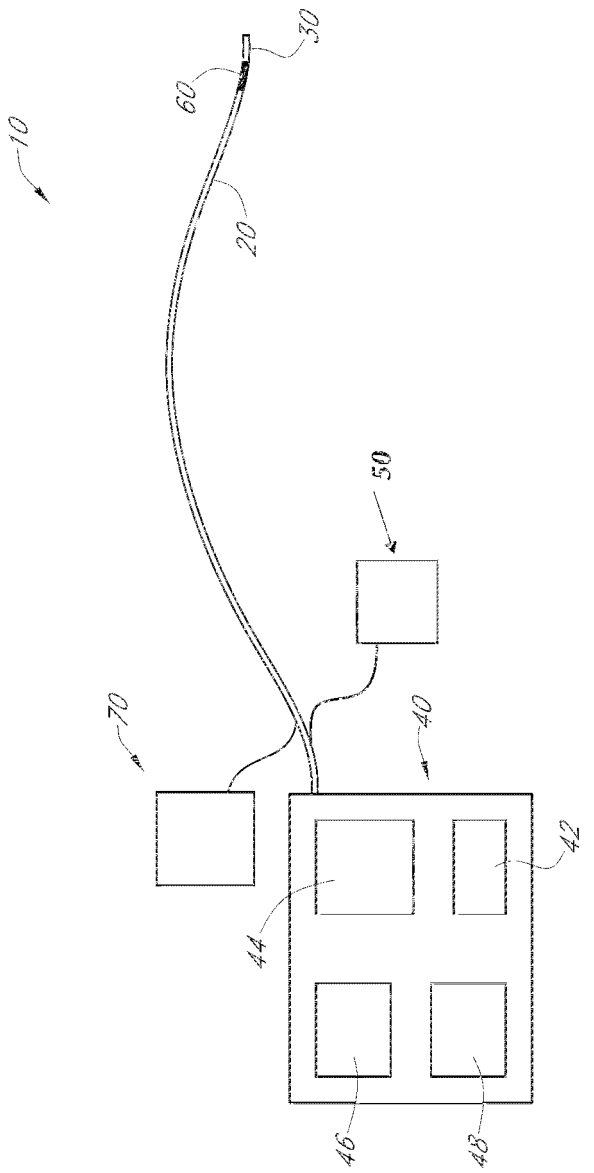

FIG. 1

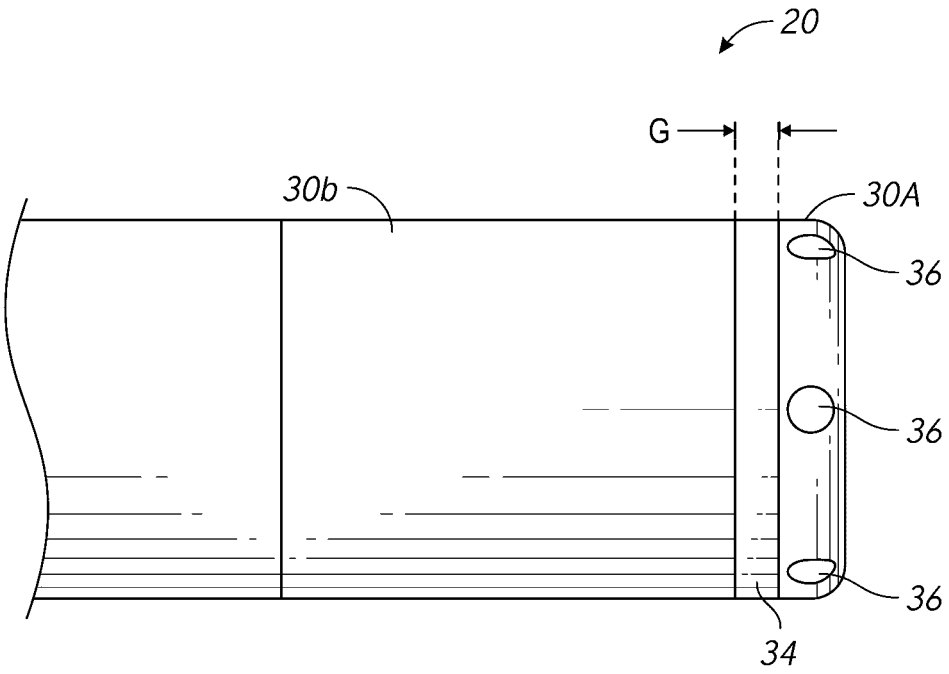

FIG. 2

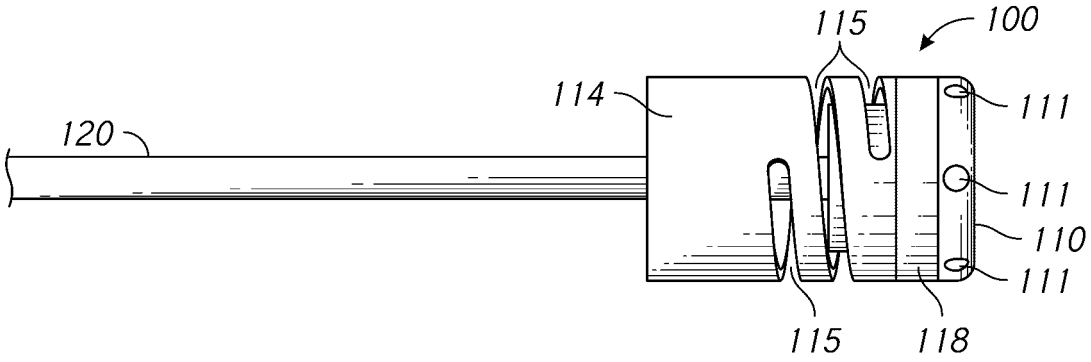
115
100
114
111
120
111
110
111
115
118

FIG. 3

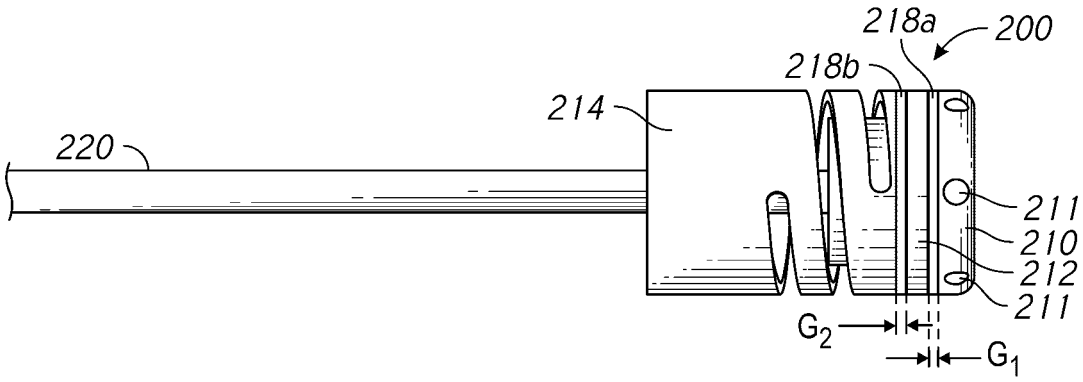
218a
200
218b
214
220
211
210
212
211
G2
G1

FIG. 4

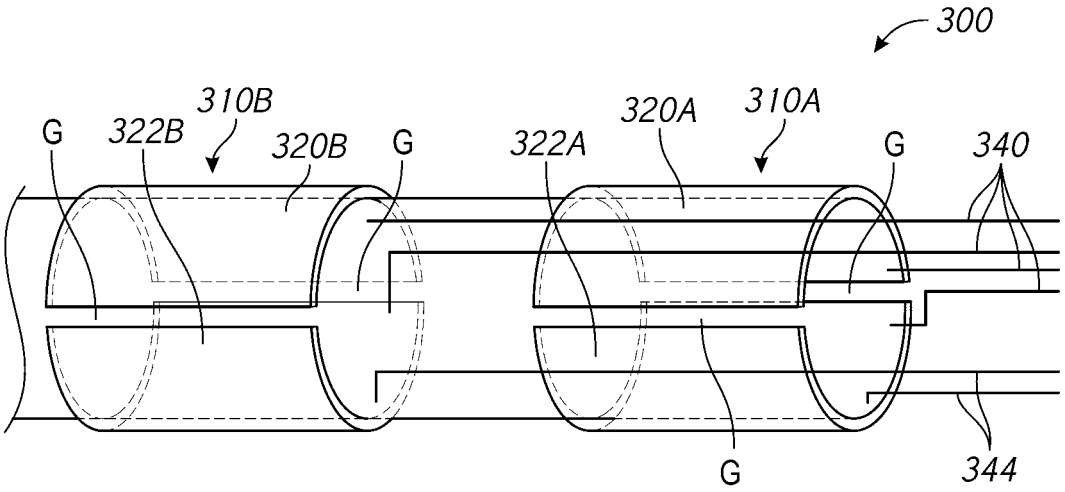
300
310B
G
322B
320B
G
322A
320A
310A
G
340
G
344

FIG. 5

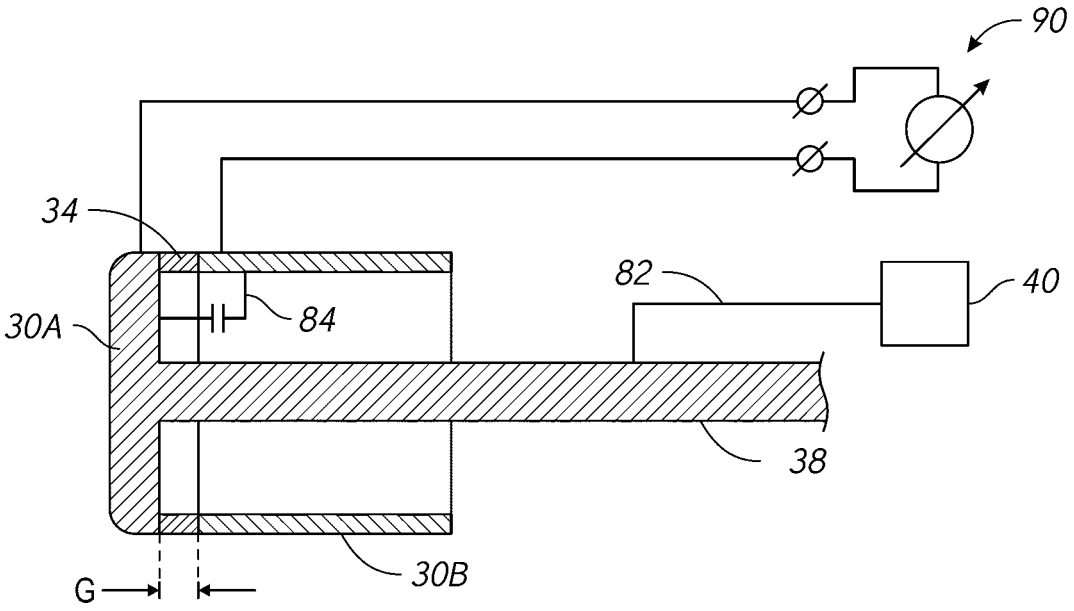
90
34
82
40
30A
84
38
30B
G

FIG. 6

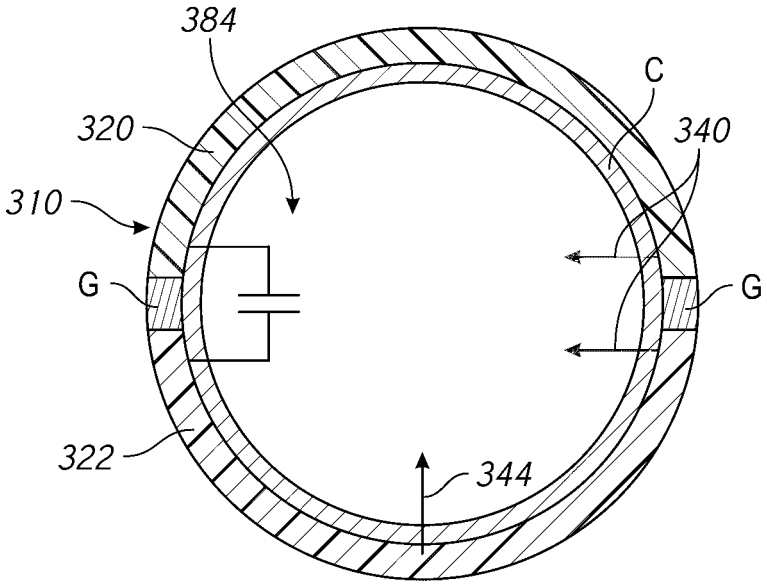

FIG. 7

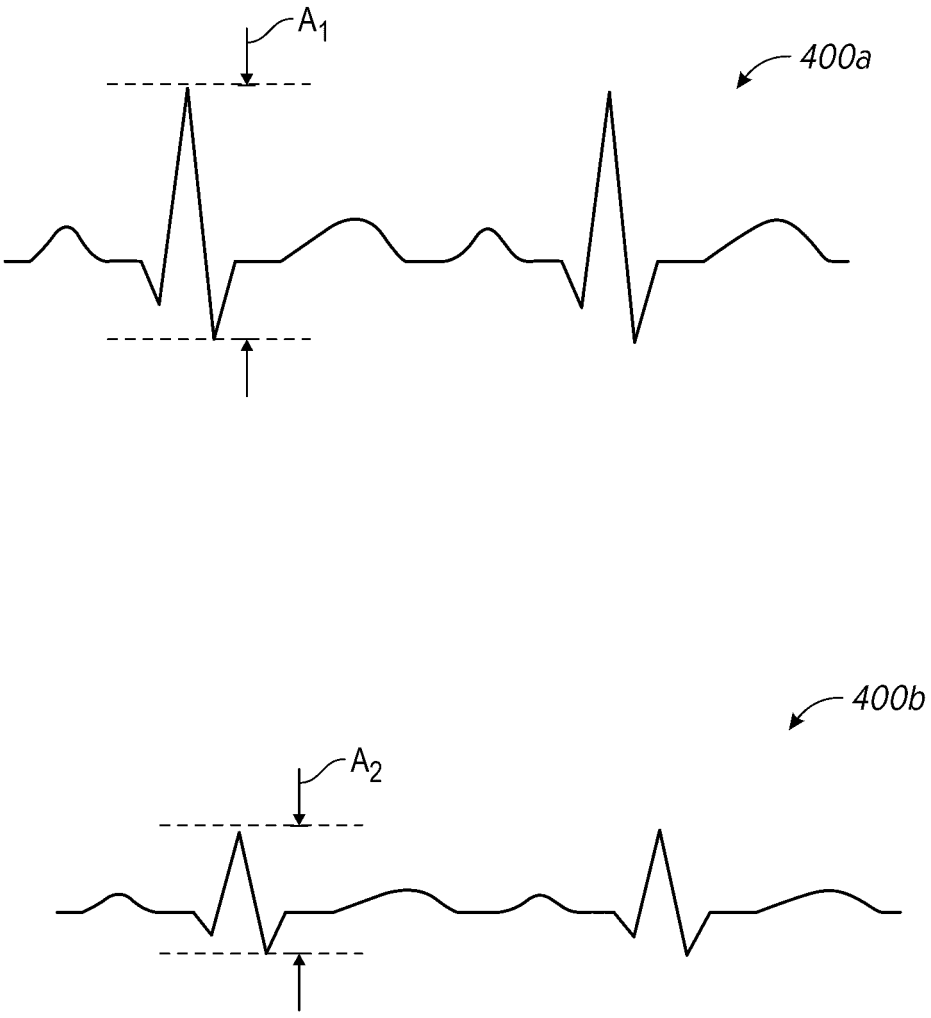

FIG. 8

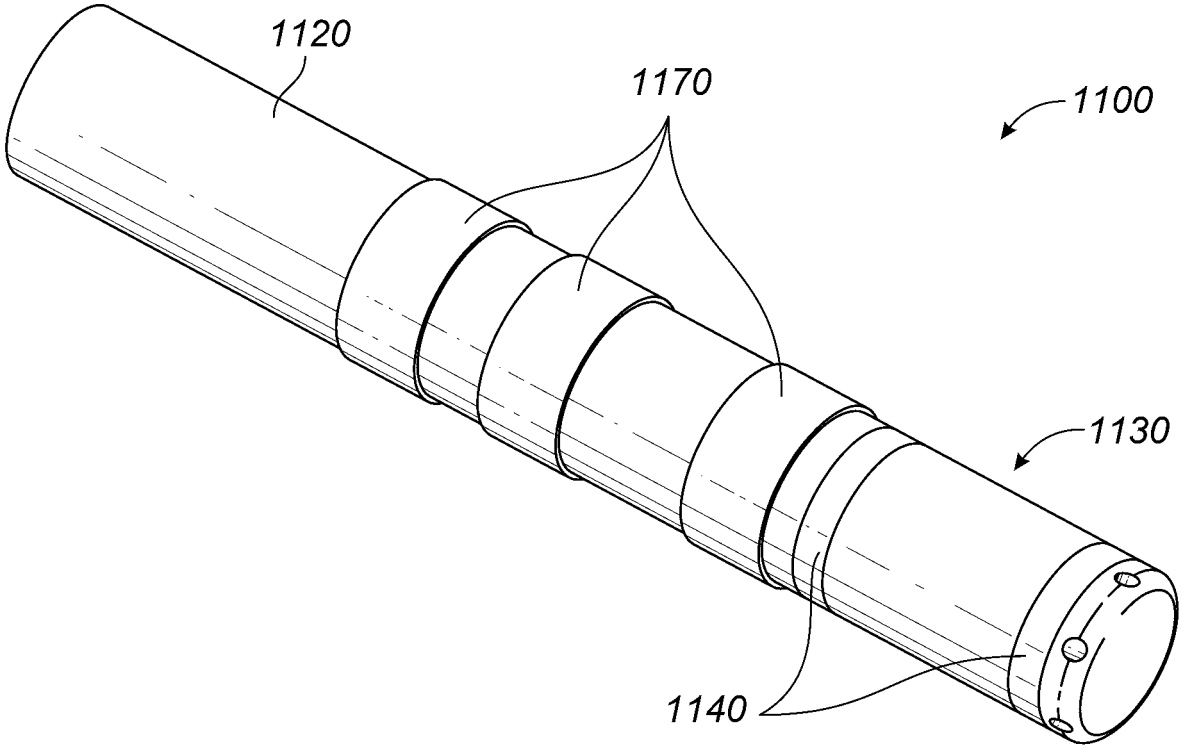

FIG. 9

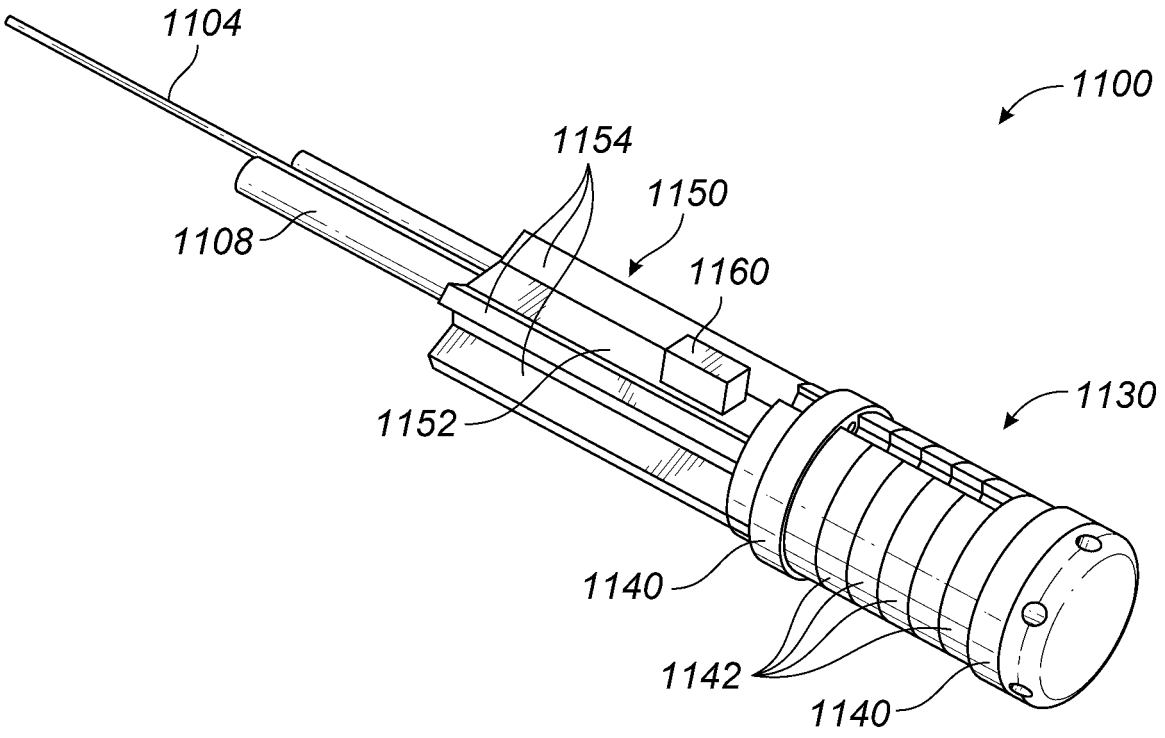

FIG. 10

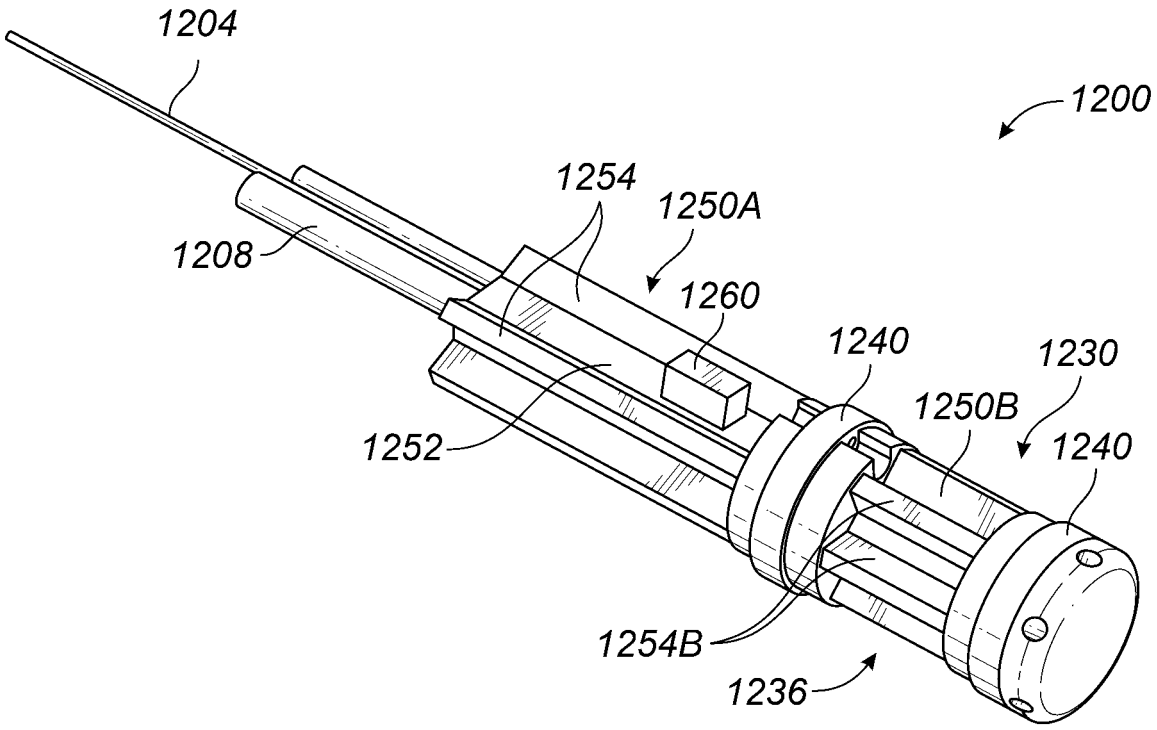
1204
1200
1254
1250A
1208
1260
1240
1230
1250B
1252
1240
1254B
1236

FIG. 11

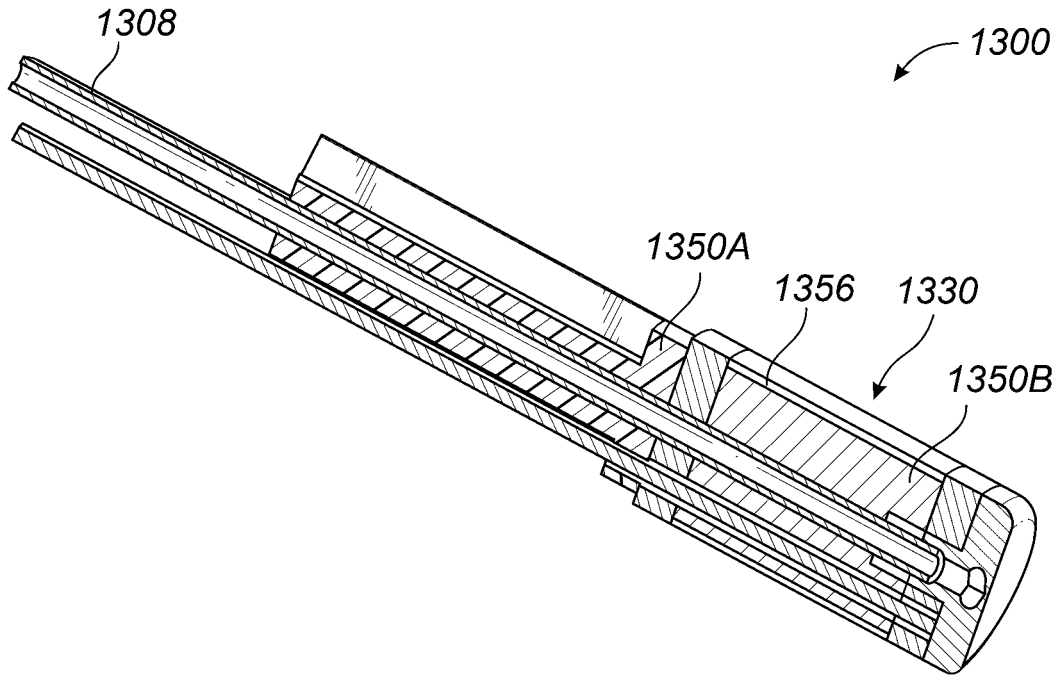

FIG. 12

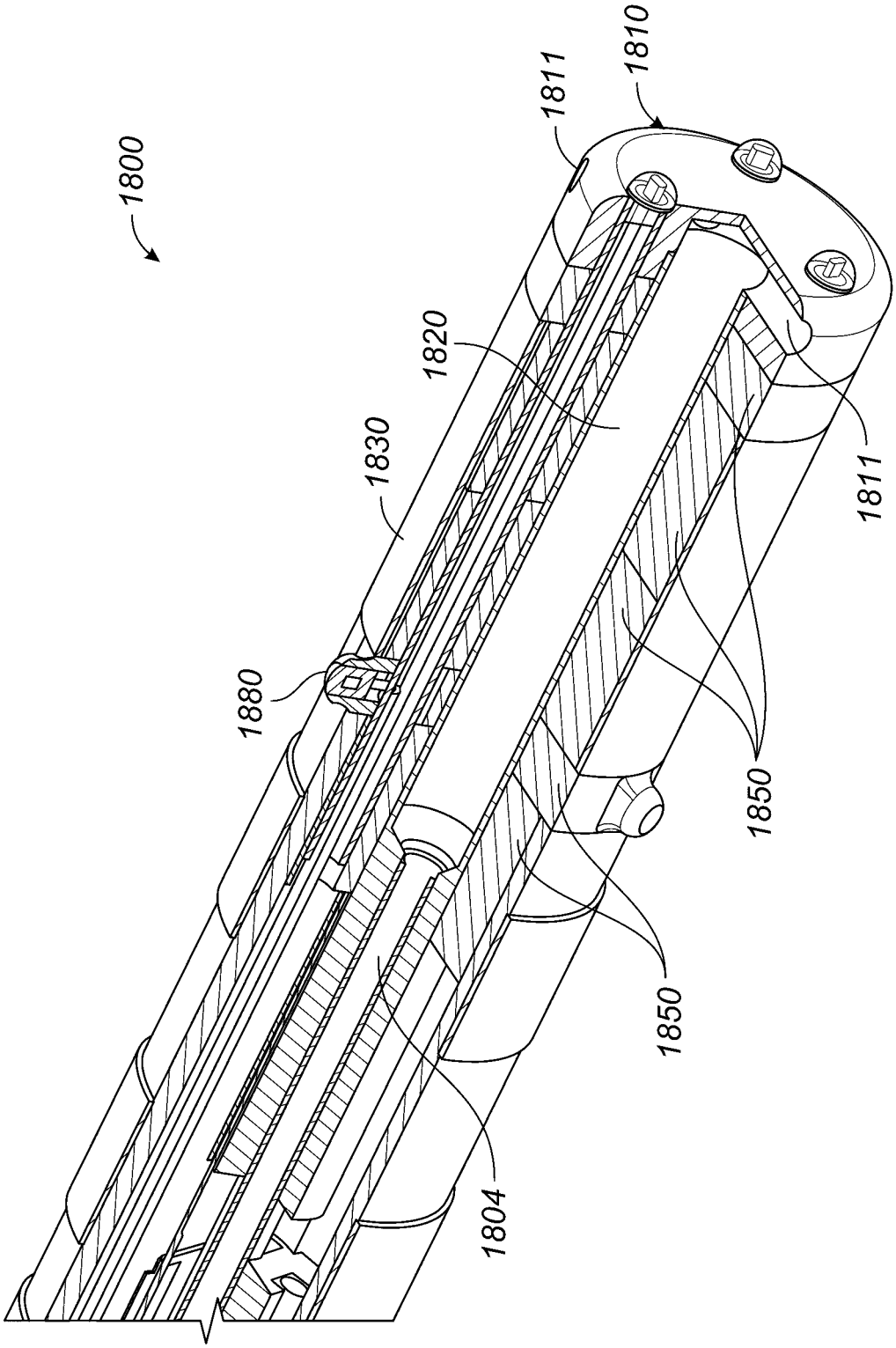

FIG.13

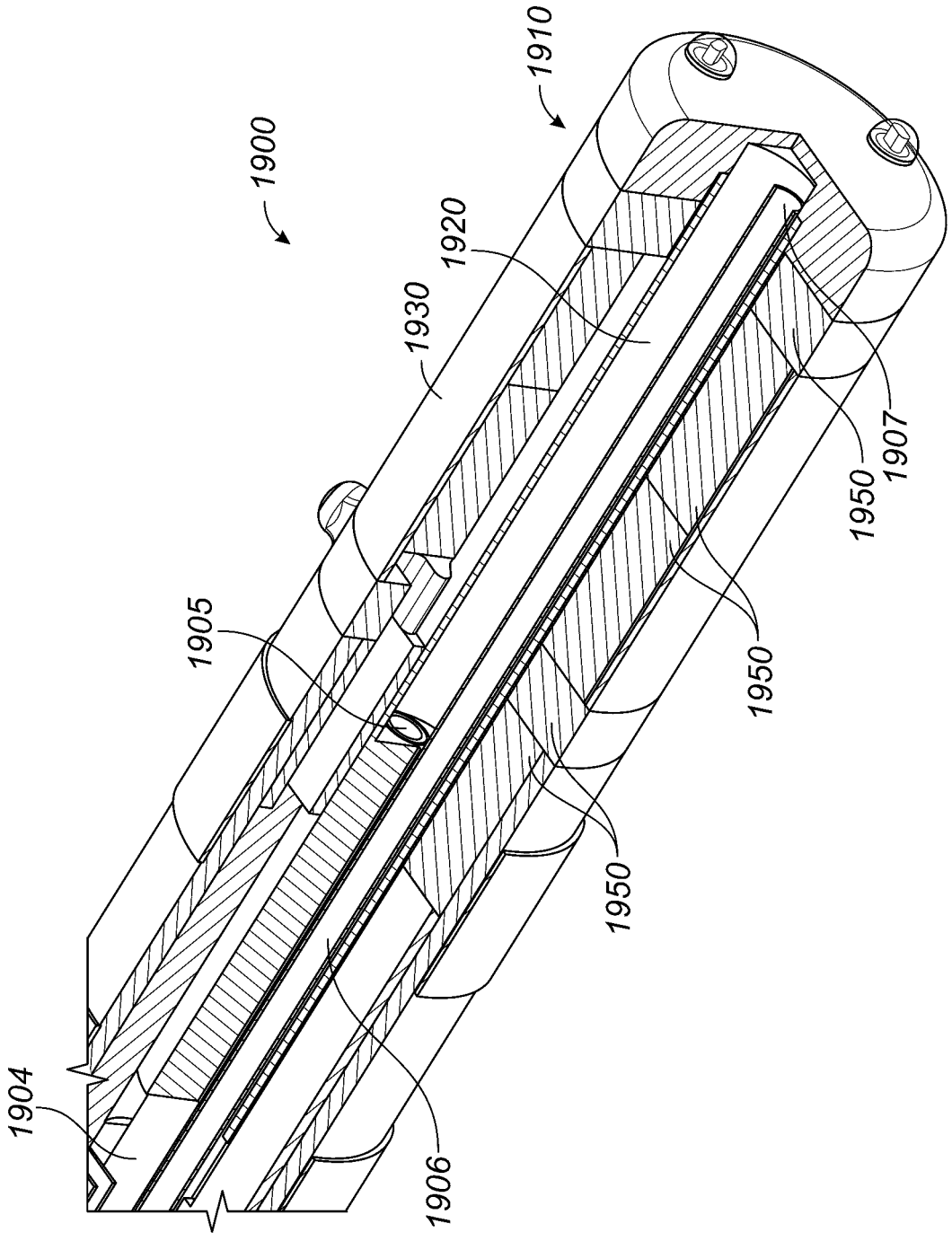

FIG. 14

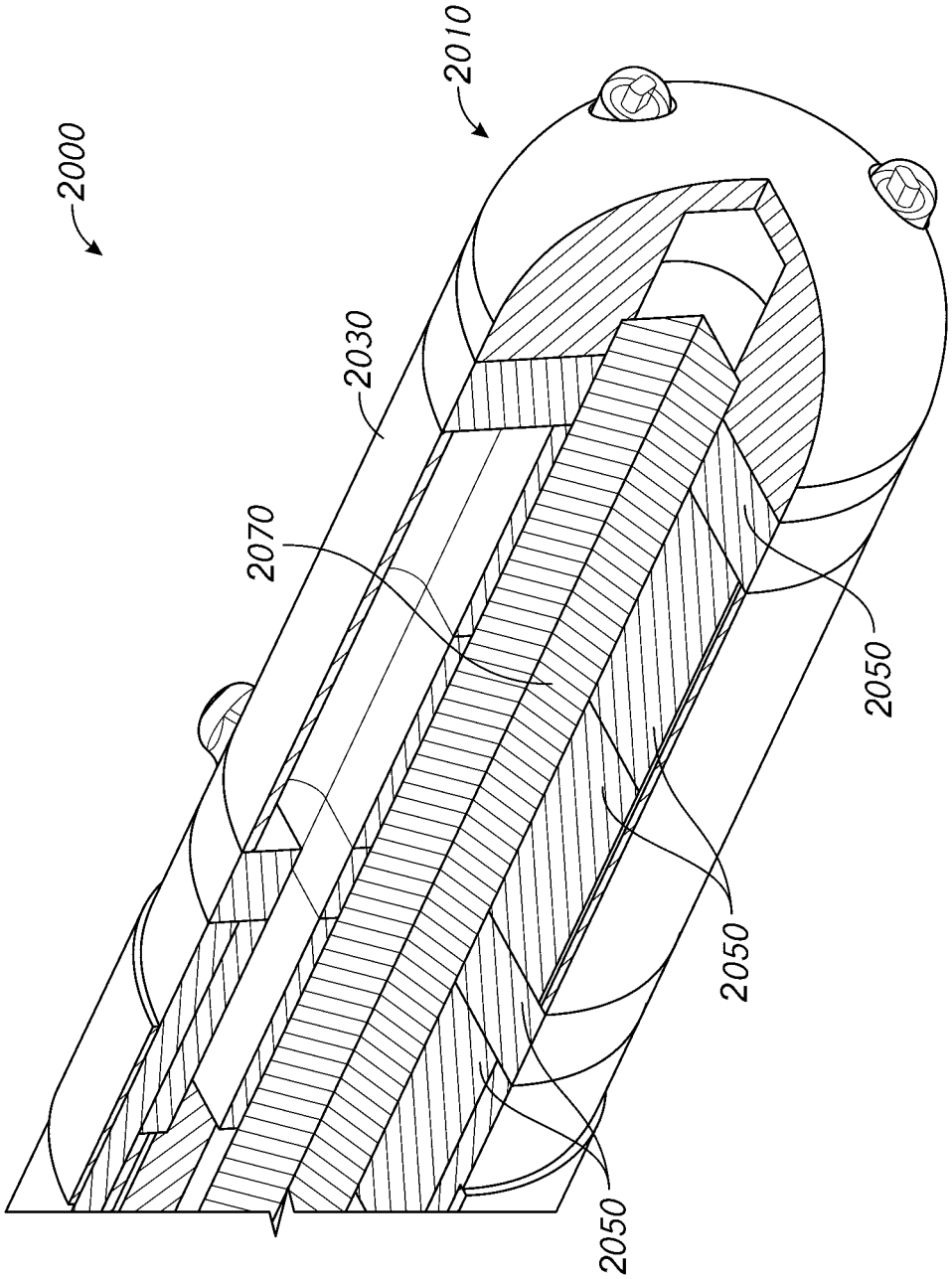

FIG. 15

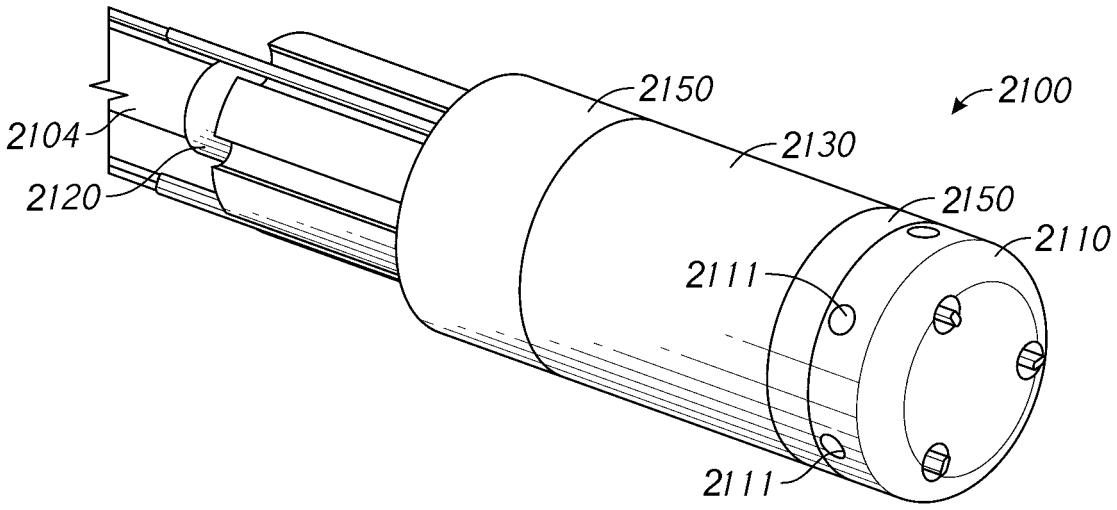

FIG. 16A

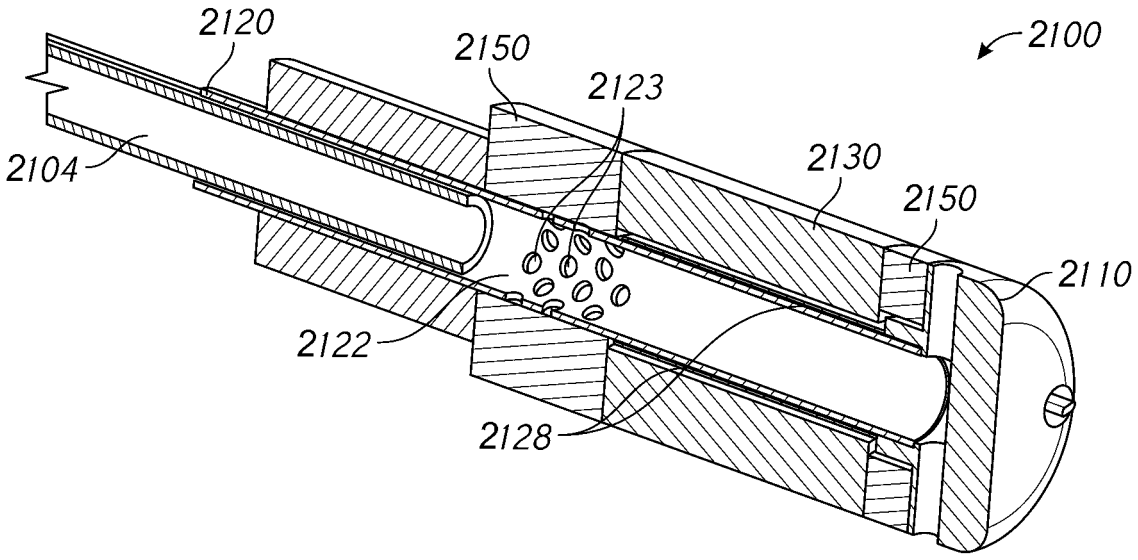

FIG. 16B

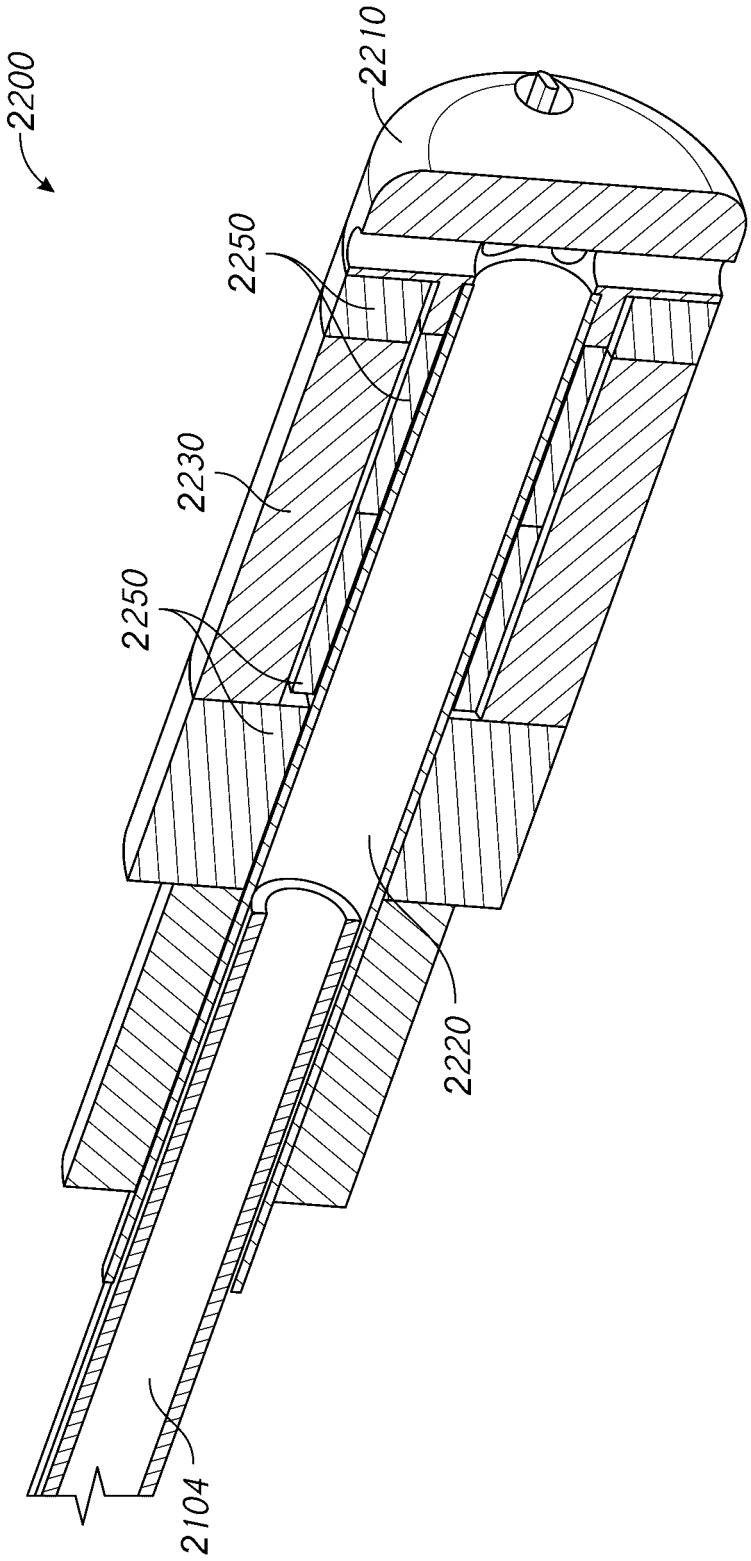

FIG. 16C

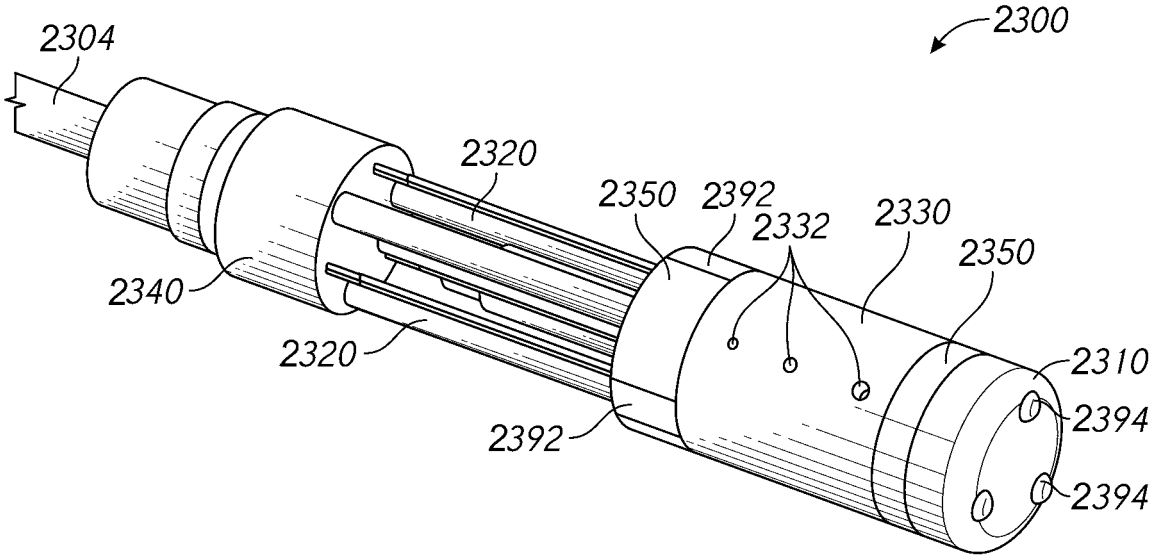

FIG. 17A

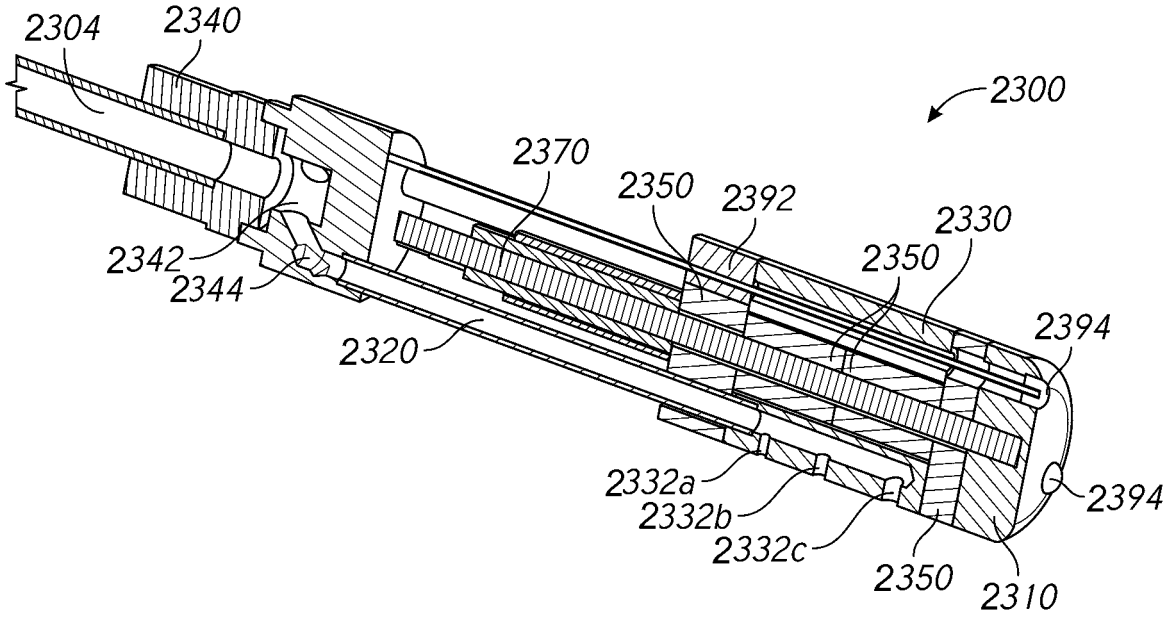

FIG. 17B

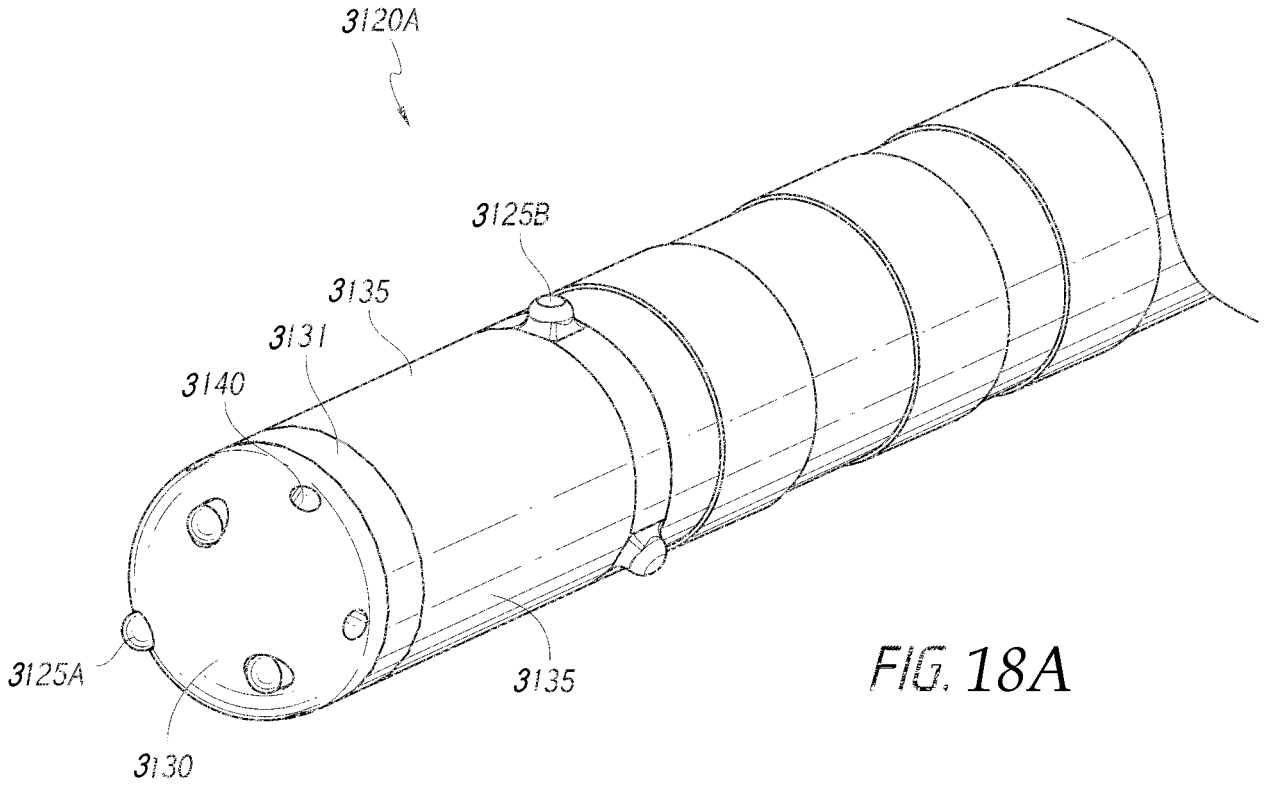

FIG. 18A

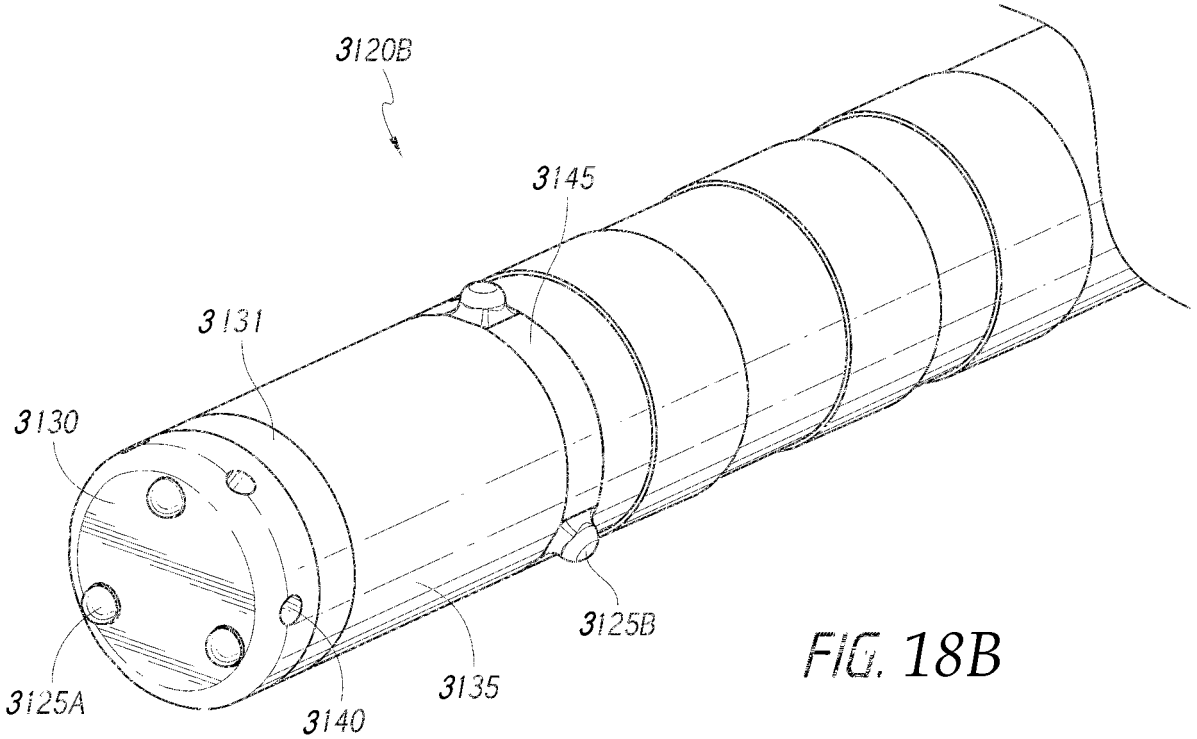

FIG. 18B

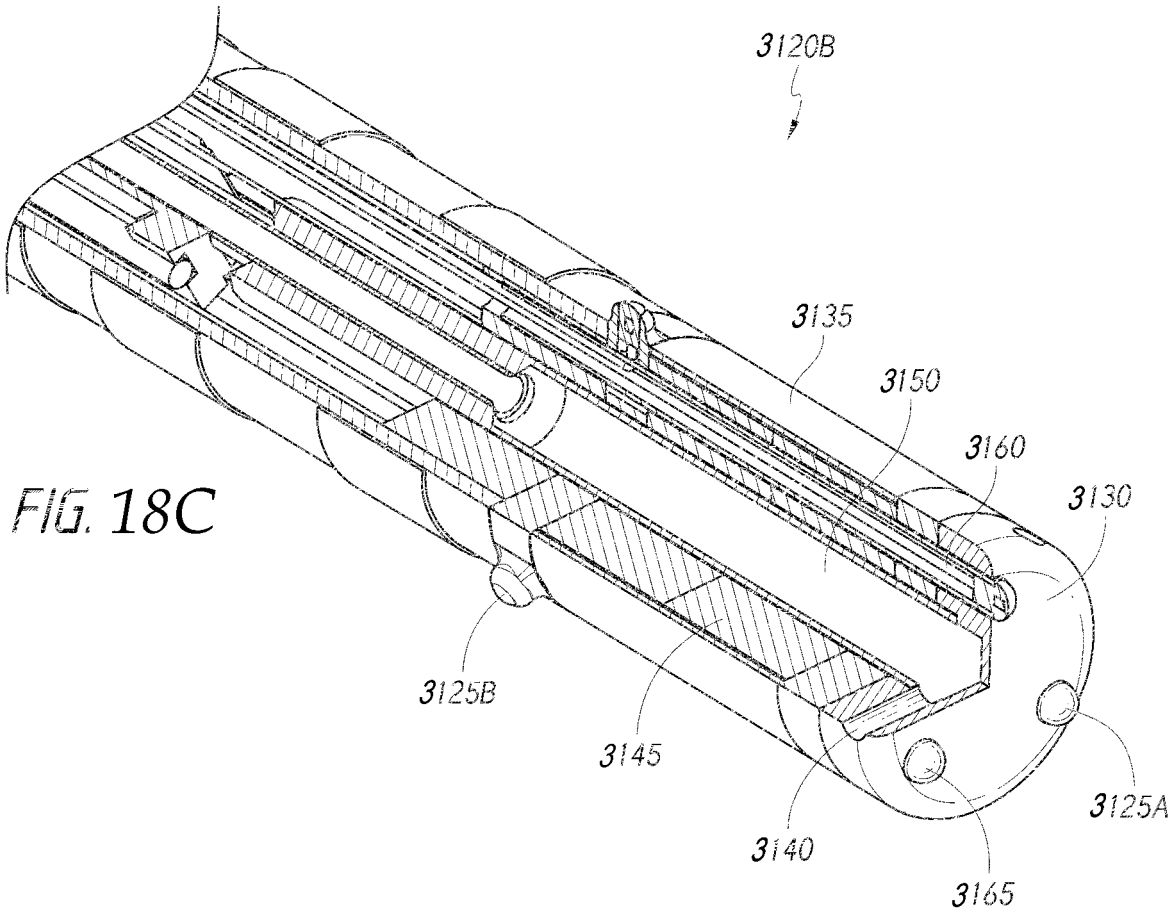

FIG. 18C

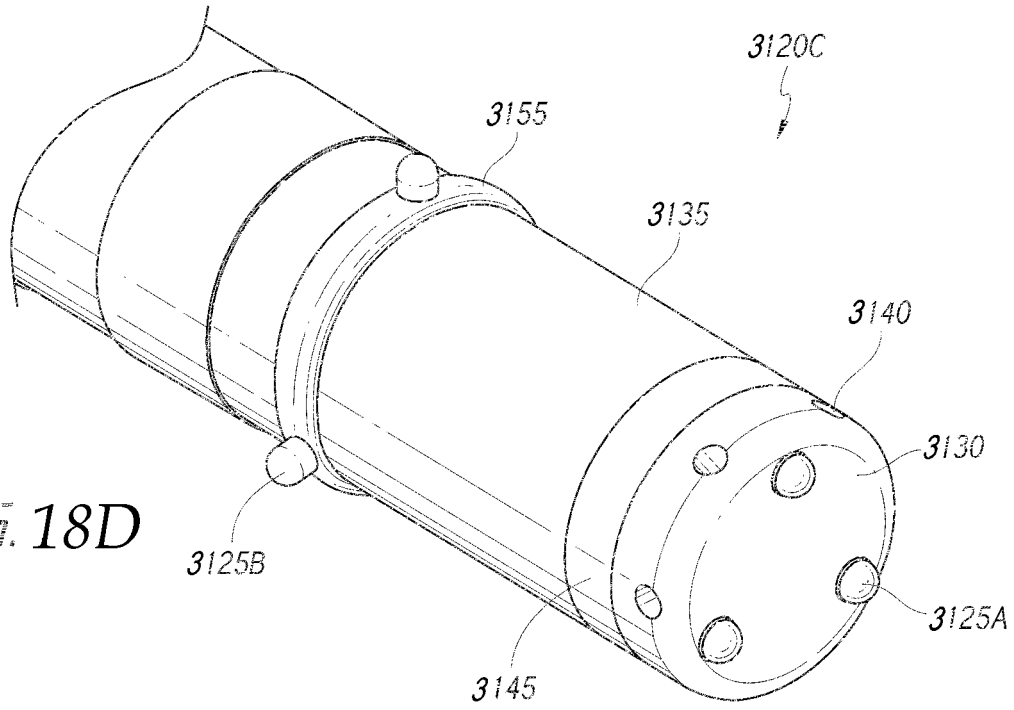

FIG. 18D

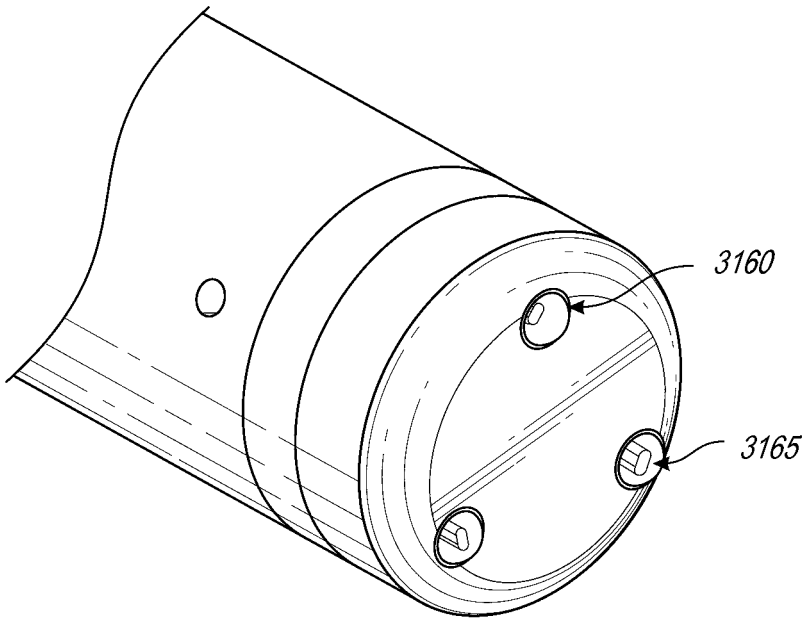

FIG. 18E

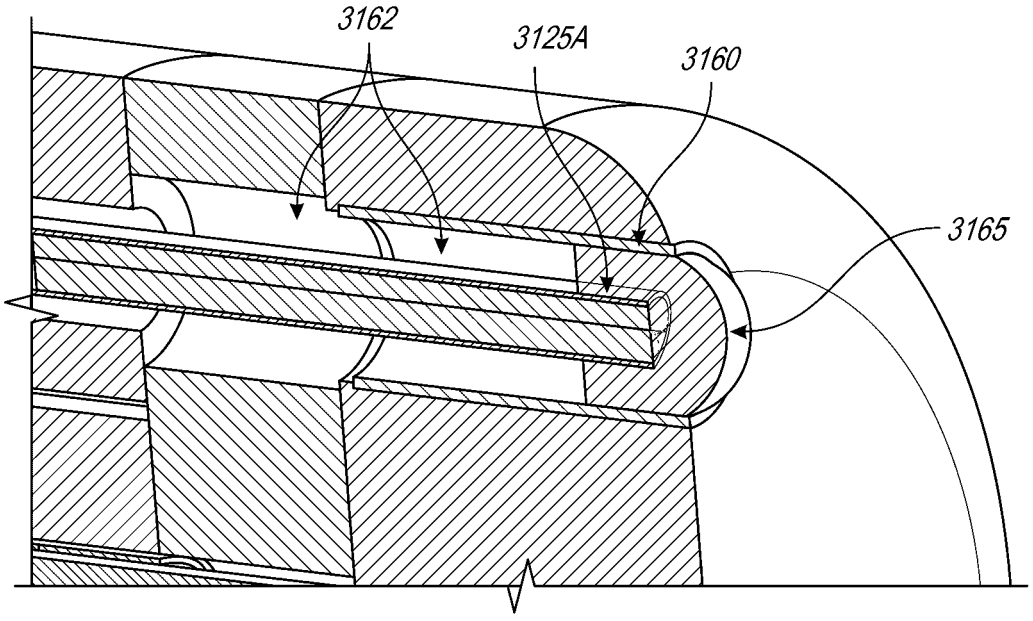

FIG. 18F

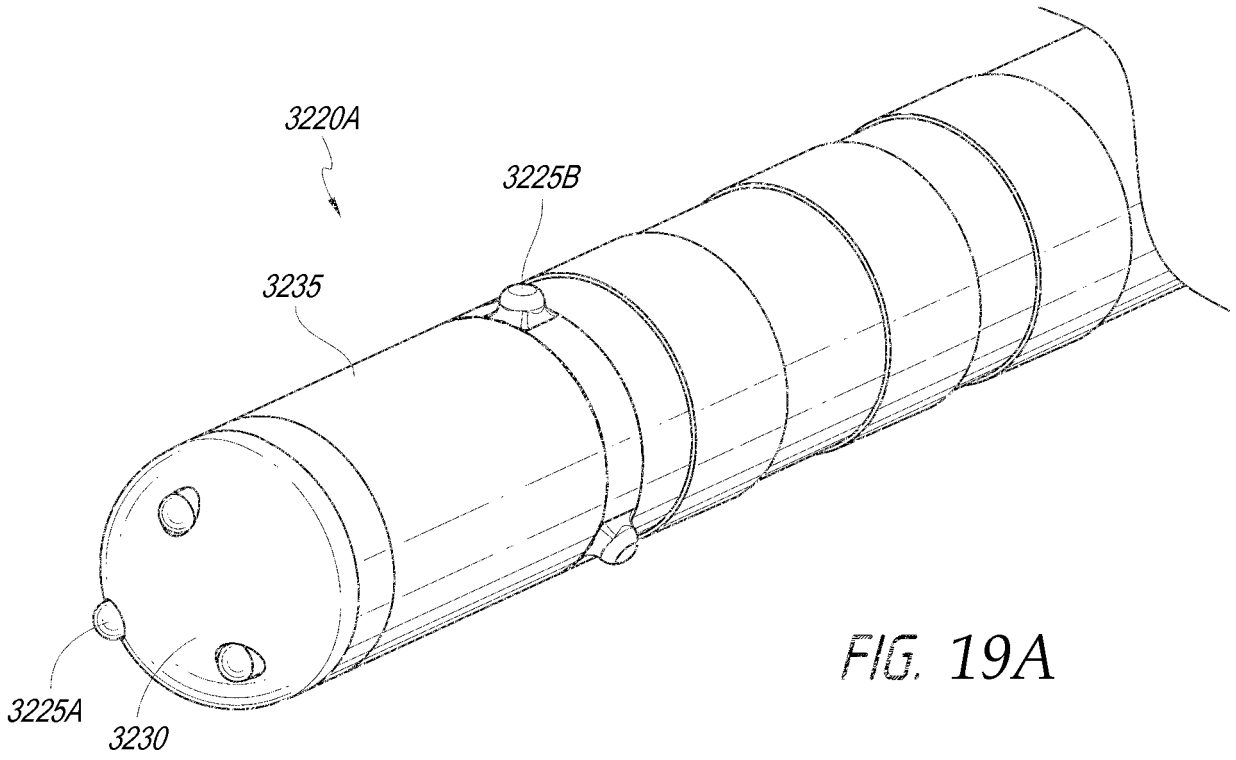

FIG. 19A

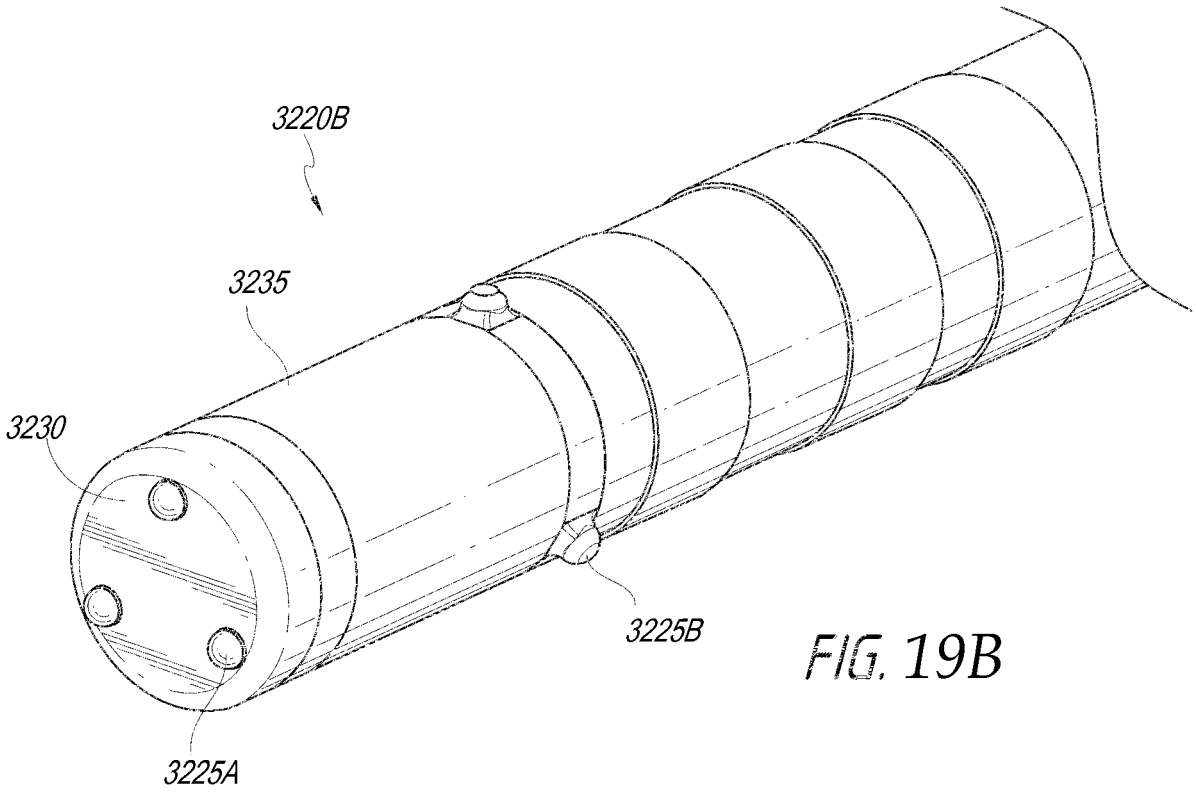

FIG. 19B

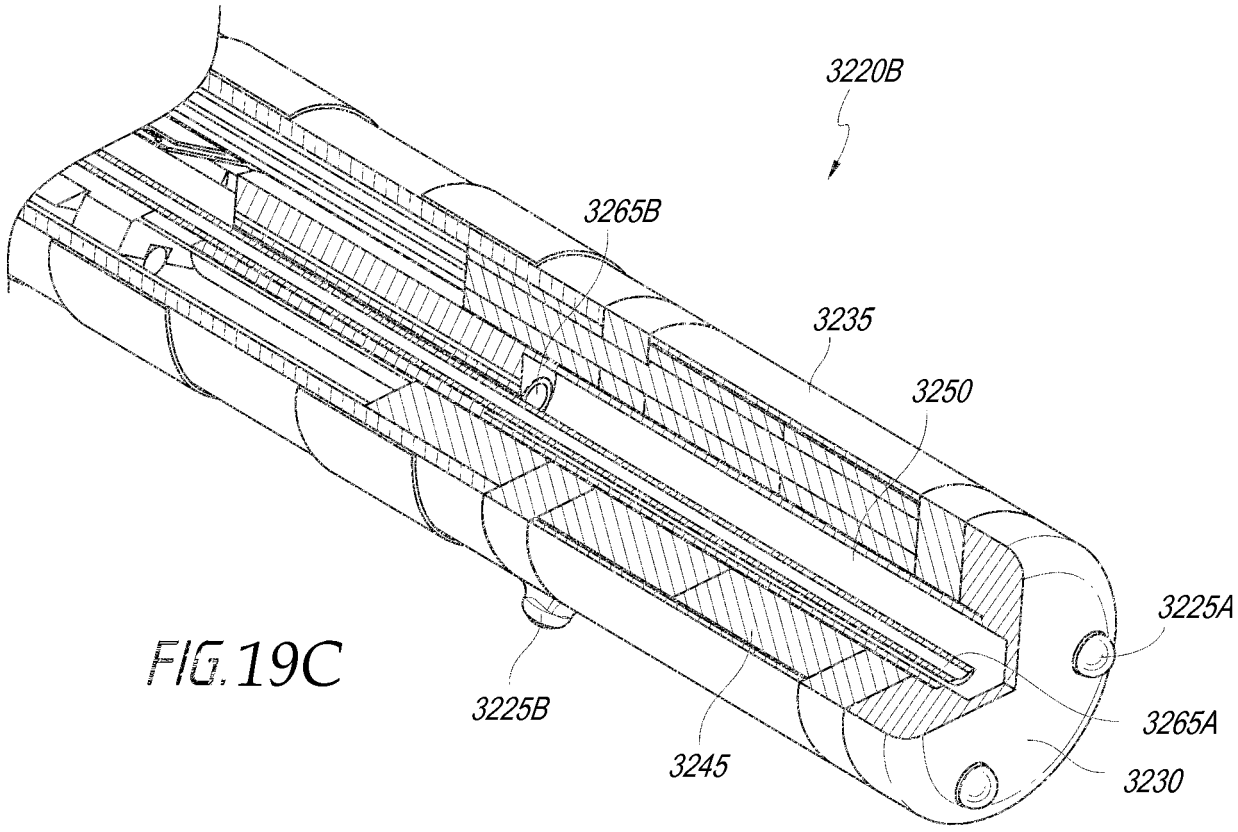

FIG. 19C

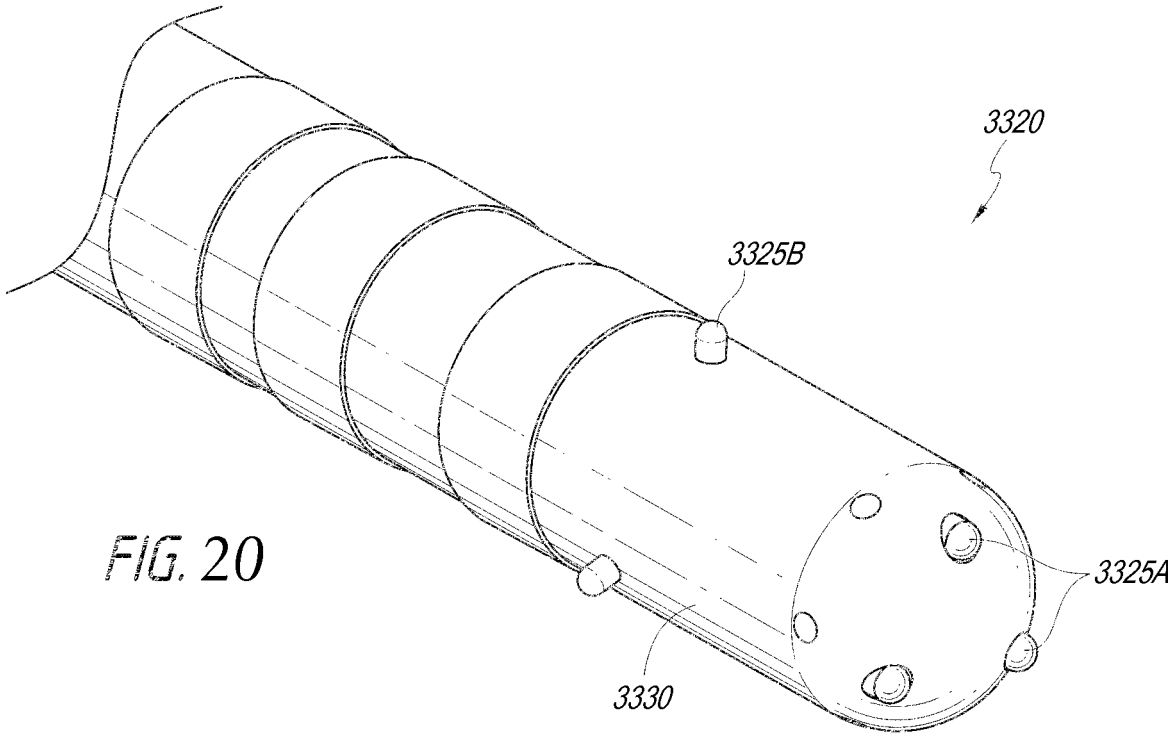

FIG. 20

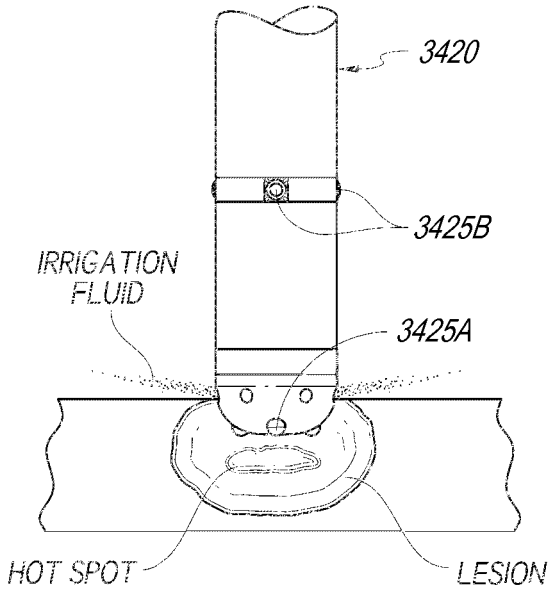

FIG. 21A

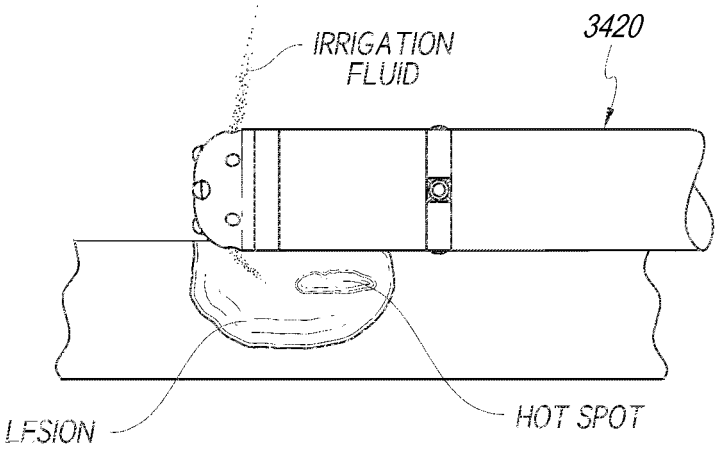

FIG. 21B

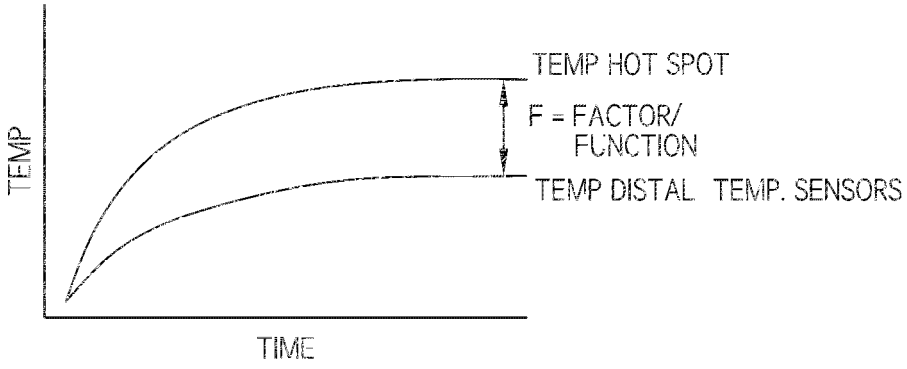

FIG. 22A

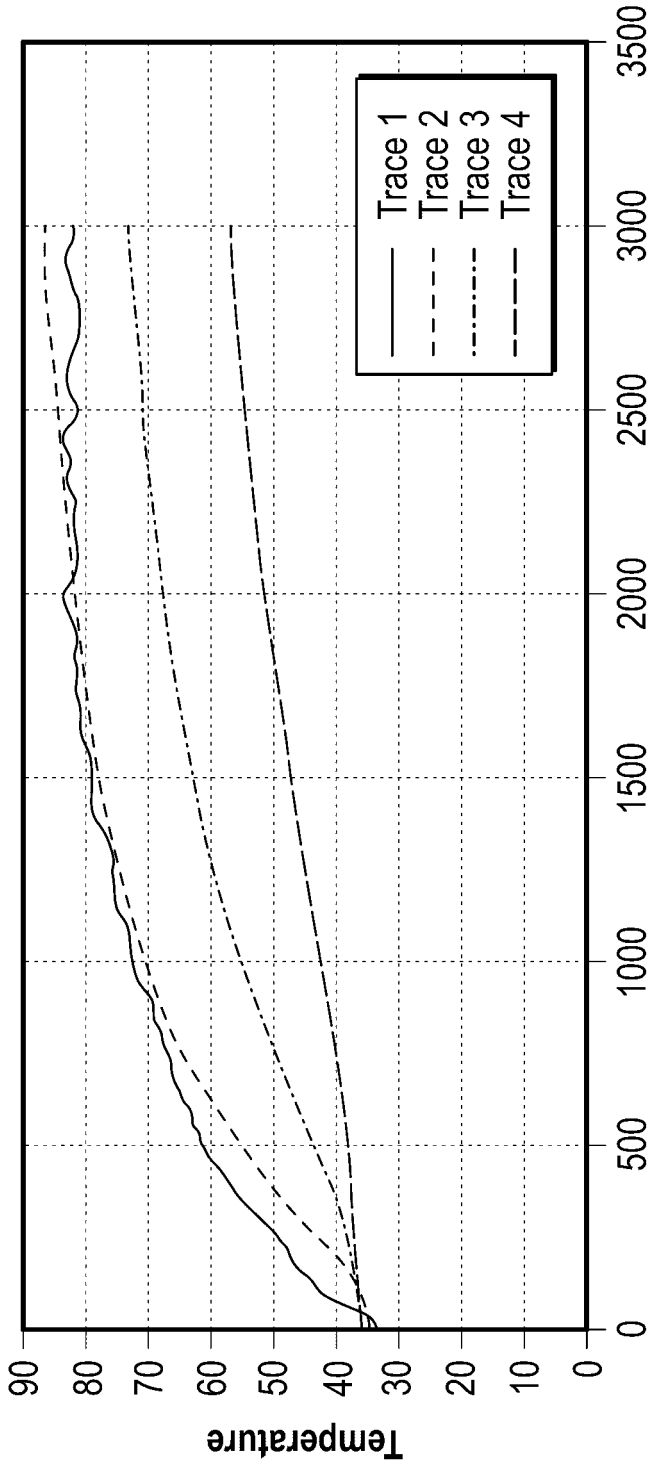
Temperature
Time
Trace 1
Trace 2
Trace 3
Trace 4
0
10
20
30
40
50
60
70
80
90
0
500
1000
1500
2000
2500
3000
3500

FIG. 22B

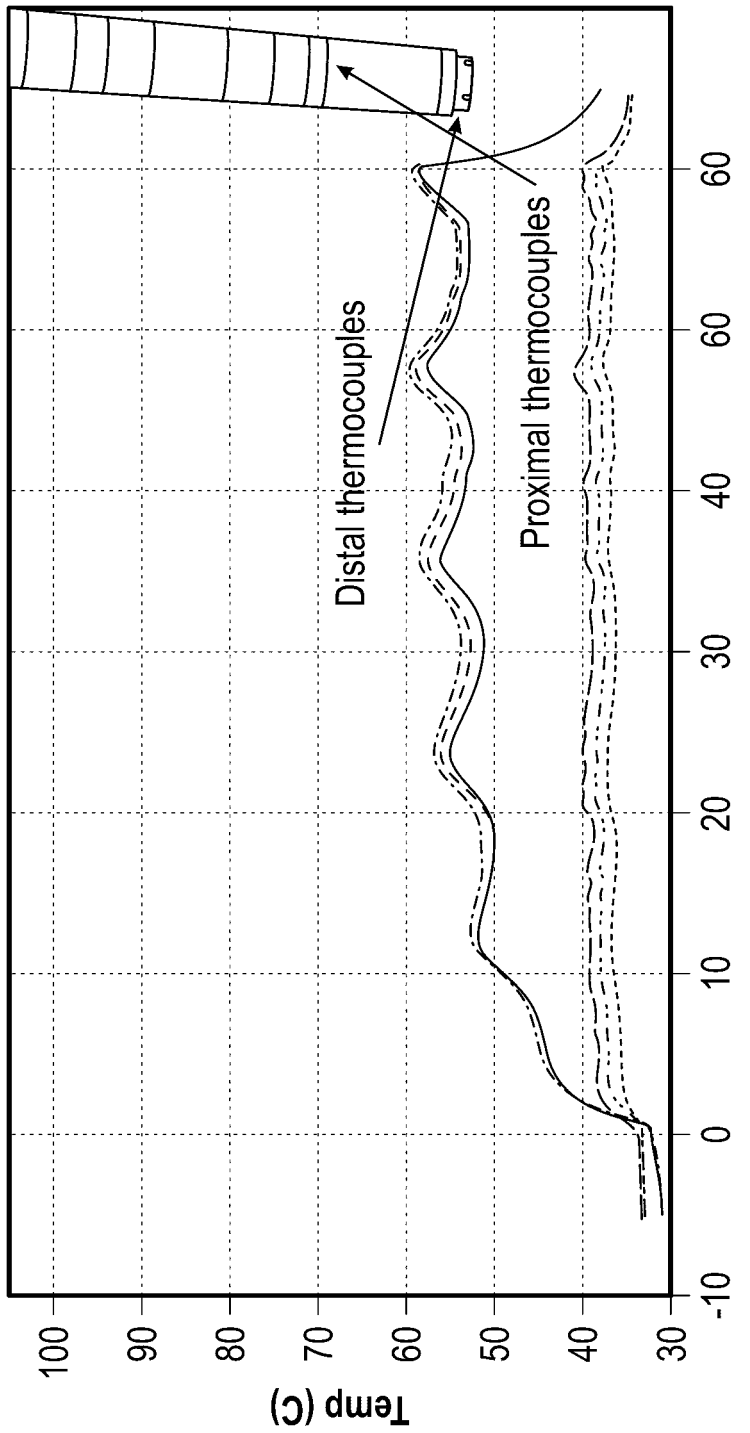
Temp (C)
100
90
80
70
60
50
40
30
-10
0
10
20
30
40
60
60
time (sec)
Distal thermocouples
Proximal thermocouples

FIG. 23A

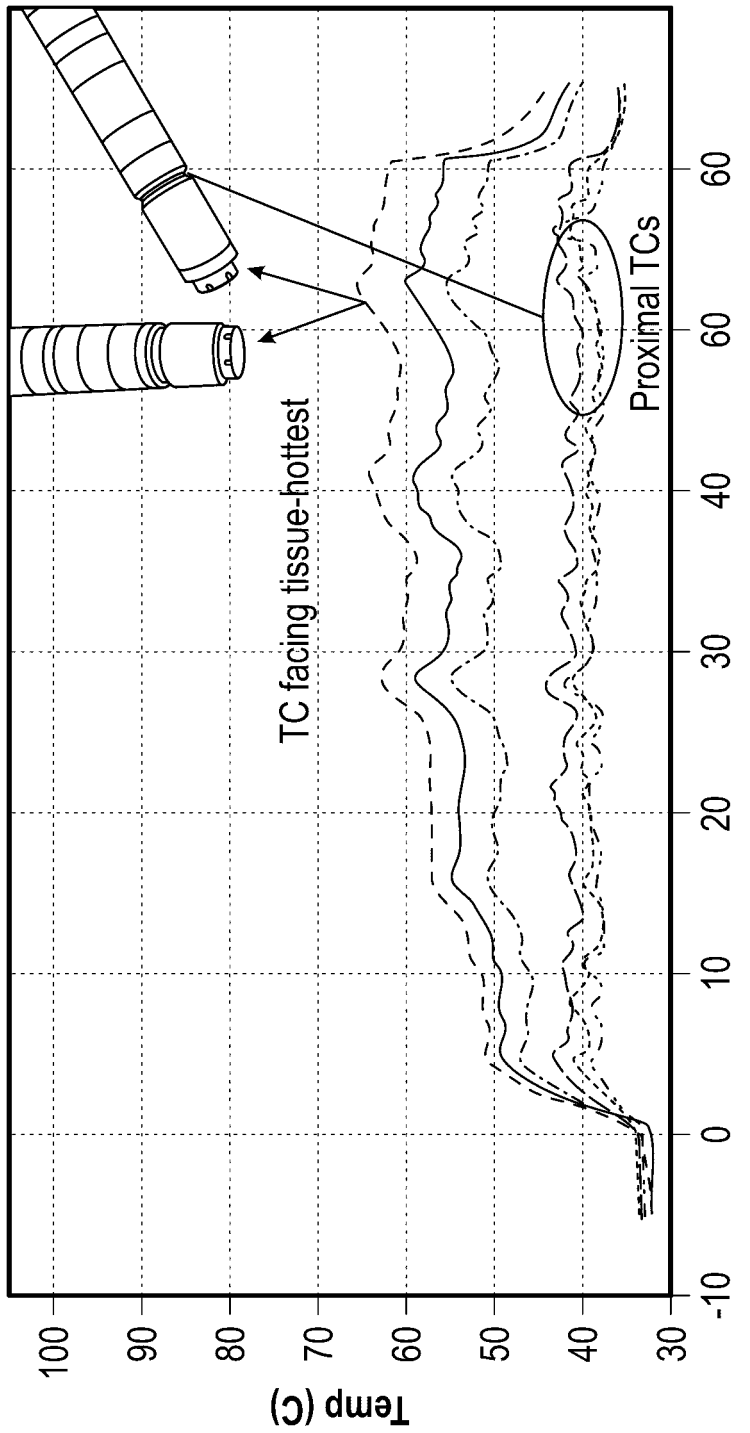
Temp (C)
100
90
80
70
60
50
40
30
-10
0
10
20
30
40
60
60
time (sec)
TC facing tissue-hottest
Proximal TCs

FIG. 23B

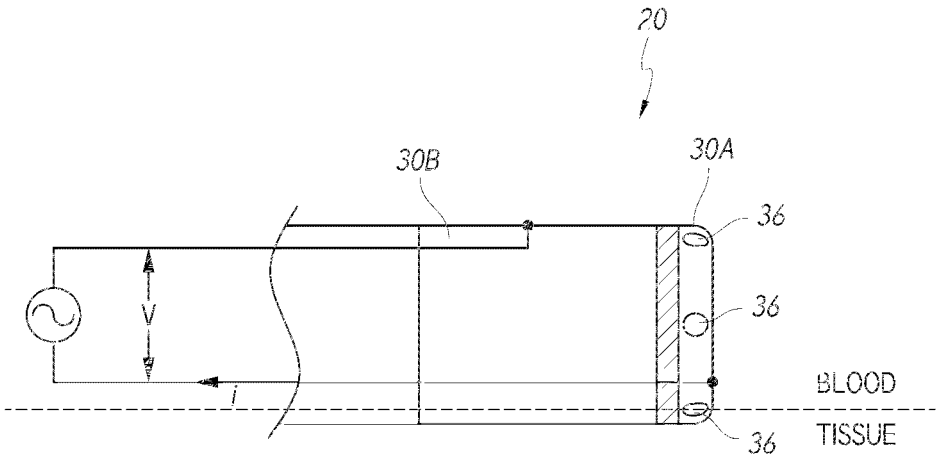

FIG. 24

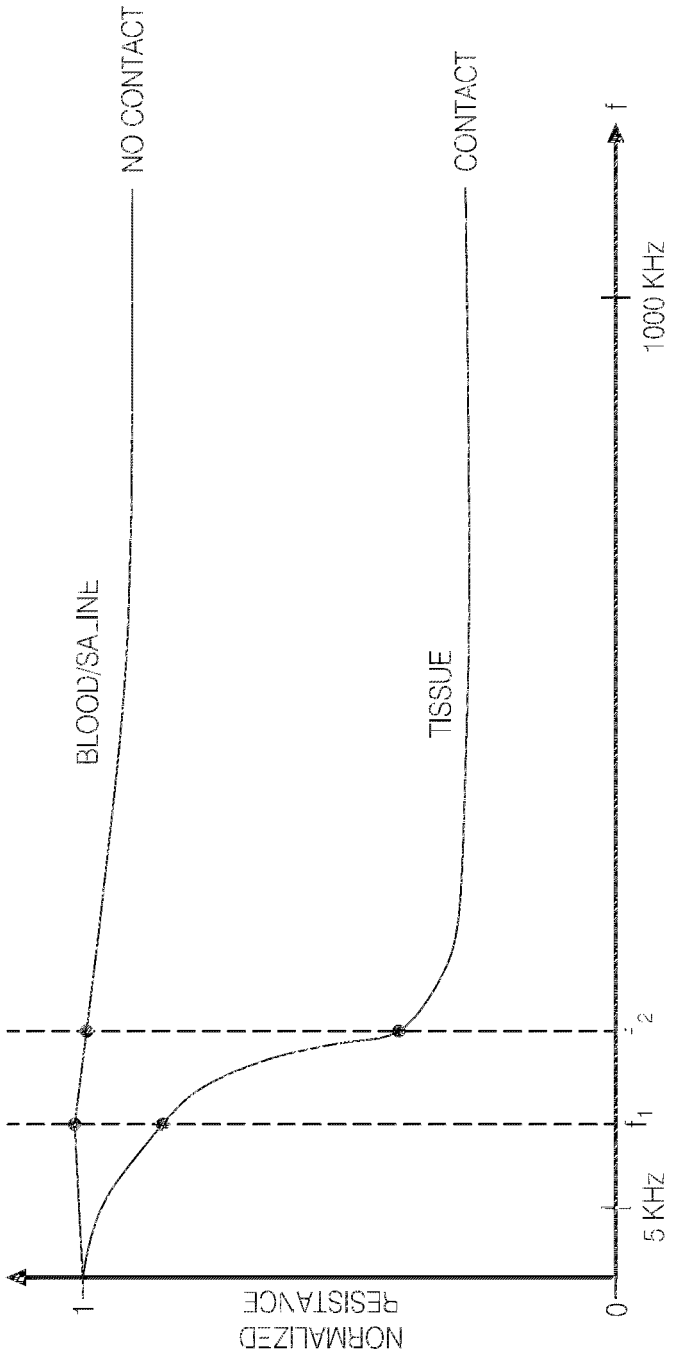
NO CONTACT
CONTACT
BLOOD/SALINE
TISSUE
f
1000 KHz
5 KHz
f_1
f_2
1
0
NORMALIZED
RESISTANCE

FIG. 25A

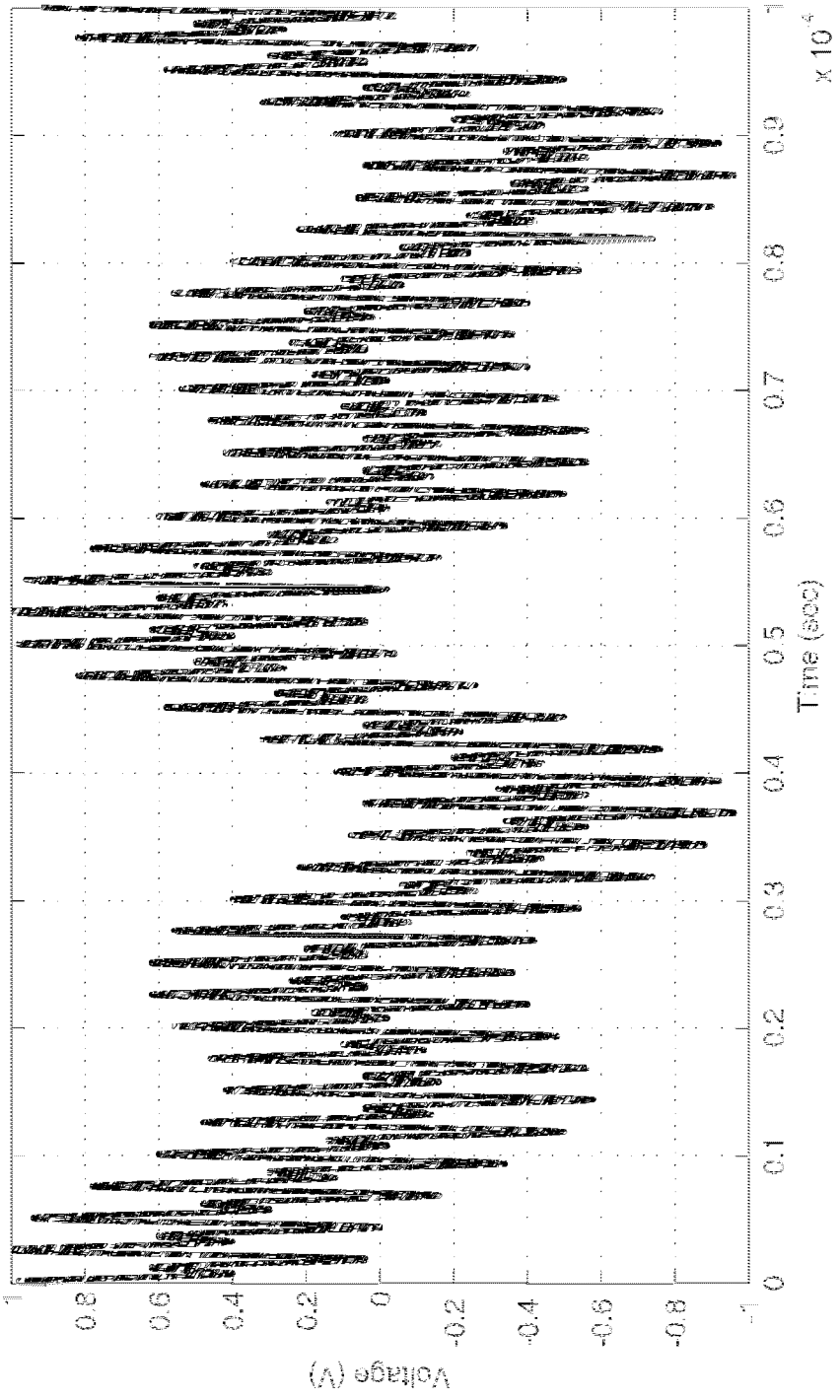
Voltage (V)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time (sec)
x 10^-4

FIG. 25B

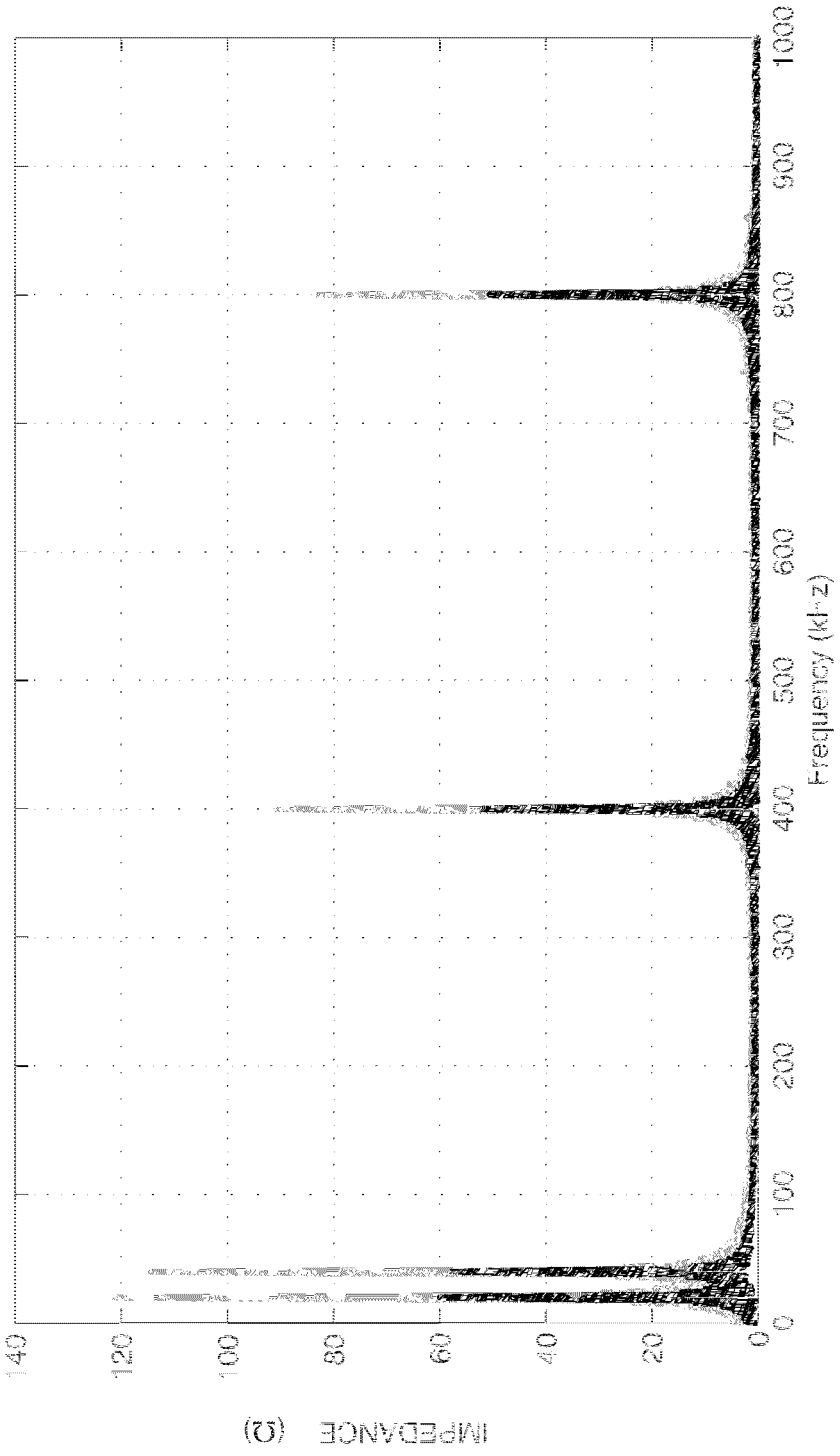
IMPEDANCE (Ω)
140
120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
800
900
1000
Frequency (kHz)

FIG. 25C

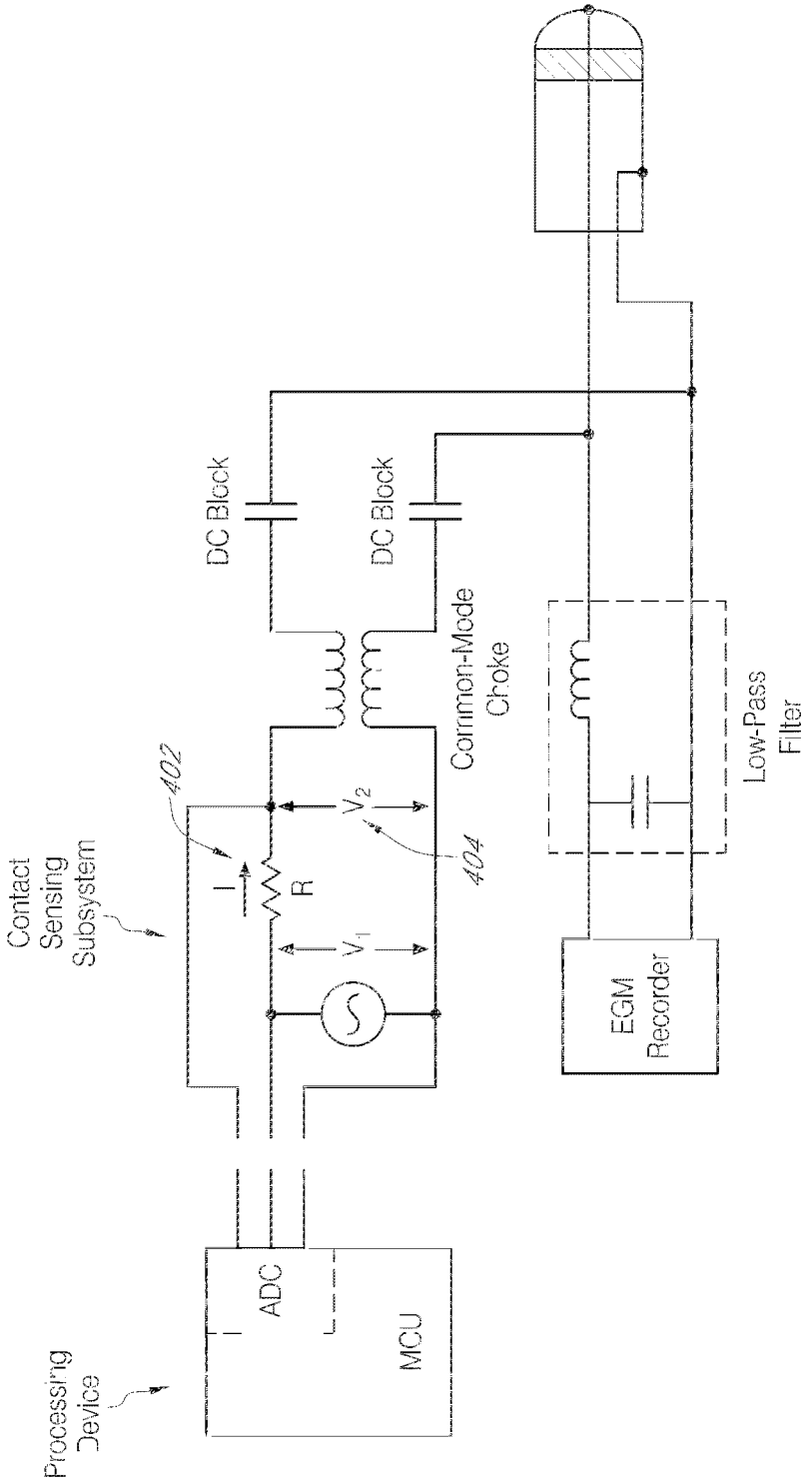
Processing Device
ADC
MCU
Contact Sensing Subsystem
402
I
R
V1
V2
404
DC Block
DC Block
Common-Mode Choke
Low-Pass Filter
EGM Recorder

FIG. 25D

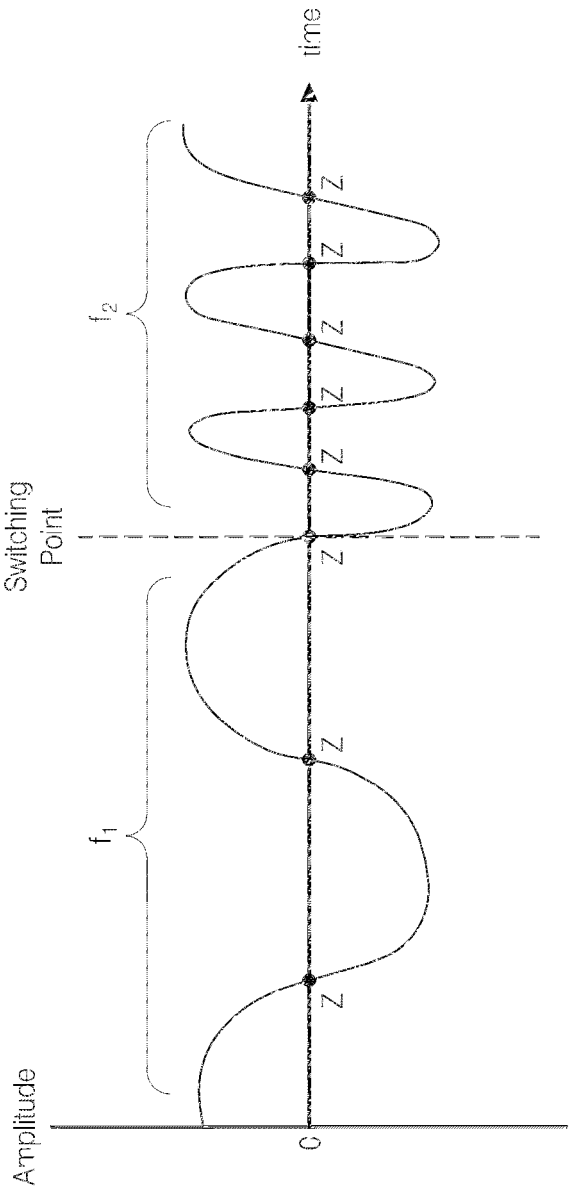

FIG. 26A

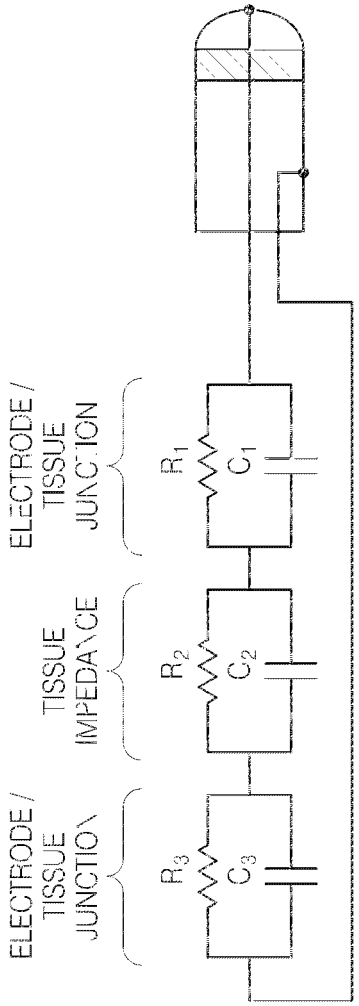
ELECTRODE / TISSUE JUNCTION
TISSUE IMPEDANCE
ELECTRODE / TISSUE JUNCTION
R1
C1
R2
C2
R3
C3

FIG. 26B

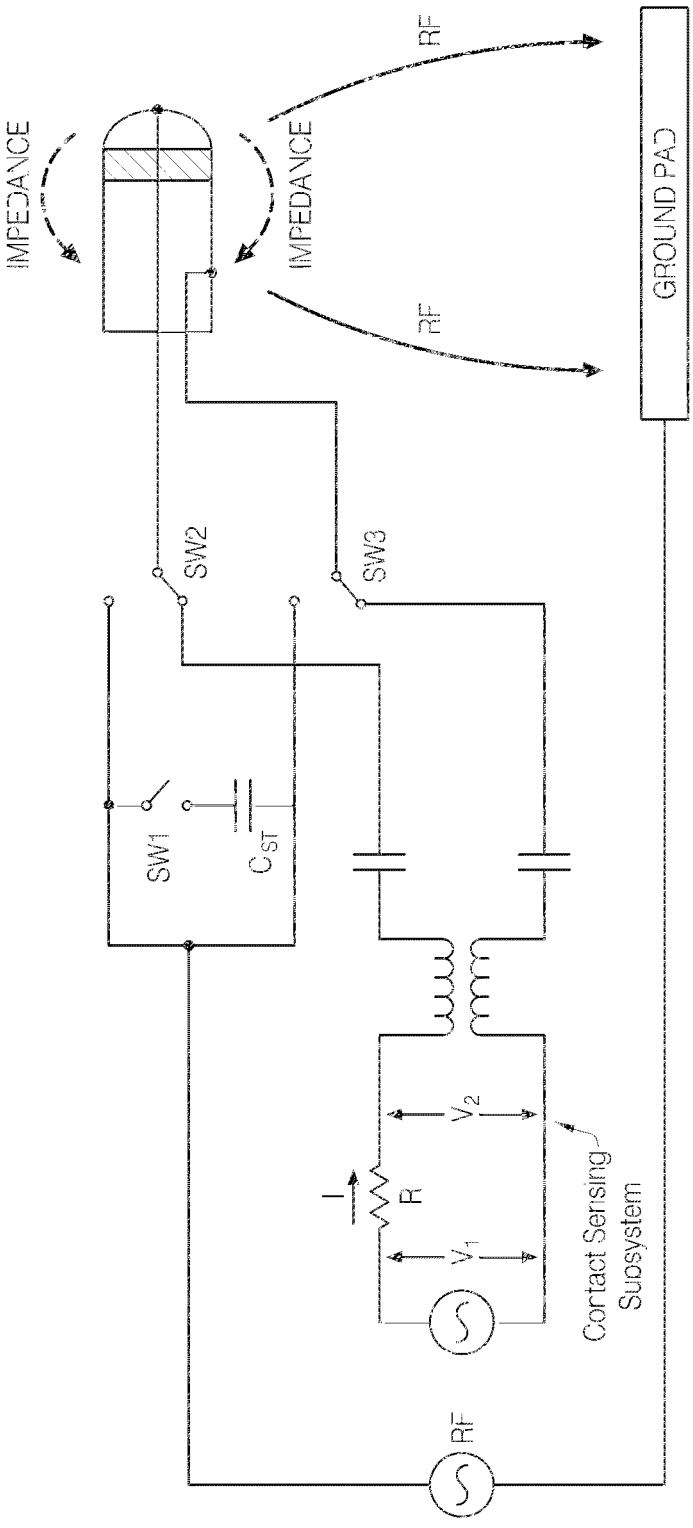
IMPEDANCE
IMPEDANCE
RF
RF
GROUND PAD
SW2
SW3
SW1
C_{ST}
R
V_1
V_2
I
Contact Sensing Subsystem
RF

FIG. 26C

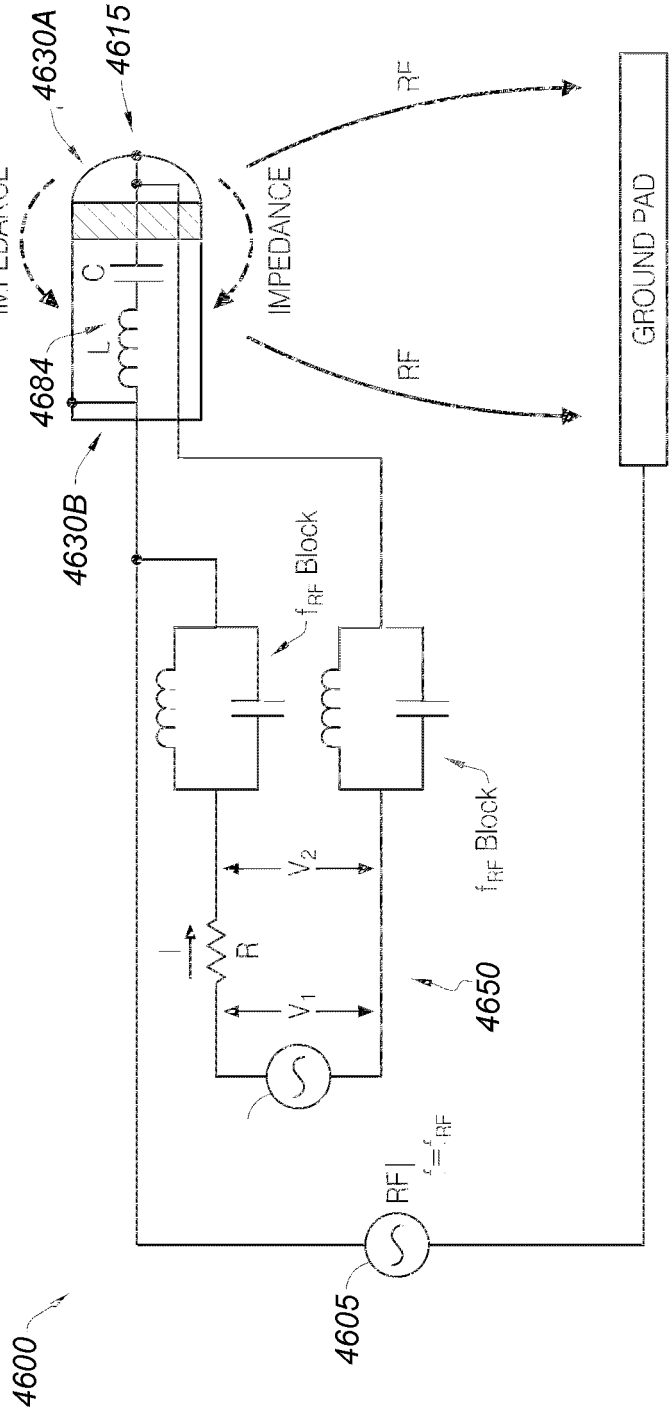
4630A
4615
IMPEDANCE
IMPEDANCE
RF
RF
GROUND PAD
4684
L
C
4630B
f_{RF} Block
f_{RF} Block
V_2
R
V_1
4650
RF
$f = f_{RF}$
4605
4600

FIG. 27

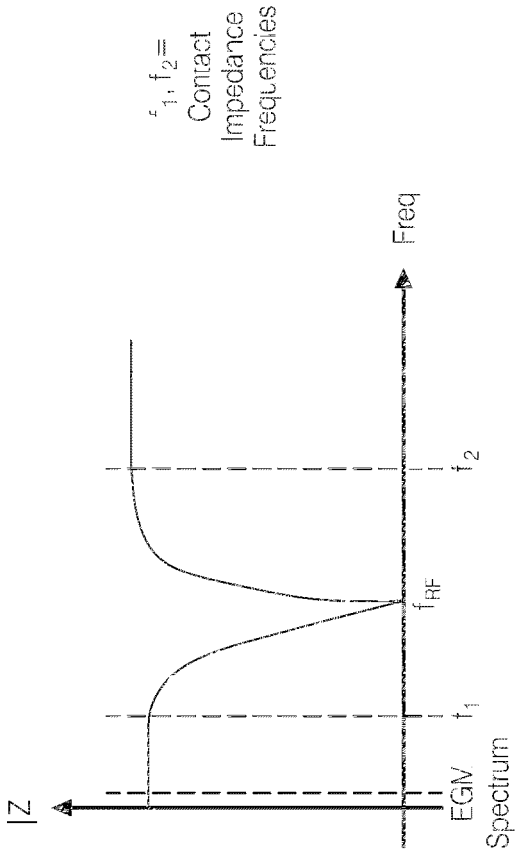
f1, f2 = Contact Impedance Frequencies
Freq
|Z|
EGM Spectrum
f1
fRF
f2

FIG. 28

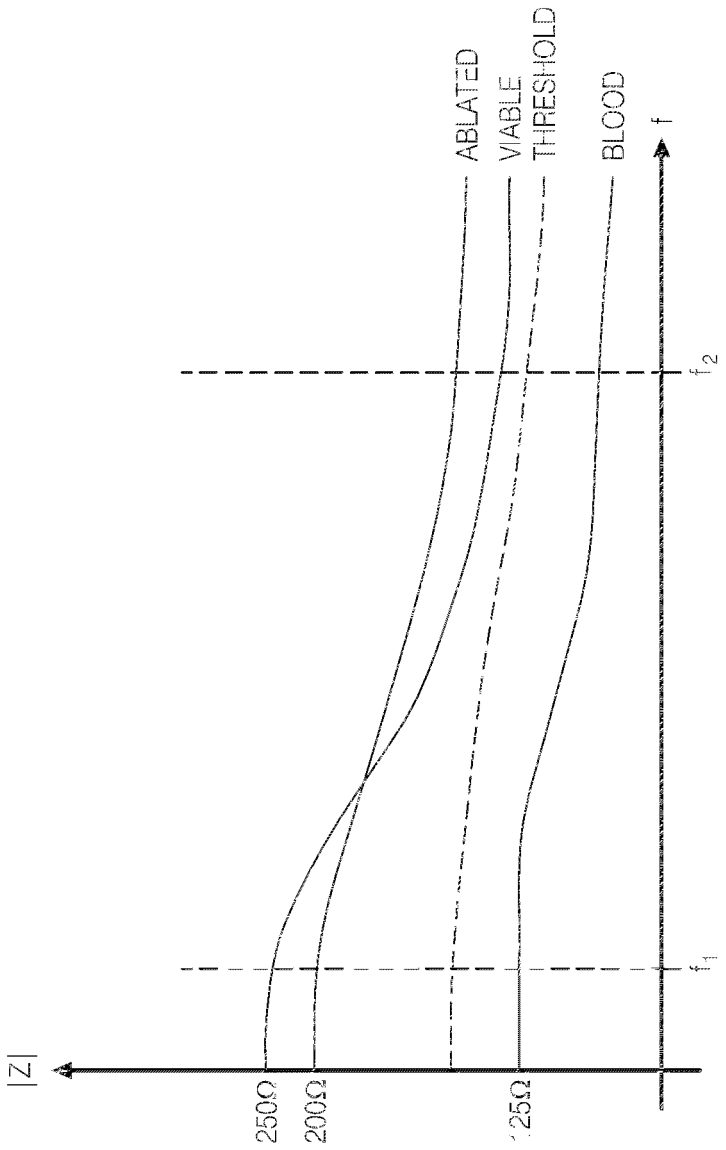

FIG. 29

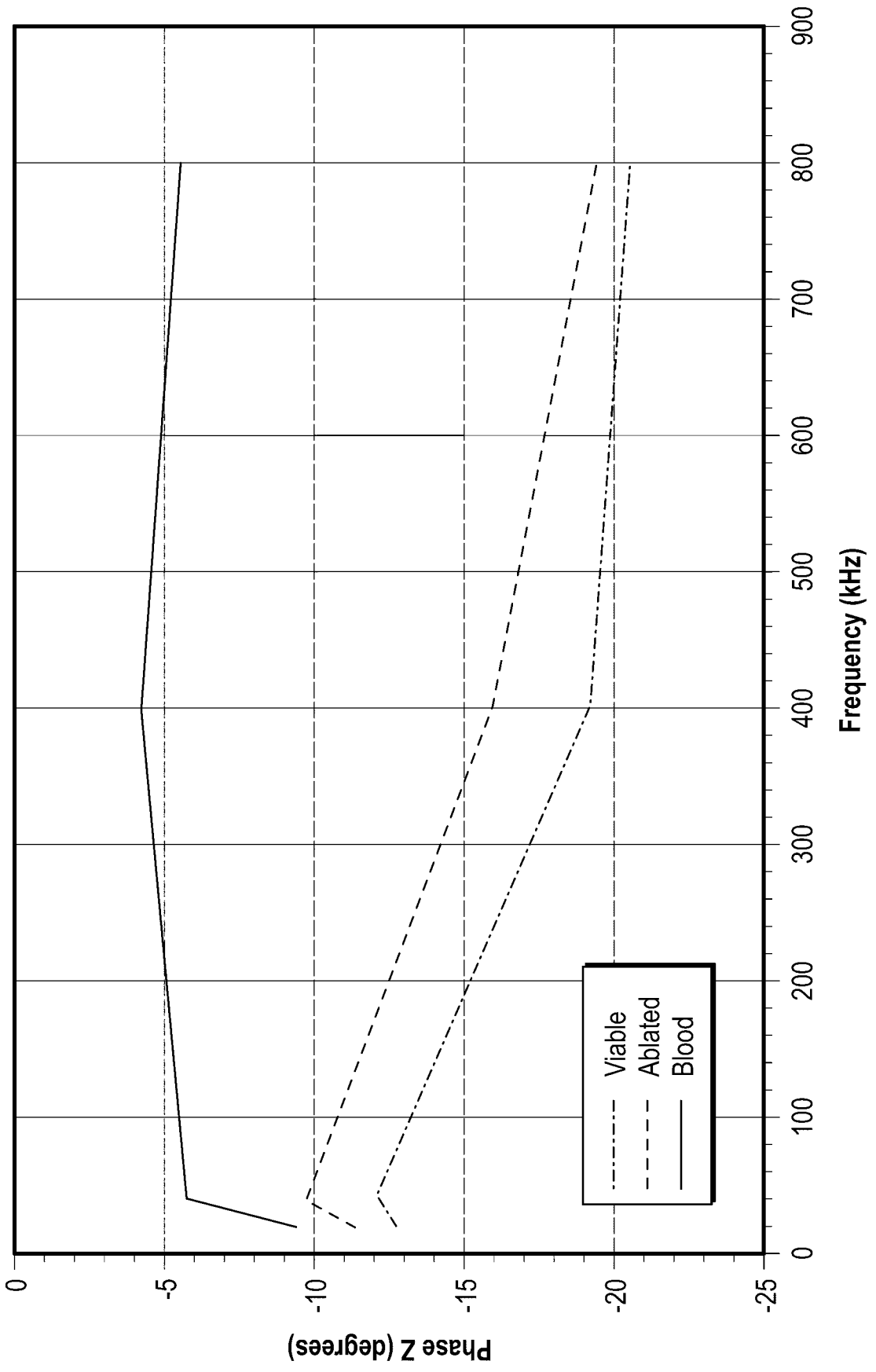
Phase Z (degrees)
0
-5
-10
-15
-20
-25
Frequency (kHz)
0
100
200
300
400
500
600
700
800
900
Viable
Ablated
Blood

FIG. 30

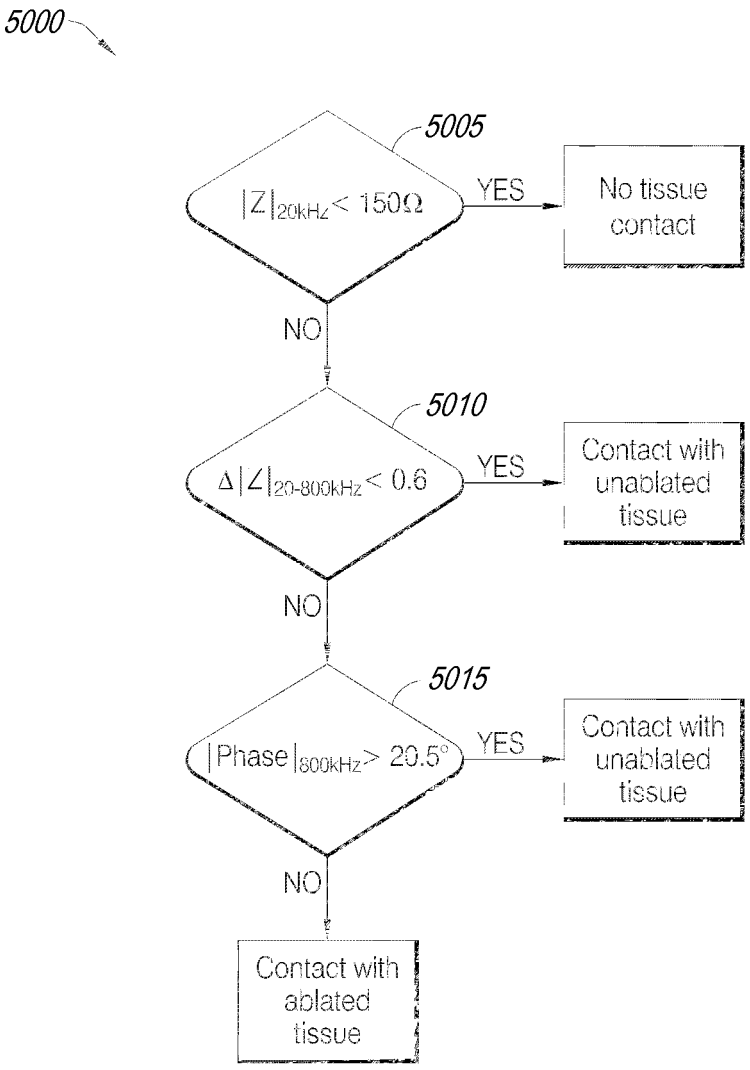
5000
5005
$|Z|_{20kHz} < 150\Omega$
YES
No tissue contact
NO
5010
$\Delta|\angle|_{20\text{-}800kHz} < 0.6$
YES
Contact with unablated tissue
NO
5015
$|Phase|_{800kHz} > 20.5°$
YES
Contact with unablated tissue
NO
Contact with ablated tissue

FIG. 31

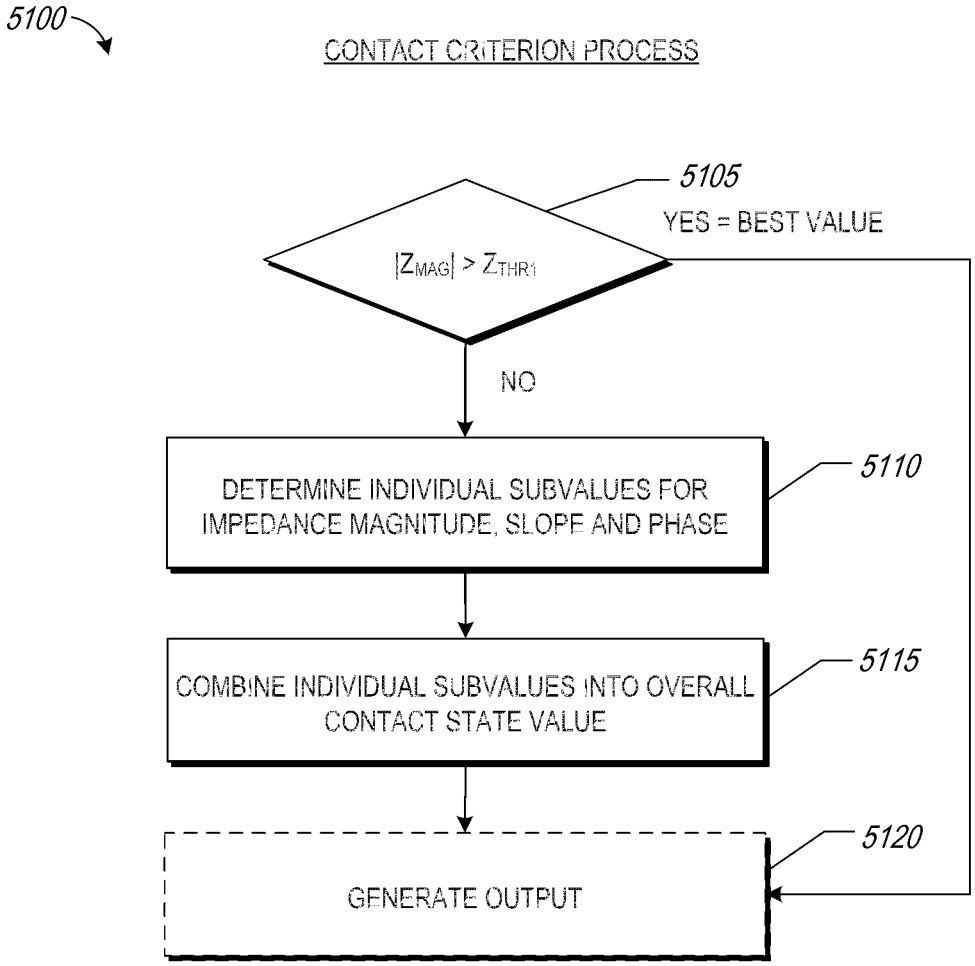
5100
CONTACT CRITERION PROCESS
5105
YES = BEST VALUE
$|Z_{MAG}| > Z_{THR1}$
NO
DETERMINE INDIVIDUAL SUBVALUES FOR IMPEDANCE MAGNITUDE, SLOPE AND PHASE
5110
COMBINE INDIVIDUAL SUBVALUES INTO OVERALL CONTACT STATE VALUE
5115
GENERATE OUTPUT
5120

FIG. 32

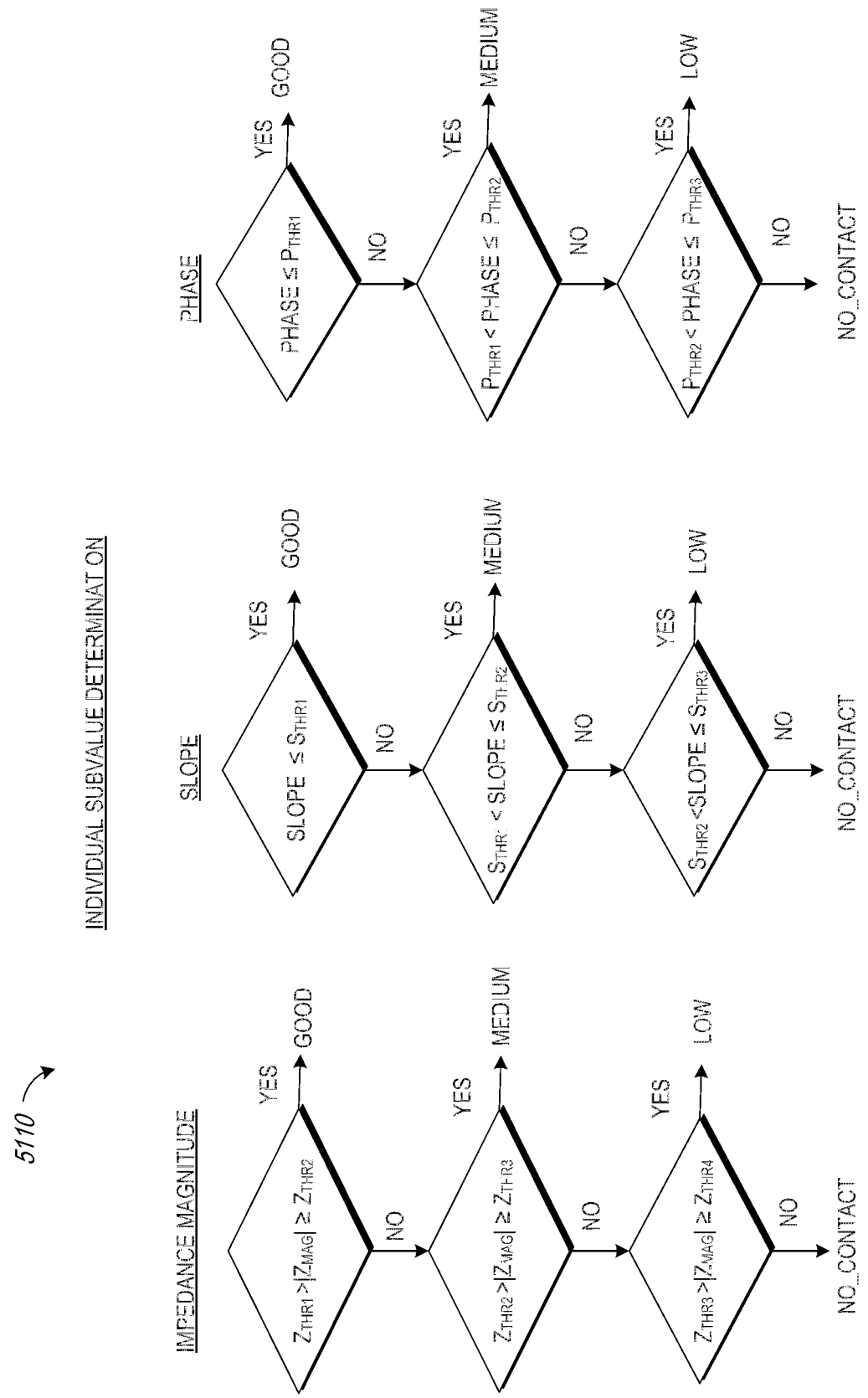
5110
INDIVIDUAL SUBVALUE DETERMINATION
IMPEDANCE MAGNITUDE
SLOPE
PHASE
YES
NO
GOOD
MEDIUM
LOW
NO_CONTACT
$Z_{THR1} > |Z_{MAG}| \geq Z_{THR2}$
$Z_{THR2} > |Z_{MAG}| \geq Z_{THR3}$
$Z_{THR3} > |Z_{MAG}| \geq Z_{THR4}$
SLOPE $\leq S_{THR1}$
$S_{THR1} <$ SLOPE $\leq S_{THR2}$
$S_{THR2} <$SLOPE $\leq S_{THR3}$
PHASE $\leq P_{THR1}$
$P_{THR1} <$ PHASE $\leq P_{THR2}$
$P_{THR2} <$ PHASE $\leq P_{THR3}$

FIG. 32A

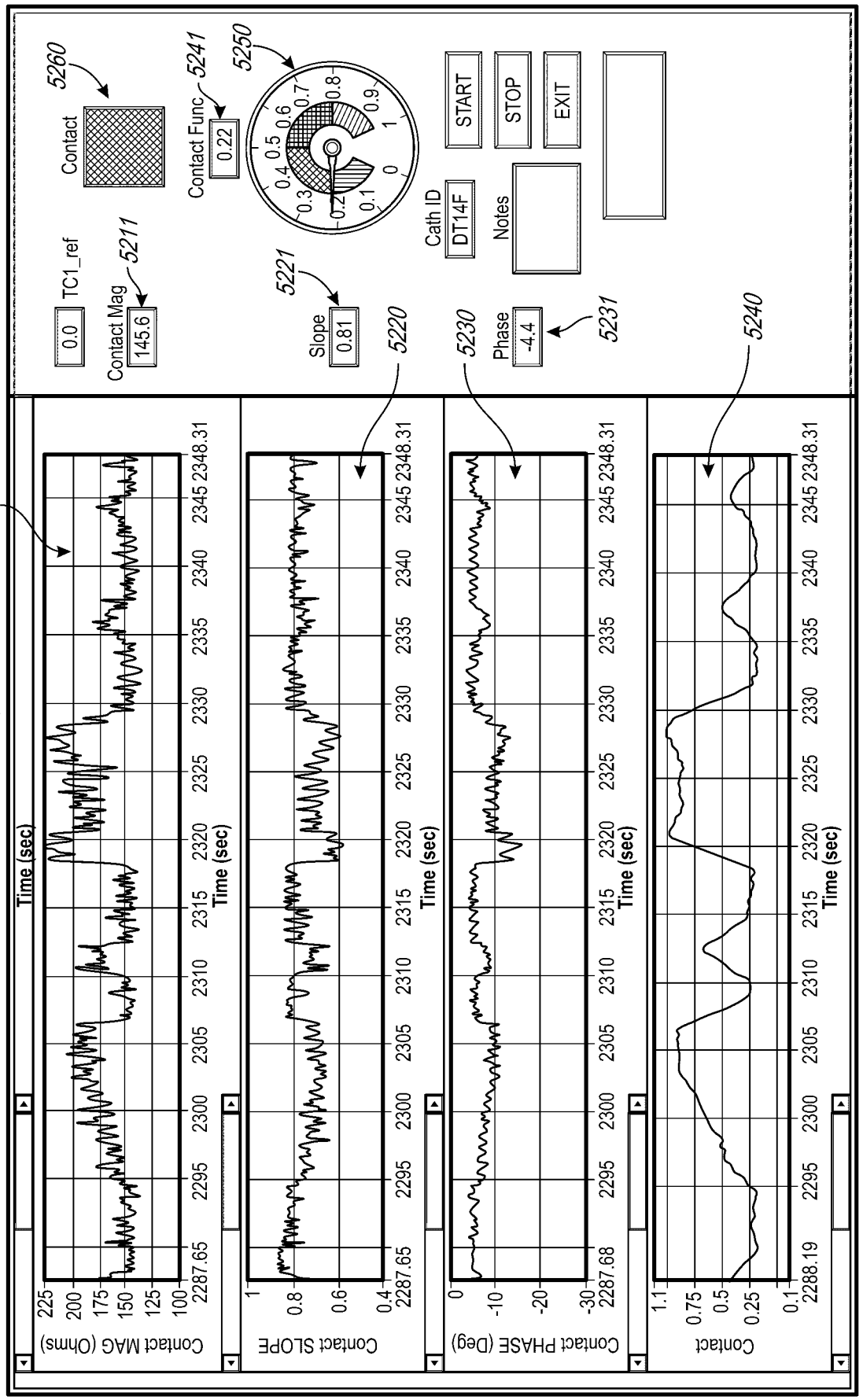
5200
5210
5211
5220
5221
5230
5231
5240
5241
5250
5260
TC1_ref
0.0
Contact Mag
145.6
Slope
0.81
Phase
-4.4
Contact Func
0.22
Contact
Cath ID
DT14F
Notes
START
STOP
EXIT
Contact MAG (Ohms)
Contact SLOPE
Contact PHASE (Deg)
Contact
Time (sec)

FIG. 33

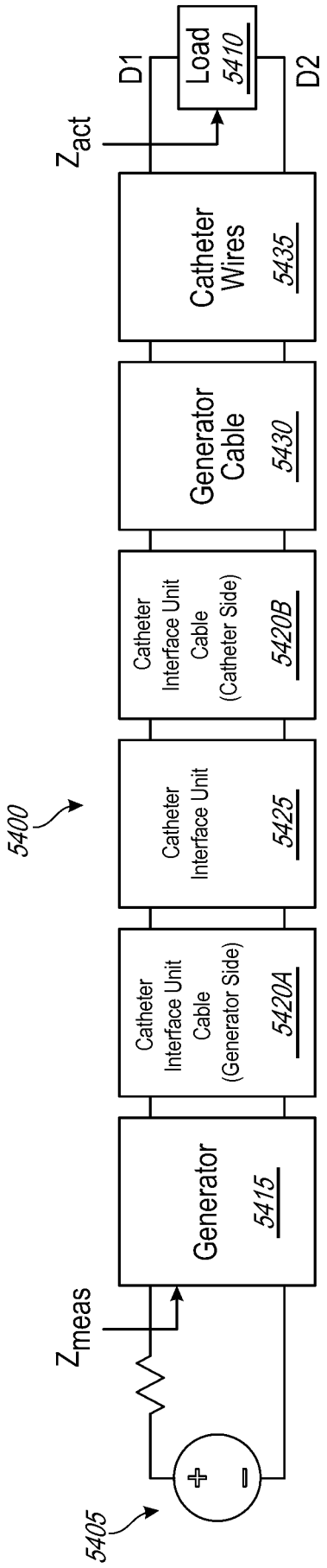

FIG. 34A

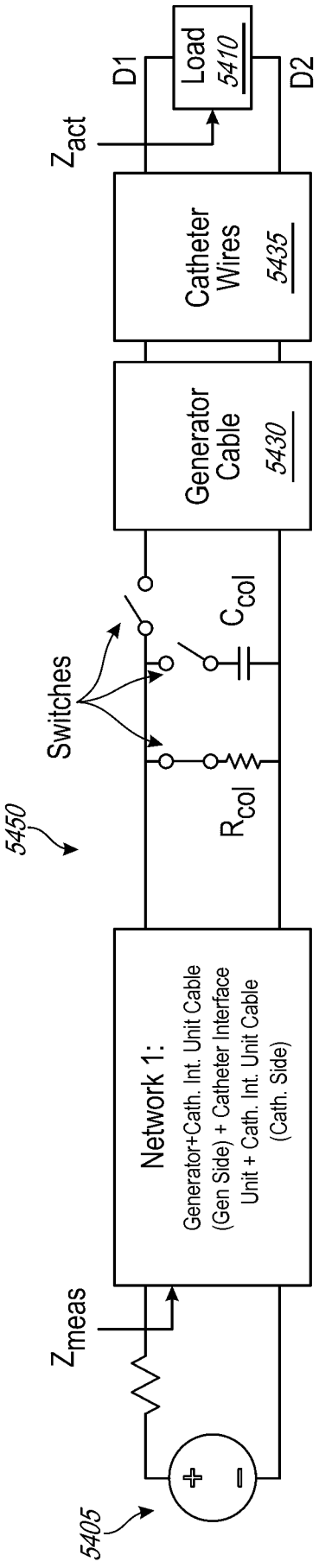

FIG. 34B

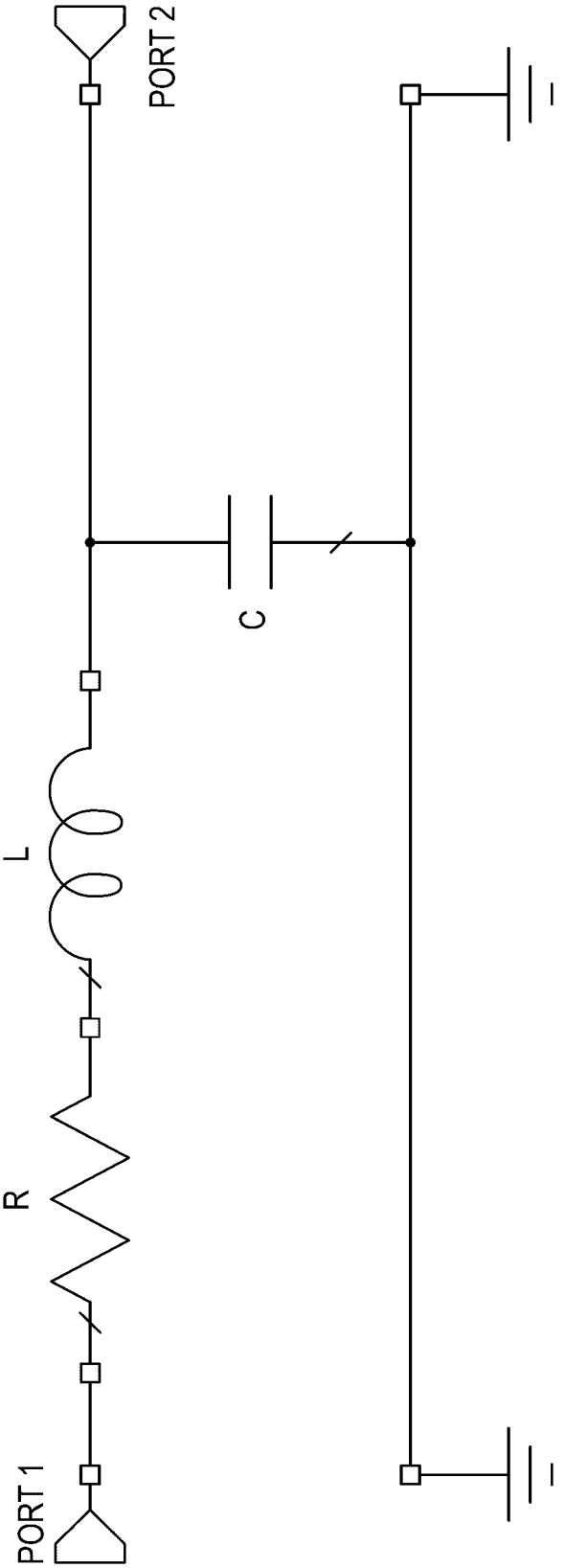

FIG. 34C

WO 2016/081650 PCT/US2015/061419

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US15/61419

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: -***-See Supplemental Page-***-
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-16 are directed toward an electrical separator in a cardiac electrode.
Group II: Claims 31-33, 53-56, 77-82, and 96 are directed toward a filtering element electrically coupling the first electrode to the second electrode.
Group III: Claims 101-106, 121-127, 133-146, 154-160, 168-171, and 182-185 are directed toward a thermal shunt in a cardiac electrode.
Group IV: Claims 201-205, 211-218, 238-244, 254-256, 263-267, 273-276, 279-281, and 285-300 are directed toward temperature-measurement devices in a cardiac electrode.
Group V: Claims 301-303, 322-325, 340-342, 357, 359-361, 364, 378-383, 391-394, 404-409, 418-423, and 433-436 are directed toward an impedance sensing system in a cardiac electrode.
-***-See Supplemental Page-***-

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-16

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.