

【Title of Document】 Specification

【Title of the Invention】 Electrostatic Precipitation Apparatus for Room Ventilation and Ventilation System Incorporating Same

【Technical Field】

[0001]

The present invention relates to an electrostatic precipitation apparatus for room ventilation, and more particularly, to an electrostatic precipitation apparatus for room ventilation, which is configured to send a constant current to an ionization section and apply a particle collection section with a predetermined voltage, in response to the occurrence of an anomalous discharge such as sparking in the dust collection section, reduce the predetermined voltage to automatically recover from the anomalous discharge and perform a normal dust collecting action, and in response to the normal dust collecting action sustained for a set time, allow the dust collection section to be applied with the predetermined voltage as before the anomalous discharge, on the assumption that the cause of the anomalous discharge was eliminated. The present invention also relates to a ventilation system which incorporates the electrostatic precipitation apparatus for room ventilation.

【Description of Background Art】

[0002]

Ventilation in rooms is important in order to keep an air environment therein hygienically. In business offices and the like, building management rules have already dictated such countermeasures as introduction of fresh and clean external air into offices for keeping healthy those employees who work within the offices. In addition to the ventilation in offices, as to individual houses, limited only to newly built ones, however, a law reform obligates house owners to take an external air of a volume equivalent to that of their residences every two hours. However, the external air is not always clean, but contains dust, pollen, insects, and the like. Recently, yellow sand, PM2.5, and the like have been regarded as problematic. Accordingly, from the spirit of the building management rules and building standard acts, external air should be introduced into rooms after removing floating particles contained in the external air, such as the aforementioned dust, pollen, insects, yellow sand, PM2.5, and the like.

[0003]

A filter is required for removing the above-mentioned substances contained in external air. In the past, mechanical filters having relatively rough meshes have been employed to remove dust, pollen, insects, and the like within external air. However, since yellow sand, PM2.5, and the like, which is regarded as problematic in view of health, have particle diameters of approximately 1 μ m, and are so fine that conventional mechanical filters are incapable of removing them. For this reason, a high-performance mechanical filter having an extremely fine mesh, referred to as a "HEPA filter," have been employed in increasingly more cases. While the high-performance mechanical filter is advantageous in its abilities to remove the aforementioned yellow sand, PM2.5, and the like, its fine mesh of the mechanical filter results in a large air flow resistance, and moreover, removed floating particles deposit on the mechanical filter in layers to gradually increase the air flow resistance. Thus, a fan is required to have a relatively high pressure, but involves gradually increasing power consumption and gradually larger noise. On top of that, the amount of external air passing through the mechanical filter could possibly decrease, though gradually, leading to a reduction or a shortage of the required amount of ventilation.

[0004]

To solve the foregoing problem, an electrostatic precipitation apparatus is provided for serving as a filter capable of trapping yellow sand, PM2.5, and the like which have the diameter of approximately 1 μ m. A ventilation and air-conditioning apparatus intended for persons that have any allergies are known (for example, see Patent Document 1 (JP-2009-36395A), where the electrostatic precipitator is incorporated for ventilation of room. As shown in Fig. 6, the electrostatic precipitation apparatus used in this prior art example, comprises an ionization section 52, a particle collection section 55, and a power supply 56 for supplying electric power to the ionization section 55 and particle collection section 55. The ionization section has ionization lines 50 and ionization electrodes 51 for charging floating particles within air, such as dust, pollen, yellow sand, PM2.5, and the like, through corona discharge or the like. The particle collection section 55 comprises particle collection electrode plates 53 and opposing particle collection electrode plates 54 which are alternately arranged at equal intervals by spacers, in order to trap the charged floating particles with a coulomb force. The power supply 56 is configured to supply electric power to the ionization section 52 and dust collection section 55. Then, this

electrostatic precipitation apparatus is used to keep the environment favorable by charging floating particles in the air with the ionization section 52, and collecting the charged floating particles with the particle collection section 55 to remove the floating particles in the air.

[0005]

In the past, the ionization section 52 and particle collection section 55 are powered from the power supply 56 by methods which are roughly classified into a constant-voltage method and a constant-current method. The constant-voltage method involves applying a constant voltage to the ionization section 52 and particle collection section 55, while the constant-current method involves applying a constant current to the ionization section 52 but applies a constant voltage to the particle collection section 55. These power supply methods are implemented by a control unit 57.

[0006]

An electrostatic precipitation apparatus which employs the conventional constant-voltage method may suffer from contamination and/or oxidization on the surface of the ionization lines 50 of the ionization section 50 due to floating particle, as the electrostatic precipitation apparatus continues the particle collection. Consequently, a lower current value may be generated by the initially set constant voltage, causing corona discharging to occur with more difficulties, with the result that the particle collection efficiency is lowered. Moreover, an anomalous discharge such as sparking can be caused by the floating particles collected by and deposited on the particle collection electrode plates 53 and opposing particle collection electrode plates 54 of the particle collection section 55. Once an anomalous discharge such as sparking occurs, the anomalous discharge such as sparking will continue unless the application of a high predetermined voltage is stopped from the power supply 56 to the particle collection electrode plates 53 and opposing particle collection electrode plates 54. In the worst case, a fire accident could occur. As such, the power supply 56 is prohibited from applying the constant voltage, but as long as the cause of the anomalous discharge is eliminated, the anomalous discharge such as sparking would immediately follow if the power supply 56 started applying the constant voltage. Thus, the electrostatic precipitation apparatus remains missing a function of removing floating particles in the air to maintain a favorable environment, which is expected to the electrostatic precipitation apparatus, while the cause of the

anomalous discharge is not eliminated.

[0007]

On the other hand, the conventional constant-current method is not affected by corona discharging or the like or does not suffer from a lower particle collection efficiency, even if a continuous particle collection causes the surface of the ionization lines 50 to be contaminated or oxidized by floating particles, because a constant current is flowing through the ionization lines 50. However, since the particle collection section 55 is likewise applied with a constant voltage in the constant-current method as well, the conventional constant-current method is similar to the constant-voltage method in that an anomalous discharge such as sparking can occur due to floating particles collected by and deposited on the particle collection electrode plates 53 and opposing particle collection electrode plates 54 of the particle collection section 55.

[0008]

To address situations as described above, a power supply device has been provided for an electrostatic precipitation apparatus. This power supply device comprises power supply means for supplying power to electrodes; detecting means for detecting a voltage which is applied to the electrodes when they are being supplied with electric power from the power supply means or detecting an insulation resistance of the electrodes; and determining means for determining whether or not humidity is attributable to a reduced voltage or a reduced insulation resistance of the electrodes detected by the detecting means by supplying the electrodes with power lower than that supplied by the power supply means, specifically, 30 - 100% of the voltage applied by the power supply means and 1 - 30% of the current applied by the power supply means. In this way, the power supply device determines whether or not a reduced voltage on the electrodes of an associated electrostatic precipitation apparatus should be regarded as a critical case caused by an anomalous discharge such as sparking or an immaterial accident caused by humidity or the like, which can be recovered without taking any action therefor. When a critical case is determined, the power supply means is instructed to stop supplying the power to the electrodes to prevent the electrostatic precipitation apparatus from damaging, and a maintenance is performed to remove the cause of the trouble. On the other hand, when an immaterial case is determined, the power supply means is allowed to continue the supply of the power to the electrodes, expecting a spontaneous recovery, so that the

electrostatic precipitation apparatus can continue the function of removing floating particles in the air to maintain a favorable environment (for example, see Patent Document 2, JP-2008-68207A).

【Summary of the Invention】

【Problems to be Solved by the Invention】

[0010]

In the electrostatic precipitator used in a ventilation air-conditioning apparatus intended for persons that have any allergies, as presented by Patent Document 1, the ionization section 52 may encounter difficulties in stably generating a corona discharge due to high humidity in the air, dew condensation caused by a large difference in temperature, and/or continued collection of particles. In addition, the particle collection section 55 can suffer from an anomalous discharge such as a spark discharge involving furious spark, resulting in a lower particle collection efficiency for floating particles in the air and in a potential cause of fire accident if collected floating particles are inflammable.

[0011]

The power supply device for an electrostatic precipitation apparatus according to the foregoing Patent Document 2 is configured to determine whether a reduced voltage on the electrodes of the electrostatic precipitation apparatus is caused by a critical trouble or an immaterial trouble such as humidity and can be recovered without taking any actions. When the trouble is determined to be critical, the supply of the power is stopped and maintenance is performed. When the trouble is determined to be immaterial, the power is supplied to the electrostatic precipitation apparatus such that it continues the function of removing floating particles in the air to maintain a favorable environment. However, even when the determining means determines a critical case, an anomalous discharge such as sparking can be solved simply by slightly reducing the voltage when the power is supplied to the electrodes. Even in such a case, the power supply means is instructed to stop supplying the power to the electrodes, followed by the performance of maintenance still kept for removing the cause of the trouble. As such, the electrostatic precipitation apparatus remains inoperative until the maintenance is over to remove the cause. During this period of time, the electrostatic precipitation apparatus cannot only continue the function of

removing floating particles in the air to maintain a favorable environment, but the maintenance is frequently performed.

[0012]

The present invention has been made to address the situation described above, and it is an object of the invention to provide an electrostatic precipitation apparatus for room ventilation which is capable of reducing the frequency of maintenance operations. Specifically, the electrostatic precipitation apparatus is capable of stably continuing a corona discharge in an ionization section, and promptly resuming the formation of a normal electric field by reducing an applied voltage, even if an anomalous discharge such as sparking occurs in a particle collection section due to fluctuations in environment such as humidity or due to continued dust collection, to continue a particle collecting action. Additionally, when the cause of an anomalous discharge is removed naturally, the electrostatic precipitation apparatus increases the applied voltage to promptly continue the particle collecting action. It is another object of the present invention to provide a ventilation system which incorporates the electrostatic precipitation apparatus for room ventilation.

【Means for Solving the Problems】

[0013] (**said, return)

The present invention has been proposed to achieve the foregoing objects, and is characterized by comprising the following configurations.

Specifically, an invention according to claim 1 is directed to an electrostatic precipitation apparatus for room ventilation, which has a two-stage charging type electrostatic precipitator comprising an ionization section for charging floating particles in the air, a particle collection section for collecting charged floating particles with a coulomb force, and a power supply for supplying electric power to the ionization section and the particle collection section. The apparatus includes a constant-current control unit interposed between the power supply and the ionization section for supplying the ionization section with a constant current which does not cause a predefined voltage to be exceeded; a sensing unit interposed between the power supply and the particle collection section for sensing an applied voltage value and current value at all times when the particle collection section is applied with a predetermined voltage; a voltage step control unit for receiving the applied voltage value and current value from the sensing unit for issuing a command to increase or

decrease the predetermined voltage so as to prevent the particle collection section from anomalously discharging in response to an anomalous discharge caused by a sudden fluctuation of the applied voltage value and current value and a continued fluctuation of the applied voltage value and current value within a certain range; and a voltage changing unit for changing the predetermined voltage in response to a command from the voltage step control unit to control a current and a voltage sent from the power supply to the particle collection section. The apparatus is characterized in that the ionization section is applied with a constant current through the constant-current control unit; the particle collection section is applied with the predetermined voltage through the voltage step control unit; upon occurrence of an anomalous discharge, the voltage step control unit once stops supplying power to the particle collection section; the voltage changing unit subsequently changes the predetermined voltage to a level at which an anomalous discharge does not occur, the changed predetermined voltage applied to the particle collection section to continue a particle collecting action; and when the applied voltage value and current value continue to fluctuate within a certain range for a predefined time, a determination is made that a cause of the anomalous discharge has been eliminated, allowing the voltage step control unit to issue a command to the voltage changing unit to increase the predetermined voltage, the increased predetermined voltage being applied to the particle collection section to continue a particle collecting action.

[0014]

Also, the invention according to claim 2 is directed to the electrostatic precipitation apparatus for room ventilation, wherein the voltage step control unit operates in a cleaning mode, the cleaning mode including, upon occurrence of an anomalous discharge due to the predetermined voltage applied to the particle collection section, once shutting off the power supply to the particle collection section with a command from the voltage step control unit, causing the voltage changing unit to apply a voltage higher than the predetermined voltage to the particle collection section to clean the particle collection section.

[0015]

Also, the invention according to claim 3 is directed to the electrostatic precipitation apparatus for room ventilation, wherein the voltage step control unit outputs a PWM (pulse width modulation) signal having a predetermined value from a CPU (central processing unit) to an amplifier circuit, such that the particle collection

section is applied with the predetermined voltage commensurate with the PWM signal from the voltage changing unit.

[0016]

Also, the invention according to claim 4 is directed to the electrostatic precipitation apparatus for room ventilation, wherein the voltage changing unit includes n resistors ($R_1 < R_2 \dots < R_{n-1} < R_n$) arranged in parallel between the particle collection section and the power supply, when the sensing unit senses an anomalous discharge while a resistor R_1 is connected between the particle collection section and the power supply, the voltage step control unit issues a command to the voltage changing unit to once shut off the particle collection section from the power supply and subsequently switch the resistor R_1 to a resistor R_2 having a larger resistance value between the particle collection section and the power supply, the particle collection section being applied with the predetermined voltage, and the voltage step control unit subsequently switches ($n-2$) arranged resistors to resistors $R_3 \cdot R_n$ having larger resistance values to change in steps the predetermined voltage, and applies the changed predetermined voltage to the particle collection section.

[0017]

Also, the invention according to claim 5 is directed to the electrostatic precipitation apparatus for room ventilation, wherein the voltage changing unit includes n resistors ($R_1 < R_2 \dots < R_{n-1} < R_n$) arranged in parallel between the particle collection section and the power supply, when the applied voltage value or current value fluctuate within a certain range for a predefined time while one of the n resistors except for R_1 ($< R_2 \dots < R_{n-1} < R_n$) is connected between the particle collection section and the power supply, the voltage step control unit issues a command to the voltage changing unit to once shut off the particle collection section from the power supply, and subsequently switches the one resistor to another resistor $R_1 \cdot R_{n-1}$ having a sequentially smaller resistance value between the particle collection section and the power supply to increase the predetermined voltage in steps, the particle collection section being applied with the predetermined voltage, and applies the increased predetermined voltage to the particle collection section.

[0018]

Also, the invention according to claim 6 is directed to the ventilation system characterized by utilizing an electrostatic precipitation apparatus for room ventilation as described above.

[0019]

The first problem solving means (claim 1) performs the following actions. Specifically, the ionization section is applied with a constant current from the power supply through the constant-current control unit to generate a stable corona discharge or the like in the ionization section to charge floating particles in the air which pass through the ionization section. The particle collection section is applied with a predetermined voltage from the power supply through the voltage step control unit to generate a stable electric field in the particle collection section to trap charged floating particles passing therethrough. When the sensing unit senses, during the trapping process, sudden fluctuations in the applied voltage value and current value, the particle collection section is once shut off from the power supply by the voltage step control unit on the assumption that an anomalous discharge occurs in the particle collection section. Then, the voltage changing unit reduces the predetermined voltage to a level at which an anomalous discharge is free, and the reduced predetermined voltage is applied to the particle collection section to continue the particle collecting action. Subsequently, when the sensing unit senses that the applied voltage value and current value in the particle collection section have continued fluctuations within a certain range for a predefined time, the voltage step control unit determines that the cause of the anomalous discharge has been eliminated, and once shuts off the particle collection section from the power supply. Then the voltage changing unit increases the predetermined voltage, and the increased predetermined voltage is applied to the particle collection section to continue the particle collecting action. Afterwards, a sequence of the occurrence of anomalous discharge, temporary shut-off of the anomalous discharge, reduction of the predetermined voltage, elimination of anomalous discharge, continuation of particle collecting action, continued application of the reduced predetermined voltage for a predefined time, temporary shut-off of application of the predetermined voltage, and increase of the predetermined voltage is performed an allowed number of times.

[0020]

In actions by the second problem solving means (claim 2) described above, upon occurrence of an anomalous discharge due to the predetermined voltage applied to the particle collection section, the power supply to the particle collection section is once shut off, the voltage changing unit applies a voltage higher than the predetermined voltage to the particle collection section to remove substances causing

the anomalous discharge from the particle collection section, followed by cleaning the particle collection section.

[0021]

In actions by the third problem solving means (claim 3) described above, upon receipt of anomalous discharge information or anomalous discharge cause elimination information, the voltage step control unit once shuts off the particle collection section from the power supply, and then, outputs a PWM (pulse width modulation) signal having a predetermined value, in accordance with the anomalous discharge information or anomalous discharge cause elimination information from the CPU (central processing unit) to the amplifier circuit, such that the particle collection section is applied with the predetermined voltage commensurate with the PWM signal to continue the particle collecting action. Subsequently, the PWM signal is modified to decrease or increase the predetermined voltage in steps, and the resulting predetermined voltage is applied to the particle collection section to continue a suitable particle collection as well after the occurrence of the anomalous discharge or after the elimination of the cause of the anomalous discharge.

[0022]

In actions by the fourth problem solving means (claim 4) described above, when the resistor R1 is connected between the particle collection section and the power supply, the voltage step control unit, which has received the anomalous discharge information from the sensing unit, once shuts off the particle collection section from the power supply. Then, the resistor R1 is switched to a resistor R2 having a larger resistance value between the particle collection section and the power supply, and the resulting predetermined voltage is applied to the particle collection section to continue the particle collecting action. Subsequently, (n-2) resistors R3 - Rn are sequentially switched from one to another having a next larger resistance value to reduce the predetermined voltage in steps. The resulting predetermined voltage is applied to the particle collection section to continue the particle collecting action as well after the occurrence of the anomalous discharge.

[0023]

In actions by the fifth problem solving means (claim 5) described above, when the resistor R2 is connected between the particle collection section and the power supply, the voltage step control unit, which has received the anomalous discharge information from the sensing unit, once shuts off the particle collection

section from the power supply. Then, the resistor R2 is switched to a resistor R1 having a smaller resistance value between the particle collection section and the power supply, and the resulting predetermined voltage is applied to the particle collection section to continue the particle collecting action. Subsequently, (n-2) resistors R3 - Rn are sequentially switched from one to another having a next smaller resistance value to reduce the predetermined voltage in steps. The resulting predetermined voltage is applied to the particle collection section to continue even a higher particle collecting action after the occurrence of the anomalous discharge.

[0024]

In actions by the sixth problem solving means (claim 6) described above, the ventilation system implements the actions of the electrostatic precipitation apparatus for room ventilation as they are.

【Effects of the Invention】

[0025]

As described above in detail, the present invention provides advantageous effects as follows.

The invention according to claim 1 can stably continue a corona discharge or the like in the ionization section, can reduce the predetermined voltage to promptly resume the formation of a normal electric field to continue a particle collecting action even if an anomalous discharge such as sparking occurs due to fluctuations in environment such as humidity, collected particles caused by a continued particle collection, and the like. Once the cause of the anomalous discharge has been eliminated, the applied voltage is increased to promptly resume the particle collecting action. The particle collecting action can be performed at a high efficiency as a whole against an anomalous discharge due to humidity or the like from which the apparatus can be naturally recovered or an anomalous discharge due to deposited particles or the like from which the apparatus can be naturally recovered with difficulties. Moreover, the frequency of maintenance can be reduced.

[0026]

In addition to the advantages described above, the invention according to claim 2 can advantageously perform the particle collecting action even at a higher efficiency and more reduce the frequency of maintenance if substances causing an anomalous discharge can be removed from the particle collection section in the cleaning mode.

[0027]

In the invention according to claim 3, in addition to the advantages described above, the voltage step control unit can freely output a PWM signal commensurate with anomalous discharging information in the CPU, so that the particle collection section can be applied with a finer predetermined voltage. Advantageously, a suitable particle collecting action can be continued as well after the occurrence of the anomalous discharge or after the elimination of the cause of the anomalous discharge.

[0028]

Further, in the invention according to claim 4, in addition to the advantages described above, the voltage step control unit is simply comprised of n resistors arranged in parallel between the particle collection section and the power supply, and the sensing unit for sensing anomalous discharging in the particle collection section. Advantageously, in spite of a simple configuration, a normal electric field can be promptly formed again, even if an anomalous discharge once occurs such as sparking, thus making it possible to continue an appropriate particle collecting action.

[0029]

Further, in the invention according to claim 5, in addition to the advantages described above, the voltage step control unit is simply comprised of n resistors arranged in parallel between the particle collection section and the power supply, and the sensing unit for sensing elimination of a cause for an anomalous discharge in the particle collection section. Advantageously, even if an anomalous discharge once occurs such as sparking, a normal electric field can be promptly formed again, after eliminating the cause for the anomalous discharge, in spite of a simple configuration, thus making it possible to continue an appropriate particle collecting action.

[0030]

Also, the invention according to claim 6 can advantageously provide a ventilation system which has the advantages of the electrostatic precipitation apparatus for room ventilation described above.

[0031]

【Fig. 1】

Fig. 1 is a conceptual diagram showing an electrostatic precipitation unit in an electrostatic precipitation apparatus for room ventilation according to an embodiment of the present invention.

【Fig. 2】

Fig. 2 is a block circuit diagram showing a voltage changing unit of the electrostatic precipitation apparatus in the embodiment of the present invention.

【Fig. 3】

Fig. 3 is a block circuit diagram showing another voltage changing unit of the electrostatic precipitation apparatus in the embodiment of the present invention.

【Fig. 4】

Fig. 4 is a conceptual diagram showing a ventilation system which incorporates the electrostatic precipitation apparatus for room ventilation of the embodiment.

【Fig. 5】

Fig. 5 is a conceptual diagram showing another ventilation system which incorporates the electrostatic precipitation apparatus for room ventilation of the embodiment.

【Fig. 6】

Fig. 6 is a conceptual diagram similar to Fig. 1 showing an electrostatic precipitation unit in a conventional electrostatic precipitation apparatus for room ventilation.

【Detailed Description of Preferred Embodiments】

[0033]

Referring to the drawings, an electrostatic precipitation apparatus 1 for room ventilation comprises an electrostatic precipitation unit 2. The electrostatic precipitation unit 2, which is referred to as a two-stage charging type, comprises an ionization section 3 for charging floating particles in the air; a particle collection section 4 for collecting the charged particles by the action of coulomb force; and a power supply 5 for supplying electric power to the ionization section 3 and particle collection section 4. The electrostatic precipitation unit 2 also comprises a constant-

current control unit 6 which provides a function of applying the ionization section 3 with a constant current so as not to exceed a set voltage; and a sensing unit 7 for constantly sensing an applied voltage value and current value when the particle collection section 4 is applied with a predetermined voltage. The electrostatic precipitation unit 2 further comprises a voltage step control unit 8 which receives the applied voltage value and current value from the sensing unit 7 for issuing a command to change the predetermined voltage up and down in steps in such a manner that the particle collection section 4 does not suffer from an anomalous discharge due to abrupt fluctuations in the applied voltage value and current value or due to continued fluctuations within a certain range. The electrostatic precipitation unit 2 further comprises a voltage changing unit 9 for changing the predetermined voltage up and down in response to the command from the voltage step control unit 8. In this way, the electrostatic precipitation unit 2 is provided with a function of controlling the current and voltage fed from the power supply 5 to the particle collection section 4. The ionization section 3 is applied with a constant current from the power supply 5 through the constant-current control unit 6, while the particle collection section 4 is applied with a predetermined voltage from the power supply through the voltage step control unit 8. When the particle collection section 4 suffers from an anomalous discharge, the particle collection section 4 is once shut down from the power supply 5 in response to a command from the voltage step control unit 8. Then, the voltage applied to the particle collection section 4 is reduced by the voltage changing unit 9 to such a level that does not cause an anomalous discharge, and the particle collection section continues the dust collecting action with the reduced predetermined voltage applied thereto. When the applied voltage value and current value fluctuate within a certain range for a set period of time, the cause of the anomalous discharge is determined to have been eliminated. Then, the voltage changing unit 9, in response to a command from the voltage step control unit 8, increases the predetermined voltage which is applied to the particle collection section 4, thus allowing the particle collection section 4 to continue the particle collecting action.

[0034]

The electrostatic precipitation unit 2 is a so-called two-stage charging-type electrostatic precipitation apparatus, and comprises the ionization section 3, particle collection section 4, and power supply 5. The electrostatic precipitation

apparatus 1 for room ventilation comprises the constant-current control unit 6 interposed between the power supply 5 and the ionization section 3 within the electrostatic precipitation unit 2, and also comprises the voltage stage control unit 8, including the sensing unit 7, and voltage changing unit 9 interposed between the power supply 5 and the particle collection section 4.

[0035]

The ionization section 3 of the electrostatic precipitation unit 2 comprises ionization lines 10 and ionization electrodes 11 for charging floating particles in the air through corona discharging or the like. The ionization lines 10 are connected to a plus terminal 5a of the power supply 5, while the ionization electrodes 11 are connected to a minus terminal 5b of the power supply 5, respectively.

[0036]

The particle collection section 2 of the electrostatic precipitation unit 2 comprises particle collection electrode plates 12 and opposing particle collection electrode plates 13 for collecting charged floating particles with the coulomb force. The particle collection electrode plates 12 and opposing particle collection electrode plates 13 are alternately arranged at equal intervals by spacers, and are connected to the power supply 5 so that a high predetermined voltage can be applied between the particle collection electrode plates 12 and opposing particle collection electrode plates 13 to form a high electric field therebetween. In addition, high resistors 14 are connected between the respective particle collection electrode plates 12 and the power supply 5. Then, the particle collection electrode plates 12 are connected to the plus terminal 5a of the power supply 5, while opposing particle collection electrode plates 13 are connected to the minus terminal 5b of the power supply 5.

[0037]

The power supply 5 is provided to supply the ionization section 3 and particle collection section 4 of the electrostatic precipitation unit 2 with a necessary voltage and current, and is not particularly limited in any aspect as long as this condition is satisfied. In Fig. 1, a switch 15 is provided for switching on/off the connection between the power supply 5 and the ionization section 3 and particle collection section 4.

[0038]

The constant-current control unit 6 of the power supply control system 1 is configured to send a constant current from the power supply 5 to the ionization

lines 10 of the ionization section 3, for example, a constant current in a range of 0.3 to 2.0 mA. In this event, a proper voltage should be within a range of 7,000 V to 8,000 V. However, this constant-current control unit 6 comprises a known function for preventing the voltage from deviating significantly from the range of 7,000 V to 8,000 V, for example, preventing the voltage from reaching 10,000 V or more, in order to send a constant current in the range of 0.3 to 2.0 mA as described above.

[0039]

The voltage step control unit 8 of the power supply control system 1 for room ventilation is configured to issue a command for applying the particle collection electrode plates 12 of the particle collection section 4 with a predetermined voltage, for example, in a range of 1,500 V to 4,800 V from the power supply 5. In this event, a current associated with this operation lies in a range of 0.05 to 0.1 mA. Further, the sensing unit 7 is configured to sense an anomalous discharge which could introduce abrupt fluctuations in the voltage and current applied to the particle collection section 4. For example, when a normal electric field is being formed by applying the particle collection section 4 with a voltage of 4,000 V in a normal mode and a current of 0.1 mA, the sensing unit 4 senses an anomalous discharge which would cause a sudden change in the environment of the particle collection section 4 for some reason, such as humidity, dew condensation, introduction of foreign matters, and the like, or due to deposition of collected particles and the like, giving rise to abrupt fluctuations in the voltage in a range of 1,000 to 1,500 V and in the current to 0.3 mA.

[0040]

Then, when the sensing unit 7 senses an anomalous discharge as described above in the particle collection section 4, the voltage step control unit 8 receives information indicative of the anomalous discharge. Upon receipt of the anomalous discharge information, the voltage step control unit 8 once shuts down the particle collection section 4 from the power supply 5 through the switch 15. Then, putting an eye on the fact that the anomalous discharge can be avoided if the predetermined voltage applied to the particle collection section 4 is reduced, the voltage step control unit 8 transmits a command to the voltage changing unit 9 to change the predetermined voltage to such a level at which the anomalous discharge does not occur. The voltage changing unit 9, upon receipt of the voltage changing command, reduces the predetermined voltage to a level at which the anomalous discharge does not occur, for example, reduces the predetermined voltage by 900 V to

400 V from 3,900 V - 4,100 V, i.e., to 3,200 V - 3,500 V. Subsequently, when the particle collection section 4 again suffers from an anomalous discharge, the power supply control system 1 copes with the anomalous discharge by further reducing the predetermined voltage in steps in the procedure described above, for example, to 2,200 V - 2,600 V.

[0041]

Further, the particle collecting action is continued with the reduced predetermined voltage of 3,200 V - 3,500 V. During the continued particle collecting action, it may be determined that the cause of the anomalous discharge has been eliminated if the voltage value and current value have not presented fluctuations in a certain range, for example, fluctuations reaching to 1,000 V - 1,500 V or 0.3 mA. Even if such fluctuations have been presented, when the fluctuations of less than five times continue for a predefined time, for example, two - ten minutes, the cause of the anomalous discharge can be determined to be eliminated. Then, the voltage step control unit 8 instructs the voltage changing unit 9 to increase the predetermined voltage to 3,900 V - 4,100 V in the normal mode, which is applied to the particle collection section 4 to continue the particle collecting action.

[0042]

Alternatively, when the anomalous discharge occurs, the particle collection section 4 may be once shut off from the power supply 5, thus entering the electrostatic precipitation apparatus 1 into a cleaning mode 16. The cleaning mode 16 is provided, focusing on the fact that substances causing an anomalous discharge, for example, foreign matters can be removed by setting the predetermined voltage applied to the particle collection section 4 higher than that applied in a normal particle collecting action, resulting in avoidance of anomalous discharges. Specifically, the cleaning mode 16 is added to the voltage step control unit 8. When an anomalous discharge occurs with the particle collection section 4 being applied with the predetermined voltage of 3,900 V - 4,100 V in the normal mode. The power supply to the particle collection section 4 is once stopped by a command issued by the voltage step control unit 8. Further, the voltage changing unit 6 increases the predetermined voltage by 300 V - 500 V from the aforementioned 3,900 V - 4,100 V, i.e., to 4,200 V - 4,600 V. This increased voltage is then applied to the particle collection section 4 for a predefined time, for example, three - 30 seconds to clean the particle collection section 4. After the cleaning is over, the predetermined voltage is

set back to 3,900 V - 4,100 V before the occurrence of the anomalous discharge.

[0043]

In regard to the change of the predetermined voltage by the voltage step control unit 8 and voltage changing unit 9, for example, as shown in Fig. 2, a CPU 20 of the voltage step control unit 8 which has received the anomalous discharge information compares the received anomalous discharge information with previously stored information, determines a predetermined voltage at a level which does not cause the particle collection section 4 to anomalously discharge, and transmits the resulting voltage changing command to an amplifier circuit 21 in the form of PWM (pulse width modulation) signal. Then, through the voltage changing unit 9 which is composed of the amplifier circuit 21 which has received the PWM signal, a booster transformer 22, and a booster circuit 23, the particle collection section 4 is applied with a predetermined voltage commensurate with the PWM signal.

[0044]

Alternatively, the change of the predetermined voltage by the voltage step control unit 8 and voltage changing unit 9 may be implemented, for example, as shown in Fig. 3. Specifically, a voltage step control unit 8A issues a command to a voltage changing unit 9A which has n resistors ($R1 < R2 < \dots < R_{n-1} < R_n$) arranged in parallel between the particle collection section 4 and the power supply 5. Then, as the sensing unit 7 senses an anomalous discharge while the resistor $R1$ is connected between the particle collection section 4 and the power supply 5, the particle collection section 4 is once shut off from the power supply 5 through the switch 15. Next, the resistor $R1$ is switched to the resistor $R2$ having a larger resistance value between the particle collection section 4 and the power supply 5, and thereafter, the particle collection section 4 is applied with a predetermined voltage at a level at which an anomalous discharge does not occur, allowing the particle collection section 4 to recover the normal particle collection even after the anomalous discharge. Subsequently, the particle collection section 4 continues the normal particle collection as long as an anomalous discharge does not occur again. Afterwards, $(n-2)$ resistors R arranged between the particle collection section 4 and the power supply 5 are sequentially switched to resistors $R3 - R_n$ having larger resistance values to change in steps the predetermined voltage which is then applied to the particle collection section 4, thus allowing the particle collection section 4 to continue the particle collecting action even after the anomalous discharge.

[0045]

It should be noted that n resistors R have resistance values within several $M\Omega$, and are in the relationship of $R_1 < R_2 < \dots < R_{n-1} < R_n$. While the resistors R are not particularly limited in number, three to five resistors may be a proper quantity.

[0046]

Also, when the cleaning mode 16 is added to the voltage step control unit 8, a resistor pR having a resistance value lower than that of the resistor R_1 ($pR < R_1$) may be provided for the cleaning mode. The particle collection section 4 is applied with the predetermined voltage of 3,900 V - 4,100 V for the normal mode through the resistor R_1 . When an anomalous discharge occurs, the power supply is once shut off, the resistor R_1 is switched to the resistor pR , and the predetermined voltage is increase to 4,200 V - 4,600 V. The particle collection section 4 is applied with the increased voltage for a predefined time for cleaning the same. Subsequently, the predetermined voltage may be again reduced to 3,900 V 0 4,100 V for the normal mode. Further alternatively, the resistor pR may not be provided, and one of the n resistors, e.g., R_1 may be used for the cleaning mode 16, in which case a resistor R_2 may be used as a resistor for the normal mode at the onset of particle collection.

[0047]

Further alternatively, the change of the predetermined voltage by the voltage step control unit 8 and voltage changing unit 9 may be implemented in the following manner. Specifically, a voltage step control unit 8A issues a command to the voltage changing unit 9A which has n resistors ($R_1 < R_2 < \dots < R_{n-1} < R_n$) arranged in parallel between the particle collection section 4 and the power supply 5. Then, when the applied voltage value and current value continue to fluctuate for a predefined time within a certain range as described above while any of the n resistors except for R_1 ($R_2 < \dots < R_{n-1} < R_n$) is connected between the particle collection section 4 and the power supply 5, the particle collection section 4 is once shut off from the power supply 5. Next, the resistor is switched to another one having the next smaller resistance value between the particle collection section 4 and the power supply 5, and the resulting predetermined voltage is applied to the particle collection section 4. Afterwards, $(n-2)$ resistors R arranged between the particle collection section 4 and the power supply 5 may be sequentially switched to resistors $R_1 \sim R_{n-1}$ having next smaller resistance values to increasingly change in steps the

predetermined voltage, which is then applied to the particle collection section 4.

[0048]

The electrostatic precipitation apparatus 1 for room ventilation configured as described above may be combined with a heat exchanger 30, and mounted in a building 32 as a ventilation system 31. Specifically, the electrostatic precipitation apparatus 1 for room ventilation may be mounted near an air supply port 33 of the building 32, and may be connected to an inlet port 35 of a room 34 through the heat exchanger 30. The room 34 has an outlet port 36 connected to an air discharge port 37 of the building 32 through the heat exchanger 30. Then, external air entering from the air supply port 33 of the building 32 by the action of an air supply fan 39 connected between the heat exchanger 30 and the air discharge port 37, is purified by the electrostatic precipitation apparatus 1 for room ventilation, and is introduced into the room 34 from the inlet port 35 as heated or cooled fresh air. On the other hand, stagnant air within the room 34 goes out from the outlet port 36 by the action of a ventilation fan 39 connected between the heat exchanger 30 and air discharge port 37, passes through the heat exchanger 30 to heat or cool external air which has entered from the air supply port 33. The stagnant air itself is cooled or heated, and goes out from the air discharge port 37 of the building 32.

[0049]

Also, the electrostatic precipitation apparatus 1 for room ventilation may be combined, for example, with an air conditioner 40, instead of the heat exchanger, as shown in Fig. 5, and may be mounted in a building 32 for use as a ventilation system 32A. Since the rest of the configuration and actions in Fig. 5 are similar to those of the ventilation system 31 shown in Fig. 4, similar elements in Fig. 5 are designated by the same reference numerals used in Fig. 4, and a description thereon is omitted. Notably, stagnant air within the room may be entirely or partially returned to the electrostatic precipitation apparatus 1 for room ventilation after it goes out from the outlet port 36.

[0050]

In the following, a detailed description will be given of the operation of the electrostatic precipitation apparatus 1 for room ventilation as described above, in connection with a ventilation system 21 or 21A.

First, the ventilation system 21 or 21A is made operative, and the power supply 5 of the electrostatic precipitation apparatus 1 is turned ON. In this

state, as external air supplied from the air supply port 33 of the building 32 enters into the ionization section 3 of the electrostatic precipitation unit 2 from a direction indicated by an arrow K in Fig. 1. The floating particles in the air, such as dust, pollen, insects, yellow sand, PM2.5, and the like, are charged through a corona discharge or the like which is present between the ionization lines 10 and the ionization electrodes 11 in the ionization section 3. Then, due to contamination on and/or oxidization of the surfaces of the ionization lines 10, and the like, associated with a continuous operation of the electrostatic precipitation unit 2, the corona discharge tends to stably occur with more difficulties unless a higher voltage is applied to the electrostatic precipitation unit 2 than the initially applied voltage. However, the ionization lines 10 of the ionization section 3 is applied with a constant current, for example, a constant current in a range of 0.3 to 2.0 mA from the power supply 5 through the constant-current control unit 6, so that even if the ionization lines 10 are contaminated, oxidized, or the like on the surface, the initially applied voltage can be effectively changed to a higher voltage, allowing the corona discharge to occur with stability. Accordingly, the ionization section 3 is free from degradations in the ability to charge floating particles, and therefore free from degradations in particle collection efficiency due to such influences as contamination, oxidization, and the like on the surfaces of the ionization lines 10.

[0051]

Further, as the air including the charged floating particles enters into the particle collection section 4, the charged floating particles are collected by a plurality of particle collection electrode plates 12 or opposing particle collection electrode plates 13 with the coulomb force by a high electric field which is generated by applying a predetermined voltage, for example, 3,900 V - 4,100 V for the normal mode, between a plurality of particle collection electrode plates 12 and a plurality of opposing particle collection electrode plates 13 of the particle collection section 4. Then, clean air is emitted from the particle collection section 4 after the particle collection. When an anomalous discharge such as sparking occurs due to a varying environment between a plurality of particle collection electrode plates 12 or opposing particle collection electrode plates 13, possibly caused by humidity, dew condensation, foreign matters, deposited floating particles, or the like, a high electric field cannot be maintained between a plurality of particle collection electrode plates 12 and a plurality of opposing particle collection electrode plates 13, or a predetermined voltage

cannot even be applied thereto. However, the voltage step control unit 8 and voltage changing unit 9 once stop the predetermined voltage applied from the power supply 5 to the plurality of particle collection electrode plates 12 of the particle collection section 4, and subsequently reduce the predetermined voltage in steps to 3,200 V - 3,500 V and further to 2,200 V - 2,600 V to once eliminate the anomalous discharge, and then generate a high electric field again. As such, even after the anomalous discharge occurs between a plurality of particle collection electrode plates 12 and a plurality of opposing particle collection electrode plates 13, the particle collecting action is continued, though the particle collection efficiency is slightly lowered due to the reduction in the predetermined voltage applied to the particle collection section 4, thus making it possible to extend a period between maintenances for washing the particle collection section 4, and the like.

[0052]

With the cleaning mode 16 added to the voltage step control unit 8 as described above, when the particle collection section 4 is applied with the predetermined voltage of 3,900 V - 4,100 V for the normal mode, the cleaning mode 16 causes the predetermined voltage to be increased by 300 V - 500 V, i.e., to 4,200 V - 4,600 V. The increased predetermined voltage is then applied to the particle collection section 4 for a predefined time to clean the same. Subsequently, the predetermined voltage is set back to 3,900 V - 4,100 V as before the occurrence of the anomalous discharge. In another case, if an anomalous discharge occurs when the particle collection section 4 is being applied with the predetermined voltage of 3,200 V - 3,500 V, the predetermined voltage is increased to original 3,900 V - 4,100 V, which is applied to the particle collection section 4 for a predefined time to clean the same. Subsequently, the predetermined voltage is set back to 3,900 V - 4,100 V as before the occurrence of the anomalous discharge. Likewise, the particle collection section 4 can be cleaned in the same manner when it is applied with the predetermined voltage of 2,200 V - 2,600 V.

[0053]

In this way, external air, from which floating particles have been removed, such as dust, pollen and insects, yellow sand and PM2.5, and the like, enters from the inlet port 35 into the room 34 through the heat exchanger 30 as cooled or heated purified fresh air when the ventilation system 31 is implemented as shown in Fig. 4. On the other hand, stagnant air within the room 34 goes out from the outlet

port 36 of the room 34, passes through the heat exchanger 30 to heat or cool external air entering from the air supply port 33, and exits to the outside from the air discharge port 37 of the building 32. When the ventilation system 31A is implemented as shown in Fig. 5, external air, from which floating particles have been removed, is conditioned by the air conditioner 40 to become fresh air which enters into the room 34. Stagnant air within the room 34 goes out from the room 34, again enters the air conditioner 40, and is conditioned thereby to be fresh air which enters into the room 34.

[0054]

While one embodiment of the present invention has been described above, it should be understood that the present invention is not limited to the particular configuration set forth above, but can be modified as appropriate without departing from the scope and spirit of the invention defined in claims.

【Industrial Availability】

[0055]

The electrostatic precipitation apparatus for room ventilation and the ventilation system using the same according to the present invention can stably continue corona discharge or the like in an ionization section, and can promptly resume the application of a normal voltage to continue a particle collecting action even if an anomalous discharge such as sparking occurs. Accordingly, the electrostatic precipitation apparatus and the ventilation system provide an extremely high availability when the particle collecting action is degraded due to humidity, dew condensation, and the like and can be naturally recovered. When foreign matters or collected particles can be readily removed by a simple cleaning operation, the application of a normal voltage at a higher level can be promptly resumed to allow the particle collection section to continue the particle collecting action, thus improving a particle collection efficiency as a whole, and extremely enhancing the availability of the electrostatic precipitation apparatus when one wishes to reduce the frequency of maintenance.

【Claim 1】

An electrostatic precipitation apparatus for room ventilation, having a two-stage charging type electrostatic precipitator comprising an ionization section for charging floating particles in the air, a particle collection section for collecting charged floating particles with a coulomb force, and a power supply for supplying electric power to said ionization section and said particle collection section,

said apparatus comprising:

a constant-current control unit interposed between said power supply and said ionization section for supplying said ionization section with a constant current which does not cause a predefined voltage to be exceeded;

a sensing unit interposed between said power supply and said particle collection section for sensing an applied voltage value and current value at all times when said particle collection section is applied with a predetermined voltage;

a voltage step control unit for receiving the applied voltage value and current value from said sensing unit for issuing a command to increase or decrease the predetermined voltage so as to prevent said particle collection section from anomalously discharging in response to an anomalous discharge caused by a sudden fluctuation of the applied voltage value and current value and a continued fluctuation of the applied voltage value and current value within a certain range; and

a voltage changing unit for changing the predetermined voltage in response to a command from said voltage step control unit to control a current and a voltage sent from said power supply to said particle collection section,

said apparatus characterized in that:

said ionization section is applied with a constant current through said constant-current control unit;

said particle collection section is applied with the predetermined voltage through said voltage step control unit;

upon occurrence of an anomalous discharge, said voltage step control unit once stops supplying power to said particle collection section;

said voltage changing unit subsequently changes the predetermined voltage to a level at which an anomalous discharge does not occur, said changed predetermined voltage applied to said particle collection section to continue a particle

collecting action; and

when said applied voltage value and current value continue to fluctuate within a certain range for a predefined time, a determination is made that a cause of the anomalous discharge has been eliminated, allowing said voltage step control unit to issue a command to said voltage changing unit to increase the predetermined voltage, said increased predetermined voltage being applied to said particle collection section to continue a particle collecting action.

【Claim 2】

An electrostatic precipitation apparatus for room ventilation according to claim 1, wherein:

said voltage step control unit operates in a cleaning mode, said cleaning mode including, upon occurrence of an anomalous discharge due to the predetermined voltage applied to said particle collection section, once shutting off the power supply to said particle collection section with a command from said voltage step control unit, causing said voltage changing unit to apply a voltage higher than the predetermined voltage to said particle collection section to clean said particle collection section.

【Claim 3】

An electrostatic precipitation apparatus for room ventilation according to claim 1, wherein said voltage step control unit outputs a PWM (pulse width modulation) signal having a predetermined value from a CPU (central processing unit) to an amplifier circuit, such that said particle collection section is applied with the predetermined voltage commensurate with the PWM signal from said voltage changing unit.

【Claim 4】

An electrostatic precipitation apparatus for room ventilation according to claim 1 or 2, wherein:

said voltage changing unit includes n resistors ($R_1 < R_2 \dots < R_{n-1} < R_n$) arranged in parallel between said particle collection section and said power supply,

when said sensing unit senses an anomalous discharge while a resistor R_1 is connected between said particle collection section and said power supply, said

voltage step control unit issues a command to said voltage changing unit to once shut off said particle collection section from said power supply and subsequently switch the resistor R1 to a resistor R2 having a larger resistance value between said particle collection section and said power supply, said particle collection section being applied with the predetermined voltage, and

said voltage step control unit subsequently switches (n-2) arranged resistors to resistors R3 - Rn having larger resistance values to change in steps the predetermined voltage, and applies the changed predetermined voltage to said particle collection section.

【Claim 5】

An electrostatic precipitation apparatus for room ventilation according to claim 1 or 2, wherein:

said voltage changing unit includes n resistors ($R1 < R2 \dots < R_{n-1} < R_n$) arranged in parallel between said particle collection section and said power supply,

when the applied voltage value or current value fluctuate within a certain range for a predefined time while one of the n resistors except for R1 ($< R2 \dots < R_{n-1} < R_n$) is connected between said particle collection section and said power supply, said voltage step control unit issues a command to said voltage changing unit to once shut off said particle collection section from said power supply, and subsequently switches the one resistor to another resistor R1 - Rn-1 having a sequentially smaller resistance value between said particle collection section and said power supply to increase said predetermined voltage in steps, said particle collection section being applied with the predetermined voltage, and applies the increased predetermined voltage to said particle collection section.

【Claim 6】

A ventilation system characterized by utilizing an electrostatic precipitation apparatus for room ventilation according to any of claims 1 - 5.