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(54) **AIR TREATMENT APPARATUS HAVING MULTIPLE DOWNSTREAM ELECTRODES**

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Related U.S. Application Data

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(58) **Field of Classification Search** 422/186, 422/186.04, 186.07, 121
See application file for complete search history.

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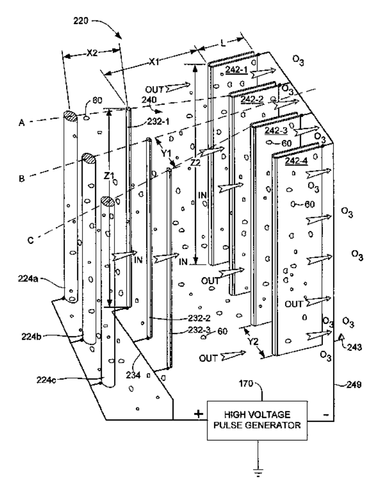
(57) **ABSTRACT**

An electro-kinetic air conditioner for removing particulates from the air creates an airflow using no moving parts. The conditioner includes an ion generator that has an electrode assembly including a first array of emitter electrodes, a second array of collector electrodes, and a high voltage generator. Preferably, a third or leading or focus electrode is located upstream of the first array of emitter electrodes, and/or a trailing electrode is located downstream of the second array of collector electrodes. The device can also include an interstitial electrode located between collector electrodes, an enhanced collector electrode with an integrally formed trailing end, and an enhanced emitter electrode with an enhanced length in order to increase emissivity.

50 Claims, 32 Drawing Sheets



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6,228,149	B1	5/2001	Alenichev et al.	95/78
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D449,097	S	10/2001	Smith et al.	D23/364
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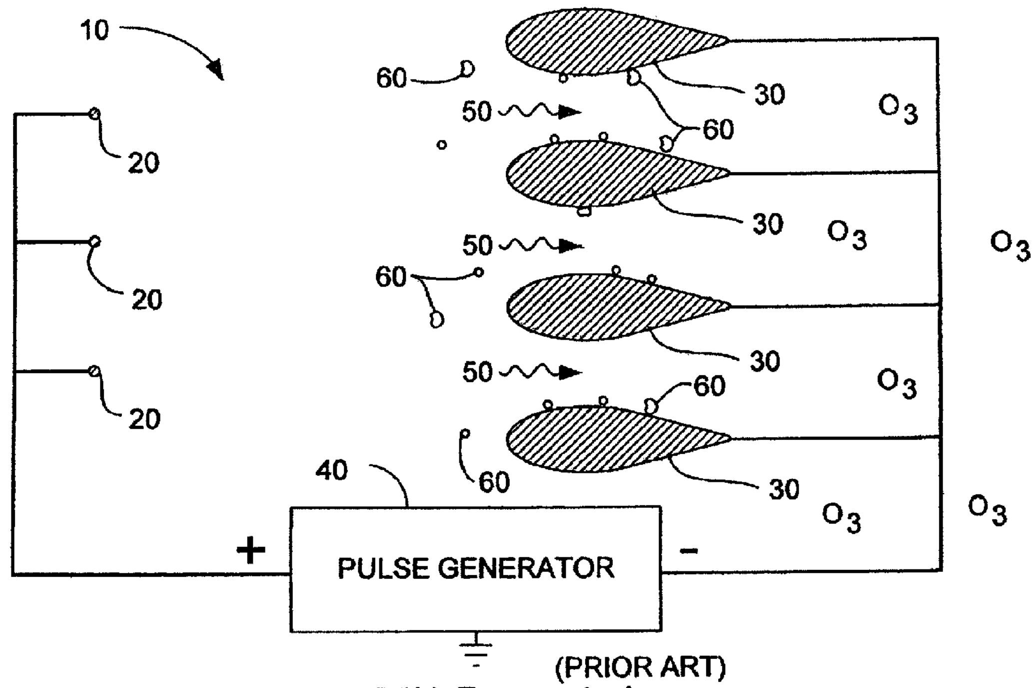
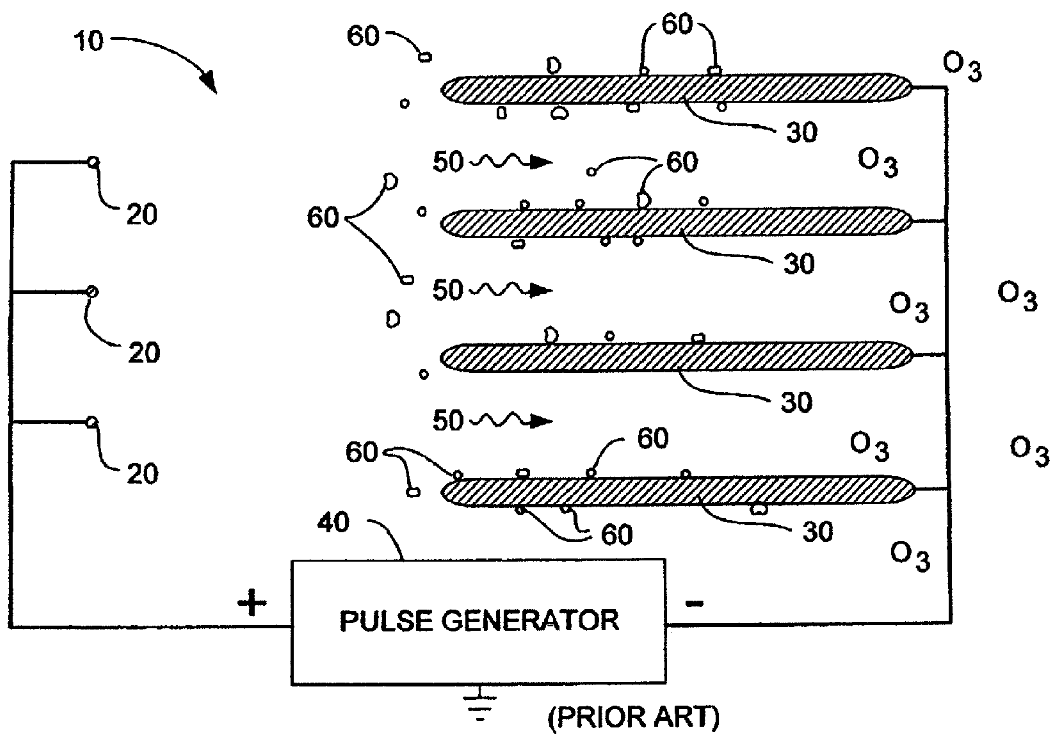


(PRIOR ART)

FIG. - 1A



(PRIOR ART)

FIG. - 1B

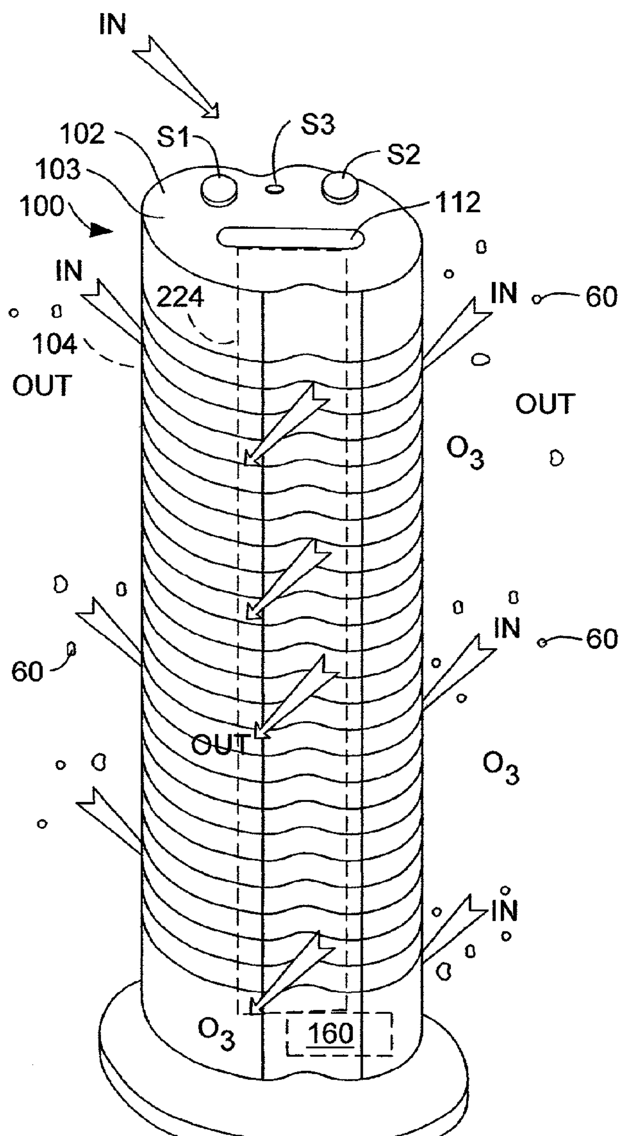

IN
102
S1
S3
S2
103
100
112
IN
224
104
OUT
IN
60
OUT
O_3
60
IN
60
OUT
O_3
IN
O_3
160

FIG. - 2A

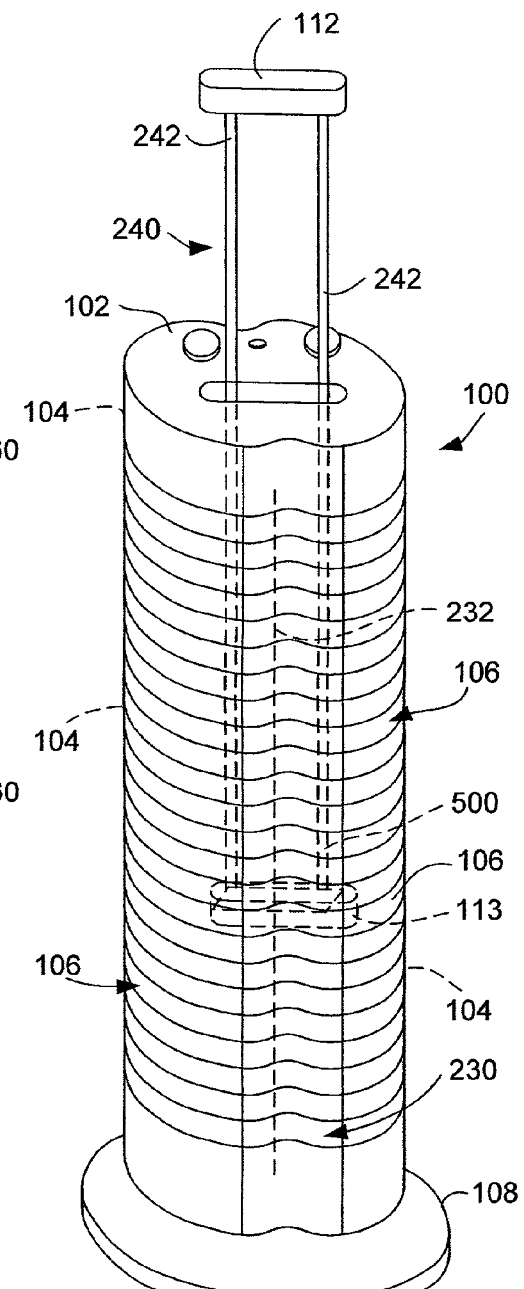

112
242
240
242
102
104
100
232
106
104
500
106
113
106
104
230
108

FIG. - 2B

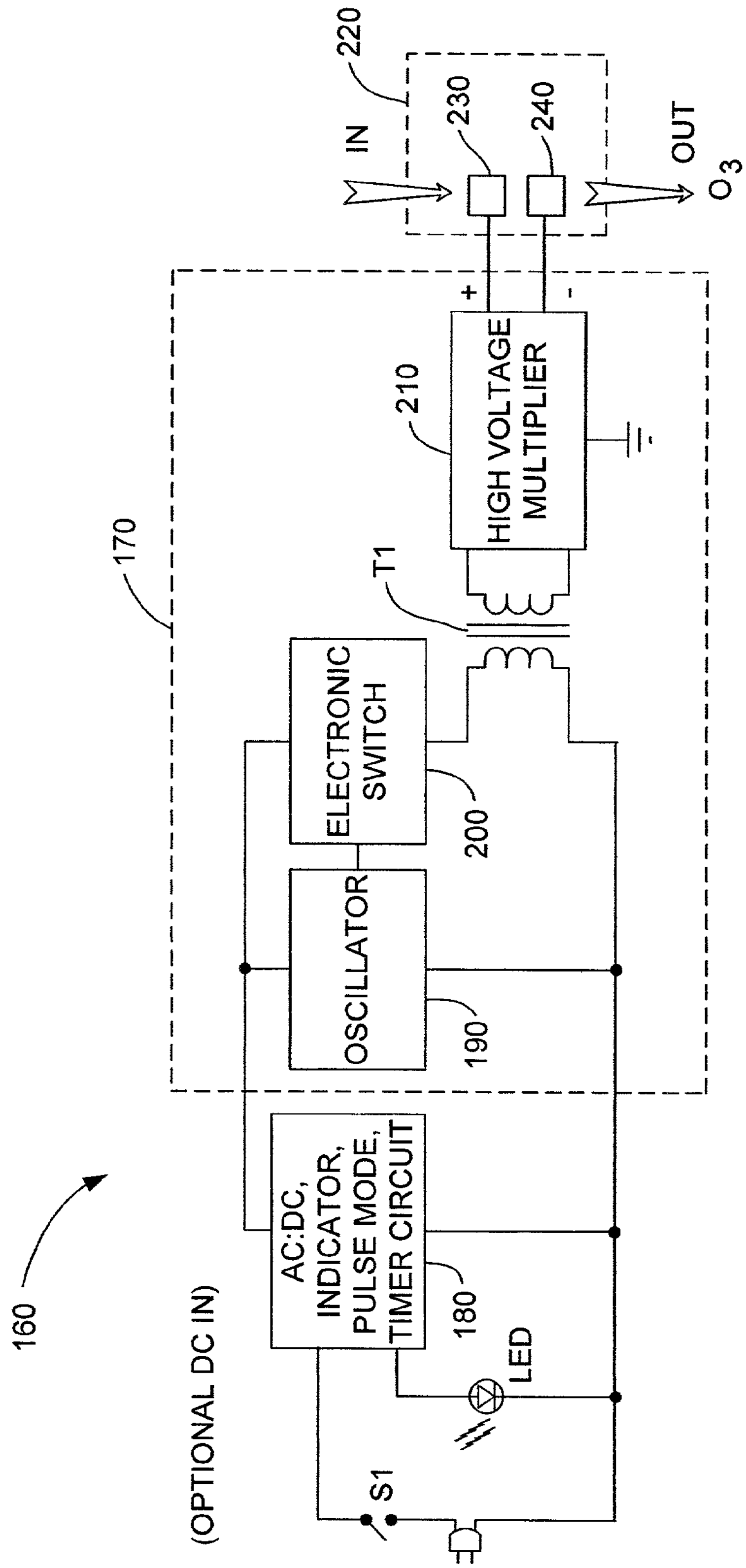
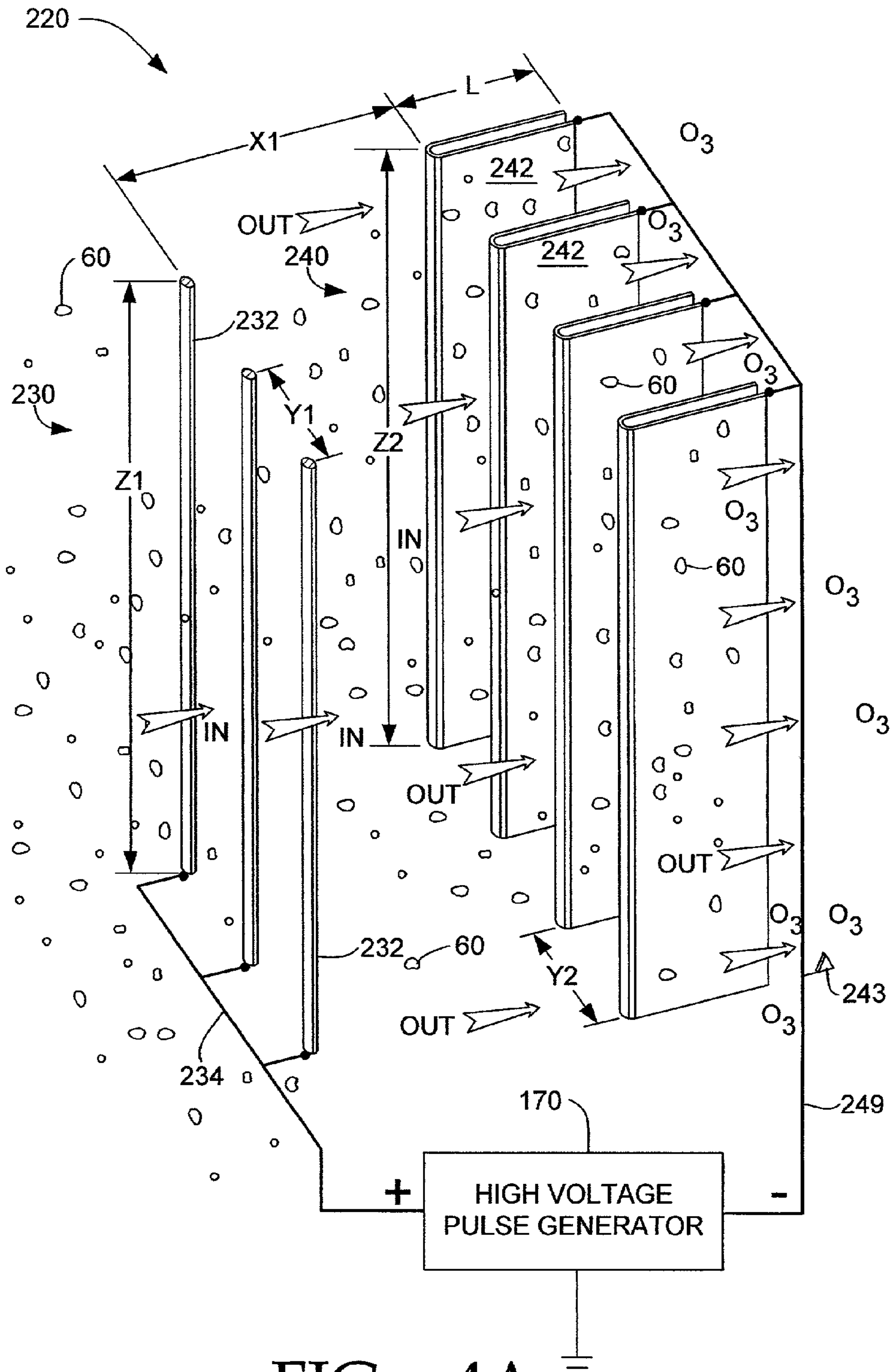

160
(OPTIONAL DC IN)
S1
LED
AC:DC, INDICATOR, PULSE MODE, TIMER CIRCUIT
180
170
OSCILLATOR
190
ELECTRONIC SWITCH
200
T1
HIGH VOLTAGE MULTIPLIER
210
+
-
220
230
240
IN
OUT
O_3

FIG. - 3



220
L
X1
O3
242
OUT
240
60
232
230
Y1
Z2
Z1
IN
OUT
Y2
243
234
170
249
HIGH VOLTAGE
PULSE GENERATOR
+
-

FIG. - 4A

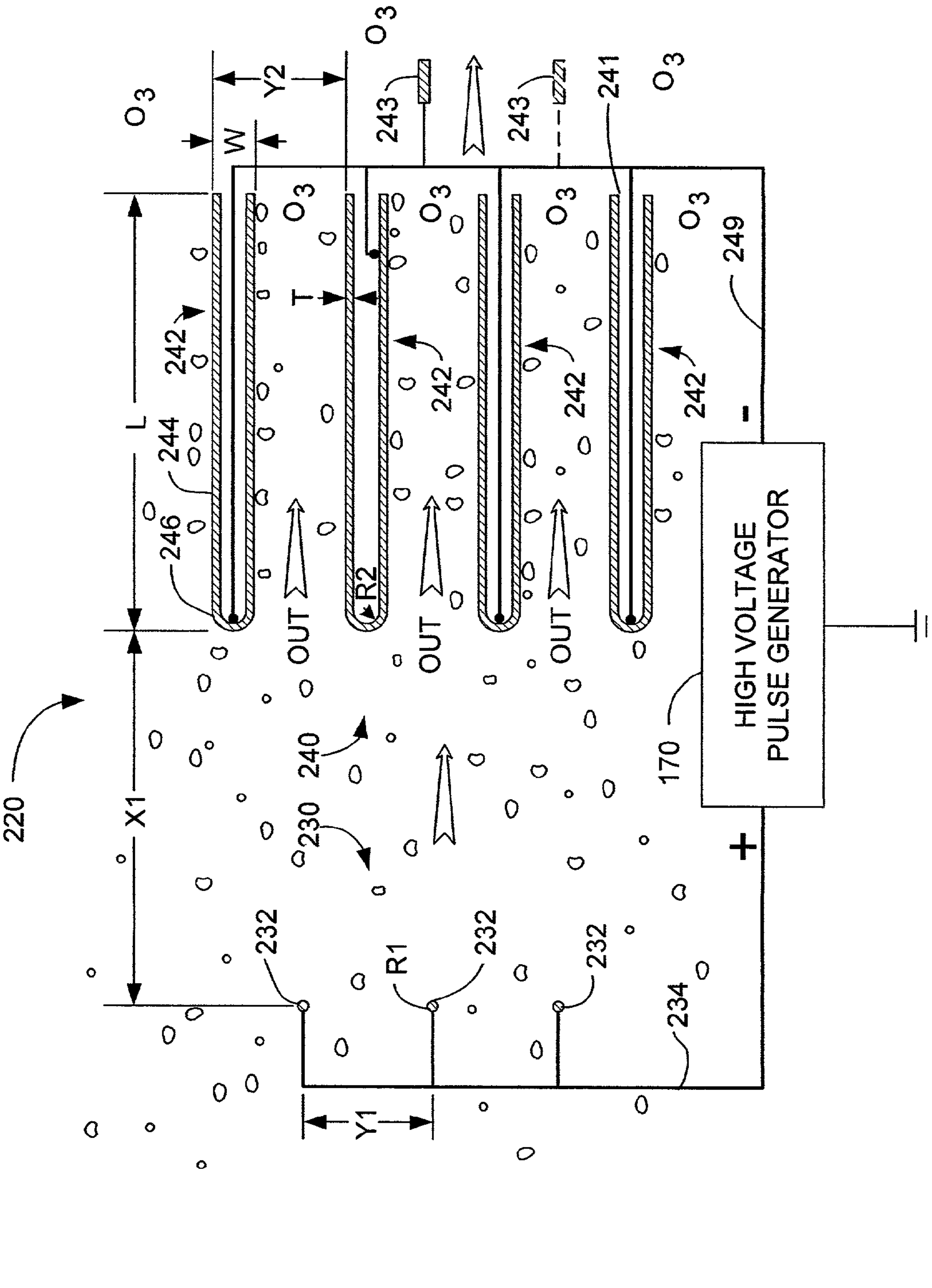
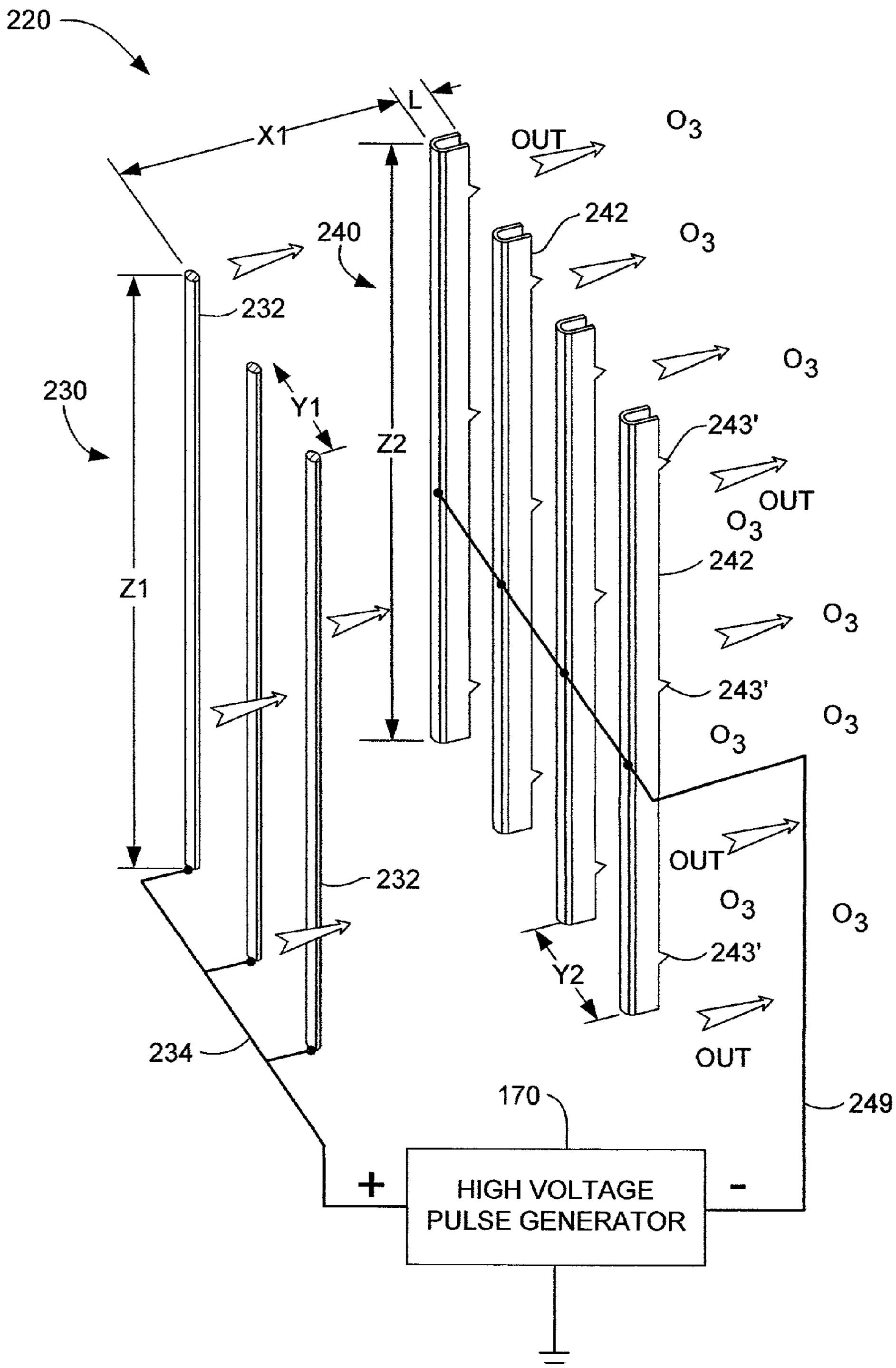

220
X1
L
W
Y2
Y1
O_3
241
242
243
244
246
249
R1
R2
T
OUT
240
230
232
234
170
HIGH VOLTAGE
PULSE GENERATOR
+
-

FIG. - 4B



220
L
X1
OUT
O_3
242
240
232
230
Y1
Z2
243'
OUT
242
Z1
243'
232
OUT
Y2
234
OUT
170
249
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 4C

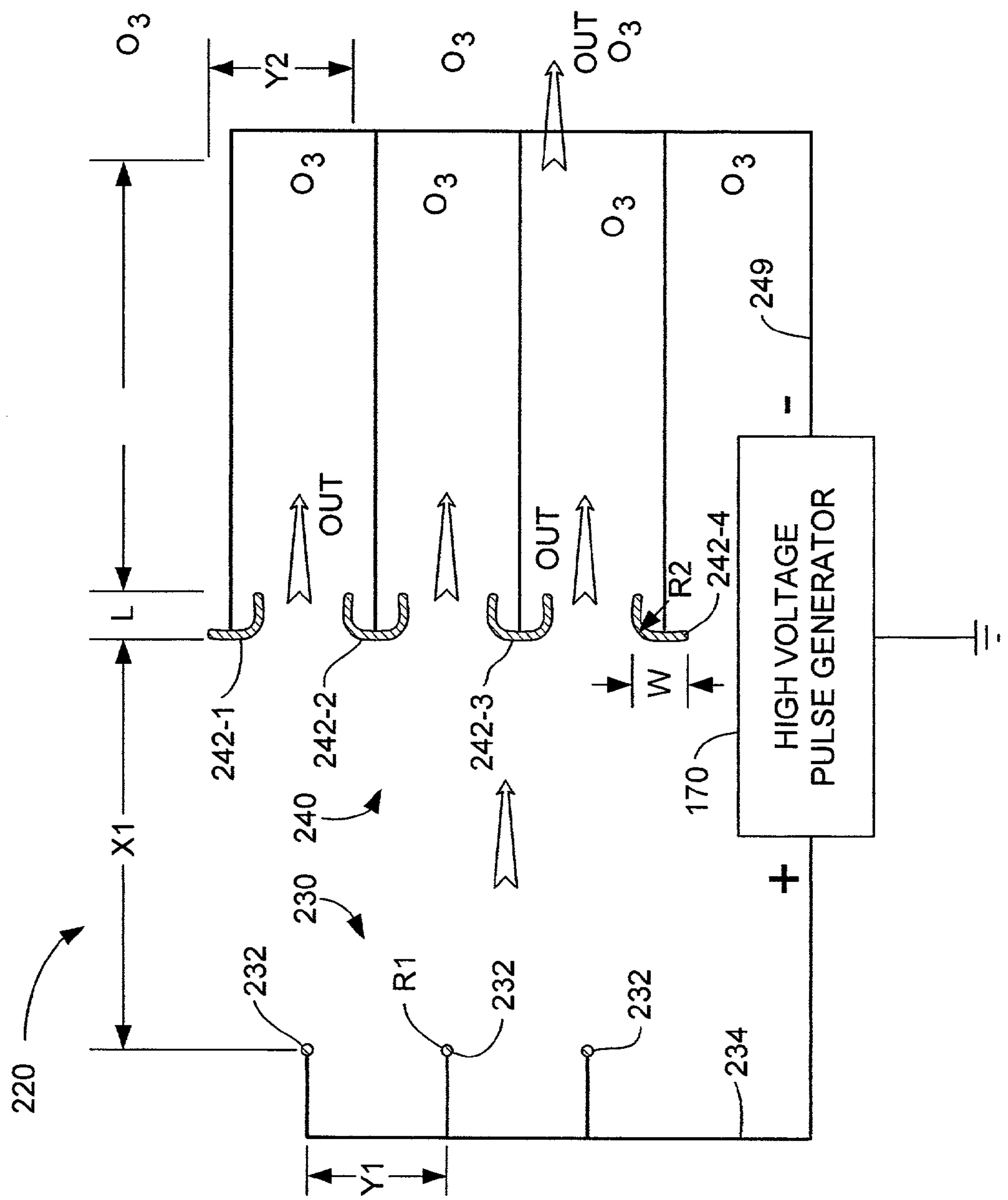

220
X1
L
Y1
Y2
232
R1
230
240
242-1
242-2
242-3
242-4
R2
W
OUT
O_3
249
234
170
HIGH VOLTAGE PULSE GENERATOR
+
-

FIG. - 4D

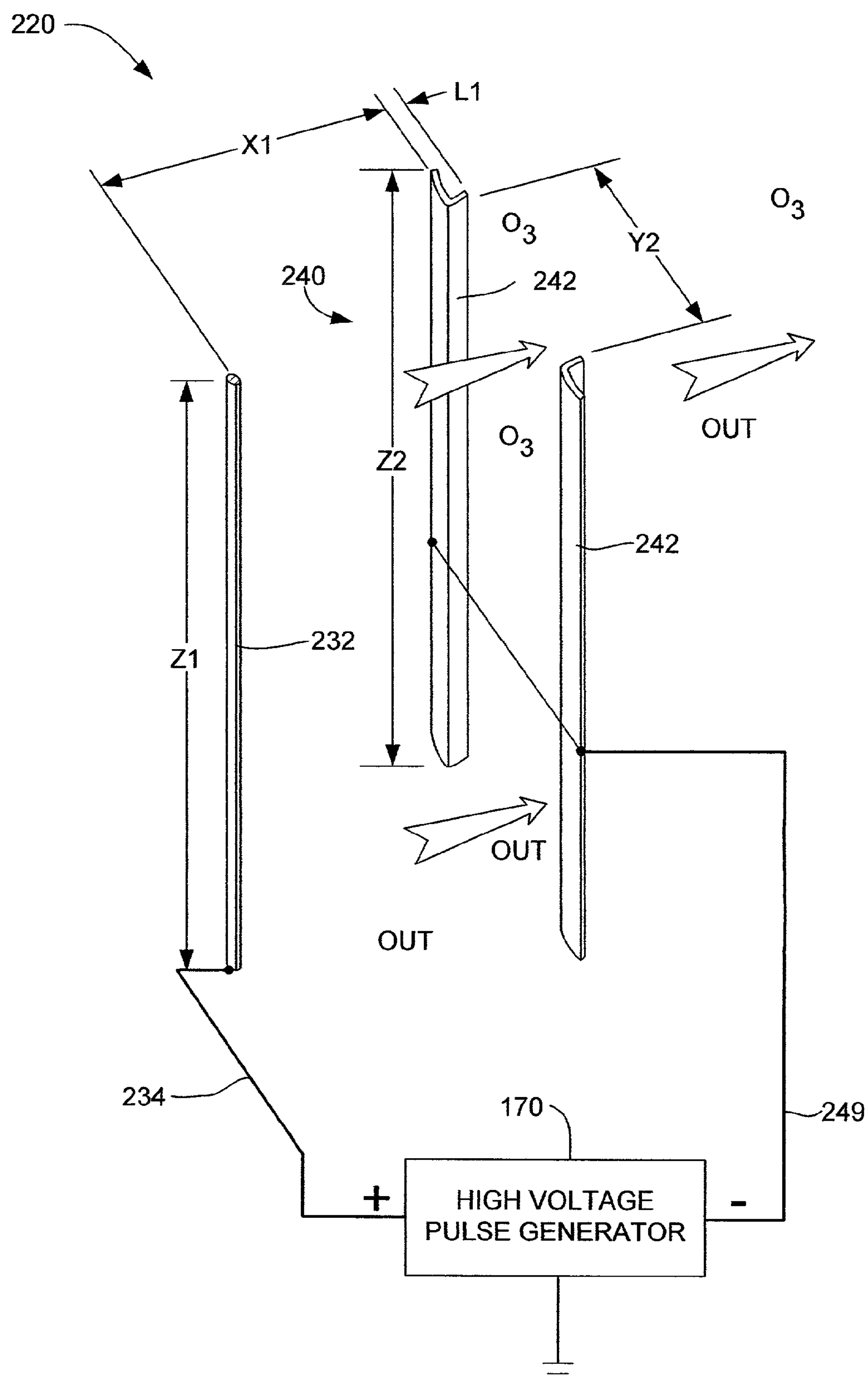

220
L1
X1
O3
O3
Y2
240
242
Z2
O3
OUT
242
Z1
232
OUT
OUT
234
170
249
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 4E

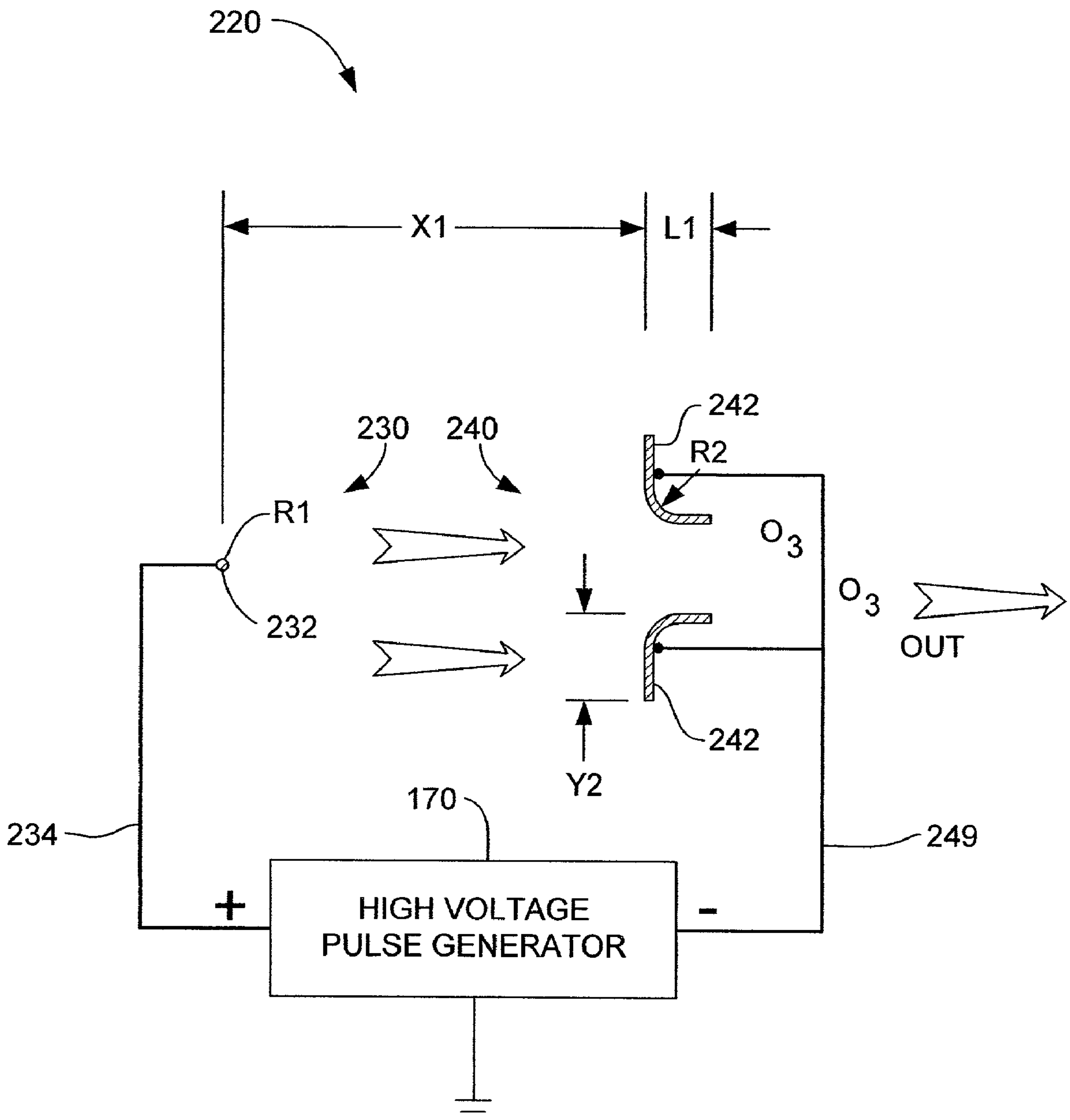

220
X1
L1
242
230
240
R2
R1
O_3
O_3
OUT
232
242
Y2
170
234
249
+
-
HIGH VOLTAGE
PULSE GENERATOR

FIG. - 4F

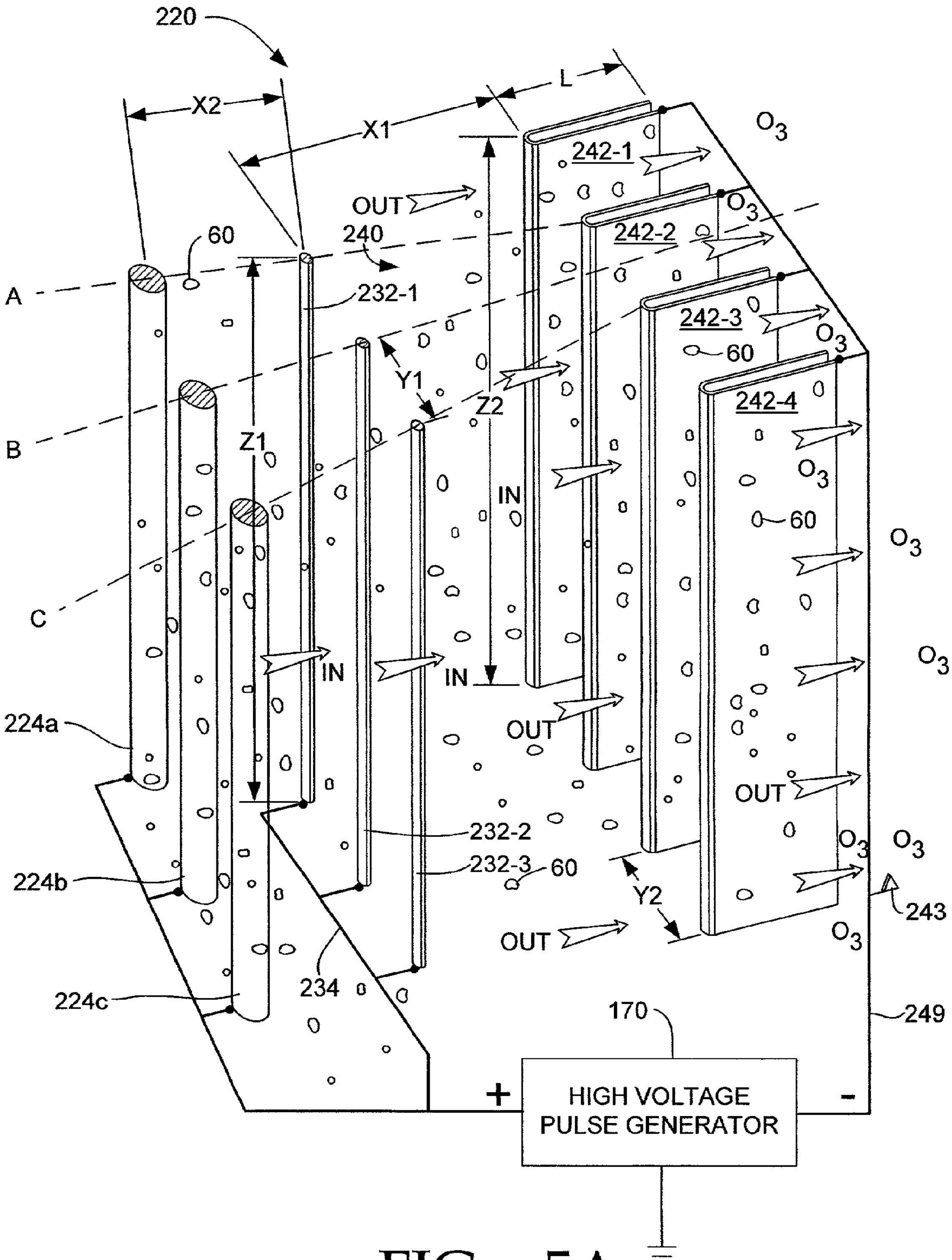
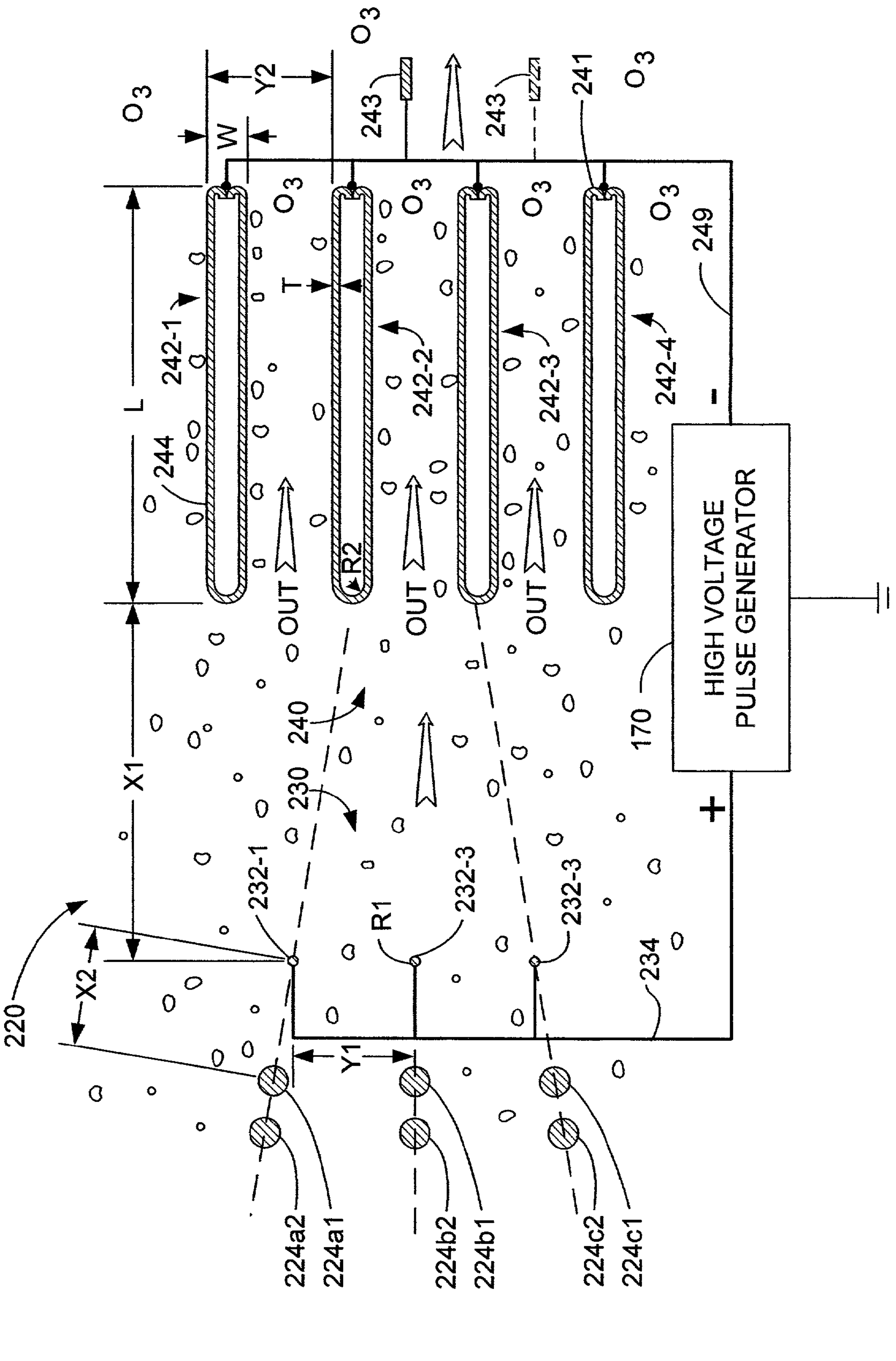

220
X2
X1
L
O3
242-1
OUT
O3
242-2
60
240
232-1
A
242-3
O3
Y1
60
Z2
242-4
B
Z1
O3
IN
60
O3
C
O3
IN
IN
224a
OUT
OUT
232-2
O3
O3
224b
232-3
60
Y2
243
OUT
O3
224c
234
170
249
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 5A



220
X2
X1
L
W
Y2
Y1
T
R1
R2
O_3
243
243
241
244
242-1
242-2
242-3
242-4
249
OUT
OUT
OUT
240
230
232-1
232-3
232-3
234
170
HIGH VOLTAGE PULSE GENERATOR
+
-
224a2
224a1
224b2
224b1
224c2
224c1

FIG. - 5B

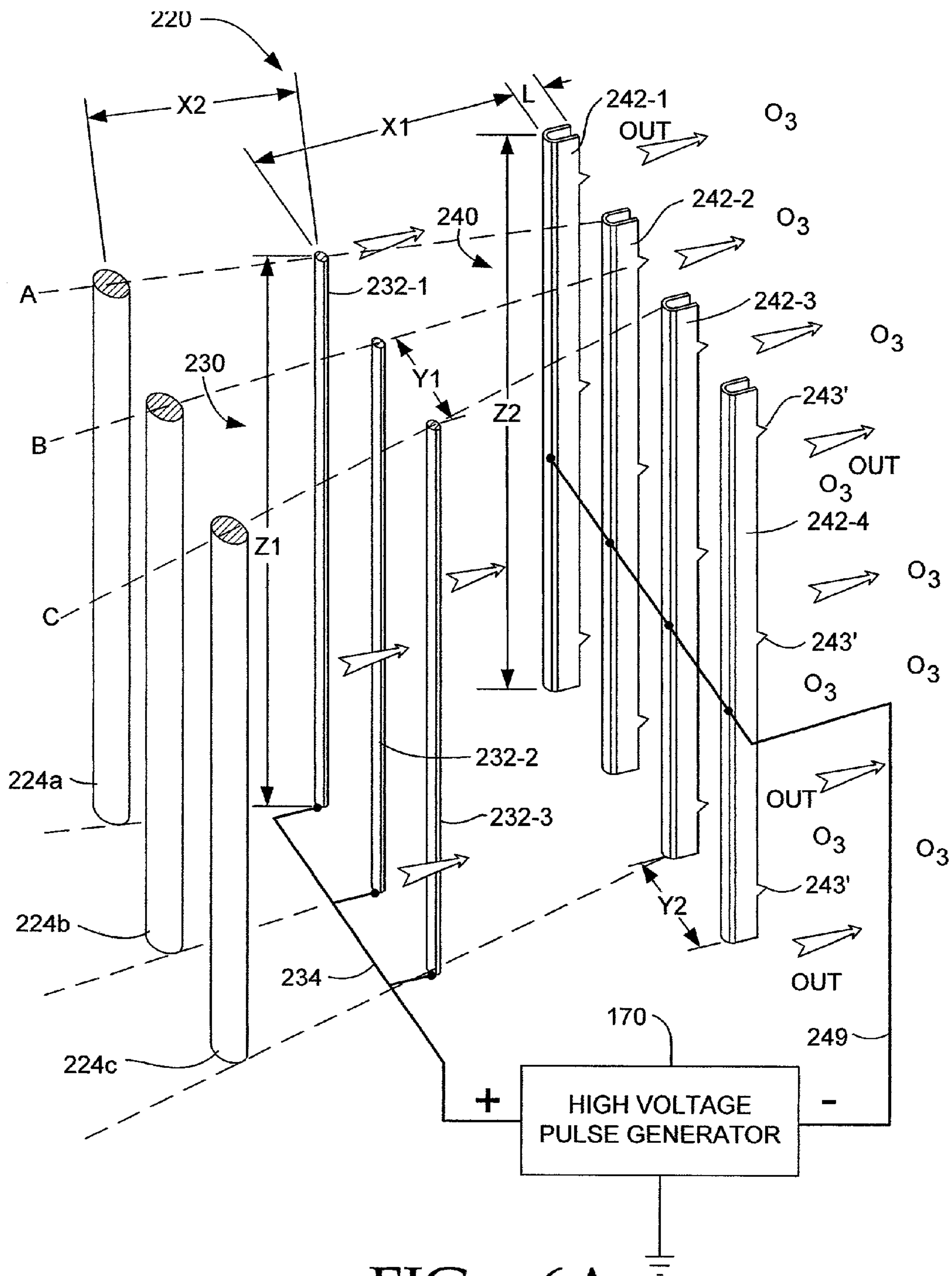

220
X2
X1
L
242-1
OUT
O_3
240
242-2
A
232-1
242-3
230
Y1
B
Z2
243'
OUT
242-4
C
Z1
243'
224a
232-2
OUT
232-3
224b
Y2
243'
234
OUT
170
249
224c
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 6A

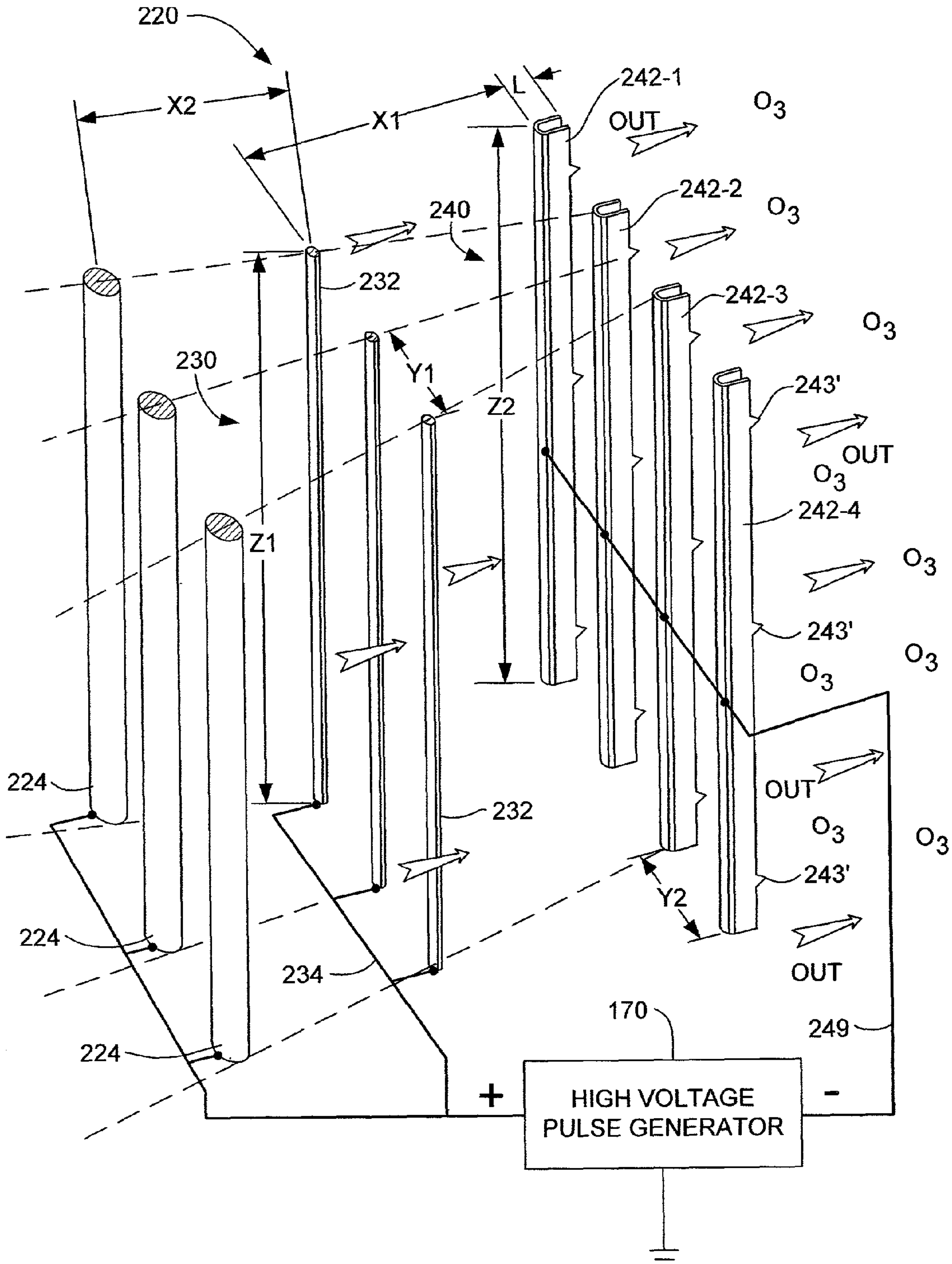
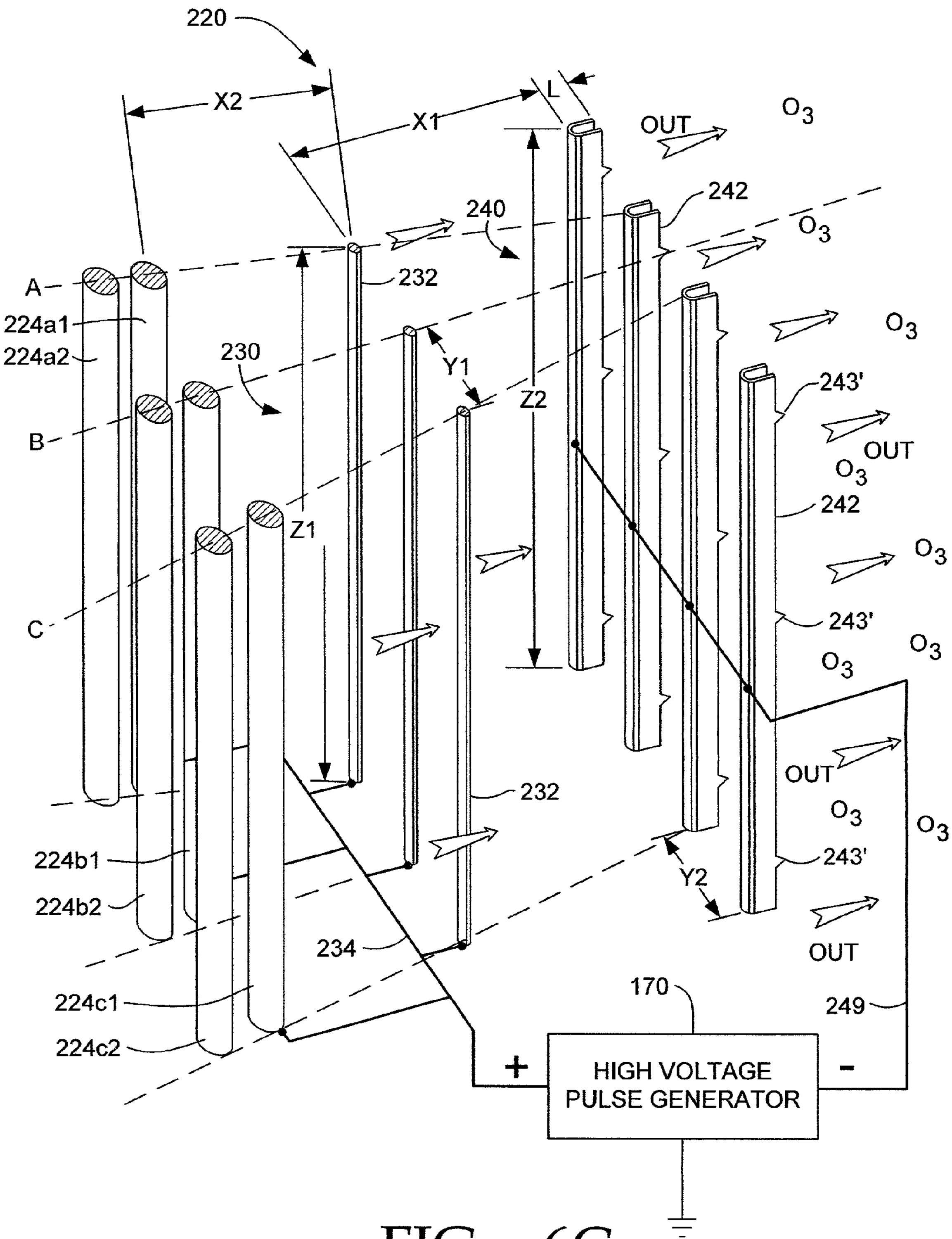
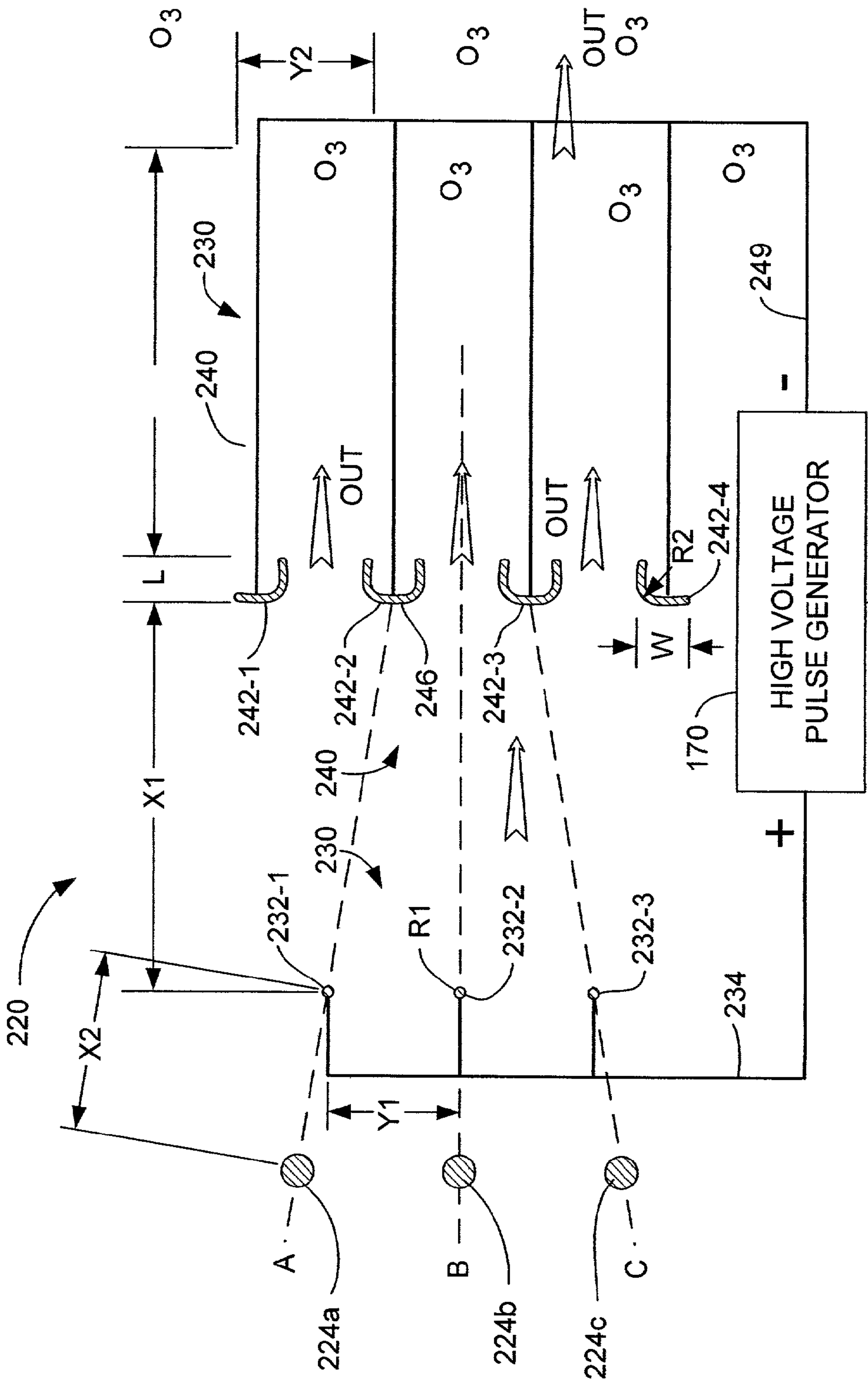

220
X2
X1
L
242-1
OUT
O_3
242-2
O_3
240
232
242-3
O_3
230
Y1
243'
Z2
OUT
O_3
242-4
Z1
O_3
243'
O_3
O_3
224
OUT
232
O_3
O_3
243'
Y2
224
234
OUT
170
249
224
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 6B



220
X2
X1
L
OUT
O_3
242
240
A
232
224a1
224a2
230
Y1
B
Z2
243'
C
Z1
224b1
224b2
234
224c1
224c2
Y2
170
249
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 6C



220
224a
224b
224c
A
B
C
X2
Y1
X1
L
Y2
232-1
232-2
232-3
R1
234
230
240
242-1
242-2
242-3
242-4
246
R2
W
OUT
O_3
249
+
-
HIGH VOLTAGE PULSE GENERATOR
170

FIG. - 6D

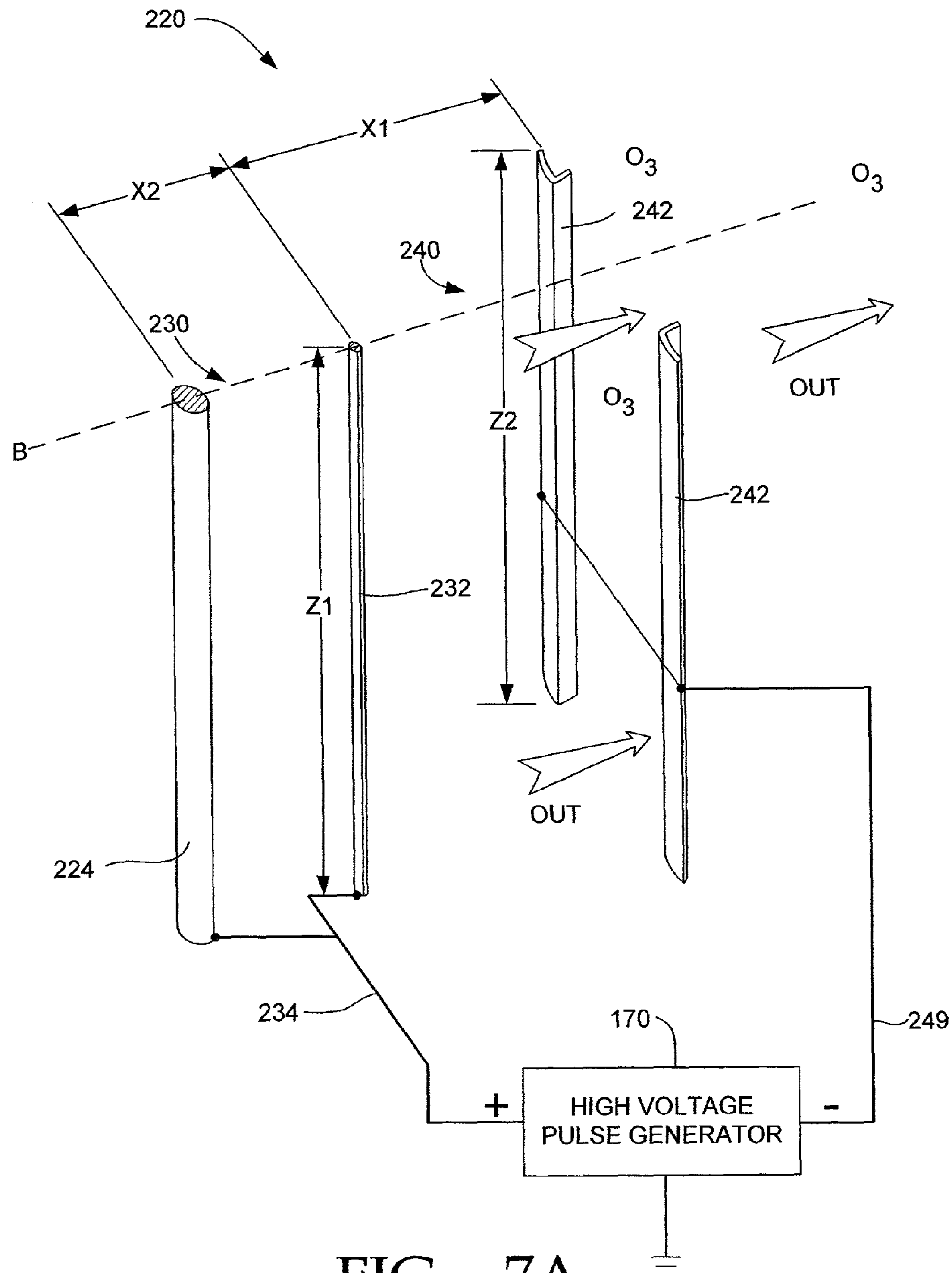

220
X1
X2
O_3
O_3
242
240
230
OUT
O_3
Z2
B
242
232
Z1
OUT
224
234
170
249
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 7A

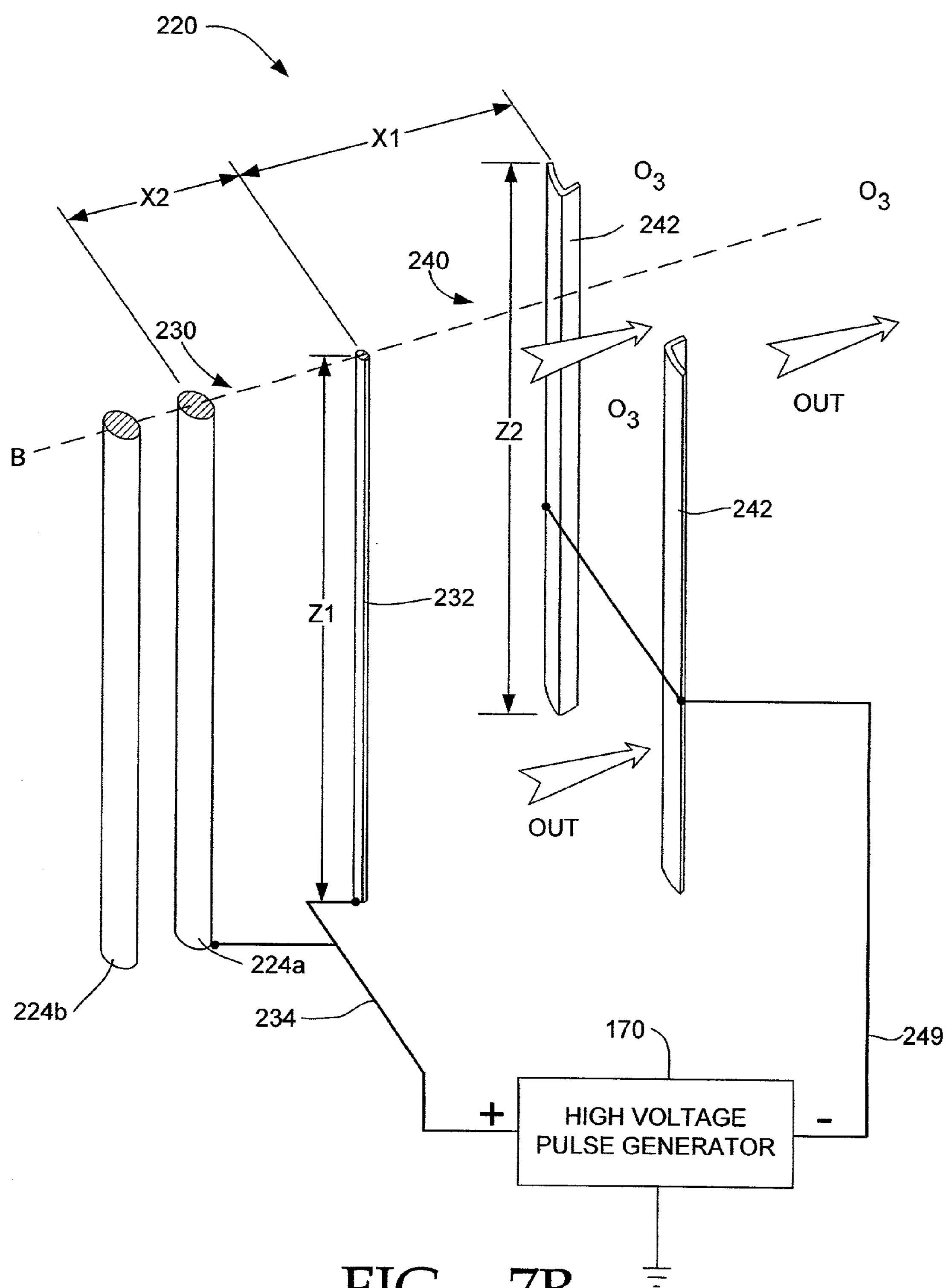
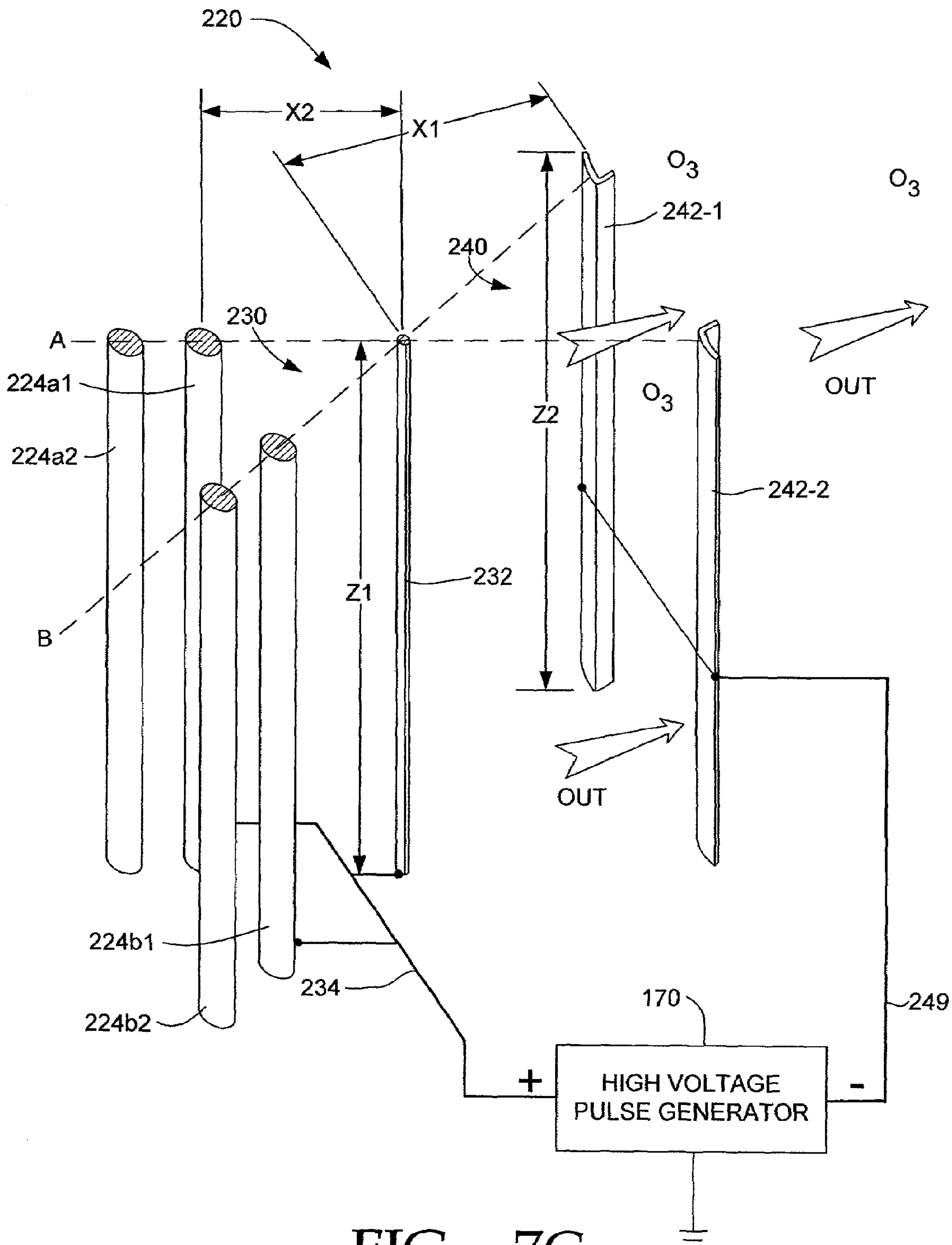
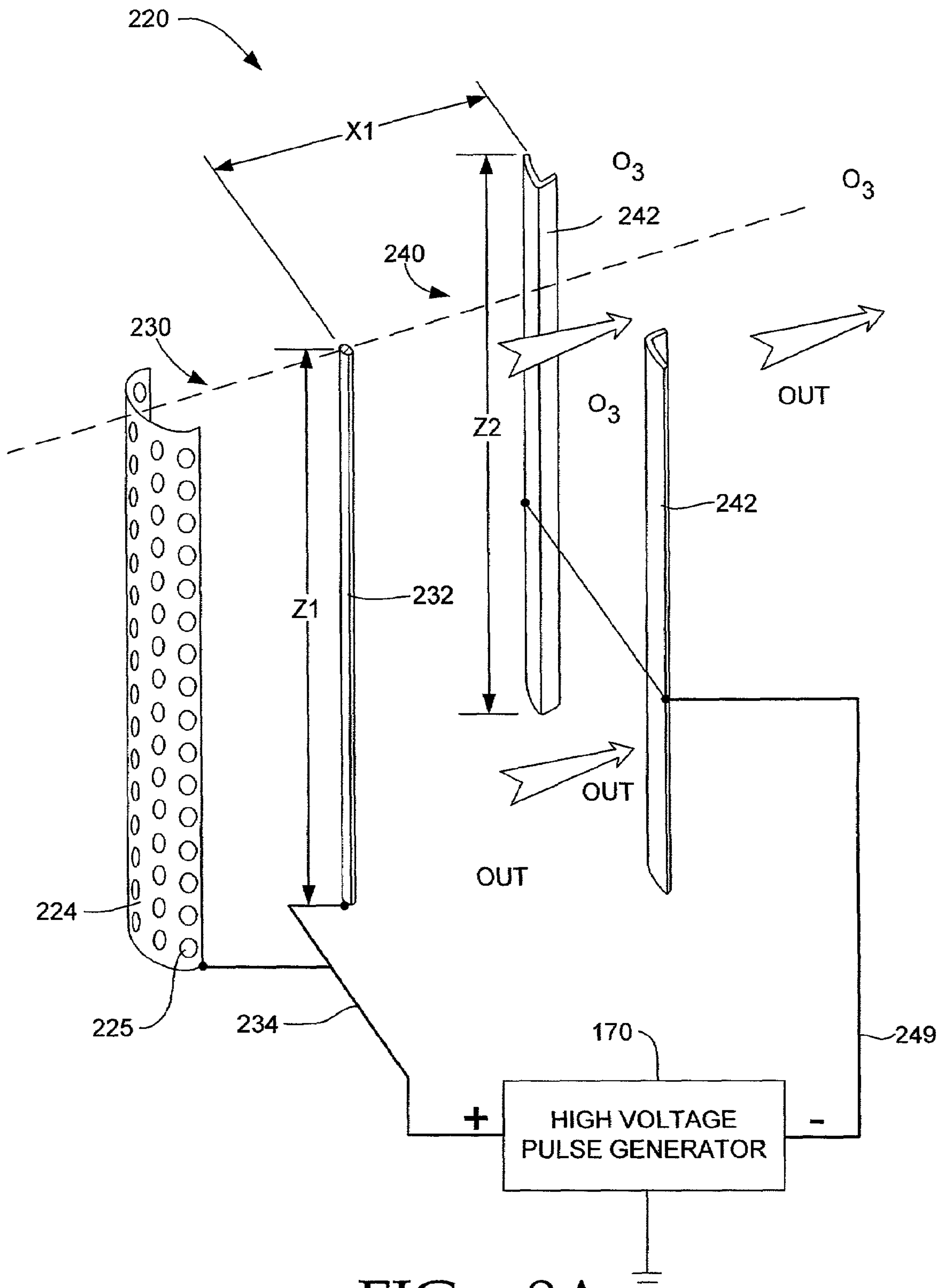

220
X1
X2
O_3
O_3
242
240
230
B
Z2
Z1
OUT
O_3
242
232
OUT
224a
224b
234
170
249
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 7B



220
X2
X1
O_3
O_3
242-1
240
230
A
224a1
224a2
O_3
OUT
Z2
242-2
232
Z1
B
OUT
224b1
234
170
249
224b2
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 7C



220
X1
O_3
O_3
242
240
230
Z2
O_3
OUT
242
Z1
232
OUT
OUT
224
225
234
170
249
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 8A

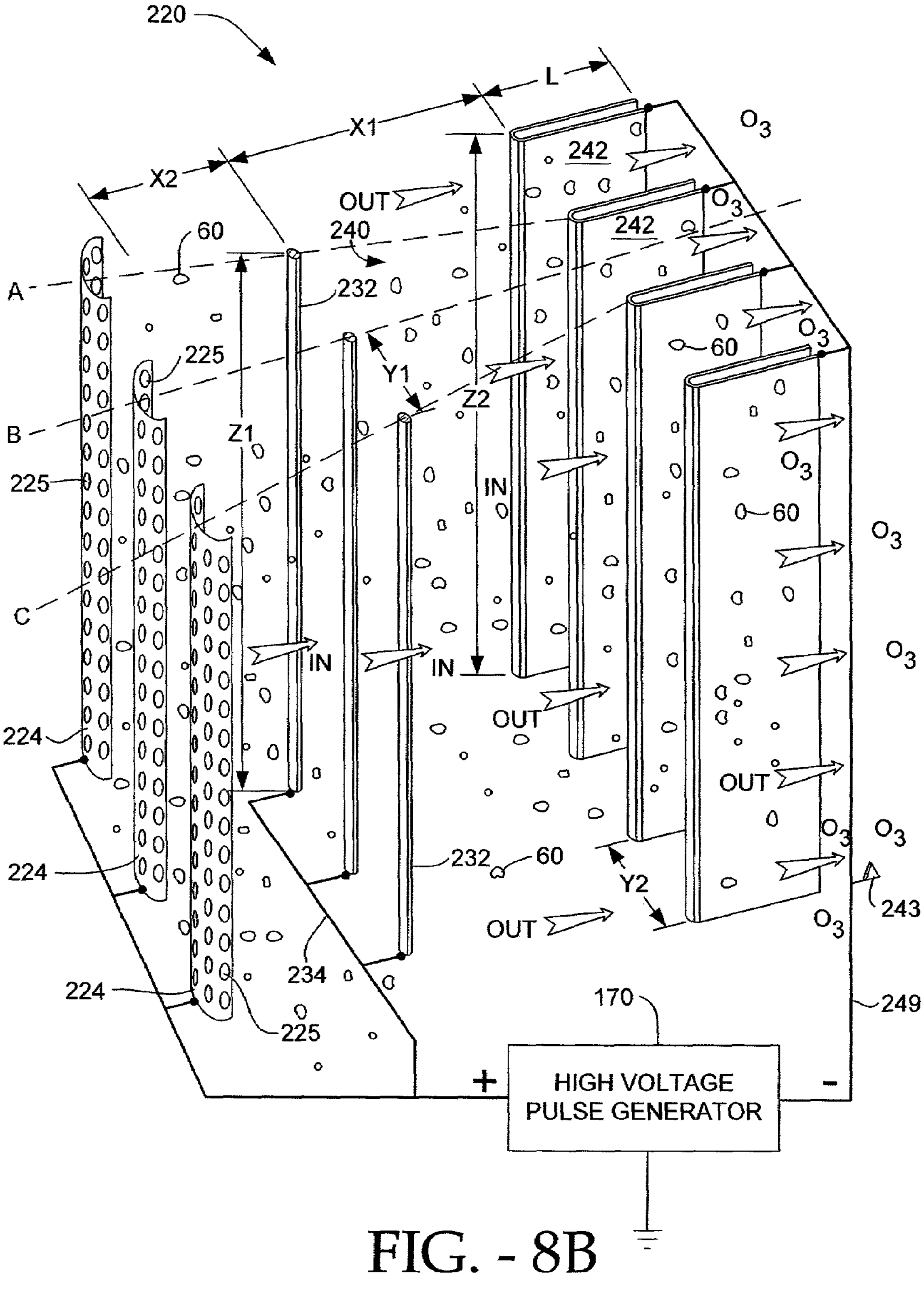
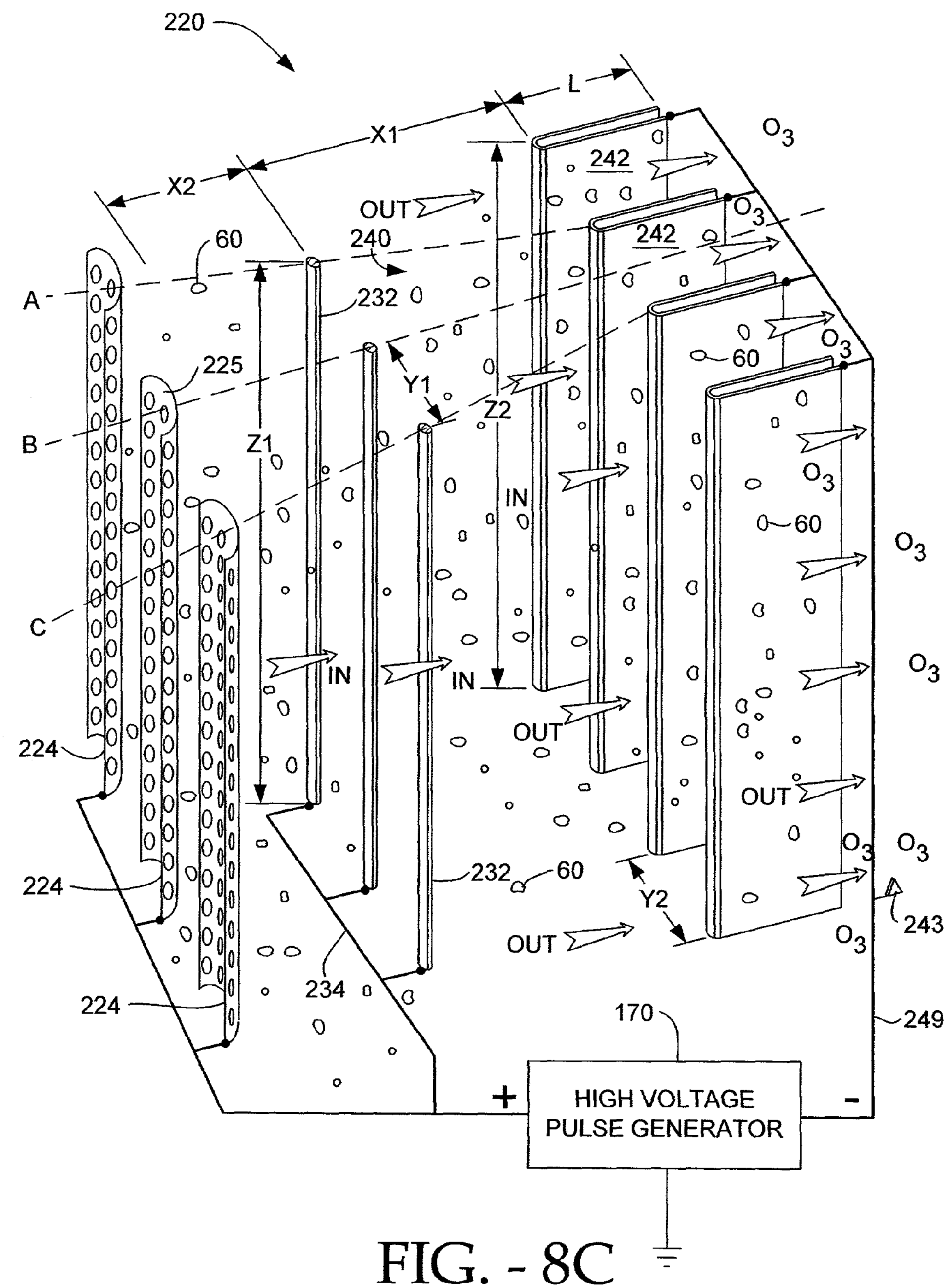

220
L
X1
X2
O_3
242
242
OUT
60
240
A
232
225
B
Y1
Z2
Z1
225
C
IN
60
IN
IN
OUT
224
224
224
232
60
234
Y2
OUT
225
243
170
249
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 8B



220
L
X1
X2
O_3
242
OUT
60
240
232
A
225
B
Y1
Z2
Z1
IN
C
224
234
Y2
243
170
249
+
-
HIGH VOLTAGE
PULSE GENERATOR

FIG. - 8C

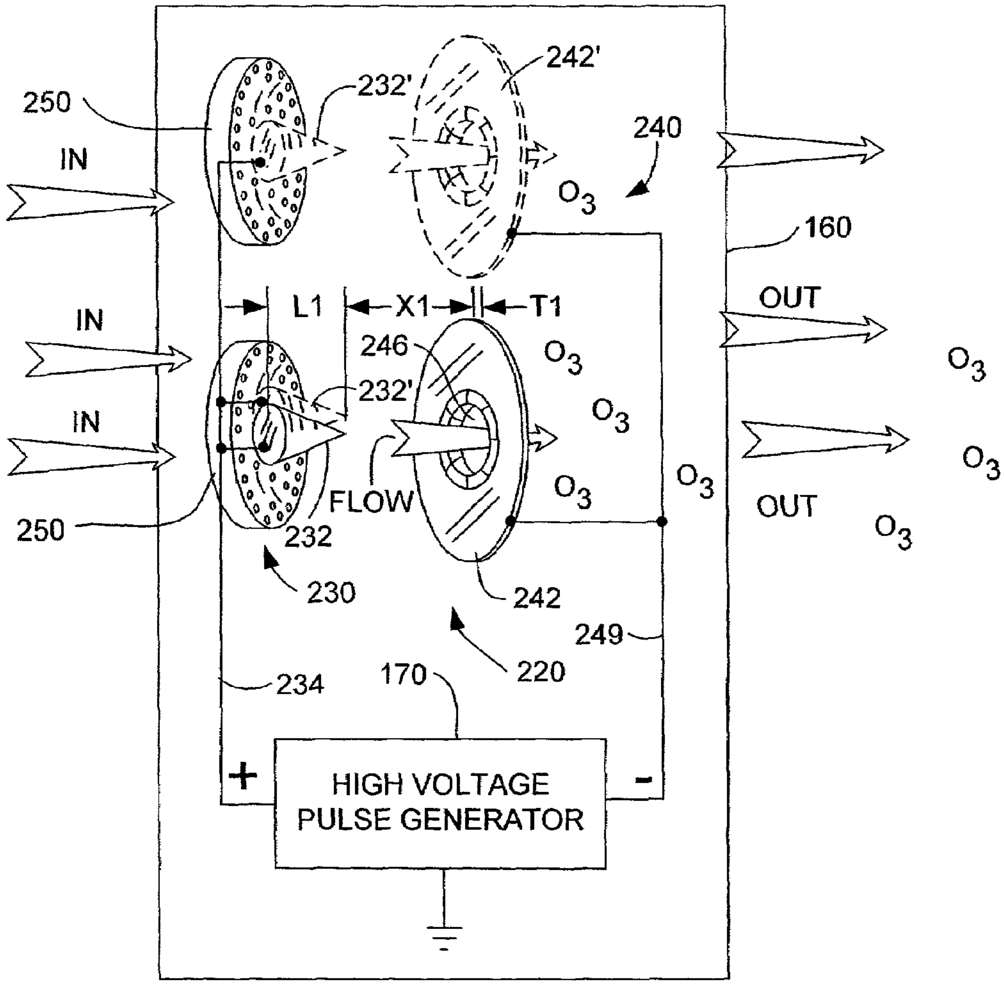


FIG. - 9A

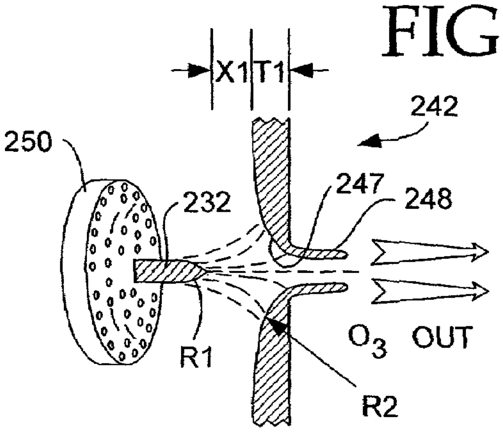


FIG. - 9B

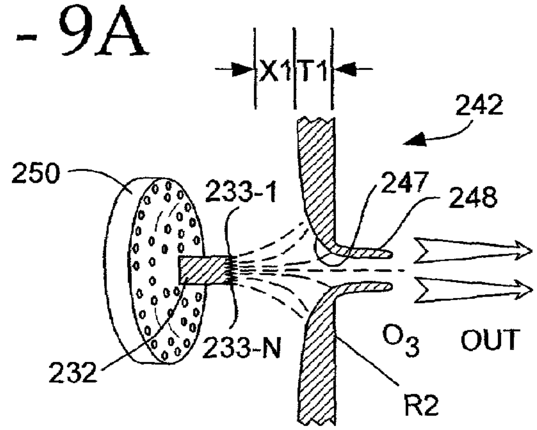
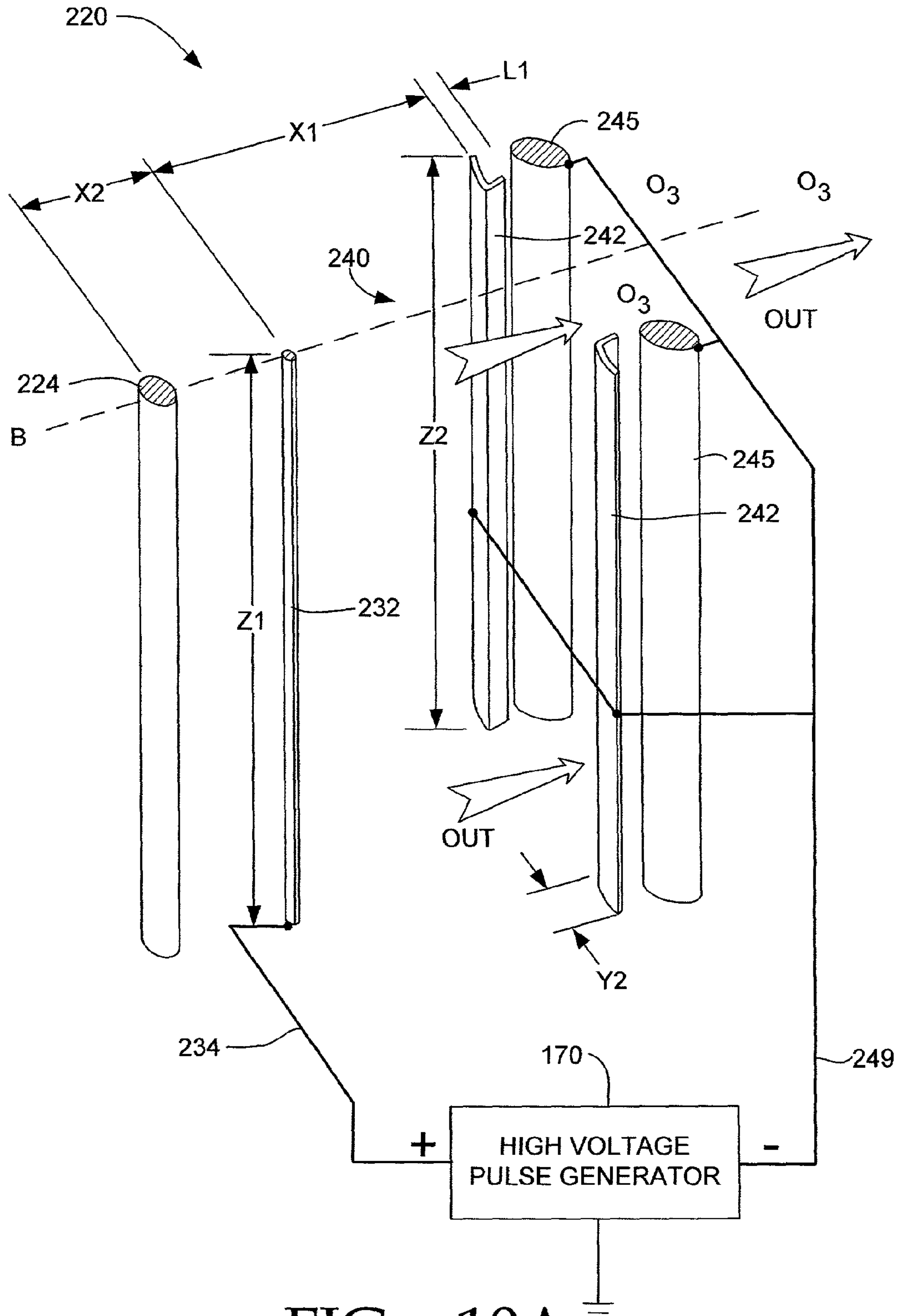


FIG. - 9C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L1
X1
245
X2
O_3
O_3
242
240
OUT
O_3
224
B
Z2
245
242
Z1
232
OUT
Y2
234
170
249
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 10A

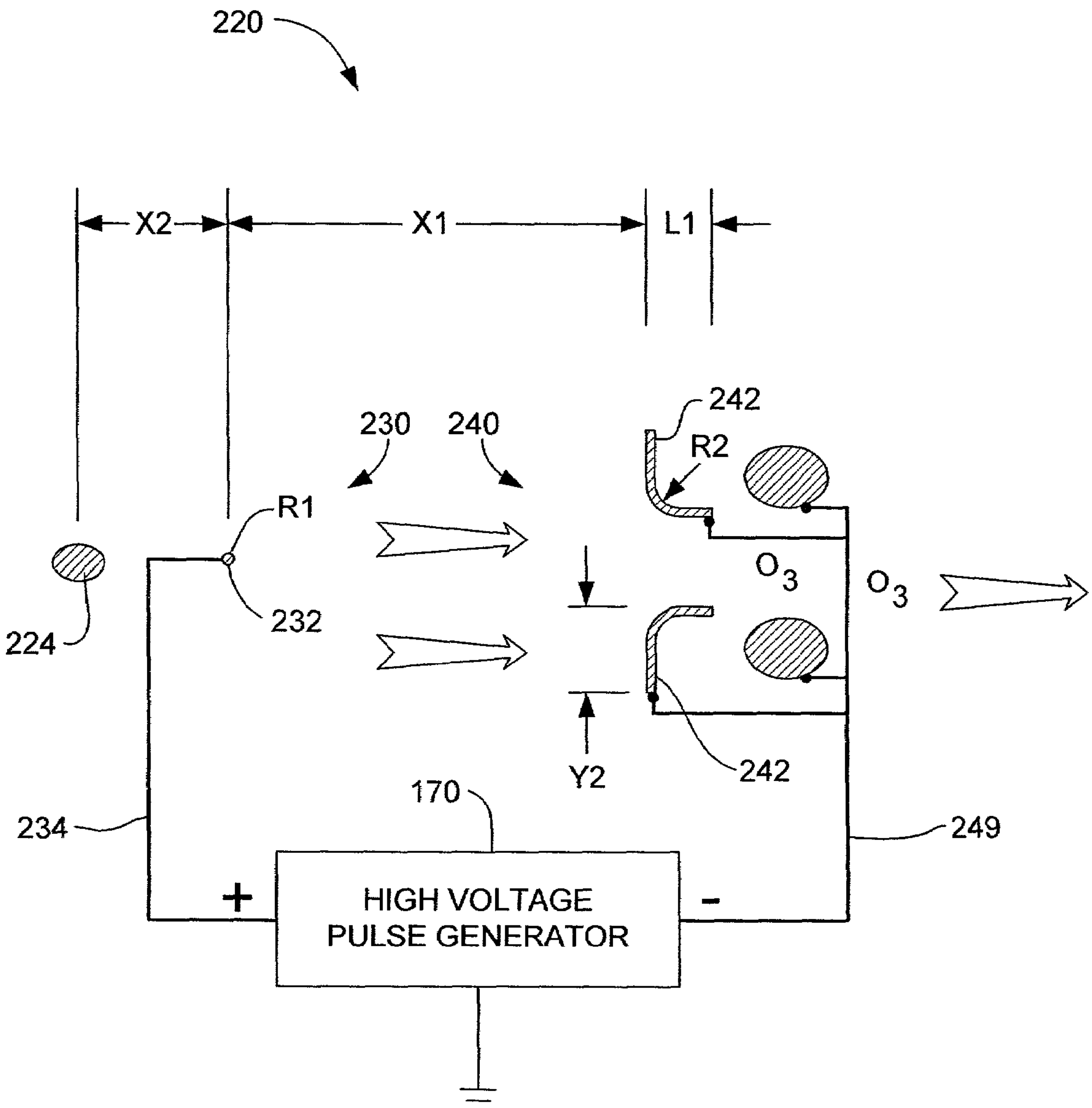
220
X2
X1
L1
242
230
240
R2
R1
O_3
O_3
232
224
242
Y2
170
234
249
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 10B

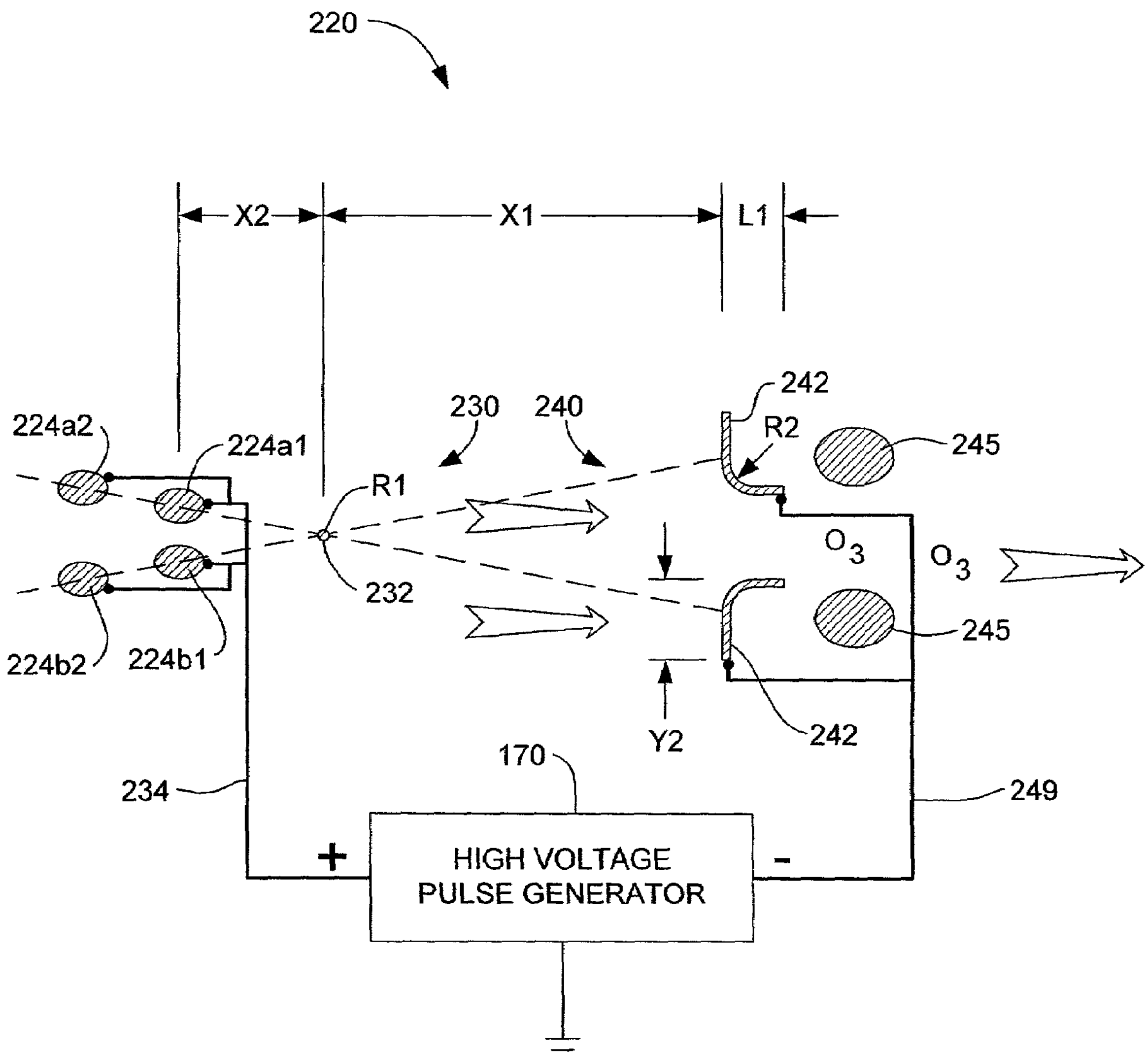
220
X2
X1
L1
242
230
240
R2
224a2
224a1
245
R1
O3
O3
232
245
224b2
224b1
242
Y2
170
234
249
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 10C

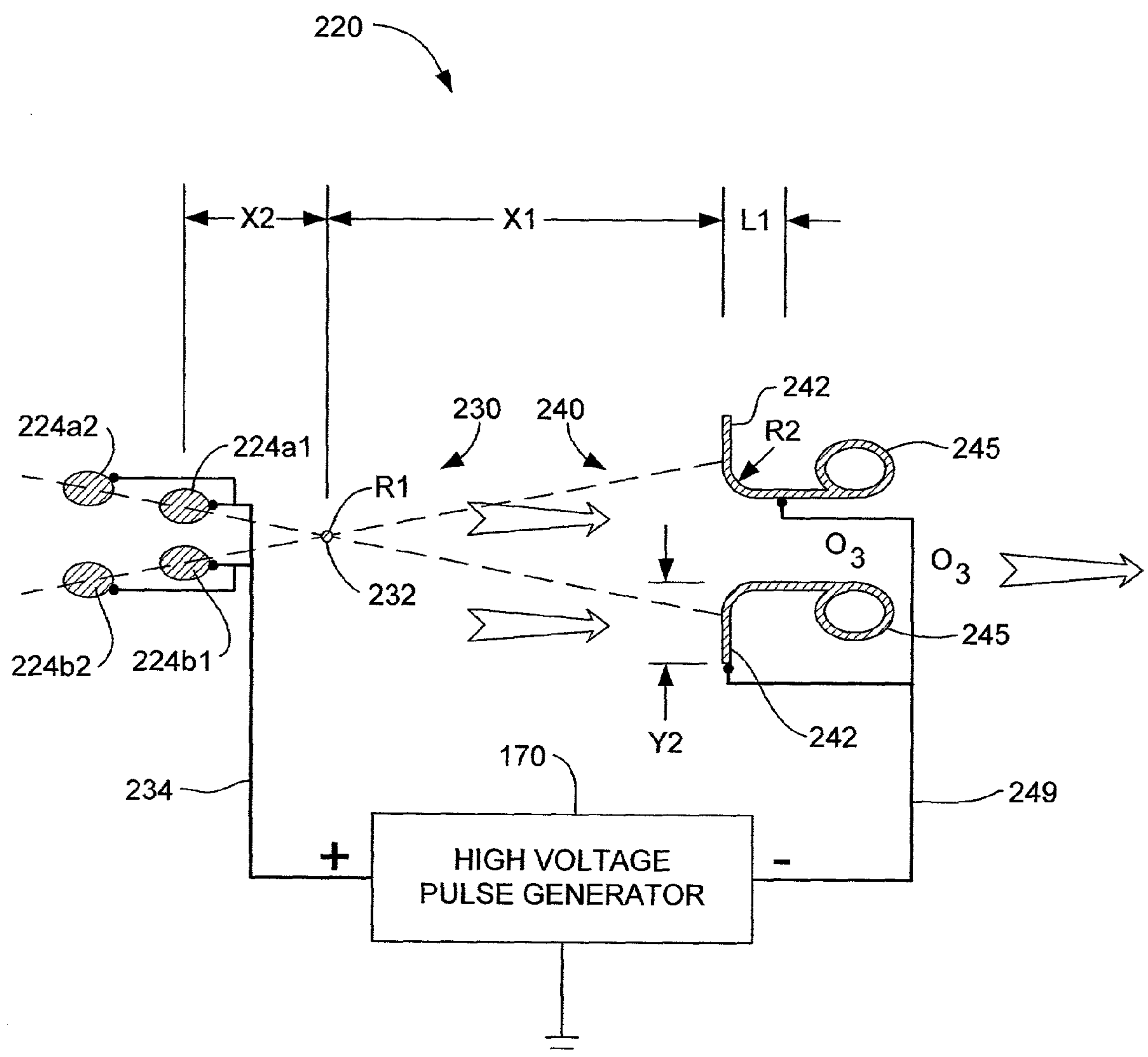
220
X2
X1
L1
242
230
240
224a2
224a1
R2
245
R1
O_3
O_3
232
245
224b2
224b1
Y2
242
170
234
249
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 10D

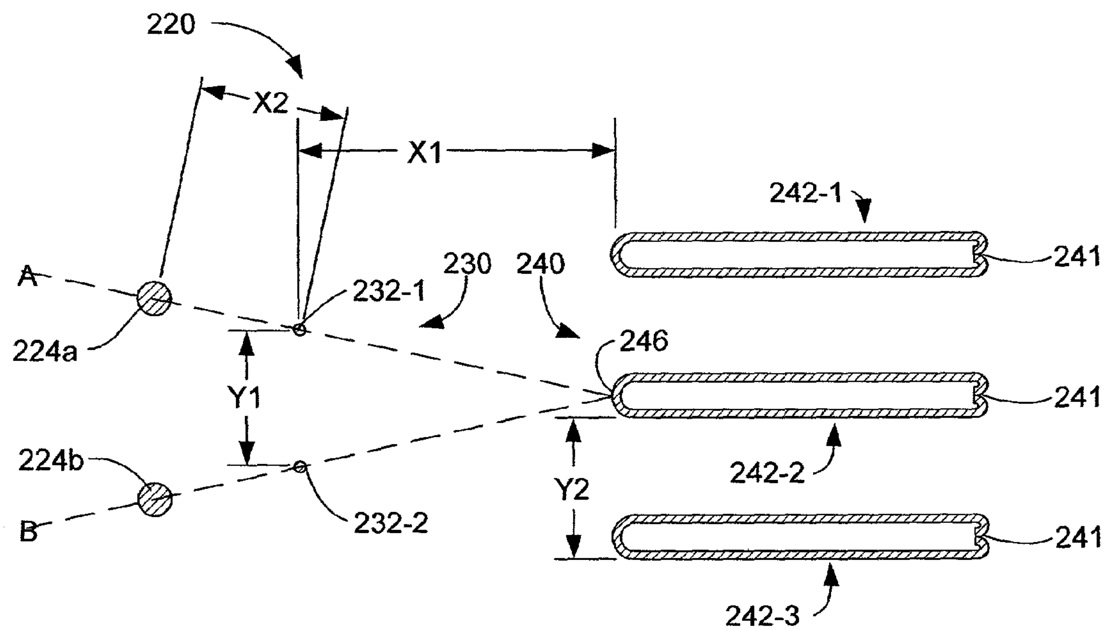

FIG. - 11A

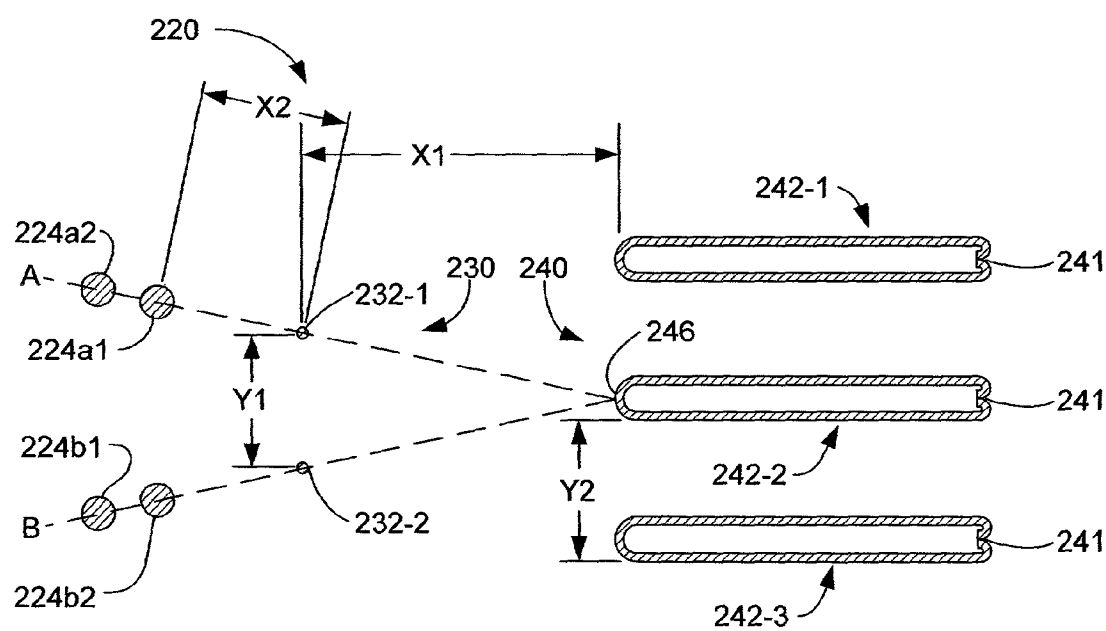

FIG. - 11B

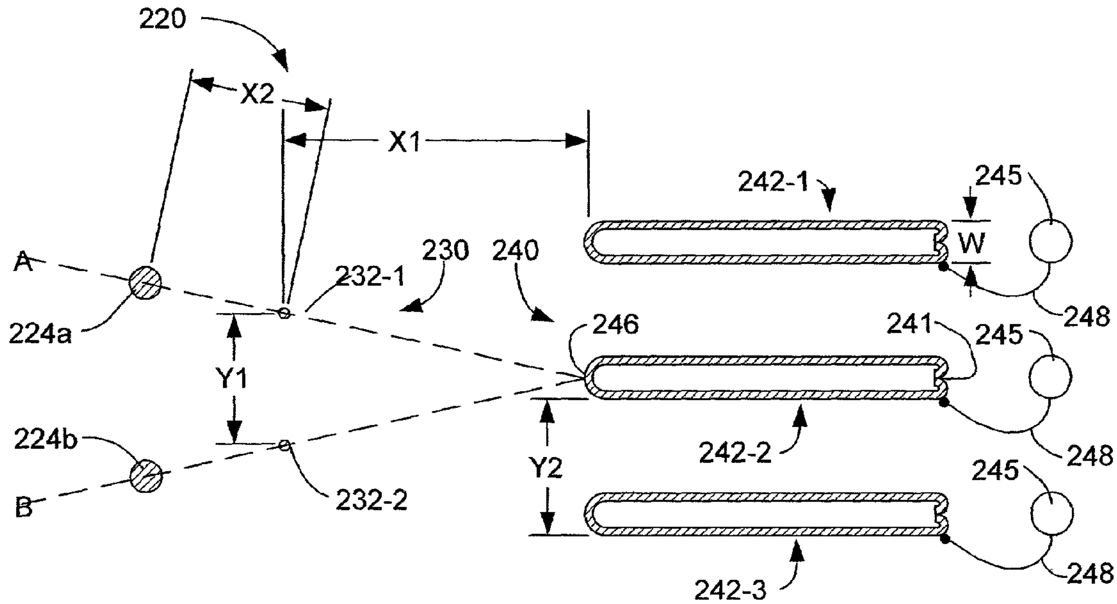

FIG. - 11C

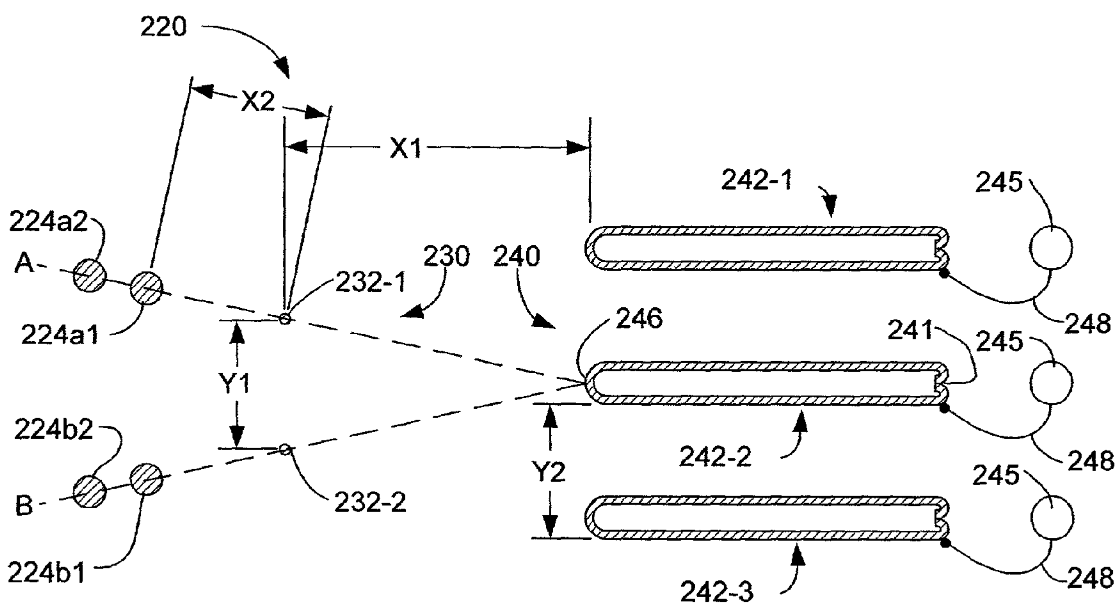

FIG. - 11D

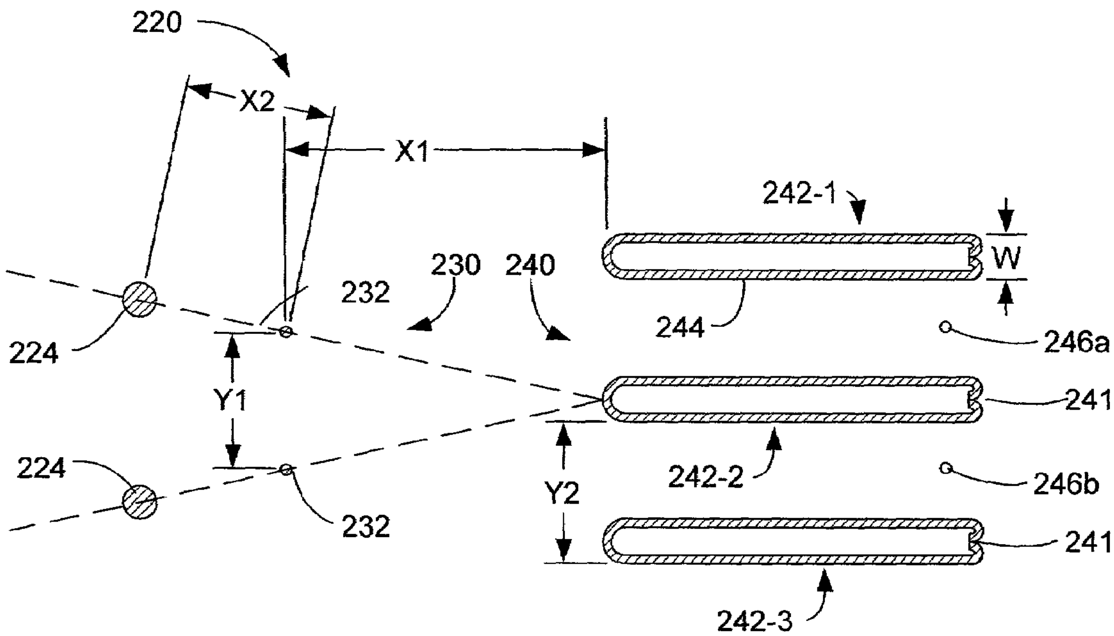

FIG. - 11E

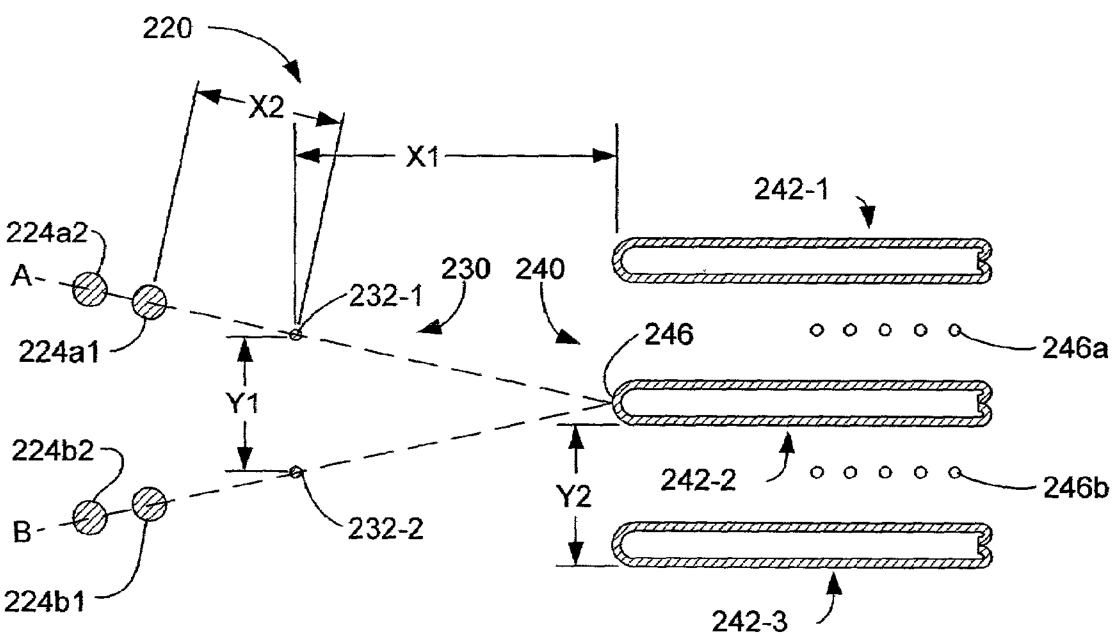

FIG. - 11F

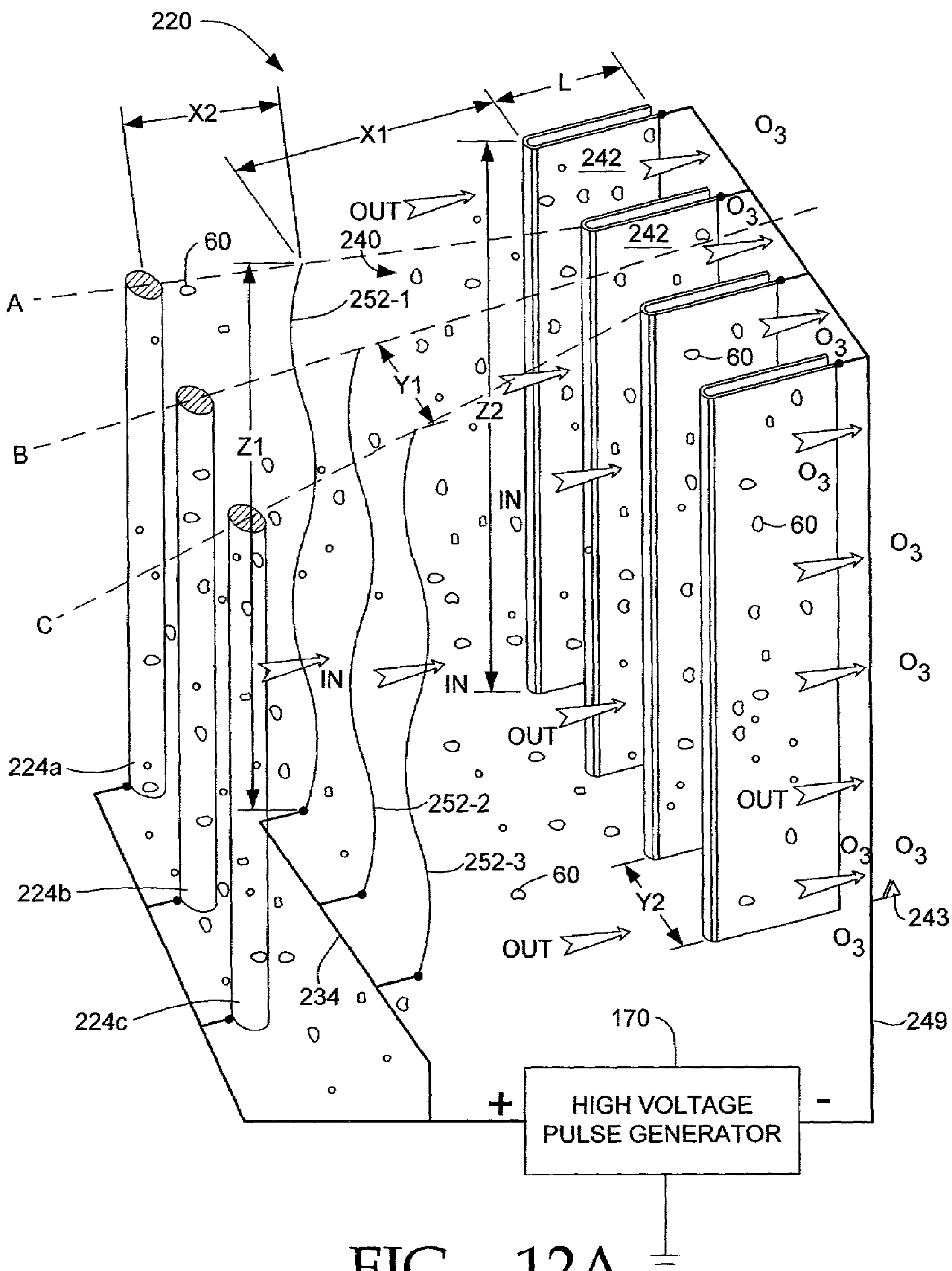
220
X2
X1
L
O_3
242
OUT
60
240
A
252-1
B
Y1
Z2
Z1
C
IN
IN
IN
OUT
224a
252-2
224b
252-3
Y2
243
234
224c
170
249
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 12A

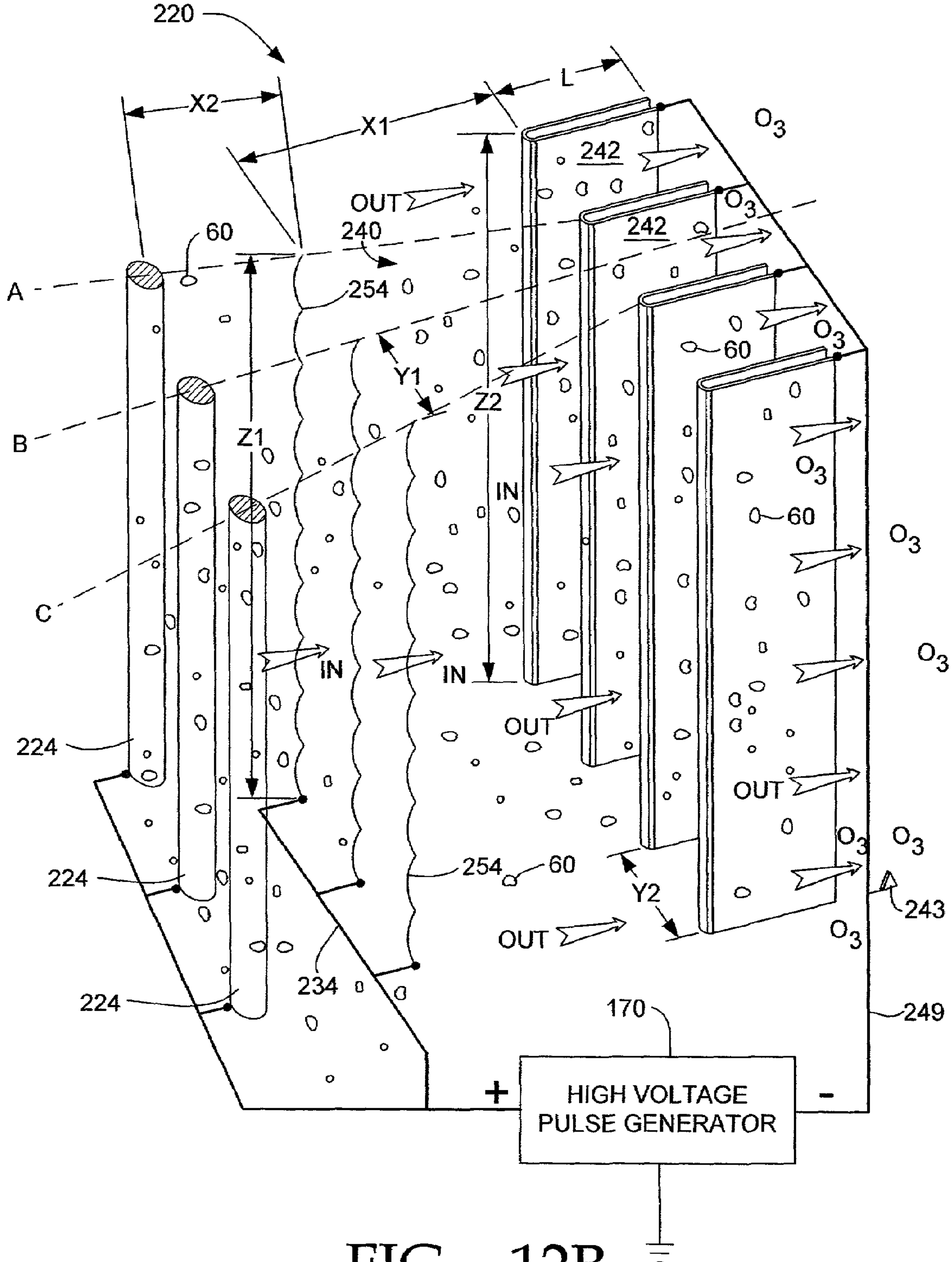
220
X2
X1
L
242
O3
OUT
240
60
A
254
Y1
Z2
B
Z1
IN
C
224
OUT
254
60
Y2
243
234
170
249
+
HIGH VOLTAGE
PULSE GENERATOR
-

FIG. - 12B

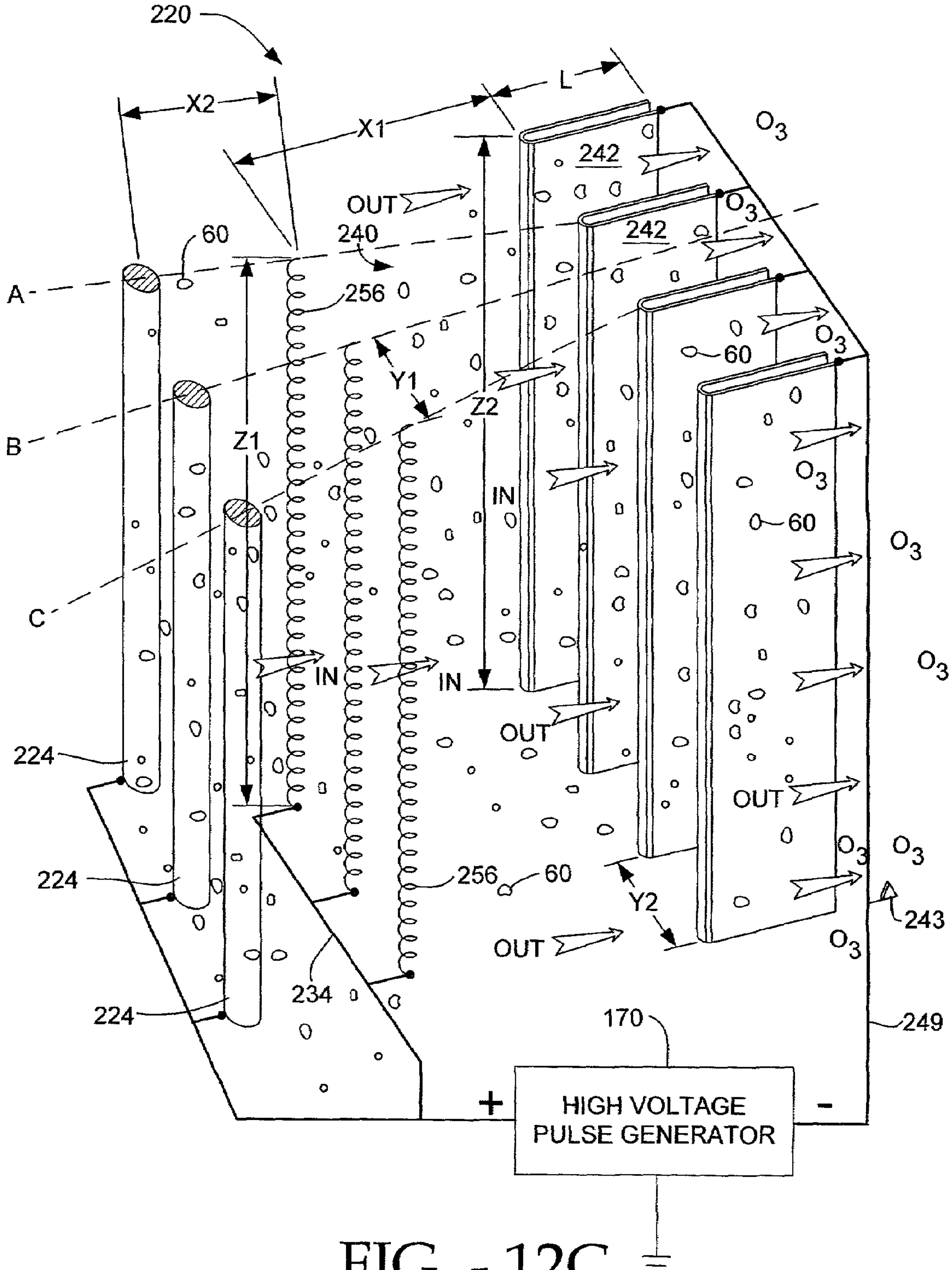
220
X2
X1
L
O_3
242
OUT
60
240
A
256
Y1
Z2
B
Z1
IN
C
60
224
234
Y2
243
170
249
HIGH VOLTAGE
PULSE GENERATOR
+
-

FIG. - 12C

AIR TREATMENT APPARATUS HAVING MULTIPLE DOWNSTREAM ELECTRODES

CLAIM OF PRIORITY

This application claims priority from the provisional application entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH TRAILING ELECTRODE," Application No. 60/341,090, filed Dec. 13, 2001 under 35 U.S.C. 119(e), now expired, which application is incorporated herein by reference. This application also claims priority from the provisional application entitled "FOCUS ELECTRODE, ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES," Application No. 60/306,479, filed Jul. 18, 2001 under 35 U.S.C. 119(e), now expired, which application is incorporated herein by reference. This application also claims priority from and is a continuation-in-part of U.S. patent application Ser. No. 09/924,624 filed Aug. 8, 2001, now abandoned, which is a continuation of U.S. Pat. No. 09/564,960 filed May 4, 2000, now U.S. Pat. No. 6,350,417, which is a continuation-in-part of U.S. patent application Ser. No. 09/186,471 filed Nov. 5, 1998, now U.S. Pat. No. 6,176,977. This application also claims priority from and is a continuation-in-part of U.S. patent application Ser. No. 09/730,499, filed Dec. 5, 2000, now U.S. Pat. No. 6,713,026, which is a continuation of U.S. patent application Ser. No. 09/186,471, filed Nov. 5, 1998, now U.S. Pat. No. 6,176,977. All of the above are incorporated herein by reference.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to the following commonly-owned co-pending patent applications:

U.S. patent application Ser. No.	Filed
90/007,276	Oct. 29, 2004
11/041,926	Jan. 21, 2005
11/091,243	Mar. 28, 2005
11/062,057	Feb. 18, 2005
11/071,779	Mar. 3, 2005
10/994,869	Nov. 22, 2004
11/007,556	Dec. 8, 2004
10/074,209	Feb. 12, 2002
10/685,182	Oct. 14, 2003
10/944,016	Sep. 17, 2004
10/795,934	Mar. 8, 2004
10/435,289	May 9, 2003
11/064,797	Feb. 24, 2005
11/003,671	Dec. 3, 2004
11/003,035	Dec. 3, 2004
11/007,395	Dec. 8, 2004
10/876,495	Jun. 25, 2004
10/809,923	Mar. 25, 2004
11/004,397	Dec. 3, 2004
10/895,799	Jul. 21, 2004
10/642,927	Aug. 18, 2003
11/823,346	Apr. 12,2004
10/662,591	Sep. 15, 2003
11/061,967	Feb. 18, 2005
11/150,046	Jun. 10, 2005
11/188,448	Jul. 25, 2005
11/188,478	Jul. 25, 2005
11/293,538	Dec. 2, 2005
11/457,396	Jul. 13, 2006
11/464,139	Aug. 11,2006
11/694,281	Mar. 30, 2007

The following applications are incorporated by reference:

U.S. patent application Ser. No.	Filed	U.S. Pat. No.
60/341,518	Dec. 13, 2001	
60/341,433	Dec. 13, 2001	
60/341,592	Dec. 13, 2001	
60/341,320	Dec. 13, 2001	
60/341,179	Dec. 13, 2001	
60/340,702	Dec. 13, 2001	
60/341,377	Dec. 13, 2001	
10/023,197	Dec. 13, 2001	
10/023,460	Dec. 13, 2001	
60/340,288	Dec. 13, 2001	
60/341,176	Dec. 13, 2001	
60/340,462	Dec. 13, 2001	
10/074,082	Feb. 12, 2002	6,958,134
10/074,207	Feb. 12, 2002	
10/074,208	Feb. 12, 2002	
10/074,339	Feb. 12, 2002	
10/074,827	Feb. 12, 2002	
10/074,096	Feb. 12, 2002	6,974,560
10/074,347	Feb. 12, 2002	6,911,186
10/074,379	Feb. 12, 2002	
10/074,549	Feb. 12, 2002	
10/074,103	Feb. 12, 2002	

FIELD OF THE INVENTION

The present invention relates generally to devices that produce an electro-kinetic flow of air from which particulate matter is substantially removed.

BACKGROUND OF THE INVENTION

The use of an electric motor to rotate a fan blade to create an airflow has long been known in the art. Unfortunately, such fans produce substantial noise, and can present a hazard to children who maybe tempted to poke a finger or a pencil into the moving fan blade. Although such fans can produce substantial airflow (e.g., 1,000 ft^3/minute or more), substantial electrical power is required to operate the motor, and essentially no conditioning of the flowing air occurs.

It is known to provide such fans with a HEPA-compliant filter element to remove particulate matter larger than perhaps 0.3 μm. Unfortunately, the resistance to airflow presented by the filter element may require doubling the electric motor size to maintain a desired level of airflow. Further, HEPA-compliant filter elements are expensive, and can represent a substantial portion of the sale price of a HEPA-compliant filter-fan unit. While such filter-fan units can condition the air by removing large particles, particulate matter small enough to pass through the filter element is not removed, including bacteria, for example.

It is also known in the art to produce an airflow using electro-kinetic techniques, by which electrical power is converted into a flow of air without mechanically moving components. One such system is described in U.S. Pat. No. 4,789,801 to Lee (1988), depicted herein in simplified form as FIGS. **1**A and **1**B and which patent is incorporated herein by reference. System **10** includes an array of first ("emitter") electrodes or conductive surfaces **20** that are spaced-apart symmetrically from an array of second ("collector") electrodes or conductive surfaces **30**. The positive terminal of a generator such as, for example, pulse generator **40** that outputs a train of high voltage pulses (e.g., 0 to perhaps +5 KV) is coupled to the first array, and the negative pulse generator terminal is coupled to the second array in this example. It is to be understood that the arrays depicted include multiple electrodes, but that an array can include or be replaced by a single electrode.

The high voltage pulses ionize the air between the arrays, and create an airflow **50** from the first array toward the second array, without requiring any moving parts. Particulate matter **60** in the air is entrained within the airflow **50** and also moves towards the second electrodes **30**. Much of the particulate matter is electrostatically attracted to the surfaces of the second electrodes, where it remains, thus conditioning the flow of air exiting system **10**. Further, the high voltage field present between the electrode arrays can release ozone into the ambient environment, which can eliminate odors that are entrained in the airflow.

In the particular embodiment of FIG. **1**A, first electrodes **20** are circular in cross-section, having a diameter of about 0.003" (0.08 mm), whereas the second electrodes **30** are substantially larger in area and define a "teardrop" shape in cross-section. The ratio of cross-sectional radii of curvature between the bulbous front nose of the second electrode and the first electrodes exceeds 10:1. As shown in FIG. **1**A, the bulbous front surfaces of the second electrodes face the first electrodes, and the somewhat "sharp" trailing edges face the exit direction of the airflow. The "sharp" trailing edges on the second electrodes promote good electrostatic attachment of particulate matter entrained in the airflow.

In another particular embodiment shown herein as FIG. **1**B, second electrodes **30** are symmetrical and elongated in cross-section. The elongated trailing edges on the second electrodes provide increased area upon which particulate matter entrained in the airflow can attach.

While the electrostatic techniques disclosed by the '801 patent are advantageous over conventional electric fan-filter units, further increased air transport-conditioning efficiency would be advantageous.

SUMMARY OF THE INVENTION

The present invention provides such an apparatus.

One aspect of the present invention is to provide an electro-kinetic air transporter-conditioner that produces an enhanced airflow velocity, enhanced particle collection, and an appropriate amount of ozone production.

An embodiment includes one or more focus or leading electrodes. Each focus or leading electrode maybe located upstream to, or even with, each first electrode. The focus or leading electrodes assists in controlling the flow of ionized particles within the airflow. The focus or leading electrode shapes the electrostatic field generated by each first electrode within the electrode assembly.

Another embodiment includes one or more trailing electrodes. Each trailing electrode can be located downstream of a second electrode. The trailing electrode can assist in neutralizing the amount of ions exiting this embodiment of the invention, and can further assist in collecting ionized particles. The trailing electrode can alternatively enhance the flow of negative ions from the transporter-conditioner. Additionally, the trailing electrodes can improve the laminar flow properties of the airflow exiting the air transporter-conditioner.

Another embodiment of the invention includes at least one interstitial electrode located between two second electrodes. The interstitial electrode can also assist in the collection of particulate matter by the second electrodes.

In yet another embodiment of the invention, one or more of the second electrodes are formed to have an enhanced protective end or trailing surface which assists in the operation and cleaning of the embodiment.

In still a further embodiment of the invention, one or more first electrode are of enhanced length in order to increase the emissivity of the first electrode.

Other objects, aspects, features and advantages of the invention will appear from the following description in which the preferred embodiments have been set forth in detail, in conjunction with the accompanying drawings and also from the following claim.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A-**1**B; FIG. **1**A is a plan, cross-sectional view, of a first embodiment of an electro-kinetic air transporter-conditioner system according to the prior art; FIG. **1**B is a plan, cross-sectional view, of a second embodiment of an electro-kinetic air transporter-conditioner system according to the prior art;

FIGS. **2**A-**2**B; FIG. **2**A is a perspective view of a typical embodiment of the housing of an electro-kinetic air transporter-conditioner; FIG. **2**B is a perspective view of the embodiment shown in FIG. **2**A illustrating the removable second electrodes;

FIG. **3** is an electrical block diagram of the present invention;

FIGS. **4**A-**4**F; FIG. **4**A is a perspective view showing an embodiment of an electrode assembly according to the present invention; FIG. **4**B is a plan view of the embodiment illustrated in FIG. **4**A; FIG. **4**C is a perspective view showing another embodiment of an electrode assembly according to the present invention; FIG. **4**D is a plan view illustrating a modified version of the embodiment of FIG. **4**C; FIG. **4**E is a perspective view showing yet another embodiment of an electrode assembly according to the present invention; FIG. **4**F is a plan view of the embodiment of FIG. **4**E;

FIGS. **5**A-**5**B; FIG. **5**A is a perspective view of still another embodiment of the present invention illustrating the leading or focus electrode added to the embodiment shown in FIG. **4**A; FIG. **5**B is a plan view of a modified embodiment of the present invention similar to that shown in FIG. **5**A illustrating a protective end on each second electrode;

FIGS. **6**A-**6**D; FIG. **6**A is a perspective view of a further embodiment of the present invention, illustrating a leading or focus electrode added to the embodiment shown in FIG. **4**C; FIG. **6**B is a perspective view of a modified embodiment of the present invention as shown in FIG. **6**A; FIG. **6**C is a perspective view of a modified embodiment of the present invention as shown in FIG. **6**B; FIG. **6**D is a modified embodiment of the present invention, illustrating a leading or focus electrode added to the embodiment in FIG. **4**D;

FIGS. **7**A-**7**C; FIG. **7**A is a perspective view of another embodiment of the present invention, illustrating a leading or focus electrode added to the embodiment shown in FIG. **4**E; FIG. **7**B is a perspective view of an embodiment modified from that shown in FIG. **7**A; FIG. **7**C is a perspective view of an embodiment modified from that shown in FIG. **7**B;

FIGS. **8**A-**8**C; FIG. **8**A is a perspective view of still a further embodiment of the present invention, illustrating another embodiment of the leading or focus electrode; FIG. **8**B is a perspective view of an embodiment modified from that shown in FIG. **5**A; FIG. **8**C is a perspective view of yet another embodiment;

FIGS. **9**A-**9**C; FIG. **9**A is perspective view of a further embodiment of the present invention; FIG. **9**B is a partial view of an embodiment modified from that shown in FIG. 10A; FIG. 9C is another embodiment modified from that shown in FIG. 9A;

FIGS. 10A-10D; FIG. 10A is a perspective view of another embodiment of the present invention, illustrating a trailing electrode added to the embodiment in FIG. 7A; FIG. 10B is a plan view of the embodiment shown in FIG. 10A; FIG. 10C is a plan view of a further embodiment of the present invention; FIG. 10D is a plan view of another embodiment of the present invention similar to FIG. 10C.

FIGS. 11A-11F; FIG. 11A is a plan view of still another embodiment of the present invention; FIG. 11B is a plan view of an embodiment modified from that shown in FIG. 11A; FIG. 11C is a plan view of a further embodiment of the present invention; FIG. 11D is a plan view of an embodiment modified from that shown in FIG. 11C; FIG. 11E is a plan view of a further embodiment of the present invention; FIG. 11F is a plan view of an embodiment modified from that shown in FIG. 11F; and

FIGS. 12A-12C; FIG. 12A is a perspective view of still another embodiment of the present invention; FIG. 12B is a perspective view of a further embodiment of the present invention; FIG. 12C is a perspective view of yet another embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Overall Air Transporter-Conditioner System Configuration:

FIGS. 2A and 2B depict an electro-kinetic air transporter-conditioner system 100 whose housing 102 includes preferably rear-located intake vents or louvers 104 and preferably front located exhaust vents 106, and a base pedestal 108. If desired a single vent can provide and be used as both an air intake and an air exhaust with an air inlet channel and an air exhaust channel communicating with the vent and the electrodes. Preferably the housing is freestanding and/or upstandingly vertical and/or elongated. Internal to the transporter housing is an ion generating unit 160, preferably powered by an AC:DC power supply that is energizable or excitable using switch S1. S1, which along with the other below described user operated switches are conveniently located at the top 103 of the unit 100. Ion generating unit 160 is self-contained in that other ambient air, nothing is required from beyond the transporter housing, save external operating potential, for operation of the present invention.

The upper surface of housing 102 includes a user-liftable handle member 112 to which is affixed a second array 240 of collector electrodes 242 within an electrode assembly 220. Electrode assembly 220 also comprises a first array of emitter electrodes 230, or a single first electrode shown here as a single wire or wire-shaped electrode 232. (The terms "wire" and "wire-shaped" shall be used interchangeably herein to mean an electrode either made from a wire or, if thicker or stiffer than a wire, having the appearance of a wire.) In the embodiment shown, lifting member 112 lifts second array electrodes 240 upward, causing the second electrode to telescope out of the top of the housing and, if desired, out of unit 100 for cleaning, while the first electrode array 230 remains within unit 100. As is evident from the figure, the second array of electrode can be lifted vertically out from the top 103 of unit 100 along the longitudinal axis or direction of the elongated housing 102. This arrangement with the second electrodes removable from the top 103 of the unit 100, makes it easy for the user to pull the second electrodes out for cleaning. In FIG. 2B, the bottom ends of second electrodes 242 are connected to a member 113, to which is attached a mechanism 500, which includes a flexible member and a slot for capturing and cleaning the first electrode 232, whenever handle member 112 is moved upward or downward by a user.

The first and second arrays of electrodes are coupled to the output terminals of ion generating unit 160, as best seen in FIG. 3.

The general shape of the embodiment of the invention shown in FIGS. 2A and 2B is that of a figure eight in cross-section, although other shapes are within the spirit and scope of the invention. The top-to-bottom height of the preferred embodiment is in one preferred embodiment, 1 m, with a left-to-right width of preferably 15 cm, and a front-to-back depth of perhaps 10 cm, although other dimensions and shapes can of course be used. A louvered construction provides ample inlet and outlet venting in an economical housing configuration. There need be no real distinction between vents 104 and 106, except their location relative to the second electrodes. These vents serve to ensure that an adequate flow of ambient air can be drawn into or made available to the unit 100, and that an adequate flow of ionized air that includes appropriate amounts of O_3 flows out from unit 100.

As will be described, when unit 100 is energized with S1, high voltage or high potential output by ion generator 160 produces ions at the first electrode, which ions are attracted to the second electrodes. The movement of the ions in an "IN" to "OUT" direction carries with the ions air molecules, thus electro-kinetically producing an outflow of ionized air. The "IN" notation in FIGS. 2A and 2B denote the intake of ambient air with particulate matter 60. The "OUT" notation in the figures denotes the outflow of cleaned air substantially devoid of the particulate matter, which particulates matter adheres electrostatically to the surface of the second electrodes. In the process of generating the ionized airflow appropriate amounts of ozone (O_3) are beneficially produced. It maybe desired to provide the inner surface of housing 102 with an electrostatic shield to reduces detectable electromagnetic radiation. For example, a metal shield could be disposed within the housing, or portions of the interior of the housing can be coated with a metallic paint to reduce such radiation.

The housing preferably has a substantially oval-shaped or-elliptically shaped cross-section with dimpled side grooves. Thus, as indicated above, the cross-section looks somewhat like a figure eight. It is within the scope of the present invention for the housing to have a different shaped cross-section such as, but not limited to, a rectangular shape, an egg shape, a tear-drop shape, or circular shape. The housing preferably has a tall, thin configuration. As will become apparent later, the housing is preferably functionally shaped to contain the electrode assembly.

As mentioned above, the housing has an inlet and an outlet. Both the inlet and the outlet are covered by fins or louvers. Each fin is a thin ridge spaced-apart from the next fin, so that each fin creates minimal resistance as air flows through the housing. The fins are horizontal and are directed across the elongated vertical upstanding housing of the unit. Thus, the fins are substantially perpendicular in this preferred embodiment to the electrodes. The inlet and outlet fins are aligned to give the unit a "see through" appearance. Thus, a user can "see through" the unit from the inlet to the outlet. The user will see no moving parts within the housing, but just a quiet unit that cleans the air passing therethrough. Alternatively the fins can be parallel with the electrodes in another preferred embodiment. Other orientations of fins and electrodes are possible in other embodiments.

As best seen in FIG. 3, ion generating unit 160 includes a high voltage generator unit 170 and circuitry 180 for converting raw alternating voltage (e.g., 117 VAC) into direct current ("DC") voltage. Circuitry **180** preferably includes circuitry controlling the shape and/or duty cycle of the generator unit output voltage (which control is altered with user switch S2). Circuitry **180** preferably also includes a pulse mode component, coupled to switch S3, to temporarily provide a burst of increased output ozone. Circuitry **180** can also include a timer circuit and a visual indicator such as a light emitting diode ("LED"). The LED or other indicator (including, if desired, an audible indicator) signals when ion generation quits occurring. The timer can automatically halt generation of ions and/or ozone after some predetermined time, e.g., 30 minutes.

The high voltage generator unit **170** preferably comprises a low voltage oscillator circuit **190** of perhaps 20 KHz frequency, that outputs low voltage pulses to an electronic switch **200**, e.g., a thyristor or the like. Switch **200** switchably couples the low voltage pulses to the input winding of a step-up transformer T**1**. The secondary winding of T**1** is coupled to a high voltage multiplier circuit **210** that outputs high voltage pulses. Preferably the circuitry and components comprising high voltage pulse generator **170** and circuit **180** are fabricated on a printed circuit board that is mounted within housing **102**. If desired, external audio input (e.g., from a stereo tuner) could be suitably coupled to oscillator **190** to acoustically modulate the kinetic airflow produced by unit **160**. The result would be an electrostatic loudspeaker, whose output airflow is audible to the human ear in accordance with the audio input signal. Further, the output air stream would still include ions and ozone.

Output pulses from high voltage generator **170** preferably are at least 10 KV peak-to-peak with an effective DC offset of, for example, half the peak-to-peak voltage, and have a frequency of, for example, 20 KHz. Frequency of oscillation can include other values, but frequency of at least about 20 KHz is preferred as being inaudible to humans. If pets will be in the same room as the unit **100**, it maybe desired to utilize and even higher operating frequency, to prevent pet discomfort and/or howling by the pet. The pulse train output preferably has a duty cycle of for example 10%, which will promote battery lifetime if live current is not used. Of course, different peak-peak amplitudes, DC offsets, pulse train wave shapes, duty cycle, and/or repetition frequencies can be used instead. Indeed, a 100% pulse train (e.g., an essentially DC high voltage) maybe used, albeit with shorter battery lifetime. Thus, generator unit **170** for this embodiment can be referred to as a high voltage pulse generator. Unit **170** functions as a DC:DC high voltage generator, and could be implemented using other circuitry and/or techniques to output high voltage pulses that are input to electrode assembly **220**.

As noted, outflow (OUT) preferably includes appropriate amounts of ozone that can remove odors and preferably destroy or at least substantially alter bacteria, germs, and other living (or quasi-living) matter subjected to the outflow. Thus, when switch S1 is closed and the generator **170** has sufficient operating potential, pulses from high voltage pulse generator unit **170** create an outflow (OUT) of ionized air and ozone. When S1 is closed, LED will visually signal when ionization is occurring.

Preferably operating parameters of unit **100** are set during manufacture and are generally not user-adjustable. For example, with respect to operating parameters, increasing the peak-to-peak output voltage and/or duty cycle in the high voltage pulses generated by unit **170** can increase the airflow rate, ion content, and ozone content. These parameters can be set by the user by adjusting switch S2 as disclosed below. In the preferred embodiment, output flowrate is about 200 feet/minute, ion content is about 2,000,000/cc and ozone content is about 40 ppb (over ambient) to perhaps 2,000 ppb (over ambient). Decreasing the ratio of the radius of the nose of the second electrodes to the radius of the first electrode or decreasing the ratio of the cross-sectioned area of the second electrode to the first electrode below about 20:1 will decrease flow rate, as will decreasing the peak-to-peak voltage and/or duty cycle of the high voltage pulses coupled between the first and second electrode arrays.

In practice, unit **100** is placed in a room and connected to an appropriate source of operating potential, typically 117 VAC. With **S1** energizing ionization unit **160**, systems **100** emits ionized air and preferably some ozone via outlet vents **106**. The airflow, coupled with the ions and ozone freshens the air in the room, and the ozone can beneficially destroy or at least diminish the undesired effects of certain odors, bacteria, germs, and the like. The airflow is indeed electro-kinetically produced, in that there are no intentionally moving parts within unit **100**. (Some mechanical vibration may occur within the electrodes.).

Having described various aspects of this embodiment of the invention in general, preferred embodiments of electrode assembly **220** are now described. In the various embodiments, electrode assembly **220** comprises a first array **230** of at least one electrode or conductive surface **232**, and further comprises a second array **240** of preferably at least one electrode or conductive surface **242**. Understandably material(s) for electrodes **232** and **242** should conduct electricity, be resistant to corrosive effects from the application of high voltage, yet be strong enough to be cleaned.

In the various electrode assemblies to be described herein, electrode(s) **232** in the first electrode array **230** are preferably fabricated from tungsten. Tungsten is sufficiently robust in order to withstand cleaning, has a high melting point to retard breakdown due to ionization, and has a rough exterior surface that seems to promote efficient ionization. On the other hand, electrode(s) **242** preferably have a highly polished exterior surface to minimize unwanted point-to-point radiation. As such, electrode(s) **242** preferably are fabricated from stainless steel and/or brass, among other materials. The polished surface of electrode(s) **232** also promotes ease of electrode cleaning.

In contrast to the prior art electrodes disclosed by the '801 patent, electrodes **232** and **242**, are light weight, easy to fabricate, and lend themselves to mass production. Further, electrodes **232** and **242** described herein promote more efficient generation of ionized air, and appropriate amounts of ozone, (indicated in several of the figures as O_3).

Electrode Assembly with First and Second Electrodes:

FIGS. **4**A-**4**F

FIGS. **4**A-**4**F illustrate various configurations of the electrode assembly **220**. The output from high voltage pulse generator unit **170** is coupled to an electrode assembly **220** that comprises a first electrode array **230** and a second electrode array **240**. Again, instead of arrays, single electrodes or single conductive surfaces can be substituted for one or both array **230** and array **240**.

The positive output terminal of unit **170** is coupled to first electrode array **230**, and the negative output terminal is coupled to second electrode array **240**. It is believed that with this arrangement the net polarity of the emitted ions is positive, e. g., more positive ions than negative ions are emitted. This coupling polarity has been found to work well, including minimizing unwanted audible electrode vibration or hum. However, while generation of positive ions is conducive to a relatively silent airflow, from a health standpoint, it is desired that the output airflow be richer in negative ions, not positive ions. It is noted that in some embodiments, one port (preferably the negative port) of the high voltage pulse generator can in fact be the ambient air. Thus, electrodes in the second array need not be connected to the high voltage pulse generator using a wire. Nonetheless, there will be an "effective connection" between the second array electrodes and one output port of the high voltage pulse generator, in this instance, via ambient air. Alternatively the negative output terminal of unit **170** can be connected to the first electrode array **230** and the positive output terminal can be connected to the second electrode array **240**.

With this arrangement an electrostatic flow of air is created, going from the first electrode array towards the second electrode array. (This flow is denoted "OUT" in the figures.) Accordingly electrode assembly **220** is mounted within transporter system **100** such that second electrode array **240** is closer to the OUT vents and first electrode array **230** is closer to the IN vents.

When voltage or pulses from high voltage pulse generator **170** are coupled across first and second electrode arrays **230** and **240**, a plasma-like field is created surrounding electrodes **232** in first array **230**. This electric field ionizes the ambient air between the first and second electrode arrays and establishes an "OUT" airflow that moves towards the second array. It is understood that the IN flow enters via vent(s) **104**, and that the OUT flow exits via vent(s) **106**.

Ozone and ions are generated simultaneously by the first array electrodes **232**, essentially as a function of the potential from generator **170** coupled to the first array of electrodes or conductive surfaces. Ozone generation can be increased or decreased by increasing or decreasing the potential at the first array. Coupling an opposite polarity potential to the second array electrodes **242** essentially accelerates the motion of ions generated at the first array, producing the airflow denoted as "OUT" in the figures. As the ions and ionized particulates move toward the second array, the ions and ionized particles push or move air molecules toward the second array. The relative velocity of this motion may be increased, by way of example, by decreasing the potential at the second array relative to the potential at the first array.

For example, if +10 KV were applied to the first array electrode(s), and no potential were applied to the second array electrode(s), a cloud of ions (whose net charge is positive) would form adjacent the first electrode array. Further, the relatively high 10 KV potential would generate substantial ozone. By coupling a relatively negative potential to the second array electrode(s), the velocity of the air mass moved by the net emitted ions increases.

On the other hand, if it were desired to maintain the same effective outflow (OUT) velocity, but to generate less ozone, the exemplary 10 KV potential could be divided between the electrode arrays. For example, generator **170** could provide +4 KV (or some other fraction) to the first array electrodes and −6 KV (or some other fraction) to the second array electrodes. In this example, it is understood that the +4 KV and the −6 KV are measured relative to ground. Understandably it is desired that the unit **100** operates to output appropriate amounts of ozone. Accordingly, the high voltage is preferably fractionalized with about +4 KV applied to the first array electrodes and about −6 KV applied to the second array electrodes.

In the embodiments of FIGS. **4**A and **4**B, electrode assembly **220** comprises a first array **230** of wire-shaped electrodes **232**, and a second array **240** of generally "U"-shaped electrodes **242**. In preferred embodiments, the number N1 of electrodes comprising the first array can preferably differ by one relative to the number N2 of electrodes comprising the second array **240**. In many of the embodiments shown, N2>N1. However, if desired, additional first electrodes **232** could be added at the outer ends of array **230** such that N1>N2, e.g., five first electrodes **232** compared to four second electrodes **242**.

As previously indicated first or emitter electrodes **232** are preferably lengths of tungsten wire, whereas electrodes **242** are formed from sheet metal, preferably stainless steel, although brass or other sheet metal could be used. The sheet metal is readily configured to define side regions **244** and bulbous nose region **246**, forming the hollow, elongated "U"-shaped electrodes **242**. While FIG. **4**A depicts four electrodes **242** in second array **240** and three electrodes **232** in first array **230**, as noted previously, other numbers of electrodes in each array could be used, preferably retaining a symmetrically staggered configuration as shown. It is seen in FIG. **4**A that while particulate matter **60** is present in the incoming (IN) air, the outflow (OUT) air is substantially devoid of particulate matter, which adheres to the preferably large surface area provided by the side regions **244** of the second array electrodes **242**.

FIG. **4**B illustrates that the spaced-apart configuration between the first and second arrays **230**, **240** is staggered. Preferably, each first array electrode **232** is substantially equidistant from two second array electrodes **242**. This symmetrical staggering has been found to be an efficient electrode placement. Preferably, in this embodiment, the staggering geometry is symmetrical in that adjacent electrodes **232** or adjacent electrodes **242** are spaced-apart a constant distance, **Y1** and **Y2** respectively. However, a non-symmetrical configuration could also be used. Also, it is understood that the number of electrodes **232** and **242** may differ from what is shown.

In the embodiment of FIG. **4**A, typically dimensions are as follows: diameter of electrodes **232**, **R1**,is about 0.08 mm, distances **Y1** and **Y2** are each about 16 mm, distance **X1** is about 16 mm, distance L is about 20 mm, and electrode heights **Z1** and **Z2** are each about 1 m. The width W of electrodes **242** is preferably about 4 mm, and the thickness of the material from which electrodes **242** are formed is about 0.5 mm. Of course other dimensions and shapes could be used. For example, preferred dimensions for distance **X1** may vary between 12-30 mm, and the distance **Y2** may vary between 15-30 mm. It is preferred that electrodes **232** have a small diameter. A wire having a small diameter, such as **R1**, generates a high voltage field and has a high emissivity. Both characteristics are beneficial for generating ions. At the same time, it is desired that electrodes **232** (as well as electrodes **242**) be sufficiently robust to withstand occasional cleaning.

Electrodes **232** in first array **230** are coupled by a conductor **234** to a first (preferably positive) output port of high voltage pulse generator **170**. Electrodes **242** in second array **240** are coupled by a conductor **249** to a second (preferably negative) output port of high voltage generator **170**. The electrodes maybe electrically connected to the conductors **234** or **249** at various locations. By way of example only, FIG. **4**B depicts conductor **249** making connection with some electrodes **242** internal to bulbous end **246**, while other electrodes **242** make electrical connection to conductor **249** elsewhere on the electrode **242**. Electrical connection to the various electrodes **242** could also be made on the electrode external surface, provided no substantial impairment of the outflow air stream results; however it has been found to be preferable that the connection is made internally.

In this and the other embodiments to be described herein, ionization appears to occur at the electrodes **232** in the first electrode array **230**, with ozone production occurring as a function of high voltage arcing. For example, increasing the peak-to-peak voltage amplitude and/or duty cycle of the pulses from the high voltage pulse generator **170** can increase ozone content in the output flow of ionized air. If desired, user-control S**2** can be used to somewhat vary ozone content by varying amplitude and/or duty cycle. Specific circuitry for achieving such control is known in the art and need not be described in detail herein.

Note the inclusion in FIGS. **4**A and **4**B of at least one output controlling electrodes **243**, preferably electrically coupled to the same potential as the second array electrodes **242**. Electrode **243** preferably defines a pointed shape in side profile, e.g., a triangle. The sharp point on electrodes **243** causes generation of substantial negative ions (since the electrode is coupled to relatively negative high potential). These negative ions neutralize excess positive ions otherwise present in the output airflow, such that the OUT flow has a net negative charge. Electrodes **243** is preferably stainless steel, copper, or other conductor material, and is perhaps 20 mm high and about 12 mm wide at the base. The inclusion of one electrode **243** has been found sufficient to provide a sufficient number of output negative ions, but more such electrodes may be included.

In the embodiments of FIGS. **4**A, **4**B and **4**C, each "U"-shaped electrode **242** has two trailing surface or sides **244** that promote efficient kinetic transport of the outflow of ionized air and ozone. For the embodiment of FIG. **4**C, there is the inclusion on at least one portion of a trailing edge of a pointed electrode region **243'**. Electrode region **243'** helps promote output of negative ions, in the same fashion that was previously described with respect to electrodes **243**, as shown in FIGS. **4**A and **4**B.

In FIG. **4**C and the figures to follow, the particulate matter is omitted for ease of illustration. However, from what was shown in FIGS. **4**A-**4**B, particulate matter will be present in the incoming air, and will be substantially absent from the outgoing air. As has been described, particulate matter **60** typically will be electrostatically precipitated upon the surface area of electrodes **242**.

As discussed above and as depicted by FIG. **4**C, it is relatively unimportant where on an electrode array electrical connection is made. Thus, first array electrodes **232** are shown electrically connected together at their bottom regions by conductor **234**, whereas second array electrodes **242** are shown electrically connected together in their middle regions by the conductor **249**. Both arrays may be connected together in more than one region, e.g., at the top and at the bottom. It is preferred that the wire or strips or other inter-connecting mechanisms be at the top, bottom, or periphery of the second array electrodes **242**, so as to minimize obstructing stream air movement through the housing **210**.

It is noted that the embodiments of FIGS. **4**C and **4**D depict somewhat truncated versions of the second electrodes **242**. Whereas dimension L in the embodiment of FIGS. **4**A and **4**B was about 20 mm, in FIGS. **4**C and **4**D, L has been shortened to about 8 mm. Other dimensions in FIG. **4**C preferably are similar to those stated for FIGS. **4**A and **4**B. It will be appreciated that the configuration of second electrode array **240** in FIG. **4**C can be more robust than the configuration of FIGS. **4**A and **4**B, by virtue of the shorter trailing edge geometry. As noted earlier, a symmetrical staggered geometry for the first and second electrode arrays is preferred for the configuration of FIG. **4**C.

In the embodiment of FIG. **4**D, the outermost second electrodes, denoted **242-1** and **242-4**, have substantially no outermost trailing edges. Dimension L in FIG. **4**D is preferably about 3 mm, and other dimensions maybe as stated for the configuration of FIGS. **4**A and **4**B. Again, the ratio of the radius or surface areas between the first electrode **232** and the second electrodes **242** for the embodiment of FIG. **4**D preferably exceeds about 20:1.

FIGS. **4**E and **4**F depict another embodiment of electrode assembly **220**, in which the first electrode array **230** comprises a single wire electrode **232**, and the second electrode array **240** comprises a single pair of curved "L"-shaped electrodes **242**, in cross-section. Typical dimensions, where different than what has been stated for earlier-described embodiments, are X**1** ≈12 mm, Y**2**≈5 mm, and L**1**≈3 mm. The effective surface area or radius ratio is again greater than about 20:1. The fewer electrodes comprising assembly **220** in FIGS. **4**E and **4**F promote economy of construction, and ease of cleaning, although more than one electrode **232**, and more than two electrodes **242** could of course be employed. This particular embodiment incorporates the staggered symmetry described earlier, in which electrode **232** is equidistant from two electrodes **242**. Other geometric arrangements, which may not be equidistant, are within the spirit and scope of the invention.

Electrode Assembly With an Upstream Focus Electrode:

FIGS. **5**A-**5**B

The embodiments illustrated in FIGS. **5**A-**5**B are somewhat similar to the previously described embodiments in FIGS. **4**A-**4**B. The electrode assembly **220** includes a first array of electrodes **230** and a second array of electrodes **240**. Again, for this and the other embodiments, the term "array of electrodes" may refer to a single electrode or a plurality of electrodes. Preferably, the number of electrodes **232** in the first array of electrodes **230** will differ by one relative to the number of electrodes **242** in the second array of electrodes **240**. The distances L, X**1**, Y**1**, Y**2**, Z**1** and Z**2** for this embodiment are similar to those previously described in FIG. **4**A.

As shown in FIG. **5**A, the electrode assembly **220** preferably adds a third, or leading, or focus, or directional electrode **224***a*, **224***b*, **224***c* (generally referred to as "electrode **224**") upstream of each first electrode **232-1**, **232-2**, **232-3**. The focus electrode **224** produces an enhanced airflow velocity exiting the devices **100** or **200**. In general, the third focus electrode **224** directs the airflow, and ions generated by the first electrode **232**, towards the second electrodes **242**. Each third focus electrode **224** is a distance X**2** upstream from at least one of the first electrodes **232**. The distance X**2** is preferably 5-6 mm, or four to five diameters of the focus electrode **224**. However, the third focus electrode **224** can be further from or closer to the first electrode **232**.

The third focus electrode **224** illustrated in FIG. **5**A is a rod-shaped electrode. The third focus electrode **224** can also comprise other shapes that preferably do not contain any sharp edges. The third focus electrode **224** is preferably manufactured from material that will not erode or oxidize, such as stainless steel. The diameter of the third focus electrode **224**, in a preferred embodiment, is at least fifteen times greater than the diameter of the first electrode **232**. The diameter of the third focus electrode **224** can be larger or smaller. The diameter of the third focus electrode **224** is preferably large enough so that third focus electrode **224** does not function as an ion emitting surface when electrically connected with the first electrode **232**. The maximum diameter of the third focus electrode **224** is somewhat constrained. As the diameter increases, the third focus electrode **224** will begin to noticeably impair the airflow rate of the units **100** or **200**. Therefore, the diameter of the third electrode **224** is balanced between the need to form a non-ion emitting surface and airflow properties of the unit **100** or **200**.

In a preferred embodiment, each third focus electrodes **224***a*, **224***b*, **224***c* are electrically connected with the first array **230** and the high voltage generator **170** by the conductor **234**. As shown in FIG. **5**A, the third focus electrodes **224** are electrically connected to the same positive outlet of the high voltage generator **170** as the first array **230**. Accordingly, the first electrode **232** and the third focus electrode **224** generate a positive electrical field. Since the electrical fields generated by the third focus electrode **224** and the first electrode **232** are both positive, the positive field generated by the third focus electrode **224** can push, or repel, or direct, the positive field generated by the first electrode **232** towards the second array **240**. For example, the positive field generated by the third focus electrode **224***a* will push, or repel, or direct, the positive field generated by the first electrode **232-1** towards the second array **240**. In general, the third focus electrode **224** shapes the electrical field generated by each electrode **232** in the first array **230**. This shaping effect is believe to decrease the amount of ozone generated by the electrode assembly **220** and increases the airflow of the units **100** and **200**.

The particles within the airflow are positively charged by the ions generated by the first electrode **232**. As previously mentioned, the positively charged particles are collected by the negatively charged second electrodes **242**. The third focus electrode **224** also directs the airflow towards the second electrodes **242** by guiding the charged particles towards the trailing sides **244** of each second electrode **242**. It is believed that the airflow will travel around the third focus electrode **224**, partially focusing the airflow towards the trailing sides **244**, improving the collection rate of the electrode assembly **220**.

The third focus electrode **224** maybe located at various positions upstream of each first electrode **232**. By way of example only, a third focus electrode **224***b* is located directly upstream of the first electrode **232-2** so that the center of the third focus electrode **224***b* is in-line and symmetrically aligned with the first electrode **232-2**, as shown by extension line B. Extension line B is located midway between the second electrode **242-2** and the second electrode **242-3**.

Alternatively, a third focus electrode **224** can also be located at an angle relative to the first electrode **232**. For example, a third focus electrode **224***a* can be located upstream of the first electrode **232-1** along a line extending from the middle of the nose **246** of the second electrode **242-2** through the center of the first electrode **232-1**, as shown by extension line A. The third focus electrode **224***a* is in-line and symmetrically aligned with the first electrode **232-1** along extension line A. Similarly, the third electrode **224***c* is located upstream to the first electrode **232-3** along a line extending from the middle of the nose **246** of the second electrode **242-3** through the first electrode **232-3**, as shown by extension line C. The third focus electrode **224c** is in-line and symmetrically aligned with the first electrode **232-3** along extension line C. It is within the scope of the present invention for the electrode assembly **220** to include third focus electrodes **224** that are both directly upstream and at an angle to the first electrodes **232**, as depicted in FIG. **5**A. Thus the focus electrodes fan out relating to the first electrodes.

FIG. **5**B illustrates that an electrode assembly **220** may contain multiple third focus electrodes **224** upstream of each first electrode **232**. Byway of example only, the third focus electrode **224***a***2** is in-line and symmetrically aligned with the third focus electrode **224***a***1**, as shown by extension line A. In a preferred embodiment, only the third focus electrodes **224***a***1**, **224***b***1**, **224***c***1** are electrically connected to the high voltage generator **170** by conductor **234**. Accordingly, not all of the third electrodes **224** are at the same operating potential.

In the embodiment shown in FIG. **5**B, the third focus electrodes **224***a***l**, **224***b***1**, **224***c***1** are at the same electrical potential as the first electrodes **232**, while the third focus electrodes **224***a***2**, **224***b***2**, **224***c***2** are floating. Alternatively, the third focus electrodes **224***a***2**, **224***b***2** and **224***c***2** maybe electrically connected to the high voltage generator **170** by the conductor **234**.

FIG. **5**B illustrates that each second electrode **242** may also have a protective end **241**. In the previous embodiments, each "U"-shaped second electrode **242** has an open end. Typically, the end of each trailing side or side wall **244** contains sharp edges. The gap between the trailing sides or side walls **244**, and the sharp edges at the end of the trailing sides or side walls **244**, generate unwanted eddy currents. The eddy currents create a "backdraft," or airflow traveling from the outlet towards the inlet, which slow down the airflow rate of the units **100** or **200**.

In a preferred embodiment, the protective end **241** is created by shaping, or rolling, the trailing sides or side walls **244** inward and pressing them together, forming a rounded trailing end with no gap between the trailing sides or side walls of each second electrode **242**. Accordingly the side walls have outer surfaces, and the outer surface of end of the side walls are bent back adjacent to the trailing ends of the side walls so that the outer surface of the side walls are adjacent to, or face, or touch each other. Accordingly a smooth trailing edge is integrally formed on the second electrode. If desired, it is within the scope of the invention to spot weld the rounded ends together along the length of the second electrode **242**. It is also within the scope of the present invention to form the protective end **241** by other methods such as, but not limited to, placing a strap of plastic across each end of the trailing sides **244** for the full length of the second electrode **242**. The rounded or capped end is an improvement over the previous electrodes **242** without a protective end **241**. Eliminating the gap between the trailing sides **244** also reduces or eliminates the eddy currents typically generated by the second electrode **242**. The rounded protective end also provides a smooth surface for purpose of cleaning the second electrode. Accordingly in this embodiment the collector electrode is a one-piece, integrally formed, electrode with a protection end.

FIGS. **6**A-**6**D

FIG. **6**A illustrates an electrode assembly **220** including a first array of electrodes **230** having three wire-shaped first electrodes **232-1**, **232-2**, **232-3** (generally referred to as "electrode **232**") and a second array of electrodes **240** having four "U"-shaped second electrodes **242-1**, **242-2**, **242-3**, **242-4** (generally referred to as "electrode **242**"). Each first electrode **232** is electrically connected to the high voltage generator **170** at the bottom region, whereas each second electrode **242** is electrically connected to the high-voltage generator **170** in the middle to illustrate that the first and second electrodes **232**,**242** can be electrically connected in a variety of locations.

The second electrode **242** in FIG. **6**A is a similar version of the second electrode **242** shown in FIG. **4**C. The distance L has been shortened to about **8**mm, while the other dimensions X1, Y1, Y2, Z1, Z2 are similar to those shown in FIG. **4**A.

A third leading or focus electrode **224** is located upstream of each first electrode **232**. The innermost third focus electrode **224***b* is located directly upstream of the first electrode **232-2**, as shown by extension line B. Extension line B is located midway between the second electrodes **242-2**,**242-3**. The third focus electrodes **224***a*, **224***c* are at an angle with respect to the first electrodes **232-1**,**232-3**. For example, the third focus electrode **224***a* is upstream to the first electrode

232-1 along a line extending from the middle of the nose **246** of the second electrode **242-2** extending through the center of the first electrode **232-1**, as shown by extension line A. The third electrode **224***c* is located upstream of the first electrode **232-3** along a line extending from the center of the nose **246** of the second electrode **242-3** through the center of the first electrode **232-3**, as shown by extension line C. Accordingly and preferably the focus electrodes fan out relative to the first electrodes as an aid for directing the flow of ions and charged particles. FIG. **6**B illustrates that the third focus electrodes **224** and the first electrode **232** may be electrically connected to the high voltage generator **170** by conductor **234**.

FIG. **6**C illustrates that a pair of third focus electrodes **224** maybe located upstream of each first electrode **232**. Preferably, the multiple third focus electrodes **224** are in-line and symmetrically aligned with each other. For example, the third focus electrode **224***a***2** is in-line and symmetrically aligned with the third focus electrode **224***a***1**, along extension line A. As previously mentioned, preferably only third focus electrodes **224***a***1**, **224***b***1**, **224***c***12** are electrically connected with the first electrodes **232** by conductor **234**. It is also within the scope of the present invention to have none or all of the third focus electrodes **224** electrically connected to the high voltage generator **170**.

FIG. **6**D illustrates third focus electrodes **224** added to the electrode assembly **220** shown in FIG. **4**D. Preferably, a third focus electrode **224** is located upstream of each first electrode **232**. For example, the third focus electrode **224***b* is in-line and symmetrically aligned with the first electrode **232-2**, as shown by extension line B. Extension line B is located midway between the second electrodes **242-2**, **242-3**. The third focus electrode **224***a* is in-line and symmetrically aligned with the first electrode **232-1**, as shown by extension line A. Similarly, the third electrode **224***c* is in-line and symmetrically aligned with the first electrode **232-3**, as shown by extension line C. Extension lines A-C extend from the middle of the nose **246** of the "U"-shaped second electrodes **242-2**, **242-3** through the first electrodes **232-1**, **232-3**, respectively. In a preferred embodiment, the third electrodes **224***a*, **224***b*, **224***c* with the high voltage generator **170** by the conductor **234**. This embodiment can also include a pair of third focus electrodes **224** upstream of each first electrode **232** as is depicted in FIG. **6**C.

FIGS. **7**A-**7**C

FIGS. **7**A-**7**C illustrate that the electrode assembly **220** shown in FIG. **4**E can include a third focus electrode upstream of the first array of electrodes **230** comprising a single wire electrode **232**. Preferably, the center of the third focus electrode **224** is in-line and symmetrically aligned with the center of the first electrode **232**, as shown by extension line B. Extension line B is located midway between the second electrodes **242**. The distances X**1**, X**2**, Y**1**, Y**2**, Z**1** and Z**2** are similar to the embodiments previously described. The first electrode **232** and the second electrode **242** may be electrically connected to the high-voltage generator **170** by conductor **234**, **249** respectively. It is within the scope of the present invention to connect the first and second electrodes to opposite ends of the high voltage generator **170** (e.g., the first electrode **232** may be negatively charged and the second electrode **242** may be positively charged). In a preferred embodiment the third focus electrode **224** is also electrically connected to the high voltage generator **170**.

FIG. **7**B illustrates that a pair of third focus electrodes **224***a*, **224***b* may be located upstream of the first electrode **232**. The third focus electrodes **224***a*, **224***b* are in-line and symmetrically aligned with the first electrode **232**, as shown by extension line B. Extension line B is located midway between the second electrodes **242**. Preferably, the third focus electrode **224***b* is upstream of third focus electrode **224***a* a distance equal to the diameter of a third focus electrode **224**. In a preferred embodiment, only the third focus electrode **224***a* is electrically connected to the high voltage generator **170**. It is within the scope of the present invention to electrically connect both third focus electrodes **224***a*, **224***b* to the high voltage generator **170**.

FIG. **7**C illustrates that each third focus electrode **224** can be located at an angle with respect to the first electrode **232**. Similar to the previous embodiments, the third focus electrode **224***a***1** and **224***b***1** is located a distance X**2** upstream from the first electrode **232**. By way of example only, the third focus electrodes **224***a***1** , **224***a***2** are located along a line extending from the middle of the second electrode **242-2** through the center of the first electrode **232**, as shown by extension line A. Similarly, the third focus electrodes **224***b***1**, **224***b***2** are along a line extending from the middle of the second electrode **242-1** through the middle of the first electrode **232**, as shown by extension line B. The third focus electrode **224***a***2** is in-line and symmetrically aligned with the third focus electrode **224***a***1** along extension line A. Similarly, the third focus electrode **224***b***2** is in line and symmetrically aligned with the third focus electrode **224***b***1** along extension line B. The third focus electrodes **224** are fanned out and form a "V" pattern upstream of first electrode **232**. In a preferred embodiment, only the third focus electrodes **224***a***1** and **224***b***1** are electrically connected to the high-voltage generator **170** by conductor **234**. It is within the scope of the invention to electrically connect the third focus electrodes **224***a* and **224***b***2** to the high voltage generator **170**.

FIGS. **8**A-**8**B

The previously described embodiments of the electrode assembly **220** disclose a rod-shaped third focus electrode **224** upstream of each first electrode **232**. FIG. **8**A illustrates an alternative configuration for the third focus electrode **224**. Byway of example only, the electrode assembly **220** may include a "U"-shaped or possibly "C"-shaped third focus electrode **224** upstream of each first electrode **232**. Further the third focus electrode **224** can have other curved configurations such as, but not limited to, circular-shaped, elliptical-shaped, and parabolically-shaped other concave shapes facing the first electrode **232**. In a preferred embodiment, the third focus electrode **224** has holes **225** extending through, forming a perforated surface to minimize the resistance of the third focus electrode **224** on the airflow rate.

In a preferred embodiment, the third focus electrode **224** is electrically connected to the high voltage generator **170** by conductor **234**. The third focus electrode **224** in FIG. **8**A is preferably not an ion emitting surface. Similar to previous embodiments, the third focus electrode **224** generates a positive electric field and pushes or repels the electric field generated by the first electrode **232** towards the second array **240**.

FIG. **8**B illustrates that a perforated "U"-shaped or "C"-shaped third focus electrode **224** can be incorporated into the electrode assembly **220** shown in FIG. **4**A. Even though only two configurations of the electrode assembly **220** are shown with the perforated "U"-shaped third focus electrode **224**, all the embodiments described in FIGS. **5**A-**12**C may incorporate the perforated "U"-shaped third focus electrode **224**. It is also within the scope of the invention to have multiple perforated "U"-shaped third focus electrodes **224** upstream of each first electrode **232**. Further in other embodiment the "U"-shaped third focus electrode **224** can be made of a screen or a mesh.

FIG. **8**C illustrates third focus electrodes **224** similar to those depicted in FIG. **8**B, except that the third focus electrodes **224** are rotated by 180° to preset a convex surface facing to the first electrodes **232** in order to focus and direct the field of ions and airflow from the first electrode **232** toward the second electrode **242**. These third focus electrodes **224** shown in FIGS. **8**A-**8**C are located along extension lines A, B, C similar to previously described embodiments.

FIGS. **9**A-**9**C

FIG. **9**A illustrates a pin-ring configuration of the electrode assembly **220**. The electrode assembly **220** contains a cone-shaped or triangular-shaped first electrode **232**, a ring-shaped second electrode **242** downstream of the first electrode **232**, and a third focus electrode **250** upstream of the first electrode **232**. The third focus electrodes **250** may be electrically connected to the high voltage generator **170**. Preferably the focus electrode **250** is spaced from the first electrode **232** a distance that is in accordance with the other embodiments described herein. Alternatively, the third focus electrode **250** can have a floating potential. As indicated by phantom elements **232'**, **242'**, the electrode assembly **220** can comprise a plurality of such pin-like and ring-like elements. The plurality of pin-ring configurations as depicted in FIG. **9**A can be positioned one above the other along the elongated housing of the invention. Such a plurality of pin-ring configurations can of course operate in another embodiment without the third focus electrode. It is understood that this plurality of pin-ring configurations can be upstanding and elongated along the elongated direction of said housing and can replace the first and second electrodes shown, for example, in FIG. **2**B and be removable much as the second electrode in FIG. **2**B is removable. Preferably, the first electrode **232** is tungsten, and the second electrode **242** is **5** stainless steel. Typical dimensions for the embodiment of FIG. **9**A are L**1**≈10 millimeters, X**1**≈9.5 millimeters, T≈0.5 millimeters and the diameter of the opening **246**≈12 millimeters.

The electrical properties and characteristics of the third focus electrode **250** is similar to the third focus electrode **224** described in previous embodiments. In contrast to the rod-shaped physical characteristic of the previous embodiments, the shape the third focus electrode **250** is a concave disc, with the concave surface preferably facing toward the second electrodes **242**. The third focus electrode **250** preferably has holes extending therethrough to minimize the disruption in airflow. It is within the scope of the present invention for the third focus electrode **250** to comprise other shapes such as, but not limited to, a convex disc a parabolic disc, a spherical disc, or other convex or concave shapes or a rectangle, or other planar surface and be within the spirit and scope of the invention. The diameter of the third focus electrode **250** is preferably at least fifteen times greater than the diameter of the first electrode **232**. The focus electrode **250** can also be made of a screen or a mesh.

The second electrode **242** has an opening **246**. The opening **246** is preferably circular in this embodiment. It is within the scope of the present invention that the opening **246** can comprise other shapes such as, but not limited to, rectangular, hexagonal or octagonal. The second electrode **242** has a collar **247** (see FIG. **9**B) surrounding the opening **246**. The collar **247** attracts the dust contained within the air stream passing through the opening **246**. As seen in the FIGS. **9**B and **9**C the collar **247** includes a downstream extending tubular portion **248** which can collect particles. As a result, the air stream emitted by the electrode assembly **220** has a reduced dust content.

Other similar pin-ring embodiments are shown in FIGS. **9**B-**9**C. For example, the first electrode **232** can comprise a rod-shaped electrode having a tapered end. In FIG. **9**B, a detailed cross-sectional view of the central portion of the second electrode **242** in FIG. **9**A is shown. Preferably, the collar **247** is positioned in relation to the first electrode **232**, such that the ionization paths from the distal tip of the first electrode **232** to the collar **247** have substantially equal path lengths. Thus, while the distal tip (or emitting tip) of the first electrode **232** is advantageously small to concentrate the electric field, the adjacent regions of the second electrode **242** preferably provide many equidistant inter-electrode paths. The lines drawn in phantom in FIGS. **9**B and **9**C depict theoretical electric force field lines emanating from the first electrode **232** and terminating on the curved surface of the second electrode **242**. Preferably, the bulk of the field emanates within about 45 degrees of coaxial axis between the first electrode **232** and the second electrode **242**.

In FIG. **9**C, one or more first electrodes **232** are replaced by a conductive block **232"** of carbon fibers, the block having a distal surface in which projecting fibers **233-1**, . . . **233**-N take on the appearance of a "bed of nails." The projecting fibers can each act as an emitter electrode and provide a plurality of emitting surfaces. Over a period of time, some or all of the electrodes will literally be consumed, where upon the block **232"** may be replaced. Materials other than graphite may be used for block **232 "** providing that the material has a surface with projecting conductive fibers such as **233**-N.

Electrode Assembly With a Downstream Trailing Electrode:

FIGS. **10**A-**10**D

FIGS. **10**A-**10**C illustrate an electrode assembly **220** having an array of trailing electrodes **245** added to an electrode assembly **220** similar to that shown in FIG. **7**A. It is understood that an alternative embodiment similar to FIG. **10**A can include a trailing electrode or electrodes without any focus electrodes and be within the spirit and scope of the inventions. Referring now to FIGS. **10**A-**10**B, each trailing electrode **245** is located downstream of the second array of electrodes **240**. Preferably, the trailing electrodes are located downstream from the second electrodes **242** by at least three times the radius R**2** (see FIG. **10**B). Further, the trailing electrodes **245** are preferably directly downstream of each second electrode **242** so as not to interfere with the flow of air. Also, the trailing electrode **245** is aerodynamically smooth, for example, circular, elliptical, or teardrops shaped in cross-section so as not to unduly interfere with the smoothness of the airflow thereby. In a preferred embodiment, the trailing electrodes **245** are electrically connected to the same outlet of the high voltage generator **170** as the second array of electrodes **240**. As shown in FIG. **10**A, the second electrodes **242** and the trailing electrodes **245** have a negative electrical charge. This arrangement can introduce more negative charges into the air stream. Alternatively, the trailing electrodes **245** can have a floating potential if they are not electrically connected. The trailing electrodes **245** can also be grounded in other embodiments. Further alternatively, as shown in FIG. **10**D, the trailing electrode **245** can be formed with the second electrode out of a sheet of metal formed in the shape of the second electrode and then extending to the position of the trailing electrode and formed as a hollow trailing electrode with a peripheral wall that is about the shape of the outer surface of the trailing electrode **245** depicted in FIG. **10**C.

When the trailing electrodes **245** are electrically connected to the high voltage generator **170**, the positively charged particles within the airflow are also attracted to and collect on, the trailing electrodes. In a typical electrode assembly with no trailing electrode **245**, most of the particles will collect on the surface area of the second electrodes **242**. However, some particles will pass through the unit **200** without being collected by the second electrodes **242**. Thus, the trailing electrodes **245** serve as a second surface area to collect the positively charged particles. The trailing electrodes **245** also can deflect charged particles toward the second electrodes.

The trailing electrodes **245** preferably also emit a small amount of negative ions into the airflow. These negative ions will neutralize the positive ions emitted by the first electrodes **232**. If the positive ions emitted by the first electrodes **232** are not neutralized before the airflow reaches the outlet **260**, the outlet fins **212** can become electrically charged and particles within the airflow may end to stick to the fins **212**. If this occurs, eventually the amount of particles collected by the fins **212** will block or minimize the airflow exiting the unit **200**.

FIG. **10**C illustrates another embodiment of the electrode assembly **200**, having trailing electrodes **245** added to an embodiment similar to that shown in FIG. **7**C. The trailing electrodes **245** are located downstream of the second array **240** similar to the previously described embodiments above. It is within the scope of the present invention to electrically connect the trailing electrodes **245** to the high voltage generator **170**. As shown in FIG. **10**C, all of the third focus electrodes **224** are electrically connected to the high voltage generator **170**. In a preferred embodiment, only the third focus electrodes **224***a***1**, **224***b***1** are electrically connected to the high voltage generator **170**. The third focus electrodes **224***a***2**, **224***b***2** have a floating potential.

Electrode Assemblies With Various Combinations of Focus Electrodes, Trailing Electrodes and Enhanced Second Electrodes With Protective Ends:

FIGS. **11**A-**11**D

FIG. **11**A illustrates an electrode assembly **220** that includes a first array of electrodes **230** having two wire-shaped electrodes **232-1**, **232-2** (generally referred to as "electrode **232**") and a second array of electrodes **240** having three "U"-shaped electrodes **242-1**, **242-2**,**242-3** (generally referred to as "electrode **242**"). This configuration is in contrast to, for example, the configurations of FIG. **9**A, wherein there are three first emitter electrodes **232** and four second collector electrodes **242**.

Upstream from each first electrode **232**, at a distance X**2**, is a third focus electrode **224**. Each third focus electrode **224***a*, **224***b* is at an angle with respect to a first electrode **232**. For example, the third focus electrode **224***a* is preferably along a line extending from the middle of the nose **246** of the second electrode **242-2** through the center of the first electrode **232-1**, as shown by extension line A. The third focus electrode **224***a* is in-line and symmetrically aligned with the first electrode **232-1** along extension line A. Similarly, the third focus electrode **224***b* is located along a line extending from middle of the nose **246** of the second electrode **242-2** through the center of the first electrode **232-2**, as shown by extension line B. The third focus electrode **224***b* is in-line and symmetrically aligned with the first electrode **232-2** along extension line B. As previously described, the diameter of each third focus electrode **224** is preferably at least fifteen times greater than the diameter of the first electrode **232**.

As shown in FIG. **11**A, and similar to the embodiment shown in FIG. **5**B, each second electrode preferably has a protective end **241**. In a preferred embodiment, the third focus electrodes **224** are electrically connected to the high voltage generator **170** (not shown). It is within the spirit and scope of the invention to not electrically connect the third focus electrodes **224**.

FIG. **11**B illustrates that multiple third focus electrodes **224** maybe located upstream of each first emitter electrode **232**. For example, the third focus electrode **224***a***2** is in-line and symmetrically aligned with the third focus electrode **224***a***1** along extension line A. Similarly, the third focus electrode **224***b***2** is in-line and symmetrically aligned with the third focus electrode **242***b***1** along extension line B. It is within the scope of the present invention to electrically connect all, or none of, the third focus electrodes **224** to the high-voltage generator **170**. In a preferred embodiment, only the third focus electrodes **224***a***1**, **224***b***1** are electrically connected to the high voltage generator **170**, with the third focus electrodes **224***a***2**, **224***b***2** having a floating potential.

FIG. **11**C illustrates that the electrode assembly **220** shown in FIG. **11**A may also include a trailing electrode **245** downstream of each second electrode **242**. Each trailing electrode **245** is in-line with the second electrode so as not to interfere with airflow past the second electrode **242**. Each trailing electrode **245** is preferably located a distance downstream of each second electrode **242** equal to at least three times the width W of the second electrode **242**. It is within the scope of the present invention for the trailing electrode to by located at other distances downstream. The diameter of the trailing anode **245** is preferably no greater than the width W of the second electrode **242** to limit the interference of the airflow coming off the second electrode **242**.

One aspect of the trailing electrode **245** is to direct the air trailing off the second electrode **242** and provide a more laminar flow of air exiting the outlet **260**. Another aspect of the trailing electrode **245** is to neutralize the positive ions generated by the first array **230** and collect particles within the airflow. As shown in FIG. **11**C, each trailing electrode **245** is electrically connected to a second electrode **242** by a conductor **248**. Thus, the trailing electrode **245** is negatively charged, and serves as a collecting surface, similar to the second electrode **242**, attracts the positively charged particles in the airflow. As previously described, the electrically connected trailing electrode **245** also emits negative ions to neutralize the positive ions emitted by the first electrodes **232**.

FIG. **11**D illustrates that a pair of third focus electrodes **224** maybe located upstream of each first electrode **232**. For example, the third focus electrode **224***a***2** is upstream of the third focus electrode **224***a***1** so that the third focus electrodes **224***a***1**, **224***a***2** are in-line and symmetrically aligned with each other along extension line A. Similarly, the third focus electrode **224***b***2** is in line and symmetrically aligned with the third focus electrode **224***b***1** along extension line B. As previously described, preferably only the third focus electrodes **224***a***1**, **224***b***1** are electrically connected to the high voltage generator **170**, while the third focus electrodes **224***a***2**, **224***b***2** have a floating potential. It is within the spirit and scope of the present invention to electrically connect all, or none, of the third focus electrodes to the high voltage generator **170**.

Electrode Assemblies With Second Collector Electrodes Having Interstitial Electrodes:

FIGS. **11**E-**11**F

FIG. **11**E illustrates another embodiment of the electrode assembly **220** with an interstitial electrode **246**. In this embodiment, the interstitial electrode **246** is located midway between the second electrodes **242**. For example, the interstitial electrode **246***a* is located midway between the second electrodes **242-1**, **242-2**, while the interstitial electrode **246***b* is located midway between second electrodes **242-2**,**242-3**.

Preferably, the interstitial electrode **246***a*, **246***b* are electrically connected to the first electrodes **232**, and generate an electrical field with the same positive or negative charge as the first electrodes **232**. The interstitial electrode **246** and the first electrode **232** then have the same polarity. Accordingly, particles traveling toward the interstitial electrode **246** will be repelled by the interstitial electrode **246** towards the second electrodes **242**. Alternatively, the interstitial electrodes can have a floating potential or be grounded.

It is to be understood that interstitial electrodes **246***a*, **246***b* may also be closer to one second collector electrode than to the other. Also, the interstitial electrodes **246***a*, **246***b* are preferably located substantially near or at the protective end **241** or ends of the trailing sides **244**, as depicted in FIG. **11**E. Still further the interstitial electrode can be substantially located along a line between the two trailing portions or ends of the second electrodes. These rear positions are preferred as the interstitial electrodes can cause the positively charged particle to deflect towards the trailing sides **244** along the entire length of the negatively charged second collector electrode **242**, in order for the second collector electrode **242** to collect more particles from the airflow.

Still further, the interstitial electrodes **246***a*, **246***b* can be located upstream along the trailing side **244** of the second collector electrodes **244**. However, the closer the interstitial electrodes **246***a*, **246***b* get to the nose **246** of the second electrode **242**, generally the less effective interstitial electrodes **246***a*, **246***b* are in urging positively charged particles toward the entire length the second electrodes **242**. Preferably, the interstitial electrodes **246***a*, **246***b* are wire-shaped and smaller or substantially smaller in diameter than the width "W" of the second collector electrodes **242**. For example, the interstitial electrodes can have a diameter of, the same as, or on the order, of the diameter of the first electrodes. For example, the interstitial electrodes can have a diameter of one-sixteenth of an inch. Also, the diameter of the interstitial electrodes **246***a*, **246***b* is substantially less than the distance between second collector electrodes, as indicated by Y2. Further the interstitial electrode can have a length or diameter in the downstream direction that is substantially less than the length of the second electrode in the downstream direction. The reason for this size of the interstitial electrodes **246***a*, **246***b* is so that the interstitial electrodes **246***a*, **246***b* have a minimal effect on the airflow rate exiting the device **100** or **200**.

FIG. **11**F illustrates that the electrode assembly **220** in FIG. **11**E can include a pair of third electrodes **224** upstream of each first electrode **232**. As previously described, the pair of third electrodes **224** are preferably in-line and symmetrically aligned with each other. For example, the third electrode **224***a***2** is in-line and symmetrically aligned with the third electrode **224***a***1** along extension line A. Extension line A preferably extends from the middle of the nose **246** of the second electrode **242-2** through the center of the first electrode **232-1**. As previously disclosed, in a preferred embodiment, only the third electrodes **224***a***1**, **224***b***1** are electrically connected to the high voltage generator **170**. In FIG. **11**F, a plurality of interstitial electrode **296***a* and **246***b* are located between the second electrodes **242**. Preferably these interstitial electrodes are in-line and have a potential gradient with an increasing voltage potential on each successive interstitial electrode in the downstream direction in order to urge particles toward the second electrodes. In this situation the voltage on the interstitial electrodes would have the same sign as the voltage of the first electrode **232**.

Electrode Assembly With an Enhanced First Emitter Electrode Being Slack:

FIGS. **12**A-**12**C

The previously described embodiments of the electrode assembly **220** include a first array of electrodes **230** having at least one wire-shaped electrode **232**. It is within the scope of the present invention for the first array of electrodes **230** to contain electrodes consisting of other shapes and configurations.

FIG. **12**A illustrates that the first array of electrodes **230** may include curved wire-shaped electrodes **252**. The curved wire-shaped electrode **252** is an ion emitting surface and generates an electric field similar to the previously described wire-shaped electrodes **232**. Also similar to previous embodiments, each second electrode **242** is "downstream," and each third focus electrode **224** is "upstream," to the curved wire-shaped electrodes **252**. The electrical properties and characteristics of the second electrode **242** and the third focus electrode **224** are similar to the previously described embodiment shown in FIG. **5**A. It is to be understood that an alternative embodiment of FIG. **12**A can exclude the focus electrodes and be within the spirit and scope of the invention.

As shown in FIG. **12**A, positive ions are generated and emitted by the first electrode **252**. In general, the quantity of negative ions generated and emitted by the first electrode is proportional to the surface area of the first electrode. The height Z**1** of the first electrode **252** is equal to the height Z**1** of the previously disclosed wire-shaped electrode **232**. However, the total length of the electrode **252** is greater than the total length of the electrode **232**. By way of example only, and in a preferred embodiment, if the electrode **252** was straightened out the curved or slack wire electrode **252** is 15-30% longer than a rod or wire-shaped electrode **232**. The electrode **252** is allowed to be slack to achieve the shorter height Z**1**. When a wire is held slack, the wire may form a curved shape similar to the first electrode **252** shown in FIG. **12**A. The greater total length of the electrode **252** translates to a larger surface area than the wire-shaped electrode **232**. Thus, the electrode **252** will generate and emit more ions than the electrode **232**. Ions emitted by the first electrode array attach to the particulate matter within the airflow. The charged particulate matter is attracted to, and collected by, the oppositely charged second collector electrodes **242**. Since the electrodes **252** generate and emit more ions than the previously described electrodes **232**, more particulate matter will be removed from the airflow.

FIG. **12**B illustrates that the first array of electrodes **230** may include flat coil wire-shaped electrodes **254**. Each flat coil wire-shaped electrode **254** also has a larger surface area than the previously disclosed wire-shaped electrode **232**. Byway of example only, if the electrode **254** was straightened out, the electrode **254** will have a total length that is preferably **10**% longer than the electrode **232**. Since the height of the electrode **254** remains at Z1, the electrode **254** has a "kinked" configuration as shown in FIG. **12**B. This greater length translates to a larger surface area of the electrode **254** than the surface area of the electrode **232**. Accordingly, the electrode **254** will generate and emit a greater number of ions than electrode **232**. It is to be understood that an alternative embodiment of FIG. **12**B can exclude the focus electrodes and be within the spirit and scope of the invention.

FIG. **12**C illustrates that the first array of electrodes **230** may also include coiled wire-shaped electrodes **256**. Again, the height Z1 of the electrodes **256** is similar to the height Z1 of the previously described electrodes **232**. However, the total length of the electrodes **256** is greater than the total length of the electrodes **232**. In a preferred embodiment, if the coiled electrode **256** was straightened out the electrodes **256** will have a total length two to three times longer than the wire-shaped electrodes **232**. Thus, the electrodes **256** have a larger surface area than the electrodes **232**, and generate and emit more ions than the first electrodes **232**. The diameter of the wire that is coiled to produce the electrode **256** is similar to the diameter of the electrode **232**. The diameter of the electrode **256** it self is preferably 1-3 mm, but can be smaller in accordance with the diameter of first emitter electrode **232**. The diameter of the electrode **256** shall remain small enough so that the electrode **256** has a high emissivity and is an ion emitting surface. It is to be understood that an alternative embodiment of FIG. **12**C can exclude the focus electrodes and be within the spirit and scope of the invention.

The electrodes **252**,**254** and **256** shown in FIGS. **12**A-**12**C maybe incorporated into any of the electrode assembly **220** configurations previously disclosed in this application.

The foregoing description of the preferred embodiments of the present invention has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations will be apparent to the practitioner skilled in the art. Modifications and variations maybe made to the disclosed embodiments without departing from the subject and spirit of the invention as defined by the following claims. Embodiments were chosen and described in order to best describe the principles of the invention and its practical application, thereby enabling others skilled in the art to understand the invention, the various embodiments and with various modifications that are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the following claims and their equivalents.

We claim:

1. An electrode assembly configured to create a flow of air comprising:

a. a first electrode;

b. a second electrode located downstream from the first electrode;

c. a trailing electrode located at least partially downstream from the second electrode, the trailing electrode operating at the same polarity as the second electrode and being configured to cause a generation of ions; and

d. a voltage generator operatively coupled to the first electrode, the second electrode and the trailing electrode.

2. The electrode assembly of claim **1** wherein the second electrode is configured to collect charged particles in the air.

3. The electrode assembly of claim **1** wherein the trailing electrode is configured to assist in a collection of charged particles in the air.

4. The electrode assembly of claim **1** wherein the trailing electrode is configured to assist in a neutralization of oppositely charged particles in the air.

5. The electrode assembly of claim **1** wherein the trailing electrode is configured to emit negative ions.

6. The electrode assembly of claim **1** wherein the trailing electrode and the second electrode are each configured to emit negative ions.

7. The electrode assembly of claim **1** wherein at least one end of the trailing electrode has a pointed portion.

8. The electrode assembly of claim **1** wherein the second electrode is adapted to be removably coupled to a housing of an electro-kinetic air transporter conditioner.

9. The electrode assembly of claim **1** wherein the second electrode is adapted to be removably coupled to a housing of an electro-kinetic air transporter conditioner for cleaning purposes.

10. The electrode assembly of claim **8** wherein the second electrode is attached to a handle, wherein the handle allows a user to remove the second electrode from the housing of the electro-kinetic air transporter conditioner.

11. The electrode assembly of claim **1** wherein the second electrode further comprises an elongated fin having a first end and a second end configured vertically opposite of the first end.

12. The electrode assembly of claim **11** wherein the trailing electrode is positioned proximal to the first end of the second electrode.

13. The electrode assembly of claim **1** wherein the voltage generator is located within an elongated housing of an electro-kinetic air transporter conditioner.

14. The electrode assembly of claim **1** wherein the second electrode further comprises a plurality of elongated plates each having a first end and a second end configured vertically opposite of the first end, wherein the elongated plates are configured parallel to each other.

15. The electrode assembly of claim **14** wherein the trailing electrode is positioned proximal to the first end of the second electrode.

16. The electrode assembly of claim **1** wherein the second electrode further comprises three elongated plates each having a first end and a second end configured vertically opposite of the first end, wherein the elongated plates are configured parallel to each other.

17. The electrode assembly of claim **1** wherein the first electrode emits positive ions and the second electrode emits negative ions.

18. The electrode assembly of claim **17** wherein the trailing electrode emits negative ions.

19. The electrode assembly of claim **1** wherein the first electrode charges particulates in the air and the second electrode collects the charged particulates flowing from the first electrode.

20. The electrode assembly of claim **1** wherein the trailing electrode has at least one pointed surface, the at least one pointed surface of the trailing electrode being configured to face downstream.

21. The electrode assembly of claim **1** wherein at least one pointed surface of the trailing electrode is configured to face in a direction substantially perpendicular to the downstream flow of air.

22. An air treatment apparatus having an ion generator, the air treatment apparatus comprising:

a. a first electrode assembly;

b. a second electrode assembly downstream of the first electrode assembly;

c. a trailing electrode at least partially downstream of the second electrode assembly, the trailing electrode being configured to cause a generation of ions; and

d. a voltage generator electrically coupled to the second electrode assembly and the trailing electrode, wherein the second electrode assembly and the trailing electrode are charged at a same potential.

23. The air treatment apparatus of claim **22** wherein the second electrode has a particle collector.

24. The air treatment apparatus of claim **22** wherein the trailing electrode has a particle collector.

25. The air treatment apparatus of claim **23** wherein the second electrode assembly is removable through a top surface of the housing.

26. An air treatment apparatus comprising:

a. first electrode assembly;

b. a second electrode assembly downstream of the first electrode assembly;

c. a trailing electrode at least partially downstream of the second electrode assembly, the trailing electrode being configured to cause a generation of ions; and

d. a voltage generator electrically coupled to the second electrode assembly and the trailing electrode, wherein the second electrode assembly and the trailing electrode are charged at a substantially identical potential.

27. The air treatment apparatus of claim **26** wherein the trailing electrode is configured to collect charged particles in the air.

28. The air treatment apparatus of claim **26** wherein the trailing electrode is configured to neutralize oppositely charged particles in the air.

29. The air treatment apparatus of claim **26** wherein the trailing electrode is configured to emit negative ions.

30. The air treatment apparatus of claim **26** wherein the trailing electrode and the second electrode are configured to emit negative ions.

31. The air treatment apparatus claim **26** wherein the second electrode assembly is removable through a top surface of a housing.

32. The air treatment apparatus of claim **26** wherein the first electrode assembly emits positive ions and the second electrode assembly emits negative ions.

33. The air treatment apparatus of claim **32** wherein the trailing electrode is configured to emit negative ions.

34. The air treatment apparatus of claim **26** wherein the trailing electrode has a pointed end, the pointed end of the trailing electrode being configured to face the downstream direction.

35. The air treatment apparatus of claim **26** wherein the trailing electrode has a pointed end, the pointed end of the trailing electrode being configured to face in a direction substantially perpendicular to the downstream direction.

36. The air treatment apparatus of claim **22** wherein the first electrode assembly further comprises a plurality of wire-like electrodes.

37. The air treatment apparatus of claim **22** wherein the second electrode assembly further comprises a plurality of plates parallel to one another.

38. The air treatment apparatus of claim **26** wherein the first electrode assembly further comprises a plurality of wire-like electrodes.

39. The air treatment apparatus of claim **26** wherein the second electrode assembly further comprises a plurality of plates parallel to one another.

40. The air treatment apparatus of claim **26** wherein the second electrode assembly is configured to collect charged particles in the air.

41. An electro-kinetic air flow producing device comprising:

a first electrode;

a second electrode assembly positioned downstream of the first electrode;

a voltage generator having opposing supply terminals electrically coupled to the first electrode and to the second electrode assembly, respectively, to ionize air proximate to the first electrode and to accelerate the ionized air toward the second electrode assembly; and

a trailing electrode at least partially downstream of the second electrode assembly, wherein the second electrode assembly and the trailing electrode are charged at a substantially identical potential and the trailing electrode is configured to neutralize at least some excess ions of the ionized air.

42. The electro-kinetic air flow producing device of claim **41**,

wherein the trailing electrode is electrically coupled a same supply terminal of the voltage generator as the second electrode assembly.

43. The electro-kinetic air flow producing device of claim **41**,

wherein the trailing electrode is electrically coupled to the second electrode assembly.

44. The electro-kinetic air flow producing device of claim **41**,

wherein the trailing electrode is uncoupled to the voltage generator but floats to the substantially identical potential.

45. The electro-kinetic air flow producing device of claim **41**,

wherein the trailing electrode is configured to emit negative ions to neutralize at least some excess positive ions emitted proximate to the first electrode.

46. The electro-kinetic air flow producing device of claim **41**,

wherein a second electrode of the second electrode assembly includes an elongated fin having a first end and a second end configured vertically opposite of the first end; and

wherein the trailing electrode is positioned proximate to the first end of the second electrode.

47. The electro-kinetic air flow producing device of claim **41**,

wherein a second electrode of the second electrode assembly includes a pair of elongated plates each having a first end and a second end configured vertically opposite of the first end; and

wherein the trailing electrode is positioned proximate to the first ends of the elongated plates.

48. The electro-kinetic air flow producing device of claim **41**,

wherein the trailing electrode has at least one pointed surface, the at least one pointed surface of the trailing electrode being configured to face downstream.

49. The electro-kinetic air flow producing device of claim **41**,

wherein at least one pointed surface of the trailing electrode is configured to face in a direction substantially perpendicular to the downstream flow of air.

50. A method of manufacturing an air treatment apparatus, the method comprising:

a. providing a housing;

b. configuring a first electrode in the housing;

c. configuring a second electrode in the housing downstream from the first electrode;

d. configuring a trailing electrode in the housing at least partially downstream from the second electrode; and

e. coupling a voltage generator electrically to the first electrode, the second electrode and the trailing electrode, wherein the trailing electrode has the same polarity as the second electrode and is operable to cause a generation of ions.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,695,690 B2
APPLICATION NO. : 10/074209
DATED : April 13, 2010
INVENTOR(S) : Charles E. Taylor and Jim L. Lee

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title page, in the Related U.S. Application Data section after the paragraph numbered "(63)" please insert the following:

--(60) Provisional application No. 60/341,090, filed on Dec. 13, 2001, and provisional application No. 60/306,479, filed on Jul. 18, 2001.--

In column 2, line 38, please replace "maybe" with --may be--;

In column 3, line 46, please replace "maybe" with --may be--;
line 48, please replace "electrodes" with --electrode--;
line 67, please replace "are" with --is--;

In column 4, line 4, please replace "electrode" with --electrodes--;
line 10, please replace "claim" with --claims--;

In column 5, line 34, please replace "front located" with --front-located--;
line 45, please add --than-- after "other";
line 65, please delete the "," after "100";

In column 6, line 33, please replace "particulates" with --particulate--;
line 35, please replace "maybe" with --may be--;
line 36, please replace "reduces" with --reduce--;
line 42, please replace "or-elliptically shaped" with --or elliptically-shaped--;

In column 7, line 14, please insert --,-- after "190";
line 36, please replace "maybe" with --may be--;
line 44, please replace "maybe" with --may be--;
line 66, please replace "flowrate" with --flow rate--;

Signed and Sealed this
Twenty-ninth Day of March, 2011

David J. Kappos
Director of the United States Patent and Trademark Office

In column 8, line 11, please replace "systems" with --unit--;
line 29, please insert --and-- before "yet";

In column 10, line 55, please replace "maybe" with --may be--;

In column 11, line 18, please replace "electrodes" with --electrode--;
line 25, please replace "surface" with --surfaces--;
line 67, please replace "maybe" with --may be--;

In column 13, line 1, please replace "electrodes" with --electrode--;
line 2, please replace "are" with --is--;
line 18, please replace "believe" with --believed--;
line 32, please replace "maybe" with --may be--;
line 61, please replace "Byway" with --By way--;

In column 14, line 5, please replace "maybe" with --may be--;
line 22, please replace "side walls" with --sidewalls--;
line 23, please replace "side walls" with --sidewalls--;
line 24, please replace "side walls" with --sidewalls--;
line 25, please replace "side walls" with --sidewalls--;
line 39, following "for" please insert --the--;

In column 15, line 14, please replace "maybe" with --may be--;

In column 16, line 39, please replace "Byway" with --By way--;

In column 17, line 49, please insert --,-- following "disc";
line 66, please delete "a" before "reduced";

In column 18, line 25, please replace "where upon" with --whereupon--;
line 46, please replace "teardrops shaped" with --teardrop-shaped--;
line 66, please delete "," following "on";

In column 19, line 42, please replace "242-2,242-3" with --242-2, 242-3--;

In column 20, line 5, please replace "maybe" with --may be--;
line 25, please replace "by" with --be--;
line 44, please replace "maybe" with --may be--;

In column 21, line 36, please delete "," following "order" and insert --,-- following "of";
line 60, please replace "electrode" with --electrodes--;

In column 22, line 52, please replace "Byway" with --By way--;

In column 23, line 9, please replace “it self” with --itself--;
line 17, please replace “maybe” with --may be--;
line 24, please replace “maybe” with --may be--;

In column 25, in claim 31, line 19, please insert --of-- following “apparatus”;