US012390264B2

(12) United States Patent
Witt et al.

(10) **Patent No.:** **US 12,390,264 B2**

(45) **Date of Patent:** **Aug. 19, 2025**

(54) **SYSTEMS AND METHODS FOR MANAGING FLUID AND SUCTION IN ELECTROSURGICAL SYSTEMS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1087 days.

(21) Appl. No.: **17/320,941**

(22) Filed: **May 14, 2021**

(65) **Prior Publication Data**

US 2021/0338309 A1 Nov. 4, 2021

Related U.S. Application Data

(62) Division of application No. 15/720,831, filed on Sep. 29, 2017, now Pat. No. 11,033,323.

(51) **Int. Cl.**

A61B 18/14 (2006.01)
A61B 18/00 (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***A61B 18/14*** (2013.01); ***A61B 18/1402*** (2013.01); *A61B 2018/00023* (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC . A61B 18/14; A61B 18/1442; A61B 18/1402; A61B 18/1492;

(Continued)

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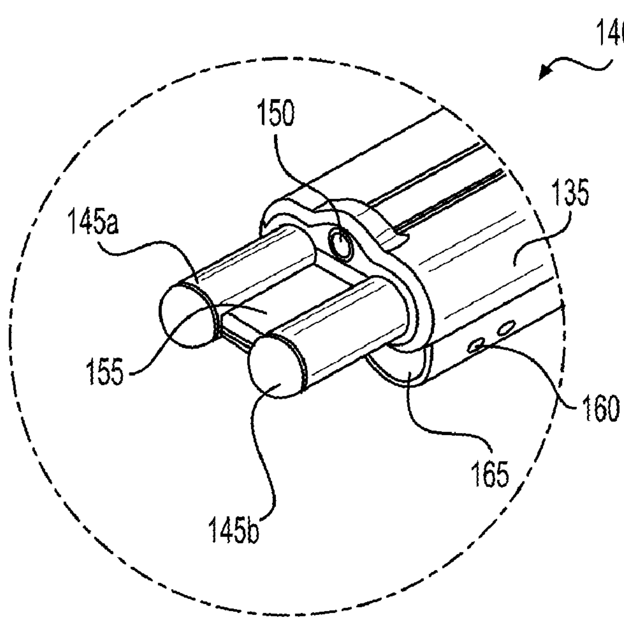
Primary Examiner — Thomas A Giuliani

(57) **ABSTRACT**

Aspects of the present disclosure include control systems of an electrosurgical system for managing the flow of fluid, such as saline, and rates of aspiration or suction, in response to various states of conditions at a surgical site. The control system(s) may monitor and adjust to impedance at the surgical site, temperature of the surgical tissue, and/or RF current of electrodes, and may account for certain undesirable conditions, such as the electrodes sticking. The control systems may include various automatic sensing scenarios, while also allowing for several manual conditions.

14 Claims, 26 Drawing Sheets



(51) **Int. Cl.**
A61B 18/04 (2006.01)
A61B 18/12 (2006.01)
A61M 39/28 (2006.01)

(52) **U.S. Cl.**
CPC *A61B 2018/00035* (2013.01); *A61B 2018/00196* (2013.01); *A61B 2018/00589* (2013.01); *A61B 2018/00595* (2013.01); *A61B 2018/00648* (2013.01); *A61B 2018/00678* (2013.01); *A61B 2018/00744* (2013.01); *A61B 2018/00779* (2013.01); *A61B 2018/00791* (2013.01); *A61B 2018/00827* (2013.01); *A61B 2018/00863* (2013.01); *A61B 2018/00875* (2013.01); *A61B 2018/00892* (2013.01); *A61B 2018/00922* (2013.01); *A61B 2018/00946* (2013.01); *A61B 2018/00952* (2013.01); *A61B 2018/048* (2013.01); *A61B 2018/126* (2013.01); *A61B 2018/1465* (2013.01); *A61B 2218/002* (2013.01); *A61B 2218/007* (2013.01); *A61M 39/283* (2013.01); *A61M 39/288* (2013.01)

(58) **Field of Classification Search**
CPC .. A61B 2018/1472; A61B 2018/00011; A61B 2018/00023; A61B 2018/00029; A61B 2018/00035; A61B 2018/00636; A61B 2018/00642; A61B 2018/00648; A61B 2018/00744; A61B 2018/00791; A61B 2018/00827; A61B 2018/00863; A61B 2018/00875; A61B 2018/00589; A61B 2018/00595; A61B 2018/00678; A61B 2018/00779; A61B 2018/00892; A61B 2018/048; A61B 2018/126; A61B 2218/002; A61B 2218/007
USPC 606/34, 38, 42, 49, 51, 52; 607/104, 607/105, 115, 116
See application file for complete search history.

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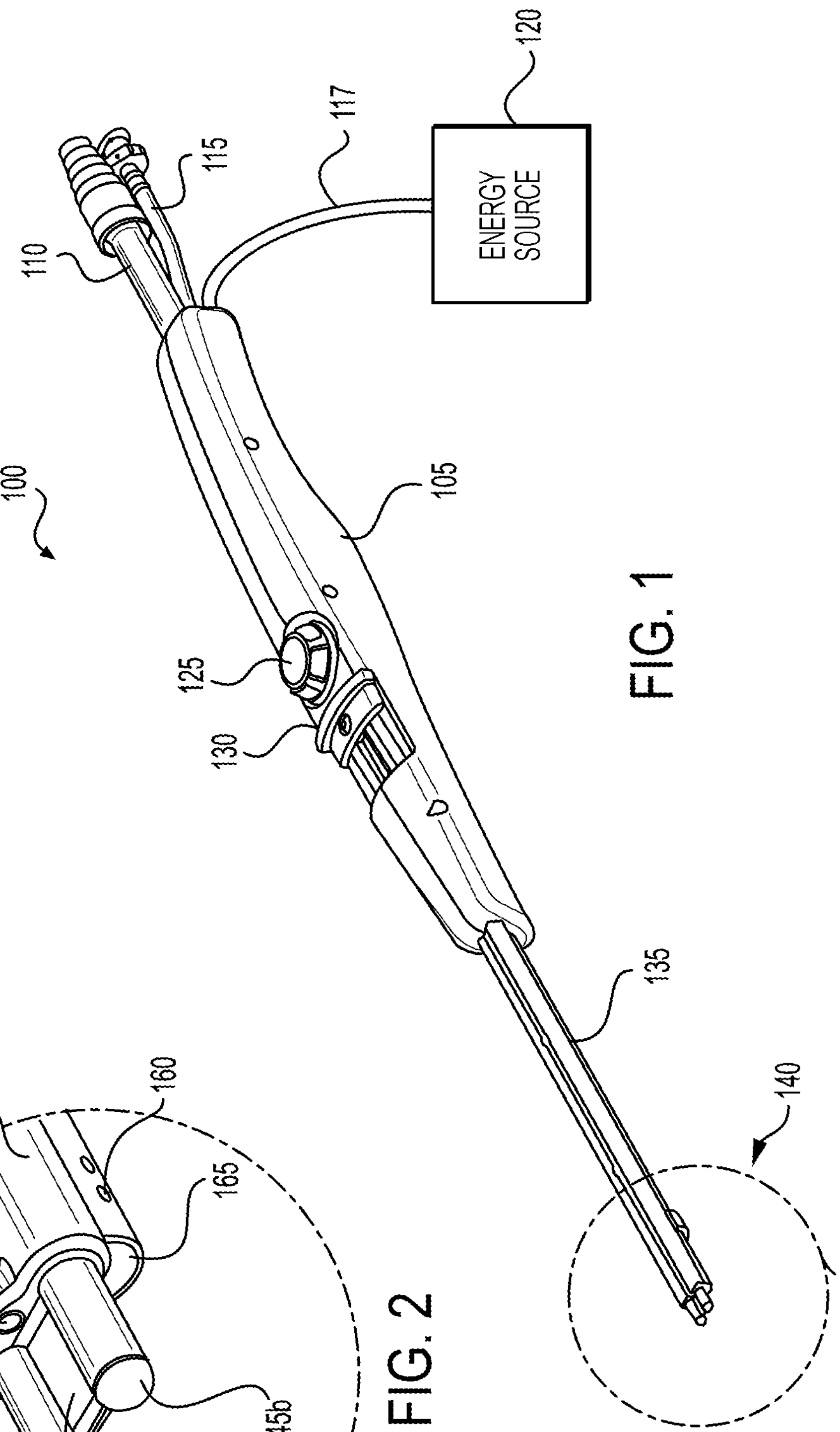
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110
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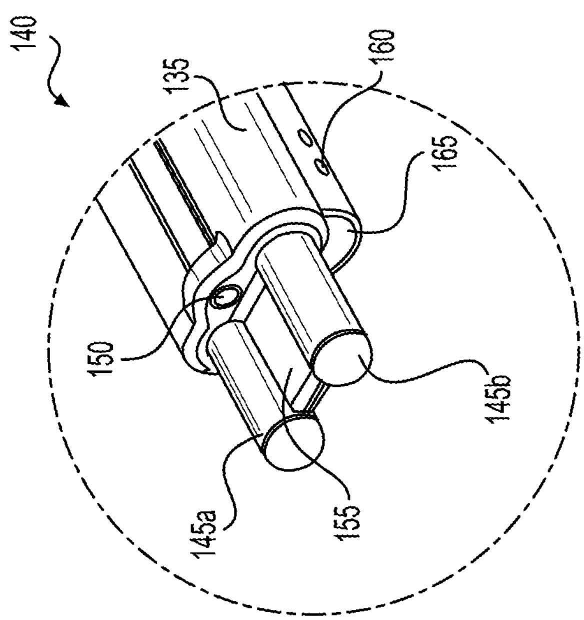
SEE FIG. 2

FIG. 1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145a
155

FIG. 2

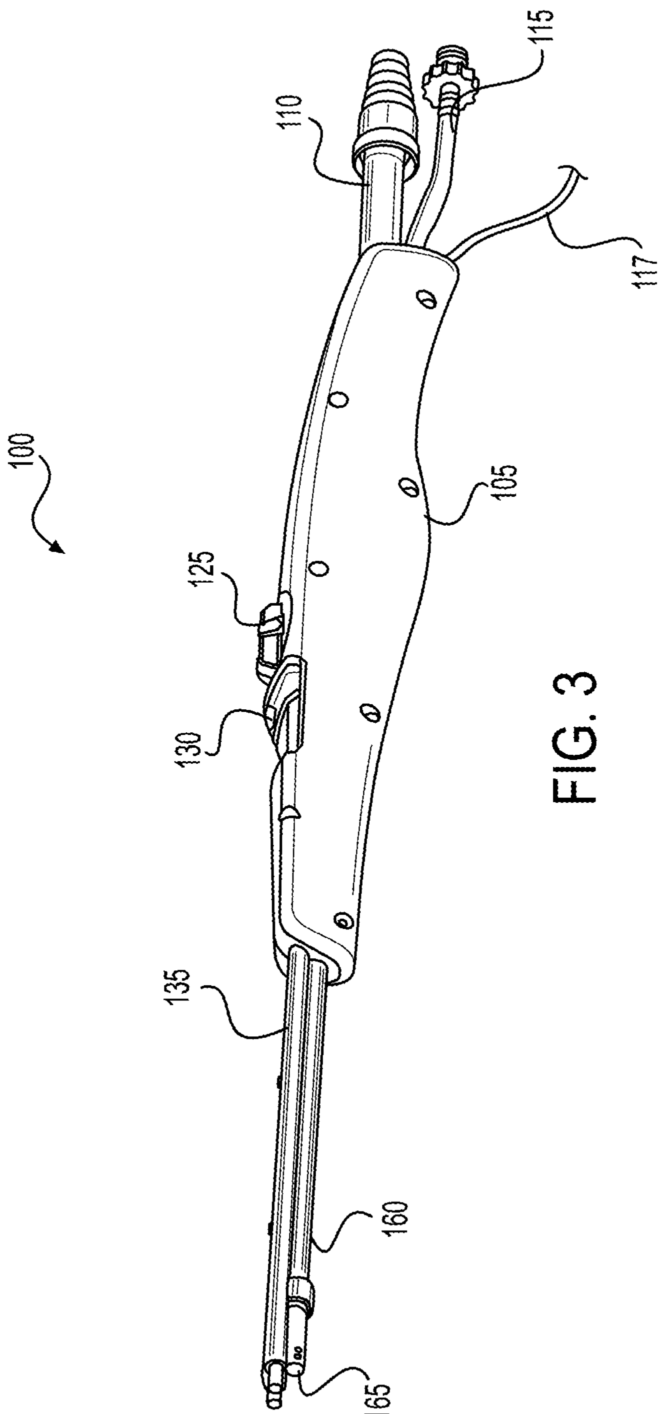


FIG. 3

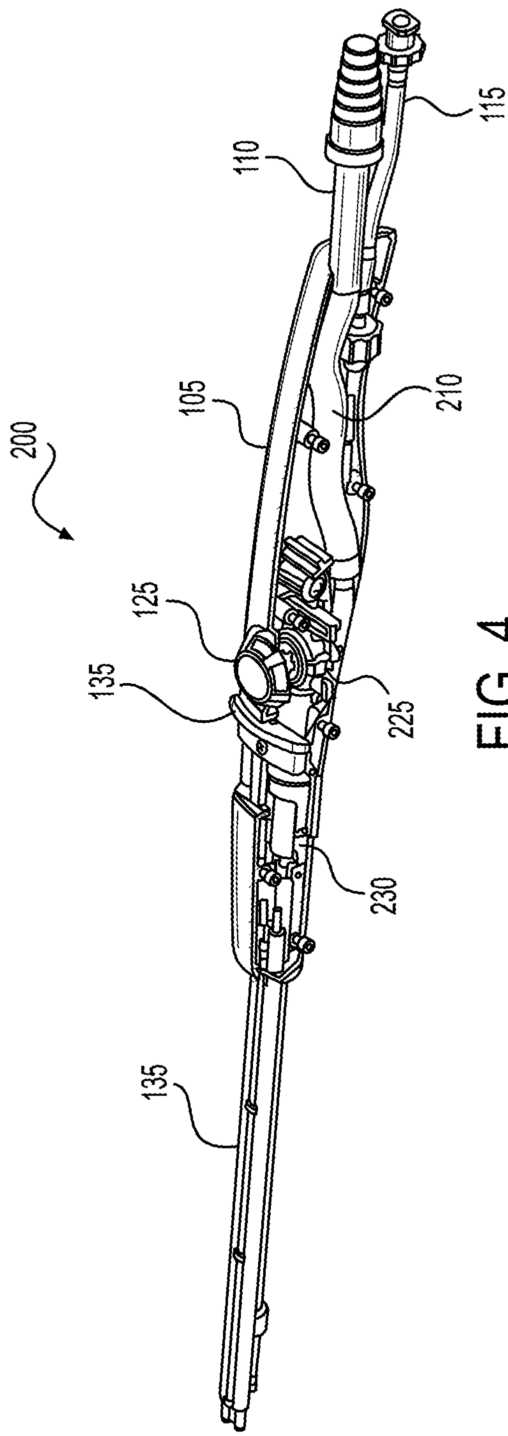


FIG. 4

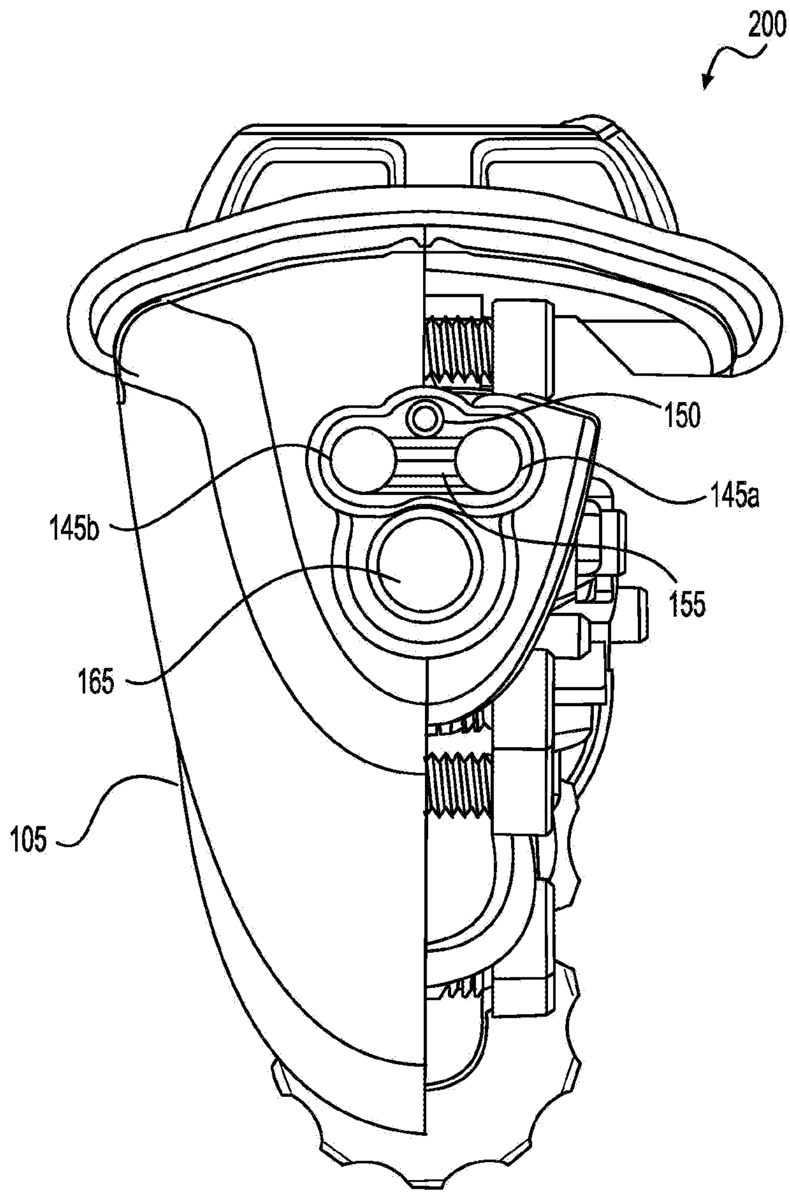


FIG. 5

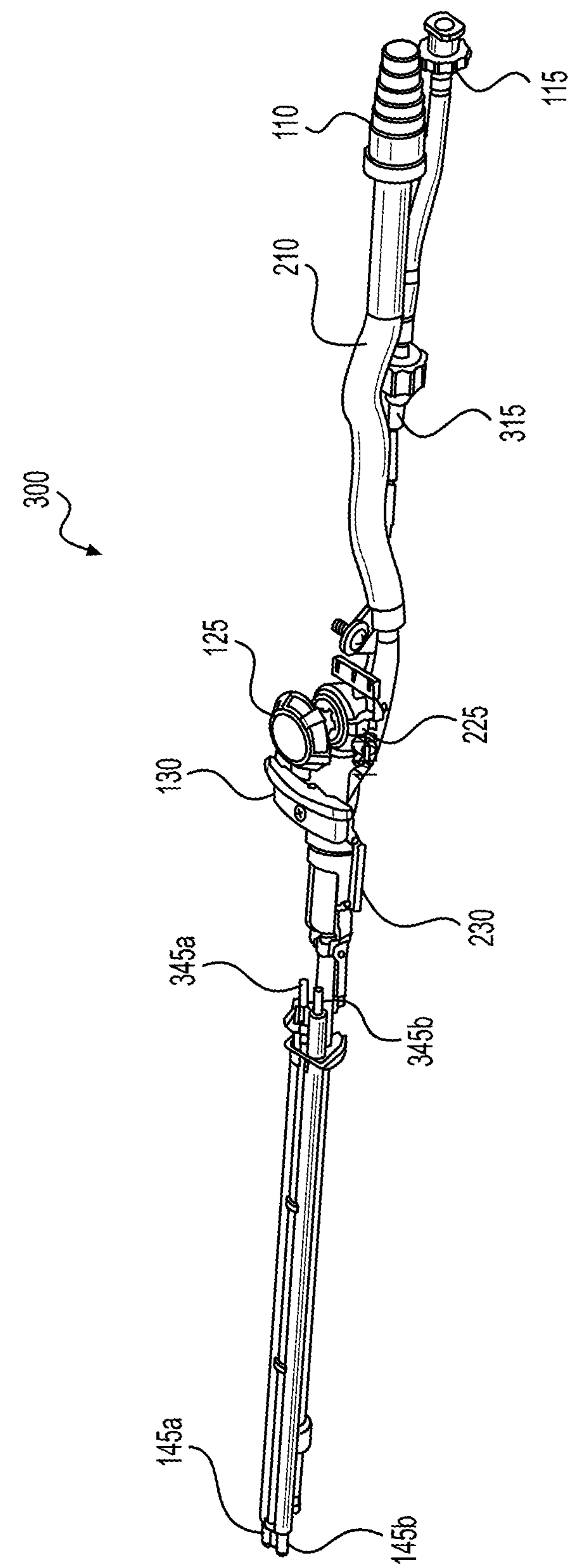


FIG. 6

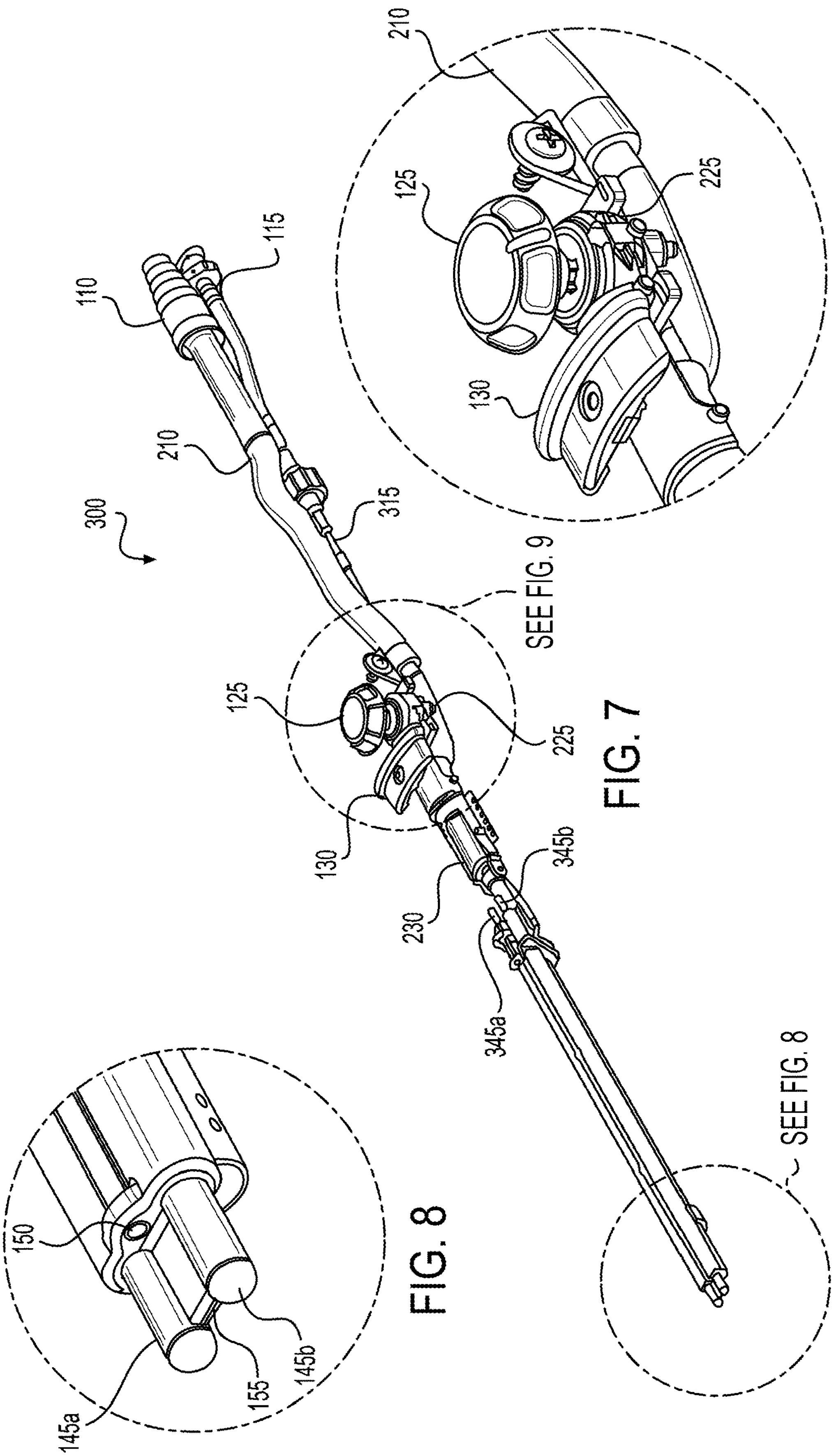


FIG. 9

FIG. 7

FIG. 8

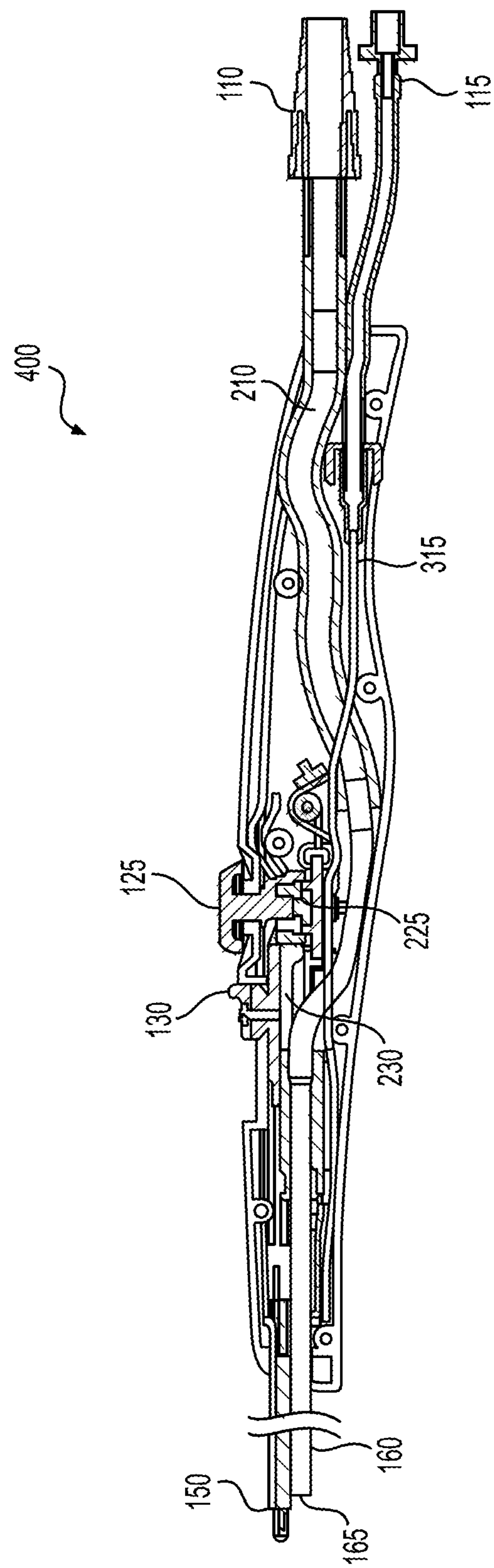


FIG. 10

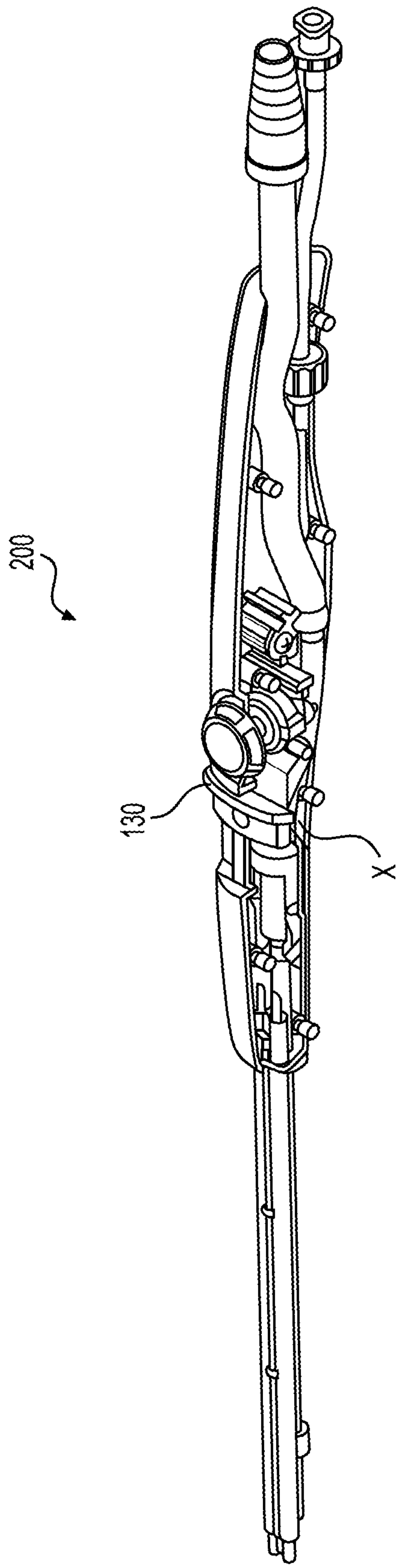


FIG. 11

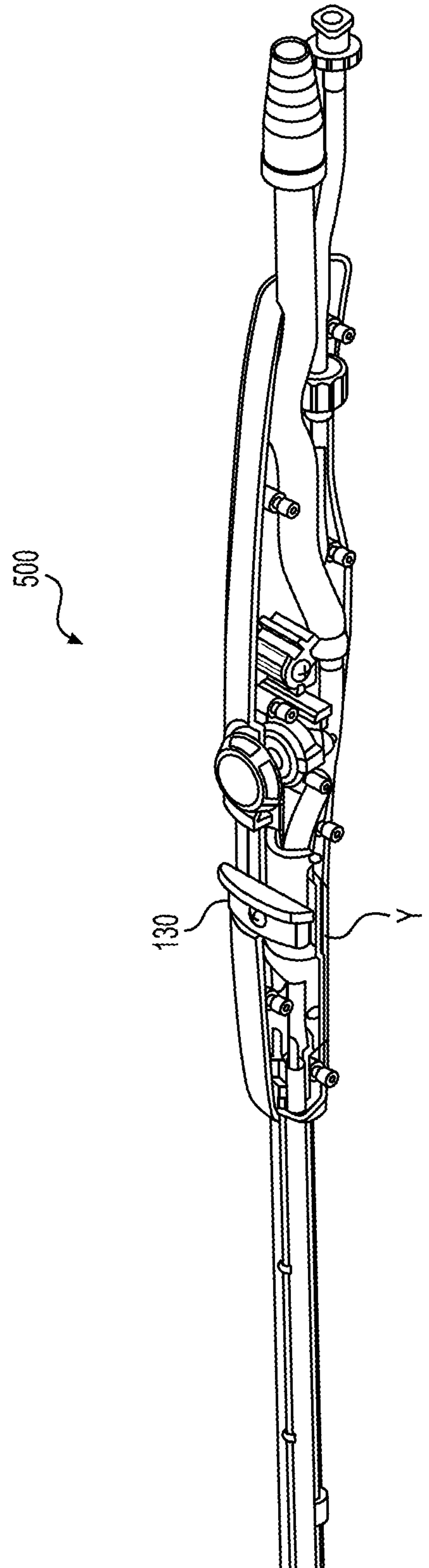


FIG. 12

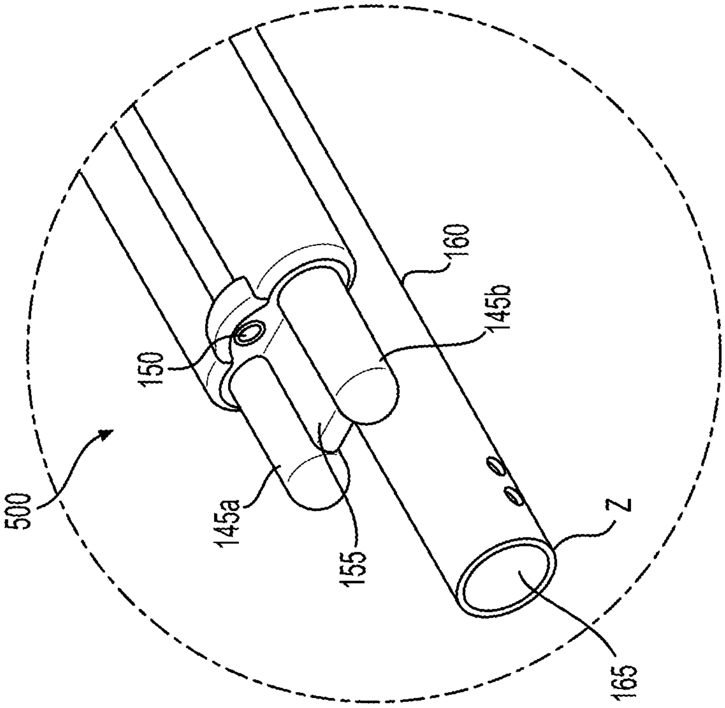

500
160
145b
150
145a
155
Z
165

FIG. 14

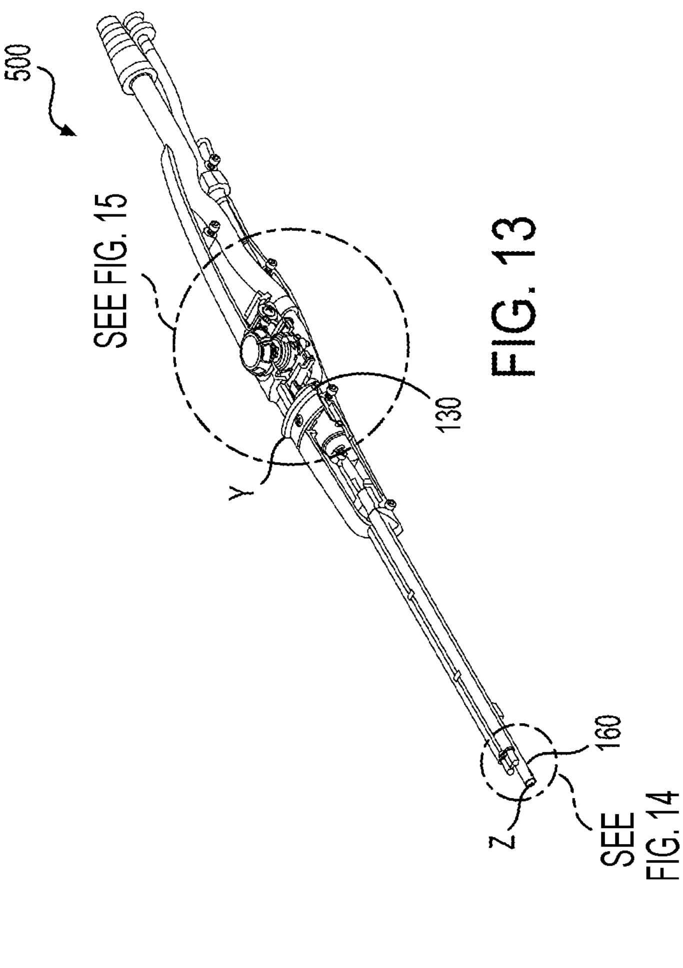

500
SEE FIG. 15
130
Y
160
Z
SEE
FIG. 14

FIG. 13

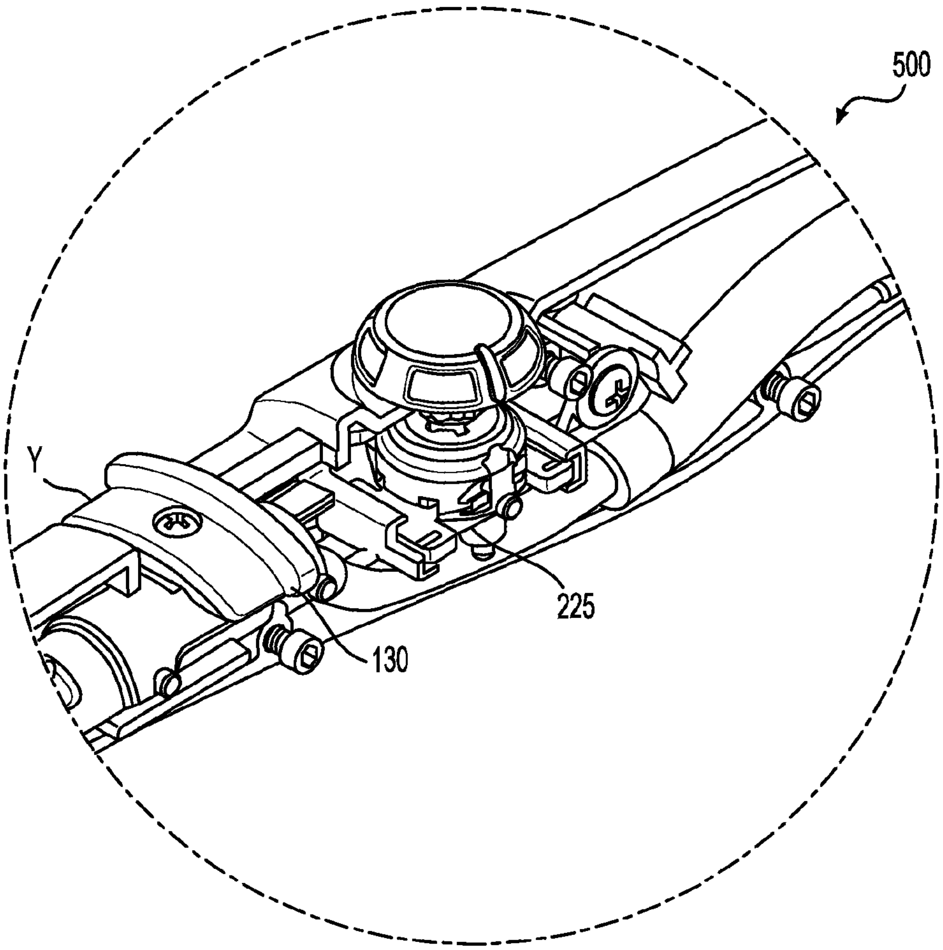


FIG. 15

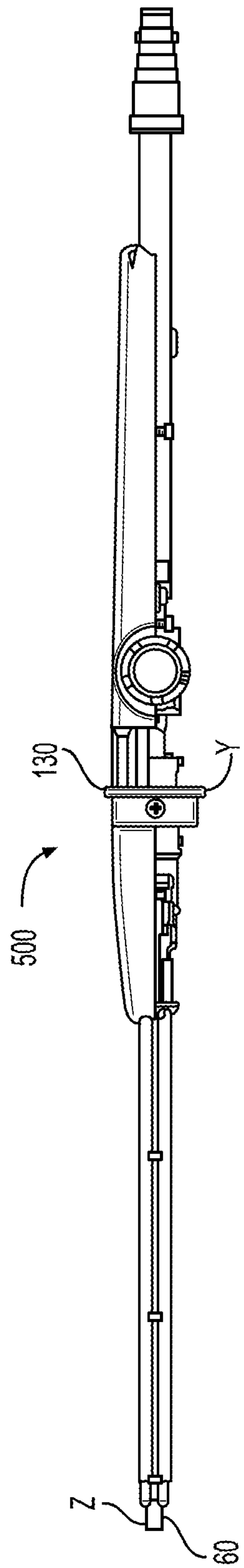


FIG. 16

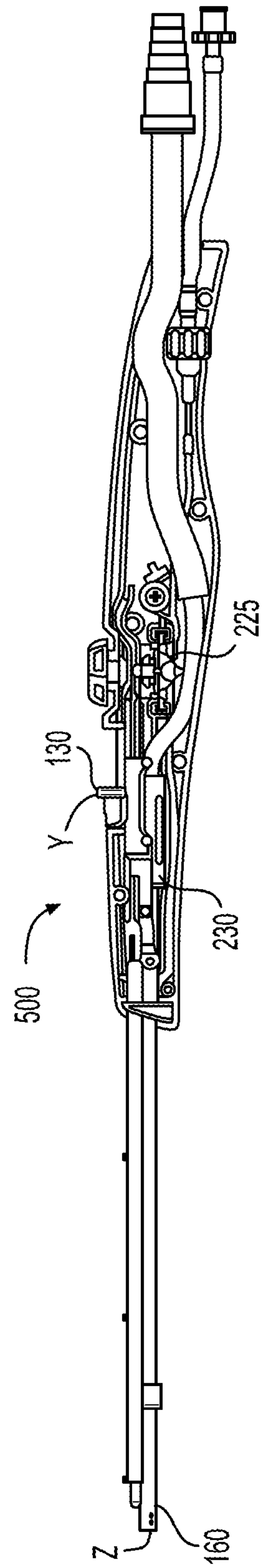


FIG. 17

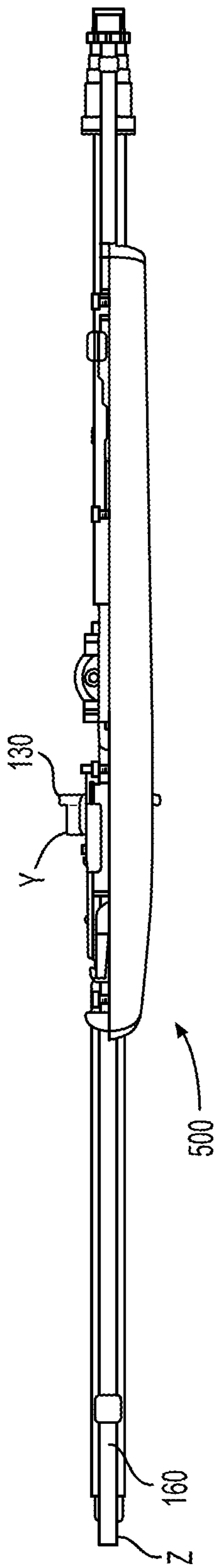


FIG. 18

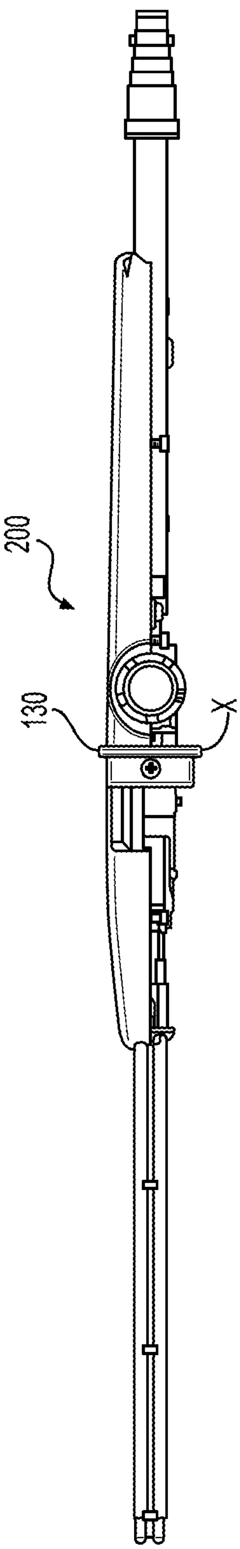


FIG. 19

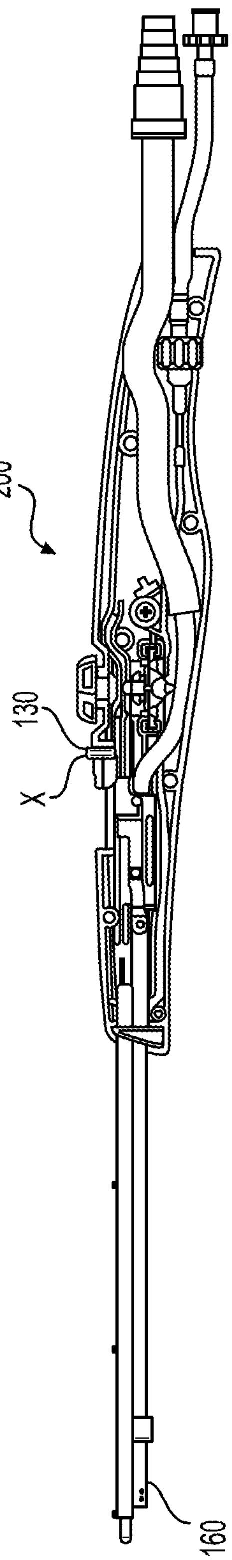


FIG. 20

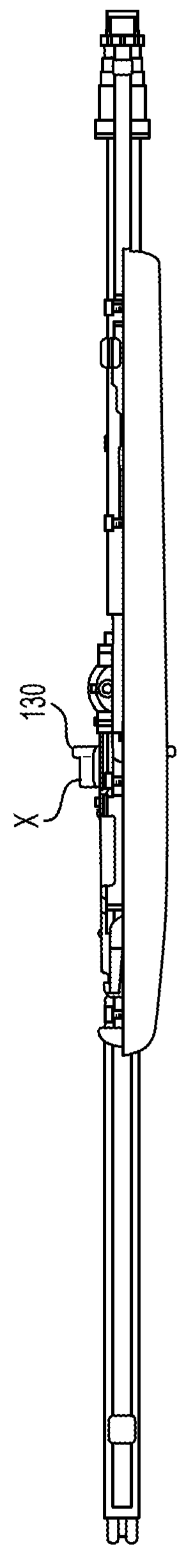


FIG. 21

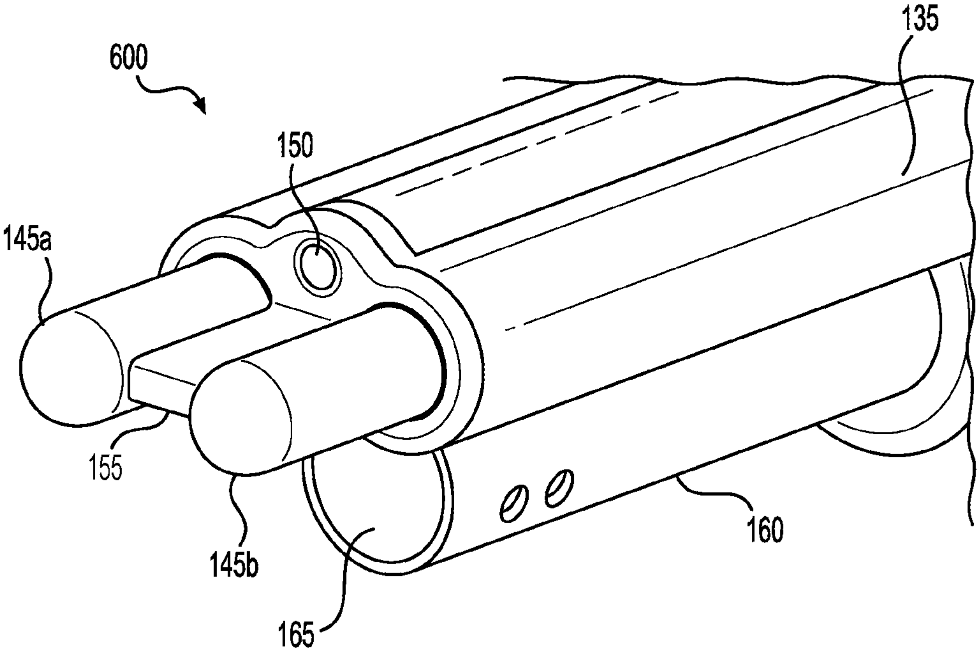


FIG. 22

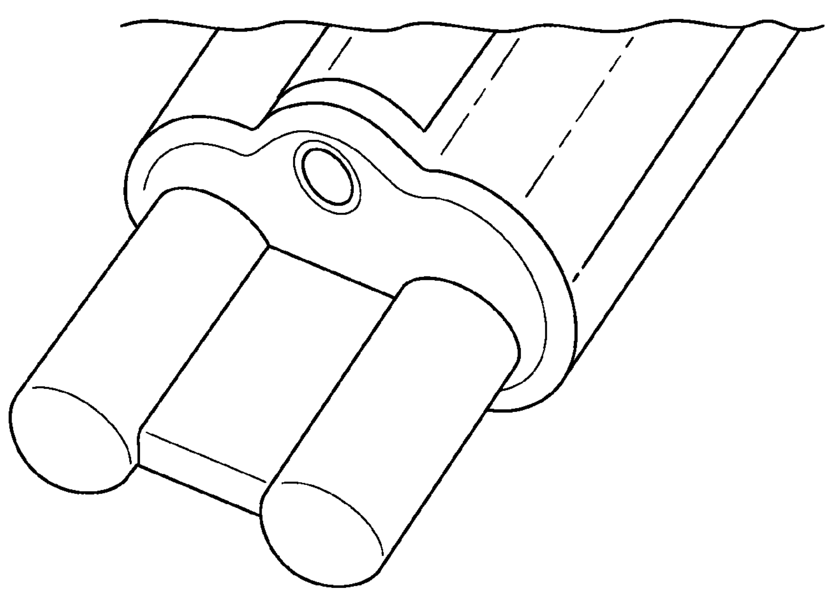


FIG. 23

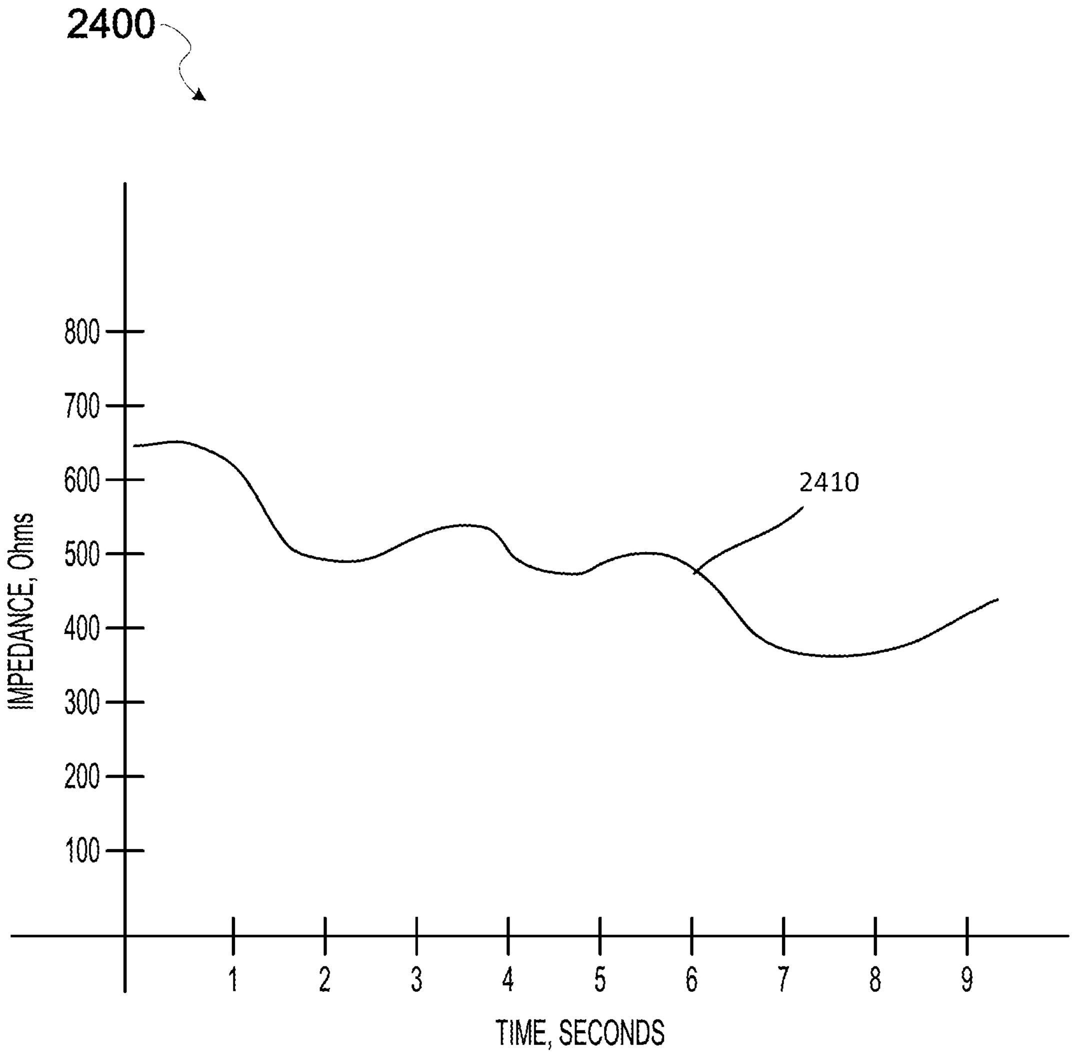

2400
800
700
600
500
400
300
200
100
IMPEDANCE, Ohms
2410
1
2
3
4
5
6
7
8
9
TIME, SECONDS

FIG. 24

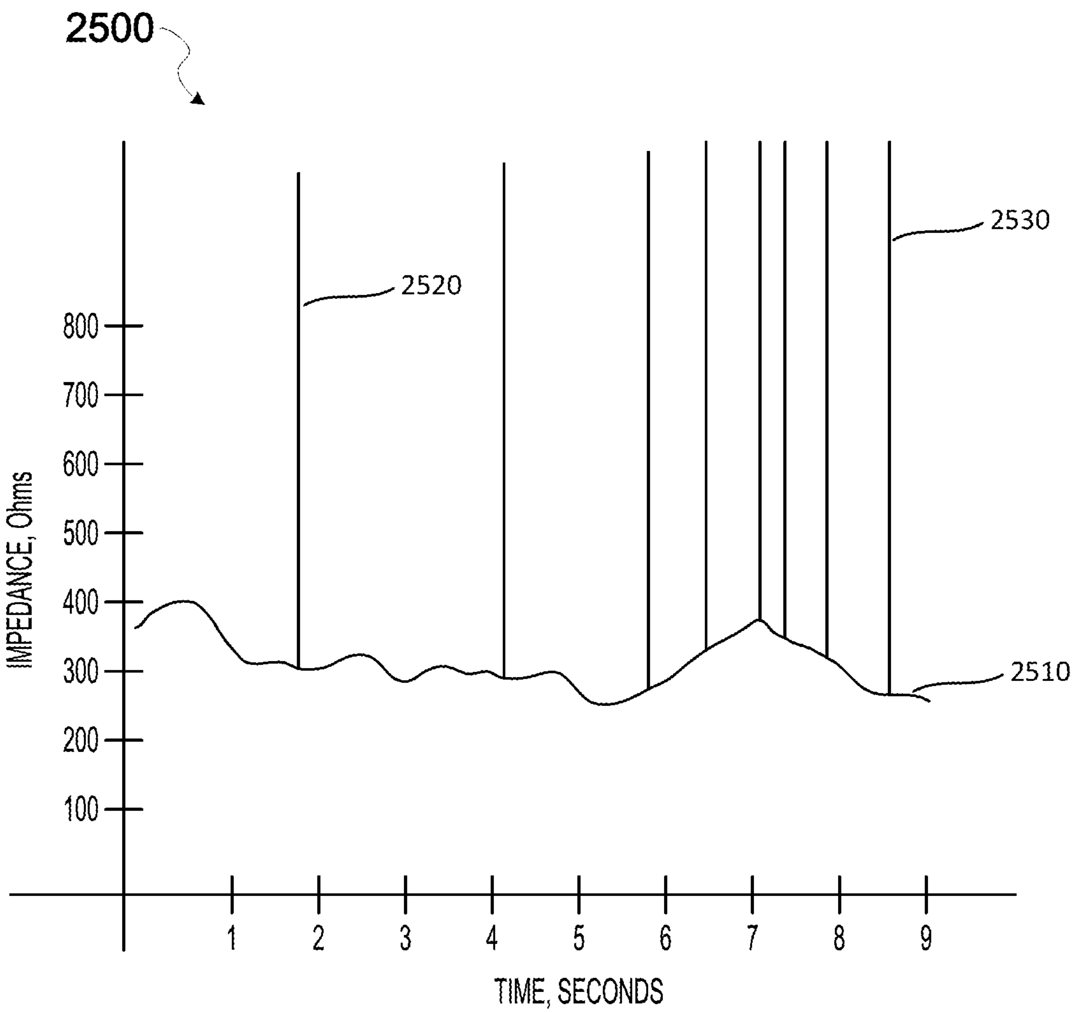

2500
2520
2530
2510
800
700
600
500
400
300
200
100
IMPEDANCE, Ohms
1
2
3
4
5
6
7
8
9
TIME, SECONDS

FIG. 25

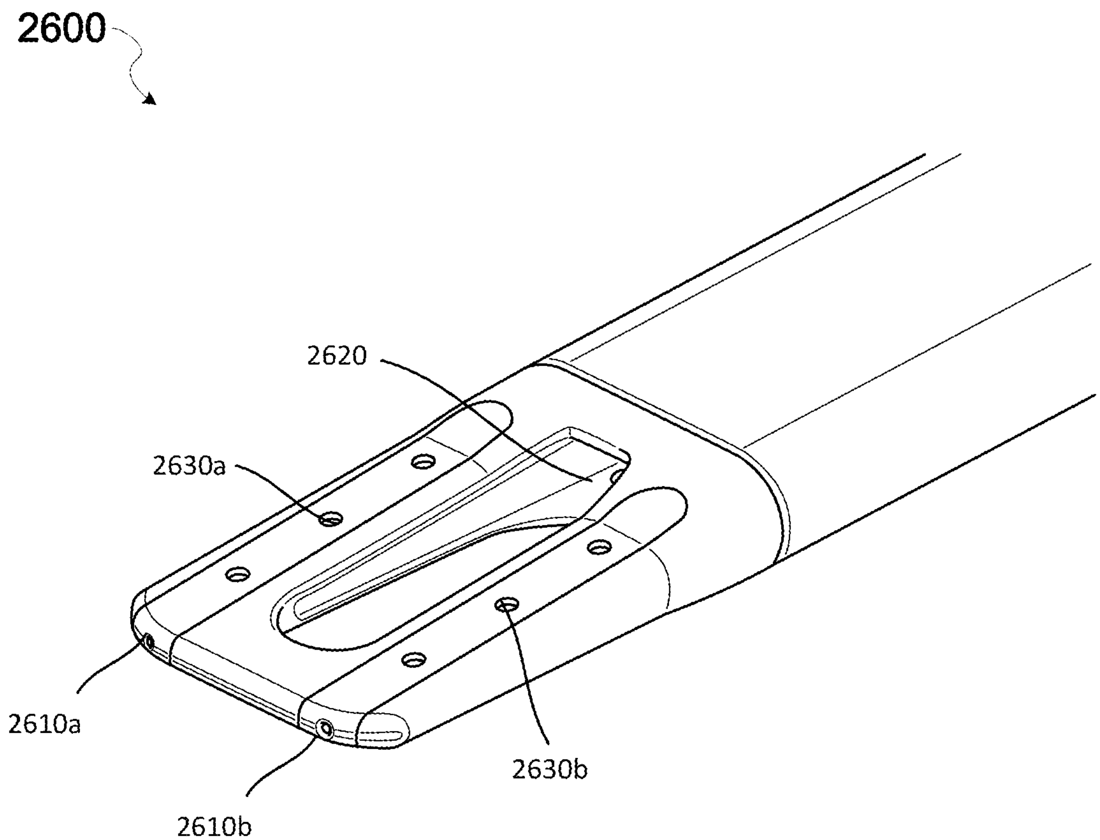


FIG. 26

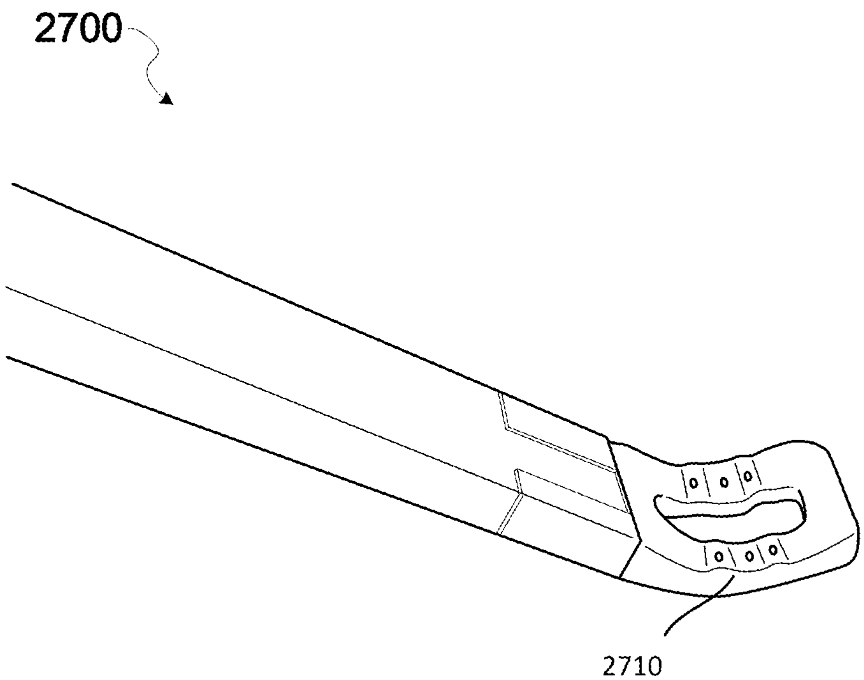


FIG. 27

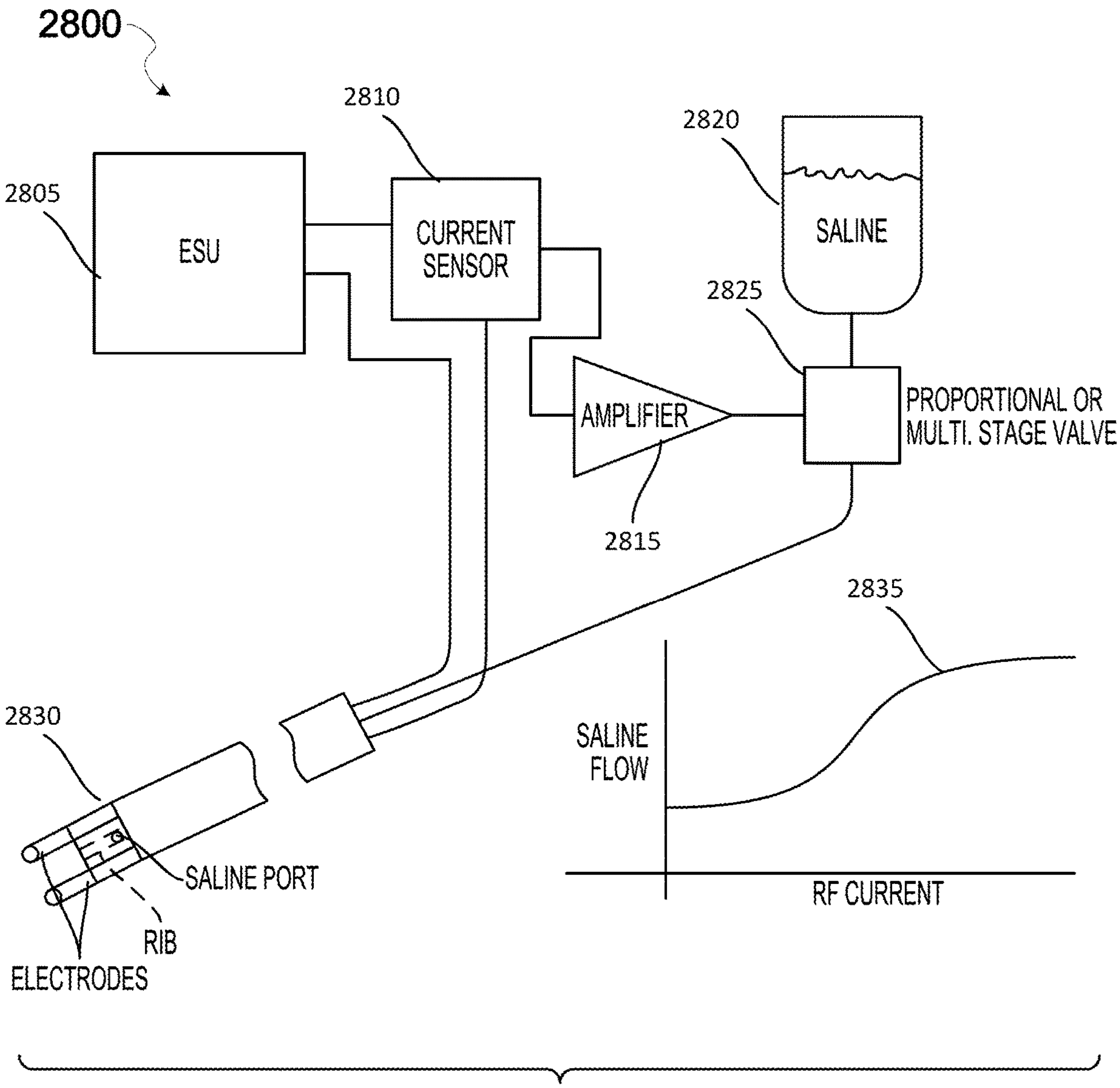

2800
2810
2820
2805
ESU
CURRENT SENSOR
SALINE
2825
AMPLIFIER
PROPORTIONAL OR MULTI. STAGE VALVE
2815
2835
2830
SALINE FLOW
SALINE PORT
RF CURRENT
RIB
ELECTRODES

FIG. 28

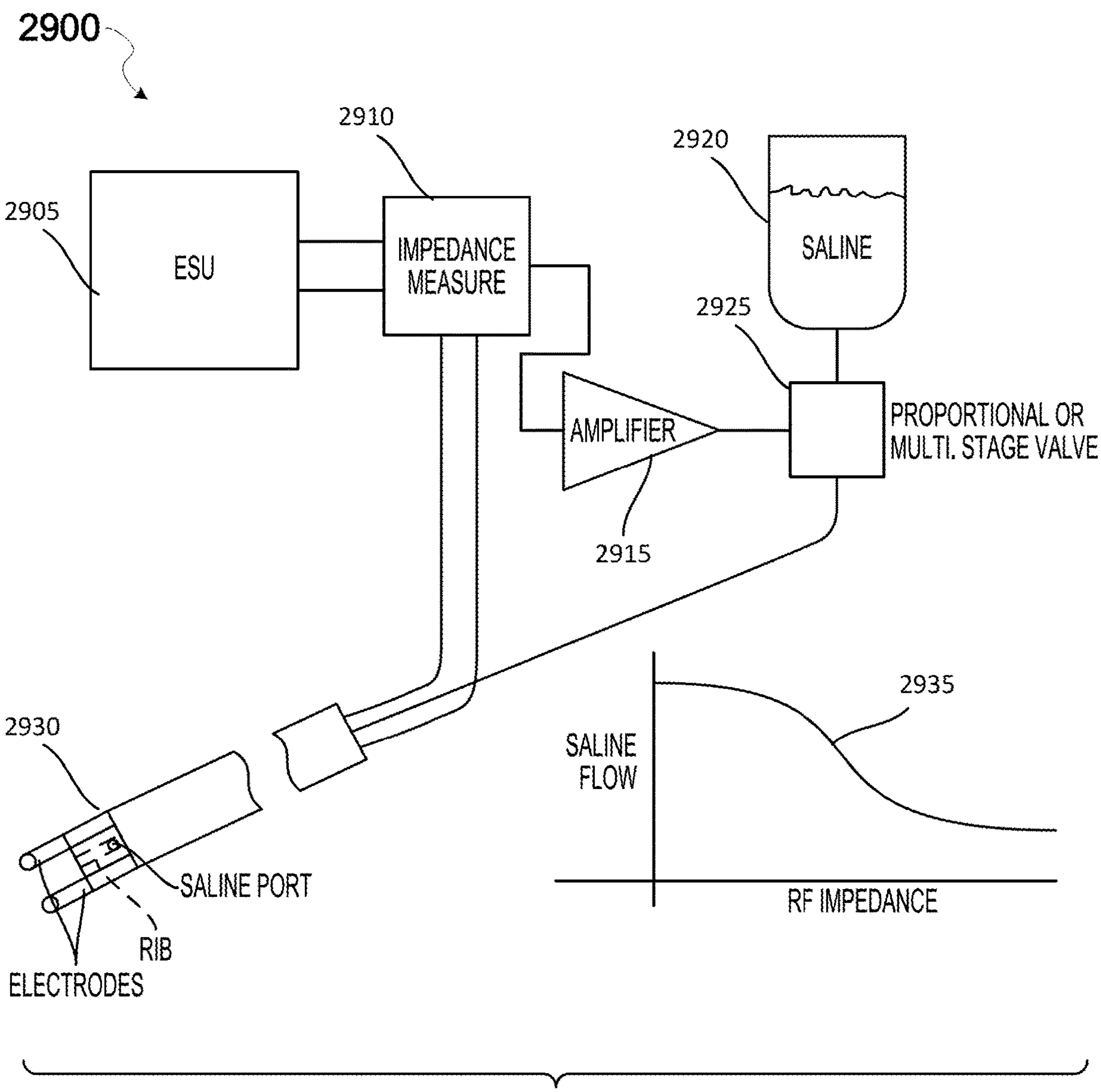

2900
2910
2920
2905
ESU
IMPEDANCE MEASURE
SALINE
2925
AMPLIFIER
PROPORTIONAL OR MULTI. STAGE VALVE
2915
2935
2930
SALINE FLOW
SALINE PORT
RF IMPEDANCE
RIB
ELECTRODES

FIG.29

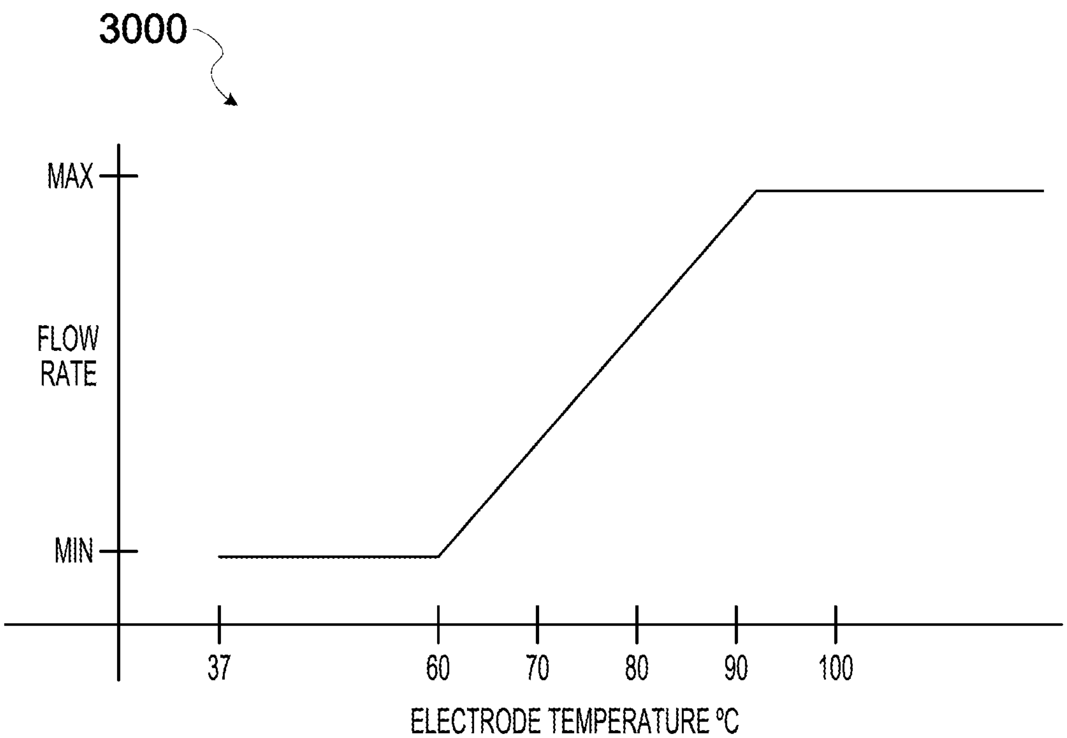

3000
MAX
FLOW
RATE
MIN
37
60
70
80
90
100
ELECTRODE TEMPERATURE ºC

FIG. 30

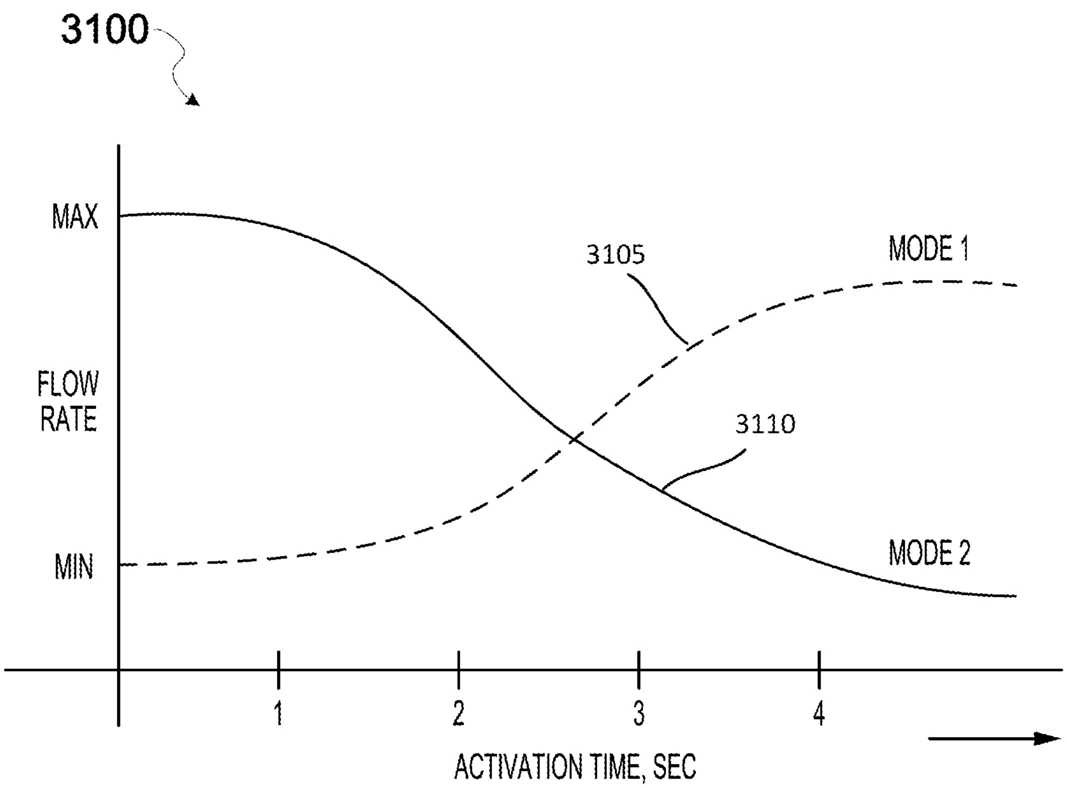
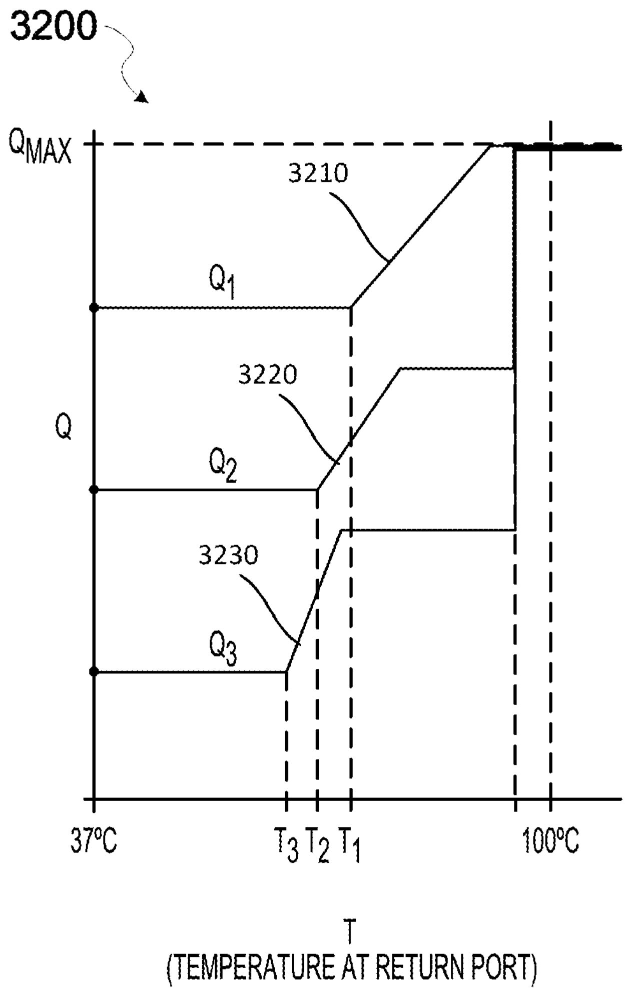

3100
MAX
FLOW
RATE
MIN
3105
MODE 1
3110
MODE 2
1
2
3
4
ACTIVATION TIME, SEC

FIG. 31



3200
Q_MAX
3210
Q_1
3220
Q
Q_2
3230
Q_3
37°C
T_3 T_2 T_1
100°C
T
(TEMPERATURE AT RETURN PORT)

FIG. 32

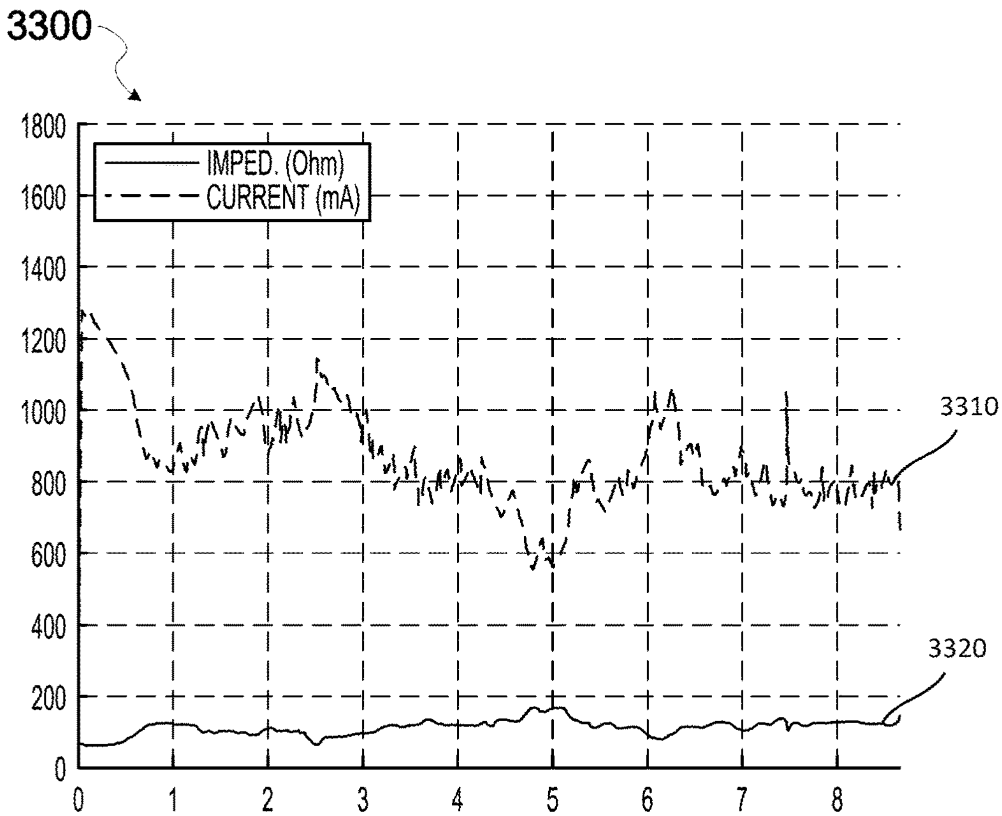

3300
IMPED. (Ohm)
CURRENT (mA)
1800
1600
1400
1200
1000
800
600
400
200
0
0
1
2
3
4
5
6
7
8
3310
3320

FIG. 33

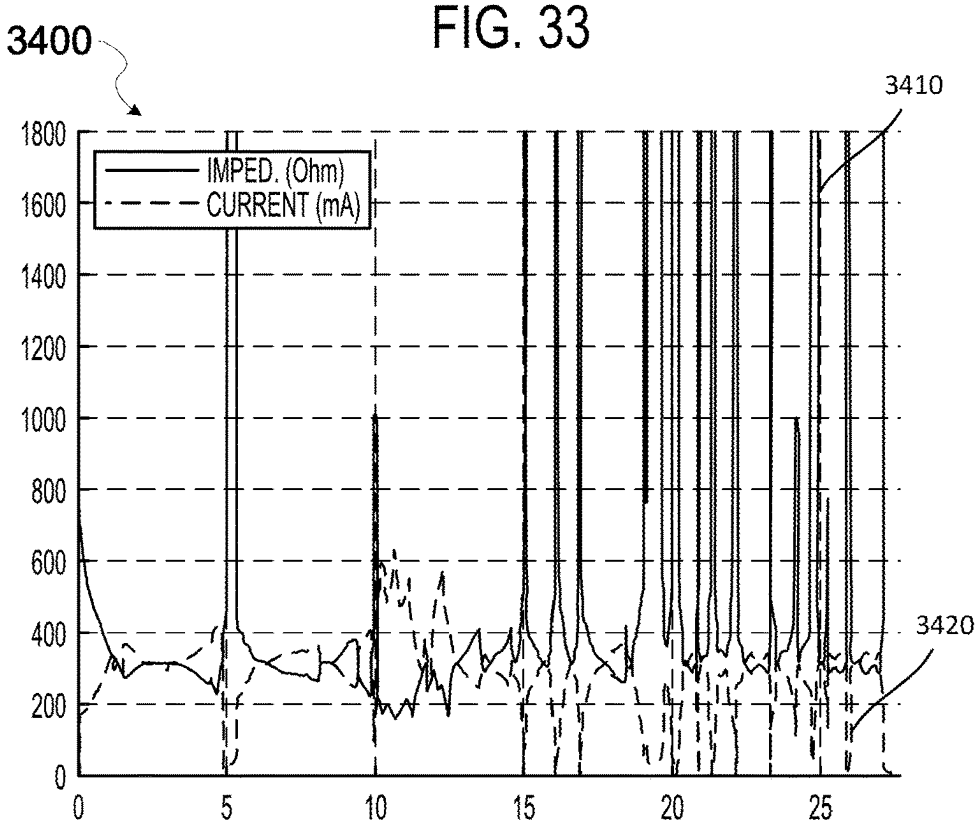

3400
IMPED. (Ohm)
CURRENT (mA)
1800
1600
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
3410
3420

FIG. 34

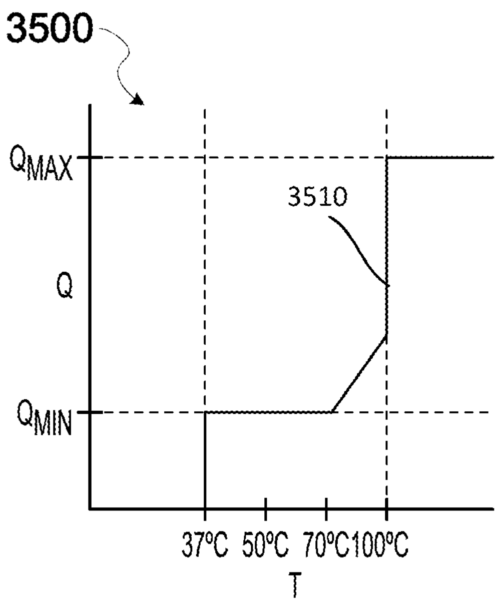


FIG. 35

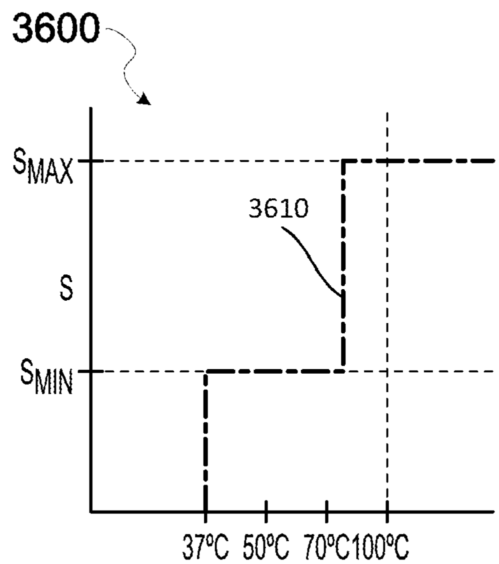


FIG. 36

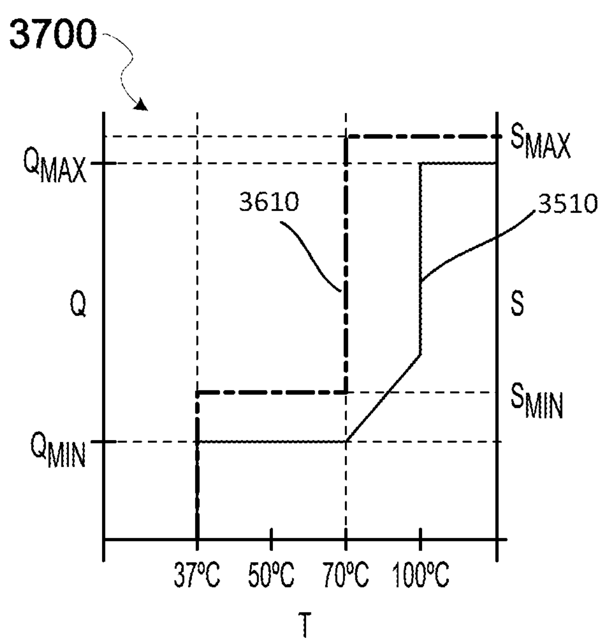


FIG. 37

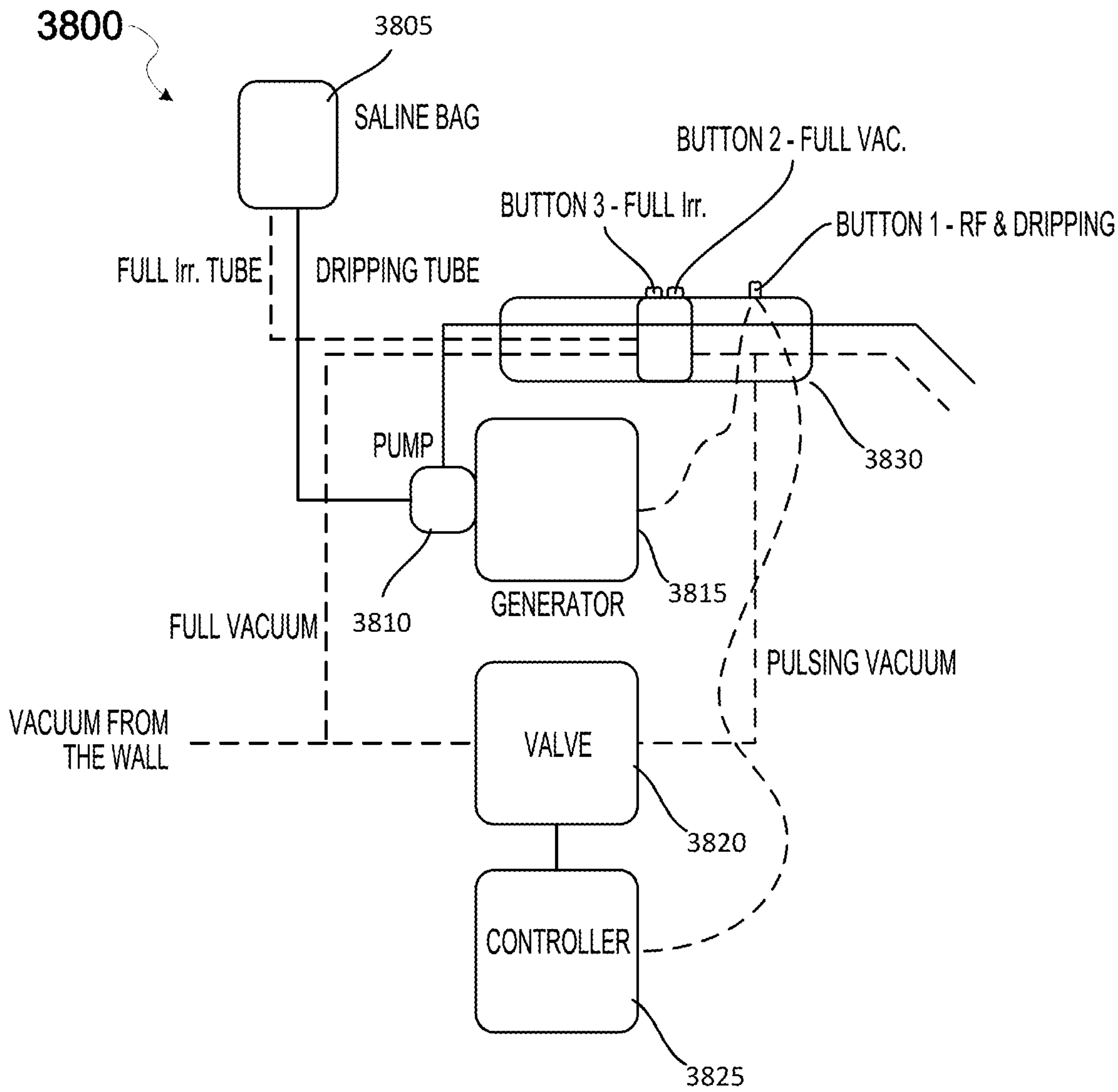

3800
3805
SALINE BAG
BUTTON 2 - FULL VAC.
BUTTON 3 - FULL Irr.
BUTTON 1 - RF & DRIPPING
FULL Irr. TUBE
DRIPPING TUBE
3830
PUMP
3815
GENERATOR
3810
FULL VACUUM
PULSING VACUUM
VACUUM FROM THE WALL
VALVE
3820
CONTROLLER
3825

FIG. 38

SYSTEMS AND METHODS FOR MANAGING FLUID AND SUCTION IN ELECTROSURGICAL SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a divisional patent application claiming priority under 35 U.S.C. § 121 to U.S. patent application Ser. No. 15/720,831, entitled SYSTEMS AND METHODS FOR MANAGING FLUID AND SUCTION IN ELECTROSURGICAL SYSTEMS, which issued on Jun. 15, 2021 as U.S. Pat. No. 11,033,323, the entire disclosure of which is hereby incorporated by reference herein.

BACKGROUND

Many internal surgical procedures require the removal of tissue as part of the surgical procedure. The removal of such tissue invariably results in severing multiple blood vessels leading to localized blood loss. Significant blood loss may comprise the patient's health by potentially leading to hypovolemic shock. Even minor blood loss may complicate the surgery by resulting in blood pooling into the surgical site, thereby obscuring the visibility of the tissue from the surgeons and surgical assistants. The problem of blood loss into the surgical site may be especially important in broad area surgeries, such as liver resection, in which multiple blood vessels may be severed during the procedure.

Typically, an electrosurgical device is used to seal the blood vessels, thereby preventing blood loss. Such electrosurgical devices may include bipolar devices that incorporate a pair of electrodes that are powered by RF (radiofrequency) energy to heat and coagulate the tissue and blood vessels. Direct application of the electrodes to the tissue may lead to unwanted effects such as localized tissue charring and fouling of the electrodes by charred tissue matter sticking to them.

A method to reduce charring and fouling may include introducing a saline fluid into the surgical site to irrigate the site. Alternatively, the saline fluid may be heated by the electrodes to form a steam to coagulate the tissue. In this manner, the tissue is not placed in direct contact with the electrodes and electrode fouling is prevented. Although a saline fluid may be used, any electrically conducting fluid (for example, an aqueous mixture containing ionic salts) may be used to promote steam-based coagulation. After the steam coagulates the tissue by transferring its heat thereto, the steam may condense to water. The resulting water may be used to clear the surgical site of unwanted material such as the remnants of the coagulated tissue. An aspirator or other vacuum device may be used to remove the mixture of water and tissue remnants. It may be difficult and inefficient for the surgeon to coagulate and aspirate the tissue especially if separate devices are required. Thus, a device incorporating the coagulation and aspiration functions is desirable.

The incorporation of both a saline source and an evacuation source for aspiration into a bipolar electrosurgical coagulation instrument may be problematic. If the aspirator operates continuously, then the saline may not reside in contact with the electrodes long enough to be heated and form steam. If the saline source operates continuously, then excess saline may be delivered to the surgical site and obscure the area from the surgeon. It is possible to have a device with multiple actuators to allow the surgeon to selectively emit a fluid to be vaporized by the electrodes and evacuate the surgical site. However, such multiple actuators may be clumsy to use and lead to hand and finger fatigue during a long surgical procedure.

Nevertheless, it is still possible that the electrodes may experience fouling from charred tissue matter sticking to them. Such charred material may interfere with the operation of the electrodes by acting as localized insulators at the electrode surfaces. Such localized insulation may distort or even reduce the electric fields produced by the electrodes, thereby reducing the effectiveness of the coagulation process. As a result, tissue coagulation may be reduced or impeded, thereby permitting blood to continue to flow into the surgical site despite the application of the electrical field to the electrodes. One method to address electrode fouling may be to remove the electrosurgical device from the surgical site and to manually remove the material from the electrodes. However, this method is not optimal as it may permit un-coagulated tissue to continue bleeding and will present an unwanted interruption to the surgical procedure.

Therefore, it is desirable to have an electrosurgical device that permits a surgeon to efficiently remove charred material from the surface of the electrodes while permitting the device to remain in situ.

SUMMARY

In one aspect, an electrosurgical device is presented that includes: a housing; a shaft extending distally from the housing; an end effector coupled to a distal end of the shaft, the end effector comprising: an electrode; a suction port; and a fluid port; and a control system communicatively coupled to the suction port and the fluid port and configured to control a rate of fluid flowing out of the fluid port and a rate of suction flowing into the suction port.

In another aspect, the electrosurgical device further includes: a first fluid path in fluid communication with the fluid port; and a second fluid path in fluid communication with the suction port; wherein the housing is configured to enclose a first portion of the first fluid path and a first portion of the second fluid path; and wherein the shaft is configured to enclose a second portion of the first fluid path and a second portion of the second fluid path.

In another aspect, the electrosurgical device further includes an impedance sensor configured to measure impedance experienced at the electrode.

In another aspect of the electrosurgical device, the control system is configured to control the rate of fluid flowing out of the fluid port based on the measured impedance experienced at the electrode.

In another aspect of the electrosurgical device, the control system is further configured to control the rate of suction flowing into of the suction port based on the measured impedance experienced at the electrode.

In another aspect, the electrosurgical device further includes a radio frequency (RF) current sensor configured to measure RF current applied to the electrode.

In another aspect of the electrosurgical device, the control system is configured to control the rate of fluid flowing out of the fluid port based on the measured RF current applied to the electrode.

In another aspect of the electrosurgical device, the control system is further configured to control the rate of suction flowing into of the suction port based on the measured RF current applied to the electrode.

In another aspect, the electrosurgical device further includes a temperature sensor configured to measure temperature of the fluid suctioned into the suction port.

In another aspect of the electrosurgical device, the control system is configured to control the rate of fluid flowing out of the fluid port based on the measured temperature of the fluid into the suction port.

In another aspect of the electrosurgical device, the control system is further configured to control the rate of suction flowing into of the suction port based on the measured temperature of the fluid into the suction port.

In another aspect of the electrosurgical device, the end effector further comprises a partially deflectable member that is configured to increase the rate of fluid out of the fluid port as the partially deflectable member increases in deflection.

In another aspect of the electrosurgical device, the control system is further configured to increase the rate of fluid flowing out of the fluid port the longer the electrode applies energy.

In another aspect of the electrosurgical device, the control system is further configured to decrease the rate of fluid flowing out of the fluid port the longer the electrode applies energy.

In another aspect, the electrosurgical device further includes a user interface console communicatively coupled to the control system and configured to receive an input from a user to manually control an initial fluid rate of the fluid port.

In another aspect of the electrosurgical device, the control system is further configured to automatically increase the fluid rate of the fluid port after the initial fluid rate is manually specified from the user interface console; wherein the automatic increase of the fluid rate occurs based on an earlier rise in measured temperature of the fluid at the suction port if the initial fluid rate is manually specified at a slower fluid rate, and the automatic increase of the fluid rate occurs based on a later rise in measured temperature of the fluid at the suction port if the initial fluid rate is manually specified at a faster fluid rate.

In another aspect of the electrosurgical device, the control system is configured to: detect an impedance spike based on a drastic change in impedance from the impedance sensor; and in response, increase the rate of fluid flowing out of the fluid port.

In another aspect, a method of a control system of an electrosurgical device is presented, the method comprising: accessing data from one or more sensors related to a physical characteristic of a function occurring at an end effector of the electrosurgical device; controlling a rate of fluid flowing to a fluid port of the electrosurgical device, based on the data related to the physical characteristic; and controlling a rate of suction flowing from a suction port of the electrosurgical device, based on the data related to the physical characteristic.

In another aspect of the method, the physical characteristic comprises a measure of impedance experienced at an electrode of the end effector of the electrosurgical device.

In another aspect of the method, the physical characteristic comprises a measure of RF current applied to an electrode of the end effector of the electrosurgical device.

In another aspect of the method, the physical characteristic comprises a temperature of fluid measured at the suction port at the end effector of the electrosurgical device.

BRIEF DESCRIPTION OF THE FIGURES

The features of the various aspects are set forth with particularity in the appended claims. The various aspects, however, both as to organization and methods of operation, together with advantages thereof, may best be understood by reference to the following description, taken in conjunction with the accompanying drawings as follows:

FIG. **1** illustrates a perspective view of one aspect of an electrosurgical device.

FIG. **2** illustrates an expanded view of one aspect of an end effector of the electrosurgical device depicted in FIG. **1**.

FIG. **3** illustrates a side perspective view of one aspect of the electrosurgical device depicted in FIG. **1**.

FIG. **4** illustrates a partial sectional perspective view of one aspect of the electrosurgical device depicted in FIG. **1**.

FIG. **5** illustrates a partial sectional plan front (distal) view of one aspect of the electrosurgical device depicted in FIG. **1**.

FIG. **6** illustrates a perspective view of one aspect of the interior components of the electrosurgical device depicted in FIG. **1**.

FIG. **7** illustrates an additional perspective view of one aspect of the interior components of the electrosurgical device depicted in FIG. **1**.

FIG. **8** illustrates an expanded perspective view of one aspect of an end effector of the electrosurgical device depicted in FIG. **7**.

FIG. **9** illustrates an expanded perspective view of one aspect of activation controls of the electrosurgical device depicted in FIG. **7**.

FIG. **10** illustrates a cross-sectional view of one aspect of the electrosurgical device depicted in FIG. **4**.

FIG. **11** illustrates partial sectional perspective view of one aspect of the electrosurgical device depicted in FIG. **4** illustrating a first position of one aspect of a slide switch.

FIG. **12** illustrates partial sectional perspective view of one aspect of the electrosurgical device depicted in FIG. **4** illustrating a second position of one aspect of a slide switch.

FIG. **13** illustrates an additional perspective view of one aspect of the interior components of the electrosurgical device depicted in FIG. **4** illustrating a second position of one aspect of a slide switch.

FIG. **14** illustrates an expanded perspective view of one aspect of an end effector of the electrosurgical device depicted in FIG. **13** illustrating an extended position of one aspect of an aspiration tube.

FIG. **15** illustrates an expanded perspective view of one aspect of activation controls of the electrosurgical device depicted in FIG. **13** illustrating a second position of one aspect of a slide switch.

FIGS. **16**, **17**, and **18** illustrate plan views of the top, side, and bottom, respectively, of one aspect of the electrosurgical device depicted in FIG. **13** illustrating a second position of one aspect of a slide switch.

FIGS. **19**, **20**, and **21** illustrate plan views of the top, side, and bottom, respectively, of one aspect of the electrosurgical device depicted in FIG. **4** illustrating a first position of one aspect of a slide switch.

FIG. **22** illustrates a perspective view of one aspect of an end effector of the electrosurgical device depicted in FIG. **1**.

FIG. **23** illustrates a perspective view of a model of one aspect of an end effector of the electrosurgical device depicted in FIG. **1**.

FIG. **24** shows an example plot of an amount of impedance experienced by an end effector providing electrosurgical energy to coagulate tissue at the surgical site, over a period of time.

FIG. **25** shows an example of an undesirable impedance plot, including many impedance spikes, amidst an ordinary level of impedance over time as indicated by the plot line.

FIG. **26** provides an additional example of an end effector with a physically deflectable member to help regulate fluid flow, according to some aspects.

FIG. **27** provides an example of how this physically deflectable member of FIG. **26** may appear and operate when deflected by pressing against a surface.

FIG. **28** shows a block diagram of various functional components of an electrosurgical system configured to vary the saline flow at the end effector based on measured RF current, according to some aspects.

FIG. **29** shows a block diagram of various functional components of an electrosurgical system configured to vary the saline flow at the end effector, based on measured RF impedance, according to some aspects.

FIG. **30** shows how, in some aspects, the amount of saline flow may be measured against electrode temperature.

FIG. **31** shows how, in some aspects, the saline flow may depend on activation time of the electrodes.

FIG. **32** shows how, in some aspects, at least a portion of the flow rate may be adjustable by the user, while other portions thereafter may be adjusted automatically.

FIG. **33** provides a data plot of both a level of impedance and of current at a surgical site over time, where the data plot shows a smooth impedance line over time, indicating no sticking at the surgical site.

FIG. **34** shows a data plot including a large number of impedance spikes, along with a plot of the current, over time.

FIG. **35** shows a data plot of an example of automatic adjustment of fluid flow rate (Q) as a function of the measured temperature of exiting fluid (T).

FIG. **36** shows a data plot of an example of automatic adjustment of suction (S) as a function of the measured temperature of exiting fluid (T).

FIG. **37** shows a superposition of the data plots of FIG. **35** and FIG. **36**.

FIG. **38** shows a block diagram of an example of functional elements that are used in implementing a control system for managing fluid flow and suction.

DETAILED DESCRIPTION

Applicant of the present application owns the following patent applications filed concurrently herewith and which are each herein incorporated by reference in their respective entireties:

U.S. patent application Ser. No. 15/720,810, titled BIPOLAR ELECTRODE SALINE LINKED CLOSED LOOP MODULATED VACUUM SYSTEM, by inventors David A. Witt et al., filed on Sep. 29, 2017, now U.S. Patent Application Publication No. 2019/0099209.

U.S. patent application Ser. No. 15/720,822, titled IMPROVING SALINE CONTACT WITH ELECTRODES, by inventors Mark A. Davison et al., filed on Sep. 29, 2017, now U.S. Patent Application Publication No. 2019/0099212.

U.S. patent application Ser. No. 15/720,840, titled FLEXIBLE ELECTROSURGICAL INSTRUMENT, by inventors David A. Witt et al., filed on Sep. 29, 2017, now U.S. Patent Application Publication No. 2019/0099217.

Aspects of the present disclosure include control systems of an electrosurgical system for managing the flow of fluid, such as saline, and rates of aspiration or suction, in response to various states of conditions at a surgical site. The control systems may monitor and adjust to impedance at the surgical site, temperature of the surgical tissue, RF current of electrodes, and may account for certain undesirable conditions, such as the electrodes sticking. The control systems may include various automatic sensing scenarios, while also allowing for several manual conditions. Rather than rely on a user to manually control settings to adjust for fluid rate and suction rate, the control system(s) may relieve a user of these tasks and control more reliably the fluid and suction rates to produce more reliable results. The control systems described herein may increase safety and produce more accurate surgical procedures, due to the surgeon being able to devote more attention to perform the acts of surgery and not have to divert attention to manually controlling rates of suction and fluid flow.

FIGS. **1-3** depict views of one example of such an electrosurgical device **100**, according to aspects of the present disclosure. For FIGS. **1-22**, common reference numbers refer to common components within the figures.

The electrosurgical device **100** may include a housing **105** with a shaft **135** extending distally from the housing **105**. The housing **105** may include, on a proximal end, a proximal fluid source port **115** and a proximal fluid evacuation port **110**. In some electrosurgical device systems, the proximal fluid source port **115** may be placed in fluid communication with a source of a fluid, for example saline, buffered saline, Ringer's solution, or other electrically conducting fluids such as aqueous fluids containing ionic salts. The fluid source may operate as a gravity feed source or it may include components to actively pump the fluid into the proximal fluid source port **115**. An actively pumping fluid source may include, without limitation, a power supply, a pump, a fluid source, and control electronics to allow a user to actively control the pumping operation of the actively pumping fluid source. In some electrosurgical device systems, the fluid evacuation port **110** may be placed in fluid communication with a vacuum source. The vacuum source may include a power supply, a pump, a storage component to store material removed by the vacuum source, and control electronics to allow a user to actively control the pumping operation of the vacuum source.

In addition, the housing **105** may include a connector to which a cable **117** of an energy source **120** may be attached. The energy source **120** may be configured to supply energy (for example RF or radiofrequency energy) to the electrodes **145***a,b*. The energy source **120** may include a generator configured to supply power to the electrosurgical device **100** through external means, such as through the cable **117**. In certain instances, the energy source **120** may include a microcontroller coupled to an external wired generator. The external generator may be powered by AC mains. The electrical and electronic circuit elements associated with the energy source **120** may be supported by a control circuit board assembly, for example. The microcontroller may generally comprise a memory and a microprocessor ("processor") operationally coupled to the memory. The electronic portion of the energy source **120** may be configured to control transmission of energy to electrodes **145***a,b* at the end effector **140** of the electrosurgical device **100**. It should be understood that the term processor as used herein includes any suitable microprocessor, microcontroller, or other basic computing device that incorporates the functions of a computer's central processing unit (CPU) on an integrated circuit or at most a few integrated circuits. The processor may be a multipurpose, programmable device that accepts digital data as input, processes it according to instructions stored in its memory, and provides results as output. It is an example of sequential digital logic, as it has internal memory. Processors operate on numbers and symbols represented in the binary numeral system. The energy source **120** may also include input devices to allow a user to program the operation of the energy source **120**.

The housing **105** may also include one or more activation devices to permit a user to control the functions of the electrosurgical device **100**. In some non-limiting examples, the electrosurgical device **100** may include a metering valve **125** that may be activated by a user to control an amount of fluid flowing through the electrosurgical device and provide, at the distal end, an amount of the fluid to the end effector **140**. In some non-limiting examples, the metering valve **125** may also permit the user to control an amount of energy supplied by the energy source **120** to the electrodes **145***a,b* at the end effector **140**. As an example, the metering valve **125** may comprise a screw activation pinch valve to regulate the flow of fluid through the electrosurgical device **100**. Additionally, the metering valve **125** may have a push-button activation function to permit current to flow from the energy source **120** to the electrodes **145***a,b* upon depression of the push-button by a user. It may be recognized that in some non-limiting examples, the housing **105** may include the metering valve **125** to allow regulation of fluid flow through the electrosurgical device **100** and a separate energy control device to control the amount of current sourced to the electrodes **145***a,b*.

The housing **105** may also be attached to a shaft **135** at a distal end of the housing **105**. An end effector **140** may be associated with a distal end of the shaft **135**. The end effector **140** may include electrodes **145***a,b* that may be in electrical communication with the energy source **120** and may receive electrical power therefrom. In some non-limiting examples, a first electrode **145***a* may receive electrical energy of a first polarity (such as a positive polarity) from the energy supply **120** and the second electrode **145***b* may receive electrical energy of a second and opposing polarity (such as a negative polarity) from the energy supply **120**. Alternatively, the first electrode **145***a* may be connected to a ground terminal of the energy supply **120**, and the second electrode **145***b* may be connected to a varying AC voltage terminal of the energy supply **120**. The electrodes **145***a,b* may extend beyond the distal end of the shaft **135**. The extended ends of the electrodes **145***a,b* be separated by a diverter **155**. The diverter **155** may contact the first electrode **145***a* at a first edge of the diverter **155**, and the diverter **155** may contact the second electrode **145***b* at a second edge of the diverter **155**. The diverter **155** may comprise an electrically insulating material and/or a heat resistant material, which may include, without limitation, a plastic such as a polycarbonate or a ceramic. The diverter **155** may be deformable or non-deformable. In some non-limiting examples, the housing **105** may include a mechanism to control a shape of a deformable diverter **155**.

The end effector **140** may also include a fluid discharge port **150** that may be in fluid communication with the fluid source port **115** through a first fluid path. The first fluid path, such as a source fluid path (see **315** in FIG. **6**), may permit the fluid to flow from the fluid source port **115** to the fluid discharge port **150**. In some non-limiting examples, the fluid discharge port **150** may be positioned above the diverter **155** so that a fluid emitted by the fluid discharge port **150** may be collected on a top surface of the diverter **155**. The end effector may also include a fluid aspiration port **165** that may be in fluid communication with the fluid evacuation port **110** through a second fluid path. The second fluid path, such as an aspirated fluid path (see **210** in FIGS. **7** and **9**), may permit a liquid mixture generated at the surgical site to flow from the fluid aspiration port **165** to the fluid evacuation port **110**. The liquid mixture may then be removed from the electrosurgical device **100** by the vacuum source and stored in the storage component for later removal.

In some non-limiting examples, the fluid aspiration port **165** may be formed at the distal end of an aspiration tube **160**. The aspiration tube **160** may also form part of the aspirated fluid path **210**. The aspiration tube **160** may be located within the shaft **135** or it may be located outside of and beneath the shaft **135**. An aspiration tube **160** located outside of the shaft **135** may be in physical communication with an external surface of the shaft **135**. In some examples, the aspiration tube **160** may have a fixed location with respect to the shaft **135**. In some alternative examples, the aspiration tube **160** may be extendable in a distal direction with respect to the shaft **135**. Extension of the extendable aspiration tube **160** may be controlled by means of an aspiration tube control device. As one non-limiting example, the aspiration tube control device may comprise a slide switch **130**. The slide switch **130**, in a first position (for example, in a proximal position), may cause the aspiration tube **160** to remain in a first or retracted position in which the aspiration port **165** is located essentially below the fluid discharge port **150**. However, the slide switch **130** in a second position (for example in a distal position), may cause the aspiration tube **160** to extend in a distal direction to a fully extended position so that the aspiration port **165** is located distal from and beneath the fluid discharge port **150**. In one example, the slide switch **130** may preferentially position the aspiration tube **160** in one of two positions, such as the retracted position and the fully extended position. It may be recognized, however, that the slide switch **130** may also permit the aspiration tube **160** to assume any position between the retracted position and the fully extended position. Regardless of the position of the aspiration tube **160** as disclosed above, the aspiration port **165** may be maintained at a location beneath a plane defined by the top surface of the diverter **155**. In this manner, the diverter **155** is configured to prevent fluid emitted by the fluid discharge port **150** from directly being removed at the aspiration port **165**.

FIGS. **4** and **5** present partial interior views of an electrosurgical device **200**. In addition to the components disclosed above with respect to FIGS. **1-3**, the electrosurgical device **200** includes an aspirated fluid path **210** that forms a fluid connection between the proximal fluid evacuation port **110** and the distal fluid aspiration port **165**. Also illustrated are valve components **225** of the metering valve **125** and control components **230** of the aspiration tube such as, for example, a slide switch **130**. Fluid discharge port **150**, electrodes **145***a,b*, fluid aspiration port **165**, and a portion of housing **105** are also illustrated in FIGS. **4** and **5**.

FIGS. **6-9** present a variety of views of the interior components of electrosurgical device **300**. FIG. **8** is a close-up view of the distal end of the electrosurgical device **300** shown in FIG. **7**, and FIG. **9** is a close-up view of actuator components of the electrosurgical device **300** shown in FIG. **7** depicting the metering valve **125** and slide switch **130**. Additional components depicted in FIGS. **6-9** include the source fluid path **315** that forms a fluid connection between the proximal fluid source port **115** and the distal fluid discharge port **150**. In some examples, the valve components **225** of the metering valve **125** are disposed along the length of the source fluid path **315** permitting a user of electrosurgical device **300** to regulate a flow of fluid through the source fluid path **315** from the fluid source port **115** to the fluid discharge port **150**. In some examples of the valve components **225**, a screw actuator, such as a pinch valve, may be used to compress a portion of the source fluid path **315**, thereby restricting a flow of fluid therethrough. It may be recognized that any number of fluid control valves may be used as valve components **225** including, without limitation, a ball valve, a butterfly valve, a choke valve, a needle valve, and a gate valve. It may be understood from FIGS. **6-9** that source fluid path **315** extends from fluid source port **115** through the housing **105** and through shaft **135** to the distal fluid discharge port **150**. Similarly, it may be understood from FIGS. **6-9** that aspirated fluid path **210** extends form the proximal fluid evacuation port **110** through the housing **105** and through shaft **135** to the distal fluid aspiration port **165**. Additionally, electrodes **145***a,b* may extend from housing **105** through shaft **135** and extend distally and protrude from the end of shaft **135**. Alternatively, electrodes **145***a,b* may extend only through the shaft **135** and extend distally and protrude from the end of shaft **135**. Proximal ends **345***a,b* of the electrodes **145***a,b*, may receive connectors to place the electrodes **145***a,b* in electrical communication with energy source **120**. Electrodes **145***a,b* may receive the electrical energy from the energy source **120** to permit coagulation to the tissue in the surgical site either through direct contact of the tissue with the protruding portion of the electrodes **145***a,b*, or through heating a fluid contacting electrodes **145***a,b*.

FIG. **10** is a cross-sectional view of electrosurgical device **400**. In particular, the cross-sectional view **400** illustrates the two fluid paths through the device. Thus, FIG. **10** illustrates source fluid path **315** in fluid communication with the proximal fluid source port **115** and the distal fluid discharge port **150**. Additionally, FIG. **10** illustrates an example of a physical relationship between source fluid path **315** and the valve components **225** of the metering valve **125**. FIG. **10** also illustrates an example in which the source fluid path **315** may extend through both the housing **105** and the shaft **135** (see e.g., FIG. **4**). Further, FIG. **10** illustrates aspirated fluid path **210** in fluid communication with the proximal fluid evacuation port **110** and the distal fluid aspiration port **165**. The aspirated fluid path **210** may also include an aspiration tube **160** that may be disposed at a distal end of the aspirated fluid path **210**. The distal fluid aspiration port **165** may be formed at a distal end of the aspiration tube **160**.

FIGS. **11-21** illustrate partial interior views of an electrosurgical device **200** having an aspiration tube **160** in a proximal or retracted position and an electrosurgical device **500** (FIG. **12**) having an aspiration tube **160** in an distal or extended position Z. FIG. **11** is similar to FIG. **4** and particularly illustrates a first and proximal position X of the slide switch **130** (as a non-limiting example of an aspiration tube control device) along with a proximal or retracted position of aspiration tube **160**. FIG. **12** particularly illustrates a second and distal position Y of the slide switch **130** (as a non-limiting example of an aspiration tube control device) in addition to a distal or extended position Z of aspiration tube **160**. FIG. **13** illustrates an alternative perspective view of electrosurgical device **500**. FIG. **14** is an expanded perspective view of the distal end of the electrosurgical device **500** shown in FIG. **13**, particularly illustrating the distal end of aspiration tube **160** in the extended position Z. FIG. **15** is an expanded perspective view of actuator components of the electrosurgical device **500** shown in FIG. **13**, particularly illustrating the second or distal position X of the slide switch **130**. FIGS. **16**, **17**, and **18** present plan views of the top, side, and bottom, respectively, of electrosurgical device **500**. FIGS. **16-18** may be compared with FIGS. **19**, **20**, and **21** which present plan views of the top, side, and bottom, respectively, of electrosurgical device **200**. FIGS. **16-18** illustrate the distal positions Y and Z of slide switch **130** and aspiration tube **160**, respectively. FIGS. **19-21** illustrate the proximal position X of slide switch **130** and the proximal or retracted position of aspiration tube **160**.

FIG. **22** presents a perspective view of a general example of an end effector **600**. As disclosed above, the end effector may be composed of a pair of electrodes **145***a,b*, extending from a shaft **135**, a distal fluid discharge port **150**, a diverter **155**, and an aspiration port **165** that may be part of an aspiration tube **160**. The diverter **155** may be placed between the pair of electrodes **145***a,b* in such a manner as to form a contact of a first edge of the diverter **155** with a surface of one electrode **145***a*, and a contact of a second edge of the diverter **155** with a surface on a second electrode **145***b*. In some examples, a proximal edge of the diverter **155** may form a mechanical communication with an end surface of the shaft **135**. In this manner, fluid emitted by the distal fluid discharge port **150** may be retained on a first or top surface of the diverter **155**. The fluid on the top surface of the diverter **155** may be retained on that surface for a sufficient time to maintain contact of the fluid with a surface of both electrodes **145***a,b*. If the fluid is an ionic fluid, current passing through the fluid between the electrodes **145***a,b* may heat the fluid sufficiently to form a steam capable of cauterizing tissue.

It may be recognized that the electrodes **145***a,b* may be fabricated to have any type of geometry that may improve the effectiveness of the electrodes **145***a,b*. For example, the electrodes **145***a,b* may be chamfered to result in oval distal ends in which the respective long axes are directed towards an inner portion of the end effector and pointing towards the diverter. Alternatively the distal portion of the electrodes **145***a,b* may have a circular or oval cross section, but the electrodes **145***a,b* may have a fabiform or kidney-shaped cross section closer (proximal) to the shaft **135**.

FIG. **23** depicts a perspective view of a fabricated model of the end effector **600** as depicted in FIG. **22**.

Aspects of the present disclosure include control systems of an electrosurgical system for managing the flow of fluid, such as saline, and rates of aspiration or suction, in response to various states of conditions at the surgical site. The control systems may monitor and adjust to impedance at the surgical site, temperature of the surgical tissue, RF current of electrodes, and may account for certain undesirable conditions, such as the electrodes sticking. The control systems may include various automatic sensing scenarios, while also allowing for several manual conditions.

Referring to FIG. **24**, graph **2400** shows an example plot **2410** of an amount of impedance experienced by an end effector (e.g., end effector **140**) providing electrosurgical energy to coagulate tissue at the surgical site, over a period of time. In this example, the amount of impedance, expressed in ohms, gradually changes at the surgical site. This is a sign that amount of fluid flowing to the surgical site and appropriate amount of suction is well-managed, in that too much or too little fluid would create wild imbalances in measured impedance. The various example techniques described herein for managing flow of fluid and suction are designed to establish such a smooth curve in impedance over time.

Referring to FIG. **25**, graph **2500** shows an example of an undesirable impedance plot, including many impedance spikes, e.g., spikes **2520** and **2530**, amidst an ordinary level of impedance over time as indicated by the plot line **2510**. It has been observed that sudden impedance spikes are a precursor and an indicator of sticking by the electrodes. Unwanted sticking by the electrodes can create a danger that the electrodes may apply to much energy to a particular location at the surgical site, possibly causing errors during surgery. It is therefore desirable to adjust the fluid rate automatically as much as possible based on sensed conditions at the surgical site to prevent impedance spikes, and ultimately reduce the possibility of sticking by the electrodes. FIGS. **26-39** describe various aspects to address these problems.

Referring to FIG. **26**, illustration **2600** provides an additional example of an end effector with a physically deflectable member to help regulate fluid flow, according to some aspects. As shown, the end effector of illustration **2600** is shaped in a bendable and flat configuration, similar to a spatula. The middle is hollow, to allow space for the suction port **2620**. Electrodes **2610***a* and **2610***b* are located at the end of the end effector, while fluid ports, such as ports **2630***a* and **2630***b*, are spaced along the bendable portion of the end effector. In this example, there are a total of 12 fluid ports, six on the top and six on the bottom. In other examples not shown, fluid ports may also be positioned at the distal end of the end effector, while the electrodes may be positioned at other strategic locations.

Referring to FIG. **27**, illustration **2700** provides an example of how this physically deflectable member may appear and operate when deflected by pressing against a surface. The deflected portion is shown at position **2710**. In some aspects, a minimum flow or "weep" of saline automatically flows even when the end effector is not deflected. In some aspects, increasing the deflection of the end effector operates the fluid valve such that more fluid flows with increasing deflection. In some aspects, this physical deflection may be combined with other mechanisms that control the flow of saline.

Referring to FIG. **28**, illustration **2800** shows a block diagram of various functional components of an electrosurgical system configured to vary the saline flow at the end effector **2830** based on measured RF current, according to some aspects. The electrosurgical system includes an electrosurgical unit (ESU) **2805** that is configured to provide power to the system. At least one current sensor **2810** is coupled to the ESU **2805** and is configured to measure an amount of RF current that is being supplied by the ESU **2005**. The RF current may be dictated by one or more mechanisms on the electrosurgical device (e.g. device **100**), and may be controlled at least in part by a human user operating the device. In some aspects, an amplifier **2815** is configured to magnify the signal of the current sensor to feed into a proportional or multistage valve **2825**. The amount of RF current, as expressed through the amplifier **2815**, can be used to control the proportional or multistage valve **2825**. The fluid, such as saline **2820**, passes through the valve **2825** at a rate according to an amount of current provided by the ESU **2805**. In some aspects, the amount of saline flow is a function of the RF current according to the graph shown in plot **2835**, as just one example. In general, the amount of saline flow may be designed to appropriately match the amount of energy supplied at the electrodes of the end effector **2830**, based on how much RF current is being supplied. The current may be proportional to the work being done in the tissue at the surgical site. Higher current tends to mean that the surgeon is in contact with a lot of tissue, and turning up the flow rate automatically would appropriately match the situation the surgeon is facing.

Referring to FIG. **29**, illustration **2900** shows a block diagram of various functional components of an electrosurgical system configured to vary the saline flow at the end effector **2930**, based on measured RF impedance, according to some aspects. Similar to illustration **2800**, the electrosurgical system includes an ESU **2905** that is configured to provide power to the system. At least one impedance measure or monitor **2910** is coupled to the ESU **2905** and the electrosurgical device (e.g. device **100**), and is configured to measure an amount of impedance experienced at the surgical site. In some aspects, the impedance monitor **2910** may include current and voltage sensor measures configured to calculate RF tissue impedance. In some aspects, an amplifier **2915** is configured to magnify the signal from the impedance measure **2910** and is fed into a proportional or multistage valve **2925**. The fluid, such as saline **2920**, passes through the valve **2925** at a rate according to an amount inversely proportional to the measured impedance. In some aspects, the amount of saline flow is a function of the measured RF impedance according to the graph shown in plot **2935**, just as one example. In general, the amount of saline flow may be designed to appropriately counterbalance the amount of measured impedance at the surgical site. The RF impedance may be inversely proportional to the saline flow. Low tissue impedance generally implies that there is a lot of work to be done in the tissue, and saline flow should therefore be increased. Higher impedance means that the surgeon is probably in contact with less tissue or the tissue is mostly coagulated, and therefore the flow can be reduced.

Referring to FIG. **30**, in some aspects, the amount of saline flow may be measured against electrode temperature. Illustration **3000** shows a plot representing how a control algorithm may be configured to vary the saline flow rate based on measured temperature of the electrodes during surgery. In this example, there are predetermined minimums and maximums of the flow rate, and the flow rate may vary in a linear proportion as the temperature increases from 60° C. to 90° C. One or more temperature sensors may be communicatively coupled to one or more of the electrodes at an end effector, which may be coupled to a proportional or multistage valve (e.g., valves **2825** or **2925**), which may be used to control the flow of saline through it. In some aspects, the control system may be configured to monitor temperature in addition to one or more of tissue impedance and RF current. That is, multiple types of sensors may be included in the control system, such that the flow rate of saline may be varied according to any of these different measurements. In some aspects, a user of the system may be able to specify which sensors would control the flow rate.

Referring to FIG. **31**, in some aspects, the saline flow may depend on activation time of the electrodes. Illustration **3100** shows a plot of two different modes that reflect different amounts of saline flow for a given amount of activation time. In certain modes of operation, saline flow is increased over a given activation time in order to provide more irrigation as the surgeon is working at the surgical site. This concept is reflected by the curve **3105** of ode 1. In this case, the amount of saline is provided substantially after a couple seconds of activation time have elapsed, reflecting providing more fluid after a brief amount of time of the electrodes working at the surgical site. Mode 1 reflects providing more fluid to cool the surgical site in order to satisfy a need that is developing at that very moment. In other modes of operation, saline flow starts at a maximum rate at the beginning of activation, and then decreases to a minimum. This provides maximum irrigation during the very first part of tissue contact and decreases as less saline is required to aid in the coagulation function. This is reflected graphically in the curve **3110** of mode 2. In some aspects, in activation button or other mechanism for activating the RF is tied to a proportional or multistage variable valve that controls the flow of saline (e.g., valves **2825** or **2925**). As the activation time increases, the control signal to the valve changes to either increase or decrease the flow according to the setting of either mode 1 or mode 2, respectively.

Referring to FIG. **32**, in some aspects, at least a portion of the flow rate may be adjustable by the user, while other portions thereafter may be adjusted automatically. Illustration **3200** provides a graph of 3 different plots **3210**, **3220**, and **3230**, showing how an initial flow rate can be set manually and then adjusted automatically thereafter. In this case, the temperature of the return port, e.g., the suction port, is monitored. A user first sets a nominal flow rate, shown as the lower horizontal line in each of the three plots **3210**, **3220**, and **3230**. As return temperature increases, the flow may be increased automatically to compensate for the higher temperature return fluid and to keep the coagulation and tissue effect at or near a desired temperature. This is reflected in the rise of lines in each of the plots after the 1st horizontal lines. In this example, the settings initially at lower temperatures start rising at an earlier increase in temperature (e.g., T3, T2, and T1, respectively, where T3<T2<T1). If ever the measure temperature at the return port reaches a near maximum temperature, the flow rate may then be increased to a maximum in response, for all cases, as shown in illustration **3200**. In some aspects, this concept to partially manually select and partially auto adjust may be applied to different measurements, such as temperature of the electrodes, tissue impedance, or RF current. In other words, the concept of enabling a portion of the control system to be manually selectable may be applied to any of the previous control systems described herein.

Referring to FIGS. **33** and **34**, in some aspects, a control system to manage the fluid flow of an electrosurgical system may also be configured to monitor impedance spikes in order to prevent or reduce the occurrence of the electrodes sticking to the tissue at the surgical site. In general, keeping the electrodes cool and lubricated with fluid, such as saline, helps reduce the occurrence of sticking. Increasing the flow of saline as appropriate, according to various indicia, will offset heat generated at the surgical site and prevent or at least reduce the occurrence of sticking. One notable sign is an impedance spike. It has been observed that sudden spikes in the impedance are a precursor and an indicator of sticking. Thus, in some aspects, the control system may be configured to adjust the flow to increase automatically upon observation of an impedance spike. FIG. **33** provides a data plot **3300** of both a level of impedance **3320** and of current **3310** at a surgical site over time. Data plot **3300** shows a smooth impedance line over time, indicating no sticking at the surgical site.

In contrast, referring to FIG. **34**, data plot **3400** shows a large number of impedance spikes (e.g., spike **3410**, etc.), along with a plot of the current, over time. A control system may be configured to determine whenever an amount of impedance drastically increases over a short amount of time, say over one or two sampling points. This is highly likely to represent an impedance spike, and as a result, the control system may be configured to automatically increase the flow of saline or other fluid automatically. It is noted that this conditional check occurring in the control system can be implemented with any of the other control algorithms described herein. That is, the control system may be configured to perform normally according to any of the other conditions described in the control algorithms previously, and then may perform an override procedure to automatically increase the flow of saline or other fluid when an impedance spike is detected.

Still referring to FIG. **34**, is worth noting that the current plot **3420** shows corresponding drops in current whenever there are impedance spikes. This makes sense because of the general inverse nature of impedance to current, and also when contemplating the fact that an impedance spike tends to suggest that a circuit through the electrodes and the surgical site cannot be completed anymore, there by causing a drop in the current reading. As such, in some aspects, the control system may be configured to monitor sudden drops in current while power is still being applied, as an alternative or additional way to determine when to automatically increase the flow of saline or other fluid.

Aspects of the present disclosure also include methods for controlling the suction functionality of the electrosurgical device in order to vary the amount of suction applied at the surgical site. In general, it is desirable to generate an amount of suction that is portion it to the amount of fluid at the surgical site. A rate of suction that is constant may fail to account for a sufficient number of scenarios that have varying amounts of fluid flow. Too much vacuum may not allow the intended tissue to coagulate, which then allows the tissue to dry out quickly, causing the electrodes to stick to the tissue. Too little vacuum tends to leave extra saline unattended at the tissue surface, which then leads to unintended extra surface burning. In general, it is desirable to change the rate of suction at an amount or frequency that is appropriate to the other factors at the surgical site, such as the amount of saline flowing and the temperature in the target tissue or at the surgical site generally.

Thus, in some aspects, the suction can be modulated on and off with a variable duty cycle and rate, such as two seconds on one second off, which can repeat. This is an example of a 66% duty cycle at a three second rate. This can be accomplished, for example, by turning on and off the vacuum order, opening and closing bypass valves, opening and closing direct valves on the vacuum line, and so forth. A control system may be configured to control these different mechanisms according to a control algorithm that specifies an appropriate variable duty cycle rate. The duty cycle rate may be changeable by the control system, in order to increase or decrease the amount of suction.

In some aspects, the suction can be modulated as a function of the power settings on the generator or a measure of the power delivered to the tissue. For example, an increase of power would result in a corresponding increase in the suction. This increase, or any change in the suction, can be accomplished by changing the rate and duty cycle as previously described, or by increasing or decreasing apertures, remote from the tissue site, on the vacuum line that effectively bypasses the suction at the tissue site. In general, the control system may be configured to manipulate the duty cycle rate and/or the control of these apertures.

Referring to FIGS. **35-37**, shown are plots that illustrate how a rate of suction can correspond to a rate of fluid flow, according to some aspects. In FIG. **35**, plot **3500** shows an example of automatic adjustment of the fluid flow rate (Q), as a function of measured temperature of exiting fluid (T). The solid line **3510** shows that the rate of fluid starts at a minimum at certain measured low temperatures. The flow rate may increase steadily once the temperature is measured between 70 to 100° C. The flow rate may then be set to a maximum upon reaching a maximum temperature of 100° C. This is just one example of how the flow rate may be automatically adjusted, and other control algorithms as described above may also apply here.

Referring to FIG. **36**, plot **3600** shows an example of automatic adjustment of the suction (S), as a function of the measured temperature of exiting fluid (T). The dashed and dotted line **3610** shows that the rate of suction starts at a minimum at certain measured low temperatures. The suction rate may increase to be at a maximum prior to reaching a maximum fluid temperature, as shown.

Referring to FIG. **37**, plot **3700** shows a superposition of the two lines **3510** and **3610** to illustrate more clearly the interactions between the rate of suction and the rate of fluid flow, according to some aspects. In this example, it can be seen that the minimum rate of suction is higher than the minimum flow rate, and the maximum suction rate is higher than the maximum flow rate. Also, all temperatures, the rate of suction is generally higher than the rate of fluid flow. However, the rate of suction is not drastically higher than the rate of fluid flow at any given temperature, which reflects the desire to sufficiently vacuum the fluid but not drastically so that the surgical site gets to hot and burns.

Referring to FIG. **38**, block diagram **3800** provides one example of functional elements that are used in implementing a control system for managing fluid flow and suction, according to some aspects of the present disclosure. In this example, a fluid source, such as saline bag **3805** is fluidically coupled to the electrosurgical device **3830**. In this example, there are two tubes connected to the saline bag **3805**: a full irrigation tube and a dripping tube. The full irrigation tube may allow for steady flow of the fluid directly into the electrosurgical device **3830**. This may be accessed when maximum fluid flow is desired. In other cases, the dripping tube may be used, which is connected to a pump **3810** that is controlled by a generator **3815**. The generator **3815** may be activated by a button or switch on the electrosurgical device, e.g., button **1** as shown. In some cases, the switch may be a dial or keypad that allows the user to select multiple options for more specific settings to control the flow rate. In this example, another button, e.g., button **3**, may be used to enable the full irrigation functionality. In other cases, a single button or switch may be used to activate irrigation generally, which may be tied to the generator **3815** as well as the full irrigation tube. In other cases, a single button or switch may be used to activate irrigation through a single flow tube from the saline bag **3005**, in which a pump **3810** and a generator **3815** may be used to control all flow rates, including enabling full irrigation. Examples of these systems are described in previous figures, above.

Still referring to FIG. **38**, the vacuum or aspiration system may include a vacuum source, such as a vacuum from the wall, and a valve **3820** and controller **3825**. The vacuum source may come from a generator and is plugged into a wall, as an alternative example. In this example, the electrosurgical device **3830** allows for two paths of enabling the vacuum functionality: a full vacuum path and the pulsing vacuum path. In this example, a tube running directly from the vacuum is connected to the electrosurgical device **3830** to allow for maximum vacuum functionality. A separate tube may connect from the valve **3822** another port and the electrosurgical device **3830** to allow for pulsing vacuum functionality. The controller **3825** may be configured to control the valve **3820**, to allow for a ratio of opening and closing of the valve **3820** to mimic or simulate pulsing vacuuming, which may effectively produce varying or fractional amounts of the suction. In this example, button **1** may control the pulsing vacuum functionality, as it is connected to the controller **3025**. Button **2** may control the full vacuum functionality. In other examples, a single button or switch may be used to activate the vacuum or suction generally, which may be tied to the controller **3025** as well as a full vacuum tube. In this way, the valve **3820** may be configured to allow for full suction when it is completely open, as well as fractional rates of suction due to the controller **3825** creating a duty cycle rate of opening and closing, or by having the valve **3820** include or be a part of multiple valves that can be opened to relieve vacuum pressure. Examples of these systems are described in previous figures, above.

It will be appreciated that the terms "proximal" and "distal" are used throughout the specification with reference to a clinician manipulating one end of an instrument used to treat a patient. The term "proximal" refers to the portion of the instrument closest to the clinician and the term "distal" refers to the portion located furthest from the clinician. It will further be appreciated that for conciseness and clarity, spatial terms such as "vertical," "horizontal," "up," or "down" may be used herein with respect to the illustrated aspects. However, surgical instruments may be used in many orientations and positions, and these terms are not intended to be limiting or absolute.

Various aspects of surgical instruments are described herein. It will be understood by those skilled in the art that the various aspects described herein may be used with the described surgical instruments. The descriptions are provided for example only, and those skilled in the art will understand that the disclosed examples are not limited to only the devices disclosed herein, but may be used with any compatible surgical instrument or robotic surgical system.

Reference throughout the specification to "various aspects," "some aspects," "one example," "one aspect," "an aspect," "one form," or "a form" means that a particular feature, structure, or characteristic described in connection with the aspect is included in at least one example. Thus, appearances of the phrases "in various aspects," "in some aspects," "in one example," or "in one aspect" in places throughout the specification are not necessarily all referring to the same aspect. Furthermore, the particular features, structures, or characteristics illustrated or described in connection with one example may be combined, in whole or in part, with features, structures, or characteristics of one or more other aspects without limitation.

While various aspects herein have been illustrated by description of several aspects and while the illustrative aspects have been described in considerable detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications may readily appear to those skilled in the art. For example, it is generally accepted that endoscopic procedures are more common than laparoscopic procedures. Accordingly, the present invention has been discussed in terms of endoscopic procedures and apparatus. However, use herein of terms such as "endoscopic", should not be construed to limit the present invention to an instrument for use only in conjunction with an endoscopic tube (e.g., trocar). On the contrary, it is believed that the present invention may find use in any procedure where access is limited to a small incision, including but not limited to laparoscopic procedures, as well as open procedures.

It is to be understood that at least some of the figures and descriptions herein have been simplified to illustrate elements that are relevant for a clear understanding of the disclosure, while eliminating, for purposes of clarity, other elements. Those of ordinary skill in the art will recognize, however, that these and other elements may be desirable. However, because such elements are well known in the art, and because they do not facilitate a better understanding of the disclosure, a discussion of such elements is not provided herein.

While several aspects have been described, it should be apparent, however, that various modifications, alterations and adaptations to those aspects may occur to persons skilled in the art with the attainment of some or all of the advantages of the disclosure. For example, according to various aspects, a single component may be replaced by multiple components, and multiple components may be replaced by a single component, to perform a given function or functions. This application is therefore intended to cover all such modifications, alterations and adaptations without departing from the scope and spirit of the disclosure as defined by the appended claims.

Any patent, publication, or other disclosure material, including, but not limited to U.S. patents, U.S. patent application publications, U.S. patent applications, foreign patents, foreign patent applications, non-patent publications referred to in this specification and/or listed in any Application Data Sheet, or any other disclosure material are incorporated herein by reference in whole or in part, is incorporated herein only to the extent that the incorporated materials does not conflict with existing definitions, statements, or other disclosure material set forth in this disclosure. As such, and to the extent necessary, the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference. Any material, or portion thereof, that is said to be incorporated by reference herein, but which conflicts with existing definitions, statements, or other disclosure material set forth herein will only be incorporated to the extent that no conflict arises between that incorporated material and the existing disclosure material.

While various details have been set forth in the foregoing description, it will be appreciated that the various aspects of the techniques for operating a generator for digitally generating electrical signal waveforms and surgical instruments may be practiced without these specific details. One skilled in the art will recognize that the herein described components (e.g., operations), devices, objects, and the discussion accompanying them are used as examples for the sake of conceptual clarity and that various configuration modifications are contemplated. Consequently, as used herein, the specific exemplars set forth and the accompanying discussion are intended to be representative of their more general classes. In general, use of any specific exemplar is intended to be representative of its class, and the non-inclusion of specific components (e.g., operations), devices, and objects should not be taken limiting.

Further, while several forms have been illustrated and described, it is not the intention of the applicant to restrict or limit the scope of the appended claims to such detail. Numerous modifications, variations, changes, substitutions, combinations, and equivalents to those forms may be implemented and will occur to those skilled in the art without departing from the scope of the present disclosure. Moreover, the structure of each element associated with the described forms can be alternatively described as a means for providing the function performed by the element. 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, combinations, and variations as falling within the scope of the disclosed forms. The appended claims are intended to cover all such modifications, variations, changes, substitutions, modifications, and equivalents.

For conciseness and clarity of disclosure, selected aspects of the foregoing disclosure have been shown in block diagram form rather than in detail. Some portions of the detailed descriptions provided herein may be presented in terms of instructions that operate on data that is stored in one or more computer memories or one or more data storage devices (e.g. floppy disk, hard disk drive, Compact Disc (CD), Digital Video Disk (DVD), or digital tape). Such descriptions and representations are used by those skilled in the art to describe and convey the substance of their work to others skilled in the art. In general, an algorithm refers to a self-consistent sequence of steps leading to a desired result, where a "step" refers to a manipulation of physical quantities and/or logic states which may, though need not necessarily, take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It is common usage to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like. These and similar terms may be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities and/or states.

Unless specifically stated otherwise as apparent from the foregoing disclosure, it is appreciated that, throughout the foregoing disclosure, discussions using terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

In a general sense, those skilled in the art will recognize that the various aspects described herein which can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or any combination thereof can be viewed as being composed of various types of "electrical circuitry." Consequently, as used herein "electrical circuitry" includes, but is not limited to, electrical circuitry having at least one discrete electrical circuit, electrical circuitry having at least one integrated circuit, electrical circuitry having at least one application specific integrated circuit, electrical circuitry forming a general purpose computing device configured by a computer program (e.g., a general purpose computer configured by a computer program which at least partially carries out processes and/or devices described herein, or a microprocessor configured by a computer program which at least partially carries out processes and/or devices described herein), electrical circuitry forming a memory device (e.g., forms of random access memory), and/or electrical circuitry forming a communications device (e.g., a modem, communications switch, or optical-electrical equipment). Those having skill in the art will recognize that the subject matter described herein may be implemented in an analog or digital fashion or some combination thereof.

The foregoing detailed description has set forth various forms of the devices and/or processes via the use of block diagrams, flowcharts, and/or examples. Insofar as such block diagrams, flowcharts, and/or examples contain one or more functions and/or operations, it will be understood by those within the art that each function and/or operation within such block diagrams, flowcharts, and/or examples can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. In one form, several portions of the subject matter described herein may be implemented via an application specific integrated circuits (ASIC), a field programmable gate array (FPGA), a digital signal processor (DSP), or other integrated formats. However, those skilled in the art will recognize that some aspects of the forms disclosed herein, in whole or in part, can be equivalently implemented in integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of skill in the art in light of this disclosure. In addition, those skilled in the art will appreciate that the mechanisms of the subject matter described herein are capable of being distributed as one or more program products in a variety of forms, and that an illustrative form of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution. Examples of a signal bearing medium include, but are not limited to, the following: a recordable type medium such as a floppy disk, a hard disk drive, a Compact Disc (CD), a Digital Video Disk (DVD), a digital tape, a computer memory, etc.; and a transmission type medium such as a digital and/or an analog communication medium (e.g., a fiber optic cable, a waveguide, a wired communications link, a wireless communication link (e.g., transmitter, receiver, transmission logic, reception logic, etc.), etc.).

In some instances, one or more elements may be described using the expression "coupled" and "connected" along with their derivatives. It should be understood that these terms are not intended as synonyms for each other. For example, some aspects may be described using the term "connected" to indicate that two or more elements are in direct physical or electrical contact with each other. In another example, some aspects may be described using the term "coupled" to indicate that two or more elements are in direct physical or electrical contact. The term "coupled," however, also may mean that two or more elements are not in direct contact with each other, but yet still co-operate or interact with each other. It is to be understood that depicted architectures of different components contained within, or connected with, different other components are merely examples, and that in fact many other architectures may be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated also can be viewed as being "operably connected," or "operably coupled," to each other to achieve the desired functionality, and any two components capable of being so associated also can be viewed as being "operably couplable," to each other to achieve the desired functionality. Specific examples of operably couplable include but are not limited to physically mateable and/or physically interacting components, and/or wirelessly interactable, and/or wirelessly interacting components, and/or logically interacting, and/or logically interactable components, and/or electrically interacting components, and/or electrically interactable components, and/or optically interacting components, and/or optically interactable components.

In other instances, one or more components may be referred to herein as "configured to," "configurable to," "operable/operative to," "adapted/adaptable," "able to," "conformable/conformed to," etc. Those skilled in the art will recognize that "configured to" can generally encompass active-state components and/or inactive-state components and/or standby-state components, unless context requires otherwise.

While particular aspects of the present disclosure have been shown and described, it will be apparent to those skilled in the art that, based upon the teachings herein, changes and modifications may be made without departing from the subject matter described herein and its broader aspects and, therefore, the appended claims are to encompass within their scope all such changes and modifications as are within the true scope of the subject matter described herein. It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to claims containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should typically be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations.

In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, typically means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that typically a disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms unless context dictates otherwise. For example, the phrase "A or B" will be typically understood to include the possibilities of "A" or "B" or "A and B."

With respect to the appended claims, those skilled in the art will appreciate that recited operations therein may generally be performed in any order. Also, although various operational flows are presented in a sequence(s), it should be understood that the various operations may be performed in other orders than those which are illustrated, or may be performed concurrently. Examples of such alternate orderings may include overlapping, interleaved, interrupted, reordered, incremental, preparatory, supplemental, simultaneous, reverse, or other variant orderings, unless context dictates otherwise. Furthermore, terms like "responsive to," "related to," or other past-tense adjectives are generally not intended to exclude such variants, unless context dictates otherwise.

With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations are not expressly set forth herein for sake of clarity.

In certain cases, use of a system or method may occur in a territory even if components are located outside the territory. For example, in a distributed computing context, use of a distributed computing system may occur in a territory even though parts of the system may be located outside of the territory (e.g., relay, server, processor, signal-bearing medium, transmitting computer, receiving computer, etc. located outside the territory).

A sale of a system or method may likewise occur in a territory even if components of the system or method are located and/or used outside the territory. Further, implementation of at least part of a system for performing a method in one territory does not preclude use of the system in another territory.

In summary, numerous benefits have been described which result from employing the concepts described herein. The foregoing description of the one or more forms has been presented for purposes of illustration and description. It is not intended to be exhaustive or limiting to the precise form disclosed. Modifications or variations are possible in light of the above teachings. The one or more forms were chosen and described in order to illustrate principles and practical application to thereby enable one of ordinary skill in the art to utilize the various forms and with various modifications as are suited to the particular use contemplated. It is intended that the claims submitted herewith define the overall scope.

Various aspects of the subject matter described herein are set out in the following numbered clauses:

Example 1: An electrosurgical device comprising: a housing; a shaft extending distally from the housing; an end effector coupled to a distal end of the shaft, the end effector comprising: an electrode; a suction port; and a fluid port; and a control system communicatively coupled to the suction port and the fluid port and configured to control a rate of fluid flowing out of the fluid port and a rate of suction flowing into the suction port.

Example 2: The electrosurgical device of Example 1, further comprising: a first fluid path in fluid communication with the fluid port; and a second fluid path in fluid communication with the suction port; wherein the housing is configured to enclose a first portion of the first fluid path and a first portion of the second fluid path; and wherein the shaft is configured to enclose a second portion of the first fluid path and a second portion of the second fluid path.

Example 3: The electrosurgical device of one or more of Examples 1-2, further comprising an impedance sensor configured to measure impedance experienced at the electrode.

Example 4: The electrosurgical device of Example 3, wherein the control system is configured to control the rate of fluid flowing out of the fluid port based on the measured impedance experienced at the electrode.

Example 5: The electrosurgical device of Example 4, wherein the control system is further configured to control the rate of suction flowing into of the suction port based on the measured impedance experienced at the electrode.

Example 6: The electrosurgical device of one or more of Examples 1-5, further comprising a radio frequency (RF) current sensor configured to measure RF current applied to the electrode.

Example 7: The electrosurgical device of Example 6, wherein the control system is configured to control the rate of fluid flowing out of the fluid port based on the measured RF current applied to the electrode.

Example 8: The electrosurgical device of Example 7, wherein the control system is further configured to control the rate of suction flowing into of the suction port based on the measured RF current applied to the electrode.

Example 9: The electrosurgical device of one or more of Examples 1-8, further comprising a temperature sensor configured to measure temperature of the fluid suctioned into the suction port.

Example 10: The electrosurgical device of Example 9, wherein the control system is configured to control the rate of fluid flowing out of the fluid port based on the measured temperature of the fluid into the suction port.

Example 11: The electrosurgical device of Example 10, wherein the control system is further configured to control the rate of suction flowing into of the suction port based on the measured temperature of the fluid into the suction port.

Example 12: The electrosurgical device of one or more of Examples 1-11, wherein the end effector further comprises a partially deflectable member that is configured to increase the rate of fluid out of the fluid port as the partially deflectable member increases in deflection.

Example 13: The electrosurgical device of one or more of Examples 1-12, wherein the control system is further configured to increase the rate of fluid flowing out of the fluid port the longer the electrode applies energy.

Example 14: The electrosurgical device of one or more of Examples 1-13, wherein the control system is further configured to decrease the rate of fluid flowing out of the fluid port the longer the electrode applies energy.

Example 15: The electrosurgical device of one or more of Examples 1-14, further comprising a user interface console communicatively coupled to the control system and configured to receive an input from a user to manually control an initial fluid rate of the fluid port.

Example 16: The electrosurgical device of Example 15, wherein the control system is further configured to automatically increase the fluid rate of the fluid port after the initial fluid rate is manually specified from the user interface console; wherein the automatic increase of the fluid rate occurs based on an earlier rise in measured temperature of the fluid at the suction port if the initial fluid rate is manually specified at a slower fluid rate, and the automatic increase of the fluid rate occurs based on a later rise in measured temperature of the fluid at the suction port if the initial fluid rate is manually specified at a faster fluid rate.

Example 17: The electrosurgical device of one or more of Examples 3-16, wherein the control system is configured to: detect an impedance spike based on a drastic change in impedance from the impedance sensor; and in response, increase the rate of fluid flowing out of the fluid port.

Example 18: A method of a control system of an electrosurgical device, the method comprising: accessing data from one or more sensors related to a physical characteristic of a function occurring at an end effector of the electrosurgical device; controlling a rate of fluid flowing to a fluid port of the electrosurgical device, based on the data related to the physical characteristic; and controlling a rate of suction flowing from a suction port of the electrosurgical device, based on the data related to the physical characteristic.

Example 19: The method of Example 18, wherein the physical characteristic comprises a measure of impedance experienced at an electrode of the end effector of the electrosurgical device.

Example 20: The method of one or more of Examples 18-19, wherein the physical characteristic comprises a measure of RF current applied to an electrode of the end effector of the electrosurgical device.

Example 21: The method of one or more of Examples 18-20, wherein the physical characteristic comprises a temperature of fluid measured at the suction port at the end effector of the electrosurgical device.

What is claimed is:

1. A method of a control system of an electrosurgical device, the method comprising:

accessing data from one or more sensors related to a physical characteristic of a function occurring at an end effector of the electrosurgical device, wherein the end effector comprises:

a first electrode and a second electrode; and

a diverter comprising a planar top surface, a planar bottom surface in opposition to the planar top surface, a first terminal lateral side in mechanical communication with an inner side of an exposed longitudinal extent of the first electrode and a second terminal lateral side in mechanical communication with an inner side of an exposed longitudinal extent of the second electrode;

controlling a rate of fluid flowing to a fluid port of the electrosurgical device, the fluid port disposed above the planar top surface of the diverter, based on the data related to the physical characteristic; and

controlling a rate of suction flowing from a suction port of the electrosurgical device, the suction port disposed below the planar bottom surface of the diverter, based on the data related to the physical characteristic.

2. The method of claim **1**, wherein accessing data from one or more sensors related to a physical characteristic of a function comprises accessing the data from the one or more sensors measuring an impedance experienced at the first electrode or the second electrode of the end effector of the electrosurgical device.

3. The method of claim **2**, wherein accessing the data from the one or more sensors measuring an impedance experienced at the first electrode or the second electrode of the end effector of the electrosurgical device comprises accessing the data from the one or more sensors detecting an impedance spike at the first electrode or the second electrode of the end effector of the electrosurgical device.

4. The method of claim **1**, wherein accessing data from one or more sensors related to a physical characteristic of a function comprises accessing the data from the one or more sensors measuring an RF current applied to the first electrode or the second electrode of the end effector of the electrosurgical device.

5. The method of claim **1**, wherein accessing data from one or more sensors related to a physical characteristic of a function comprises accessing the data from the one or more sensors measuring a temperature of fluid at the suction port at the end effector of the electrosurgical device.

6. The method of claim **1**, wherein accessing data from one or more sensors related to a physical characteristic of a function comprises accessing the data from the one or more sensors measuring an activation time of the first electrode or the second electrode disposed at the end effector.

7. The method of claim **1**, wherein controlling a rate of fluid flowing to a fluid port of the electrosurgical device, based on the data related to the physical characteristic comprises controlling an operation of a proportional valve fluidically coupled to a source of a saline fluid based on the data related to the physical characteristic.

8. The method of claim **1**, wherein controlling a rate of fluid flowing to a fluid port of the electrosurgical device, based on the data related to the physical characteristic comprises controlling an operation of a multi-stage valve fluidically coupled to a source of a saline fluid based on the data related to the physical characteristic.

9. The method of claim **1**, wherein controlling a rate of fluid flowing to a fluid port of the electrosurgical device, based on the data related to the physical characteristic comprises controlling a first portion of the rate of fluid flowing to the fluid port of the electrosurgical device, based on the data related to the physical characteristic.

10. The method of claim **9**, further comprising manually adjusting a second portion of the rate of fluid flowing to the fluid port of the electrosurgical device by a user.

11. The method of claim **1**, wherein controlling a rate of suction flowing from a suction port of the electrosurgical device, based on the data related to the physical characteristic comprises controlling the rate of suction flowing from the suction port of the electrosurgical device based on a measurement of power delivered to a tissue.

12. The method of claim **1**, wherein controlling a rate of suction flowing from a suction port of the electrosurgical device, based on the data related to the physical characteristic comprises controlling the rate of suction flowing from the suction port of the electrosurgical device, based on a temperature of fluid measured at the suction port at the end effector of the electrosurgical device.

13. The method of claim **1**, wherein controlling a rate of suction flowing from a suction port of the electrosurgical device, based on the data related to the physical characteristic comprises generating an amount of suction at the suction port of the electrosurgical device proportional to an amount of fluid at a surgical site.

14. The method of claim **13**, wherein generating an amount of suction at the suction port of the electrosurgical device comprises modulating a variable duty cycle of a vacuum controlling valve.

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