Aug. 22, 1967 H. LUEDER 3,337,784

METHOD FOR THE PRODUCTION OF UNIPOLAR IONS IN THE AIR AND FOR ENRICHING THE AIR OF A ROOM WITH THEM

Filed Feb. 5, 1963 4 Sheets-Sheet 1

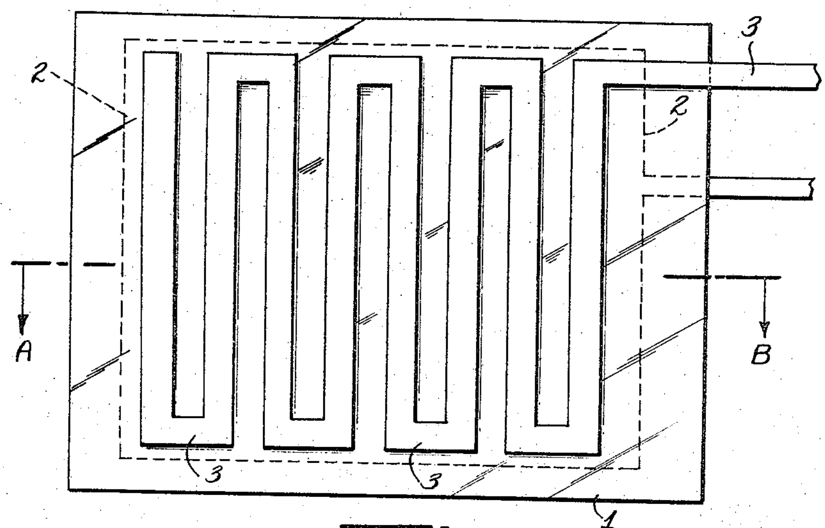

Fig. 1.

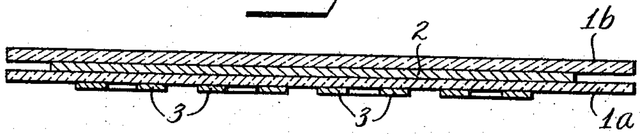

Fig. 1A.

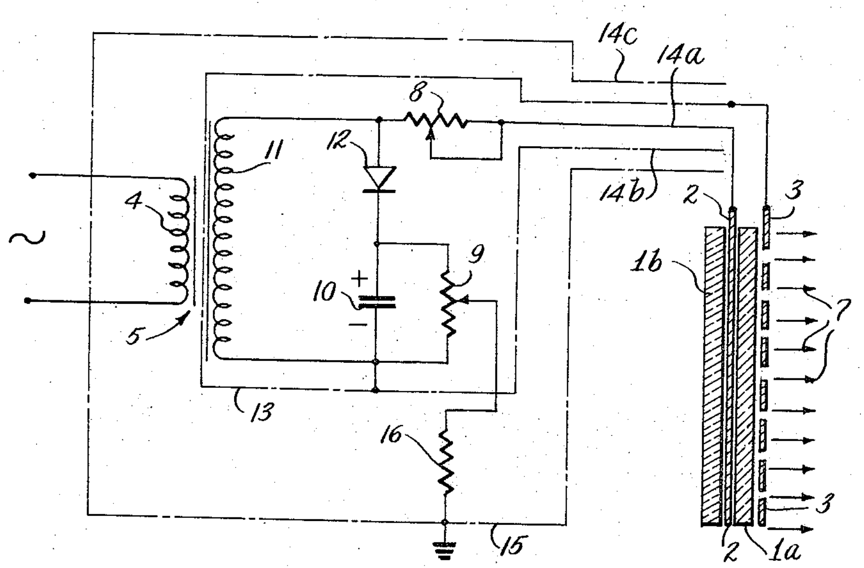

Fig. 2.

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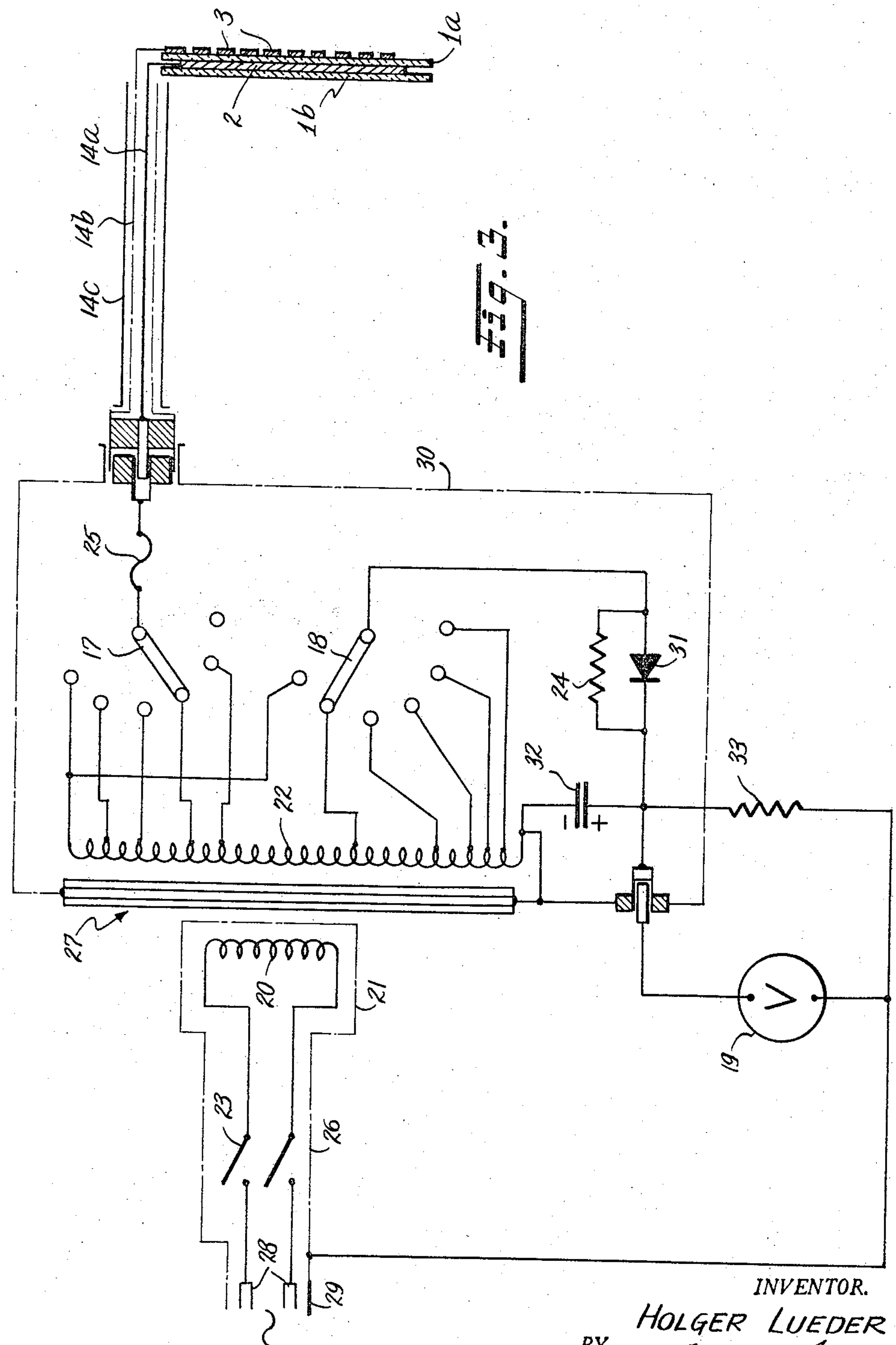

Fig. 3.

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METHOD FOR THE PRODUCTION OF UNIPOLAR IONS
IN THE AIR AND FOR ENRICHING THE AIR
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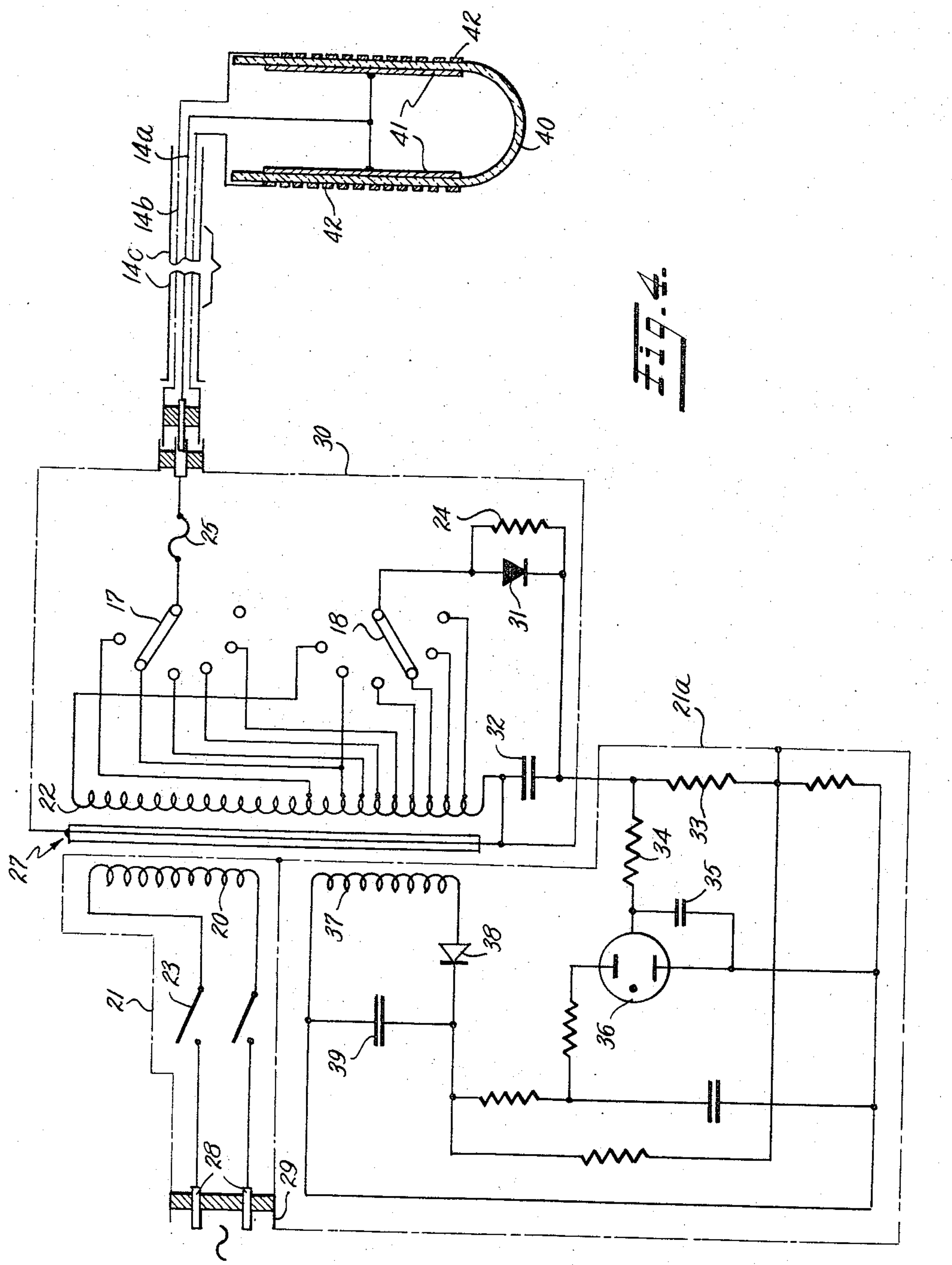
Filed Feb. 5, 1963 4 Sheets-Sheet 3



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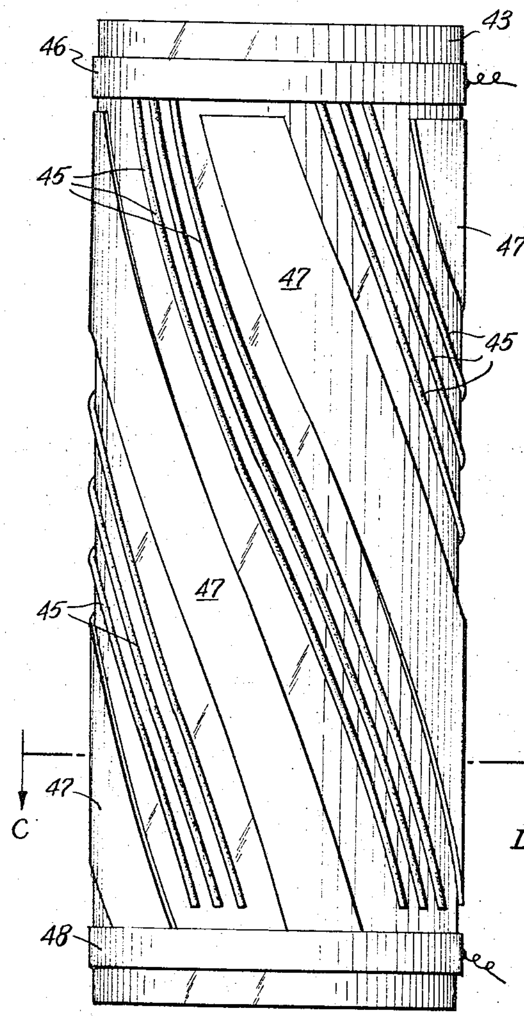

Fig. 5.

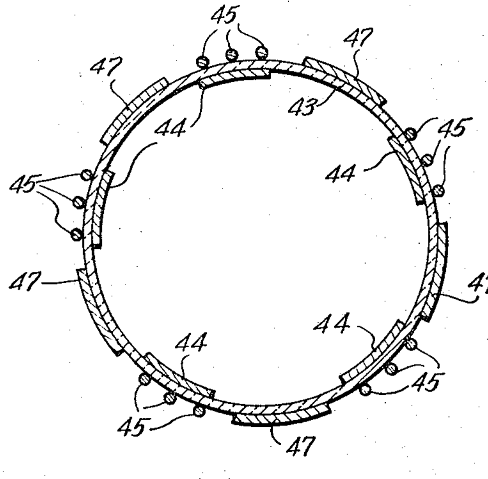

Fig. 5A.

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3,337,784

METHOD FOR THE PRODUCTION OF UNIPOLAR IONS IN THE AIR AND FOR ENRICHING THE AIR OF A ROOM WITH THEM

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Claims priority, application Switzerland, Feb. 9, 1962, 1,641/62
4 Claims. (Cl. 317—262)

The present invention relates to a method of and devices for the production of unipolar ions and for enriching the air of a room using oxygen ions and electrical fields while simultaneously deodorizing and removing from the air minute odor and suspension particles. It is known that man's well-being in closed rooms in agreeable temperature and humidity conditions depends on both the freedom from dust and odors of the air and on the electrical conditions present in the room. The last mentioned conditions are substantially determined by the ionization of the air. Through oxygen ion osmosis in the lungs, good electrical conditions exercise a healthy effect on the basic factors of life being capable, on the one hand, of enhancing resistance to pathogens, vital capacity and the performance of the nerves and, on the other hand, to produce more rapid recovery after excessive stress and work. Such conditions are found in nature largely in the places long since known as air resorts, but never in closed rooms. In the air of closed rooms, the positive carbon dioxide ions almost regularly exceed the negative oxygen ions because the positive ions, owing to their inferior mobility cannot deposit on the surfaces enclosing the room as rapidly as the negative oxygen ions.

Two fundamentally different principles have so far been employed in order to enrinch the air of rooms with negative oxygen ions:

(a) An air stream is passed over an ion source, such as a radioactive material, a surface irradiated with light and emitting electrons or an electrical corona discharge, and the ions having the undesirable charge are retained by an electrical D.C. field. While the harmful ion source can be protected against tampering and, respectively, the persons present in the room completely protected against its radiation, there remains the disadvantage of its lack of efficacy caused by the fact that the electrical space charge entering the room together with the air stream will be largely deposited, owing to its self-consistent field, on the surfaces enclosing the rooms before it can be evenly distributed in the latter. For the same reason, it is hardly possible to distribute the oxygen ions in the rooms supplied along with an air stream unipolarly ionized in an air conditioning equipment.

(b) A stream of negative oxygen ions has also been produced without circulating the air and supplied to the air breathed, but the ion source had to be placed in the room without a protective jacket. However, owing to the hazard of radiation and, respectively, high voltage inherent in radioactive and corona discharge ionizators, this is possible only where the rooms are continuously supervised by trained service personnel. This is one of the reasons why ionization of air in enclosed rooms has so far been effected only infrequently in private apartments and most frequently in special treatment units of hospitals and institutions. While the hazards of high voltage can be obviated in ultraviolet light ionizators by current limitation with a sufficiently high internal resistance, it is generally not easy to screen the persons present in a room against UV light. UV light and corona discharge ionizators moreover display the disadvantage that the generation of ions is accompanied by the development of ozone or even nitric oxides which are highly toxic in more powerful concentration.

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It is an object of the invention to eliminate the combination of ion production with the generation of ozone and nitric oxides as well as the hazard of high voltage hitherto common in the art. The method according to this invention is based on the following process: the ions are produced at the edges of a thin electrode resting on a dielectric layer, by means of glow or corona discharges maintained by an alternating voltage source, the other surface of the said dielectric layer being covered by a laminar counterelectrode. If thickness of the dielectric layer and the alternating voltage applied to the two electrodes is kept within certain limits, the stabilized glow and corona discharges on the insulating layer are kept to a length of fractions of a millimeter and at limited intensity, in which case the generation of ozone and nitric oxides is negligible, according to test results. But at the same time the negative oxygen ions are withdrawn from the discharge and admixed to the breath air in an amount corresponding to a concentration up to 10^6 ions per cubic cm. by means of an electrostatic field produced in the surroundings of the discharge electrode. Owing to the limitation of the glow and corona discharge to a length of a fraction of a millimeter, the ion source is operated under conditions which allow mixing with the air, according to the electric field strength, up to 10^6 unipolar ions but not more than about $30 \cdot 10^{-12}$ grams of ozone per cubic cm. of the air, an amount of ozone which is substantially imperceptible and physiologically insignificant.

Owing to the limitation in respect of dimension and intensity of the glow and corona discharge it has for the first time becomes possible to obtain, by means of electrical discharges the negative oxygen ions independent of the ozone production rate, in a dosage determined by the intensity of the electrostatic field and to supply same to the persons present in the room. The electrostatic field may be generated by means of semiconducting electrodes such as formed by the furniture and the normal delimiting surfaces of the room.

On the other hand, as desirable in rooms having an odor, the ozone generations may be intensified independently of the maintained ion concentration, to an amount which deodorizes the room air without exceeding the allowable concentration of $30 \cdot 10^{-12}$ grams ozone per cubic cm; this is obtained by control of the alternating voltage at the counterelectrode. To maintain the glow or corona discharges, alternating voltages between 1,000 and 4,000 volts are required; to generate the electrostatic field, direct voltages up to 4,000 volts are required. Danger to life normally involved in voltages of that magnitude is eliminated, according to the invention, by insulating the laminar counterelectrode on all sides, fusing it and enclosing its power supply and the entire AC source in a metallic jacket connected to the other pole of the AC source. On the other hand, owing to the low intensity of the ion flow in the constant electrical field, the DC source may be provided with an internal resistance of at least 10^9 ohms without noticeable voltage loss so that, in the event that the conducting electrode is touched, the voltage is limited to a harmless or non-perceptible magnitude.

The unipolar ionization of the air, however, commonly involves the further hazard that the fine aerosol particles having a dimension in the magnitude of 1 micron, which are contained in the air, are highly charged and will largely be retained, owing to such charge, in the depths of the tracheo-bronchial tree. In industrial areas, respiration of unipolarly ionized air may cause toxic substances to deposit on the sensitive respiratory epithelium which, when not charged, are normally almost completely expelled or deposited in the upper portions of the respiratory tract. This may cause the osmosis of oxygen in the respiratory epithelium to be so severely affected that transistory losses of consciousness and symptoms of suffocation are experienced.

This hazard is present principally when the methods summarized under (a) above are employed unless the air passed over the ionizator is almost completely cleared of suspended particles by means of a so called absolute filter. With the methods described under (b) hereof it is eliminated if a large portion of the particles having a unipolar charge have, with the passage of time, been removed from the air by the electrical space field and deposited on the surfaces delimiting the room and of all objects located in the room. The arrangement for the performance of the method will then, constitute an electrical precipitator device in the room itself, which cleans the air rather efficiently, despite an electrode distance ten to a hundred times larger than in a normal electric precipitator equipment because the air remains between the electrodes many hundred times longer.

By virtue of the method according to the invention, the air of a room is freed from suspended and aerosol particles with particular efficiency if, according to a further object of the invention, several glow or corona discharge devices designed as ion sources are suspended from the ceiling or placed on tables at various points in order to fill the room more uniformly with oxygen ions. They are charged by a DC source with adjustable voltage via an internal resistance of at least 10^9 ohms. It is furthermore advantageous to distribute a plurality of glow or corona discharge devices serving as ion sources over the room underneath an intermediate ceiling insulated from the main ceiling and serving as an additional electrode; the negative oxygen ions produced by the said sources are drawn out therefrom into the room by an electrostatic field produced by a negative charge on the intermediate ceiling.

In the said two variants of the method according to this invention, the negative oxygen ions pass directly into the air. However, it must be admitted that the human body is passed by an electrical current directed not downwards as in the positive atmospheric electrical fine-weather field, but upwards. As it is known from the treatment of the human body with galvanic low currents, no favorable physiological effects are obtained with this current direction, it is in many cases advisable to modify the method according to the invention in such a manner that the body is subjected to a vertically downwardly directed field while the negative oxygen ions flow upwards. In this case the glow or corona discharge device serving as the ion sources must be distributed on the floor or, in theatres and lecture halls, in the back-rests of the front seats or, charged by DC sources of which the voltage can be adjusted, placed freely on the floor or on low tables below the level of heads. The oxygen ions supplied by the ion sources are drawn, according to a further object of the invention, into the air by means of a positive electrical field generated by means of a ceiling electrode where by the intensity of this field may continuously fluctuate between a great value and a low value in a rhythm determined by the distribution of the oxygen ions. The amplitude and cycle of this positive space field must be so adjusted to one another that the negative oxygen ions are drawn out from the ion sources during the interval of low electric field strength are lifted vertically upwards to the head level in the interval of great electrical field strenth and, in the subsequent interval of low field strength distributed mainly in the horizontal direction so as to pass into the air in the desired concentration despite a positive residual space charge at head level, by the action of air convection and by diffusion.

A further condition to be met is that the maximum rate of the change in the field intensity of the positive space field in the body does not generate displacement currents larger than those generated in a constant electrical field of 3,000 volts/m. by physical motion.

As in the first two variants of the method according to this invention, the oxygen ion concentration in the air is adjusted by the negative operating voltage of the glow or corona discharge devices to the level desired, which is done largely independently of the ozone generation of the discharges. The latter may again be adjusted, independent of the flow of oxygen ions, by means of an adjustable current limiting resistance or a voltage source with adjustable voltage in the AC circuit of the discharge electrodes to a value which just suffices to neutralize the odor particles but does not exceed an amount of about $30 \cdot 10^{-12}$ grams of ozone per cubic cm. of air.

In the second and third variants of the method according to this invention it is possible to support the transport of oxygen ions from the individual ion sources by means of a filtered fresh-air or supply-air stream. In the third variant, application is dependent thereon if the individual ion source is located behind a protective grid connected with ground.

In the second and third variants, the method enables a comparatively uniform homogeneous supply of oxygen ions to be passed into the entire room, in particular if the ceiling field is rendered homogeneous also in the vicinity of the walls. Homogeneization of the ceiling field may, according to the invention, be obtained by a double-layer wall and ceiling covering of which the layer adjacent the wall and ceiling is electrically highly insulating and the layer above it semiconductive.

In order to set up the vertical electrical field by means of an adjustable DC source, the semi-conductive layer is provided with two metallically conductive current-supply electrode strips of which the one establishes electrical contact everywhere at the skirting and the other everywhere along the lagging. In order to avoid inhomogeneities of the field at windows and walls, window and wall curtains have their upper and lower seams provided with current supply lines of superior semi-conductivity or metallic conductivity which are electrically connected at their level to the semiconductive wall covering and, respectively, to the said metallically conductive supply electrode strips.

As the particles suspended in the air will gradually be deposited on the ceiling, it is recommended that the semi-conductive ceiling covering be provided with a washable coating which does not noticeably obstruct the ion stream owing to its thinness.

Further objects of the invention appear from the devices described hereinafter for the performance of the method and from the embodiments illustrated in the drawings, in which:

FIG.1 is a plan view of a form of electrode for practicing the present invention. FIG. 1–A is a sectional view of the device of FIG. 1 taken along the line A–B of FIG. 1.

FIG. 2 is a diagrammatic circuit of an embodiment according to the invention.

FIGS. 3 and 4 are further embodiments according to the invention.

FIG. 5 is a front view of an electrical electrode arrangement and FIG. 5–A is a sectional view taken along the line C–D of FIG. 5.

The method according to the invention for the production of unipolar ions while preventing the generation of undesired high amounts of ozone is based on a new knowledge concerning the rate of ozone generation as a function of the spatial extension of the glow and corona discharge on an electrode. In an electrode arrangement according to FIG. 1 the glow and corona electrode **3** is designed as a flat and very thin metal film carried by a dielectric insulation sheet **1***a*. The back surface of the sheet **1***a* is covered by a metallic counter electrode **2** which is protected by a second insulation sheet **1***b*. In an embodiment of the electrode arrangement of FIG. 1 the sheets **1***a* and **1***b* being of glass having a thickness of about 1 mm .and carrying as electrode **3***a* 0.1 mm. thick metal foil affixed to the glass surface in the form shown in FIG. 1. Preferably the foil is made from a metal not easily vaporized, for example from alloyed steel of the well known trade type V4A. The counterelectrode **2** is made from the same metal and has a thickness of about 0.5 mm. The two glass sheets **1***a* and **1***b* are both affixed to the counter electrode **2**.

Operating an electrode arrangement according to FIG. 1 by an adjustable high voltage A.C. source, a glow and corona discharge of the so-called stabilized type occurs at sufficiently high voltages, mainly along the edges of the discharge electrode **3**. It has been discovered that an electrode arrangement of this design when operated with reduced spatial extension of the discharge to a fraction of one millimeter is suitable for use as an ion source of sufficient yield yet which generates only a negligible amount of ozone. Hence such an electrode arrangement can be used as an ion source for producing up to 10^6 ions per cubic cm. to the surrounding air by means of an electric field without causing a concentration of ozone exceeding a value of $30 \cdot 10^{-12}$ grams per cubic cm. of air.

An embodiment of the equipment according to the invention suitable for operating an electrode arrangement as described above in connection with FIG. 1 is shown in FIG. 2, comprising a high voltage A.C. source to maintain a glow and corona discharge at the electrode arrangement and a high voltage D.C. source to generate an electric field to withdraw unipolar ions from the discharge to the room surrounding this ion source. The high voltage A.C. source is provided with a high voltage power transformer **5** designed to have a breakdown voltage of at least 5000 volts and an insulation of the windings against the core of at least 10^{11} ohms. The primary winding **4** is supplied by 50 c.p.s. A.C. current from the normal power line for example at a voltage of 220 volt. The secondary winding **11** is connected at one end to the screen **13** and at its other end through an adjustable resistor **8** to the inner conductor **14***a* of a coaxial high voltage supply cable for the electrode arrangement. The outer conductor **14***b* of this cable is connected to the screen **13** which also surrounds the secondary winding **11** of the transformer **5**.

The electrode equipment shown in FIG. 2 corresponds to the arrangement of FIG. 1 and is provided with two insulation sheets **1***a* and **1***b* enclosing the protected high voltage carrying electrode **2** connected to the inner conductor **14***a* of the high voltage supply cable, and the glow and corona electrode **3** affixed to the outside surface of the insulation sheet **1***a* and connected to the outer conductor **14***b* of the supply cable. The high voltage supply cable is enclosed in a metallic screening or wrapper **14***c* which is connected to the grounded metallic case **15** of the high voltage equipment.

The high voltage D.C. source comprise a rectifier **12** and a condenser **10** bridged by a potentiometer **9** and is supplied by the secondary winding **11** of the transformer **5**. The tap of the potentiometer **9** is connected through a resistor **16** of at least 10^9 ohms to the grounded metal case **15**. Depending upon the adjustment of the potentiometer **9**, the screen **13**, the outer conductor **14***b* and the discharge electrode **3** carry a lower or higher negative D.C. voltage relative to the case **15** and also relative to the ground. Hence the adjustable high voltage D.C. source generates an electric field **7** effecting the withdrawing of negative oxygen ions from the ion source (electrode **3**) in the direction of the arrows.

To free the outer unprotected discharge electrode **3** from an appreciable A.C. voltage it is necessary to reduce the capacitance to ground of the electrode **3** and the whole circuit enclosed in the screen **13**. It is therefore advantageous to connect the poor earth capacity end of the secondary winding **11** to the screen **13**. The screen **13**, the enclosed circuitry therein, the outer conductor **14***b* of the high voltage supply cable and the electrode **3** should have all together an insulation resistance against the ground of at least 10^{11} ohms.

The embodiment of the invention according to FIG. 2 described above permits control of the enrichment of negative oxygen ions in the air of a room by adjusting the potentiometer **9** and control of the rate of ozone generation and concentration in the air by adjusting the resistor **8**.

Another embodiment of the invention is shown in FIG. 3 using the electrode arrangement according to FIG. 1 which is supplied by a high voltage cable **14***a*, **14***b* and **14***c* of the same type as described above in connection with the equipment of FIG. 2. The grounded metal case enclosing the whole equipment and being connected to the metal wrapper **14***c* of the high voltage cable is not shown in FIG. 3. The high voltage power transformer **27** has a screened primary winding **20** which is connected through a main switch **23** to the input terminals **28**. The screen of the primary winding **20** is a part of a screening metal case **21** surrounding the switch **23** and the terminals **28**. The screening case **21** is connected to the input plug **29** intended for connection to a grounded neutral line conductor.

The secondary winding **22** is connected at one end to a metal screen **30** enclosing the high voltage A.C. and D.C. sources. This screen **30** is in contact with the outer conductor **14***b* which is also connected to the discharge electrode **3**. The voltage carrying protected counter electrode **2** is connected through the inner conductor **14***a* and a safety fuse **25** to a step switch **17** for selecting one of different taps of the secondary winding **22** of the transformer **27**.

Another step switch **18** with taps on the secondary winding **22** is provided for the high voltage D.C. source comprising a rectifier **31**, bridged by a resistor **24**, and a condenser **32**. The D.C. voltage across the condenser **32** is connected to the screen **30** and to the neutral plug **29**, respectively, through the resistor **33** of at least 10^9 ohms. Hence the discharge electrode **3** carries a negative voltage from this D.C. source, relative to ground.

The step switch **17** is provided with an idle position in which the A.C. current circuit to the counter electrode **2** is interrupted. This position is used for checking the insulation resistance of the electrode arrangement, the high voltage supply cable and the whole circuit enclosed in the screen **30** against ground by means of an electrostatic voltmeter **19** indicating the voltage across the resistor **33**. The insulation resistance has a sufficiently high value only when the voltage across the resistor **33**, during checking, is low compared with the voltage across the condenser **32**.

Furthermore the voltage across the resistor **33** is a quantitative measure of the number of ions flowing per second from the ion source into the room. If the ion source is freely suspended or mounted in a room, then within a distance of 100 cm. from the ion source a current of 10^5 to 10^6 highly mobile negative ions is flowing through an area of 1 square cm. when the voltage across the resistor **33** of about 10^{10} ohms has a value of 20 to 200 volts. It is appropriate to arrange the taps on the secondary winding **22** connected to the step switch **18** in such a manner that the D.C. voltage and the said ion flow is reduced by equal amounts when switching from the higher to the lower positions, for example reduced to ⅓ with each step.

The resistor **24** in the high voltage D.C. source has a high value but being chosen such that the D.C. voltage at the condenser **32** follows fast enough during changing the position of the step switch **18**.

The rate of delivered ions may be indicated, in lieu of the electrostatic voltmeter **19**, by an electronic counter circuit shown in the embodiment of the inventiton according to FIG. 4. The high voltage A.C. and D.C. sources enclosed in the screen **30** are identical to the corresponding circuits of the equipment according to FIG. 3. The counter circuit, enclosed in a screen **21***a* which is a part of the screen **21** surrounding the primary power supply circuit, comprises a cold cathode glow discharge tube **36** having a control electrode connected through a resistor **34** to the resistor **33**. The value of the resistor **34** is at least three times larger than the value of the resistor **33**. The anode circuit of the tube **36** is supplied by a separate D.C. source comprising the winding **37** of the transformer **27**, the rectifier **38** and the condenser **39**. The tube **36** is ignited when the condenser **35** is charged to a voltage exceeding the ignition voltage of the tube **36**, but is immediately extinguished after an ignition owing to the discharge of the condenser **35** which is slowly charged through the very high resistance of the resistor **34**. Each ignition of the tube **36** is visible and gives an indication that, since the preceding ignition, an amount of negative ions has been delivered corresponding to the time constant of the condenser **35** and the resistor **34**.

To prevent the flow of an A.C. current through the resistor **33** which could effect a premature ignition of the tube **36** the metallic screen **21***a* enclosing the winding **37** of the transformer **27** and the whole electronic counter circuit is grounded through the neutral plug **29**. Furthermore the use of control knobs for the step switches **17** and **18** having shafts made of insulation material and grounded metal parts may minimize any influence therethrough.

Designing the circuits according to FIGS. 2, 3 and 4 it is important to minimize the ground capacitance of the metal screen casings **13** and **30**, respectively and to prevent the occurrence of a prickling spark when touching the unprotected discharge electrodes of the ion source during operation. Hence the metal screen casings **13** and **30** should be surrounded by an insulating plastic case and the grounded metal screens **21** and **21***a* should be as small as possible in dimensions.

The equipments according to FIG. 3 and 4 are provided with a safety fuse **25** in the connection to the inner conductor **14***a* of the high voltage supply cable to the electrode arrangement which is designed to be fused if the glass parts of the electrode arrangement are destroyed, and to interrupt the connection to the high voltage winding of the power transformer. It is pointed out that the electrode arrangement may be surrounded by a strong metal grid connected electrically to the outer metal wrapper **14***c* of the high voltage supply cable on the premises that the grid is provided with meshes wide enough to allow a sufficient influence from the electrostatic field outside the grid to the discharge electrode inside the grid.

The embodiment of the invention according to FIG. 4 shows an electrode arrangement in form of a glass bulb or tube **40** being on its inside with a conductive layer **41** connected to the inner conductor **14***a* of the high voltage supply cable and forming the protected voltage carrying electrode. The discharge electrode **42** connected to the outer conductor **14***b* of the high voltage supply cable being arranged as a winding of thin metal wires or metal strips affixed to the outer surface of the bulb. For example the glass bulb **40** may have a wall thickness of 0.8 mm. and the winding **42** may be made from a wire 0.1 mm. thick with a distance between adjacent windings of about 4 mm.

It is known that glow and corona discharges when used to produce ions cause a so called "ion wind" in the direction of the ion flow and hence a return air stream. In order to prevent the return air stream from depositing uncharged dust on the insulating layer or body in the vicinity of the discharge, according to the invention the outer surface of the electrode arrangement is equipped not only with the metallic discharge electrode but the space between adjacent parts of the discharge electrode is covered by a further plane auxiliary electrode which carries a lower voltage relative to ground than the discharge electrode. The auxiliary electrode is designed merely as a depositing electrode for the particles contained in the return air stream. FIG. 5 shows an embodiment of such an electrode arrangement comprising a glass tube **43** having its inside surface provided with a conductive layer **44** as a counter electrode and its outside surface with thin wires **45** of a diameter of about 0.1 mm. to form the discharge electrode. All wires **45** are connected to a conductive ring **46** and extend spirally on the outside surface of the tube **43**. The strips **47** of metal foil, which may be cemented to the glass tube **43**, being the depositing electrodes for the dust contained in the return air stream and are connected to a second conductive ring **48**. The two rings **46** and **48** being the terminals and are supplied with the above mentioned higher and lower voltage, respectively, relative to ground.

What I claim is:

1. The method of producing a preponderance of unipolar ions in an air space, comprising the steps of: producing an electric glow and corona discharge in said air space by applying an A.C. voltage to spaced electrodes; maintaining the spatial extension of said glow and corona discharge to a fraction of a millimeter; holding said A.C. voltage to a value such that said glow and corona discharge delivers up to about 10^6 ions per second to each cubic centimeter of said space while holding the production of ozone to no more than 30.1^{-12} grams per cubic centimeter; and applying a D.C. voltage across said air space to impress an electric field thereacross to thereby withdraw ions of the desired polarity from said glow and corona discharge into said air space.

2. The method defined in claim **1** including the step of varying said D.C. voltage cyclically at a frequency of a fraction of a cycle per minute.

3. The method of claim **2** wherein said D.C. voltage is held low for a period sufficient to produce a space charge in said air space and is changed to a higher value only long enough to move the ions of said space charge upwardly in said space to about the level of the head of a person therein and which then move horizontally at about said level.

4. The method of claim **2** wherein said frequency is held to such low value that induced currents in the body of a person in said field do not exceed those caused by body movements in a constant field strength of about 3000 volts per meter.

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