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Patil et al.

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(54) **VOLTAGE ASSISTED PAINTING SYSTEM**

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B05B 5/03 (2006.01)
B05B 5/053 (2006.01)

(52) **U.S. Cl.**
CPC ***B05B 5/087*** (2013.01); ***B05B 5/0533*** (2013.01); *B05B 5/03* (2013.01)

(58) **Field of Classification Search**
CPC B05D 5/00; B05D 3/12; B06B 1/0292; B05B 12/082; B05B 12/18; B05B 7/0012; B05B 7/0884; B05B 17/0607; B05B 5/087; B05B 5/0533; B05B 5/03
See application file for complete search history.

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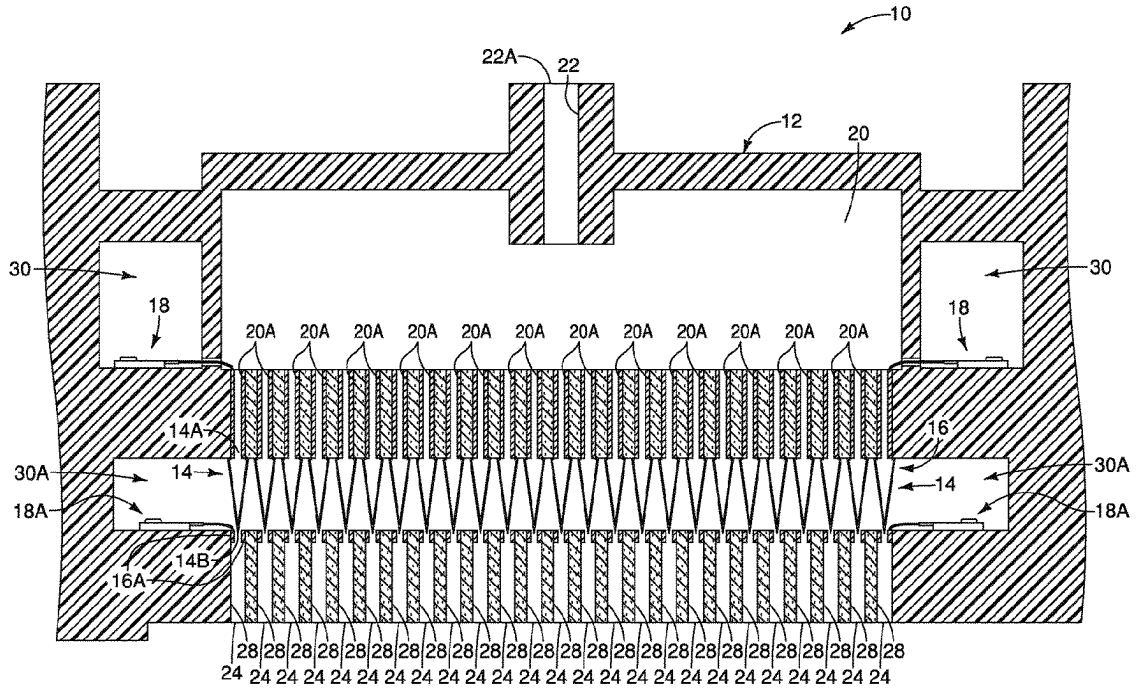
(57) **ABSTRACT**

A voltage assisted painting system includes a housing, at least one nozzle, and at least one electrode. The housing has a conduit for receiving paint from an external source into the housing. The at least one nozzle is disposed in the housing. The at least one nozzle has an inlet that is fluidly connected to the conduit to receive paint from the conduit. The at least one nozzle has an outlet that dispenses paint. The at least one electrode is provided at the housing at a location downstream of the inlet with respect to the conduit. The at least one electrode is configured to generate a magnetic field in the vicinity of the outlet.

18 Claims, 14 Drawing Sheets



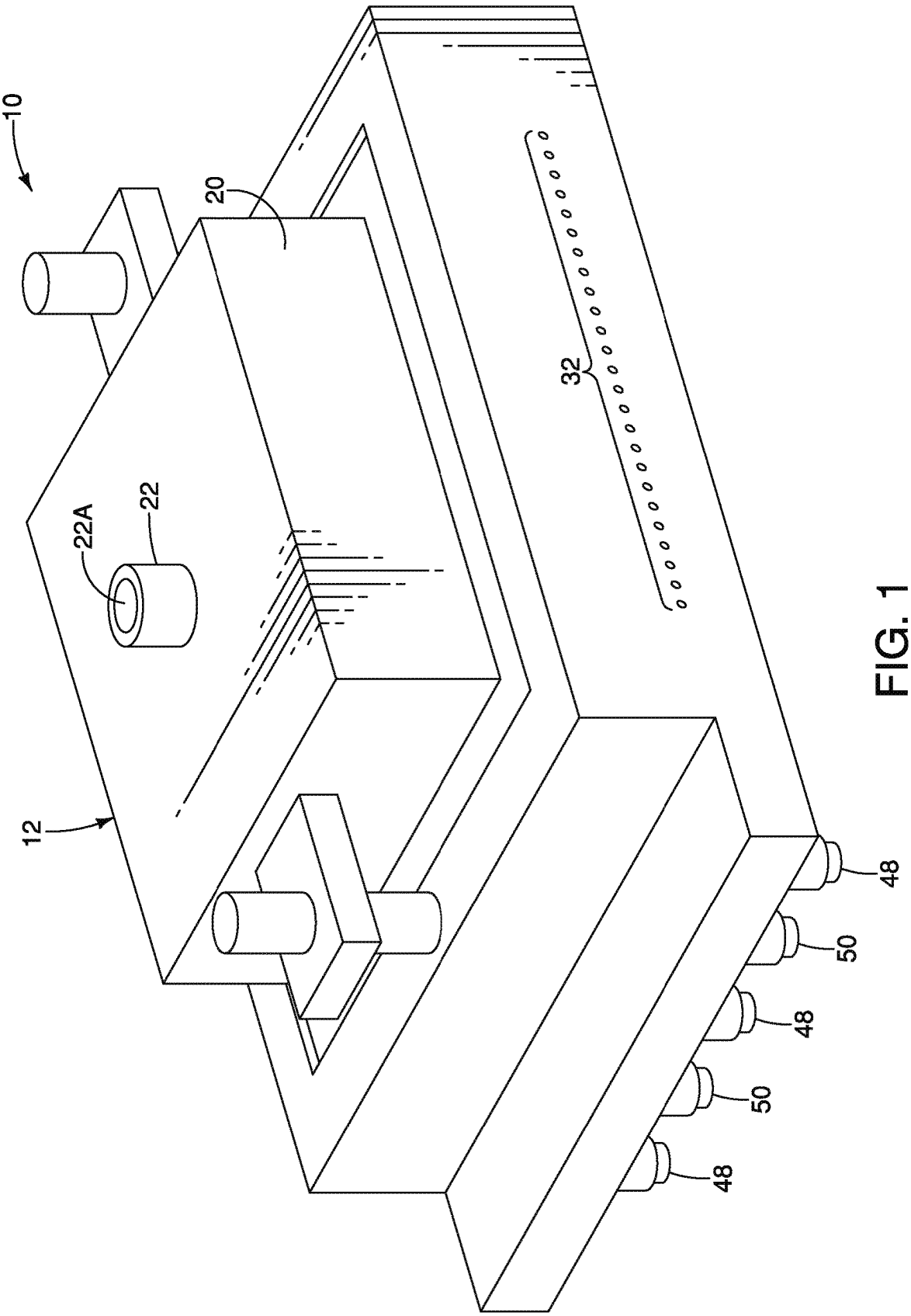


FIG. 1

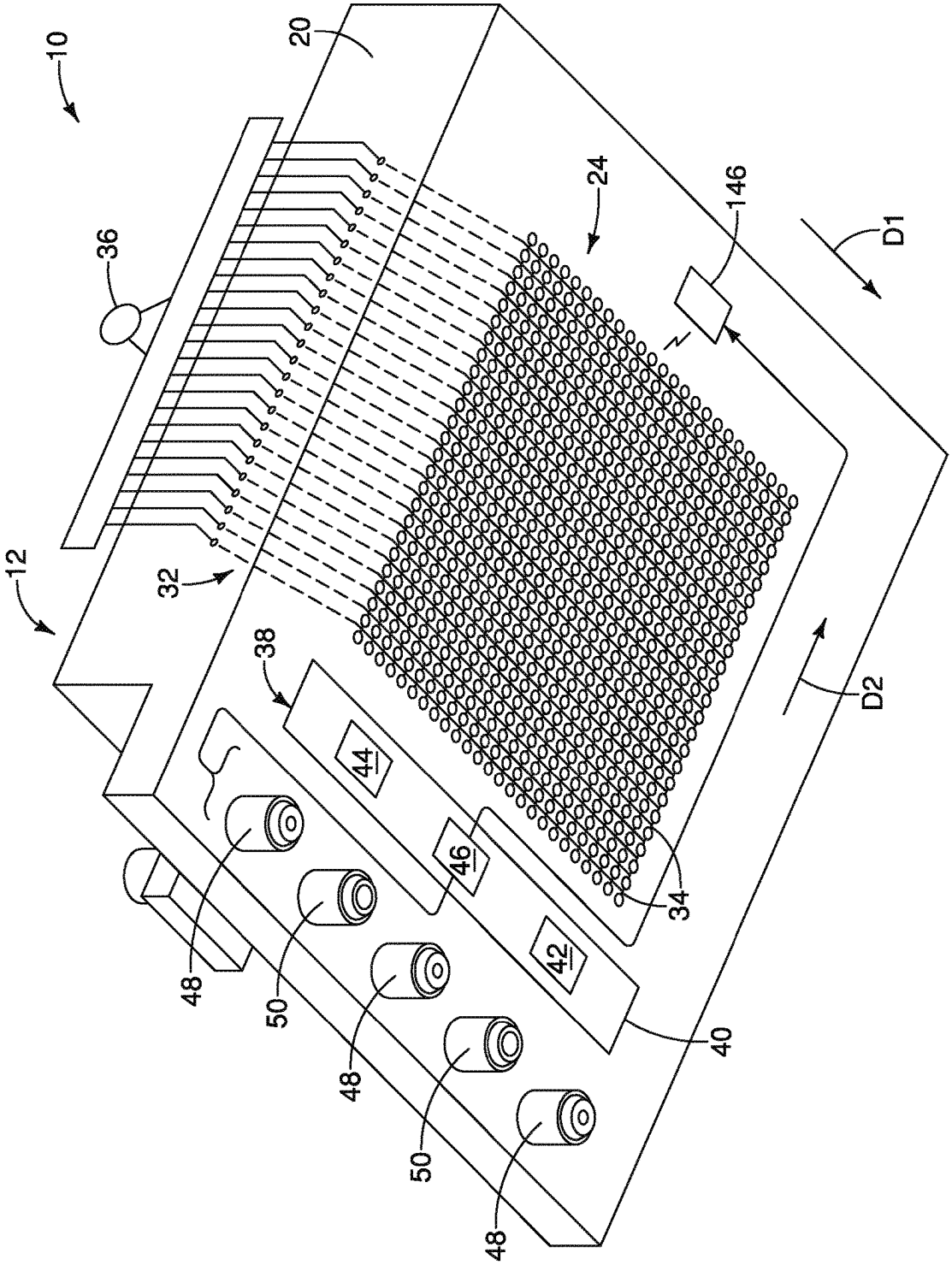


FIG. 2

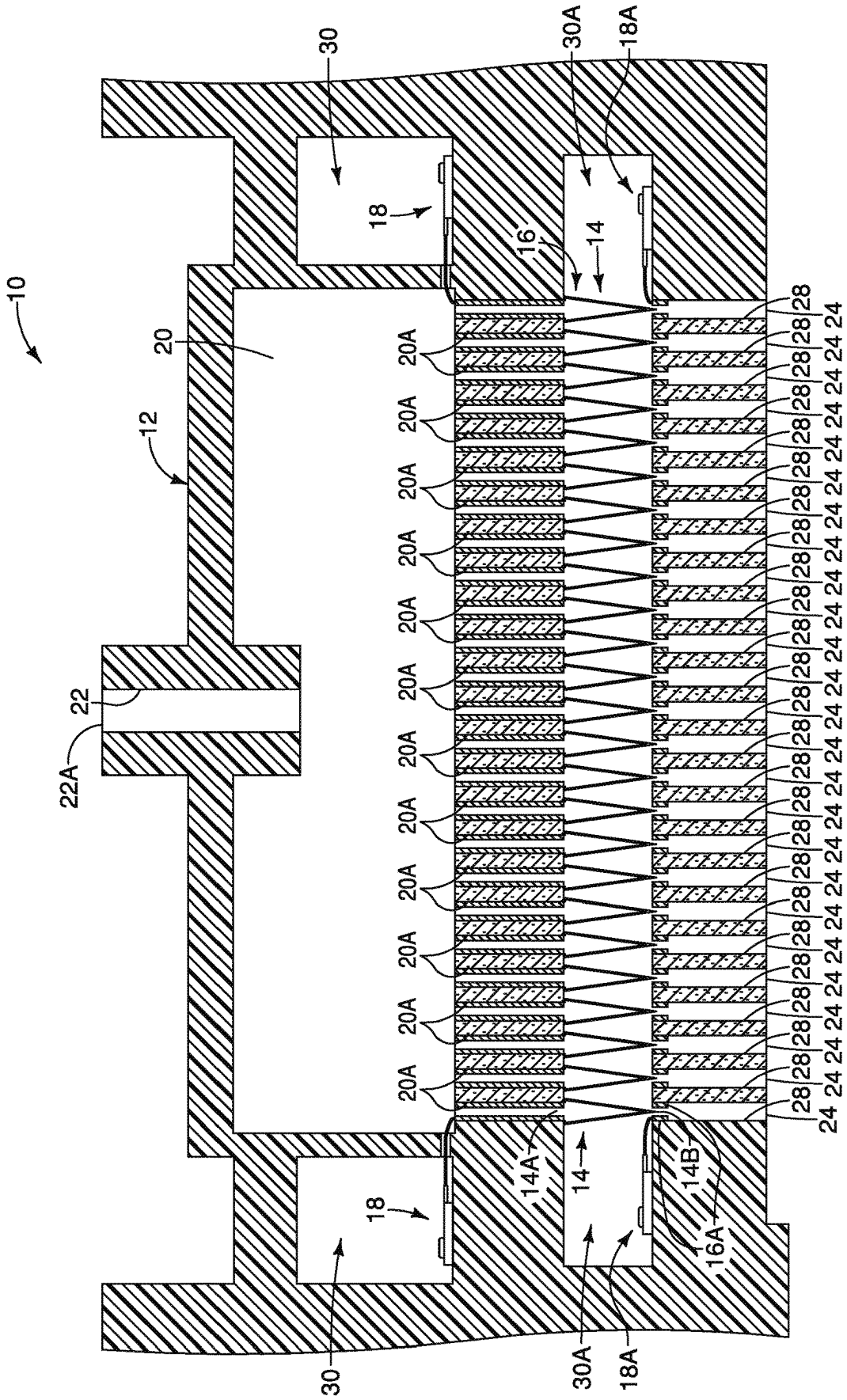
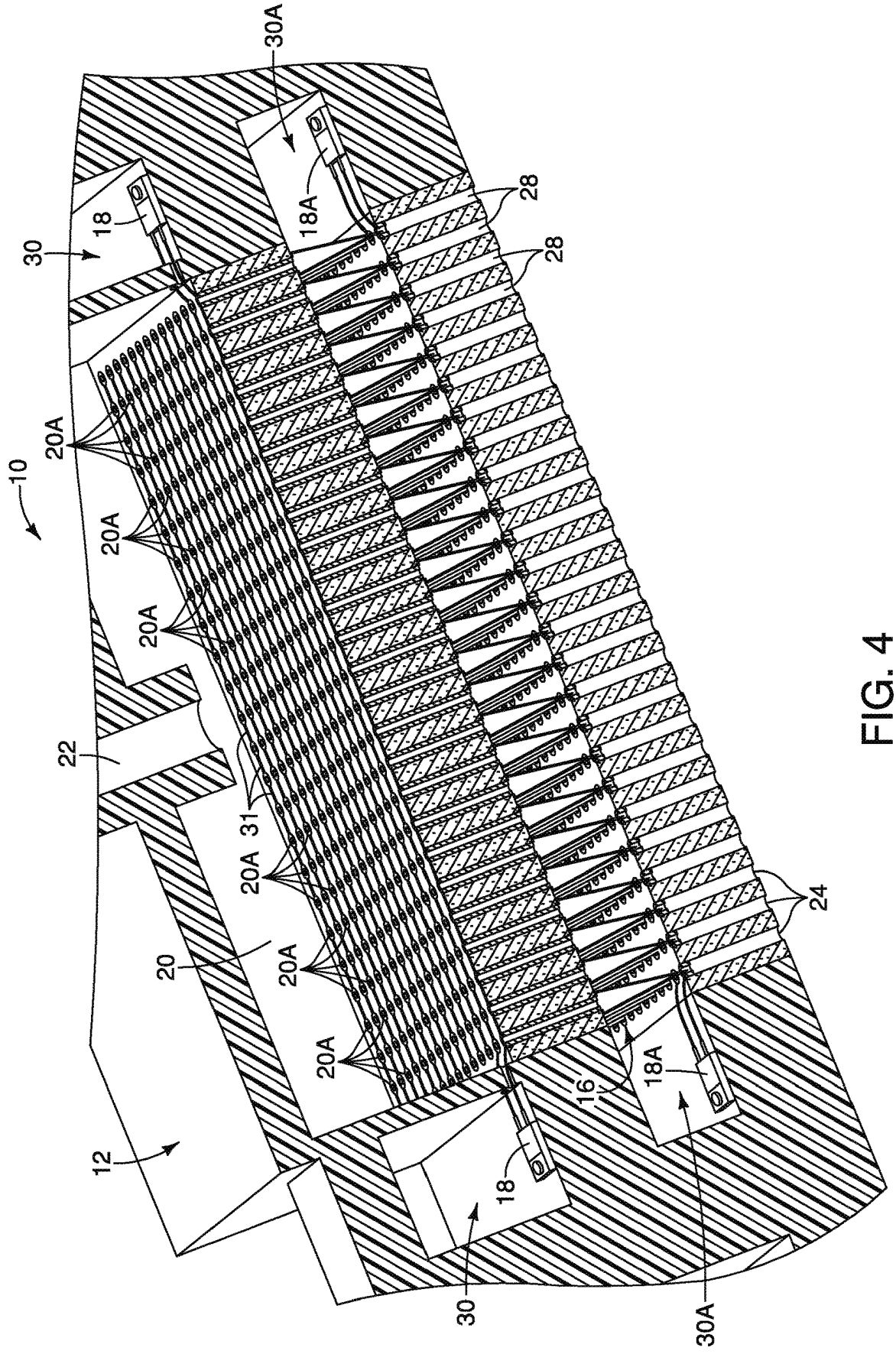


FIG. 3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18
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18A
16
12
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30
30A

FIG. 4

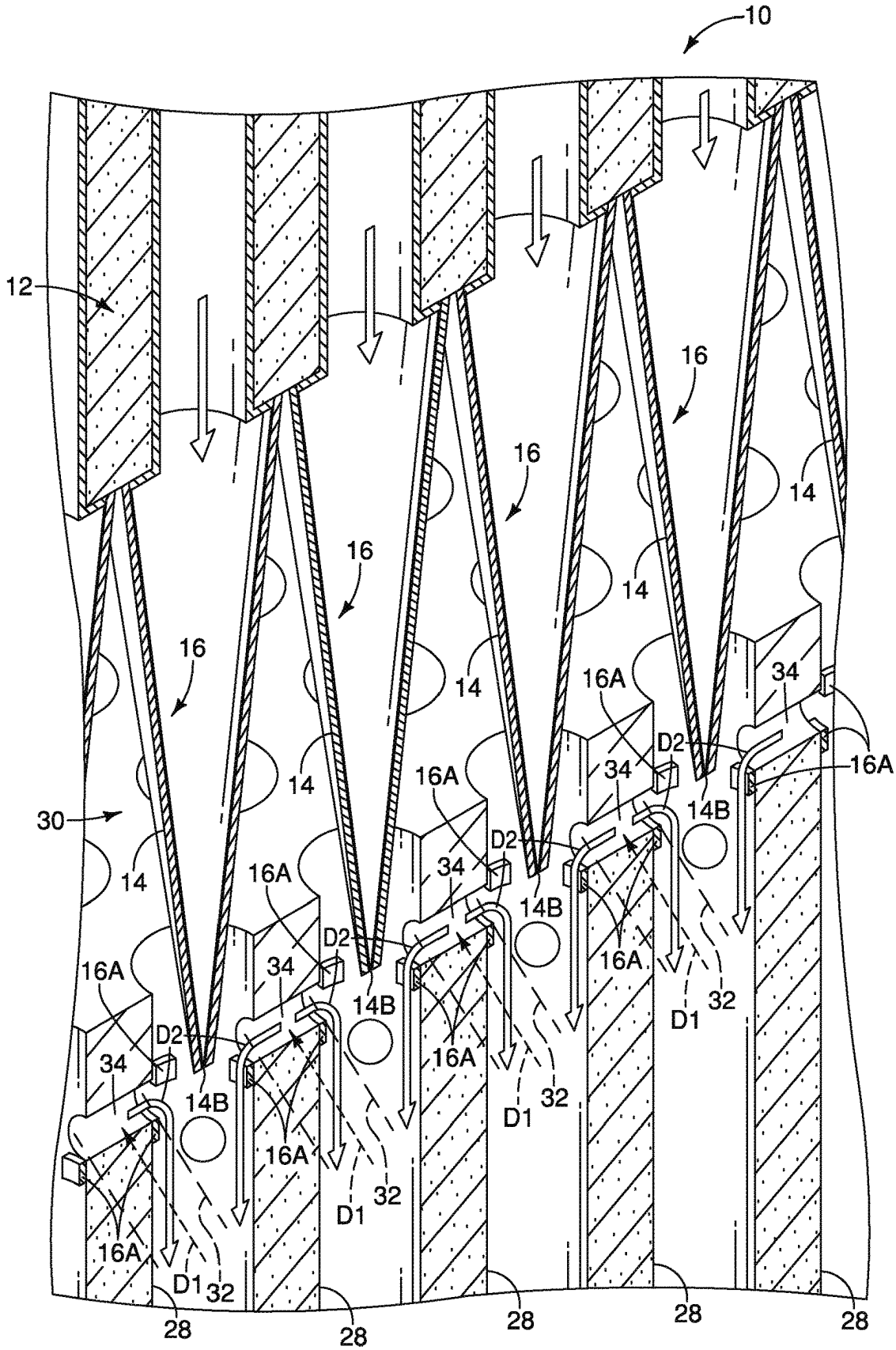


FIG. 5

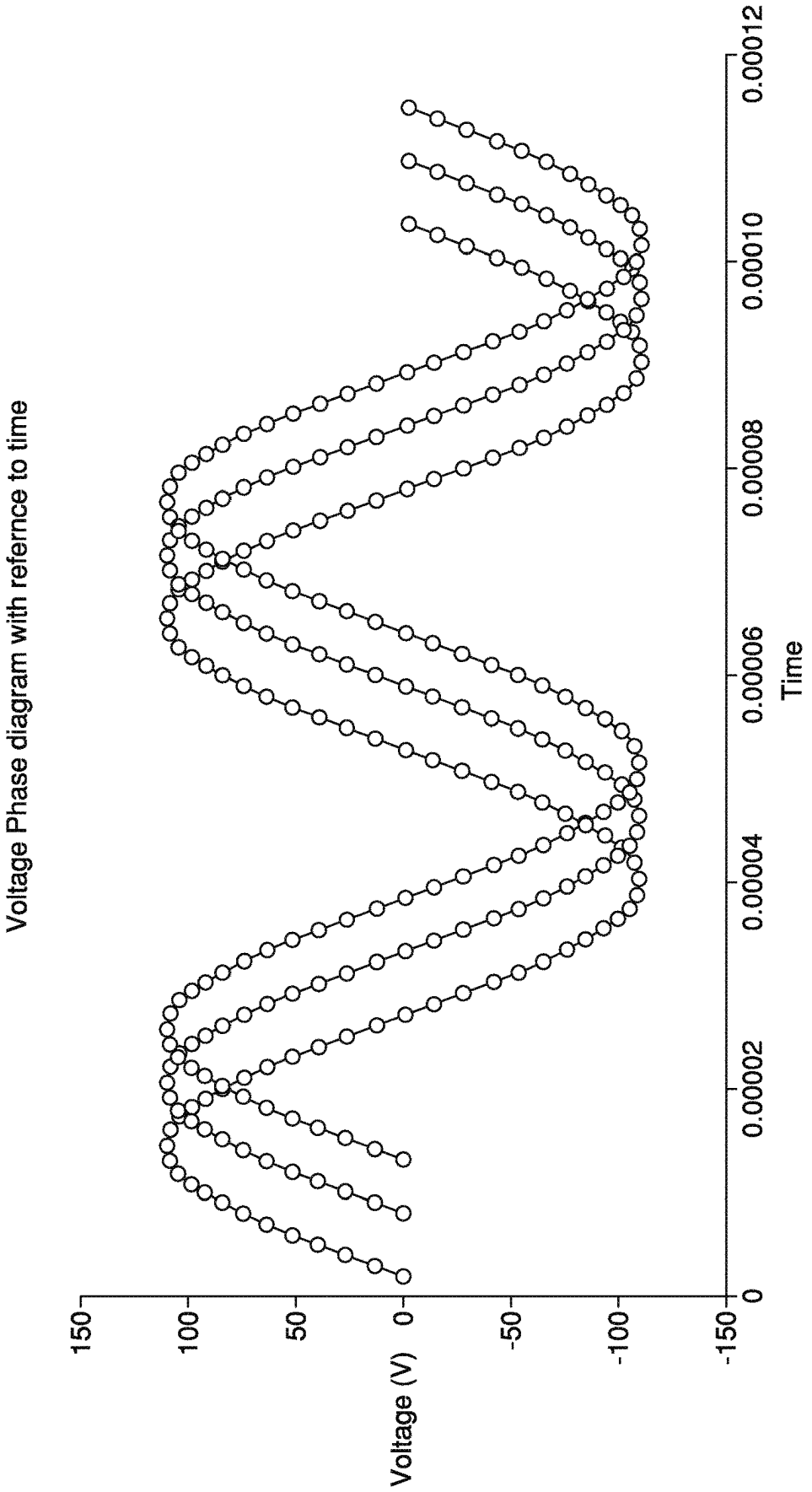
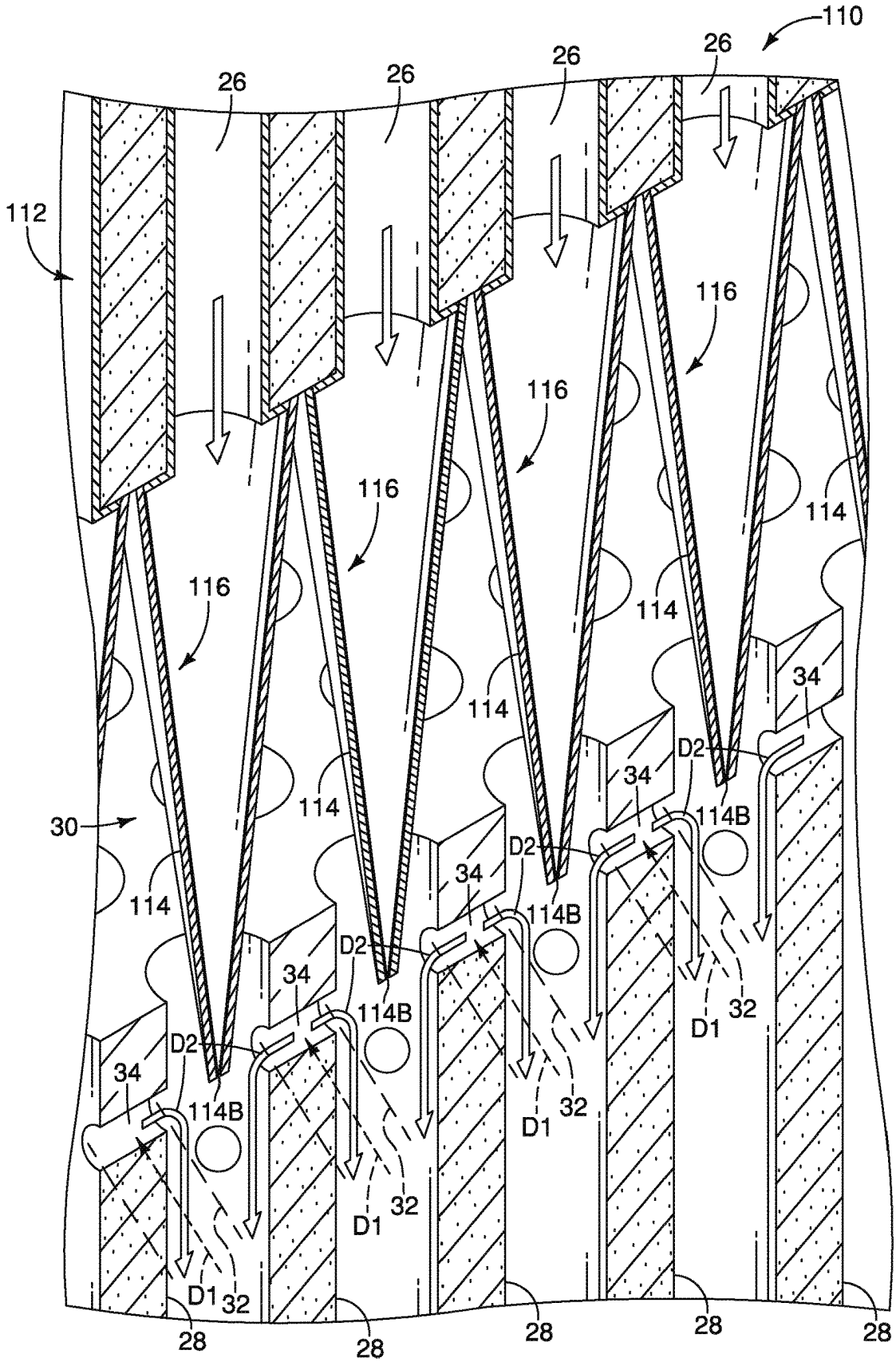

Voltage Phase diagram with refernce to time
Voltage (V)
150
100
50
0
-50
-100
-150
0
0.00002
0.00004
0.00006
0.00008
0.00010
0.00012
Time

FIG. 6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114B
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114B
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D1
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FIG. 7

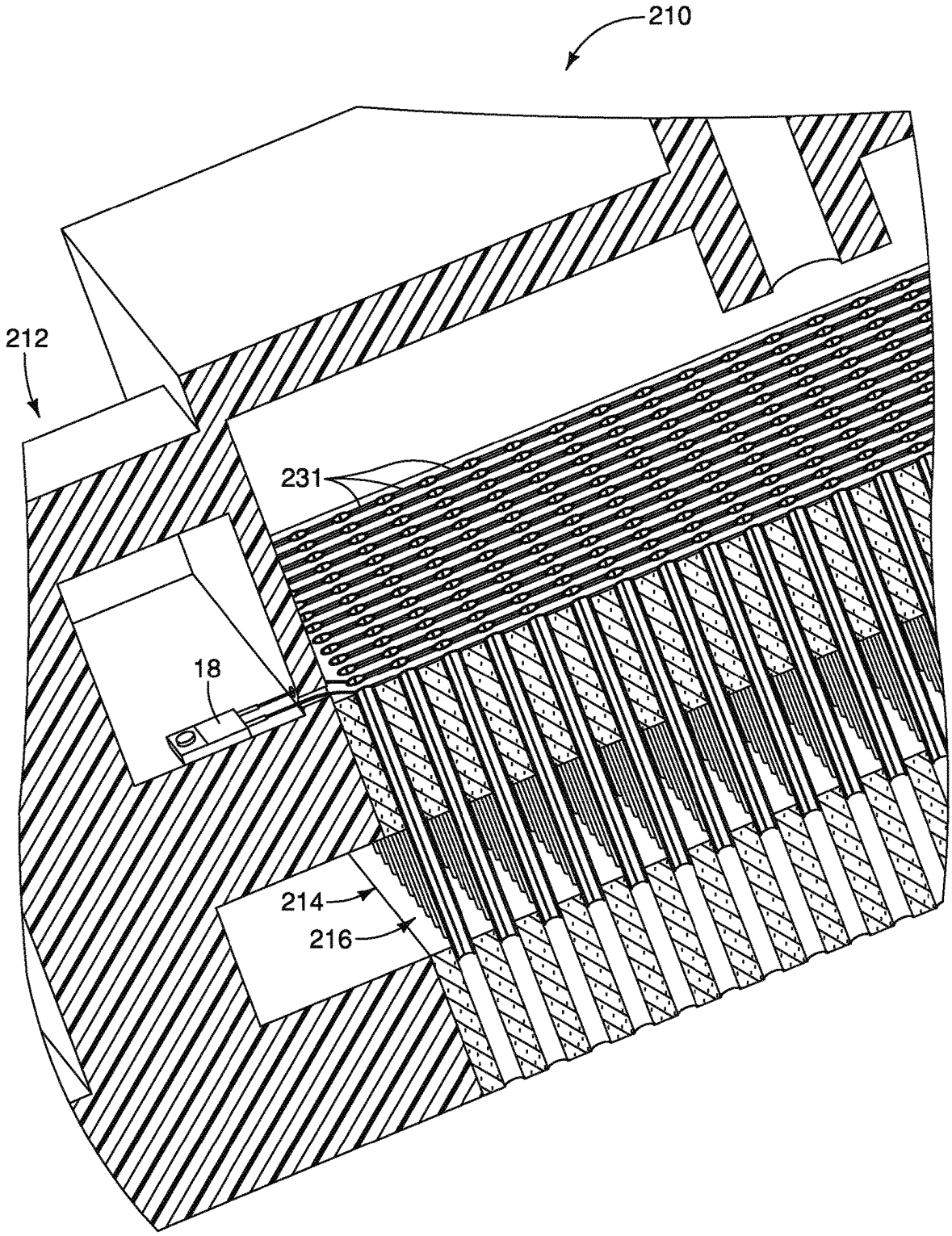

FIG. 8

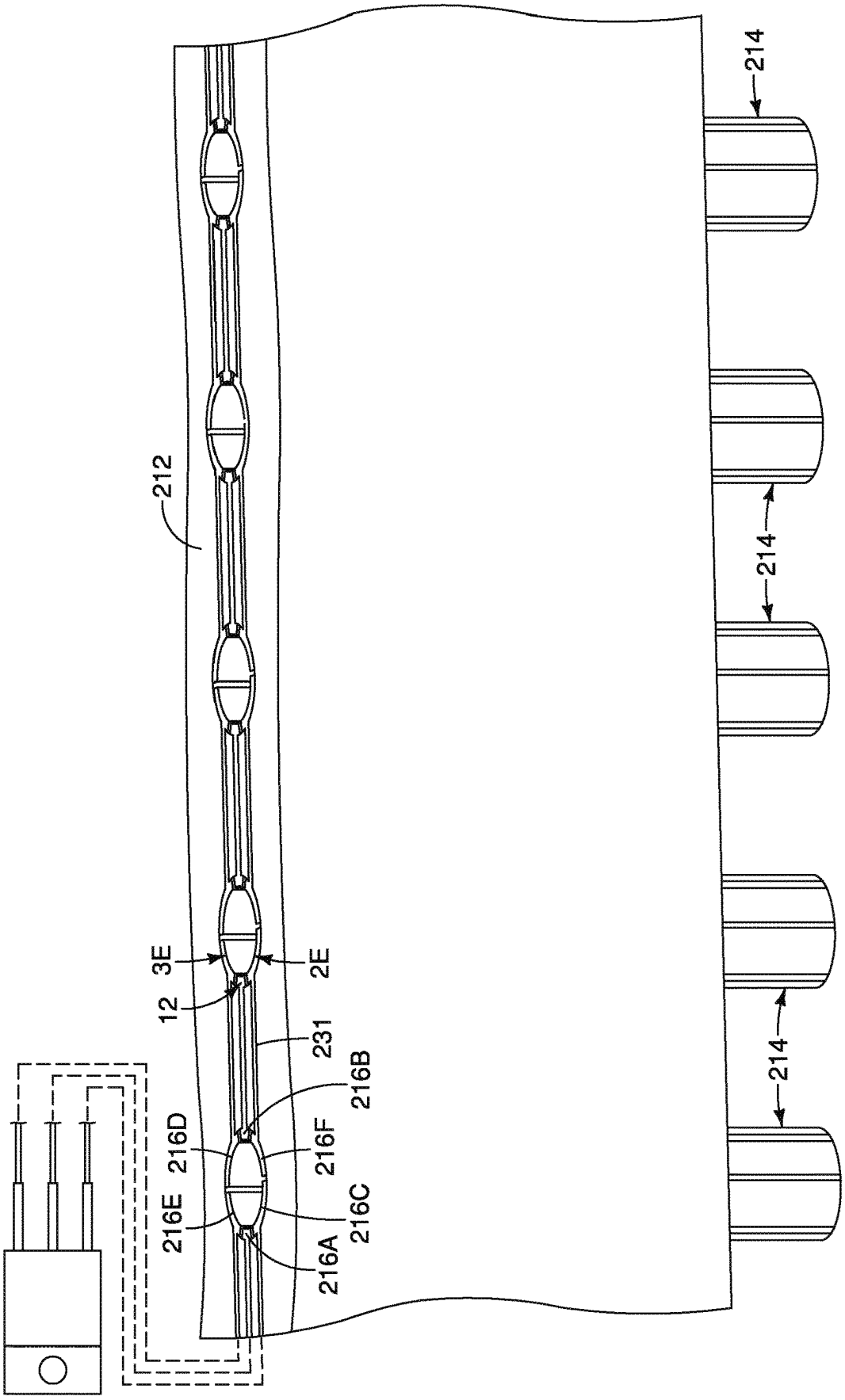

FIG. 9

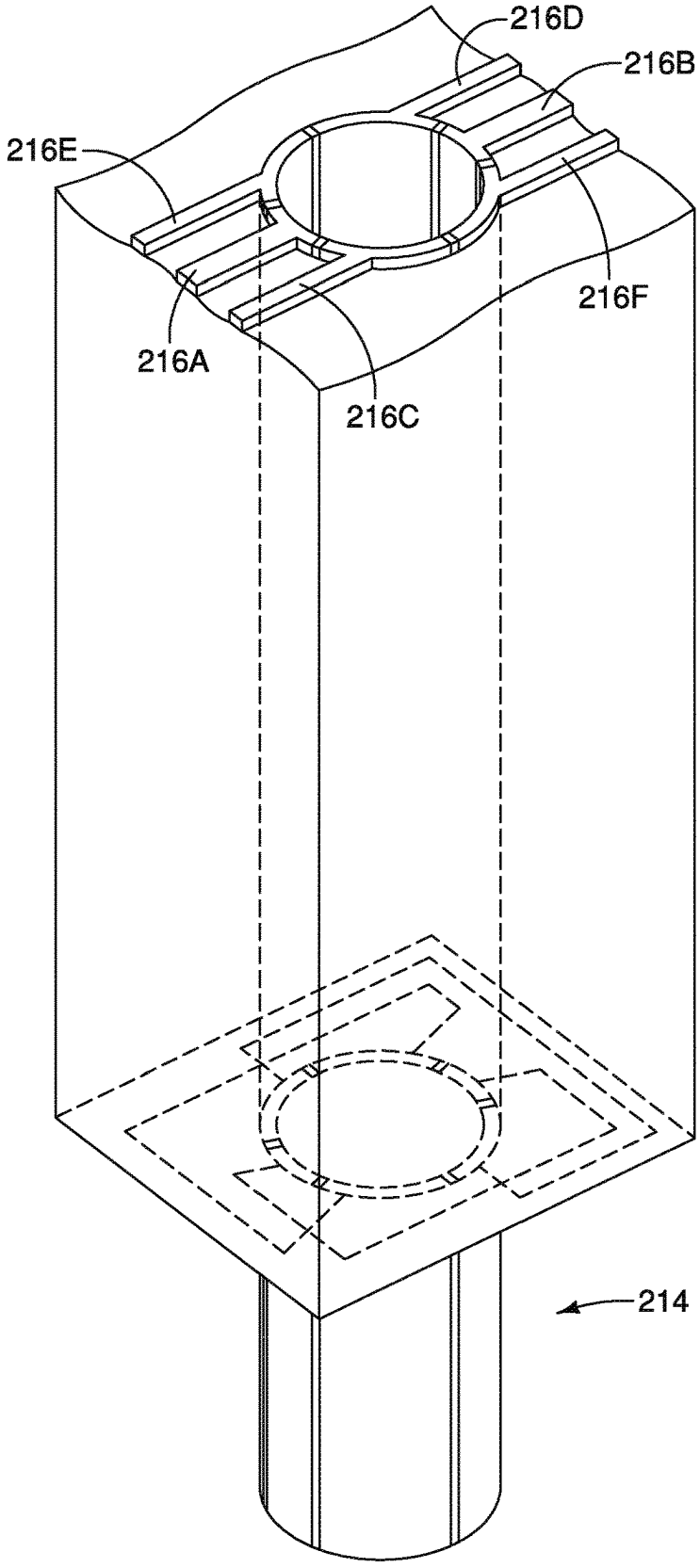

FIG. 10

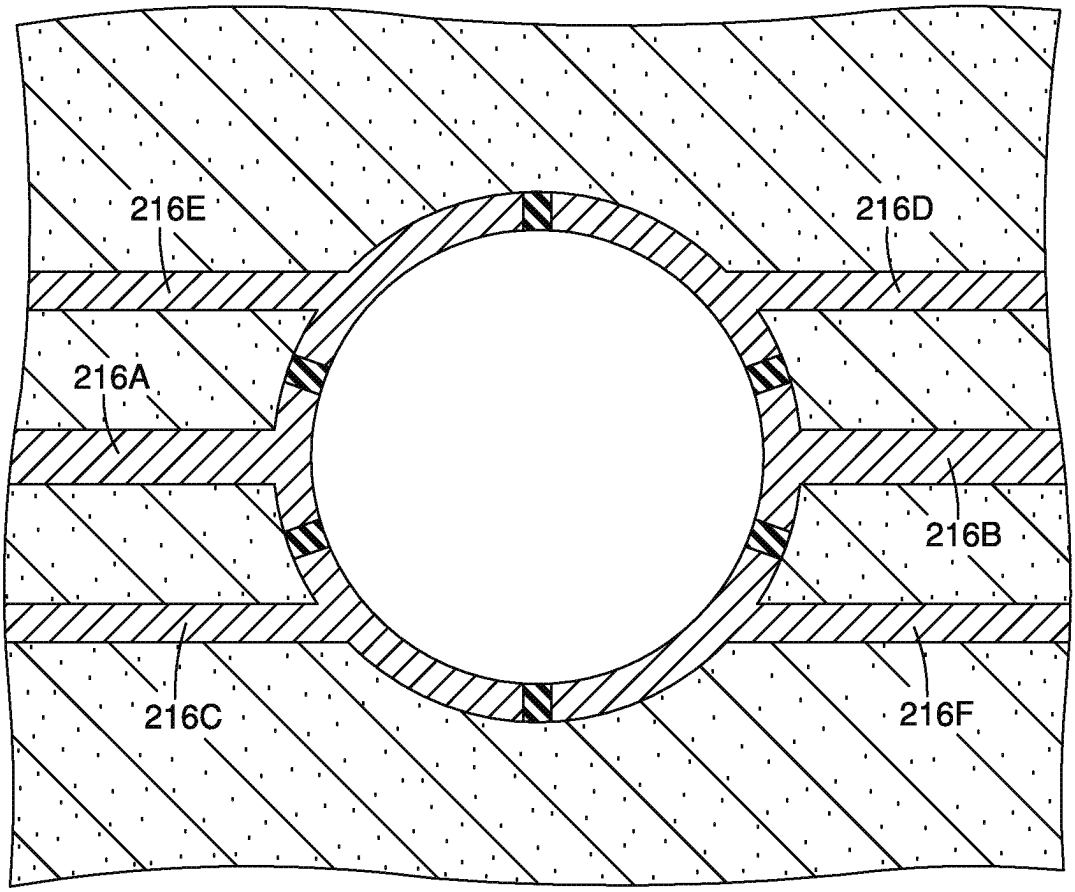

FIG. 11

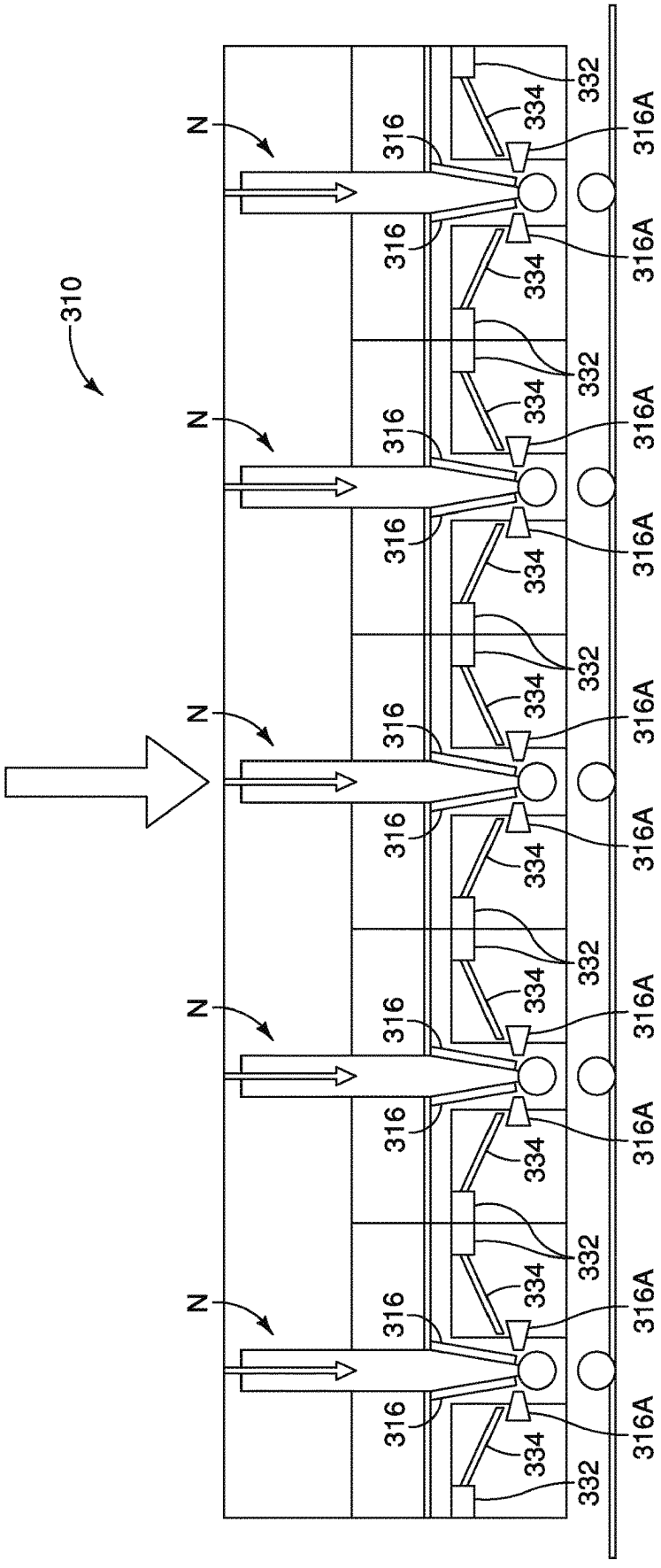

FIG. 12

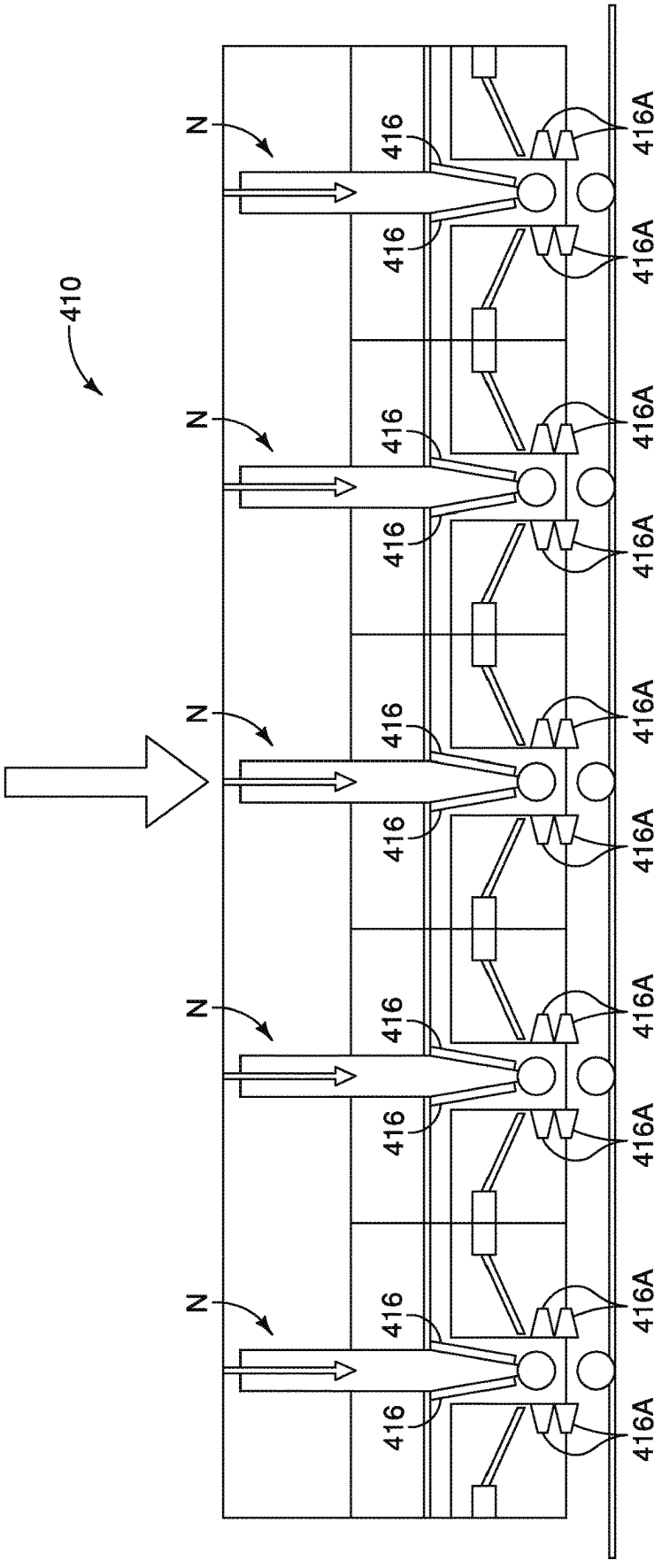

FIG. 13

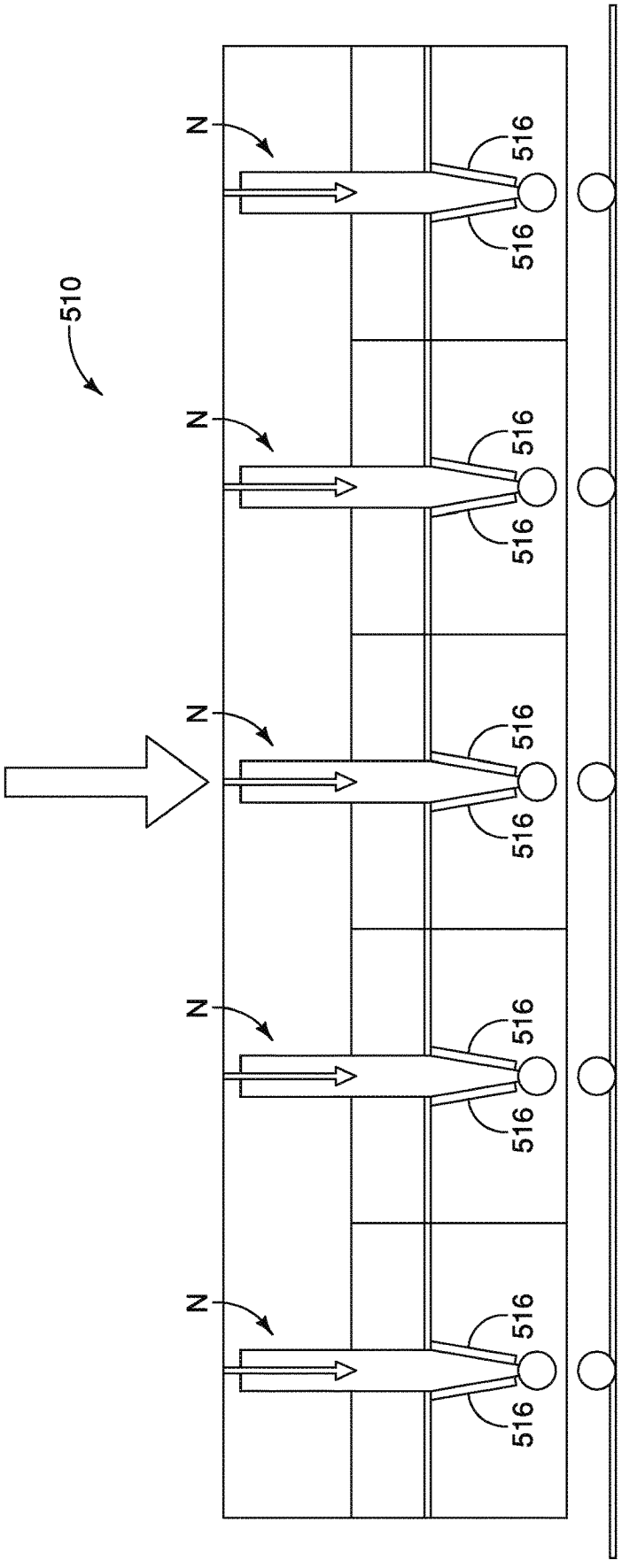

FIG. 14

VOLTAGE ASSISTED PAINTING SYSTEM

BACKGROUND

Field of the Invention

The present invention generally relates to a voltage assisted painting system. More specifically, the present invention relates to a voltage assisted painting system for applying paint to a vehicle body.

Background Information

Vehicle paints are typically applied using rotary atomizers that include a rotating bell cup having a generally conical overflow surface that opens to an atomizing edge. The paint that is dispensed from rotary atomizers tends to be tortuous and non-uniform as the atomizing process results in a turbulent path of the paint droplets. Conventional rotary bell atomizers cannot handle high low-shear viscosity paint fluid. Thus, current commercial paint has to contain about 50% of solvent which requires drying through a baking process. Additionally, the atomizing process tends to result in waste and it is difficult to utilize for customizations and application of multi-tone paint.

SUMMARY

In view of the state of the known technology, one aspect of the present disclosure is to provide a voltage assisted painting system comprising a housing, at least one nozzle, and at least one electrode. The housing has a conduit for receiving paint from an external source into the housing. The at least one nozzle is disposed in the housing. The at least one nozzle has an inlet that is fluidly connected to the conduit to receive paint from the conduit. The at least one nozzle has an outlet that dispenses paint. The at least one electrode is provided at the housing at a location downstream of the inlet with respect to the conduit. The at least one electrode is configured to generate a magnetic field in the vicinity of the outlet.

Also other objects, features, aspects and advantages of the disclosed voltage assisted painting system will become apparent to those skilled in the art from the following detailed description, which, taken in conjunction with the annexed drawings, discloses one embodiment of the voltage assisted painting system.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the attached drawings which form a part of this original disclosure:

FIG. **1** is a perspective view of a housing for a voltage assisted painting system in accordance with an illustrated embodiment;

FIG. **2** is a perspective view of an underside of the housing of FIG. **1**;

FIG. **3** is a cross-sectional view of the housing of FIGS. **1** and **2**;

FIG. **4** is another cross-sectional view of the housing of FIGS. **1** to **3**;

FIG. **5** is an enlarged cross-sectional view of a portion of the housing of FIGS. **1** to **4**;

FIG. **6** is a graph of a voltage phase diagram illustrating an example of an electronic control of the voltage assisted painting system;

FIG. **7** is an enlarged cross-sectional view of a first modified voltage assisted painting system;

FIG. **8** is a cross-sectional view of a second modified voltage assisted painting system;

FIG. **9** is an enlarged partial perspective view of the second modified voltage assisted painting system;

FIG. **10** is an enlarged partial perspective view of one of the nozzles of the second modified voltage assisted painting system;

FIG. **11** is a cross-sectional view of the nozzle of FIG. **10**

FIG. **12** is a schematic view of a first example of an array of nozzles that can be implemented with any of the voltage assisted painting systems of FIGS. **1** through **11**;

FIG. **13** is a schematic view of a second example of an array of nozzles that can be implemented with any of the voltage assisted painting systems of FIGS. **1** through **11**; and

FIG. **14** is a schematic view of a third example of an array of nozzles that can be implemented with any of the voltage assisted painting systems of FIGS. **1** through **11**.

DETAILED DESCRIPTION OF EMBODIMENTS

Selected embodiments will now be explained with reference to the drawings. It will be apparent to those skilled in the art from this disclosure that the following descriptions of the embodiments are provided for illustration only and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

Referring initially to FIGS. **1** to **5**, an voltage assisted painting system **10** is illustrated in accordance with an embodiment. The voltage assisted painting system **10** of the illustrated embodiment can be utilized for applying paint to various types of substrate such as a vehicle body (not shown). The voltage assisted painting system **10** comprises a housing **12**, at least one nozzle **14** and at least one electrode **16**. The electrodes **16** of the illustrated embodiment can be one or more solid electric conductors that is capable of carrying out an electric current or an electric field to the contents of the nozzles **14**. The electrodes **16** are preferably made of good electric conducting materials, such as copper.

In the illustrated embodiment, the housing **12** houses a plurality of nozzles **14** and a plurality of electrodes **16**. As will be described, in the illustrated embodiment, the electrodes **16** can be provided as part of the nozzles **14** or can be provided exterior to the nozzles **14**. In the illustrated embodiment, the voltage assisted painting system **10** is illustrated as a multi-nozzle painting system. However, it will be apparent to those skilled in the vehicle field from this disclosure that the voltage assisted painting system **10** can be utilized as a single-nozzle painting system with one or more electrodes provided for the single nozzle.

As best seen in FIGS. **3** and **4**, the voltage assisted painting system **10** includes one or more voltage regulator **18** that is housed in the housing **12**. As shown, the housing **12** includes a plurality of voltage regulators **18**. In other words, the voltage assisted painting system **10** of FIGS. **1** to **5** includes the plurality of nozzles **14** and can include one or more plurality of voltage regulators **18** each supplying electric current to the electrodes **18**. The voltage assisted painting system **10** is provided for paint application to a vehicle body using assistance from the voltage regulators **18** and the electrodes **16**.

In the illustrated embodiment, the term "paint" will refer to any material including, but not limited to, one or more of the following substances: traditional paint, ink, polymers, water, solvents, and other fluids imparting color to a substrate and mixtures of the above-mentioned substances.

"Paint" can also refer to material(s) having viscosities significantly higher and significantly lower than traditional paint viscosities.

The voltage assisted painting system **10** of the illustrated embodiment uses electric ionization to induce droplet formation formed at the nozzles **14**. In particular, the voltage assisted painting system **10** utilizes the electrodes **16** to produce electromagnetic or electric fields near or at the nozzles **14** to induce a continuous droplet formation process from the nozzles **14**. Thus, the voltage regulators **18** of the voltage assisted painting system **10** are electrically connected to each of the plurality of nozzles **14** to regulate electric current to the electrodes **16**. As stated, the voltage assisted painting system **10** can comprise one or more voltage regulators **18** that are connected to the nozzles **14** to deliver and regulate electric current to the electrodes **16**. The voltage regulators **18** are illustrated as being connected to some of the nozzles **14** schematically for simplicity.

As the voltage regulators **18** are identical, only one of the voltage regulators **18** will be further described herein. The voltage regulator **18** can include a circuit that creates and maintains a fixed output voltage. The voltage regulator **18** is connected to a power supply (not shown) that can be internally provided to the housing **12** or can be external to the housing **12**. The applied voltage from the voltage regulator **18** can produce an electric field at or near the nozzles **14** to fine tune the size or diameter of the droplets that are formed at the nozzles **14**. The application of voltage from the voltage regulator **18** can also help discharge the droplets that are formed at the tips of the nozzles **14** to facilitate a continuous droplet deposition onto the substrate.

In particular, the application of voltage creates an electric field generated from the electrodes **16**. The electric field can form a continuous stream of droplets having diameters that are much smaller than typical droplets formed without electrostatic assistance, such that the paint droplets formed by the voltage assisted painting system **10** has a lower viscosity and can be a continuous stream that can be sprayed onto a substrate. Therefore, in the illustrated embodiment, the application of a high voltage electric field from the electrodes **16** helps eject the droplets from the nozzles **14** to form charged droplets.

The voltage assisted painting system **10** further utilizes a series of air flow channels to apply gas to the droplets at the nozzles **14**. Therefore, the voltage assisted painting system **10** utilizes a combination of electric field application and air flow application to facilitate droplet formation, as will be further described below. In the illustrated embodiment, the voltage assisted painting system **10** can increase the voltage application to the electrodes **16** to increase the intensity of the electric field(s) created by the electrodes **16**. By doing so, the size of the droplets formed at the nozzles **14** can decrease. Increasing the voltage application can also increase the frequency of droplet formation at the nozzles **14**.

The voltage assisted painting system **10** preferably applies argon (Ar), helium (He) or nitrogen (N_2) gas to the droplets that are formed at the nozzles **14** to help pull or discharge the droplets from the nozzles **14** by providing further momentum to the droplets, as will be further described below. Preferably, the application of air from the air flow channels also helps spray the formed droplets such that the housing **12** can act as a spray chamber.

Conventional vehicle paint has high viscosity that result in the formation of large-sized paint droplets during application of the paint to the vehicle body. Therefore, the voltage assisted painting system **10** of the illustrated embodiment is provided for forming and dispensing uniformly-sized paint droplets from the housing **12** to the vehicle body. The voltage assisted painting system **10** is provided to apply continuous pressure of the paint droplets that are dispensed from the housing **12**.

Referring to FIGS. **3** and **4**, the housing **12** includes a reservoir **20** for storing paint. The housing **12** includes a conduit **22** that fluidly receives paint from an external source (not shown) to be stored in the reservoir **20**. The conduit **22** fluidly connects the reservoir **20** with the external source to receive paint into the housing **12**. The conduit **22** includes an opening that defines an inlet **22**A that can be considered an inlet **22**A for the housing **12**. While the housing **12** is illustrated as being provided the reservoir **20** therein, it will be apparent to those skilled in the vehicle field from this disclosure that the housing **12** can be modified such that the conduit **22** connects directly to the nozzles **14**. That is, it will be apparent to those skilled in the vehicle field from this disclosure that the housing **12** does not need to include the reservoir **20**. Rather, a reservoir can be provided separately from the housing **12** to deliver paint into the housing **12**. Therefore, it will be apparent to those skilled in the vehicle field from this disclosure that the voltage assisted painting system **10** can include a reservoir that is separately provided from the housing **12**.

As seen in FIG. **2**, the housing **12** includes a plurality of outlets **24** positioned at an underside surface that is opposite side on the housing **12** with respect to the conduit **22**. The paint is dispensed from the outlets **24** to be applied to the vehicle body. In the illustrated embodiment, each of the outlets **24** of the housing **12** correspond to one of the nozzles **14**. That is, the outlets **24** of the housing **12** receive paint from the nozzles **14** to dispense, as will be further described. While the housing **12** is illustrated as including a single conduit **22** it will be apparent to those skilled in the vehicle field from this disclosure that the housing **12** can include a plurality of conduits **22** for receiving different colors and/or types of paint. Additionally, while the housing **12** is illustrated as including a single reservoir **20** that is fluidly connected to all of the nozzles **14**, it will be apparent to those skilled in the vehicle field from this disclosure that the housing **12** can include a plurality of reservoirs **20** for storing different colors and/or types of paint.

As best seen in FIGS. **3** and **4**, the reservoir **20** is a space that receives paint from the conduit **22**. The reservoir **20** is preferably is small feedstock reservoir that does not carry significant weight to the housing **12**. Thus, the reservoir **20** is configured to continuously receive paint from the conduit **22** during use of the voltage assisted painting system **10**. The reservoir **20** includes a plurality openings **20**A that extend into the nozzles **14**. The housing **12** can further includes a plurality of channels **28** that receive paint from the nozzles **14**. The channels **28** include the outlets **24** of the housing **12** that open to the exterior. Therefore, the channels **28** are fluidly connected to the nozzles **14** to receive paint from the reservoir **20**.

Thus, the nozzles **14** are fluidly connected to the reservoir **20** and the outlets **24** of the housing **12**. That is, the nozzles **14** fluidly connect the reservoir **20** with the outlets **24** of the housing **12** to dispense the paint. As seen in FIGS. **3** to **5**, each of the nozzles **14** has an inlet **14**A and an outlet **14**B. The inlets **14**A of the nozzles **14** are fluidly connected to the conduit **22** to receive paint. Each of the outlets **14**B of the nozzles **14** dispenses paint into respective ones of the channels **28** that lead to the outlets **24** of the housing **12**. Therefore, each of the nozzles **14** has an outlet **14**B that dispenses paint. It will be apparent to those skilled in the

vehicle field from this disclosure that the housing **12** can be reconfigured without the channels **28**. Therefore, the outlets **14**B of the nozzles **14** can alternatively extend directly to the exterior of the housing **12**.

As shown in FIGS. **3** to **5**, the nozzles **14** are shaped as tubes having a consistent volume along the longitudinal lengths of the nozzles **14**. The nozzles **14** preferably taper towards the outlets **14**B so to decrease the volume of the nozzles **14** near the outlets **14**B to the formation of small droplets at the nozzles **14** and increase the frequency of droplet formation.

It will be apparent to those skilled in the vehicle field from this disclosure that the sizes of the nozzles **14** can vary depending on the intensity of the voltage that is applied to the droplets from the voltage regulators **18**. Therefore, the sizes of the nozzles **14** can vary depending the intensity of the voltage that is emitted by the voltage regulators **18**. Therefore, it will be apparent to those skilled in the vehicle field from this disclosure that the outlets **14**B of the nozzles **14** can be larger when the voltage regulators **18** emit a higher voltage.

As stated, the nozzles **14** are made of any conducting material capable of conducting electricity, such as copper. Preferably, the nozzles **14** are metallic bodies or tubes. Each metallic body has the at least one electrode **16**. In the illustrated embodiment, the nozzles **14** can define the electrodes **16** of the voltage assisted painting system **10**. Alternatively speaking, each of the electrodes **16** of the voltage assisted painting system **10** is provided at each of the nozzles **14**. In the illustrated embodiment, the housing **12** is preferably made of an electric insulating material such as ceramic. In the illustrated embodiment, the nozzles **14** can be considered the electrodes **16** that generate electric fields upon receiving voltage application, as will be further discussed below. The at least one electrode **16** is formed as part of the metallic body of the nozzles **14**.

The voltage assisted painting system **10** further includes one or more additional electrodes **16**A that are provided offset of the nozzles **14**. Therefore, the voltage assisted painting system **10** includes electrodes **16** that are the nozzles **14**, and additional electrodes **16**A that can work in conjunction with the nozzles **14** to provide an electric field to the droplets. In particular, the additional electrodes **16**A are preferably provided near the outlets **14**B of the nozzles **14**. Therefore, in the embodiment illustrated in FIGS. **3** to **5**, the voltage assisted painting system **10** includes electrodes **16** that includes the nozzles **14** or are portions of the nozzles **14**, and also includes the additional electrodes **16**A that are exterior of the nozzles **14**.

As best seen in FIGS. **3** to **5**, the additional electrodes **16**A are provided at the housing **12** at a location downstream of the inlet **22**A with respect to the conduit **22**. The electrode **16** is configured to generate a magnetic field at the vicinity of the outlet **14**B. Therefore, the additional electrodes **16**A are provided adjacent to the outlets **14**B. The additional electrodes **16**A are arranged in a symmetrical array around each of the outlets **14**B. While only three additional electrodes **16**A are shown, the illustrated embodiment includes four additional electrodes **16**A provided as an array around the outlets **14**B. It will also be apparent to those skilled in the vehicle field from this disclosure that the additional electrodes **16**A can include further electrodes **16**B (such as six or eight electrodes **16**B) arranged in a symmetrical array around the outlets **14**B as needed and/or necessary.

Therefore, in the embodiment of FIGS. **3** to **5**, the voltage regulators **18** can apply voltage either to the bodies of the nozzles **14** or just to the additional electrodes **16**A at the outlets **14**B. The housing **12** further includes a chamber **30** that houses the voltage regulators **18**. In other words, the voltage regulators **18** are disposed in the chamber **30**. The chamber **30** is positioned between the reservoir **20** and the channels **28**. Therefore, the voltage regulators **18** are positioned between the reservoir **20** and the channels **28**. The nozzles **14** extend through the chamber **30** and are primarily disposed in the chamber **30** but extend partially in the channels **28**. In particular, the outlets **14**B of the nozzles **14** are disposed in the channels **28**.

Preferably, the housing **12** further includes an additional chamber **30**A that houses additional voltage regulators **18**A. The additional chamber **30**A is downstream of the chamber **30** such that the additional voltage regulators **18**A are downstream of the voltage regulators **18**. The additional chamber **30**As are positioned near the inlets of the channels **28**. In the illustrated embodiment, the voltage regulators **18** deliver electric voltage to the nozzles **14** which act as the electrodes **16**. The additional voltage regulators **18**A deliver electric voltage to the additional electrodes **16**A. It will be apparent to those skilled in the vehicle field from this disclosure that the arrangement and the positioning of the chambers **30** and **30**A and the voltage regulators **18** and **18**A within the housing **12** can vary depending on the arrangement of the nozzles **14** and the electrodes **16** and **16**A. Therefore, the housing **12** being depicted as having a pair of chambers **30** and a pair of additional chambers **30**A disposed on either side of the housing **12** are illustrated as an example only.

In the illustrated embodiment, a direction of paint flow flows from the conduit **22**, to the reservoir **20**, to the nozzles **14**, to the channels **28**, to the outlets **24**. That is, the reservoir **20** is upstream of the nozzles **14** and the nozzles **14** are upstream of the outlets **24**. In the illustrated embodiment, the chamber(s) **30** that houses the voltage regulator(s) **18** are disposed downstream of the reservoir **20** and upstream of the outlets **24** of the housing **12**. As best seen in FIGS. **3** and **4**, the chamber **30** is upstream of the outlets **14**B of the nozzles **14**. That is, the voltage regulators **18** are preferably upstream of the outlets **14**B of the nozzles **14**.

As best seen in FIG. **4**, each of the plurality of nozzles **14** of the illustrated embodiment are in electric communication with each other. In particular, the nozzles **14** are electrically connected together via electrical conductors **31** such as metallic bars or strips. The nozzles **14** can be electrically connected at the inlets **14**A of the nozzles **14**. The voltage regulators **18** are electrically connected to one of the nozzles **14** so that the electrical charge or voltage provided to the nozzle **14** can be transmitted through all of the nozzles **14** via the electrical conductors **31**. The voltage regulators **18** can be connected to the nozzle **14** via one or more electrical wires.

Similarly, the additional voltage regulators **18**A can be electrically connected to an array of additional electrodes **16**A to provide voltage to the additional electrodes **16**A. It will be apparent to those skilled in the vehicle field from this disclosure that the number and arrangement of voltage regulators **18** that can be implemented with the housing **12** can vary. It will also be apparent to those skilled in the vehicle field from this disclosure that the positions of the voltage regulators **18** within the chamber **30** can vary. Therefore, the illustration of the electrical connection between the voltage regulators **18** and **18**A with the nozzles **14** and the additional electrodes **16**A are illustrated as an example only.

As best seen in FIGS. **1**, **2** and **5**, the housing **12** includes a first airflow channel **32** and a second airflow channel **34**.

The first airflow channel **32** extends through the channels **28** in a first direction D**1** to enable external air to flow through the channels **28** in the first direction D**1**, as best seen in FIG. **2**. As best seen in FIG. **5**, the second airflow channel **34** extends through the channels **28** in a second direction D**2** that is transverse to the first direction D**1** to enable external air to flow in the second direction D**2** The first and second airflow channels **32** and **34** are arranged and configured to generate air flow forces to help detach the droplets from the outlets **14**B of the nozzles **14**. In particular, air flow forces can be directed towards the droplets. Alternatively, as best seen in FIG. **5**, air flow can enter the channels **28** tangentially from the first airflow channel **32** to create a swirling moment at the droplets that have been detached from the outlets **14**B.

The first airflow channel **32** opens to the exterior of the housing **12**, as shown in FIGS. **1** and **2**. As best seen in FIG. **2**, the voltage assisted painting system **10** further includes an external airflow source, such as an air pump **36**. The air pump **36** is in direct communication with the first airflow channel **32** to pump air from the exterior of the housing **12** into the first airflow channel **32**. As shown in FIGS. **2** and **5**, the first and second airflow channels **32** and **34** are in communication with each other such that air flows from the first airflow channel **32** to the second airflow channel **34**.

The second airflow channels **34** intersect with the channels **28** of the housing **12** to enable airflow from the second airflow channels **34** to the channels **28**. In particular, as best seen in FIG. **5**, the second airflow channels **34** intersect with the channels **28** at a location in the vicinity of the outlets **14**B of the nozzles **14** so that air from the second airflow channels **34** is applied to the droplets dispensed from the outlets **14**B of the nozzles **14**.

In the illustrated embodiment, air flow forces flow from the air pump **36**, to the first airflow channels **32**, to the second airflow channels **34**, to the channels **28**. In this way, air is pumped from the exterior to the channels **28** to apply airflow forces that will help push the droplets that have been detached from the outlets **14**B downward into the channels **28**. Therefore, the air flows through the first and second airflow channels **32** and **34** to apply airflow force to the nozzles **14**.

Referring to FIG. **4**, the nozzles **14** are arranged in an array of successive rows and columns within the housing **12**. Each of the nozzles **14** preferably has the same size and dimension with respect to each other to ensure uniformity of the droplets that are formed. The inlets **14**A of the nozzles **14** are preferably approximately 250 micros (μm) in diameter. The droplets formed at the outlets **14**B of the nozzles **14** preferably has a size between 50 μm to 100 μm.

As stated, the additional electrodes **16**A are provided to increase the intensity of the electric field around the outlets **14**B where the droplets are formed. The additional electrodes **16**A are capable of being charged to generate electric fields as a series of arrays around the outlets **14**B. Referring to FIGS. **2** to **4**, the voltage assisted painting system **10** of the illustrated embodiment can include a control system **38** programmed to control the components of the housing **12**, such as the nozzles **14** and the voltage regulators **18** and **18**A. The control system **38** can include an electronic controller **40** for controlling the nozzles **14** and voltage regulators **18**, either in combination or selectively as will be described below. The electronic controller **40** is preferably a microcomputer that includes one or more processor(s) **42** and one or computer memory device(s) **44**.

The electronic controller **40** can control the voltage regulators **18** to apply voltage to the nozzles **14** as the paint is traveling down the bodies of the nozzles **14**. The electronic controller **40** can also control the additional voltage regulators **18**A to apply voltage to the additional electrodes **16**A once droplets begin forming at the outlets **14**B. The electronic controller **40** can control the additional voltage regulators **18**A to apply voltage to all the additional electrodes **16**A in the array in conjunction.

Alternatively, the electronic controller **40** can control the additional voltage regulators **18**A to apply voltage to the additional electrodes **16**A in sequence or one at a time. The sequential control of the additional electrodes **16**A one at a time sequentially can create a series of electric fields around the outlets **14**B to generate rotation of the droplets from the outlets **14**B. The electronic controller **40** can also control the voltage regulators **18** and **18**A to adjust the voltage level that is applied to the nozzles **14** and/or the electrodes **16** and **16**A. The electronic controller **40** can control the voltage regulators **18** and the additional voltage regulators **18**A in order to stagger the velocity (e.g., the stop and start flow) of the discharge of droplets from the nozzles **14**, or provide a constant velocity of droplet discharge from the nozzles **14**.

The control system **38** can include memory **44** such as any computer storage device or any computer readable medium with the sole exception of a transitory, propagating signal. For example, the memory **44** can be nonvolatile memory and volatile memory, and can includes a ROM (Read Only Memory) device, a RAM (Random Access Memory) device, a hard disk, a flash drive, etc. The storage device can be any a non-transitory computer readable medium such as a ROM (Read Only Memory) device, a RAM device, a hard disk, a flash drive, etc. The memory **44** is configured to store settings, programs, data, calculations and/or results of the processor **42**(*s*).

The electronic controller **40** can be programmed to control the sequence, frequency and/or the voltage level emitted by the voltage regulators **18** and **18**A. For example, the electronic controller **40** can be programmed to modulate the electrodes **16** and **16**A to change the oscillation (e.g. frequency, phase and/or amplitude) of the voltage emitted by the voltage regulators **18** and **18**A. The electronic controller **40** can control the oscillation of the electrodes **18**A to modulate voltage upon detection that droplets have formed at the outlets **14**B of the nozzles **14** and/or that the droplets have been formed are at a predetermined size.

In view of this, the housing **12** can include one or more detector(s) (not shown) disposed at the nozzles **14** or in the vicinity of the nozzles **14** to detect the presence and size of droplets forming at the outlets **14**B of the nozzles **14**. The detectors can be any type of sensor as needed and/or appropriate. For example, the detector(s) can utilize thermal imaging or acoustic imaging to measure a size or profile of the droplets. The detectors can be equipped with wireless communication devices to send detection signals to the electronic controller **40**.

The memory **44** of the electronic controller **40** can store parameters for the frequencies emitted by the electrodes **16**. The memory **44** can be programmed to set these parameters or programmed to pre-store these parameters. For example, the memory **44** can store ranges of modulation frequencies that correspond to detected size(s) of the droplets. For example, the electronic controller **40** can be programmed to control the electrodes **16** and **16**A to increase electric field emission when the droplets are detected to be greater than a predetermined size to dislodge the droplets. The electronic controller **40** can also include a timer such that the electronic controller **40** is programmed to control the electrodes **16** to automatically emit pre-determined electric field intensity

based on pre-set time periods. The electronic controller **40** can control the electrodes **16** and **16**A in accordance with a voltage phase diagram as illustrated in FIG. **6**.

Referring to FIGS. **1** and **2**, the voltage assisted painting system **10** can further include an inspection system for quality insurance of the paint application. For example, the inspection includes one or more detectors, such as cameras **48**, for detecting the paint that is dispensed from the outlets **24** of the housing **12**. As shown, the cameras **48** are preferably disposed on a bottom side of the housing **12** in the vicinity of the outlets **24** of the housing **12**. The cameras **48** can utilize thermal imaging or acoustic imaging to measure a size or profile of the droplets that are ejected from the outlets **24** of the housing **12**. Additionally, as seen in FIG. **2**, the cameras **48** are in electronic communication with the electronic controller **40** via wireless communication device(s). The electronic controller **40** can be programmed to measure a thickness or uniformity of the paint that is applied to the vehicle body based on the information detected by the cameras **48**.

Referring now to FIG. **7**, a first modified voltage assisted painting system **110** is illustrated. The first modified voltage assisted painting system **110** includes a housing **112** that is identical to the housing **12** of the voltage assisted panting system **10**. Therefore, the housing **112** includes a reservoir for storing paint, a conduit that fluidly receives paint from an external source (not shown) to be stored in the reservoir, similar to that described in the voltage assisted painting system **10**. In the illustrated embodiment, first modified voltage assisted painting system **110** also includes a plurality of nozzles **114** and one or more voltage regulators **18** that are identical to the voltage regulators **18** described in the voltage assisted painting system **10**. As shown, the first modified voltage assisted painting system **110** is a multi-nozzle system for paint application.

Due to the similarities between the first modified voltage assisted painting system **110** and the voltage assisted painting system **10**, identical components in the first modified voltage assisted painting system **110** will receive the same reference numerals as the voltage assisted painting system **10**. Modified components of the first modified voltage assisted painting system **110** will receive the same reference numerals as corresponding components of the voltage assisted painting system **10** but increased by 100.

The first modified voltage assisted painting system **110** includes a plurality of nozzles **114** that are identical to the nozzles **14** of the voltage assisted painting system **10**. The nozzles **114** are made of any conducting material capable of conducting electricity, such as copper. Preferably, the nozzles **114** are metallic bodies or tubes. Each metallic body has the at least one electrode **116**. Thus, the nozzles **114** defines the electrodes **116** of the voltage assisted painting system **110**. Alternatively speaking, each of the electrodes **116** of the voltage assisted painting system **110** is provided at each of the nozzles **114**. In the illustrated embodiment, the housing **112** is preferably made of an electric insulating material such as ceramic. In the illustrated embodiment, the nozzles **114** can be considered the electrodes **116** that generate electric fields upon receiving voltage application, as will be further discussed below. The at least one electrode **116** is formed as part of the metallic body in the first modified voltage assisted painting system **110**.

The first modified voltage assisted painting system **110** does not include the additional electrodes **16**A at the outlets of the nozzles **114**. The first modified voltage assisted painting system **110** also does not include the additional voltage regulators **18**A. Therefore, in the first modified voltage assisted painting system **110**, the electrodes **116** that provide electric charge to the paint is the nozzles **114** themselves.

With the first modified voltage assisted painting system **110**, the voltage regulators (similar to the voltage regulators **18** of the voltage assisted painting system **10**) can apply voltage to the nozzles **114** with a positive charge. The vehicle body (e.g., the substrate) has a negative charge. The application of paint using the first modified voltage assisted painting system **110** can use electrostatic forces utilized in electrostatic spray systems.

Referring now to FIGS. **8** to **11**, a second modified voltage assisted painting system **210** is illustrated. The second modified voltage assisted painting system **210** includes a housing **112** that is identical to the housing **112** of the first modified voltage assisted panting system **110**, and will not be further described herein. Due to the similarities between the second modified voltage assisted painting system **210** and the first modified voltage assisted painting system **110**, identical components in the second modified voltage assisted painting system **210** will receive the same reference numerals as the first modified voltage assisted painting system **110**. Modified components of the second modified voltage assisted painting system **210** will receive the same reference numerals as corresponding components of the first modified voltage assisted painting system **110** but increased by 100.

The second modified voltage assisted painting system **210** includes a plurality of second modified nozzles **214**. The second modified nozzles **214** are made of any conducting material capable of conducting electricity, such as copper. Preferably, the second modified nozzles **214** are metallic bodies or tubes. The metallic tubes of the modified nozzles **214** are formed of different sections, as will be further described herein. In the illustrated embodiment, each metallic body has the at least one electrode **216**. Thus, the second modified nozzle **214** define the electrodes **216** of the second modified voltage assisted painting system **210**. Alternatively speaking, each of the electrodes **216** of the second modified voltage assisted painting system **210** is provided at each of the second modified nozzles **214**. In the illustrated embodiment, the second modified nozzles **214** can be considered the electrodes **216** that generate electric fields upon receiving voltage application, as will be further discussed below. The at least one electrode **216** is formed as part of the metallic body in the second modified voltage assisted painting system **210**.

As best seen in FIGS. **8** and **9**, the second modified nozzles **214** are electrically connected together via electrical conductors **231** such as metallic bars or strips. The second modified nozzles **214** are electrically connected at the inlets of the second modified nozzles **214**. The second modified voltage assisted painting system **210** can include one or more voltage regulators **18** that are identical to the voltage regulators **18** of the voltage assisted painting system **10** previously described. The voltage regulators **18** are electrically connected to one of the second modified nozzles **214** so that the electrical charge or voltage provided to the second modified nozzles **214** can be transmitted through all of the second modified nozzles **214** via the electrical conductors **231**. The voltage regulators **18** can be connected to the second modified nozzles **214** via one or more electrical wires that are schematically shown. In the second modified voltage assisted painting system **210**, the electrical conductors **231** can be formed as part of the electrodes **216**, as will be further described.

Referring now to FIGS. **9** to **11**, the metallic bodies of the second modified nozzles **214** will now be discussed. As the second modified nozzles **214** are identical with respect to each other, only one of the second modified nozzles **214** will be further described herein for brevity. The metallic body includes a first section **216**A and a second section **216**B. The metallic body further includes a third section **216**C and a fourth section **216**D. The metallic body further includes a fifth section **216**E and a sixth section **216**F.

The first and second sections **216**A and **216**B are disposed on opposite sides of the second modified nozzle **214** with respect to each other. The third and fourth sections **216**C and **216**D are disposed on opposite sides of the second modified nozzle **214** with respect to each other. The fifth and sixth sections **216**E and **216**F are disposed on opposite sides of the second modified nozzle **214** with respect to each other. Each of the sections are separated from the next one of the sections by insulation **250** such as rubber.

As best seen in FIGS. **10** and **11**, the first and second section **216**B are electrically connected so that the first and second sections **216**A and **216**B together define a first electrode **1**E of the metallic body. The third section **216**C and fourth section **216**D are electrically connected so that the third and fourth sections **216**C and **216**D together define a second electrode **2**E of the metallic body. The fifth and sixth sections **216**E and **216**F are electrically connected so that the fifth and sixth sections **216**E and **216**F together define a third electrode **3**E of the metallic body. Therefore, the second modified voltage assisted painting system **210** includes first, second and third electrodes **1**E, **2**E and **3**E that are defined by the metallic bodies of the second modified nozzles **214**.

The voltage regulator **18** can send voltage to the first, second and third electrodes **1**E, **2**E and **3**E in a sequential pattern to charge the first, second and third electrodes **1**E, **2**E and **3**E one at a time. The voltage regulator **18** can stagger the voltage application to the first, second and third electrodes **1**E, **2**E and **3**E to create electric fields that will cause rotation of the droplet formation inside the metallic body. That is, the control of the first, second and third electrodes **1**E, **2**E and **3**E creates a rotational magnetic field inside the body of the second modified nozzle **214**. The voltage regulator **18** can be controlled by an electronic controller similar to the electronic controller described for the voltage assisted painting system.

While the second modified nozzles **214** of the second modified voltage assisted painting system **210** are illustrated as including first, second and third electrodes **1**E, **2**E and **3**E each, it will be apparent to those skilled in the vehicle field from this disclosure that the number of electrodes similar to that described herein can vary depending as needed and/or desired. The electronic controller can be programmed to control multiple numbers of electrodes to generate electric fields that will cause rotation of the droplets formed inside the nozzles **214**.

As best seen in FIG. **9**, the first through sixth sections **1**A to **1**F are illustrated as forming the electrical conductors **231** that conduct voltages across the nozzles **214**. That is, the second, fourth and sixth sections **216**B, **216**B and **216**F of one of the nozzles **214** can extend down the housing to then define the first, third and fifth sections **216**A, **216**C and **216**E of the next adjacent one of the nozzles **214**. It will be apparent to those skilled in the vehicle field from this disclosure that the electrical conductors **231** can be provided separately from the electrodes **216** to transmit electric voltage from one nozzle **214** to the next.

Referring now to FIGS. **12** to **14**, schematic examples arrays of nozzles N that can be implemented with any of the voltage assisted painting systems **10**, **110** and **210** described in FIGS. **1** through **11** are illustrated. The nozzles N are arranged to receive electric voltage from one or more voltage regulators (not shown), as described previously. As seen in FIG. **12**, a first array of nozzles **310** are provided as having first electrodes **316** provided on the nozzles N. As shown, the first electrodes **316** are provided along outlets of the nozzles N. The first electrodes **316** can be formed as part of the nozzles N as metallic bars or strips along the nozzles N. The first electrodes **316** can alternatively be provided onto the nozzles N as an additional component. As shown, the first array of nozzles **310** are also provided with second electrodes **316**A provided near the outlets. The second electrodes can be similar in function and configuration to the additional electrodes **16**A of the voltage assisted painting system.

As shown, the first array of nozzles **310** are also provided with modified first and second air flow channels **332** and **334**. The modified first and second air flow channels **332** and **334** are similar in function to the first and second air flow channels **32** and **34** of the voltage assisted painting system **10**. The only difference is that the second air flow channels **334** extend at an angle with respect to the first air flow channels **332** towards the outlets.

As seen in FIG. **13**, a second array of nozzles **410** are provided as having first electrodes **416** provided on a plurality of nozzles N identically to the first electrodes of the first array of nozzles. As shown, the second array of nozzles **410** are also provided with second electrodes **416**A provided near the outlets. The second electrodes **416**A can be similar in function and configuration to the additional electrodes **16**A of the voltage assisted painting system **10** and the second electrodes **416**A provided with the first array of nozzles **310**. The second electrodes **416**A include a double row of electrodes arranged in a symmetrical array configuration around the outlets. It will be apparent to those skilled in the vehicle field from this disclosure that the second electrodes **416**A provided near the outlets can include a varying plurality if rows of second electrodes **416**A to help discharge the droplets from the outlets.

As seen in FIG. **14**, a third array of nozzles **510** are provided as having first electrodes **516** provided on the nozzles N identical to the first electrodes **516** of the first array of nozzles **310**. The third array of nozzles **510** are basically identical to the first array of nozzles **310**, except the third array of nozzles **510** are not provided with second electrodes. Therefore, the third array of nozzles **510** are examples of a simplified array of nozzles. The third array of nozzles **510** can be provided for electrostatic spray techniques in which the nozzles N are charged to create an electric field with the substrate (e.g., a vehicle body).

General Interpretation of Terms

In understanding the scope of the present invention, the term "comprising" and its derivatives, as used herein, are intended to be open ended terms that specify the presence of the stated features, elements, components, groups, integers, and/or steps, but do not exclude the presence of other unstated features, elements, components, groups, integers and/or steps. The foregoing also applies to words having similar meanings such as the terms, "including", "having" and their derivatives. Also, the terms "part," "section," "portion," "member" or "element" when used in the singular can have the dual meaning of a single part or a plurality of

parts. Also as used herein to describe the above embodiment(s), the following directional terms "forward", "rearward", "above", "downward", "vertical", "horizontal", "below" and "transverse" as well as any other similar directional terms refer to those directions of a vehicle equipped with the voltage assisted painting system. Accordingly, these terms, as utilized to describe the present invention should be interpreted relative to a vehicle equipped with the voltage assisted painting system.

The term "detect" as used herein to describe an operation or function carried out by a component, a section, a device or the like includes a component, a section, a device or the like that does not require physical detection, but rather includes determining, measuring, modeling, predicting or computing or the like to carry out the operation or function.

The term "configured" as used herein to describe a component, section or part of a device includes hardware and/or software that is constructed and/or programmed to carry out the desired function.

The terms of degree such as "substantially", "about" and "approximately" as used herein mean a reasonable amount of deviation of the modified term such that the end result is not significantly changed.

While only selected embodiments have been chosen to illustrate the present invention, it will be apparent to those skilled in the art from this disclosure that various changes and modifications can be made herein without departing from the scope of the invention as defined in the appended claims. For example, the size, shape, location or orientation of the various components can be changed as needed and/or desired. Components that are shown directly connected or contacting each other can have intermediate structures disposed between them. The functions of one element can be performed by two, and vice versa. The structures and functions of one embodiment can be adopted in another embodiment. It is not necessary for all advantages to be present in a particular embodiment at the same time. Every feature which is unique from the prior art, alone or in combination with other features, also should be considered a separate description of further inventions by the applicant, including the structural and/or functional concepts embodied by such feature(s). Thus, the foregoing descriptions of the embodiments according to the present invention are provided for illustration only, and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

What is claimed is:

1. An voltage assisted painting system comprising:

a housing having a conduit for receiving paint from an external source into the housing;

at least one nozzle disposed in the housing, the at least one nozzle having an inlet that is fluidly connected to the conduit to receive paint from the conduit, the at least one nozzle having an outlet that dispenses paint, the nozzle inlet being larger than the nozzle outlet, the inlet and the outlet being continuously connected by a sidewall of the nozzle tapering from the nozzle inlet to the nozzle outlet; and

at least one first electrode provided at the housing at a location downstream of the inlet with respect to the conduit, the at least one first electrode being provided on the at least one nozzle or the at least one nozzle defining the at least one first electrode, the at least one first electrode being configured to generate a magnetic field in the vicinity of the outlet to induce droplet formation in the paint dispensed from the nozzle outlet.

2. The voltage assisted painting system according to claim **1**, wherein

at least one second electrode is provided adjacent to the at least one outlet of the at least one nozzle.

3. The voltage assisted painting system according to claim **2**, wherein

the at least one second electrode includes a plurality of electrodes that are arranged in a symmetrical array around the at least one outlet.

4. The voltage assisted painting system according to claim **1**, wherein

the at least one nozzle includes a metallic body capable of conducting electricity.

5. The voltage assisted painting system according to claim **4**, wherein

the metallic body has the at least one first electrode.

6. The voltage assisted painting system according to claim **5**, wherein

the at least one first electrode is formed as part of the metallic body.

7. The voltage assisted painting system according to claim **6**, wherein

the metallic body includes a first section and a second section that is electrically connected to the first section so that the first and second sections together define the first electrode of the metallic body.

8. The voltage assisted painting system according to claim **7**, wherein

the metallic body further includes a third section and a fourth section that is electrically connected to the third section so that the third and fourth sections together define a second electrode of the metallic body.

9. The voltage assisted painting system according to claim **8**, wherein

the metallic body further includes a fifth section and a sixth section that is electrically connected to the fifth section so that the fifth and sixth sections together define a third electrode of the metallic body.

10. The voltage assisted painting system according to claim **9**, wherein

the first and second sections are disposed on opposite sides of the nozzle with respect to each other,

the third and fourth sections are disposed on opposite sides of the nozzle with respect to each other, and

the fifth and sixth sections are disposed on opposite sides of the nozzle with respect to each other.

11. The voltage assisted painting system according to claim **1**, wherein

the at least one nozzle includes a plurality of nozzles, each of the plurality of nozzles having a respective inlet that is fluidly connected to the conduit that receives paint.

12. The voltage assisted painting system according to claim **11**, wherein

the plurality of nozzles are arranged in an array of successive rows and columns within the housing.

13. The voltage assisted painting system according to claim **12**, wherein

the plurality of nozzles are made of metallic material capable of conducting electricity.

14. The voltage assisted painting system according to claim **13**, wherein

each of the plurality of nozzles are in electric communication with each other.

15. The voltage assisted painting system according to claim 14, further comprising

a voltage regulator that is electrically connected to each of the plurality of nozzles to regulate electric current to the nozzles.

16. The voltage assisted painting system according to claim 11, wherein

the housing includes a paint reservoir that receives paint from the conduit.

17. The voltage assisted painting system according to claim 16, wherein

the housing includes a first airflow channel extending through the plurality of channels in a first direction to enable external air to flow through the plurality of channels in the first direction.

18. The voltage assisted painting system according to claim 17, wherein

the housing includes a second airflow channel extending through the plurality of channels in a second direction that is transverse to the first direction to enable external air to flow in the second direction.

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