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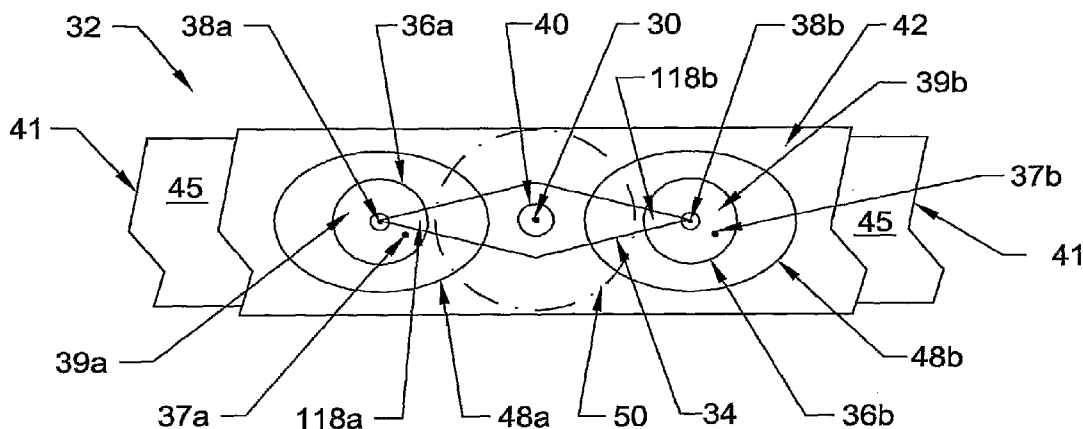
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(54) Title: AIR ASSIST FOR AC IONIZERS



(57) Abstract: At least one orifice is added to an AC ionizer with nozzles and ionizing electrodes that are used to remove static charge. The orifice is placed in a location where electrostatic forces are weak and where gas ions can be easily extracted from the ionizer. Ionizer effectiveness is enhanced by recovering gas ions that are normally trapped between the nozzles and under a portion of the ionizer from which the nozzles project. Without the orifice properly positioned, the trapped gas ions are lost by recombination or grounding. With the orifice positioned in an area of weak electrostatic forces, more gas ions are available for discharging the charged object. The combined air consumption of nozzles plus at least one orifice is the same or less than nozzles alone would consume for a given discharge time.

## TITLE OF THE INVENTION

**Air Assist for AC Ionizers**

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. non-provisional application 11/539,610,  
5 filed October 6, 2006, which claims the benefit of U.S. provisional application 60/726,874  
filed October 13, 2005 and entitled "Orifice Assist for Ionizers with Airflow Nozzles", and  
U.S. provisional application 60/778,755, filed March 03, 2006 and entitled "Fringe Field Ion  
Extraction for Ionization Systems".

## BACKGROUND OF THE INVENTION

10 Field of the Invention

The present invention relates to an alternating current (AC) ionizer that removes or  
minimizes static charge from a charged object selected for static charge removal. More  
particularly, the present invention relates to an AC ionizer that uses at least one flowing gas to  
enhance the static neutralization of the charged object.

15 Description of Related Art

It is generally known that AC ionizers, sometimes referred to as "AC static  
neutralizers", remove static charge by ionizing gas molecules, and delivering these ionized gas  
molecules, named gas ions, to a charged object. These gas ions are typically created by  
applying a high voltage to ionizing electrodes, by releasing nuclear sub-atomic particles, or by  
20 ionizing photon radiation. The location in which these gas ions are created is referred to as an  
ionizing source. Positive gas ions neutralize negative static charges, and negative gas ions  
neutralize positive static charges.

Delivering gas ions to a charged object is a factor in the static charge removal effectiveness of an AC ionizer because only the gas ions that reach the charged object produce useful charge removal, hereinafter “useful gas ions”. Static charge removal is also sometimes referred to as “static charge neutralization”. There are two at least two mechanisms  
5 responsible for gas ion loss: recombination and grounding. Both recombination and grounding losses are more probable when gas ions are held to the ionizer by strong electrostatic forces.

One approach for reducing the effects of recombination and grounding includes using at least one nozzle with flowing air or gas with an AC ionizer, such as described in U.S. Patent 6,807,044. Recombination is minimized because the flowing gas exiting a nozzle dilutes the  
10 gas ions before the positive ions and negative ions are mixed. Upon mixing, the lower gas ion density results in a lower recombination rate. In addition, the flowing gas from the nozzle propels the gas ions toward a charged object targeted for neutralization, which reduces the transport time and conserves the ions. Additionally, a nozzle can be oriented to direct generated gas ions toward the charged object, reducing the number of gas ions lost from  
15 grounding. Finally, some air nozzle geometries protect the ionizing electrodes from impurities in the environment.

For example, one type of AC ionizer places an ionizing electrode inside a nozzle. High purity air, nitrogen, or other non-reactive gas flows through each nozzle and along the ionizing electrode. This combination of nozzle and flowing gas partially protects the ionizing electrode  
20 from impurities in the environment, which reduces the cleaning frequency of ionizing electrodes, reducing the cost of maintenance and ownership. Moreover, ion balance is maximized because less buildup occurs on the ionizing electrode tips.

Although combining nozzles with an AC ionizer enhances the neutralization efficiency

of the AC ionizer, nozzles alone miss the opportunity for even better AC ionizer performance. Consequently, a need exists for enhancing the performance of an AC static neutralizer that employs at least one nozzle.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a bottom view of a portion of an AC ionizer that utilizes nozzles.

FIG. 2 is a bottom view of another portion of an AC ionizer that utilizes nozzles.

FIG. 3 is a bottom view diagram of electrostatic field lines between an ionizing  
5 electrode and nearby non-ionizing electrode having a circular edge and a reference potential,  
such as ground.

FIG. 4 shows a graph which illustrates the relationship between electrostatic field force  
on gas Ion gas ion and the distance from the source of the electrostatic field

FIG. 5 is a bottom view diagram illustrating portion of an AC ionizer that uses nozzles  
10 and an orifice disposed within a placement zone in accordance with an embodiment of the  
present invention.

FIG. 6 is a graph showing the effect of locating orifices in a weak electrostatic field,  
including the effect of reducing the number of ionizing electrodes required.

FIG. 7 is a bottom view diagram illustrating a portion of an AC ionizer that employs  
15 nozzles, an orifice in a placement zone and a single non-ionizing electrode in accordance with  
another embodiment of the present invention.

FIG. 8 is a bottom view diagram illustrating an AC ionizer that employs nozzles,  
orifices in a placement zone and two non-ionizing electrodes in accordance with another  
embodiment of the present invention.

20 FIG. 9 shows lines and angles that define a placement zone in accordance with yet

another embodiment of the present invention.

Figure 10 is an isometric bottom view of a portion of an AC ionizer according to a further embodiment of the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

While the invention has been described in conjunction with a specific best mode, it is to be understood that many alternatives, modifications and variations will be apparent to those skilled in the art in light of the following description. The use of these alternatives, modifications and variations in or with the various embodiments of the invention shown below would not require undue experimentation or further invention.

The various embodiments of the present invention described herein are generally directed to the improvement of AC ionizers that utilize nozzles by adding at least one orifice within a placement zone between adjacent ionizing electrodes. Although AC ionizers that utilize nozzles are known, such as the AC ionizer disclosed in U.S. patent 6,807,044, hereinafter the "Patent" and which is incorporated by reference as if fully set forth herein, it is not intended that the various embodiments of the present invention be limited to existing AC ionizer designs.

Although a gas is delivered through both nozzles and orifices, nozzles and orifices are different. The term "nozzle" includes a structure with a hollow inner portion. One example is a cylinder having an inner and outer diameter. An ionizing electrode is positioned within that hollow inner portion. Gas flows through that hollow inner portion, and past the ionizing electrode. The term "orifice" includes an opening through which air or gas may exit. An air orifice does not possess or contain an ionizing electrode.

The term "placement zone" is defined as the optimal location or area for placing at least one orifice between adjacent nozzles that are disposed on an AC ionizer and that each have an ionizing electrode contained generally within their inner portion. This placement zone area is

not an additional hardware structure. It is a geometrical projection onto the face or surface of a portion of an AC ionizer that contains nozzles. In accordance with one embodiment of the present invention, the placement zone has a shape in cross-section that is commonly referred to as a diamond shape.

5 AC ionizers differ from DC ionizers. With an AC ionizer, typically all ionizing electrodes are connected to the same voltage source. Unlike DC ionizers, the strongest attractive electrostatic field forces for AC ionizers are found between the ionizing electrodes and ground. And, unlike DC ionizers, electrostatic field forces between adjacent ionizing electrodes are repulsive. Gas ions produced by one ionizing electrode are repelled by an  
10 adjacent ionizing electrode because they have the same polarity. As a consequence, the optimal placement of orifices is different for an AC ionizer than it is for a DC ionizer, and gas ion delivery efficiency for AC ionizers can be improved by adding at least one orifice between adjacent nozzles that each contains an ionizing electrode.

For an AC ionizer, the placement zone between adjacent nozzles is particularly useful  
15 for two reasons. First, gas ions that would normally be lost to grounding are present in the placement zone in moderately high concentration. Recovery of these gas ions is functionally equivalent to creating more gas ions. Second, gas ions in the placement zone are not held tightly to the AC ionizer by strong electrostatic fields.

In addition, AC ionizer discharge times commonly achieved by using nozzles alone can  
20 be reduced by placing at least one orifice between adjacent ionizing electrodes within a placement zone. It has been further observed that this decrease in discharge times is achieved even when the total gas consumption from the nozzles and the orifice(s) does not exceed the consumption from the nozzles alone.

Referring now to the drawings, FIGS. 1 and 2 depict examples of AC ionizer portions 2a and 2b that use nozzles 4a and 4b and ionizing electrodes 6a and 6b, respectively. Gas ions are created by corona discharge when a high voltage is applied to ionizing electrodes 6a and 6b. In FIG. 1, gas enters nozzle 4a from a pressurized supply (not shown) through a jet 8 located besides ionizing electrode 6a, while in FIG. 2, gas enters nozzle 4b through a concentric opening 10. After exiting jet 8 or concentric opening 10, the gas flows around and past ionizing electrodes 6a or 6b, respectively.

The term "gas" is intended to include a gas or a combination of gases, such as air. This gas is supplied to nozzles 4a and 4b through tubing or through a common plenum, which is not shown to avoid overcomplicating FIGS 1 and 2.

Utilizing nozzles help protect ionizing electrodes from impurities since relatively pure or clean gas may be forced to flow past and generally along the ionizing electrode. Impurities from air within the operating environment of the ionizer are thus largely excluded from contacting the ionizing electrodes, minimizing particle buildup on the ionizing electrodes. Moreover, balance and discharge time remain constant for long time periods, and the frequency of cleaning is reduced.

Nozzles, such as nozzles 4a and 4b, also direct gas ions toward a charged object (not shown), reducing the gas ion density required for neutralizing the charged object. Also, the ion movement transit time to the object is reduced by the gas nozzle flow, which decreases ion recombination.

FIG. 3 illustrates a configuration of an ionizing electrode 12 within a nozzle 14 from an AC ionizer portion 16. Nozzle 14 receives gas from a plenum 15 and is disposed through a

cut-out 18 formed on a bottom surface 20. Plenum 15 provides a supply of pressurized gas or gases, such as air, to nozzle 14. Bottom surface 20 includes a conductive surface 22 that receives a reference potential, such as ground. When used in this manner, conductive surface 22 may be referred to as a non-ionizing electrode or as a reference electrode.

5           When conductive surface 22 is used as a reference electrode and when a sufficient voltage from a high voltage power supply (not shown) is applied to ionizing electrode 12, electrostatic field lines 24 originating at ionizing electrode 12 are grounded at the edge of the cut-out 18. Because electrostatic field lines 24 are strong in a region 26, gas exiting from jet 27 and flowing out of nozzle 14 is marginally effective for harvesting or displacing gas ions  
10 (not shown) created within region 26. Most of these gas ions will follow electrostatic field lines 24 to conductive surface 22, grounding gas ions that would have been useful for static charge neutralization, reducing the efficiency of the AC ionizer.

FIG. 4 includes a graph 28 that illustrates the relationship between the strength of electrostatic field forces and the distance from the source of the electrostatic field. Graph 28  
15 shows that electrostatic field forces on gas ion gas ion increase as the distance from an ionizing electrode decreases.

In accordance with one embodiment of the present invention, FIG. 5 illustrates the use of at least one orifice, such as orifice 30, in combination with an AC ionizer to enhance ionizer efficiency in harvesting gas ions for use in the static neutralization of a charged object (not  
20 shown). The embodiment shown includes orifice 30 disposed within a placement zone 34 that is located between adjacent nozzles 36a and 36b of AC ionizer portion 32. Nozzles 36a and 36b respectively include ionizing electrodes 38a and 38b disposed in their respective inner hollow portions 39a and 39b. Nozzles 36a and 36b utilize forced or compressed gas, which

exit from jets 37a and 37b, to harvest gas ions near or at the tips of ionizing electrodes 38a and 38b.

In the embodiment in FIG. 5, orifice 30 is nominally placed midway between ionizing electrodes 38a and 38b, which enables compressed gas exiting orifice 30 to harvest gas ions trapped under the electrostatic field generated when a high voltage is applied to ionizing electrodes 38a and 38b. Further, since orifice 30 and nozzles 36a and 36b each provide an exit from which the gas may flow, an optimal allocation of the gas is obtained, resulting in a relatively low gas ion discharge time. Orifice 30 is coupled to or form on a surface 45 of a plenum 41 and located within placement zone 34. A cut-out 40 is formed on conductive surface 42, permitting a pressurized gas to flow past conductive surface 42.

Nozzles 36a and 36b are also coupled to surface 45 of plenum 41. Cut-outs 48a and 48b are formed on conductive surface 42, permitting nozzles 36a and 36b to protrude past conductive surface 42. Conductive surface 42 is used as a non-ionizing electrode and when coupled to a reference voltage, such as ground, functions as a reference electrode. Conductive surface 42 may be located on the same side of AC ionizer portion 32 on which nozzles 36a and 36b are located. In the embodiment shown in FIG. 5, conductive surface 42 is composed of a thin relatively rigid material having electrically conductive properties, such as thin metal. The use of thin metal is not intended to be limiting. For example, conductive surface 42 may be composed of a non-metallic and electrically insulating material that has a conductive coating that faces in the same general direction as the gas flow provided by nozzles 36a and 36b.

The term "cut-out" is intended to be interpreted broadly and includes any hole or aperture that is formed on a surface, such as conductive surface 42, that will permit the use of a nozzle, an orifice or both in accordance with the embodiment described with reference to FIG.

5. Those of ordinary skill in the art after receiving the benefit of this disclosure would readily recognize that using a separate plenum and conductive surfaces, such as plenum and conductive surfaces 45 and 42, respectively, is not intended to limit the present invention. For example, a conductive plating material (not shown) may be formed on surface 45 of plenum

41. This conductive plating material would have voids that are similar in diameter and location as cut-outs 40 and 48.

Gas ions found between electrodes that receive the same polarity are not tightly held to AC ionizer portion 32. Orifice 30 permits gas to exit from it, providing a high velocity flow of gas that displaces gas ions within the vicinity of orifice 30 away from AC ionizer portion 32 and towards a charged object (not shown) selected for static neutralization. This discharge flow of gas from orifice 30 creates a low pressure area and entrains additional airflow within an air entrainment zone 50. Air entrainment zone 50 covers portions of cut-outs 48a and 48b and cut-out 40, where electrostatic fields created by ionizing electrodes 38 during operation are weak.

It is contemplated that orifice 30 and jets 37a and 37b have diameters of approximately within the range of 0.010 and 0.016 inches, providing a volume of gas discharge of approximately within the range of 0.5 and 5 liters per minute, respectively, when a supply of gas at a pressure approximately between 5 and 60 psi is provided in plenum 41. These ranges are not intended to be limiting and will vary depending on the physical characteristics and design of portion 32, including the diameters selected for the nozzle and orifices, number of nozzles and orifices used, and the like.

As shown in FIG. 6, a graph 52 illustrates that an AC ionizer having nozzles and ionizing electrodes configured with orifices in a manner similar to that described in FIG. 5 can

provide the same level of performance as an AC ionizer with roughly twice the number of nozzles and ionizing electrodes but without orifices. The values on graph 52 include measurements of time needed to reduce an electrical charge on a plate from a charge plate monitor from 1000V to 100V. These time measurements are obtained for each polarity and then averaged. Assuming all other factors constant, the ion discharge time achieved will be shorter than that of an AC ionizer that does not employ the improvement taught by the embodiment described in FIG. 5.

In accordance with another embodiment of the present invention, the embodiment disclosed in FIG. 5 may be further improved by using at least one non-ionizing electrode having the features described with reference to FIG. 7. FIG. 7 illustrates an AC ionizer portion 54 that includes at least two nozzles 56a and 56b with ionizing electrodes 58a and 58b and jets 59a and 59b, at least one orifice 60 located within a placement zone 62, and a non-ionizing electrode 66 that is used as a reference electrode. However, unlike the embodiment in FIG. 5, the example in FIG. 7 does not require cut-outs on a conductive surface since the conductive surface used as a non-ionizing electrode, such as non-ionizing electrode 66, is positioned approximately parallel to an imaginary line 68 that intersects ionizing electrodes 56a and 56b and consequently, does not impede the formation or placement of nozzles 56a and 56b and orifice 60 onto plenum surface 61. Plenum surface 61 is part of plenum 63, and plenum 63 functions as a channel or passage way through which a pressurized supply of gas may be routed to nozzles 56a and 56b and orifice 60.

Non-ionizing electrode 66 is intended to be used as a reference electrode and is thus, coupled to a reference voltage, such as ground. It is contemplated that non-ionizing electrode 66 has a shape approximately in the form of a strip. Those of ordinary skill in the art will

readily recognize that the aspect ratio of the strip-like shape of non-ionizing electrode 66 is not intended to be limiting. The shape of non-ionizing electrode 66 may vary as long as non-ionizing electrode 66 does not intersect line 68. Nozzles 56a and 56b, ionizing electrodes 58a and 58b, jets 59a and 59b, orifice 60, plenum surface 61, placement zone 62, and plenum 63 may have substantially the structure and function as nozzles 36a and 36b, ionizing electrodes 38a and 38b, jets 37a and 37b, orifice 30, orifice 30, plenum surface 45, placement zone 44 and plenum 41, respectively, in FIG. 5.

In accordance with yet another embodiment of the present invention and as disclosed in FIG. 8, the embodiment disclosed in FIG. 7 may be further improved by using at least two non-ionizing electrodes. FIG. 8 illustrates an AC ionizer portion 70 that includes at least two nozzles 70a and 70b with ionizing electrodes 72a and 72b and jets 73a and 73b, at least one orifice 74 located within a placement zone 76, two non-ionizing electrodes 80a and 80b that are used as reference electrodes, a plenum surface 77 and a plenum 78. Nozzles 70a and 70b, ionizing electrodes 72a and 72b, jets 73a and 73b, orifice 74, placement zone 76, plenum surface 77 and plenum 78 may respectively have substantially the same function and structure as nozzles 56a and 56b, ionizing electrodes 58a and 58b, jets 59a and 59b, orifice 60, placement zone 62, plenum surface 61 and plenum 63, disclosed in FIG. 7.

Non-ionizing electrodes 80a and 80b are each similar in function and in shape to non-ionizing reference electrode 66. Non-ionizing electrodes 80a and 80b are oriented so that they do not intersect an imaginary line 82 that intersects ionizing electrodes 72a and 72b. In addition, non-ionizing electrodes 80a and 80b are disposed on opposite sides of nozzles 70a and 70b, as shown.

The embodiments disclosed in FIGS. 7 and 8 achieve even less discharge time when

compared to the embodiment disclosed in FIG. 5. The embodiment in FIG. 8 takes advantage of weak field extraction of gas ions because no grounds exist between ionizing electrodes 72a and 72b, and the distances between ionizing electrodes 72a and 72 and an available reference potential, such as ground, provided by non-ionizing electrodes 80a and 80b are increased on average. Thus, proportionately more gas ions are bound with weak electrostatic forces using an AC ionizer modified according to the embodiment disclosed in FIG. 8. These gas ions are also be entrained by the action of the orifice(s) used, such as orifice 74. Further, the size of the non-ionizing electrodes that are used as reference electrodes, such as non-ionizing electrodes 80a and 80b, may be reduced which lowers overall capacitance and capacitance losses. One practical consequence of lower high voltage power losses is the capability to build AC ionizers with more ionizing electrodes without using larger power supplies.

With reference to FIG. 9, the term "placement zone", such as placement zone 85, may be defined as a location on an AC ionizer portion 83 that is defined by two first opposite corners 82a and 82b situated respectively between two adjacent ionizing electrodes 88a and 88b. Nozzles 84a and 84b have inner hollow portions 86a and 86b that contain all or part of ionizing electrodes 88a and 88b, respectively. Inner hollow portions 86a and 86b also house jets 87a and 87b, respectively. Nozzles 84a and 84b and ionizing electrodes 88a and 88b may have respectively the same function and structure as nozzles 36a and 36b and ionizing electrodes 38a and 38b disclosed in FIG. 5; nozzles 56a and 56b and ionizing electrodes 58a and 58b disclosed in FIG. 7; or nozzles 70a and 70b and ionizing electrodes 72a and 72b disclosed in FIG. 9. First opposite corners 82a and 82b respectively have first corner angles 90a and 90b that are less than or equal to 30 degrees. An imaginary straight line 92 drawn between ionizing electrodes contained within adjacent nozzles, such as ionizing electrodes 88a and 88b, bisects first corner angles 90a and 90b.

In addition, placement zone 85 may also be defined to include two second opposite corners 94a and 94b situated respectively between two adjacent ionizing electrodes, such as electrodes 88a and 88b. Second opposite corners 94a and 94b are formed by the intersection of lines 96a and 96b, and 97a and 97b, respectively. Lines 96a and 97a originate from first  
5 opposite corner 82a, while lines 96b and 97b originate from first opposite corner 82b. Second opposite corners 94a and 94b also include second corner angles 99a and 99b, respectively, which are each equal to or greater than 150 degrees. By using these descriptions with reference to FIG. 9, placement zone 85 may be said to be a geometric projection on AC ionizer portion 83 that has a “diamond-like” shape.

10 Referring now to FIG. 10, a portion 98 of an AC ionizer is shown with a placement zone 100 in accordance with yet another embodiment of the present invention. Portion 98 is part of an ionizing bar, sometimes referred to as a module, that has a plurality of nozzles containing ionizing electrodes, such as nozzles 102a and 102b and ionizing electrodes 104a and 104b, and modified to have a protrusion 114 having an orifice 106 placed within  
15 placement zone 100. Other orifices may be placed within other placement zones although in FIG. 10 only orifice 108 is shown to avoid overcomplicating the figure. Portion 98 also includes two reference electrodes 110a and 110b that each have a strip-like shape and that are orientated approximately parallel to imaginary line 112. Nozzles 102a and 102b, as well as protrusion 114 are coupled to plenum surface 116. The manner of coupling nozzles 102a and  
20 102b and protrusion 114 to plenum surface 116 is not intended to be limiting in any way. Plenum surface 116 is part of plenum 117. Nozzles 102a and 102b, ionizing electrodes 104a and 104b, orifice 106, reference electrodes 110a and 110b imaginary line 112 plenum surface 116 and plenum 117 may have approximately the same function as similarly named elements described previously above with respect to FIG. 7 or 8 above.

In accordance, with another embodiment of the present invention, the placement zones described in FIG. 5 and FIGS. 7 through 10 may be further modified by excluding sections of the placement zone that overlaps areas occupied by each nozzle and ionizing electrode.

Excluding these sections as part of the placement zone, avoids placing an orifice near a nozzle,

5 and hence, an ionizing electrode. For example, these excluded sections may include areas 118a and 118b, 120a and 120b, 122a and 122b, 124a and 124b and 126a and 126b in FIGS. 5 and 7 through 10, respectively.

As disclosed in the various embodiments of the present invention, placing an orifice, such as orifice 98, within placement zone 85 of an AC ionizer having nozzles and ionizing  
10 electrodes, such as nozzles 84a and 84b and ionizing electrodes 88a and 88b, reduces gas ion discharge times, enhances gas ion harvesting or both. However, placing an orifice within placement zone 85 or using a location that has a diamond-like shape is not intended to limit the scope of various embodiments disclosed herein. One of ordinary skill in the art would readily recognize that other locations or location shapes may be used to reduce discharge times and/or  
15 enhance gas ion harvesting through any or all of the following mechanisms.

The first mechanism is breakup of the turbulence in the vicinity of an AC ionizer portion that employs nozzles. Ions trapped in turbulence are vulnerable to recombination and grounding. Orifices prevent a stable turbulent vortex from forming beneath the ionizer portion, and propel gas ions within the vortex toward a charged object targeted for static charge  
20 removal.

The second mechanism is generation of supplemental air flow due to air entrainment (air amplification) by the high velocity air, which is delivered through the orifices. This supplemental air flow helps to remove gas ions which are trapped between the nozzles.

The third mechanism is weak electrostatic field gas ion extraction. The ionizing electrodes of an AC ionizer are connected to a common electrical bus with adjacent ionizing electrodes receiving the same polarity and voltage at any given time, which creates repellant electrostatic fields between adjacent ionizing electrodes, and the weakest electrostatic field is located between adjacent ionizing electrodes or between adjacent nozzles if such ionizing electrodes are placed within the adjacent nozzles. An orifice located between adjacent ionizing electrodes is optimally positioned for removing gas ions from the AC ionizer.

Gas from an orifice within a placement zone blows perpendicular to the electric field lines in the region of weakest electrostatic field constraint, and this gas has a high probability of removing gas ions that are constrained by an electrostatic field. The removed gas ions are, hence, available to remove static charge from the charged object.

The forth mechanism is relocation of high turbulence away from the tip of an ionizing electrode where the recombination rate is potentially the highest.

The fifth mechanism is redistribution of forced or compressed gas to achieve maximum ion output. As disclosed in the various embodiments of the present invention above, nozzles utilize forced or compressed gas to harvest gas ions near or at an ionizing electrode tip, while orifices utilize compressed gas to harvest gas ions trapped under the electrostatic field generated by the ion generation process. The optimal allocation of compressed gas results in a relatively low discharge time.

While the present invention has been described in particular embodiments, it should be appreciated that the present invention should not be construed as limited by such embodiments. Rather, the present invention should be construed according to the claims below.

## IN THE CLAIMS

We claim:

1. An AC ionizer for removing static charge from a charged object, said AC ionizer  
5 including:
  - at least two electrodes for receiving different electrical potential and including an  
ionizing electrode and a non-ionizing electrode;
  - at least one high voltage power supply connected to said electrodes;
  - at least one orifice;
  - 10 a placement zone located; and
  - wherein said orifice is located within said placement zone.
2. The AC ionizer of claim 1, wherein said non-ionizing electrode is located on the same  
side of the ionizer as the ionizing electrodes.
3. The AC ionizer of claim 1, further including a nozzle and wherein said non-ionizing  
15 electrode has cut-outs through which said nozzle is exposed.
4. The AC ionizer of claim 1, wherein said non-ionizing electrode has cut-outs through  
which said orifice is exposed.
5. The AC ionizer of claim 1, further including another ionizing electrode and wherein  
said non-ionizing electrode includes at least one conductive strip that is disposed in parallel  
20 with an line intersecting said ionizing electrodes.
6. The AC ionizer of claim 1, wherein said ionizing electrode is electrically connected to a  
high voltage output of said high voltage power supply.
7. The AC ionizer of claim 1, wherein said non-ionizing electrode is connected to  
electrical ground.
- 25 8. The AC ionizer of claim 1, wherein said non-ionizing electrode is connected to a

current controlling circuit.

9. The AC ionizer of claim 1, wherein said non-ionizing electrode is connected to a voltage controlling circuit.

10. The AC ionizer of claim 1, wherein said ionizing electrode is contained within said  
5 nozzle.

11. The AC ionizer of claim 1, wherein said ionizing electrode is contained within a nozzle and further including a pressurized supply for providing a compressed gas through said nozzle.

12. The AC ionizer of claim 1, wherein said gas also flows through said orifice.

13. The AC ionizer of claim 1, wherein said gas that flows through said nozzle is different  
10 from a gas that flows through said orifice.

14. The AC ionizer of claim 3, wherein said nozzle and said orifice have respective volumetric flow rates; and

wherein said volumetric flow rate of said nozzle is within  $\pm 10\%$  of said volumetric flow rate of said orifice.

15. The AC ionizer of claim 3, wherein said nozzle and said orifice have respective volumetric flow rates; and

wherein said volumetric flow rate of said nozzle differs more than  $\pm 10\%$  from said volumetric flow rate of said orifice.

16. The AC ionizer of claim 3, wherein said nozzle has a cross section perpendicular to an  
20 air stream formed when gas flows through said nozzle, said cross-section has a shape that includes any one of a polygon, a circle and an ellipse.

17. The AC ionizer of claim 14, wherein said flow of said gas inside said air nozzle is turbulent when passing said ionizing electrode.

18. The AC ionizer of claim 14, wherein said flow inside said nozzle is laminar when

passing said ionizing electrode.

19. The AC ionizer of claim 1, wherein said placement zone is defined by:

(a) two first opposite corners situated at two adjacent ionizing electrodes where

(1) a first corner angle of each said first opposite corner is less than or equal

to 30 or degrees, and

(2) a straight line between said two adjacent ionizing electrodes bisects said

first corner angles; and

(b) two second opposite corners situated between two adjacent ionizing electrodes

where

(1) said second opposite corners are formed by the intersection of lines which

originate from said first opposite corners, and

(2) a second corner angle for each said second opposite corner is equal to or

greater than 150 degrees.

20. The AC ionizer of claim 19, wherein said second opposite corners lie outside the

physical dimensions of the AC ionizer.

21. The AC ionizer of claim 1, further including another ionizing electrode and wherein

said placement zone has a diamond-like shape and is located between said ionizing electrodes.

22. An AC ionizer for removing static charge from a charged object using corona

discharge, the neutralizer comprising:

a plurality of ionizing electrodes;

nozzles disposed around each said ionizing electrodes; and

a plenum connected to said nozzles;

orifices disposed within a placement zone located between adjacent ionizing electrodes

and located on a side of the ionizer from which said ionizing electrodes are

disposed; and

a conductive surface for use as a non-ionizing electrode.

23. The AC ionizer of claim 22, wherein said placement zone is diamond-like shaped.

24. The AC ionizer of claim 22, wherein said placement zone includes:

5 two first opposite corners situated at two adjacent ionizing electrodes, wherein each  
said first opposite corner has a first corner angle of at least 30 degrees, and  
a straight line between said two adjacent ionizing electrodes bisects said first corner  
angles; and

two second opposite corners situated between two adjacent ionizing electrodes

10 wherein said second opposite corners are formed by the intersection of lines which  
originate from said first opposite corners, and

a second corner angle for each said second opposite corner is at least 150 degrees.

25. The AC ionizer of claim 22, wherein said non-ionizing electrode is disposed on the  
same side of the static ionizer from which said ionizing electrodes are disposed.

15 26. The AC ionizer of claim 22, wherein said non-ionizing electrode possesses cut-outs  
through which said nozzles are exposed.

27. The AC ionizer of claim 22, wherein said non-ionizing electrode possesses holes  
through which orifices deliver compressed gas.

28. The AC ionizer of claim 22, wherein said conductive surface has a shape of a strip.

20 29. The AC ionizer of claim 22, wherein said non-ionizing electrode comprises one or  
more conductive strips disposed parallel to a straight line which contains said plurality of  
ionizing electrodes.

30. A method of creating an AC ionizer, comprising:  
providing an alternating high voltage power source;

electrically coupling a first and a second ionizing electrode to said source;  
surrounding said first and second electrodes with a first and second nozzle,  
respectively;

using a conductive surface as a non-ionizing electrode;

5 coupling a source of pressurized air or gas to said first and second nozzles; and  
adding at least one orifice within a placement zone located between said first and  
second ionizing electrodes.

31 The method of claim 30, wherein said placement zone has a diamond-like shape.

32 The method of claim 30, wherein said first and second nozzles are disposed on the  
10 same side of the neutralizer from which said at least one orifice is disposed.

33 The method of claim 30, wherein said placement zone includes a first set of corners  
having equivalent angles, said first set including a first corner and a second corner.

34 The method of claim 33, further including disposing said first corner adjacent to said  
first nozzle.

15 35. The method of claim 34, further including disposing said second corner adjacent to said  
second nozzle.

36 The method of claim 33, further including disposing said first corner adjacent to said  
first electrode.

37. The method of claim 36, further including disposing said second corner adjacent to said  
20 second electrode.

38. The method of claim 30, further includes disposing said non-ionizing on a side of the  
ionizer from which said first ionizing electrode is disposed.

39. The method of claim 30, further includes forming a plurality of cut-outs on said non-  
ionizing electrode through which said first nozzle is exposed and through which said at least

one air orifice delivers a flow of gas.

40. An AC ionizer for removing static charge from a charged object, said ionizer including:

at least two nozzles;

at least two ionizing electrodes for receiving a voltage sufficient for ionization by

5 corona discharge, wherein respective portions of said ionizing electrodes are disposed with an inner portion of said nozzles;

a non-ionizing electrode for receiving a reference voltage;

at least one AC high voltage power supply for providing said voltage;

at least one orifice;

10 a placement zone located between said ionizing electrodes; and

wherein said orifice is located within said placement zone.

41. The AC ionizer of claim 40, further including a plenum coupled to said orifice and said nozzles.

42. The AC ionizer of claim 40, wherein said non-ionizing electrode is in the form of a  
15 conductive strip that is disposed in parallel with an imaginary line intersecting said two ionizing electrodes.

43. The AC ionizer of claim 40, wherein said placement zone includes two first opposite corners situated at said two ionizing electrodes, wherein a first corner angle of each said first opposite corner is less than or equal to 30 or degrees, and a straight line between said two  
20 ionizing electrodes bisects said first corner angles.

44. The AC ionizer of claim 43, wherein said placement zone further includes two second opposite corners situated between said two ionizing electrodes, wherein said second opposite corners are formed by the intersection of lines that originate from said first opposite corners, and a second corner angle for each said second opposite corner is equal to or greater than 150

degrees.

45. The AC ionizer of claim 40, wherein said placement zone has a diamond-like shape when projected onto a surface from which said two ionizing electrodes extend.

Figure 1

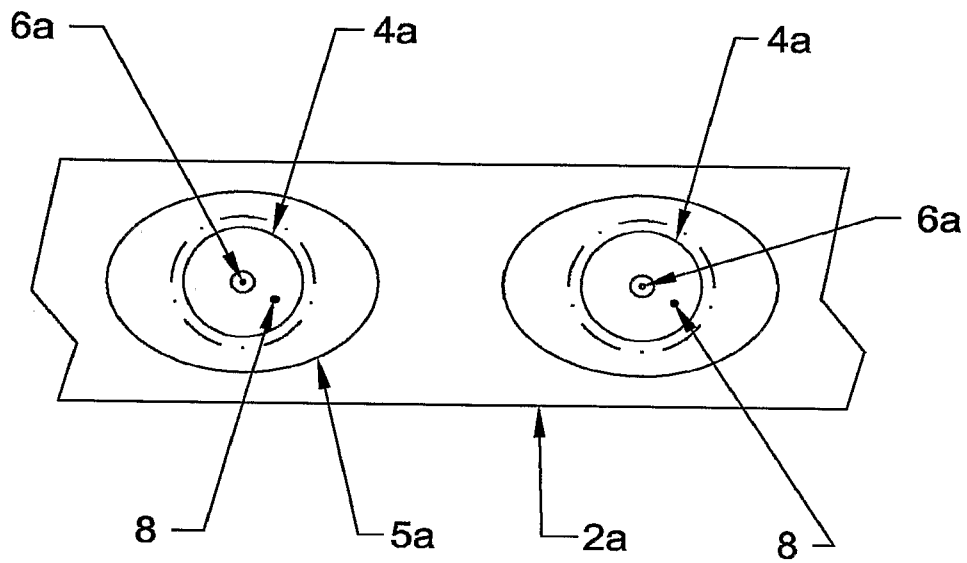
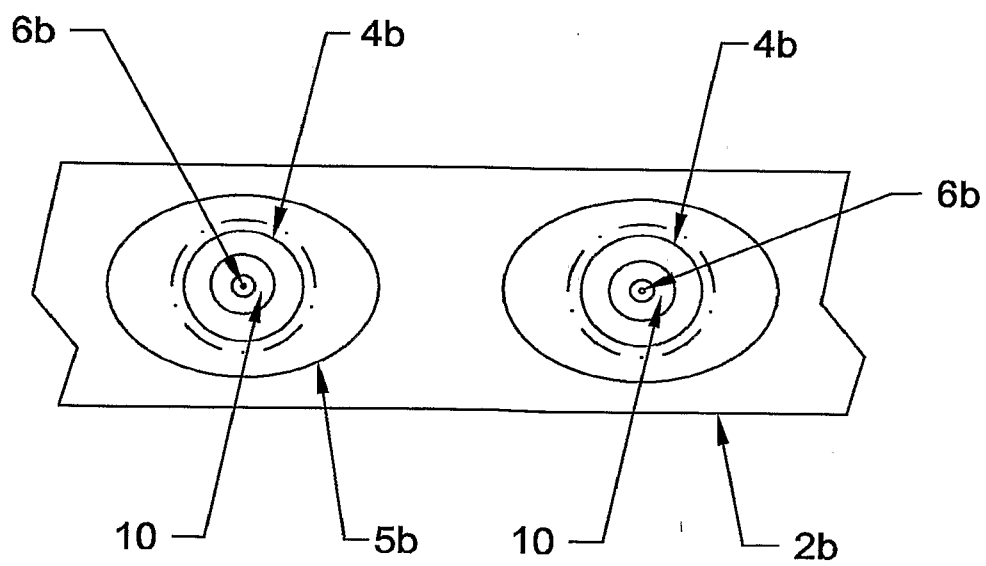
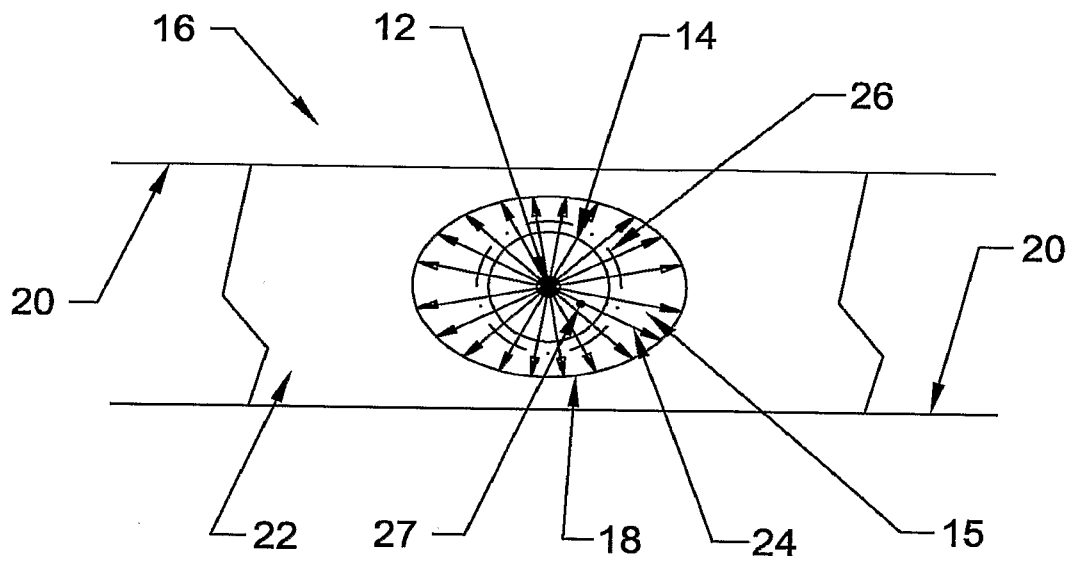
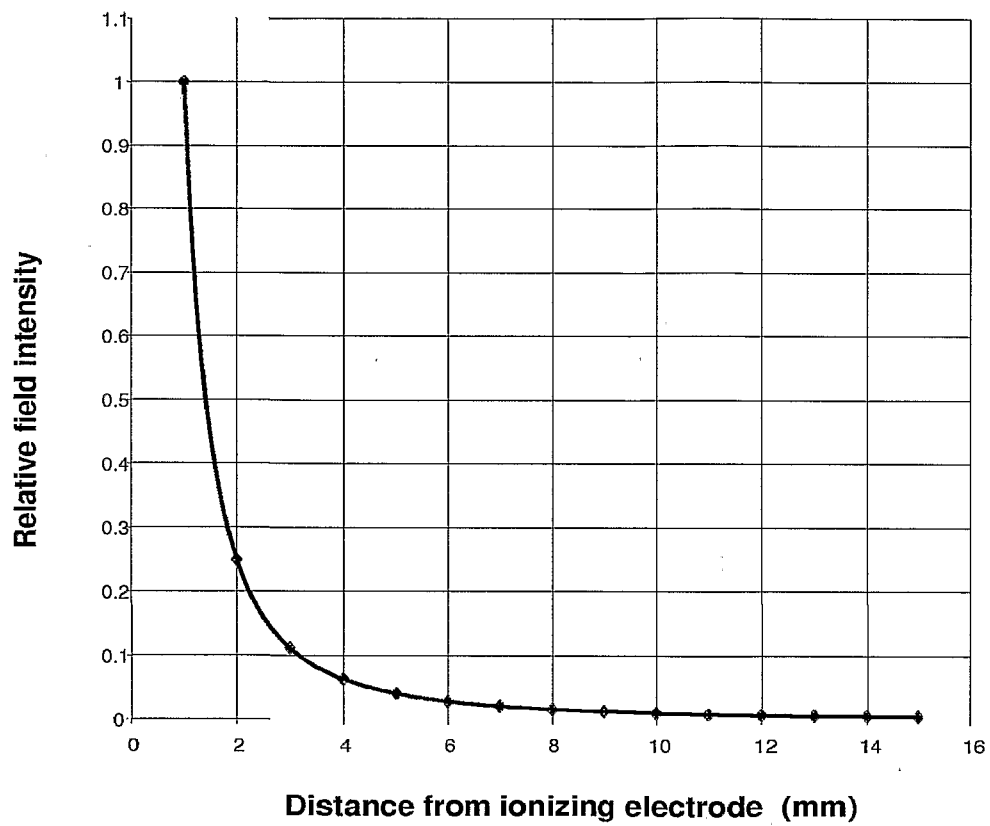


Figure 2



### Figure 3

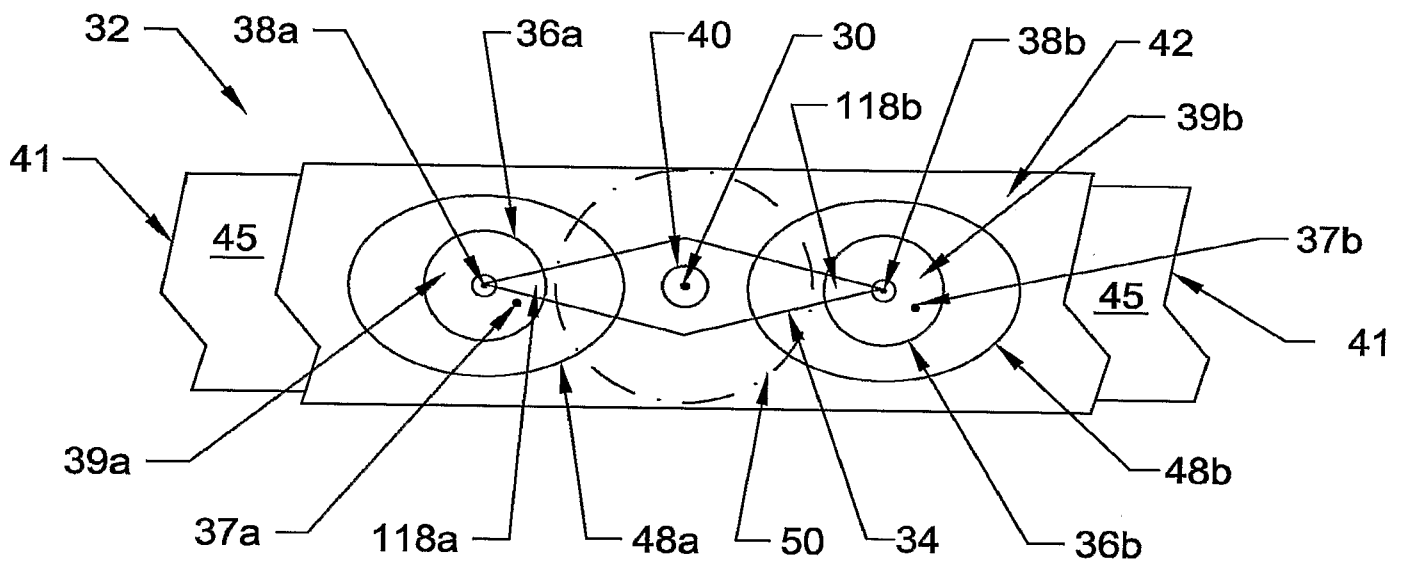




28 ↗

Figure 4

Figure 5



AC Ionizer with Nozzles and  
Ionizing Electrodes

vs.

AC Ionizer with Nozzles, Ionizing electrodes  
and Orifices disposed in placement zones.

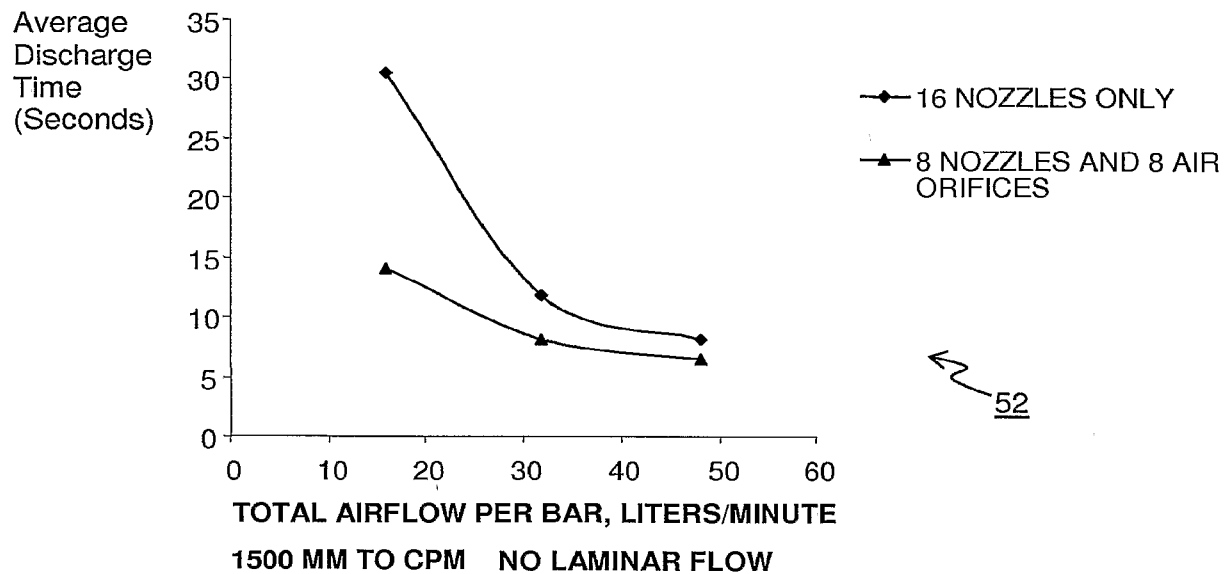


Figure 6

Figure 7

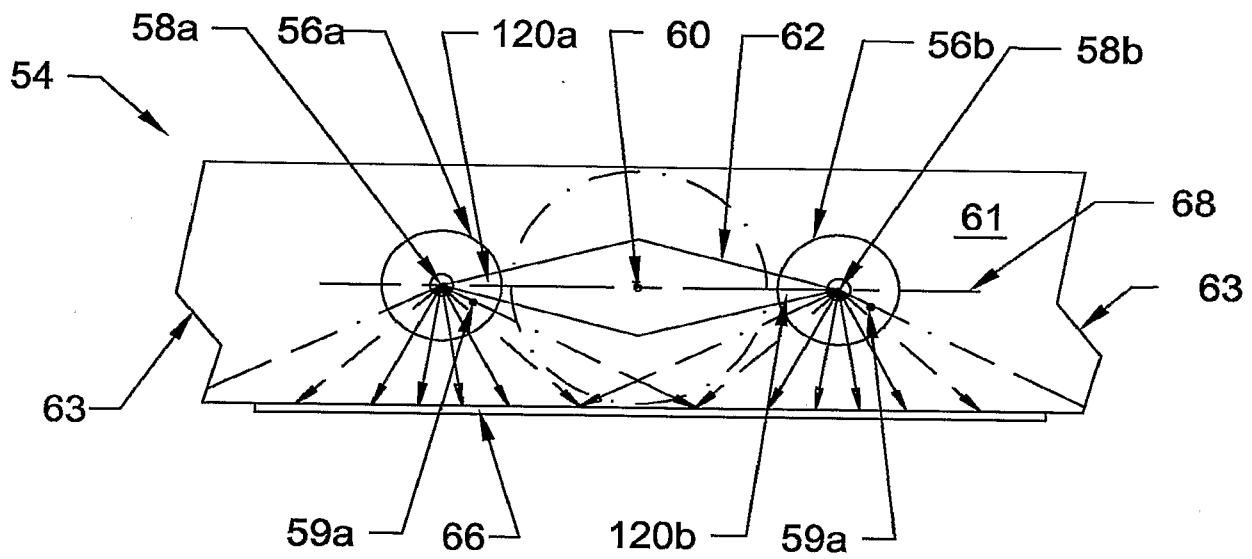


Figure 8

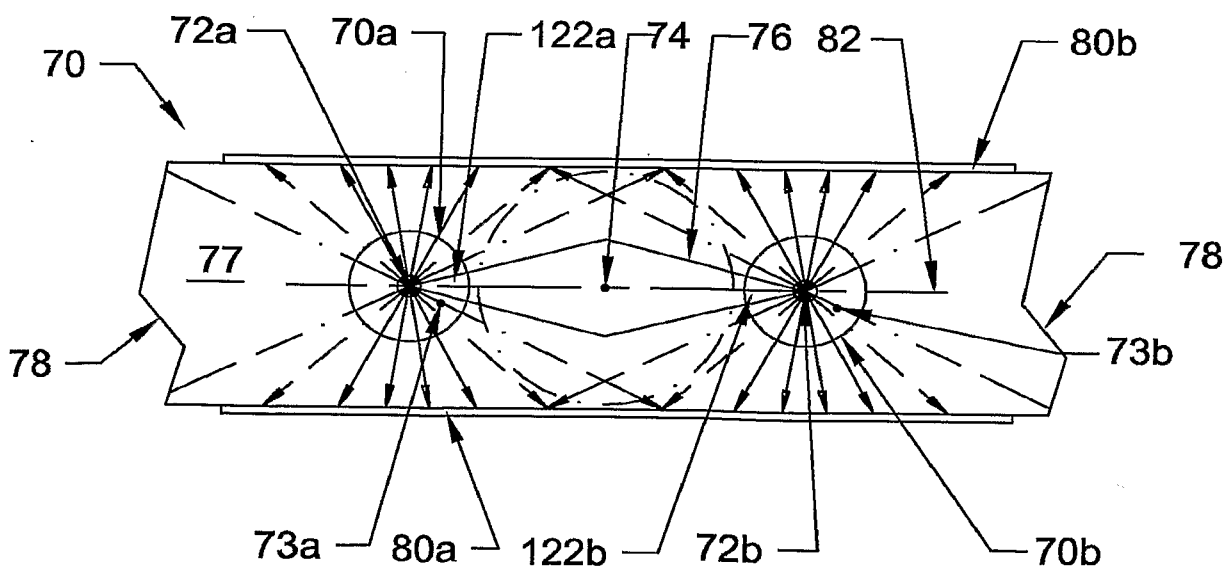
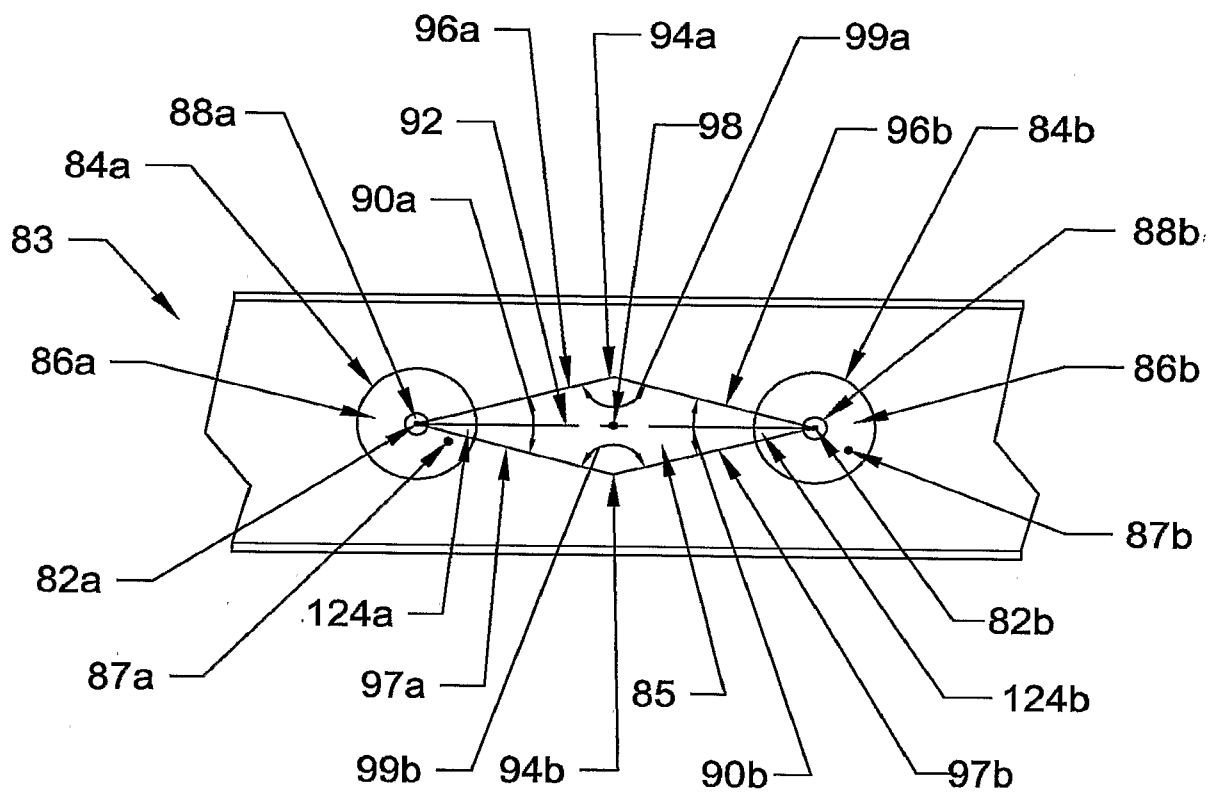


Figure 9



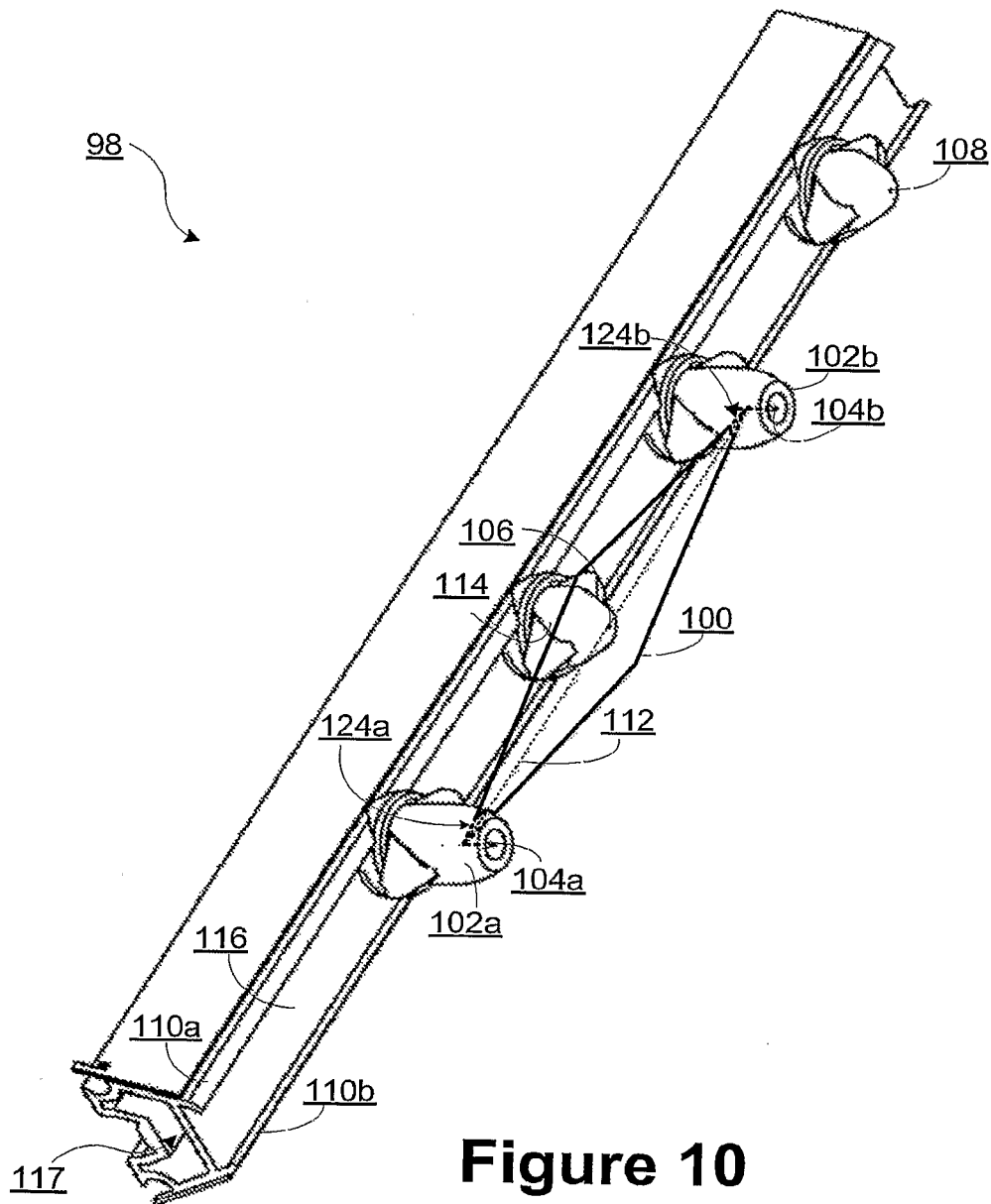


**Figure 10**