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(54) **Title:** SPACE HEATER WITH ELECTROSTATICALLY ASSISTED HEAT TRANSFER AND METHOD OF ASSISTING HEAT TRANSFER IN HEATING DEVICES

(57) **Abstract:** A space heater for heating air includes a duct for transporting air from an inlet to an outlet of the duct; a heating component; and an electrostatic discharge device within the duct for accelerating the gas through the duct from the inlet to the outlet. The electrostatic discharge device may include a high voltage power supply; at least one corona electrode connected to the high voltage power supply; and a collector electrode located proximate the corona electrode and connected to the high voltage power supply so as to induce a motion of the gas in a direction from the corona electrode toward the collector electrode.

TITLE OF THE INVENTION

SPACE HEATER WITH ELECTROSTATICALLY ASSISTED HEAT TRANSFER AND METHOD OF ASSISTING HEAT TRANSFER IN HEATING DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the priority of U.S. Provisional Patent Application Serial No. 60/863,946, filed November 1, 2006, entitled "Space Heater with Electrostatically Assisted Heat Transfer and Method ff Assisting Heat Transfer in Heating Devices", the entire disclosure of which is specifically incorporated herein in its entirety by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to heat distribution and, in particular, a heating apparatus including an electrical corona discharge device to enhance heat distribution and provide associated functionalities and corresponding method.

2. Description of the Related Art

Space heaters, such as electrically powered convection heaters, are designated for primary and supplemental heating of dwellings, offices, and other spaces. The heated air provided by the space heater provides the user with physical comfort. Unfortunately, a traditional space heater is not otherwise an efficient or very practical means for heating a home or other space. Existing space heaters have several disadvantages.

Space heaters are generally divided into two types. The first type is the so-called "radiator", which usually consist of a fluid-filled body having a large surface area which dissipates appreciable amounts of heat by radiation. The second type is the so-called "convector heater". Convection heaters typically include a housing, a heat source within the housing and a plurality of openings that allow air to convectively circulate through the housing and over the heat source. In an electrical convection heater, for example, the heat source may be a resistive heating element. In a storage heater, the primary heat source may again be a resistive heating element, but the primary source acts to heat a secondary heat source, usually in the form of a stack of bricks, in a charging mode. The secondary heat source releases heat to the convecting air when the heater is in a space heating mode. Convection heaters dissipate only very small quantities of heat by radiation.

Convection heaters are generally regarded as unsatisfactory as room heaters for a number of reasons. Firstly, because most of the heat is dissipated by convection, the tendency is for hot air from the heater to rise to and collect at the ceiling of the room. As time goes on, more and more hot air collects in the ceiling and progressively lower regions of the room heat up. However, since the heat transfer from the heater to the room is effected by heating the air as it passes over the heat source in the heater, this has the effect of gasifying any water vapor in the air, which then condenses on cool surfaces in the room. Consequently, the air collecting in the ceiling is rather dry and unpleasant to breath. Hitherto, there has been no real alternative to conventional convector heaters, apart from fan heaters, which are noisy.

Radiators, on the other hand, heat relatively little by convection and consequently do little to take the chill off the air. Rather, radiators tend to heat surfaces in the room facing the radiating surface. For a person sitting next to a radiator, this can result in one of his sides being warm and the other cold. In addition, radiators are relatively large compared with convector heaters, since the temperature to which the radiating surface can be heated is limited by safety considerations. They do, however, preserve the pleasant humidity of the air.

The only efficient way of air heating is therefore the use of fan heaters. These heaters are noisy and produce an air stream that is pulsating due to the action of the fan blades. Both of these features detract from physical comfort and prevent people from enjoying all the benefits of a heated dwelling.

Further details of such devices may be found throughout the art and, for example, in the disclosures of the following U.S. Patents, each of which is incorporated by reference in its entirety herein:

Patent No.	Title
3,935,321	Accelerated Cooling Method
4,088,870	Portable Electrical Space Heater
5,610,366	High Performance Thermoelectric Materials And Methods Of Preparation
5,747,728	Advanced Thermoelectric Materials With Enhanced Crystal Lattice Structure And Methods Of Preparation
5,769,155	Electrohydrodynamic Enhancement Of Heat Transfer
5,769,943	Semiconductor Apparatus Utilizing Gradient Freeze And Liquid-Solid Techniques
6,037,536	TPV Fireplace Insert Or TPV Indoor Heating Stove
6,047,695	Fireplace Heat Exchanger
6,145,502	Dual Mode Of Operation Fireplaces For Operation In Vented Or Unvented Mode
6,156,099	Method And Apparatus For Self-Cleaning Dust Collection Electrode Of Electronic Dust Collector And Electronic Dust Collector Having Self-Cleaning Function And Air Conditioner With Electronic Dust Collector
6,167,196	Radiant Electric Heating Appliance
6,169,851	Space Heaters
6,227,194	Fireplace
6,237,587	Woodburning Fireplace Exhaust Catalytic Cleaner
6,393,718	Hand Held Hair Dryer
6,527,548	Self Powered Electric Generating Space Heater
6,543,698	Fireplace Make-Up Air Heat Exchange System
6,550,687	Heat Exchange System
6,588,419	Fireplace Insert Thermally Generating Electrical Power Useful For Operating A Circulating Fan
6,615,612	Electrostatic Batch Preheater And Method Of Using The Same
6,648,750	Ventilation Assemblies
6,666,206	Fireplace Insert
6,729,551	Fireplace Make-Up Air Heat Exchange System
6,736,133	Air Filtration And Sterilization System For A Fireplace
6,742,516	Ventilation System And Method
6,755,138	Ventilation System And Method
6,766,798	Supplemental Air Directing Extension Frame For A Fireplace
6,886,626	Chimney Heat Exchange System
6,908,039	Heat Exchange System
6,948,454	Airflow Apparatus
7,003,216	Space Heater

SUMMARY OF THE INVENTION

Embodiments of the invention further address the above detailed and other deficiencies of the prior art. For example, another deficiency of fan space heaters according to the prior art is the failure to provide air cleaning or disinfection. Still another deficiency is the failure of prior art devices to incorporate additional entertainment features such as music, sound effects, or soothing sounds and/or reduce unpleasant and/or unwanted sound such as produced by the burning wood or outside wind whistling in the chimney.

Thus, the present invention is directed to an apparatus and method for enhancing the efficiency of a space heater, incorporating an ionic gas propulsion mechanism, such as a corona discharge device, to transport ambient air through a heat exchanger. The heat exchanger is configured to warm the ambient air using both heat energy produced by a heat source such as electrical heating, burning action (e.g., combustion), chemical reaction, hot by-product utilization or otherwise. Embodiments of the invention further include air scrubber functions for collecting particulates present in the air including biohazardous pollution. Further embodiments include audio modulation of the air to produce sound, such as music or simulated natural noise, and/or cancel or attenuate undesirable sounds and noises.

The present invention includes embodiments in the form of a device for efficiently heating a room using a heating element such as an electric heating element of electrically heated wire filament. Such devices may include an airflow path having air intake or an inlet for receiving room air and an outlet to return the heated and otherwise processed air to the room or other surrounds. A duct connecting the inlet and outlet may have an internal heating element positioned within a midsection of the duct, the duct may surround the element from behind, and/or otherwise be positioned to transfer heat energy from the heating element to the room air contained within the duct. The inlet, outlet and duct collectively define or form an airflow path.

An Electrostatic Fluid Accelerator (EFA) may be mounted within the airflow path to force room air through the airflow path from the inlet to the outlet and through the duct. A high voltage power supply (HVPS) may be mounted at some distance from EFA and connected to the EFA. The EFA is located in the hot air flow while a HVPS is preferably located in comparatively cool area suitable for operation of the electronic circuitry. High voltage cable (or wire) may be used to connect the EFA to the HVPS. This cable may be located in a special conduit made of a thermally and/or electrically insulating sleeve material. The sleeve or conduit may run along the side of the duct clear of the heating element to provide a heat-protected path from the HVPS to the EFA for the cable.

The EFA may typically include at least two electrodes. One of the electrodes is a corona electrode, preferably in the form of a sharp needle or small diameter wire. The other electrode is a collecting electrode, preferably in the form of a larger diameter wire or other geometry that provides a larger size electrode than that of the corona electrode. Respective groups of each of the electrodes (e.g., an array of corona electrodes and an array of collecting electrodes) are located parallel to each other, spaced at a distance of from several millimeters to a couple of inches but preferably between ¼" and 4" and, more preferably, between 1" and 3".

The HVPS generates and supplies a high voltage between these electrodes that typically ranges between 8 and 20 kV or even as high as 60 kV. When the voltage applied to the corona electrode relative to the collecting electrode exceeds a so called corona onset voltage a corona discharge takes place in a region surrounding and extending a short distance from the corona electrode. The corona discharge causes an emission of air ions from the corona electrodes that are attracted to the collecting electrode by the electrostatic force existing between the electrodes due to the potential difference. While transiting from one electrode to the other the ions collide with neutrally charged ambient air molecules that are thereby accelerated toward the collecting electrode creating what is sometimes termed an ionic wind.

Aspects of the invention further address certain unwanted byproducts of the ionic wind generation process. For example, in addition to accelerating and moving air, corona discharge produces by-products, most noticeably ozone, a potential health hazard in high concentrations and prolonged exposures. The excessive production of ozone may limit ionic wind application to some extent.

One aspect of embodiments of the invention is based on ozone being a relatively unstable gas that, under proper conditions, readily converts to the oxygen. The rate of conversion depends on many factors among which air temperature is predominant. Accordingly, embodiments of the invention effectively incorporate an EFA device in applications involving heated and hot air or other gases and/or fluids wherein the inherent degradation of ozone back to atomic and/or molecular oxygen is supported and/or enhanced by a high temperature environment so as to reduce or eliminate any risk of ozone exposure. Embodiments of the current invention implement this natural method to enhance ozone decay to efficiently and silently move hot air into the house. Aspects of the invention accomplish this by propelling and transporting air through the duct while maintaining an ozonated portion of the air in hot area for some appropriate time period that may be greater than the normal dwell or latency period of the ozonated air absent structure and/or methods to increase ozone degradation and conversion to O_2 (molecular oxygen).

The time for degradation of ozone back to molecular oxygen necessarily depends on the temperature to which the ozone is heated. That is, the higher temperature used the shorter the time period required for complete ozone to oxygen conversion. For instance, at temperature higher than 250°C this time is about 0.1 of second. In contrast, at a temperature of about 200^0C, the time required for ozone to convert to oxygen is about 1 second. The high temperature time needed to destroy unwanted ozone has been experimentally found to include temperatures above 300^0C such that ozone is completely destroyed in 20-50 milliseconds.

Another important factor for efficient ozone to oxygen conversion is that all, i.e., the entire volume, of ozonated air (i.e., air that passed through the corona discharge area) should pass through hot area for considerable time. Therefore, the duct and EFA itself should be designed in the way to prevent or minimize air bypass via cooler areas that do not provide sufficient temperature to reconvert the ozone back to oxygen.

Another feature of embodiments of the invention adopts an increased spacing distance between the corona electrodes (i.e. corona wires) and the opposite (i.e., collecting) electrodes. This feature addresses the primary source of ozone generation. That is, a primary and possibly only significant source of the ozone generation is within and due to the plasma region immediately surrounding the corona wire or the corona ion emitting sharp edges. The distance from the corona electrodes to the collecting electrodes defines two important factors for the ozone minimization. First, when a relatively large spacing distance is implemented (e.g., 2-3"), an equivalent corona power may be achieved using an increased corona voltage and a decreased corona current wherein power is the vector product of the two. That is, that same air flow may be induced with a larger voltage and smaller current, i.e. with the same electrical power. However, since the ozone generation rate is directly proportional to the corona current, less ozone is generated when the current is minimized. At the same time, the larger spacing distance provides more time for the generated (or other) ozone to disintegrate / dissociate into molecular oxygen.

Another design feature implemented by embodiments of the invention involve the number (or proximity to each other) of the corona wires. If the corona wires are located close to each other they have a tendency to "shadow" the electric field and thus decrease the electric field strength to the wires that are surrounded with the wires on both sides. Due to this physical phenomenon, the inner corona wires emit less corona current than do the outermost corona wires. To prevent this unevenness or variation of the resulting electrostatic field the corona wires may be positioned / located, not one per the collecting electrode (as in the prior art), but at wider internals of, for example, one corona electrode (wire) per two collecting electrodes. Any other spacing between the corona wires that is wider (greater) than the distance between the collecting electrodes is also beneficial.

Outermost corona wires preferably do not emit any current to adjacent conductive walls of the space heater and/or air duct of the space heater. Therefore, these walls should be covered with electrically insulating material having a low polarization. This insulating material should be located from the outermost corona wires at a distance approximating one half that of the distance between the corona wires themselves.

Another feature of embodiments of the present invention addresses electrode corrosion and contamination that may occur over time. That is, the electrodes of an EFA are naturally contaminated from time to time depending on the amount, type and density of air contaminants present. Embodiments of the invention may incorporate one or both of two methods of electrode cleaning.

According to one method and configuration, both the electrodes and substrates supporting the electrodes are made of washable materials that can withstand cleaning using available appliances such as home and industrial dishwashers without sustaining any damage. This substrate may be designed in a way to prevent water accumulation in cavities and holes and/or to provide water drainage and removal so as to allow water to drip freely. A combination of waterproofing and drainage paths allows the substrate to dry completely in a short time.

According to another cleaning configuration and method, the electrodes and/or the substrate are constructed of inexpensive materials and are engineered to be readily and easily fabricated. In addition to the use of inexpensive materials, minimum weight of materials facilitates distribution and replacement of replacement electrode arrays such that dirty and/or contaminated electrodes and/or electrode arrays may be easily and cost effectively replaced with new electrodes.

In order to clean the air, i.e., reduce or eliminate airborne contaminants (e.g., dust, pollen, spores, airborne pathogens and germs, etc.), in air recirculated and delivered back into the room (house) it is preferable to add one more sets of the electrodes to the EFA structure, so-called repelling electrodes. This technique is further detailed and described in Applicant's U.S. Patent Application Publication No. 20050150384, now

U.S. Patent No. 7,150,780, entitled "Electrostatic Air Cleaning Device" incorporated herein in its entirety by reference. In such a three-electrode configuration as described therein at least three cables should go to the EFA from the HVPS via a special conduit or high voltage (HV) sleeves preventing HV cables from shorting to each other or to the conductive metal portions of the space heater or associated duct.

Another design consideration incorporated into various embodiments of the invention addresses shock hazards and provides protection from the high operating voltages used by the EFA and its arrays of corona and collecting (and any repelling) electrodes. Thus, it may be important to keep the electrodes that are closer to the room interior at some safe electrical potential, preferably at a ground potential, in order to prevent a potential electrical shock hazard through accidental contact with, for example, living creatures such as humans and pets. In embodiments wherein the EFA is located before the heating element, the outboard corona electrodes are preferably maintained at some ground potential while the collecting electrode (or array of collecting electrodes) should be energized to and maintained at some high electric potential while providing a safe distance between the collecting electrode and the heating element. Preferably the collecting electrode is maintained at some negative potential relative to the corona discharge electrode such that, with the corona electrode maintained at ground potential, the collecting electrode is energized with a negative high voltage. The preference of polarities is due to the fact that positive corona discharge emits much less ozone that negative corona discharge.

In a configuration wherein the EFA is located after the heating element, the collecting electrode should be maintained at or close to ground potential to eliminate or reduce any shock hazard from the outwardly facing electrodes. In this case, the internally located corona electrodes are energized with a positive high voltage so as to generate and produce a positive corona discharge.

Further embodiments provide additional features directed to reducing device and ambient noise and/or providing desirable audio while providing heated air comfort with the silent and efficient delivery of hot air in to the room. One such feature incorporates voltage modulation across the EFA electrodes in response to an audio signal so as to create acoustic sound. When voltage modulates with frequencies between 20 Hz and 20,000 Hz the air acceleration through EFA also accelerates with corresponding frequencies and creates corresponding acoustic waves and audible sound effects. This way music, soothing sounds, or other sonic or even subsonic and supersonic audio may be generated to thereby add one more benefit to the hot air delivery and air cleaning.

In order to gain easy access to the electrodes, the electrodes (e.g., corona and/or collecting electrodes mounted in a frame or cartridge) are mounted on a pivoting frame that opens by swinging down to some open angle. This angle is large enough to allow the cartridge o be readily removed and, at the same time, does not exceed some maximum rotation angle such that the cartridge is urged under it own weight to fall down under the gravity force. The corona frame may be mounted together with the collecting and repelling electrodes as a one whole. According to another embodiment, an array of corona electrodes may be implemented as a separate frame and separately removed and replaced from the space heater as needed.

It should be noted that the geometry, materials, circuit diagrams used for embodiments of the present invention are presented in further detail and disclosed in Applicant's prior U.S. patent applications and patents of Igor Krichtafovitch et al. including

Serial No.	Filing Date	Patent or Pub. No.	Title
09/419,720	October 14, 1999	6,504,308	Electrostatic Fluid Accelerator
10/175,947	June 21, 2002	6,664,741	Method Of And Apparatus For Electrostatic Fluid Acceleration Control OfA Fluid Flow
10/188,069	July 3, 2002	6,727,657	Electrostatic Fluid Accelerator For And A Method Of Controlling Fluid Flow
10/295,869	November 18, 2002	6,888,314	Electrostatic Fluid Accelerator
10/352,193	January 28, 2003	6,919,698	Electrostatic Fluid Accelerator For And Method Of Controlling A Fluid Flow
10/187,983	July 3, 2002	6,937,455	Spark Management Method And Device
10/735,302	December 15, 2003	6,963,479	Method Of And Apparatus For Electrostatic Fluid Acceleration Control OfA Fluid Flow

Serial No.	Filing Date	Patent or Pub. No.	Title
10/847,438	May 18, 2004	7,053,565	Electrostatic Fluid Accelerator For And A Method Of Controlling Fluid Flow
11/210,773	August 25, 2005	7,122,070	Method Of And Apparatus For Electrostatic Fluid Acceleration Control OfA Fluid Flow
10/806,473	March 23, 2004	20040217720	Electrostatic Fluid Accelerator For And A Method Of Controlling Fluid Flow
10/724,707	December 2, 2003	20050116166	Corona Discharge Electrode And Method Of Operating The Same
10/752,530	January 8, 2004	20050150384	Electrostatic Air Cleaning Device
11/046,711	February 1, 2005	20050151490	Electrostatic Fluid Accelerator For And Method Of Controlling A Fluid Flow
11/119,748	May 3, 2005	20050200289	Electrostatic Fluid Accelerator
11/214,066	August 30, 2005	20060055343	Spark Management Method And Device
11/347,565	February 6, 2006	20060226787	Electrostatic Fluid Accelerator For And Method Of Controlling A Fluid Flow

all of which are incorporated herein in their entireties by reference.

Additional features and functionality may be also included in the various embodiments of the current invention such as use of a thermostat to control the EFA so that it automatically operates to blow air only when a temperature of the air is sufficiently warm, i.e., to blow hot air not cold. The rate of airflow may also be controlled in response to heater power and output so as to maintain some desirable range or optimum temperature of the heated air returned to the room or other surrounds. Thus, an output from a temperature sensor may be used to control and/or regulate a "speed" of the EFA in response to air temperature (inside the duct and/or the room to be heated) such that, according to one mode of operation, the higher the air temperature, the greater the EFA speed to maintain a constant output air temperature. The temperature sensor or thermostat may be located near the heating element(s) or remotely, such as in the room or other space to be heated. In addition or as an alternative, a temperature sensor mounted to or forming part of the heater unit proper may include an infrared (IR) sensor to remotely detect room temperature, again so that the EFA operates to maintain a desired room temperature. In addition or as an alternative to detecting a thermal characteristic of the ambient or associated objects (e.g., air temperature), some other parameter might be monitored and used as a basis to adjust EFA operation. For example, a detector or sensor may be included to measure some quality of the air to determine if it is best to recirculate or exhaust outside. As a further example, if the ozone level is increasing within the room, the EFA decreases air flow to provide for an extended dwell time of air with a high ozone concentration in a high temperature portion of the heater so as to promote degradation of the ozone and its conversion back into oxygen. Other qualities and characteristics of the air or other samples might also be considered such as odors, dust, etc., that might dictate whether air is to be recirculated or ventilated.

As described, a feature of the present invention in reducing ozone concentration including that produced by the EFA and otherwise present in a space is produced by causing ozonated air to be directed through a "hot area" in order to destroy the ozone. The time period that the ozonated air should stay within this hot area should be sufficient to ensure that all or almost all ozone is destroyed. Therefore, the distance the outflow air should propagate through a heated area (i.e., "hot area length"), air velocity and hot area temperature should be selected to satisfy ozone destruction criteria. For example, if hot area temperature is 400°C air may need to spend less time in the area than if hot area temperature is 300°C. Thus, the higher the temperature in the hot area, the shorter in physical length the hot area need be or the higher the air velocity may be.

Another important requirement is that all or substantially all of the ozonated air should pass through high temperature area. That is there should be little or no leakage or bypass for the air other than through the hot area. Thus, a feature of the current invention includes a hot area that is designed to embrace substantially all airflow exhausted through an outlet of an EFA. This way all air passing through the hot area will be heated so as to attain a desirable high temperature such that substantially all ozone is destroyed. Still another important feature is that the hot area should have sufficient temperature to destroy ozone within its entire volume. If some portions of the hot area are not maintained at a sufficiently high temperature then air that passes through this "cold" portion will still include some non-destroyed ozone. Thus, an important feature of the hot area design is that it provides what may be characterized as a "hot curtain" having a sufficient path length to keep air within this curtain for a time period sufficient to destroy ozone and reduce a level of any residual ozone to a required safe level.

There are several preferable basic configurations for locating and positioning the heating component to provide the requisite hot area. A first concern is determining where the heating components (i.e., filament heater spiral) are to be located downstream from the EFA (see, e.g., Figure 2). In this configuration accelerated air containing some amount of ozone passes through the heated area for a time "t" that depends on the physical length "s" of the hot area and the velocity "v" of the air through the hot area where t = s/v.

Another configuration is shown in the Figure 1 wherein the heating components are located in-between fins of the accelerating electrodes. The heating components heat air in substantially the entire area occupied with the accelerating fins. Since the entire length of the accelerating fins (in the direction of air movement) is hot, ozone is rapidly destroyed in this area and ozone free air is discharged and exits from the device exhaust.

Still another configuration is shown in the Figure 3. As shown, the heating components are electrically isolated from the accelerating electrode's fins. These heating components are provided with an electrical potential that is different from the electrical potential of the accelerating electrodes' fins. Such a device has an improved air cleaning ability since all charged particles entering the area between the accelerating electrodes and heating components subject to the influence of the electric field created by the potential difference between the collecting electrode's fins and the heating components.

According to one aspect of the invention, a space heater for heating air includes a duct for transporting air from an inlet to an outlet of the duct; a heating component; and an electrostatic discharge device within the duct for accelerating the gas through the duct from the inlet to the outlet.

According to a feature of the invention, the electrostatic discharge device may include a high voltage power supply; at least one corona electrode connected to the high voltage power supply; and a collector electrode located proximate the corona electrode and connected to the high voltage power supply so as to induce a motion of the gas in a direction from the corona electrode toward the collector electrode.

According to another feature of the invention, corona electrode may include a wire-like conductive member; and the collector electrode may include a conductive member having a smallest dimension at least 10 times greater than a diameter of the corona wire, the corona wire and the collecting members having major dimensions oriented substantially parallel to each other.

According to another feature of the invention the electrostatic discharge device may further comprise at least one repelling electrode.

According to another feature of the invention the high voltage power supply is connected to the corona electrode with positive voltage potential with respect to the collecting electrode.

According to another feature of the invention the high voltage power supply is connected to the repelling electrode with positive voltage potential with respect to the collecting electrode.

According to another feature of the invention the electrostatic discharge device includes a modulator connected to vary an output from the high voltage power supply so as to control the acceleration of the gas in response to an audio signal.

According to another feature of the invention the electrostatic discharge device may include a plurality of the corona electrodes and a plurality of the collector electrodes and wherein a number of the corona electrodes is equal to a number of the collector electrodes plus-minus one. (Nw = Nc +1).

According to another feature of the invention a number of the corona wires is equal to a number of the collecting members divided by two plus-minus one. (Nw = Nc/2 +1).

According to another feature of the invention a distance from the corona wires to the collecting electrodes is more than twice that of a distance between immediately adjacent collecting electrodes.

According to another feature of the invention the electrostatic discharge device may include a plurality of the corona electrodes and a plurality of the collector electrodes, wall portions of the duct immediately proximate to outermost ones of the corona electrodes being covered with an insulating material. The insulating material may have a low polarization property.

According to another feature of the invention the electrostatic discharge device may include a plurality of the corona electrodes and a plurality of the collector electrodes, a distance from outermost ones of the corona electrodes to walls of the duct being about ½ of a distance between immediately adjacent ones of the corona electrodes.

According to another feature of the invention ones of the electrodes closest to an opening of the duct are maintained at an electrical potential close to a ground potential.

According to another feature of the invention the corona electrodes and/or collecting electrodes are mounted on and/or supported by a substrate that devoid of cavities capable of collecting or storing water. The substrate may comprise an inexpensive material such thin sheet and plastic and are easily removable from the duct.

According to another feature of the invention a front portion of the collecting electrode is hollow.

According to another feature of the invention at least a portion of the collecting electrode is made of or is covered by a hydrophobic material.

According to another feature of the invention a portion of the collecting electrode is configured to be heated to a temperature above IOOOC during an operation of the space heater. Heating may be accomplished by application of, for example, an electrical current.

According to another feature of the invention the heating component comprises a filament located downstream of (i.e., nearer the air exhaust or outlet of the duct than) the electrostatic discharging device.

According to another feature of the invention the heating component comprises a filament located upstream of (i.e., nearer the air intake or inlet portion of the duct than) the electrostatic discharging device.

According to another feature of the invention the heating component comprises a filament located between the collecting electrodes.

According to another feature of the invention the heating component comprises a filament that further functions as the repelling electrode.

According to another feature of the invention a space heater further includes a sensor of air conditions selected from the group of sensor consisting of air temperature sensors, moisture sensors, ozone sensors, gas content sensors, dirtiness sensors and wherein the space heater includes circuitry for regulating a power applied to the electrostatic discharge device in response to the air conditions.

According to another feature of the invention the space heater has a minimized area though which ozonated air may escape heated zones heated by the heating component and maximize time that ozonated air travels trough these hot zones.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic diagram of the space heater according to and embodiment of the present invention;

Fig. 2 is a schematic diagram of space heater according an alternate embodiment of the present invention;

Fig. 3 is a schematic diagram of space heater according still another embodiment of the present invention;

Fig. 4 is a block diagram of the electrical space heater according an embodiment of the present invention including various sensors;

Fig. 5 is a cross section of a space heater according to an embodiment of the invention with combined collecting electrodes and heating elements;

Fig. 6 is a block diagram of the electrical space heater according another embodiment of the present invention including multiple sensors;

Fig. 7 is a cross section of an EFA depicting preferred spacing and relationships between the positioning and numbers of electrodes; and

Fig. 8 is a schematic diagram of the electronics portions of a space heater according to an embodiment of the invention..

DETAILED DESCRIPTION

In the Fig. 1 the space heater 101 is shown schematically. Space heater 101 includes of the corona wire-like electrodes 102 (shown in cross section), collecting electrodes 103 each including a leading edge of front portion 104 and trailing or tail portions 105. Filament components 106 are located between the tail portions 105 of collecting electrodes 103.

The HVPS (not shown) supplies a high voltage potential difference between the corona wires 102 and the collecting electrodes 103. As a result of the corona discharge an airflow is induced in the direction shown by the arrow 107. It is important that the filament 106 is located in such a manner as to occupy all the area between collecting electrodes 103 to prevent ozonated air to escape hot zone, i.e. where the filament is located.

In the Fig. 2 space heater 201 is shown schematically including corona wire-like electrodes 202 (shown in cross section), the collecting electrodes 203, and the filament components 206 located downstream of collecting electrodes 203.

A HVPS (not shown) supplies a potential difference between the corona wires 202 and the collecting electrodes 203. As a result of the corona discharge an air flow is induced in the direction shown by the arrow 207. Filament 204 is preferably located in such a manner as to occupy substantially all the area where air travels to prevent ozonated air from bypassing and escaping the hot zone, i.e. where the filament is located.

In the Fig. 3 the space heater 301 includes of the corona wire-like electrodes 302 (shown in cross section), collecting electrodes 303, each collecting electrode including a front portion 304 and trailing or tail portion 305, and the electrical heating filament components 306 located between the tail portions 305 of collecting electrodes 303.

A HVPS (not shown) supplies a potential difference between the corona wires 302 and the collecting electrodes 303. The HVPS also supplies the potential difference between the collecting electrodes and the filament. As a result of the corona discharge an air flow is induced in the direction shown by the arrow 307. It is preferred that electrical heating filament 306 be located in such a manner as to occupy all the area between collecting electrodes 303 to prevent ozonated air from bypassing and escaping the heated or hot zone, i.e. the area in which the filament is located. The potential difference between the collecting electrodes 303 and filament 306 provides an additional electric force helping charged dust particles to settle on the collecting electrodes 303.

Figure 4 is a block diagram of the electrical space heater according an embodiment of the present invention that employs temperature sensor, although other types of the sensors may be used as detailed below. Space heater 401 includes JS relay 402, thermal cutoff switch 403, HVPS 404 connected to the EFA 405, the Heater (e.g.

filament), auxiliary power supply 407 powering microcontroller 408. Microcontroller 408 is activated /controlled by JS relay contacts 409 and is responsive to tilt switch 410 for removing power to heater 405 and HVPS 404 if space heater 401 were to fall, topple or otherwise be placed in a dangerous operating position. Sensor 411 represent any or a number of devices that may sample air conditions (e.g., air temperature) and supply data to a microprocessor such as microcontroller 408. Microcontroller 408, in response, controls and output of HVPS 404. Microcontroller 408 may also control an amount of power supplied to heater 406 to regulate space heater temperature.

Fig. 5 is a cross section of a space heater according to an embodiment wherein the collecting electrodes are at the same time heater filaments like those used in a space heater. Note that other types of heat sources may be used, such as chemicals inside the electrodes that release heat as a result of a chemical reaction or hot fluid flowing through a hollow body portion of the electrodes. Referring to Fig. 5 the space heater 501 may include housing or case 508, corona wire-like electrodes 502 (shown in cross section), collecting electrodes 503. Collecting electrodes 503 each include outer portions 509 and internal or inner portions 510. Inner portions 510 are electrically insulated from the outer portions 509. In addition, inner portions 510 may serve as electrically operated heating filaments that are heated by an additional power supply (not shown) in the same manner as a resistive heating spiral element of the space heater is heated.

A HVPS (not shown) supplies a high voltage potential difference between corona electrodes 502 and outer surface 509 of collecting electrodes 503 and, by the mean of the electrostatic force, generates an ionic wind in the direction shown by the arrow 507.

Fig. 6 is a schematic diagram of another embodiment of the invention providing for multiple sensors for detecting various conditions pertinent to the operation of the space heater. As shown, space heater 601 includes relay 402 for controlling heating and EFA power. Typically, relay 402 is controlled by micro controller 608 to energize the EFA and heater circuitry. Thermal cutoff (TCO) 403 is connected in series with relay 402 to interrupt power to the EFA and Heater 406 in an overheat condition. In the present embodiment, HVPS 604 includes modulator 619 for modulating the high voltage signal applied to EFA 405 in response to an audio signal so as to cause EFA 405 to produce an alternating or pulsating airflow and acoustic output. The present embodiment further includes a number of sensors 611- 618 for the monitoring of parameters, including air temperature sensor 611, humidity and/or moisture sensor 612, ozone detector 613, gas detector 614, dust or particulate sensor 615, CO2 sensor 616, Smoke Detector 617 and Sound Detector 618.

Fig. 7 is a cross section of the EFA according to an embodiment of the current invention. EFA 701 includes the corona wire-like electrodes 102 (3 are shown for ease of illustration only), collecting electrodes 703 with front leading edge portions and trailing or tail portions 704, 705 (7 collecting electrodes 703 are shown for ease of illustration and in view of the number of corona electrodes depicted) and repelling electrodes 719 (6 are shown, again for purposes of illustration in view in the present example). When the HVPS (not shown) applies a high voltage potential between corona electrodes 102 and the collecting electrodes 703, an ionic wind in a desired exhaust airflow direction 707 is generated. Corona wire 102 preferably has a diameter that is, at most, one-tenth (i.e., at least 10 times smaller) than that of a diameter or thickness of a leading or front portion of collecting electrodes 703.

Repelling electrodes 719 are located between collecting electrodes 703 (and, more preferably, between tail portions 705) and serve to enhance air filtration (e.g., collection of particulates entrained in the air) when a suitable electrical potential is applied between these two groups of the electrodes. It is additionally preferable that a spacing distance 721 between the corona electrodes 102 and the collecting electrodes 703 leading edge portions 704 be more than twice the spacing distance between immediately adjacent collecting electrodes 703. It also preferable that a spacing distance 722 between the corona electrodes 102 be greater than spacing distance 720 between immediately adjacent collecting electrodes 703. According to another embodiment of the invention, spacing distance 722 is about twice as large as spacing distance 720 between collecting electrodes 703.

The duct wall (not shown) is spaced apart and separated from corona wires 102 including intervening pieces of insulating materials 412 on the top and the bottom portion of the duct adjacent outermost ones of the corona electrodes. These pieces of the insulating material 723 are preferably located from the outermost corona wires 102 at the distance approximately equal to the half of the distance 722 between the wires themselves. Insulating material 723 may have a low polarization property to prevent undesirable and unpredictable electrical field distortion. Front leading edge portions 704 of collecting electrodes 703 may be hollow. Front leading edge portions 704 may also be covered with a conductive or semiconductive hydrophobic media and/or may be heated to a temperature sufficient to prevent water accumulation (e.g., greater than 100^0C). This heating is preferably performed using a suitable electrical current flowing though these leading edge portions 704 or induced on them. The corona 102, collecting 703, and repelling electrodes 719 are each supported on their respective ends by a support of frame keeping them in designated position, i.e. parallel to each other. These supports (not shown) are preferably made in the manner preventing water accumulation on them thus making the overall structure and separate parts dishwasher safe.

Fig. 8 is a diagram of an embodiment of the invention including an array of electrostatic accelerator electrodes comprising corona electrodes 102, collecting electrodes 803 and (optionally) repelling electrodes 719 located / mounted within a section of duct (shown in cross-section). Electrical insulation 723 may be positioned proximate the outermost corona electrodes 102 so as to cover nearby portions of the duct walls. Insulation 723 may have a low polarization property. Preferably, those electrodes adjacent to any human-accessible openings (e.g., an intake port or exhaust portion of the duct) are maintained at a safe ground potential. For example, if the electrostatic accelerator electrode array of Fig. 8 were located nearest an intake vent so that corona electrodes 102 might be accessible, then it would be preferable to maintain those electrodes at or near ground potential, i.e., connect HVPS 604 with the positive voltage at ground. Conversely, if positioned at an exhaust portion of the duct so that collecting electrodes 803 and/or repelling electrodes 719 might pose a shock hazard, those electrodes would be maintained at or near ground potential with corona electrodes 102, mounted further back within the duct, powered with a positive high voltage above ground potential.

A distance d_3 from the outermost corona electrodes 102 to adjacent walls of the duct is approximately one-half *(½)* a distance d_w (722) between adjacent corona wires 102. Electronics 825 includes a high voltage power supply (HVPS) 604 for supplying a suitable high voltage to the electrostatic accelerator electrode array via suitable wiring. A modulator 619 may be included to vary the power supplied to the electrostatic accelerator electrode array to produce an alternating, modulated airflow. The modulated airflow may produce a desired sound, be used to cancel undesirable noises, vibrations, etc. Controller 608 may be included to provide for mode and operating feature selection using, for example, control panel 826. Various detectors and sensors including, for example, temperature sensor 611, vibration sensor 827, CO_2 sensor 616, sound sensor 618 (e.g., a microphone), ozone sensor / detector 613, and smoke detector 617 may provide input signals to controller 617 used to control the operation of the EFA in response to those parameters.

While various embodiments and example of the present invention have been provided for purposes of illustration, other variations and alterations may be made. Fore example, the number and arrangement of electrodes may be varied.

It should be noted and understood that all publications, patents and patent applications mentioned in this specification are indicative of the level of skill in the art to which the invention pertains. All publications, patents and patent applications are herein incorporated by reference to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated by reference in its entirety.

What is claimed is:

1. A space heater for heating air, said space heater comprising:

a duct for transporting air from an inlet to an outlet of said duct;

a heating component; and

an electrostatic discharge device within said duct for accelerating said air through said duct from said inlet to said outlet.

2. The space heater of claim 1, wherein said heating component comprises a filament located downstream of said electrostatic discharging device.

3. The space heater of claim 1, wherein said heating component comprises a filament located upstream of said electrostatic discharging device.

4. The space heater of claim 1, including a minimized area though which ozonated air may escape heated zones heated by the heating component and maximize time that ozonated air travels trough these hot zones.

5. The space heater of claim 1, said electrostatic discharge device comprising:

a high voltage power supply;

at least one corona electrode connected to said high voltage power supply; and

a collector electrode located proximate said corona electrode and connected to said high voltage power supply so as to induce a motion of the air in a direction from said corona electrode toward said collector electrode.

6. The space heater of claim 5, wherein

said corona electrode comprises a wire-like conductive member; and

said collector electrode comprises a conductive member having a dimension at least 10 times greater than a diameter of said corona wire,

said corona wire and said collecting electrode having major dimensions oriented substantially parallel to each other.

7. The space heater of claim 6, further comprising a plurality of said corona electrodes and a plurality of said collector electrodes and wherein a number of the corona electrodes (Nw) is equal to a number of the collector electrodes (Nc) within plus-minus one (Nw = Nc±l).

8. The space heater of claim 6, wherein a number of the corona electrodes (Nw) is equal to a number of the collecting electrodes (Nc) divided by two within plus-minus one (Nw = Nc/2 ±l).

9. The space heater of claim 6, wherein a number of the corona wires is at least equal to a number of the collecting members divided by two minus one (Nw = Nc/2 - 1) but is no greater than said number of the collector electrodes plus one (Nw = Nc +1).

10. The space heater of claim 6, wherein a distance from the corona wires to the collecting electrodes is greater than twice that of a distance between immediately adjacent collecting electrodes.

11. The space heater of claim 6, further a plurality of said corona electrodes and a plurality of said collector electrodes, wall portions of said duct immediately proximate outermost ones of said corona electrodes being covered with an insulating material.

12. The space heater of claim 11, wherein said insulating material has a low polarization property.

13. The space heater of claim 6 further comprising a plurality of said corona electrodes and a plurality of said collector electrodes, a distance from outermost ones of said corona electrodes to walls of said duct being about ½ of a distance between immediately adjacent ones of said corona electrodes.

14. The space heater of claim 5, further comprising at least one repelling electrode.

15. The space heater of claim 14 wherein said heating component comprises a filament that further functions as said repelling electrode.

16. The space heater of claim 5, wherein said high voltage power supply is connected to the corona electrode with positive voltage potential with respect to the collecting electrode.

17. The space heater of claim 5, where said high voltage power supply is connected to the repelling electrode with positive voltage potential with respect to the collecting electrode.

18. The space heater of claim 5, wherein said electrostatic discharge device includes a modulator connected to vary an output from said high voltage power supply so as to control said acceleration of said air in response to an audio signal.

19. The space heater of claim 5, wherein ones of said electrodes closest to an opening of said duct are maintained at an electrical potential close to a ground potential.

20. The space heater of claim 5, further comprising a substrate on which at least one of said electrodes is supported and wherein said substrate is devoid of cavities capable of collecting or storing water.

21. The space heater of claim 5, wherein said electrodes and a substrate on which said electrodes are mounted comprise an inexpensive material such as thin sheet and plastic and are easily removable from the duct.

22. The space heater of claim 5, wherein a front portion of said collecting electrode is hollow.

23. The space heater of claim 5, wherein at least a portion of said collecting electrode is made of or is covered by a hydrophobic material.

24. The space heater of claim 5, wherein a portion of said collecting electrode is configured to be heated to a temperature above 100^0C during an operation of said space heater.

25. The space heater of claim 24, wherein said collecting electrode is heated with an electrical current.

26. The space heater of claim 5, further comprising a plurality of said corona electrodes and a plurality of said collector electrodes and wherein said heating component comprises a filament located between said collecting electrodes.

27. The space heater of claim 5 wherein said heating component comprises a filament that further functions as said repelling electrode.

28. The space heater of claim 5, further comprising a sensor of air conditions selected from the group of sensor consisting of air temperature sensors, moisture sensors, ozone sensors, gas content sensors, dirtiness sensors and wherein said space heater includes circuitry for regulating a power applied to said electrostatic discharge device in response to said air conditions.

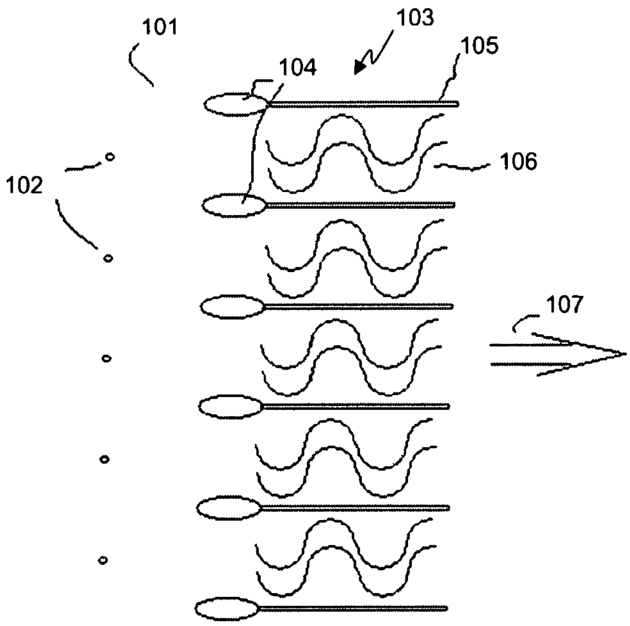


Fig. 1

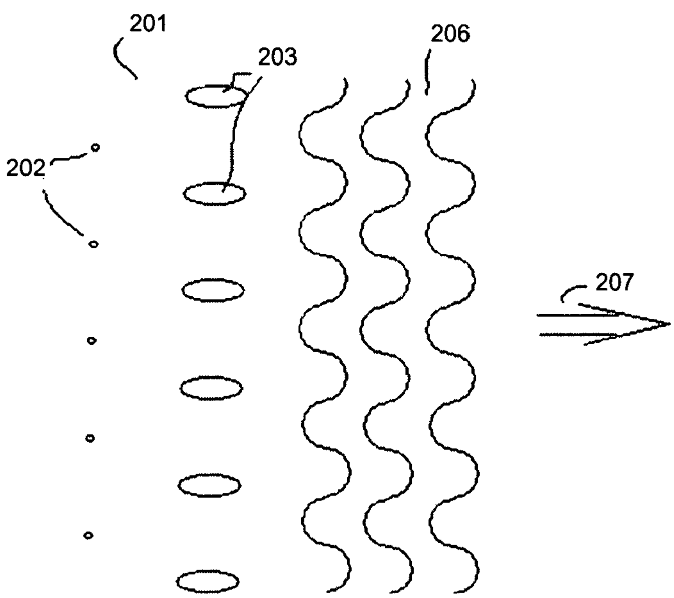


Fig. 2

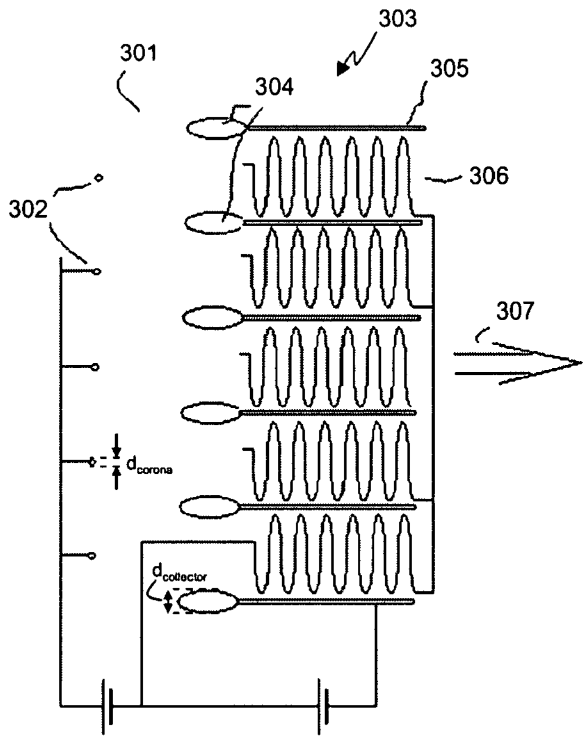
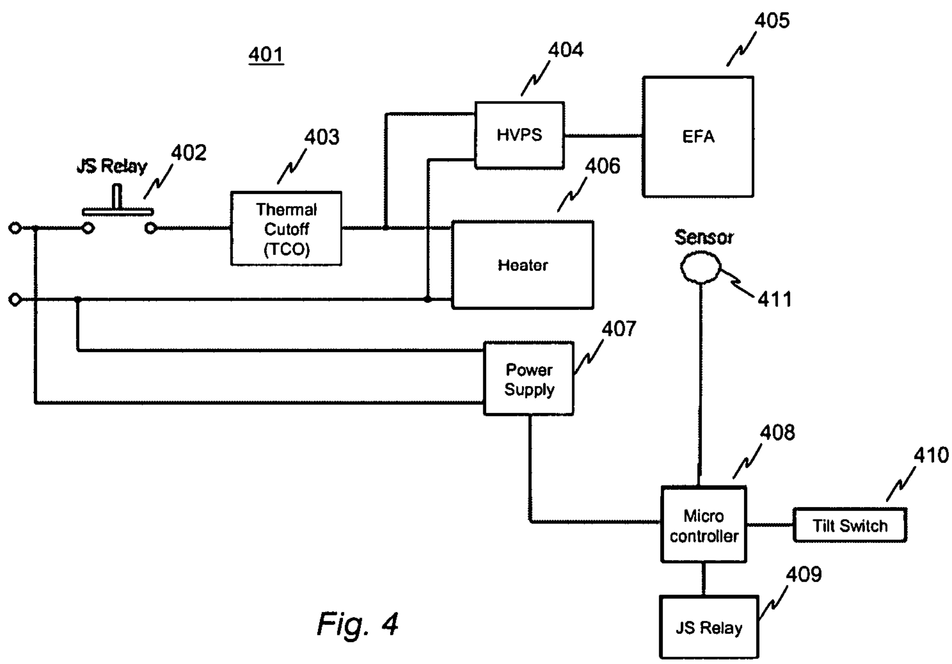

301
302
303
304
305
306
307
d_{corona}
$d_{collector}$

Fig. 3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402
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403
HVPS
404
EFA
405
Heater
406
Power Supply
407
Micro controller
408
JS Relay
409
Tilt Switch
410
Sensor
411

Fig. 4

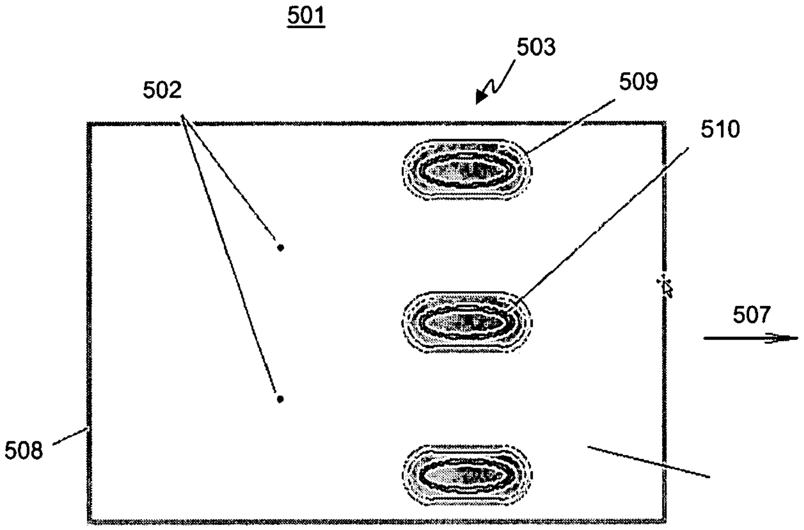
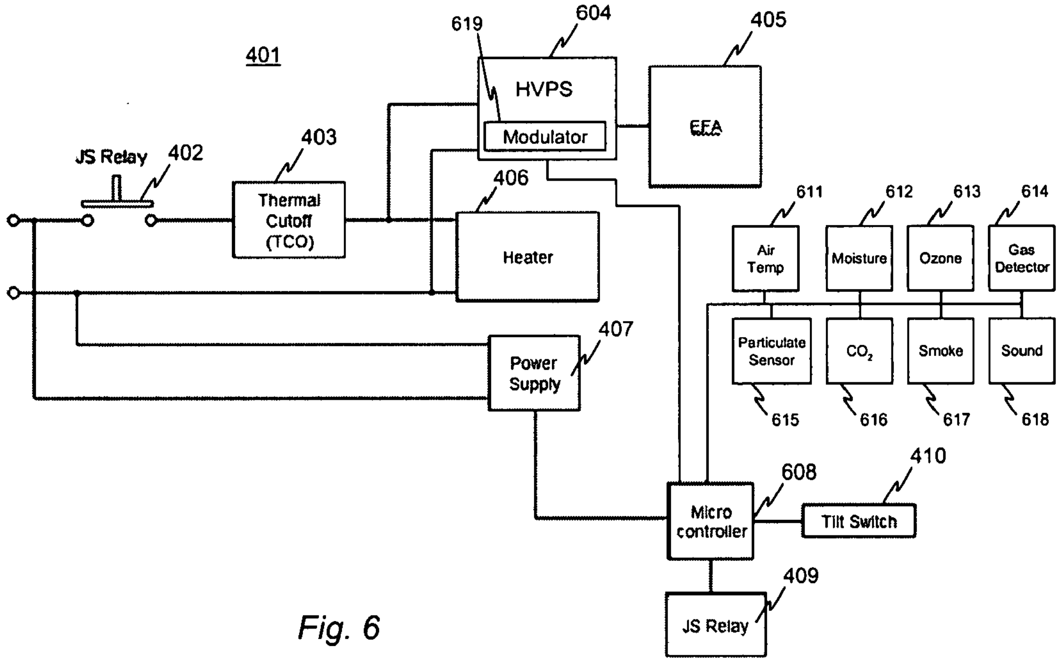

501
503
502
509
510
507
508

Fig. 5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619
604
405
HVPS
Modulator
EFA
JS Relay
402
403
Thermal Cutoff (TCO)
406
Heater
611
612
613
614
Air Temp
Moisture
Ozone
Gas Detector
Particulate Sensor
CO2
Smoke
Sound
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616
617
618
Power Supply
407
608
Micro controller
410
Tilt Switch
409
JS Relay

Fig. 6

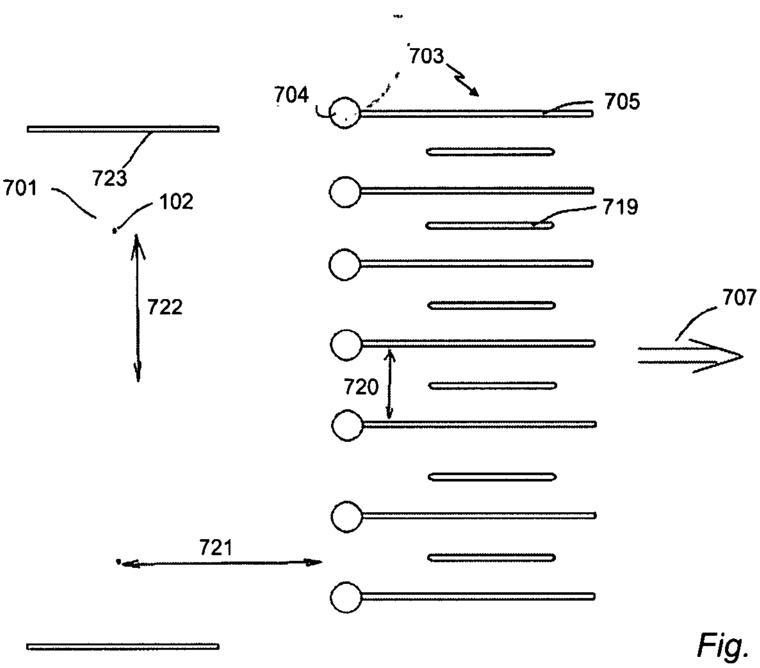
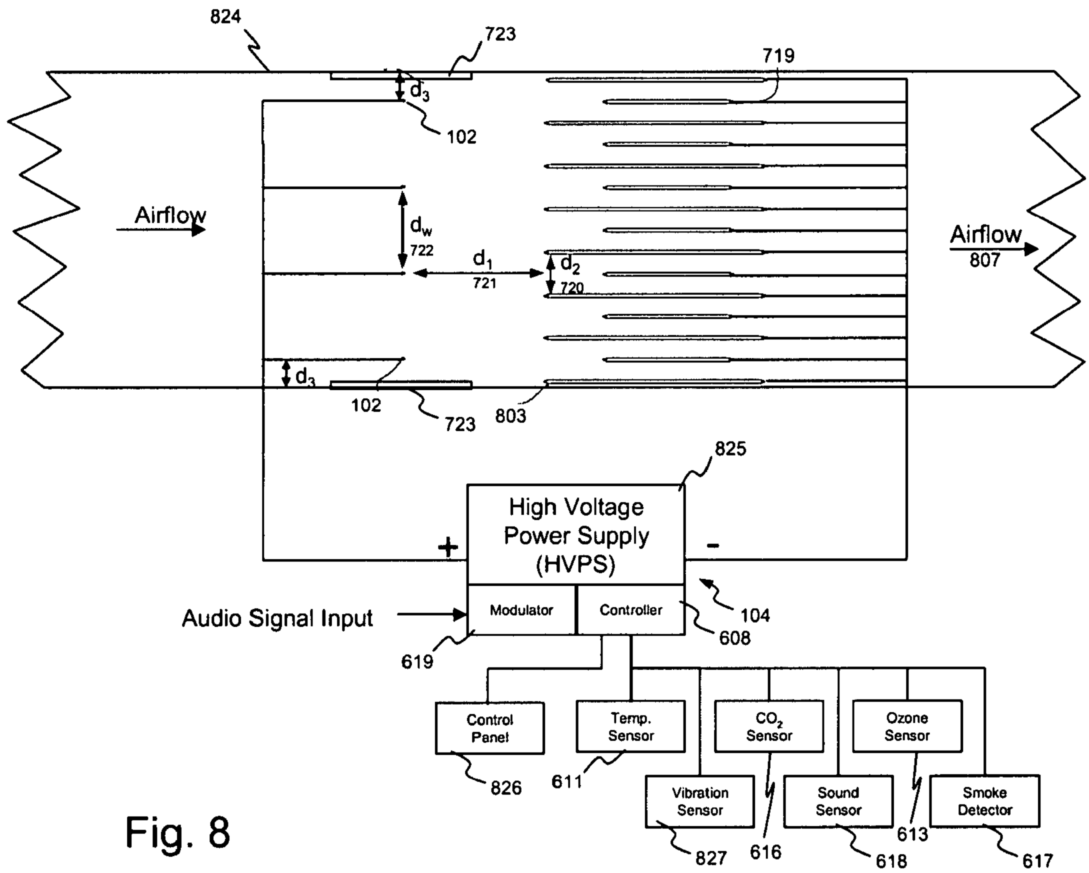

703
704
705
723
701
102
719
722
707
720
721

Fig. 7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723
719
d_3
102
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d_w
722
d_1
721
d_2
720
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d_3
102
723
803
825
High Voltage
Power Supply
(HVPS)
+
-
104
Audio Signal Input
Modulator
Controller
608
619
Control Panel
Temp. Sensor
CO_2 Sensor
Ozone Sensor
826
611
Vibration Sensor
Sound Sensor
Smoke Detector
613
827
616
618
617

Fig. 8