
206
212
r_{10}
228
230
204
234
238'
218
214'
200
232
202

FIG. 36

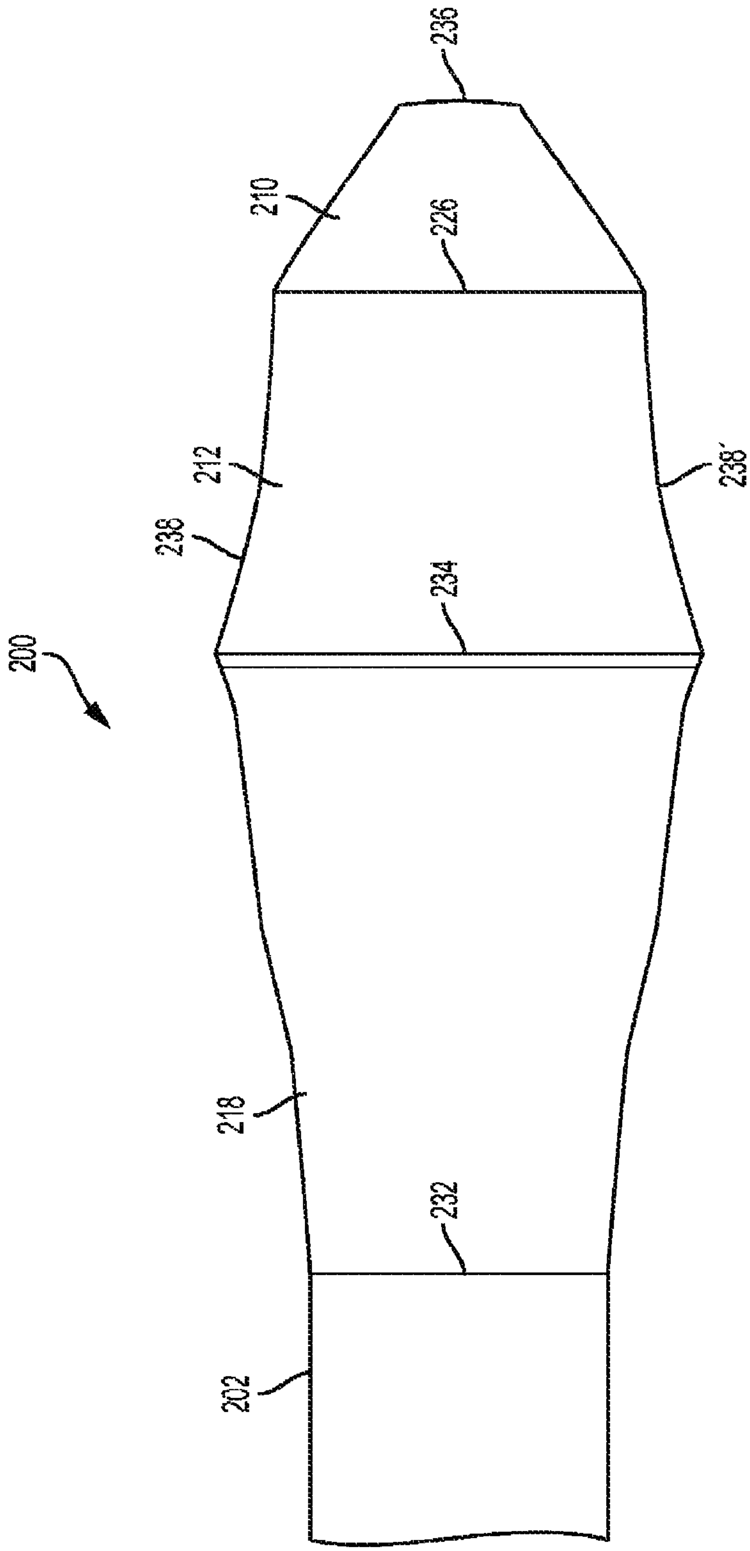


FIG. 37

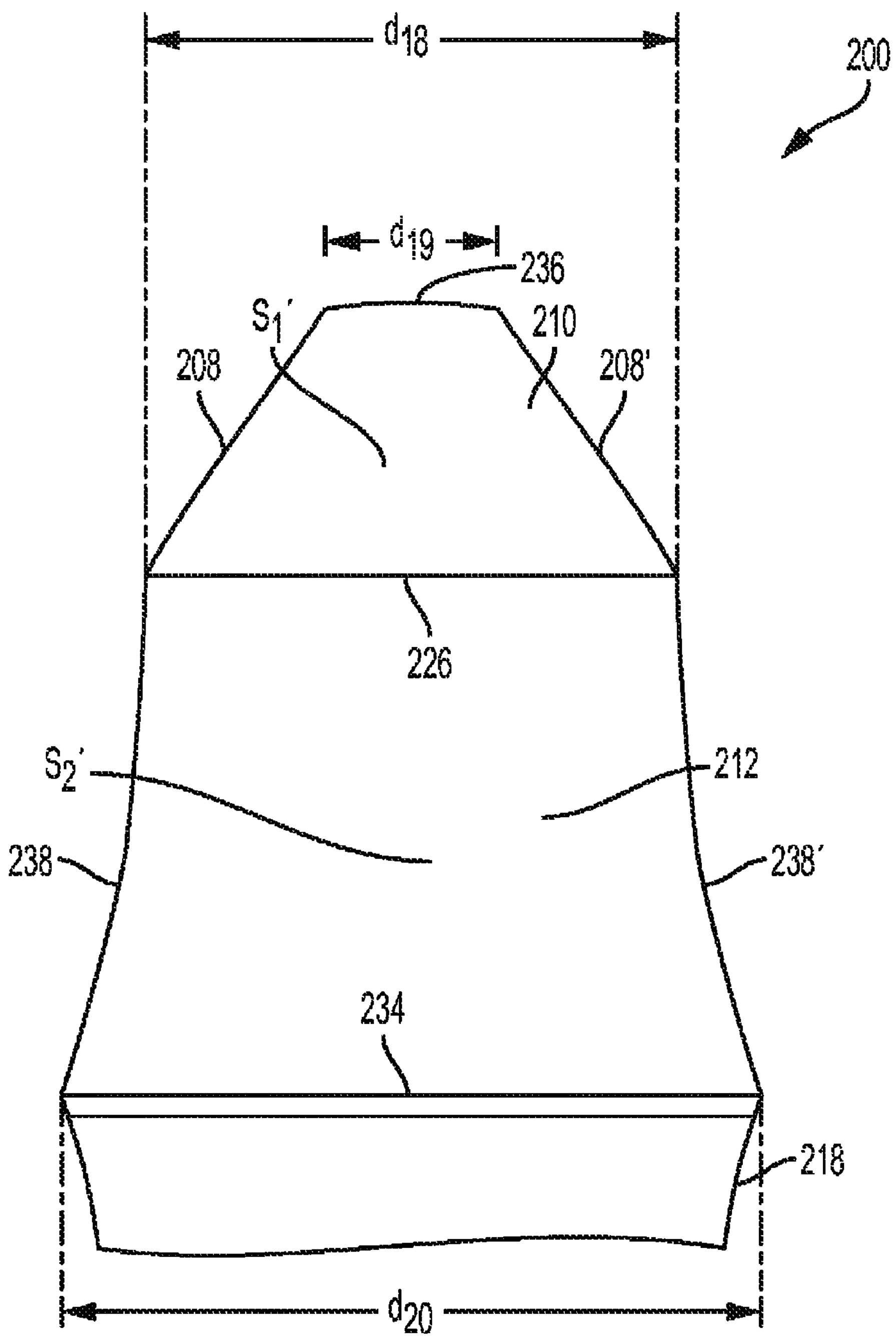


FIG. 38

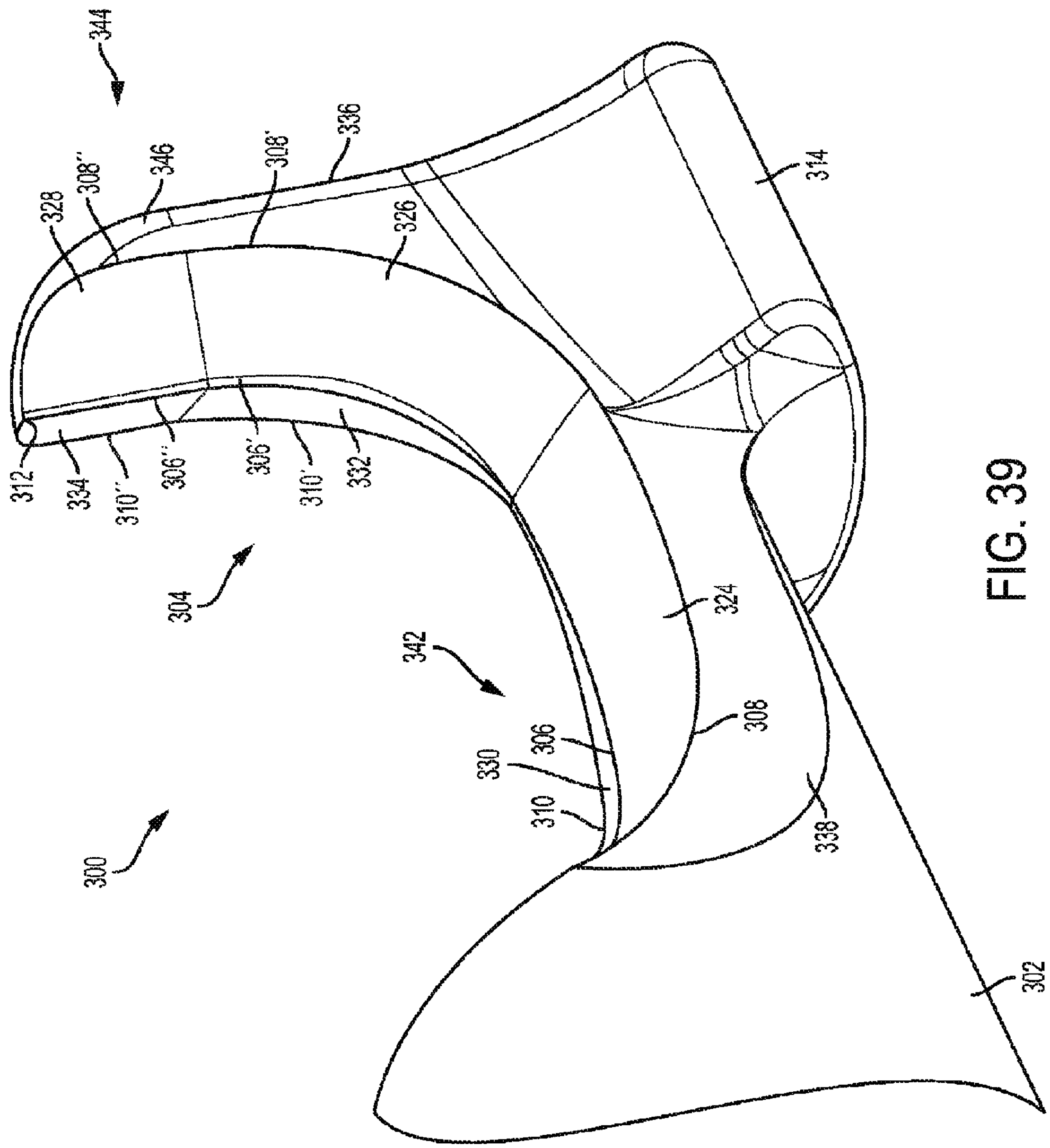

344
336
308'
346
308''
328
326
314
312
334
310''
306''
306'
310'
332
304
324
342
306
330
310
308
338
300
302

FIG. 39

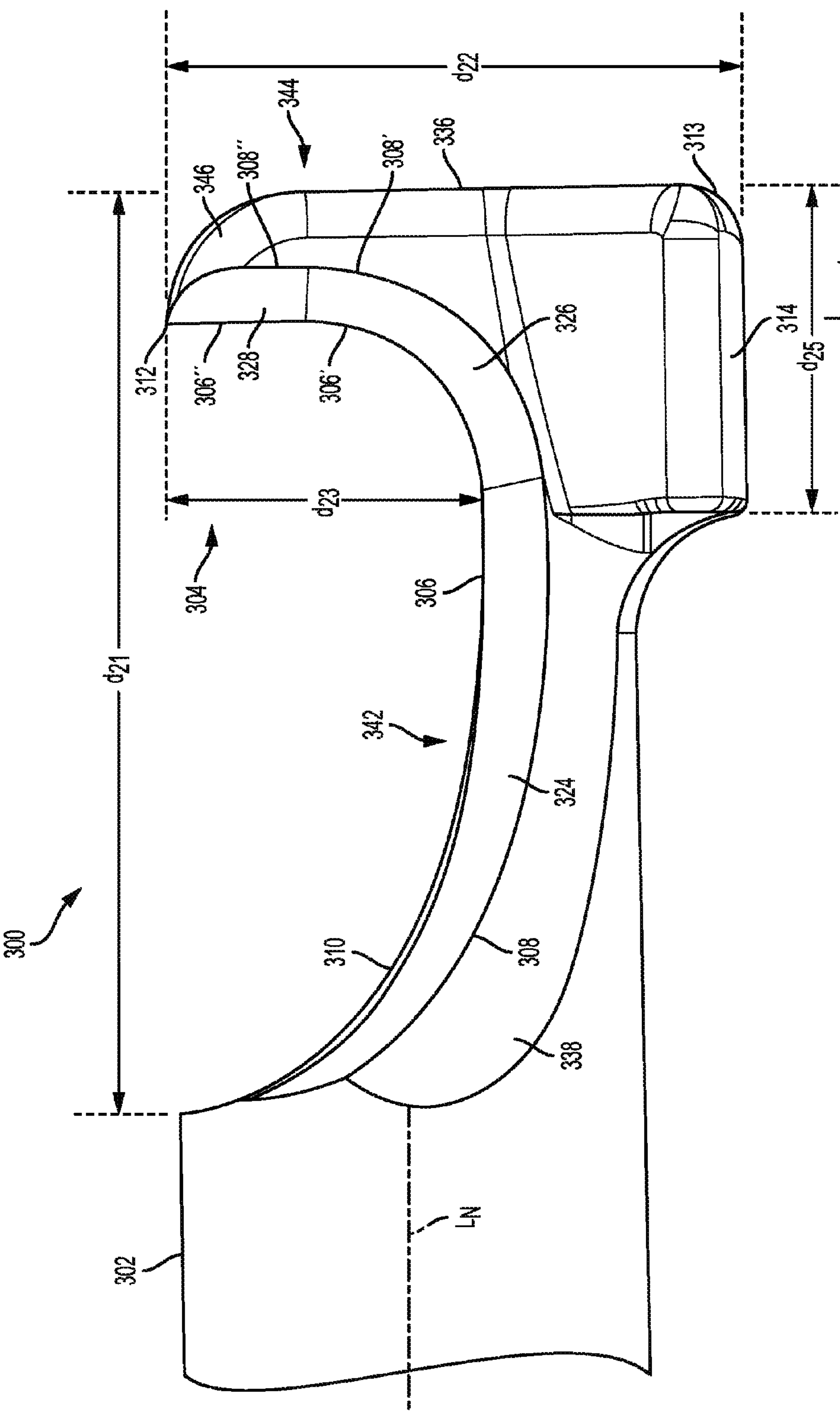

d22
344
336
313
346
308''
308'
d24
d25
314
326
312
306''
328
306'
d23
304
306
d21
342
324
300
310
308
338
L_N
302

FIG. 40

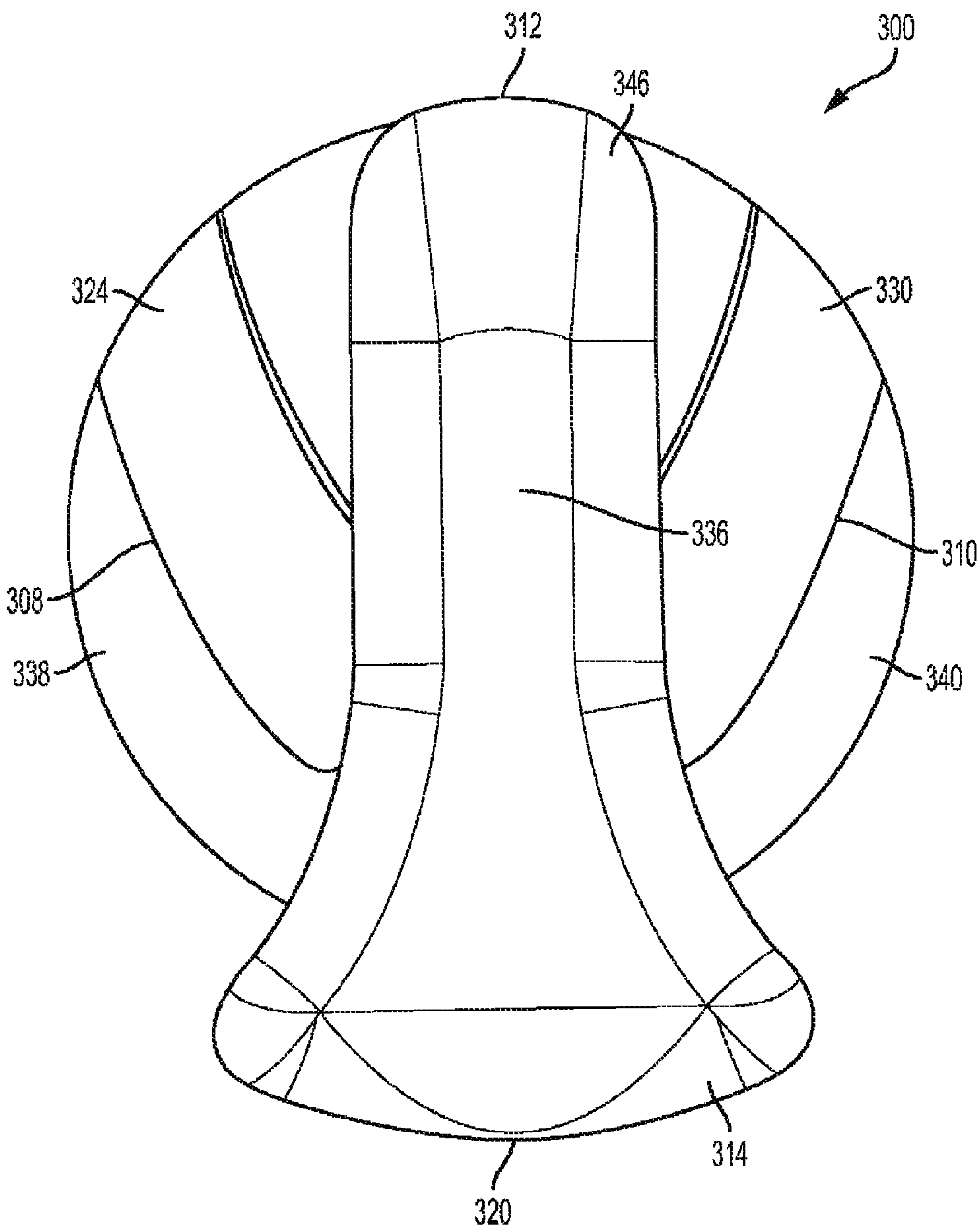


FIG. 41

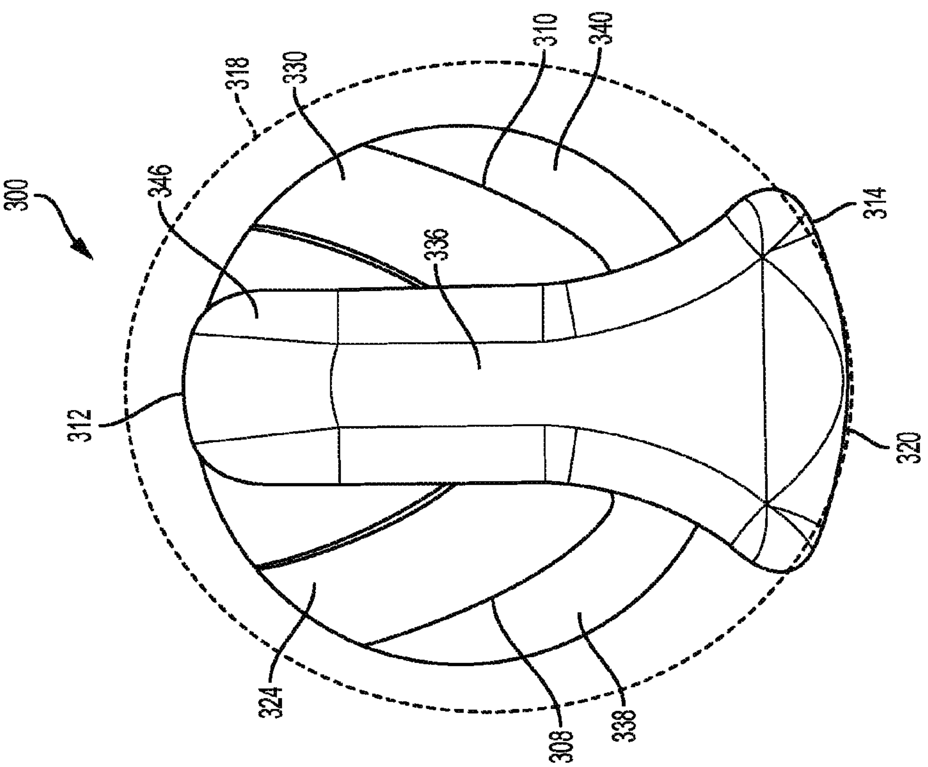

300
318
330
310
340
346
336
314
312
320
324
308
338

FIG. 43

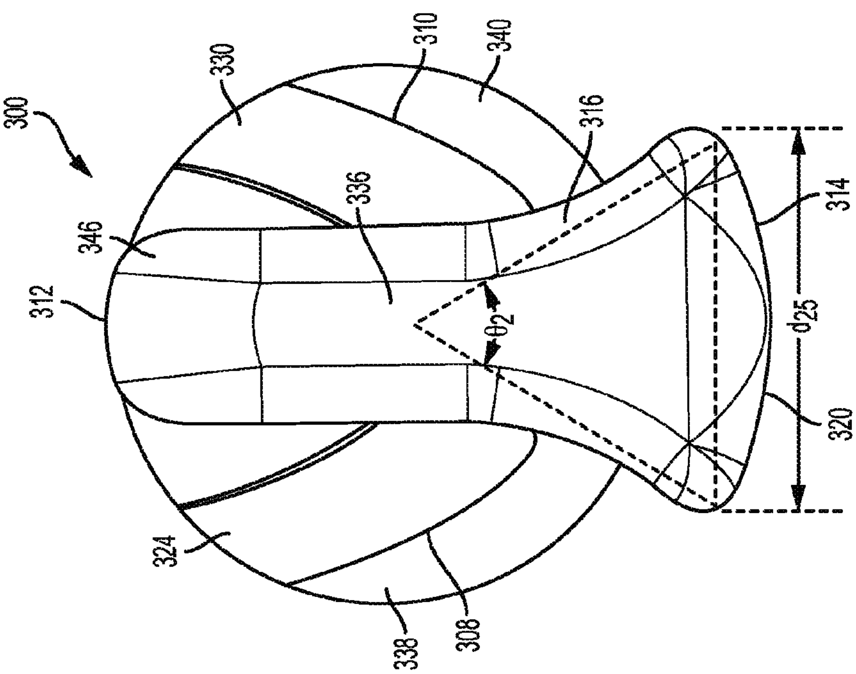

300
330
310
340
316
346
336
312
θ_2
d_{25}
314
320
324
338
308

FIG. 42

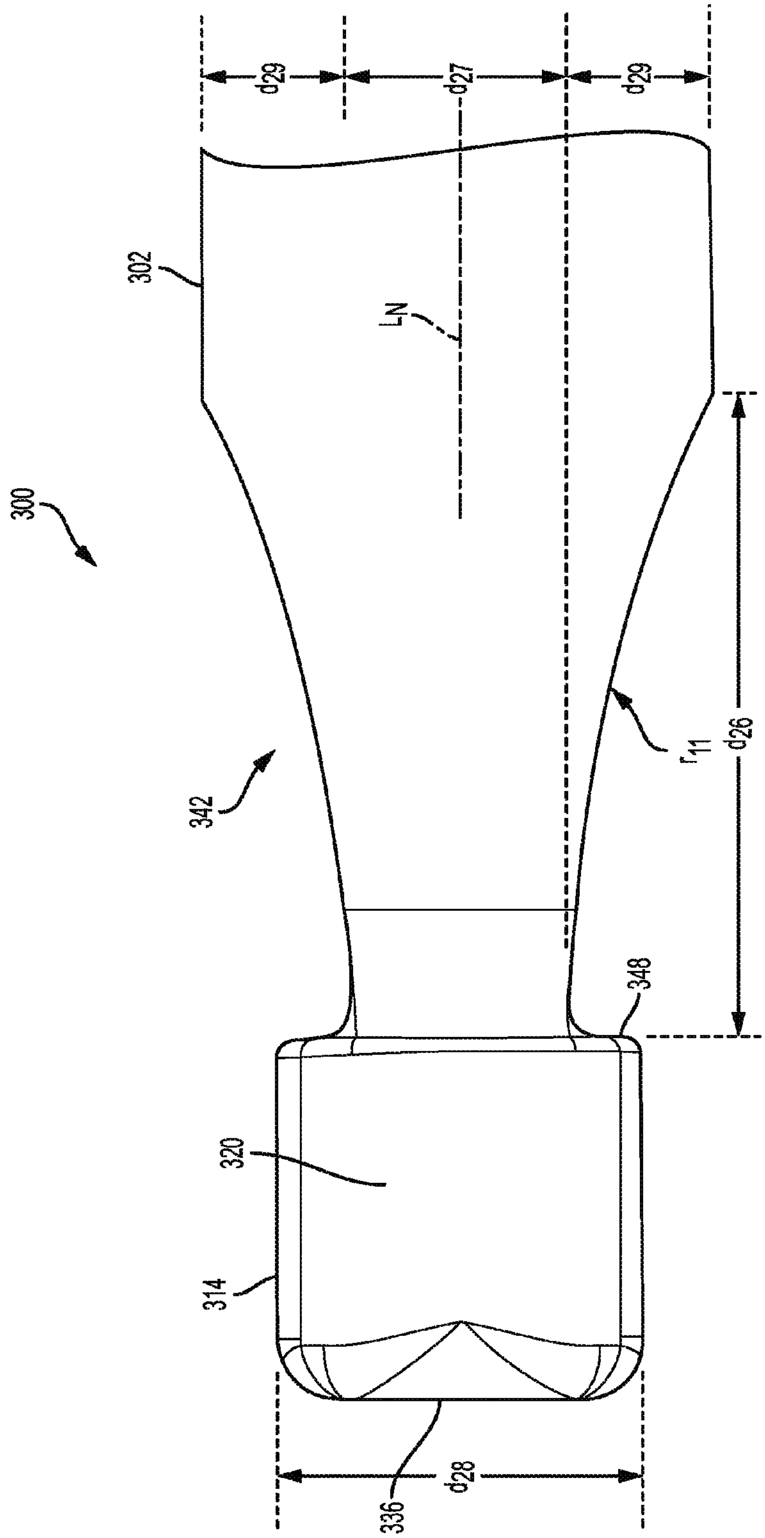


FIG. 44

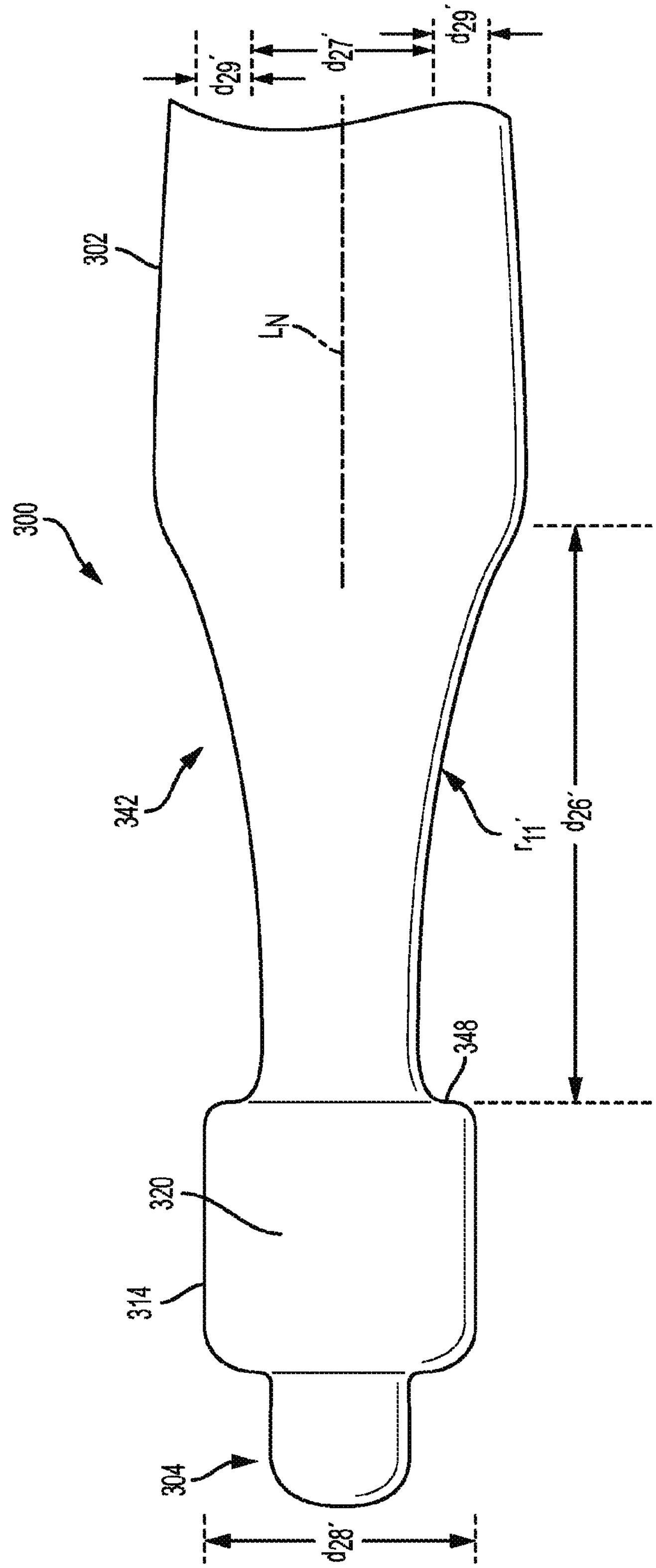


FIG. 45

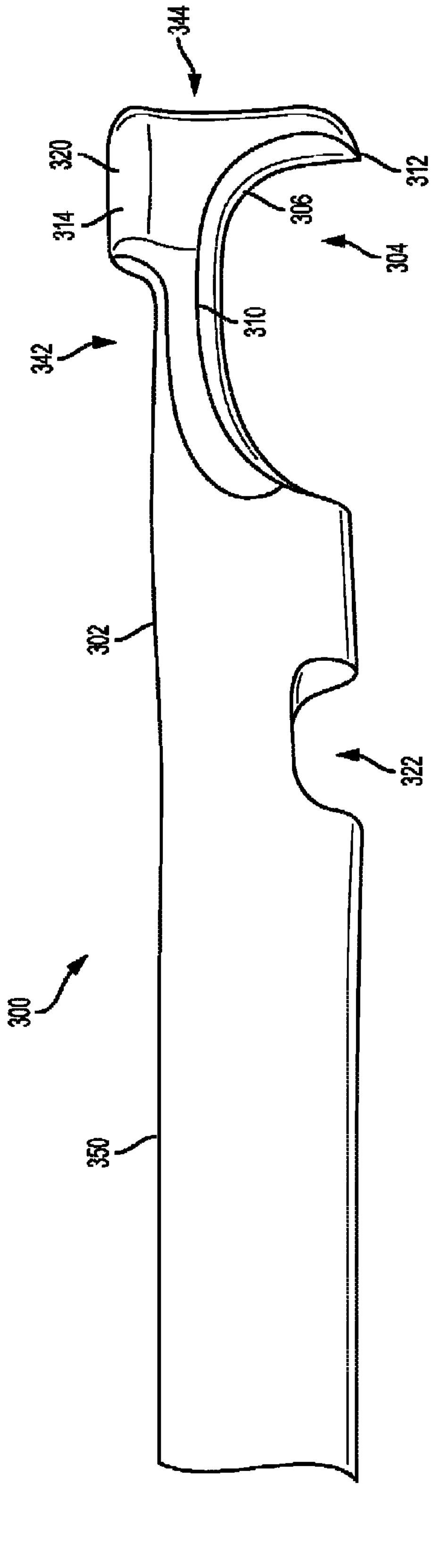


FIG. 46

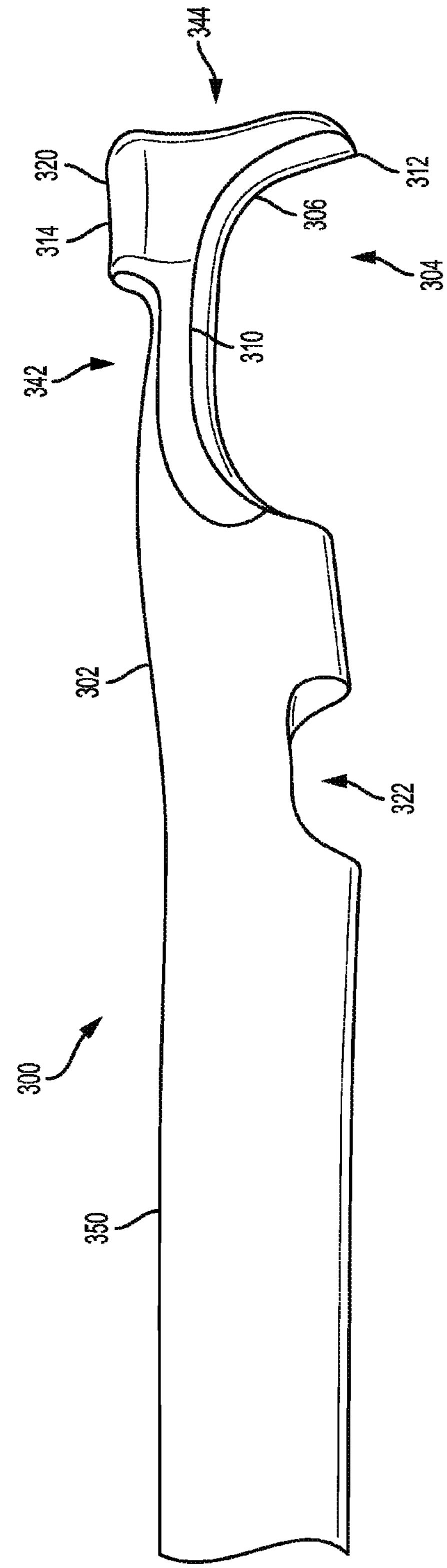


FIG. 47

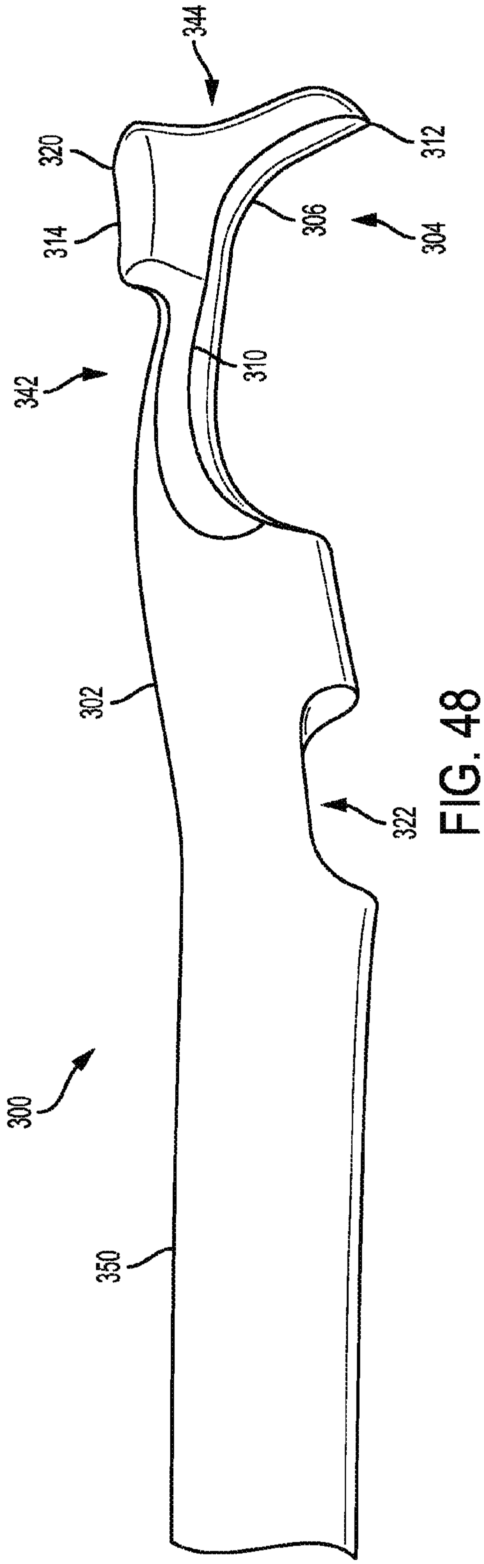


FIG. 48

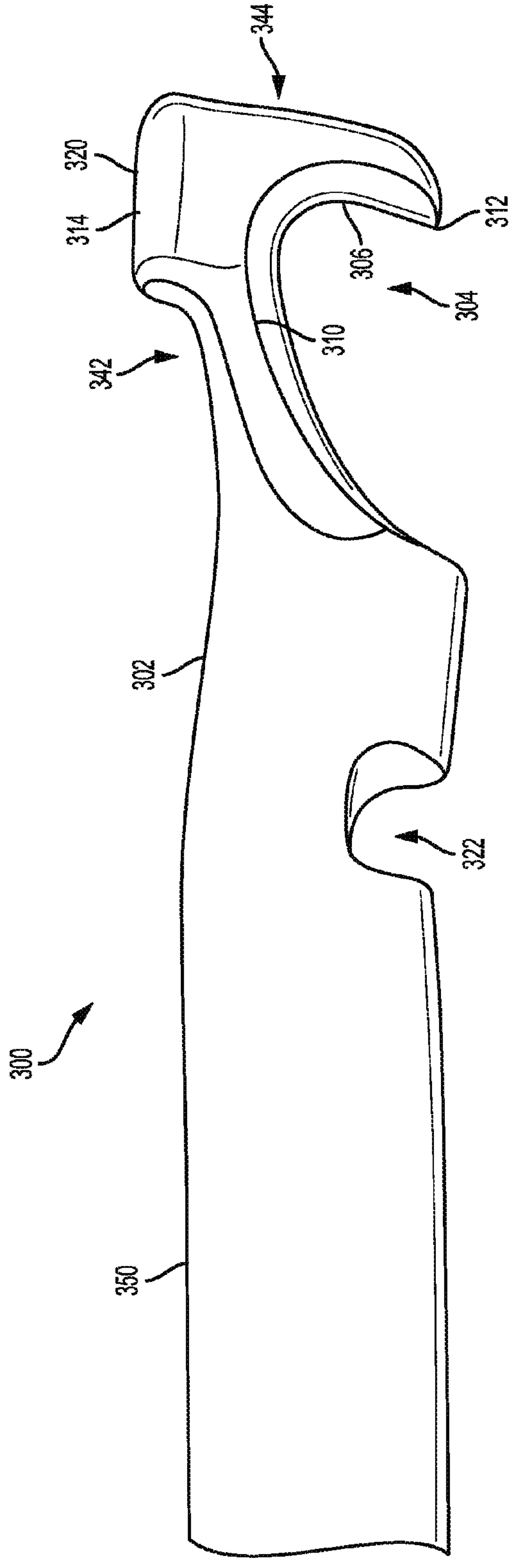


FIG. 49

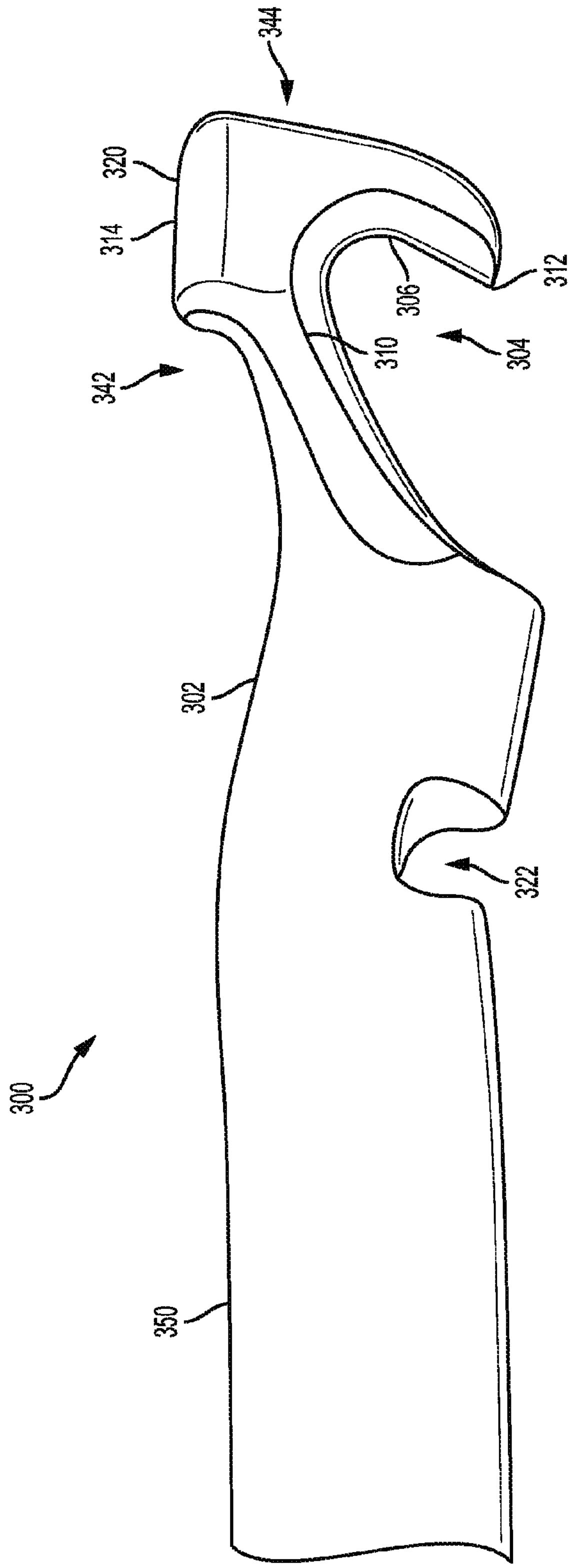


FIG. 50

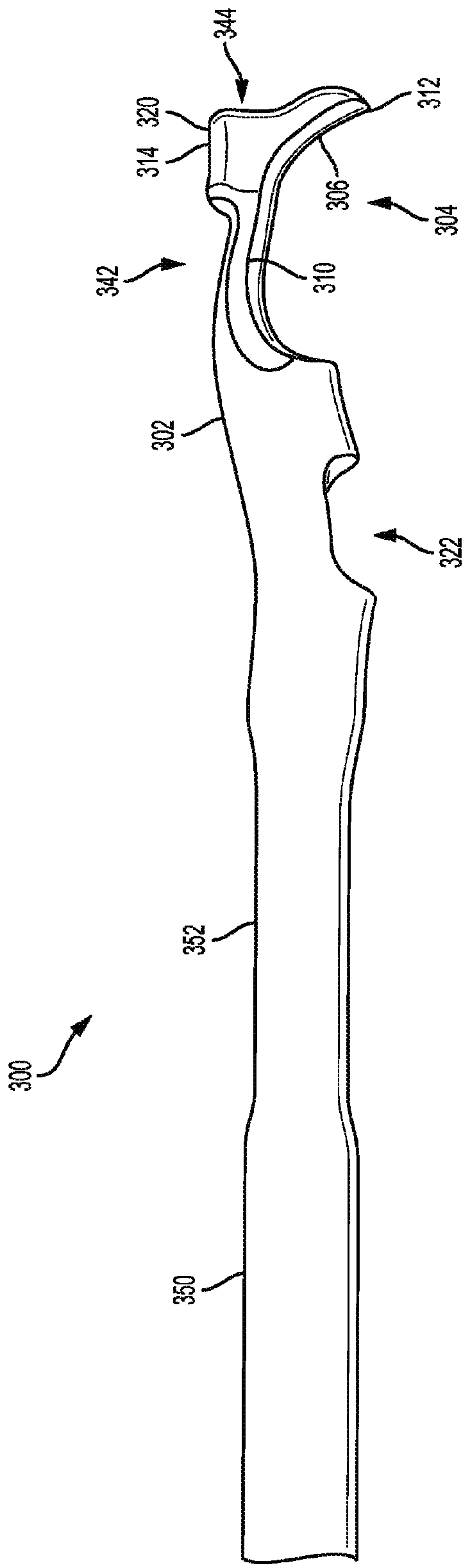


FIG. 51

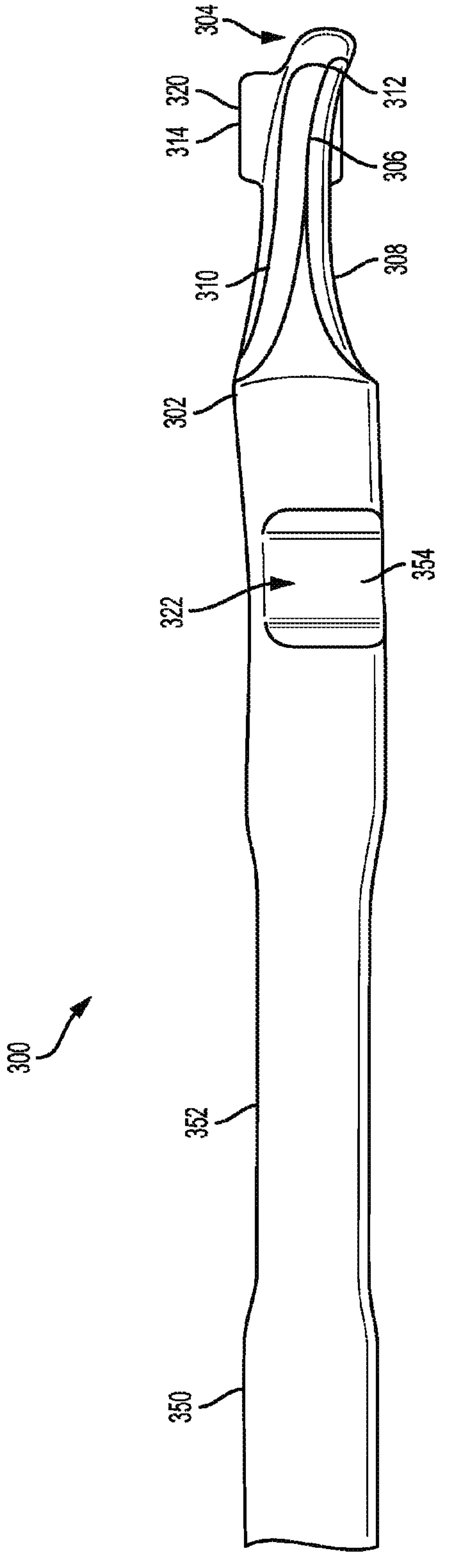


FIG. 52

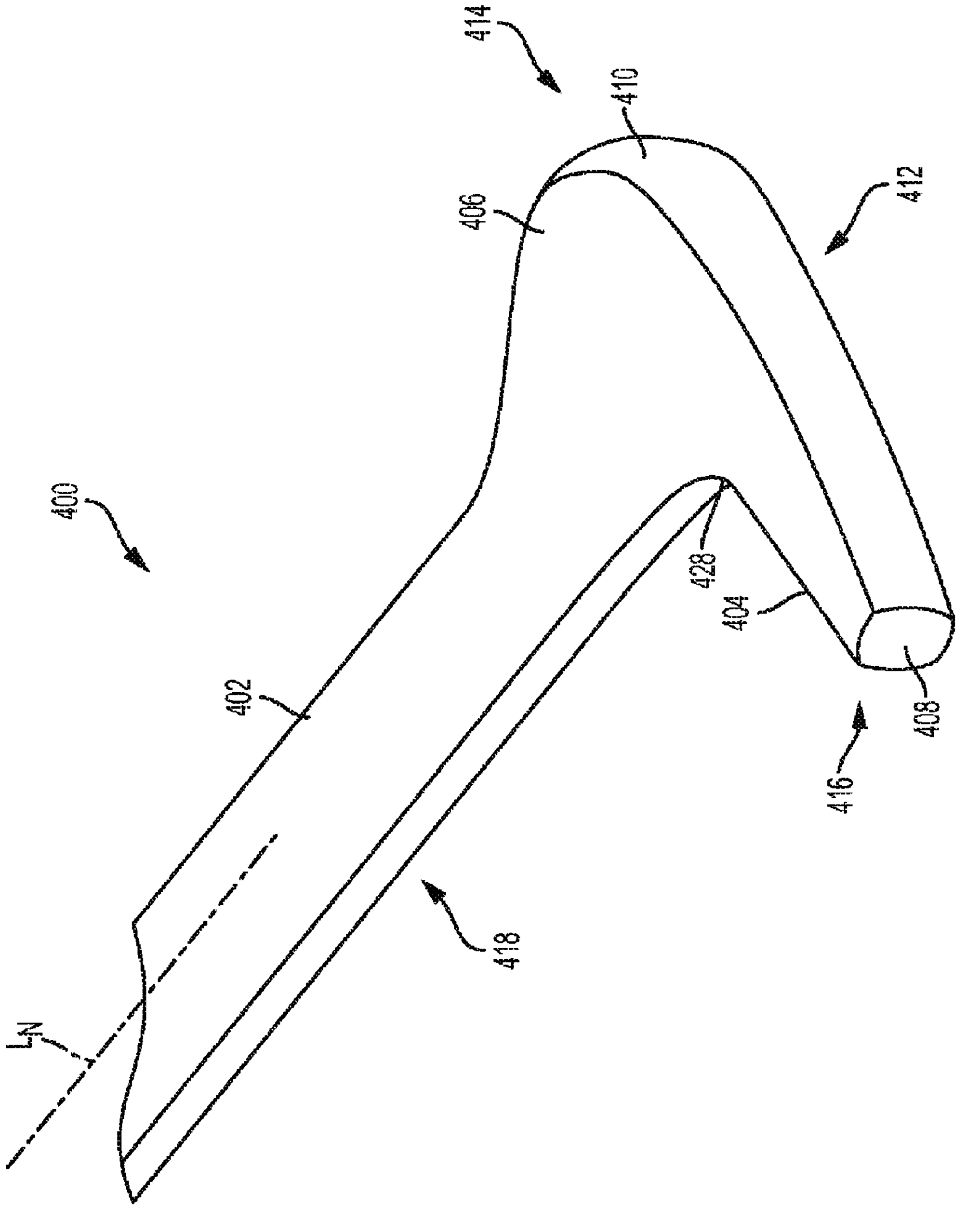


FIG. 53

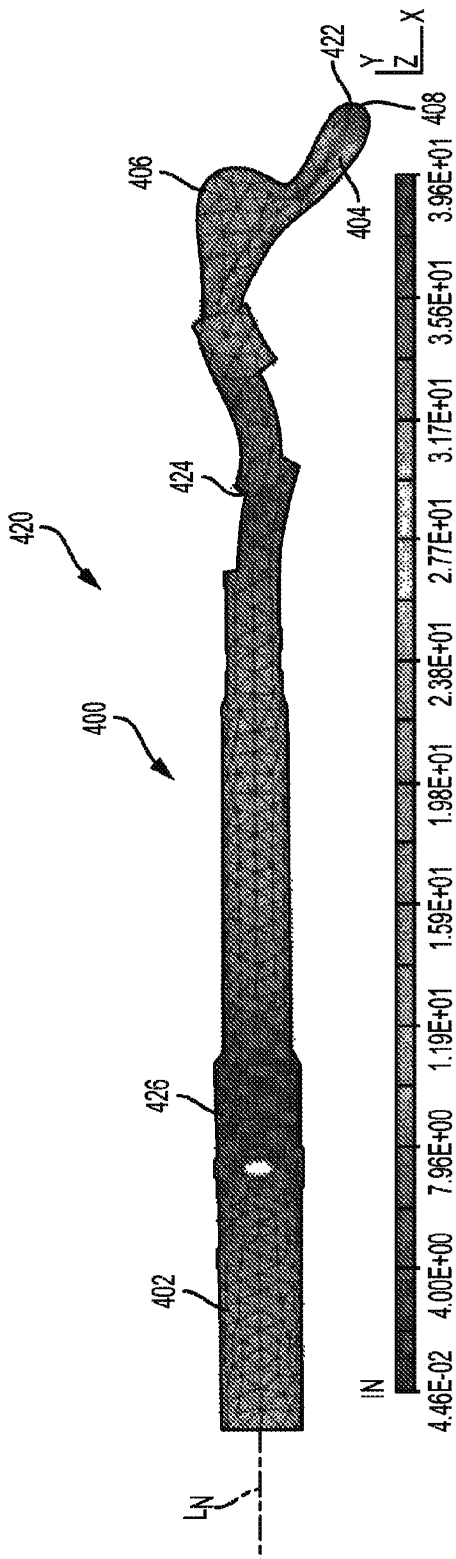

422
408
406
404
424
420
400
426
402
L_N
Y
Z
X
IN
3.96E+01
3.56E+01
3.17E+01
2.77E+01
2.38E+01
1.98E+01
1.59E+01
1.19E+01
7.96E+00
4.00E+00
4.46E-02

FIG. 54

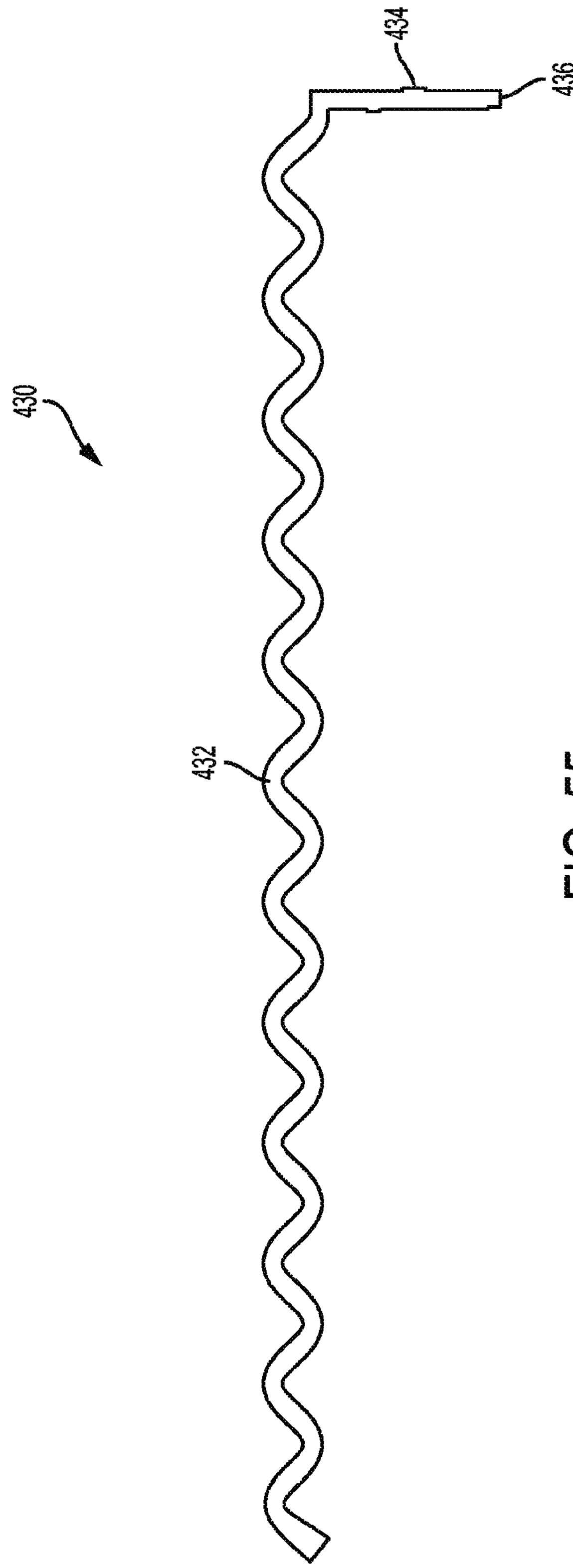


FIG. 55

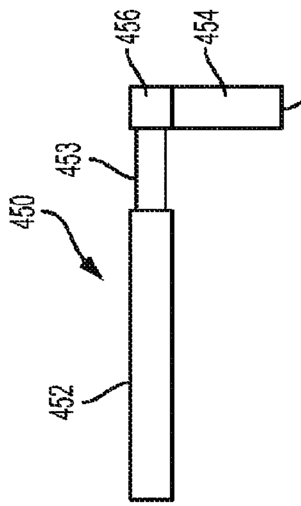


FIG. 57

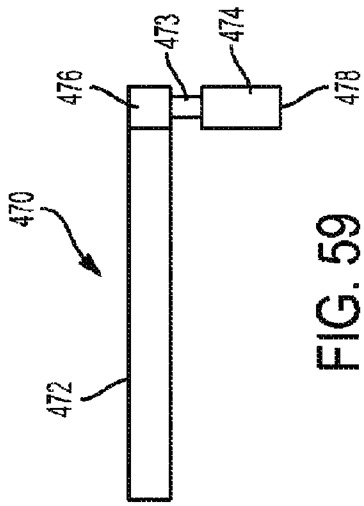


FIG. 59

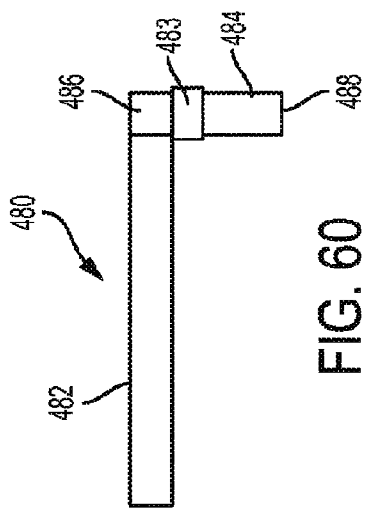


FIG. 60

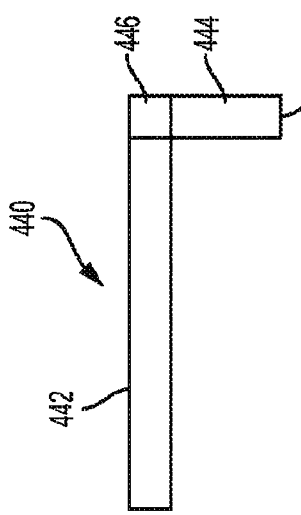


FIG. 56

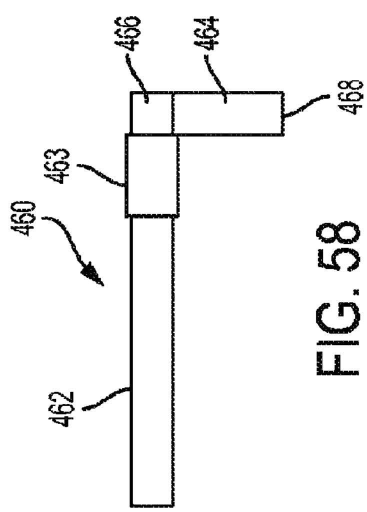


FIG. 58

ULTRASONIC SURGICAL BLADE WITH IMPROVED CUTTING AND COAGULATION FEATURES

INTRODUCTION

The present disclosure is related generally to ultrasonic blades for use in surgical instruments. In particular, the present disclosure is related to ultrasonic surgical blades for use in surgical instruments and, more particularly, to an ultrasonic surgical blade with improved cutting and coagulation features.

BACKGROUND

Ultrasonic instruments, including both hollow core and solid core instruments, are used for the safe and effective treatment of many medical conditions. Ultrasonic instruments, and particularly solid core ultrasonic instruments, are advantageous because they may be used to cut and/or coagulate organic tissue using energy in the form of mechanical vibrations transmitted to a surgical end-effector at ultrasonic frequencies. Ultrasonic vibrations, when transmitted to organic tissue at suitable energy levels and using a suitable end-effector, may be used to cut, dissect, or cauterize tissue. Ultrasonic instruments utilizing solid core technology are particularly advantageous because of the amount of ultrasonic energy that may be transmitted from the ultrasonic transducer, through the waveguide, to the surgical end-effector. Such instruments may be used for open procedures or minimally invasive procedures, such as endoscopic or laparoscopic procedures, wherein the end-effector is passed through a trocar to reach the surgical site.

Activating the end-effector (e.g., cutting blade) of such instruments at ultrasonic frequencies induces longitudinal vibratory movement that generates localized heat within adjacent tissue, facilitating both cutting and coagulation. Because of the nature of ultrasonic instruments, a particular ultrasonically actuated end-effector may be designed to perform numerous functions, including, for example, cutting and coagulation. The structural stress induced in such end-effectors by vibrating the blade at ultrasonic frequencies may have a number of undesirable effects. Such undesirable effects may include, for example, transverse motion in the instrument waveguide that may lead to, for example, excess heat generation in the waveguide or premature stress failure.

Although ultrasonic surgical instruments have been eminently successful, some areas of improvement still remain. For example, it would be desirable for improved ultrasonic blades to remove the gall bladder from the liver bed and for coagulation to facilitate the procedure. An ultrasonic blade that enables efficient dissection of the gall bladder from the liver bed using proximal and distal surfaces facilitates the surgical technique. An ultrasonic blade which has a hook or right angle or near right angle bend near the distal end would provide advantages for access and visibility. The challenges to providing such a configuration have been stress and balance related. An ultrasonic blade with such a configuration must be behave in a balanced manner and be sufficiently strong to endure the added stresses. It would, therefore, be desirable to design an improved ultrasonic surgical blade. It would further be advantageous to provide an ultrasonic surgical blade that cuts faster, while maintaining hemostasis desired by the surgeon. It would also be advantageous to provide an ultrasonic surgical blade that is more controllable and precise, to providing cutting where needed with significant control. An ultrasonic surgical instrument is described with improved cutting and coagulation features to provide these advantages and overcome the disadvantages of previous instruments.

SUMMARY

Various embodiments of ultrasonic surgical blades are disclosed.

1. In one example, an ultrasonic surgical blade comprises a solid body; a longitudinal portion having a proximal end configured to couple to an ultrasonic transmission waveguide and a distal end configured to dissect and coagulate tissue, the longitudinal portion comprising: a substantially planar longitudinal surface; and a distal hemostasis surface located opposite of the substantially planar longitudinal surface; a transverse portion extending crosswise from the distal end of the longitudinal portion, the transverse portion defining a hook having a free end configured to pull and dissect tissue, the transverse portion comprising: a curved section extending from a distal end of the substantially planar longitudinal surface; a tip surface defined at the free end; a substantially planar proximal inner surface extending from the curved surface to the tip surface; and an outer concave distal surface extending from the tip surface to the distal hemostasis surface; and a distal dissection edge defined at a surface inflection of the outer concave distal surface and the distal hemostasis surface.

2. In another example, the ultrasonic surgical blade of example 1 is disclosed, wherein the longitudinal portion comprises a proximal hemostasis surface located opposite of the substantially planar longitudinal surface.

3. In another example, the ultrasonic surgical blade of example 2 is disclosed, comprising first and second lateral surfaces extending from the body to the proximal hemostasis surface defining first and second cutting edges defined at first and second surface inflections between the first and second lateral surfaces and the proximal hemostasis surface.

4. In another example, the ultrasonic surgical blade of example 2 is disclosed, wherein the distal hemostasis surface has a surface area S1 selected form a range of 3.226 mm^2 to 6.45 mm^2 (0.005 in^2 to 0.01 in^2).

5. In another example, the ultrasonic surgical blade of example 1 is disclosed, further comprising a beveled edge defined between the tip surface and the substantially planar proximal inner surface.

6. In another example, the ultrasonic surgical blade of example 1 is disclosed, further comprising an oblique tip surface extending from the tip surface to the outer concave distal surface.

7. In another example, the ultrasonic surgical blade of example 1 is disclosed, wherein the depth of the transverse portion measured from the tip surface to the proximal hemostasis surface is selected from a range of 1.8 mm to 3.0 mm (0.071 in to 0.118 in).

8. In another example, the ultrasonic surgical blade of example 1 is disclosed, wherein the proximal hemostasis surface has a surface area S2 selected form a range of 6.45 mm^2 to 12.90 mm^2 (0.01 in^2 to 0.02 in^2).

9. In one example, an ultrasonic surgical blade comprises a solid body; a longitudinal portion having a proximal end and a distal end, the longitudinal portion comprising: a substantially planar longitudinal surface; and a distal hemostasis surface located opposite of the substantially planar longitudinal surface; a transverse portion extending crosswise from the distal end of the longitudinal portion, the transverse portion defining a hook having a free end, the transverse portion comprising: a curved section extending

from a distal end of the substantially planar longitudinal surface; a tip surface defined at the free end; a proximal inner surface extending from the curved surface to the tip surface; and an outer convex distal surface extending from the tip surface to the distal hemostasis surface.

10. In another example, the ultrasonic surgical blade of example 9 is disclosed, wherein the longitudinal portion comprises a proximal hemostasis surface located opposite of the substantially planar longitudinal surface.

11. In another example, the ultrasonic surgical blade of example 10 is disclosed, comprising first and second lateral surfaces extending from the body to the proximal hemostasis surface defining first and second cutting edges defined at first and second surface inflections between the first and second lateral surfaces and the proximal hemostasis surface.

12. In another example, the ultrasonic surgical blade of example 10 is disclosed, wherein the distal hemostasis surface has a surface area S1 selected form a range of 0.005 in^2 to 0.01 in^2 (3.226 mm^2 to 6.45 mm^2).

13. In another example, the ultrasonic surgical blade of example 9 is disclosed, wherein the depth of the transverse portion measured from the tip surface to the proximal hemostasis surface is selected from a range of 1.8 mm to 3.0 mm (0.071 in to 0.118 in).

14. In another example, the ultrasonic surgical blade of example 9 is disclosed, wherein the proximal hemostasis surface has a surface area S2 selected form a range of 0.01 in^2 to 0.02 in^2 (6.45 mm^2 to 12.90 mm^2).

15. In one example, an ultrasonic surgical blade comprises a solid body; a longitudinal portion having a proximal end and a distal end, the longitudinal portion comprising: a sharp central ridge; a distal hemostasis surface located opposite of the substantially planar longitudinal surface; and an end mass located at the distal end of the longitudinal portion; and a transverse portion extending crosswise from the distal end of the longitudinal portion and located opposite of the end mass, the transverse portion defining a hook having a free end, the transverse portion comprising a tip surface defined at the free end.

16. In another example, the ultrasonic surgical blade of example 15 is disclosed, wherein the sharp central ridge comprise at least two segments extending from a neck portion of the body to the tip surface of the hook.

17. In another example, the ultrasonic surgical blade of example 16 is disclosed, wherein the sharp central ridge comprises a proximal segment, an intermediate arcuate segment, and a distal linear segment.

18. In another example, the ultrasonic surgical blade of example 16 is disclosed, wherein the proximal segment is defined by a junction of two proximal oblique surfaces that extend downwardly and outwardly from the proximal segment, the intermediate arcuate segment is defined by a junction of intermediate arcuate oblique surfaces that extend downwardly and outwardly from the intermediate arcuate segment, and the distal linear segment is defined by a junction of distal oblique surfaces that extend distally and outwardly from the distal linear segment.

19. In another example, the ultrasonic surgical blade of example 15 is disclosed, wherein the depth of the transverse portion measured from the tip surface to the proximal hemostasis surface is selected from a range of 1.8 mm to 3.0 mm (0.071 in to 0.118 in).

20. In another example, the ultrasonic surgical instrument of example 15 is disclosed, where in the hemostasis surface is located on a surface portion of the end mass.

The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

FIGURES

The novel features of the embodiments described herein are set forth with particularity in the appended claims. The embodiments, however, both as to organization and methods of operation may be better understood by reference to the following description, taken in conjunction with the accompanying drawings as follows.

FIG. **1** is an illustration of an ultrasonic instrument according to one embodiment.

FIG. **2** is an illustration of the ultrasonic instrument shown in FIG. **1**, with the outer sheath removed to reveal the underlying ultrasonic transmission waveguide.

FIG. **3** is an illustration of the ultrasonic surgical instrument shown in FIG. **1** with the right and left shrouds removed.

FIG. **4** is an illustration of the handle assembly of the ultrasonic surgical instrument shown in FIG. **1** with the left shroud, the shaft assembly, and the nose cone removed.

FIG. **5** is a front view of the ultrasonic surgical instrument shown in FIG. **1** with the nose cone removed to show the underlying activation button assembly, the clutch plate, retainer, and support bushing.

FIG. **6** illustrates one embodiment of a surgical end-effector integrally formed with an ultrasonic transmission waveguide.

FIG. **7** is a perspective view of an ultrasonic surgical blade according to one embodiment.

FIG. **8** is a side view of the ultrasonic surgical blade shown in FIG. **7**, according to one embodiment.

FIG. **9** is a perspective view of the ultrasonic surgical blade according to one embodiment.

FIG. **10** is an illustration of the distal and proximal hemostasis surface of the ultrasonic surgical blade shown in FIGS. **7-9**, according to one embodiment.

FIG. **11** is a side view of the ultrasonic surgical blade in a neutral position illustrating the location of the distal antinode AN and the longitudinal axis L, according to one embodiment.

FIG. **12** is an illustration of the ultrasonic surgical blade shown in FIG. **11** in an intermediate position with no displacement.

FIG. **13** is an illustration of the ultrasonic surgical blade shown in FIG. **11** in a maximum proximal displacement, and

FIG. **14** is an illustration of the ultrasonic surgical blade shown in FIG. **11** in a maximum distal displacement.

FIG. **15** is a graphical representation of displacement (microns) along the vertical axis of the ultrasonic surgical blade shown in FIGS. **12-14** versus distance (in) along the ultrasonic surgical blade along the horizontal axis, according to one embodiment.

FIG. **16** is a side of the ultrasonic surgical blade shown in FIG. **7** illustrating the position of several sectional views shown in FIGS. **17-29**, according to one embodiment.

FIG. **17** is a sectional view of the ultrasonic surgical blade shown in FIG. **16** taken along section line **17-17**, according to one embodiment.

FIG. **18** is a sectional view of the ultrasonic surgical blade shown in FIG. **16** taken along section line **18-18**, according to one embodiment.

FIG. 19 is a sectional view of the ultrasonic surgical blade shown in FIG. 16 taken along section line 19-19, according to one embodiment.

FIG. 20 is a sectional view of the ultrasonic surgical blade shown in FIG. 16 taken along section line 20-20, according to one embodiment.

FIG. 21 is a sectional view of the ultrasonic surgical blade shown in FIG. 16 taken along section line 21-21, according to one embodiment.

FIG. 22 is a sectional view of the ultrasonic surgical blade shown in FIG. 16 taken along section line 22-22, according to one embodiment.

FIG. 23 is a sectional view of the ultrasonic surgical blade shown in FIG. 16 taken along section line 23-23, according to one embodiment.

FIG. 24 is a sectional view of the ultrasonic surgical blade shown in FIG. 16 taken along section line 24-24, according to one embodiment.

FIG. 25 is a sectional view of the ultrasonic surgical blade shown in FIG. 16 taken along section line 25-25, according to one embodiment.

FIG. 26 is a sectional view of the ultrasonic surgical blade shown in FIG. 16 taken along section line 26-26, according to one embodiment.

FIG. 27 is a sectional view of the ultrasonic surgical blade shown in FIG. 16 taken along section line 27-27, according to one embodiment.

FIG. 28 is a sectional view of the ultrasonic surgical blade shown in FIG. 16 taken along section line 28-28, according to one embodiment.

FIG. 29 is an illustration of a bottom view of the ultrasonic surgical blade shown in FIG. 7 showing the distal and proximal hemostasis surfaces and lateral cutting edges.

FIG. 30 is a sectional view of the ultrasonic surgical blade shown in FIG. 29 taken along section line 30-30, according to one embodiment.

FIG. 31 is a top view of the ultrasonic surgical blade shown in FIG. 29, according to one embodiment.

FIG. 32 is an end view of the ultrasonic surgical instrument showing the ultrasonic surgical blade and the outer tube/sheath, according to one embodiment.

FIG. 33 is perspective view of the ultrasonic surgical blade, according to one embodiment.

FIG. 34 is a side view of the ultrasonic surgical blade shown in FIG. 33, according to one embodiment.

FIG. 35 is an end view of the ultrasonic surgical blade shown in FIG. 33, according to one embodiment.

FIG. 36 is another perspective view of the ultrasonic surgical blade shown in FIG. 33, according to one embodiment.

FIG. 37 is a bottom view of the ultrasonic surgical blade shown in FIG. 33, according to one embodiment.

FIG. 38 is an illustration of the distal and proximal hemostasis surface of the ultrasonic surgical blade shown in FIGS. 33-37, according to one embodiment.

FIG. 39 is a perspective view of the ultrasonic surgical blade shown in FIG. 39, according to one embodiment.

FIG. 40 is a side view of the ultrasonic surgical blade shown in FIG. 39, according to one embodiment.

FIG. 41 is an end view of the ultrasonic surgical blade shown in FIG. 39, according to one embodiment.

FIG. 42 is an end view of the ultrasonic surgical blade shown in FIGS. 39-41 illustrating a triangle shaped end mass, according to one embodiment.

FIG. 43 is an end view of the ultrasonic surgical blade shown in FIGS. 39-41 illustrating a suitable diameter for trocar entry, according to one embodiment.

FIG. 44 is a bottom view of the ultrasonic surgical blade shown in FIG. 39 in compression mode, according to one embodiment.

FIG. 45 is a bottom view of the ultrasonic surgical blade shown in FIG. 39 in tension mode, according to one embodiment.

FIG. 46 illustrates the ultrasonic surgical blade shown in FIG. 39 in a neutral unexcited state.

FIG. 47 illustrates the ultrasonic surgical blade shown in FIG. 46, as the vibration process initiates, where the blade hook is displaced distally under tension mode and the gap defined by the balance feature expands.

FIG. 48 illustrates the ultrasonic surgical blade shown in FIG. 47 as the blade continues to be displaced distally under tension until it reaches a point of maximum displacement under tension.

FIG. 49 illustrates the ultrasonic surgical blade shown in FIG. 48 as the blade is now in compression mode and has begun to contract.

FIG. 50 illustrates the ultrasonic surgical blade shown in FIG. 49 as the blade has reached a point of maximum compression where its overall displacement is at a minimum and the gap defined by the balance feature is at a minimum.

FIG. 51 illustrates a point of maximum displacement of the ultrasonic surgical blade shown in FIG. 39, according to one embodiment.

FIG. 52 illustrates a bottom view of the ultrasonic surgical blade shown in FIG. 51 under maximum displacement, according to one embodiment.

FIG. 53. Illustrates one embodiment of a right angle balance blade.

FIG. 54 is an illustration of a balanced displacement plot of a right angle balanced blade, similar to the blade shown FIG. 53, in a maximum displacement state, according to one embodiment.

FIG. 55 illustrates a right angle balanced ultrasonic blade driven in transverse mode to produce longitudinal motion at an end effector section, according to one embodiment.

FIG. 56 illustrates one configuration of a right angle balanced ultrasonic surgical blade.

FIG. 57 illustrates one configuration of a right angle balanced ultrasonic surgical blade.

FIG. 58 illustrates one configuration of a right angle balanced ultrasonic surgical blade.

FIG. 59 illustrates one configuration of a right angle balanced ultrasonic surgical blade.

FIG. 60 illustrates one configuration of a right angle balanced ultrasonic surgical blade.

DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols and reference characters typically identify similar components throughout the several views, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the scope of the subject matter presented here.

The following description of certain examples of the technology should not be used to limit its scope. Other examples, features, aspects, embodiments, and advantages of the technology will become apparent to those skilled in the art from the following description, which is by way of illustration, one of the best modes contemplated for carrying out the technology. As will be realized, the technology described herein is capable of other different and obvious aspects, all without departing from the technology. Accordingly, the drawings and descriptions should be regarded as illustrative in nature and not restrictive.

It is further understood that any one or more of the teachings, expressions, embodiments, examples, etc. described herein may be combined with any one or more of the other teachings, expressions, embodiments, examples, etc. that are described herein. The following-described teachings, expressions, embodiments, examples, etc. should therefore not be viewed in isolation relative to each other. Various suitable ways in which the teachings herein may be combined will be readily apparent to those of ordinary skill in the art in view of the teachings herein. Such modifications and variations are intended to be included within the scope of the claims.

In the following description, it is to be understood that terms such as front, back, inside, outside, top, bottom and the like are words of convenience and are not to be construed as limiting terms. Terminology used herein is not meant to be limiting insofar as devices described herein, or portions thereof, may be attached or utilized in other orientations. The various embodiments will be described in more detail with reference to the drawings.

The present disclosure provides an ultrasonic instrument comprising an ultrasonic blade with improved cutting and coagulation features. FIG. **1** is an illustration of an ultrasonic instrument **100** according to one embodiment. The ultrasonic instrument **100** comprises a handle assembly **102**, a shaft assembly **104**, and a surgical end-effector **106**. The handle assembly **102** comprises right and left shrouds **108***a*, **108***b*, an activation button assembly **110**, and a nose cone **112**. The activation button assembly **110** comprises a plurality of activation buttons. Turning briefly to FIG. **5**, which is a front view of the ultrasonic instrument, it can be seen that in one embodiment, the activation button assembly **110** comprises eight activation buttons **110***a*, **110***b*, **110***c*, **110***d*, **110***e*, **110***f*, **110***g*, **110***h* distributed about the handle assembly **102**. Turning back to FIG. **1**, the shaft assembly **104** comprises an outer sheath **114**. The surgical end-effector **106** comprises an ultrasonic surgical blade **116** with improved cutting and coagulation features. The ultrasonic surgical blade **116** and ultrasonic transmission waveguide is isolated from the outer sheath **114** with multiple isolation spacers **118**, which can be overmolded over the ultrasonic transmission waveguide.

The handle assembly **102** also comprises an ultrasonic transducer acoustically coupled to an ultrasonic transmission waveguide which is acoustically coupled to the surgical end-effector **106**. The handle assembly **102** is electrically connected to an ultrasonic energy generator, which can be activated by one of the plurality of activation buttons **110***a*-**110***h*, for example the activation button **110***a*. Depressing the activation button **110***a* activates the ultrasonic generator, and delivers electrical energy to an ultrasonic transducer located in the handle assembly **102**. The ultrasonic transducer in the handle assembly **102** converts the electrical energy to ultrasonic motion, which is acoustically coupled to the ultrasonic transmission assembly and the treatment region of the surgical end-effector **106**. The treatment region vibrates at an excursion magnitude of 20 micrometers to 150 micrometers, and at a frequency of approximately 55.5 kilohertz, although other frequencies may be employed, without departing from the scope of the present disclosure.

FIG. **2** is an illustration of the ultrasonic instrument **100** shown in FIG. **1**, with the outer sheath **114** (FIG. **1**) removed to reveal the underlying ultrasonic transmission waveguide **120**. As shown, isolation spacers **118** are disposed over the ultrasonic transmission waveguide **120** to acoustically isolate the outer sheath **114** from the ultrasonic transmission waveguide **120**. Accordingly, the plurality of isolation spacers **118** are located on respective nodes along the ultrasonic transmission waveguide **120** to minimize the vibrations acoustically coupled to the outer sheath **114**. In one embodiment, the isolation spacers **118** may be overmolded over the ultrasonic transmission waveguide **120**.

FIG. **3** is an illustration of the ultrasonic surgical instrument **100** shown in FIG. **1** with the right and left shrouds **108***a*, **108***b* removed. The handle assembly **102** includes a support base **122** located proximal to the activation button assembly **110**.

FIG. **4** is an illustration of the handle assembly **102** of the ultrasonic surgical instrument **100** shown in FIG. **1** with the left shroud **108***b* (FIG. **1**), the shaft assembly **102** (FIG. **1**), and the nose cone **112** removed. As shown in FIG. **4**, below the nose cone **112** is a bridge guide **132** operatively coupled to the activation button assembly **110**. A clutch plate **134** and clutch spring **136** are disposed between the bridge guide **132** and a retainer **138**. A support bushing **140** supports the shaft assembly **102**.

FIG. **5** is a front view of the ultrasonic surgical instrument **100** shown in FIG. **1** with the nose cone **112** removed to show the underlying activation button assembly **110**, the clutch plate **134**, retainer **138**, and support bushing **140**. The activation button assembly **110** comprises a plurality activation buttons **110***a*-**110***h*, that are individually programmable to perform a particular function. For example, the activation **110***a* is electrically coupled to the ultrasonic generator and is used to energize the ultrasonic transducer to activate the surgical end-effector **106**.

Having described one embodiment of an ultrasonic surgical instrument **100** (FIGS. **1**-**5**) that can be configured to operate a surgical end-effector **106**, the present disclosure now turns to a description of one embodiment of a surgical end-effector **106** in connection with FIGS. **6**-**32**.

Ultrasonic Blade for Tissue Dissection and Hemostasis (Embodiment 1)

FIGS. **6**-**32** illustrate one embodiment of the ultrasonic surgical blade **116** configured with edges and surfaces to optimize hemostasis and dissection. In one use, the distal portion allows access to surface tissue, such as the liver bed, for efficient hemostasis. Sharp edges disposed on the distal portion of the ultrasonic surgical blade **116** deliver quick dissection. Accordingly, the disclosed ultrasonic blade **116** enables efficient dissection of the gall bladder from the liver bed using proximal and distal surfaces for ease of surgeon technique.

FIG. **6** illustrates one embodiment of a surgical end-effector **106** integrally formed with an ultrasonic transmission waveguide **120**. The surgical end-effector **106** comprises an ultrasonic surgical blade **116** having a neck **142** coupled to the ultrasonic transmission waveguide **120**. The ultrasonic transmission waveguide **120** is a component of the shaft assembly **104** and is acoustically isolated from other components of the shaft assembly **104**, such as the outer sheath **114** (FIG. **1**), by the isolation spacer **118**. The ultrasonic surgical blade **116** is configured to vibrate in response to ultrasonic energy applied thereto via the ultrasonic transmission waveguide **120**. A balance feature **143** is defined as a cutout section in the ultrasonic transmission waveguide **120** to facilitate the expansion and contraction of the ultrasonic transmission waveguide **120** during the vibratory process.

FIG. **7** is a perspective view of an ultrasonic surgical blade **116** according to one embodiment. The distal portion of the ultrasonic surgical blade **116** has a curved or angular shape that defines a blade hook **150** having a free end configured for pulling and cutting tissue during use. The ultrasonic surgical blade **116** comprises a longitudinal portion **141** extending distally from the neck **142**, where it couples to ultrasonic vibrations and a transverse portion **147** extending from a distal end of the longitudinal portion **141**. The transverse portion **147** of the ultrasonic surgical blade **116** defines the blade hook **150**. At the end of the transverse portion, the blade hook **150** defines a tip surface **144** optimized to access tissue planes. From the tip surface **144**, extending outwardly and towards the longitudinal portion **141**, the tip surface **144** transitions at a surface inflection **139** to an oblique tip surface **145** having a convex radius of curvature. Extending from the oblique tip surface **145**, at another surface inflection **153**, the blade hook **150** defines an outer distal surface **152** on a distal side of the blade hook **150**, where the outer distal surface **152** defines a contour profile configured to facilitate access to tissue planes. The distal surface **152** has a concave radius of curvature that defines a reduced size contour profile to facilitate better access to tissue planes. An angle θ_1 is defined by the tip surface **144** and the oblique tip surface.

Extending from the outer distal surface **152** through yet another surface inflection is a distal hemostasis surface **148** defining a larger surface area. The distal hemostasis surface **148** has a convex radius of curvature. A dissection edge **146** is defined at the surface inflection between the outer distal surface **152** and the distal hemostasis surface **148**. The dissection edge **146** is configured to improve the dissection or cutting speed. The contour profile of the outer distal surface **152** extends distally at the surface inflection defining the dissection edge **146** such that the transverse portion **147** of the hook **150** is tapered from the dissection edge **146** to the oblique tip surface **145**. From the surface inflection **153**, the oblique tip surface **145** extends at an angle to the tip surface **144**. The proximal end of the tip surface **144** defines a beveled edge **182**. The inner, proximal, portion of the blade hook **150** defines a substantially planar inner surface **149** on the proximal side of the blade hook **150** that extends along the transverse portion **147** from the beveled edge **182** of the tip surface **144** to a curved surface **151** having a concave radius of curvature r_1. The depth d_1 of the transverse portion **147** measured from the tip surface **144** to the planar longitudinal surface **161** may be optimized to pull tissue of various types. A proximal hemostasis surface **154** is provided on the longitudinal portion **141** of the ultrasonic surgical blade **116** and is sized to deliver suitable hemostasis while minimizing mass.

The ultrasonic surgical blade **116** also may comprise additional surfaces designed to acoustically balance the ultrasonic surgical blade **116**. These surfaces include a first lateral surface **156**, a second lateral surface **158**, and a third lateral surface **160** located on one side of the ultrasonic surgical blade **116** and corresponding lateral surfaces on the other side of the ultrasonic surgical blade **116**, which are labeled by a prime ('). The lateral surfaces **160**, **160'** are oblique and extend from a proximal body portion **159** of the blade **116** to the proximal hemostasis surface **154**. Cutting edges **165**, **165'** are defined at the surface inflections of the proximal hemostasis surface **154** and the oblique lateral surfaces **160**, **160'**. The lateral surfaces **156**, **156'** **158**, **158'**, **160**, **160'** are produced by removing mass from the blade body **159** and are contoured to balance the ultrasonic surgical blade **116** to provide stable ultrasonic vibrations when energized. The substantially planar longitudinal surface **161** is part of the longitudinal portion **141** of the ultrasonic surgical blade **116** extending from the neck **142** towards the curved surface **151** of the transverse portion **147** of the blade hook **150**.

FIG. **8** is a side view of the ultrasonic surgical blade **116** shown in FIG. **7**, according to one embodiment. As described in connection with FIG. **7**, the depth d_1 of the hook **150** is optimized to pull tissue. The dimension d_1 is the depth of the hook **150** from the upper tip **144** to the substantially planar longitudinal surface **161**. The depth d_1 is approximately 2.4 mm and may vary between 1.8 mm to 3.0 mm, without departing from the scope of the present disclosure. A cutting edge **165** is defined by a surface inflection between the proximal hemostasis surface **154** and the cutting surface **163**. The upper tip surface **144** defines a beveled edge **182**. The upper tip **144** surface has a slight convexity.

The dimension r_1 is the radius of curvature of the curved surface **151** that joins the lower section of the flat inner surface **149** to the substantially planar longitudinal surface **161**. The radius of curvature r_1 is approximately 0.823 mm and may vary between 0.635 mm to 1.010 mm, without departing from the scope of the present disclosure.

The dimension d_2 is the width of the upper surface **144** extending from the inner surface **149** to the juncture of the upper surface **144** and the oblique tip surface **145** may vary based on the particular configuration of this embodiment. The dimension d_2 is approximately 0.5075 mm and may vary from 0.38 mm to 0.635 mm, but the embodiment is not limited in this context.

The dimension d_3 is the distance from the planar inner surface **149** to the juncture of the oblique tip surface **145** and the distal surface **152**. The juncture of the of the distal surface **152** is the minimum length of the distal surface **152**, which flares out distally at a radius of curvature r_3 to the juncture with the dissection edged **146**. The dimension of d_3 is approximately 1.08 mm and may vary between 0.89 mm to 1.27 mm, without departing from the scope of the present disclosure. The dimension of r_3 given the same centerline is approximately 8.57 mm and may vary between 8.38 mm to 8.76 mm, without departing from the scope of the present disclosure.

The dimension r_2 is the radius of curvature of the oblique tip surface **145**, which has a convex curvature. The radius of curvature r_2 is approximately 2.985 mm and may vary between 2.8 mm to 3.17 mm, without departing from the scope of the present disclosure.

The distance from the juncture of the tip surface **144** and the oblique tip surface **145** defines the degree of obliqueness of the oblique tip surface **145**. This dimension may vary depending on the particular configuration of this embodiment.

The length extending orthogonally from a point where the curved surface **151** meets the longitudinal flat surface **161** to a point on the distal surface **152** defines the base of the transverse portion **147**. This dimension may vary depending on the particular configuration of this embodiment.

The dimension d_4 is the length from the juncture of the tip surface **144** and the planar inner surface **149** to the most distal point defined by the dissection edge **146**. The dimension of d_4 is approximately 1.58 mm may vary between 1.39 mm to 1.77 mm, without departing from the scope of the present disclosure.

The length of the distal surface **152** extends from the juncture with the oblique tip surface **145** to the juncture of the distal surface **152** and the dissection edge **146** at a radius of curvature of r_3. This dimension may vary depending on the particular configuration of this embodiment. The radius of curvature of the distal hemostasis surface **148**, may vary depending on the particular configuration of this embodiment.

The length of the longitudinal hemostasis surface **154** extends from the surface inflection **155** between the proximal hemostasis surface **148** and the distal hemostasis surface **154** and the surface inflection **157** between the distal hemostasis surface **154** and the blade body **159**. This dimension may vary depending on the particular configuration of this embodiment.

The dimension d_5 is the distance from the longitudinal surface **154** to the surface inflection between the blade body **159** and the substantially planar longitudinal surface **161**. The dimension of d_5 is approximately 4.375 mm and can vary from 3.75 mm to 5.00 mm, without departing from the scope of the present disclosure.

FIG. **9** is a perspective view of the ultrasonic surgical blade **116** according to one embodiment. The view illustrated in FIG. **9** shows the width of the junctures **155**, **157** of the distal and proximal hemostasis surfaces **148**, **154**, respectively, and the surface areas of each surface **148**, **154**. The sizes of the distal and proximal hemostasis surfaces **148**, **154** are dimensioned to deliver suitable hemostasis while minimizing mass.

FIG. **10** is an illustration of the distal and proximal hemostasis surface **148**, **154** of the ultrasonic surgical blade **116** shown in FIGS. **7-9**, according to one embodiment. The distal hemostasis surface **148** defines a distal dissection edge **146** and lateral sharp cutting edges **172**, **172'**. The dimension d_6 is the maximum width of the distal hemostasis surface **148** and dimension d_7 is the minimum width of the distal hemostasis surface **148** and the minimum width of the proximal hemostasis surface **154**. The dimension of d_6 may vary according to the particular configuration of this embodiment. The distal hemostasis surface **148** has an effective surface area **51** of approximately 4.838 mm^2 and may vary over a range of 3.226 mm^2 to 6.45 mm^2 (0.005 in^2 to 0.01 in^2). The proximal hemostasis surface **154** defines lateral sharp cutting edges **170**, **170'**. The dimension d_7 is the minimum width of the proximal hemostasis surface **154**. The dimension d_8 is the maximum width of the proximal hemostasis surface **154**. The dimension of d_8 may vary according to the particular configuration of this embodiment. The proximal hemostasis surface **154** has an effective surface area S2 of approximately 9.675 mm^2 and may vary over a range of 6.45 mm^2 to 12.90 mm^2 (0.01 in^2 to 0.02 in^2).

FIG. **11** is a side view of the ultrasonic surgical blade **116** in a neutral position illustrating the location of the distal antinode AN and the longitudinal axis L, according to one embodiment. It is well known that a standing wave that set up in the ultrasonic waveguide defines nodes and antinodes, where the nodes represent regions of minimal or no displacement and the antinodes represent regions of maximum displacement. The nodes and antinodes occur periodically based on the driving frequency of approximately 55.5 kilohertz, for example. The nodes and antinodes are located at one quarter wavelength apart. Accordingly, the transverse portion **147** of the blade hook **150** is located at the antinode AN, thus is located at a point of maximum displacement.

FIGS. **12-14** illustrate the ultrasonic surgical blade **116** in three states of motions, where FIG. **12** is an illustration of the ultrasonic surgical blade **116** shown in FIG. **11** in an intermediate position with no displacement, FIG. **13** is an illustration of the ultrasonic surgical blade **116** shown in FIG. **11** in a maximum proximal displacement, and FIG. **14** is an illustration of the ultrasonic surgical blade **116**. FIG. **11** in a maximum distal displacement. Accordingly, with reference to FIGS. **12-14**, the ultrasonic surgical blade **116** moves between maximum and minimum displacement as the handle assembly **102** (FIG. **1**) converts electrical energy into ultrasonic motion of ultrasonic transmission assembly **120** and the treatment region of the surgical ultrasonic surgical blade **116**. The ultrasonic surgical blade **116** vibrates at an excursion magnitude of 20 micrometers to 150 micrometers, and at a frequency of approximately 55.5 kilohertz. As shown in FIGS. **13** and **14** the maximum displacement is represented by the tip surface **144** of the hook **150**. Also, the balance feature **143** portion assists the ultrasonic transmission waveguide **120** to flex during the vibration process.

FIG. **15** is a graphical representation of displacement (microns) along the vertical axis of the ultrasonic surgical blade **116** shown in FIGS. **12-14** versus distance (in) along the ultrasonic surgical blade **116** along the horizontal axis, according to one embodiment. The distance along the blade indicated as 0.000 in. corresponds to the most proximal location where the ultrasonic transmission waveguide **120** and the distance along the blade indicated as 14.000 in. corresponds to the most distal location where the ultrasonic tip **144** of the ultrasonic surgical blade **116** is displaced. With reference now also to FIG. **11**, the blade displacement waveform **164** represented by the solid line is a standing waveform set up in the ultrasonic transmission waveguide and end effector ultrasonic surgical blade **116** along the longitudinal axil L as shown in FIG. **11**. The displacement waveform **164** includes periodic nodes **174** and antinodes **176**, **176'** at locations along the longitudinal axis L. The nodes **174** are locations along the standing waveform **164** where there is no displacement and antinodes **176** are locations where displacement is maximum positive, and antinodes **176'** where displacement is maximum negative. In accordance with the periodic nature of the ultrasonic vibrations and the properties of a standing wave **164**, the nodes **174** and antinodes **176**, **176'** are located at a distance equal to one quarter wavelength $\lambda/4$, where the wavelength λ proportional to the frequency of vibrations f_0 and the speed c of sound in the material of the transmission waveguide and the ultrasonic surgical blade **116** according to the following relationship $f_0=2\pi\lambda/c$. Due to the design of the ultrasonic surgical blade **116**, it can be seen that the absolute maximum displacement occurs at the distal antinode **178**, which corresponds to the location of the antinode AN in FIG. **11**.

FIG. **16** is a side of the ultrasonic surgical blade **116** shown in FIG. **7** illustrating the position of several sectional views shown in FIGS. **17-29**, according to one embodiment.

FIG. **17** is a sectional view of the ultrasonic surgical blade **116** shown in FIG. **16** taken along section line **17-17**, according to one embodiment. The sectional view shows the cross-section of the neck **142**. The diameter of the neck **142** increases from an initial diameter d_9 to a final diameter d_{10}. The isolation spacer **118** is disposed about the proximal neck **142'** portion of the neck **142** to isolate the ultrasonic surgical blade **116** from the outer sheath **114**. The isolation spacer **118** is located at a node of the ultrasonic transmission waveguide. The outer diameter d_{11} of the outer sheath **114** is sized to be slidably received within a trocar. The ultrasonic surgical blade **116** is sized to fit within the inner diameter d_{12} of the outer sheath **114**.

FIG. **18** is a sectional view of the ultrasonic surgical blade **116** shown in FIG. **16** taken along section line **18-18**, according to one embodiment. As shown in the view of FIG. **18**, the ultrasonic surgical blade **116** has an overall dimension to fit within the outer sheath **114**. The junctures **157**, **157'** of the distal hemostasis surfaces **154**, **154'** and the cutting surface **163** section of the lateral surface **160** define din the blade body **159** define sharp edges that can be used to assist in dissection. The overall width d_{16} of the ultrasonic surgical blade **116** is defined as the distance between the cutting edges **165**, **165'**. The lateral surface **160**, **160'** also are shown as straight surfaces in FIG. **18**. The radius of curvature of the neck **142** is defined as r_4.

FIG. **19** is a sectional view of the ultrasonic surgical blade **116** shown in FIG. **16** taken along section line **19-19**, according to one embodiment. As shown, the blade body **159** widens and defines flat sidewall portions of the lateral surfaces **160**, **160'**.

FIG. **20** is a sectional view of the ultrasonic surgical blade **116** shown in FIG. **16** taken along section line **20-20**, according to one embodiment. The radius of curvature of the blade body **159** at section **20-20** is defined as r_5.

FIG. **21** is a sectional view of the ultrasonic surgical blade **116** shown in FIG. **16** taken along section line **21-21**, according to one embodiment. At section line **21-21**, the cross sectional are of the blade body **159** is less than the cross sectional are shown in FIGS. **19** and **20**. This is due to the lateral surfaces **158**, **158'** that are defined by the blade body **159** to balance the ultrasonic vibrations of the ultrasonic surgical blade **116**. As shown, the lateral surfaces **158**, **158'** are contoured and define contoured lateral walls **180**, **180'** cut, ground, or otherwise formed in the blade body **159**. Also, a gap d_{14} is defined between the proximal hemostasis surface **154** and the inner diameter of the outer sheath **114**. The gap d_{14} enables the knife **116** to be slidably received and move within the outer sheath **114** as desired, and to fit within the diameter of a trocar. The flat portion **161'** of the longitudinal surface **161** is also shown. The bottom surface **154** is the proximal hemostasis surface.

FIG. **22** is a sectional view of the ultrasonic surgical blade **116** shown in FIG. **16** taken along section line **22-22**, according to one embodiment. This sectional view illustrates the contoured lateral walls **180**, **180'** of the respective lateral surfaces **158**, **158'** defined in the blade body **159**. This view also shows the cutting surfaces **163**, **163'** that extend from the contoured lateral walls **180**, **180'** of the respective lateral surfaces **158**, **158'**. This view also shows the length of the dimension d_{15} of the planar inner surface **149** that extends from the tip surface **144** to the beginning of the curved surface **151** having a concave radius of curvature. This view also shows the dimension d_{16} of the beveled edge **182** defined in the upper tip **144**. The dimension of d_{15} and the dimension of d_{16} may vary according to the particular configuration of this embodiment. The flat dimension of the planar longitudinal surface **161** is also shown. The bottom surface **154** is the proximal hemostasis surface.

FIG. **23** is a sectional view of the ultrasonic surgical blade **116** shown in FIG. **16** taken along section line **23-23**, according to one embodiment. FIG. **23** shows the flat portion **161'** of the longitudinal surface **161**, the lateral surfaces **158**, **158'**, and the contoured lateral walls **180**, **180'** of the lateral surfaces **158**, **158'**. The cutting surfaces **163**, **163'** flare out laterally from the blade body **159** to a surface inflection that defines cutting edges **165**, **165'**. The bottom surface **154** is the proximal hemostasis surface.

FIG. **24** is a sectional view of the ultrasonic surgical blade **116** shown in FIG. **16** taken along section line **24-24**, according to one embodiment. The section line **24-24** is taken to show the full dimension d_{19} of the curved surface **151** portion of the blade hook **150**. Also, shown is the full dimension d_{15} of the inner surface **149** portion of the blade hook **150** as well as the dimension d_{16} of the beveled edge **182** of the tip surface **144**. This view also shows the flat portion **161'** of the longitudinal surface **161**, the straight lateral sidewalls of the blade hook **150** defined by the sidewalls of the beveled edge **182**, the inner surface **149**, and the curved surface **151**. In this view, the dimension of the curved surface **151** is given by d_{17}. Extending below the flat portion **161'** of the longitudinal surface **161** is the sectional view of the blade body **159** that defines the sidewalls of the lateral surfaces **158**, **158'** and the contoured lateral sidewalls **180**, **180'** of the lateral surfaces **158**, **158'** defined by the body **159**. The bottom surface **154** is the proximal hemostasis surface. As previously discussed, the depth of the hook **150** is given by dimension d_1.

FIG. **25** is a sectional view of the ultrasonic surgical blade **116** shown in FIG. **16** taken along section line **25-25**, according to one embodiment. The section view **25-25** is taken at the transition between the tip surface **144** and the oblique tip surface **145**. This view shows the full dimension of the ultrasonic surgical blade **116** located within the outer tube/sheath **114**. The straight sidewalls **184**, **184'** of the blade hook **150** and the contoured lateral sidewalls **180**, **180'** of the lateral surfaces **158**, **158'** defined by the body **159**. The contoured lateral sidewalls **180**, **180'** define the juncture **155** of the distal and proximal hemostasis surfaces **148**, **154**. Also shown is the distal hemostasis bottom surface **148** relative to the straight sidewall **184**, **184'** of the blade hook **150**.

FIG. **26** is a sectional view of the ultrasonic surgical blade **116** shown in FIG. **16** taken along section line **26-26**, according to one embodiment. This view shows the straight sidewalls **184**, **184'** of the blade hook **150** which extends into the contoured lateral walls **180**, **180'** defined by the body **159**. The contoured lateral walls **180**, **180'** define the juncture **155** of the distal and proximal hemostasis surfaces **148**, **154**. The distal hemostasis bottom surface **148** has a radius of curvature of r_6.

FIG. **27** is a sectional view of the ultrasonic surgical blade **116** shown in FIG. **16** taken along section line **27-27**, according to one embodiment. As illustrated in the sectional view shown in FIG. **27**, the lateral surfaces **158**, **158'** have a radius of curvature of r_8. The radius of curvature of r_8 may vary according to the particular configuration of this embodiment. Also shown is the longitudinal extending portion **141** of the blade hook **150**.

FIG. **28** is a sectional view of the ultrasonic surgical blade **116** shown in FIG. **16** taken along section line **28-28**, according to one embodiment. This view also shows the radius of curvature r_7 of the lateral surfaces **158**, **158'** and the cutting edges **165**, **165'** defined by the surface inflection between the proximal hemostasis surface **154** and the cutting surface **163** (FIG. **8**).

FIGS. **29-32** provide additional views of the ultrasonic surgical blade **116** shown in FIG. **7**, according to one embodiment. FIG. **29** is an illustration of a bottom view of the ultrasonic surgical blade **116** shown in FIG. **7** showing the distal and proximal hemostasis surfaces **148**, **154** and lateral cutting edges **172**, **172"**, **170**, **170'**. This view also shows the edges **155'**, **155"** defined by the surface inflection **155** between the distal and proximal hemostasis surfaces **148**, **154**. The most distal portion of the distal hemostasis surface **148** defines the dissection edge **146**, which is defined as the surface inflection between the distal hemostasis surface **148** and the distal surface **152** (FIG. **8**). Another surface inflection **157** between the proximal hemostasis surface **154** and the blade body **159** defines edges **157'**, **157''** from which the cutting edges **165**, **165'** extend until they meet the lateral cutting edges **170**, **170'**. The blade body **159** transitions to the ultrasonic transmission waveguide **142** through surface loft **186**. For completeness, the ultrasonic transmission waveguide **142** is shown extending proximally into the outer tube/sheath **114**.

FIG. **30** is a sectional view of the ultrasonic surgical blade **116** shown in FIG. **29** taken along section line **30-30**, according to one embodiment. This sectional view is taken along the longitudinal centerline to show the relevant features of the ultrasonic surgical blade **116** previously described. From right to left, as the blade body **159** extends from the blade neck **142**, the ultrasonic surgical blade **116** defines a first surface inflection **168** between the blade body **159** and the planar longitudinal surface **161**. The hook portion **150** is defined in part by the curved surface **151** and the inner surface **149** up to the beveled surface **182**. The tip surface **144** transitions to the oblique tip surface **145** at surface inflection **139**. The oblique tip surface **145** transitions to the distal surface **152** at surface inflection **153** and the distal surface **152** transitions to the distal hemostasis surface **148** at surface inflection **146**, which also defines the dissection edge **146**. For purposes of the present disclosure, the surface inflection **146** and the dissection edge **146** refer to the same elements. The distal hemostasis surface **148** transitions to the proximal hemostasis surface **154** at surface inflection **155**. Moving to the right from there, the proximal hemostasis surface **154** transitions to the blade body **159** at surface inflection **165**.

FIG. **31** is a top view of the ultrasonic surgical blade **116** shown in FIG. **29**, according to one embodiment. The top view of FIG. **31** is the opposite of the bottom view of FIG. **29**. From left to right, the ultrasonic transmission waveguide **142** extends distally from the outer tube/sheath **114** and transitions into the blade body **159** portion at surface inflection **186**. The blade body **159** defines several surfaces for cutting and/or pulling tissue, applying hemostasis to the tissue, and/or acoustically balancing the ultrasonic surgical blade **116**. The planar longitudinal surface **161** extends from a proximal end of the blade body **159** to the curved surface **151** of the blade hook **150**. The inner surface **149** of the blade hook **150** extends from the curved surface **151** to the beveled surface **182** of the tip surface **144**. The tip surface **144** transitions to the oblique tip surface **145** at surface inflection **139**. The oblique tip surface **145** transitions to the distal surface **152** at surface inflection **153**. The most distal portion of the distal surface **152** defines the dissection edge **146**, which is also the surface inflection between the distal surface **152** and the distal hemostasis surface **148** (FIG. **29**). The top view of FIG. **31** also shows the lateral surfaces **158**, **158'** and the cutting edges **165**, **165'** defined by the surface inflection between the proximal hemostasis surface **154** and the lateral surfaces **160**, **160'**. The cutting edges **170**, **170'** are defined by the surface inflection of the proximal hemostasis surface **154** and the lateral surfaces **158**, **158'**.

FIG. **32** is an end view of the ultrasonic surgical instrument **100** showing the ultrasonic surgical blade **116** and the outer tube/sheath **114**, according to one embodiment. As shown, the transverse portion **147** of the ultrasonic surgical blade **116** comprises a tip surface **144** that transitions into an oblique tip surface **145** at surface inflection **139**. The distal surface **152** extends from the oblique tip surface **145** at surface inflection **153**. The distal surface **152** defines the dissection edge **146** between the distal hemostasis surface **154** and the distal surface **152**. The lateral surfaces **158**, **158'** extend proximally from the blade hook **150** and the walls define a radius of curvature r_8 on each side. The cutting edges **155'**, **155''** are defined by the surface inflection **155** between the distal and proximal hemostasis surfaces **148**, **154**. The cutting edges **165**. **165'** are defined by the surface inflection between the proximal hemostasis surface **154** and the lateral surfaces **160**, **160'**. The lateral surfaces **160**, **160'** also define cutting surface **163**, **163'**. The ultrasonic surgical blade **116** extends distally from the outer tube/sheath **114**. The isolation spacer **118** isolates the ultrasonic surgical blade **116** from the outer tube/sheath **114**. The isolation spacer **118** is disposed about the proximal neck **142'** portion of the ultrasonic surgical blade **116**.

Ultrasonic Blade for Tissue Dissection and Hemostasis (Embodiment 2)

FIGS. **33-38** illustrate one embodiment of an ultrasonic surgical blade **200** configured with edges and surfaces to optimize hemostasis and dissection. In one use, the distal portion allows access to the surface of tissue, such as the liver bed, for efficient hemostasis. Sharp edges disposed on the distal portion of the ultrasonic surgical blade **200** deliver quick dissection. Accordingly, the disclosed ultrasonic blade **200** enables efficient dissection of the gall bladder from the liver bed using proximal and distal surfaces for ease of surgeon technique.

FIG. **33** is perspective view of the ultrasonic surgical blade **200**, according to one embodiment. FIG. **34** is a side view of the ultrasonic surgical blade **200** shown in FIG. **33**, according to one embodiment. FIG. **35** is an end view of the ultrasonic surgical blade **200** shown in FIG. **33**, according to one embodiment. FIG. **36** is another perspective view of the ultrasonic surgical blade **200** shown in FIG. **33**, according to one embodiment. FIG. **37** is a bottom view of the ultrasonic surgical blade **200** shown in FIG. **33**, according to one embodiment.

With reference now to FIGS. **33-38**, in one embodiment, the ultrasonic surgical blade **200** is configured and adapted to operate with the ultrasonic surgical instrument **100** shown and described connection with FIGS. **1-5**. Accordingly, the ultrasonic surgical blade **200** comprises a blade body **218** that transitions into a blade neck **202** at surface inflection **232**. The blade neck **202** extends proximally to form or couple to an ultrasonic transmission waveguide, having a proximal end configured to acoustically couple to an ultrasonic transducer piezoelectric stack. In the distal direction, the blade body **218** defines several surfaces suitable for cutting and/or pulling tissue, applying hemostasis to the tissue, and/or acoustically balancing the ultrasonic surgical blade **200**.

Still with reference to FIGS. **33-38**, the ultrasonic surgical blade **200** comprises a longitudinal portion **222** and a transverse portion **224**. The longitudinal portion **222** extends distally from the blade body **218** and defines a substantially planar longitudinal surface **220** and multiple lateral surfaces **214**, **216** are defined on each lateral portion of the blade body **218**. The lateral surfaces **214**, **214'** extend from the substantially planar longitudinal surface **220** to a proximal hemostasis surface **212** and define sharp cutting edges **238**, **238'**. A portion of the lateral surfaces **214**, **214'** extend to the distal hemostasis surface **210** and define sharp cutting edges **208**, **208'**. The sharp cutting edges **208**, **208'**, **238**, **238'** aid in fast dissection when using the side of the ultrasonic blade **200** and the distal surface **236**. The lateral surfaces **216**, **216'** extend from the substantially planar longitudinal surface **220** and the transverse hook portion **204** of the ultrasonic surgical blade **200** to the distal surface **236** to define portions of the sharp cutting edges **208**, **208'**. The sharp cutting edges **208**, **208"** have a radius of curvature r_9 that may vary between 2.45 to 2.75 mm, without departing from the scope of the disclosure.

Still with reference to FIGS. **33-38**, the transverse portion **224** of the ultrasonic surgical blade **200** defines the blade hook **204**, which is suitable for pulling and cutting tissue and may be configured to access the tissue plane between the gull bladder and the liver. The blade hook **204** comprise a curved surface **230** having a radius of curvature r_{10} extending from the substantially planar longitudinal surface **220** to the inner surface **228**. The radius of curvature r_{10} may vary between 0.635 mm to 1.010 mm, without departing from the scope of the disclosure. The inner surface **228** extends to a tip surface **206**. The tip surface **206** extends towards the distal surface **236**, which extends to the distal hemostasis surface **210**. The distal hemostasis surface **210** defines a larger surface area on the bottom and distal side of the ultrasonic surgical blade **200** to aid hemostasis. The distal hemostasis surface **210** transitions to the proximal hemostasis surface **212** at surface inflection **226**. The proximal hemostasis surface **212** transitions into the body portion **218** of the ultrasonic surgical blade **200** at surface inflection **234**. The blade body **218** eventually transitions into the blade neck **202** at surface inflection **232**. Other dimensions of the ultrasonic surgical blade **200** may be similar to the dimensions of the ultrasonic surgical blade **116** shown and described in connection with FIGS. **6-32**, although the embodiments are not limited in this context.

FIG. **38** is an illustration of the distal and proximal hemostasis surface **210**, **212** of the ultrasonic surgical blade **200** shown in FIGS. **33-37**, according to one embodiment. The distal hemostasis surface **210** is continuous with the distal surface **236** and transitions to the proximal hemostasis surface **212** at surface inflection **226**. The proximal hemostasis surface **212** transitions into the body portion **218** of the ultrasonic surgical blade **200** at surface inflection **234**. The distal hemostasis surface **210** and the proximal hemostasis surface define a surface inflection **226** therebetween. The distal hemostasis surface **210** defines sharp cutting edges **208**, **208'**. The dimension d_{18} is the maximum width of the distal hemostasis surface **236** and dimension d_{19} is the minimum width of the distal hemostasis surface **212** and the minimum width of the proximal hemostasis surface **210**. The dimension of d_{19} may vary according to the particular configuration of this embodiment. The dimension d_{19} is the minimum width of the proximal hemostasis surface **210**. The dimension d_{20} is the maximum width of the proximal hemostasis surface **212**. The dimension of d_{20} may vary according to the particular configuration of this embodiment. The distal hemostasis surface **210** has an effective surface area S1' of approximately 54.1935 mm^2 and may vary over a range of 3.226 mm^2 to 105.161 mm^2 (0.005 in^2 to 0.163 in^2). The proximal hemostasis surface **212** defines sharp cutting edges **238**, **238'**. The proximal hemostasis surface **212** has an effective surface area S2' of approximately 9.6765 mm^2 and may vary over a range of 6.45 mm^2 to 12.903 mm^2 (0.01 in^2 to 0.02 in^2).

Ultrasonic Blade for Tissue Dissection and Hemostasis (Embodiment 3)

FIGS. **39-52** illustrate one embodiment of an ultrasonic surgical blade **300** configured with edges and surfaces to optimize hemostasis and dissection. In one use, the distal portion allows access to the surface of tissue, such as the liver bed, for efficient hemostasis. Sharp edges disposed on the distal portion of the ultrasonic surgical blade **300** deliver quick dissection. Accordingly, the disclosed ultrasonic blade **300** enables efficient dissection of the gall bladder from the liver bed using proximal and distal surfaces for ease of surgeon technique.

FIG. **39** is a perspective view of the ultrasonic surgical blade **300** shown in FIG. **39**, according to one embodiment. FIG. **40** is a side view of the ultrasonic surgical blade **300** shown in FIG. **39**, according to one embodiment. FIG. **41** is an end view of the ultrasonic surgical blade **300** shown in FIG. **39**, according to one embodiment.

With reference now to FIGS. **39-41**, in one embodiment the ultrasonic surgical blade **300** comprises a neck **302** configured to acoustically couple to an ultrasonic transmission waveguide which is configured and adapted to acoustically couple to a piezoelectric ultrasonic transducer. From the neck **302**, the ultrasonic surgical blade **300** extends distally as a substantially longitudinal section **342**, defined by dimension d_{21}, and transitions to a substantially transverse section **344** to define a blade hook **304**. A sharp central ridge comprised of three distinct segments **306**, **306'**, **306"** extends from the neck **320** to a tip **312** of the hook **304** of the transverse section **344** defined by dimension d_{22}. As best seen in FIG. **40**, a proximal segment **306** extends substantially longitudinally but has an arcuate component such that it extends downwardly from the neck **320** to an inflection point with an arcuate intermediate segment **306'**, which extends to a substantially linear distal segment **306"**. The substantially linear distal segment **306"** extends from the junction of the arcuate intermediate section **306'** to the tip **312** of the blade hook **304**.

The proximal segment **306** of the sharp central ridge is defined by the junction of two proximal oblique surfaces **324**, **330** that extend downwardly and outwardly from the proximal sharp central ridge **306**. A first lateral sharp cutting edge **308** is defined by the junction of the proximal oblique surface **324** and the lateral surface **338**. On the other side of the blade **300**, a second lateral sharp cutting edge **310** is defined by the junction of the proximal oblique surface **330** and the other lateral surface **340** (FIG. **41**).

The intermediate arcuate segment **306'** of the sharp central ridge is defined by junction of intermediate arcuate oblique surfaces **326**, **332** that extend downwardly and outwardly from the intermediate arcuate segment **306'** of the sharp central ridge. A sharp cutting edge **308'** is defined by the junction of the intermediate arcuate oblique arcuate surface **326** and an end mass **314** that is located below the transverse section **344** of the blade hook **304** and partially below the longitudinal section **342**. An arcuate section of a sharp cutting edge **310'** is defined by the junction of the intermediate arcuate oblique surface **332** and the end mass **314**. The end mass **314** is used to acoustically balanced the ultrasonic surgical blade **300**.

The distal linear segment **306"** of the sharp central ridge is defined by junction of distal oblique surfaces **328**, **334** that extend distally and outwardly from the distal linear segment **306"** of the sharp central ridge. A sharp cutting edge **308"** is defined by the junction of the distal oblique arcuate surface **328** and a body portion of the blade hook **304**. A sharp cutting edge **310"** is defined by the junction of the distal oblique surface **334** and a body portion of the blade hook **304**.

As shown in FIG. **40**, the depth or height of the blade hook **304** of the transverse section **344** defined by dimension d_{23} should be maximized so the surgeon can hook and drag tissue to dissect the tissue along a plane. The dimension d_{23} can be optimized to enable the surgeon to hook and drag to dissect the gall bladder from the liver bad, for example. The dimension d_{23} of the hook **304** is approximately 2.794 mm and may vary between 1.016 mm to 4.572 mm (0.040 in to 0.180 in), without departing from the scope of the disclosure. The dimension d_{21} of the longitudinal section **342** of the blade **300** is approximately 10.414 mm and may vary between 1.778 mm to 19.050 mm (0.070 in to 0.750 in), without departing from the scope of the disclosure. The end mass **314** extends proximally from the distal surface **336** of the hook **304** and has a dimension d_{25}. The dimension d_{25} of the end mass **314** is approximately 5.207 mm and may vary between 0.889 mm to 9.525 mm (0.035 in to 0.375 in), without departing from the scope of the disclosure. The dimension d_{22} of the transverse portion **344** of the blade hook **304** is approximately 4.2545 mm (0.1675 in) and may vary from 3.4036 mm to 5.1054 mm (0.1340 in to 0.2010 in). The dimension d_{24} is approximately 0.9525 mm (0.0375 in) and can vary from 0.762 mm to 1.143 mm (0.0300 in to 0.0450 in). A straight line segment extending from the tip **312** of the blade hook **304** to a point **313** toward the distal end of the end mass **314** has a dimension of approximately 4.3510 mm (0.1713 in) and can vary from 3.4808 mm to 5.2200 mm (0.1370 in to 0.2055 in).

FIG. **42** is an end view of the ultrasonic surgical blade **300** shown in FIGS. **39-41** illustrating a triangle shaped end mass **314**, according to one embodiment. With reference now to FIGS. **40** and **42**, the depth of the blade hook **304** of the transverse section **344** defined by transverse dimension d_{23} and longitudinal dimension d_{21} of the longitudinal section **342** creates a large overhung mass relative to the neutral axis L_N of the ultrasonic transmission waveguide that extends proximally from the neck section **302** of the ultrasonic surgical blade **300**. To counteract the unbalancing effects of the large overhung mass, a local balance element is provided. In the illustrated embodiments, the local balance element is provided by the end mass **314**. In one embodiment, balance is achieved locally via a triangle **316** shaped end mass **314** that extends proximally by a dimension of d_{25}. In one embodiment, the triangle **316** shaped end mass **314** is define by an angle θ_2. Increasing or decreasing the angle θ changes the local mass and thus alters the balance of the blade **300**. Accordingly, the balance of the blade **300** can be adjusted by changing the angle θ_2. It will be appreciated that the balance end mass **314** element adjusts the acoustic balance of the ultrasonic surgical blade **300**.

FIG. **43** is an end view of the ultrasonic surgical blade **300** shown in FIGS. **39-41** illustrating a suitable diameter **318** for trocar entry, according to one embodiment. As shown in FIG. **43**, the total outer diameter **318** of the ultrasonic blade **300** is sized and configured to be slidably received in a trocar. In one embodiment, the maximum diameter **318** is about 5 mm fro trocar entry.

FIG. **44** is a bottom view of the ultrasonic surgical blade **300** shown in FIG. **39** in compression mode, according to one embodiment. The bottom surface **320** of the end mass **314** can be employed as a spot coagulation surface, otherwise referred to as a hemostasis surface. Only about a 3% amplitude drop in ultrasonic vibration amplitude has been observer across the face of the coagulation surface **320**. The illustrated geometry of the end mass **314** and the coagulation surface **320** provides positive tissue effects. When the blade **300** is excited by ultrasonic energy, it oscillates between a compression mode and an tension mode repeatedly. Such oscillation between compression and tension modes creates the displacement necessary to provide the desired tissue effects such as cutting and coagulating tissue. In compression mode, the blade **300** defines its most compact form along the longitudinal axis L_N. As shown in FIG. **44**, in the compression mode, the blade **300** illustrated in FIG. **44** can be characterized by several dimensions. For example, in compression mode, the blade **300** defines length d_{26} between the neck section **302** and a proximal wall **348** of the end mass **314**. The longitudinal section **342** of the blade **300** over the dimension d_{26} defines a radius of curvature r_{11}. The width of the longitudinal section **342** where it meets the proximal wall **348** of the end mass **314** is defined by dimension d_{27} and the width of the end mass **314** is defined by dimension d_{28}. The dimension d_{29} is the distance between the narrowest portion of the longitudinal section **342** to the outer diameter of the longitudinal section **342**.

FIG. **45** is a bottom view of the ultrasonic surgical blade **300** shown in FIG. **39** in tension mode, according to one embodiment. The dimensions of the surgical blade **300** in tension mode are labeled by a prime (') as compared to the dimensions of the blade **300** in compression mode as shown in FIG. **44**. As will be appreciated, when the blade **300** is in tension mode it defines its most elongated form along the longitudinal axis L_N. As shown in FIG. **45**, in the tension mode, the blade **300** illustrated in FIG. **45** can be characterized by several dimensions. For example, in tension mode, the blade **300** defines length d_{26}' between the neck section **302** and the proximal wall **348** of the end mass **314**. The longitudinal section **342** of the blade **300** over the distance defined by d_{26}' defines a radius of curvature r_{11}'. The width of the longitudinal section **342** where it meets the proximal wall **348** of the end mass **314** is defined by dimension d_{27}' and the width of the end mass **314** is defined by dimension d_{28}'. As the blade **300** transitions for the compression mode to the tension mode the dimensions of the blade **300** decrease in width and increase in length. Accordingly, with reference to FIGS. **44** and **45**, the length $d_{26}<d_{26}'$ and $r_{11}<r_{11}'$. However, dimensions $d_{29}>d_{29}'$, $d_{27}>d_{27}'$, and $d_{28}>d_{28}'$.

FIGS. **46-50** illustrate a displacement cycle of the ultrasonic surgical blade **300**, according to one embodiment. FIG. **46** illustrates the ultrasonic surgical blade shown in FIG. **39** in a neutral unexcited state. The longitudinal section **342** and the transverse section **344** are in a neutral state. A balance feature **322** is defined as a cutout portion in the ultrasonic transmission waveguide **350** to facilitate the expansion and contraction of the ultrasonic transmission waveguide **350** and the blade **300** during the vibratory process. As shown in FIG. **47**, as the vibration process initiates, the blade **300** hook **304** is displaced distally under tension mode and the gap defined by the balance feature **322** expands. The blade **300** continues to be displaced distally under tension until it reaches a point of maximum displacement under tension as shown in FIG. **48**. The diameter dimensions are at their minimum dimension, the length of the blade **300** is at a maximum or highest displacement, and the gap defined by the balance feature **322** is at a maximum. Once the blade **300** reaches the point of maximum displacement in tension mode as shown in FIG. **48**, the blade **300** transitions to compression mode and begins to contract. As shown in FIG. **49**, the blade **300** is now in compression mode and has begun to contract. The gap defined by the balance feature **322** has decreased in size to facilitate the compression process. As shown in FIG. **50**, the blade **300** has reached a point of maximum compression where its overall displacement is at a minimum and the gap defined by the balance feature **322** is at a minimum. FIGS. **48** and **50** provide a good visual representation of the maximum and minimum longitudinal displacement of the blade hook **304** and how the blade hook **304** can be effectively used for dissecting tissue. Also, the longitudinal displacement of the blade **300** also displaces the end mass **314** to enable the coagulation surface **320** of the end mass **314** to be used to effectively coagulate tissue.

FIG. **51** illustrates a point of maximum displacement of the ultrasonic surgical blade **300**, according to one embodiment. As shown in FIG. **51**, the tip **312** of the blade hook **304** is at its point of maximum longitudinal displacement and the gap defined by the balance feature **322** is maximally expanded. A distal section **352** of the ultrasonic waveguide **350** has a reduced diameter.

FIG. **52** illustrates a bottom view of the ultrasonic surgical blade **300** shown in FIG. **51** under maximum displacement, according to one embodiment. As shown in FIG. **52**, the maximum stress area **354** is located in the balance feature **322** of the ultrasonic transmission waveguide **350**. In use, the balance feature **322** should be protected by the outer sheath of the instrument.

Right Angle Ultrasonic Surgical Blades
(Embodiment 4)

The present disclosure now turns to various embodiments of an ultrasonic surgical blade comprising a right angle or near right angle bend near the distal end to provide advantages in tissue access and visibility. As previously discussed in connection with the foregoing embodiments, the challenges with a right angle ultrasonic blade or a hook-type ultrasonic blade include stress and balance. The embodiments disclosed in FIGS. **53-60** provide an ultrasonic blade with a mass distributed in such a manner that the blade behaves in a balanced fashion and is sufficiently strong to withstand the stresses.

FIG. **53**. Illustrates one embodiment of a right angle balance blade **400**. The right angle balance blade **400** comprises a longitudinal section **418** and a transverse section **412**. The transverse section **412** of the blade **400** may be at or close to 90° relative to the longitudinal section **418**. The longitudinal section **418** extends longitudinally along an ultrasonic waveguide section **402** of the blade **400**. A centerline is defined along the longitudinal axis L_N of the blade **400**. The distal end of the blade **400** defines a transverse section **412** relative to the longitudinal section **418**. The distal end includes a working side defining a thin elongated right angle member **404** section and back side **414** defining a mass **406**. A tip **408** having a relatively small surface area is employed for tissue dissection and a rounded end **410** having a larger surface area is employed for coagulation.

In the illustrated embodiment, the right angle balanced blade **400** comprises a mass distributed such that, at the distal end **412**, the back side **414** of the blade **400** has a large mass **406** distributed relatively close to a centerline L_4 of the blade **400**. The working side **416** of the blade **400** has a mass distributed in a relatively long, thin section right angle member **404** section when compared to the back side **414** mass **406**. This may resemble some designs of golf putters, for example. Additionally, if necessary, balance features may be added, such as notches, to reduce the transverse motion accompanying the desired longitudinal mode.

FIG. **54** is an illustration of a balanced displacement plot **420** of a right angle balanced blade, similar to the blade **400** shown FIG. **53**, in a maximum displacement state, according to one embodiment. As shown, the area of maximum stress **422** occurs at the tip of the blade **400** whereas the areas of minimum stress occur at the blade neck section **424** and the transition section **426** from the blade **400** to the ultrasonic transmission waveguide **402**.

With reference to FIGS. **53** and **54**, the right angle balanced blade **400** provides a waveguide **402** with the blade tip **408** extending at a right angle or near right angle relative to the longitudinal section **418**. The blade **400** provides the same utility as derived from a simple monopolar RF hook. The technical challenges with the right angle balanced blade **400** includes transmitting longitudinal motion around the corner **428**, defined as the point where the transverse section **412** extends from the longitudinal section **418**, without creating transverse motion. The transverse motion in the distal right-angle end effector can be used to create hemostasis using the surface area **410** of the back end **414** of the blade **400**.

In one embodiment, rather than driving the waveguide **402** in longitudinal motion and compensating for the ensuing transverse motion, the waveguide **402** is driven in transverse motion, and the whipping motion of the end drive the right angle member **404** section in longitudinal motion as shown in FIG. **54**. One way to illustrate this concept is by analogy to a transversely vibrating rod with a free end such as end **408**. In a transversely vibrating rod with a freed end, the end "whips" up and down and the slope of the end is relatively high. If a concentrated mass, such as mass **406**, is added to the tip **408**, it weighs down the free-end. If the mass is zero, the end acts as a free end, and for example has a positive slope. If the mass **406** is infinite, it acts as a pinned condition and the corresponding slope would be negative. A mass **406** can be selected such that the slope is zero, and then the end **408** moves up and down with near zero slope. If the right angle member **404** works as that mass, where the waveguide **402** and the right angle member **404** join at the corner **428**, the loaded end **408** just pushes the right angle member **404** up and down in a longitudinal motion. In another aspect, when the right angle member **404** is a half wave resonator, it presents zero dynamic load (i.e., zero driving point impedance), so the end of the waveguide **403** just pulls the right angle member **404** up and down with it, because it experiences no load.

FIG. **55** illustrates a right angle balanced ultrasonic blade **430** driven in transverse mode to produce longitudinal motion at an end effector **434** section, according to one embodiment. The right angle balanced ultrasonic blade **430** comprises a longitudinal waveguide section **432** and a right angle end effector member **434** positioned transverse to the longitudinal waveguide section **432**. As described above, driving the waveguide section **432** in transverse mode causes the transverse right angle end effector member **434** to be displaced from a proximal end to a distal end to effectively create longitudinal motion suitable for dissecting tissue with the tip **436** of the transverse right angle end effector member **434**.

FIGS. **56-60** illustrate several embodiments of right angle balanced ultrasonic surgical blades. FIG. **56** illustrates one configuration of a right angle balanced ultrasonic surgical blade **440**. The right angle balanced ultrasonic surgical blade **440** comprises a longitudinal waveguide section **442**, a corner section **446**, and an end effector section **444** positioned transverse to the longitudinal waveguide section **442** extending from the corner section **446**. A tip section **448** is used to dissect tissue. The tip section **448** moves longitudinally as the waveguide section **442** is excited transversely.

FIG. **57** illustrates one configuration of a right angle balanced ultrasonic surgical blade **450**. The right angle balanced ultrasonic surgical blade **450** comprises a longitudinal waveguide section **452**, a corner section **456**, and an end effector section **454** positioned transverse to the longitudinal waveguide section **452** extending from the corner section **456**. A balance feature **453** is positioned along the waveguide section **452** between the waveguide section **452** and the corner section **456**. In the right angle balanced ultrasonic surgical blade **450**, the balance feature **453** is a reduced mass portion of the longitudinal waveguide section **452**. A tip section **458** is used to dissect tissue. The tip section **458** moves longitudinally as the waveguide section **452** is excited transversely.

FIG. **58** illustrates one configuration of a right angle balanced ultrasonic surgical blade **460**. The right angle balanced ultrasonic surgical blade **460** comprises a longitudinal waveguide section **462**, a corner section **466**, and an end effector section **464** positioned transverse to the longitudinal waveguide section **462** extending from the corner section **466**. A balance feature **463** is positioned along the waveguide section **462** between the waveguide section **462** and the corner section **466**. In the right angle balanced ultrasonic surgical blade **460**, the balance feature **463** is an increased mass portion of the longitudinal waveguide section **462**. The tip section **468** is used to dissect tissue. The tip section **468** moves longitudinally as the waveguide section **462** is excited transversely.

FIG. **59** illustrates one configuration of a right angle balanced ultrasonic surgical blade **470**. The right angle balanced ultrasonic surgical blade **470** comprises a longitudinal waveguide section **472**, a corner section **476**, and an end effector section **474** positioned transverse to the longitudinal waveguide section **472** extending from the corner section **476**. A balance feature **473** is positioned on the end effector section **474** between the corner section **476** and the tip section **478**. In the right angle balanced ultrasonic surgical blade **470**, the balance feature **473** is a reduced mass portion of the end effector section **474**. The tip section **478** is used to dissect tissue. The tip section **478** moves longitudinally as the waveguide section **472** is excited transversely.

FIG. **60** illustrates one configuration of a right angle balanced ultrasonic surgical blade **480**. The right angle balanced ultrasonic surgical blade **480** comprises a longitudinal waveguide section **482**, a corner section **486**, and an end effector section **484** positioned transverse to the longitudinal waveguide section **482** extending from the corner section **486**. A balance feature **483** is positioned on the end effector section **484** between the corner section **486** and the tip section **488**. In the right angle balanced ultrasonic surgical blade **480**, the balance feature **483** is an increased mass portion of the end effector section **484**. The tip section **488** is used to dissect tissue. The tip section **488** moves longitudinally as the waveguide section **482** is excited transversely.

As discussed herein, any reference to "one aspect," "an aspect," "one embodiment," or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the aspect is included in at least one aspect. Thus, appearances of the phrases "in one aspect," "in an aspect," "in one embodiment," or "in an embodiment" in various places throughout the specification are not necessarily all referring to the same aspect. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner in one or more aspects.

Although various embodiments have been described herein, many modifications, variations, substitutions, changes, and equivalents to those embodiments may be implemented and will occur to those skilled in the art. Also, where materials are disclosed for certain components, other materials may be used. It is therefore to be understood that the foregoing description and the appended claims are intended to cover all such modifications and variations as falling within the scope of the disclosed embodiments. The following claims are intended to cover all such modification and variations.

Although various embodiments have been described herein, many modifications, variations, substitutions, changes, and equivalents to those embodiments may be implemented and will occur to those skilled in the art. Also, where materials are disclosed for certain components, other materials may be used. It is therefore to be understood that the foregoing description and the appended claims are intended to cover all such modifications and variations as falling within the scope of the disclosed embodiments. The following claims are intended to cover all such modification and variations.

The invention claimed is:

1. An ultrasonic surgical blade, comprising:
a solid body;
a longitudinal portion having a proximal end configured to couple to an ultrasonic transmission waveguide and a distal end configured to dissect and coagulate tissue, the longitudinal portion comprising:
a substantially planar longitudinal surface; and
a distal hemostasis surface located opposite of the substantially planar longitudinal surface, the distal hemostasis surface having a surface area S1 defined by a distal surface inflection, a first proximal surface inflection, and first and second lateral cutting edges extending from the distal surface inflection to the first proximal surface inflection, wherein the distal surface inflection defines a minimum width of the distal hemostasis surface and the first proximal surface inflection defines a maximum width of the distal hemostasis surface;
a transverse portion extending crosswise from the distal end of the longitudinal portion, the transverse portion defining a hook extending above the ultrasonic transmission waveguide having a free end configured to pull and dissect tissue, the transverse portion comprising:
a curved section extending from a distal end of the substantially planar longitudinal surface;
a tip surface defined at the free end;
a substantially planar proximal inner surface extending from the curved section to the tip surface; and
an outer concave distal surface extending from the tip surface to the distal hemostasis surface; and
a distal dissection edge defined at a surface inflection of the outer concave distal surface and the distal hemostasis surface.

2. The ultrasonic surgical blade of claim **1**, wherein the longitudinal portion comprises a proximal hemostasis surface located opposite of the substantially planar longitudinal surface, the proximal hemostasis surface having a surface area S2 defined by the first proximal surface inflection defining a junction of the distal hemostasis surface and the proximal hemostasis surface, a second proximal surface inflection, and third and fourth lateral cutting edges extending from the first proximal surface inflection to the second proximal surface inflection.

3. The ultrasonic surgical blade of claim **2**, wherein the depth of the transverse portion measured from the tip surface to the proximal hemostasis surface is selected from a range of 1.8 mm to 3.0 mm.

4. The ultrasonic surgical blade of claim 2, wherein the surface area S2 is selected from a range of 6.45 mm^2 to 12.90 mm^2.

5. The ultrasonic surgical blade of claim 2, wherein the third and fourth lateral cutting edges define a maximum width of the proximal hemostasis surface at a location between the first and second proximal surface inflections.

6. The ultrasonic surgical blade of claim 1, wherein the surface area S1 is selected from a range of 3.226 mm^2 to 6.45 mm^2.

7. The ultrasonic surgical blade of claim 1, further comprising a beveled edge defined between the tip surface and the substantially planar proximal inner surface.

8. The ultrasonic surgical blade of claim 1, further comprising an oblique tip surface extending from the tip surface to the outer concave distal surface.

9. An ultrasonic surgical blade, comprising:

a solid body;

a longitudinal portion having a proximal end and a distal end, the longitudinal portion comprising:

a substantially planar longitudinal surface; and

a distal hemostasis surface located opposite of the substantially planar longitudinal surface, the distal hemostasis surface having a surface area S1 defined by a distal surface inflection, a first proximal surface inflection, and first and second lateral cutting edges extending from the distal surface inflection to the first proximal surface inflection, wherein the distal surface inflection defines a minimum width of the distal hemostasis surface and the first proximal surface inflection defines a maximum width of the distal hemostasis surface;

a transverse portion extending crosswise from the distal end of the longitudinal portion, the transverse portion defining a hook having a free end, the transverse portion comprising:

a curved section extending from a distal end of the substantially planar longitudinal surface;

a tip surface defined at the free end;

a proximal inner surface extending from the curved section to the tip surface; and

an outer concave distal surface extending from the tip surface to the distal hemostasis surface.

10. The ultrasonic surgical blade of claim 9, wherein the longitudinal portion comprises a proximal hemostasis surface located opposite of the substantially planar longitudinal surface, the proximal hemostasis surface having a surface area S2 defined by the first proximal surface inflection defining a junction of the distal hemostasis surface and the proximal hemostasis surface, a second proximal surface inflection, and third and fourth lateral cutting edges extending from the first proximal surface inflection to the second proximal surface inflection.

11. The ultrasonic surgical blade of claim 10, wherein the depth of the transverse portion measured from the tip surface to the proximal hemostasis surface is selected from a range of 1.8 mm to 3.0 mm.

12. The ultrasonic surgical blade of claim 10, wherein the surface area S2 is selected from a range of 6.45 mm^2 to 12.90 mm^2.

13. The ultrasonic surgical blade of claim 10, wherein the third and fourth lateral cutting edges define a maximum width of the proximal hemostasis surface at a location between the first and second proximal surface inflections.

14. The ultrasonic surgical blade of claim 9, wherein the surface area S1 is selected from a range of 3.226 mm^2 to 6.45 mm^2.

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