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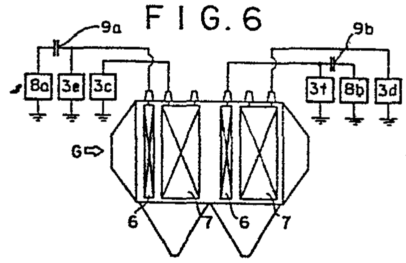
(54) **Two-stage electrostatic precipitator.**

(57) A two-stage electrostatic precipitator includes a charging unit for mainly charging dust and a dust collecting unit for mainly collecting dust, wherein the charging unit utilizes a discharging electrode having a uniform cross section and the discharging electrode is applied with a high voltage pulse superimposed on a direct current high voltage, then the electrostatic precipitator is further improved in that a dust collecting electrode of the collecting unit is disposed polygonally and a small section damper for cutting off the flow of gas is provided downstream of the collecting unit, so that the economical efficiency and the dust collecting efficiency of the precipitator are improved.

F I G. 6



EP 0 161 205 A2

BACKGROUND OF THE INVENTION:

(i) FIELD OF THE INVENTION

The present invention relates to the improvement of a two-stage electrostatic precipitator including a charging unit and a dust collecting unit.

(ii) DESCRIPTION OF THE PRIOR ART

Generally, the dust collecting performance of the electrostatic precipitator is determined by an electric resistance of dust contained in gas.

In a prior art electrostatic precipitator (hereinafter referred to as EP), when the electric resistance of dust is increased and the specific resistance thereof exceeds 10"Ω-cm, the dust collecting efficiency is greatly reduced since the isolation breakdown, that is, the inverse ionization phenomenon is produced in a layer of dust deposited on the dust collecting electrode. Accordingly, when the high resistance dust is handled as in the EP for use in a thermal power plant using coal and a sintering machine, the dust collecting capacity of the EP is generally required to be increased in order to compensate the reduction of the collecting efficiency.

Accordingly, various countermeasures for the high resistance dust have been made. One of them is a two-stage EP which has widely been put to practical use in an air cleaner and the like. This EP is divided into a charging unit for charging dust and a dust collecting unit for collecting dust by using a high electric field and there is an attempt that a manner in which the inverse ionization is suppressed by minimizing current in the high electric field portion (the starting condition of the inverse ionization is $\rho d \times id \geqq Edc$. When the current id flowing in the dust layer is less, the breakdown voltage Edc of the dust layer is not exceeded even if the electric resistance of the dust is high.) is intended to be applied to general industries.

However, even in this case, it is difficult to suppress the inverse ionization in the dust charging unit. Various methods have been attempted hitherto.

By way of example, there is a manner in which a pipe is used as a dust collecting electrode which is cooled by flowing water into the pipe to decrease an electric resistance of the dust so that the inverse ionization is suppressed. Further, there is another manner using a third electrode disposed between the dust collecting electrode and the discharging electrode, in which the inverse ionization is suppressed by absorbing inversely polarized ions which are produced in the inverse ionizing state.

There has been proposed a particle charging device (Japanese Patent Application No. 106400/77 and others) named a boxer charger in which dust is charged without the inverse ionization by controlling the charge.

However, any of these manners is difficult to be put to practical use in a commercial scale for the general industries and is not put to practical use.

On the other hand, there is a pulse charge manner which is intended to improve the performance of a prior art EP by controlling the charge. In this manner, a high voltage in the form of pulse is instantly supplied to apply a high peak voltage and obtain uniform current so that the dust collecting efficiency is increased. However, in this case, there are problems such as a cost of the pulse supply source and reduction of the power consumption.

In a prior art EP shown in FIGS. 1 to 5, when dust collecting electrodes 1 and discharging electrodes 2 shown in FIGS. 2 and 3 are applied with a high voltage by DC high voltage generators 3a and 3b shown in FIG. 1, a current-voltage characteristic as shown by (a) of FIG. 4 is obtained in a normal stage. Thus, the EP can operate in the stage in which high current and high voltage are applied and hence high collecting efficiency is obtained. However, when the inverse ionization is generated by the collection of high resistance dust, the characteristic as shown in (b) of FIG. 4 is obtained in which the operating voltage is low and an effective current is limited to P2 with the other current being dissipated as reactive current in the inverse ionization portion, so that the collecting efficiency is reduced.

Therefore, as shown in FIG. 1, high voltage pulse generators 8c and 8d are added to the DC high voltage generators 3a and 3b through coupling condensers 9c and 9d to change the charging characteristic as shown by dashed line h of FIG. 4. Thus, by utilizing the uniform discharge characteristic of the pulse charging, the operation is made with high current density to improve the performance.

However, in the prior art EP, since the dust charging and collection are made together in respective gas flow ducts, the discharging electrode is formed of one having the good discharge characteristic such as the electrode 2 having spines as shown by (A), (B) and (C) of FIG. 5 or the electrode 2 having small radius of curvature (d=1-3 mm ϕ) as shown by (D) and (E) of FIG. 5. Therefore, when the charging pulse is superimposed, current effective to charge dust can be increased but the increase of the electric field effective to collect dust can not expected and great improvement is not attained.

Further, when all area of the flow duct for gas in EP is charged by the pulse charging, the pulse generator is expensive. When energy is dissipated as Joule's heat by a waveforming resistance in order to generate a voltage pulse, the power consumption is increased.

Prior arts of the present invention are as follows:

(1) U.S. Patent Nos. 4138233, 3980455, 4094653, 4183736, 4209306 and 3763632.

(2) U.S. Patent Nos. 3570218, 4018577 and 4126434.

On the other hand, another prior art electrostatic precipitator includes, as shown in FIG. 17, a plurality of dust collecting units 12 which are disposed in a body 11 of the apparatus along the flowing direction of gas shown by an arrow G and collect dust in gas. The dust collecting unit 12 comprises a plurality of dust collecting electrodes 21 disposed in parallel with the flowing direction of gas and in opposed relationship with each other and a plurality of discharging electrodes 22 disposed between the collecting electrodes 21 as shown in FIG. 18. More particularly, the collecting unit 12 is constructed so that a high voltage is applied between the collecting electrodes 21 and the discharging electrodes 22 to produce the corona discharge and charge dust in gas so that dust is collected on the collecting electrodes 21. The collecting electrodes 21 on which dust is collected are hit and vibrated by hammers 13 provided in the body 11 so that the dust collected by the collecting unit 12 is shaken down into hoppers 14 disposed under the collecting unit 12 and exhausted outside by a conveyor 15.

In such a prior art electrostatic precipitator, when the electric resistance of the dust is equal to 10"Ω·cm or more, the inverse ionization is produced and the collection efficiency is reduced. Further, while the dust collected by the collecting unit 12 is shaken down into the hoppers 14 by the hammers 13, a portion of the dust is scattered again into the flow of gas and can not be collected by the hoppers 14, so that the dust collection efficiency is reduced.

A prior art of the present invention with respect to the above apparatus is disclosed in U.S. Patent No. 4178156.

SUMMARY OF THE INVENTION:

The present invention is made in order to resolve the above drawbacks.

(i) It is an object of the present invention to provide an electrostatic precipitator with compact structure and high performance and utilizing a pulse supply source economically in total.

(ii) It is another object of the present invention to provide an electrostatic precipitator with high dust collection efficiency by combination of a charging unit for charging dust as much as possible and a dust collecting unit having an improved structure of a dust collecting electrode.

(iii) It is still another object of the present invention to provide an electrostatic precipitator which prevents the reduction of the collection performance due to the inverse ionization phenomenon and re-scattering of dust and can collect dust in gas effectively.

Accordingly, the gist of the present invention is as follows.

A two-stage electrostatic precipitator including a charging unit for mainly charging dust and a dust collecting unit for mainly collecting dust is featured by the following items (i), (ii), (iii), (iv) and (v), respectively.

(i) The charging unit uses a discharging electrode having substantially uniform cross section and the discharging electrode is applied with a high voltage pulse superimposed on a DC high voltage.

(ii) The charging unit comprises a discharging electrode having substantially uniform cross section and a plate-like or round dust collecting electrode and a high voltage pulse superimposed on a DC high voltage is applied between both the electrodes.

(iii) Dust collecting electrodes in the form of a rod disposed in the direction substantially perpendicular to the flowing direction of gas and having substantially uniform cross section are disposed to form a polygon and a charging unit includes a discharging electrode disposed at a substantially equally spaced position from each apex of the polygon formed by the collecting electrode.

(iv) Dust collecting electrodes in the form of a rod disposed in the direction substantially perpendicular to the flowing direction of gas and having substantially uniform cross section are disposed to form a polygon and a charging unit includes a discharging electrode disposed at a substantially equally spaced position from each apex of the polygon formed by the collecting electrodes, and a high voltage pulse superimposed on a DC high voltage is applied between the discharging electrodes and the collecting electrodes.

(v) A charging unit and a dust collecting unit are disposed along the flowing direction of gas and a small sectional damper for cutting off the flow of gas is disposed downstream of the dust collecting unit.

The present invention provided with the above construction attains the following effects.

(i) The function of the charging unit for charging dust rapidly can be greatly improved. Since the dust is charged previously in the charging unit, the supply of current in the dust collecting unit may be a minimum value required to prevent the re-scattering of the dust. Therefore, a high electric field can be maintained without the inverse ionization and the high dust collection efficiency can be attained. Accordingly, the electrostatic precipitator with compact structure in total and high efficiency can be achieved.

Further, since a cost of the pulse supply source and the power consumption are proportional to a capacitance between the discharging electrode and the dust collecting electrode, it is very economical to utilize the pulse supply source while limiting to only the charging unit.

In this manner, the present invention is to provide a two-stage electrostatic precipitator with compact structure and high performance and capable of utilizing the pulse supply source economically.

(ii) The electrode structure of the present invention can form uniform current density near the dust collecting electrode and high electric field near the discharging electrode and the collecting electrode. By utilizing this characteristics, dust is charged uniformly and high operating electric field for the high resistance dust is obtained, so that the function of the two-stage EP is improved.

Further, when the high voltage pulse is applied by the high voltage pulse generator connected through the coupling condenser, the effects is more remarkable.

(iii) According to the present invention, the charging unit for charging dust in gas and the collecting unit for collecting dust charged by the charging unit by the coulomb force are disposed along the flowing direction of gas and the small sectional damper for cutting off the flow of gas is provided downstream of the collecting unit. Accordingly, there can be provided the electrostatic precipitator which prevents the reduction of the collection performance due to the inverse ionization and the re-scattering of dust and can collect dust in gas effectively.

BRIEF DESCRIPTION OF THE DRAWINGS:

FIG. 1 shows a construction of a prior art electrostatic precipitator;

FIG. 2 is a plan view of the precipitator of FIG. 1;

FIG. 3 is an enlarged view of an electrode unit;

FIG. 4 is a characteristic diagram showing a relation of electric current and voltage of the electrode unit of FIG. 3;

FIG. 5 is perspective views showing electrodes;

FIG. 6 is a structural diagram of a two-stage electrostatic precipitator showing an embodiment of the present invention;

FIG. 7 is a plan view of the precipitator of FIG. 6;

FIG. 8 is an enlarged view of an electrode unit of the precipitator;

FIG. 9 shows a combinational layout of a charging unit and a collecting unit of the precipitator;

FIG. 10 is a characteristic diagram showing a relation of electric current and voltage of the charging unit;

FIG. 11 is perspective views of discharging electrodes of the precipitator;

FIG. 12 is plan views showing layouts of the collecting electrodes and the discharging electrodes of the present invention, in which (A) shows a square layout and (B) shows a equilateral triangle layout;

FIG. 13 shows an electrode construction of a prior art two-stage electrostatic precipitator;

FIG. 14 shows current density distribution characteristics of the collecting electrode, in which (A) shows a characteristic of the present invention and (B) shows a prior art characteristic;

FIG. 15 shows characteristics of electric field strength distribution, in which (A) shows area having high electric field of the present invention, (B) shows an electric field strength distribution curve in (A), (C) shows area having high electric field of the prior art and (D) shows an electric field strength distribution curve in (C);

FIG. 16 is a side view schematically illustrating a construction of another prior art electrostatic precipitator;

FIG. 17 is a perspective view showing a construction of a dust collecting unit of FIG. 16;

FIGS. 18 to 20 show an embodiment of the present invention; in which

FIG. 18 is a side view schematically illustrating a construction of a two-stage electrostatic precipitator;

FIG. 19 is a perspective view schematically illustrating a charging unit and a collecting unit;

FIG. 20 is a perspective view showing an example of small sectional dampers;

FIG. 21 is a side view of a multi-stage electrostatic precipitator showing another embodiment of the present invention; and

FIG. 22 is a side view of an electrostatic precipitator showing a modified example of the present invention.

DETAILED DESCRIPTION OF THE INVENTION:

The present invention will now be described in detail based on embodiments shown in FIGS. 6 to 12, 14, 15 and 18 to 22.

The first embodiment will now be described with reference to FIGS. 6 to 11.

Referring to FIGS. 6 and 7, the electrostatic precipitator includes charging units 6 and dust collecting units 7. The charging units and the collecting units are disposed in combination in the form of a single or a plurality of combinations of the charging unit and the collecting unit or the charging unit, the collecting unit and the collecting unit as shown in FIG. 9.

The charging unit 6 is composed of discharging electrodes 4 which are in the form of a round wire of 3 to 10 mm as shown by (A) of FIG. 11, or in the form of a square wire of diagonal width 4 to 10 mm as shown by (B) of FIG. 11, or in the form similar to the wire and having a uniform cross section along the length thereof as shown by (C) and (D) of FIG. 11, and plate-like or round dust collecting electrodes 1a which have less unevenness and can form uniform electric field on the surface thereof as shown in FIG. 8, A DC high voltage is applied between both the electrodes 4 and 1a from a DC high voltage generators 3c and 3f shown in FIG. 6 and further a high voltage pulse of several tens ns to several hundreds μs is applied from a high voltage pulse generators 8a and 8b through coupling condensers 9a and 9b therebetween while superimposed on the DC high voltage.

Even if the collecting unit 7 is composed of a combination of dust collecting electrodes and discharging electrodes which have been widely used hitherto, it is effective by combining it with the above charging unit 6. However, as a more effective combination, there is considered a combination of the discharging electrodes 5 and the dust collecting electrodes 1b which can obtain a voltage as high as possible by minimizing a pitch between the discharging electrodes 5 along the flow of gas or by making large the radius of curvature of the discharging electrodes 5 or the equivalent radius of curvature of the electrodes 5 which are not round.

Since the electrostatic precipitator of the embodiment of the present invention is constructed above, a high electric field is generated but current does not flow as shown by c or d of FIG. 10 when a normal DC high voltage is applied. However, when the high voltage pulse is superimposed on the charging unit 6 composed of the discharging electrodes 4 and the collecting electrodes la having a characteristic of less current flowing, there is obtained a current and voltage characteristic that a relatively high current density is obtained while maintaining a high electric field as shown by e of FIG. 10 in the case of high resistance dust. Hence, dust can be charged highly.

The charging unit 6 charges dust mainly but possesses a dust collecting function to a certain extent. Accordingly, the unit 6 is constructed so that dust is shaken down by hammers in the same manner as in a ordinary electrostatic precipitator.

The charged dust is then collected on the collecting electrodes by the force of the electric field in the collecting unit 7. The electrodes of the collecting unit 7 are constructed so that current does not almost flow and a high electric field strength is obtained. The collecting unit 7 is combined with the above charging unit 6 to obtain the high dust collection efficiency.

In the same manner as the general two-stage EP, the discharging electrode may be formed of a plate and the collecting unit may be formed of the parallel plates generating a high electric field.

In the embodiment, the discharging electrodes 4 having a uniform section without spine as shown in FIG. 11 are used to be applied with the high voltage pulse of several tens ns to several hundreds μs superimposed on the ordinary DC high voltage and the electrodes are functioned as the charging unit 6 for mainly charging dust in the EP. Further, the charging unit 6 is combined with the collecting unit 7 of the next stage which is a charging section of low current and high electric field to obtain the high dust collection performance.

(1) When the discharging electrodes 4 having uniform cross section without spine are applied with the ordinary DC high voltage, current does not almost flow as shown by a curve c or d of FIG. 10 and the state then shifts to a spark generating state, or the state shifts to the inverse ionizing state under the very low current and high voltage condition. However, by superimposing the pulse voltage of several tens ns to several hundreds μs on the DC high voltage, the current and voltage characteristic as shown by curve e of FIG. 10 is obtained and the operation can be made as shown by P4 of FIG. 10 without generation of the inverse ionization at a higher current density as compared with the inverse ionization start condition P3 in which the pulse voltage is not superimposed. Accordingly, the function of promptly charging dust can be greatly improved.

In this case, when the prior art discharging electrode 2 shown in FIG. 5 is used, since the current and voltage characteristic is as shown by curve f of FIG. 10 in the ordinary charging state or as shown by curve g of FIG. 10 in the pulse voltage superimposed state, the voltage is low while the current density can be obtained. Accordingly, the amount of saturation charge for dust is limited to low and hence dust is not sufficiently charged.

(2) In the prior art, even if the current is increased more than the inverse ionization start condition (P4) of the current and voltage characteristic of FIG. 10, since the current is consumed due to the increase of ions of reverse porality and voltage is not increased, the dust collection efficiency is not increased.

However, in the present embodiment, since the dust is incresingly charged even in the operating range over P4, the dust collection efficiency in total can be improved due to improvement of the dust collection efficiency in the latter stage of the high electric field portion, while the dust collection efficiency of only the charging unit is not improved. In the prior art charging manner, when the inverse ionization is generated, the current flows locally and the current is consumed by the local portion only. When the pulse voltage is superimposed, the current flows uniformly in the inverse ionization generating state.

Accordingly, while the ions of reverse porality are increased, the absolute supply of ions is increased by increasing the current, so that the dust is increasingly charged. This is confirmed by experiments.

(3) In the embodiment, the function of the EP is divided into two stages and the high voltage pulse of several tens ns to several hundreds μs superimposed on the DC high voltage is applied to only the charging unit 6 for mainly charging dust, so that the pulse supply source can be utilized economically and effectively.

In the electrostatic precipitator of the embodiment, a particle of 1 micron, for example, can be charged 65% of the saturated charge quantity for the charging time of o.1 second and 95% for 1 second on the basis of a calculation in the condition of the current density of 0.2 mA/m^2 and the electric field strength of 3 kV/cm. Accordingly, if the velocity of gas is 1 m/s, it is sufficient practically that the length of the charging portion is several tens cm to 1 m.

As described above, according to the present invention, the discharging electrode having the substantially uniform cross section and the characteristic that the corona start voltage is high and the current is difficult to flow when the ordinary DC high voltage is applied is combined with the dust collecting electrode capable of forming the uniform and high electric field on the surface thereof and the high voltage pulse having a pulse width of several tens ns to several hundreds μs superimposed on the DC high voltage is applied between both the electrodes so that the high current density is obtained while maintaining the high electric field strength for the high resistance dust. In view of this characteristic, this conception is mainly utilized as the charging unit of dust and the subsequent charging section for applying the DC high voltage is utilized as the dust collecting unit. Accordingly, the present invention is to provide the electrostatic precipitator with compact structure and high performance and utilizing the pulse supply source economically in total by combination of the charging unit and the collecting unit.

Another embodiment of the present invention will now be described with reference to FIGS. 12, 14 and 15.

Referring to FIG. 12(A), the dust collecting electrodes 1a have a circular or similar uniform cross section in the direction perpensicular to the gas flow G and the discharging electrode 2a is disposed at the equal distance from each apex of the polygon in the polygon formed by the centers of the collecting electrodes 1a.

The collecting electrodes 1a form squares in FIG. 12(A) and form equilateral triangles in FIG. 12(B). The combination of the electrodes is not limited to the square or the equilateral triangle and may be any polygon such as a rectangle or an isosceles triangle which has a point at the equal distance from each apex thereof. However, the polygon such as the square or the equilateral triangle is desirable.

In FIG. 12, the number of the polygons in the flowing direction of gas shown by a arrow G is two for one charging unit. The number is not limited to two and may be single or three or more. In FIG. 12, numeral 3 denotes a DC high voltage generator, numeral 8 a high voltage pulse generator and numeral 9 a coupling condenser for applying a pulse voltage.

The prior art two-stage EP includes a charging unit Y and the dust collecting unit Z constructed integrally as shown in FIG. 13. The charging unit is composed of a combination of a pair of discharging electrodes 2b and a dust collecting electrode 1b and the collecting unit is composed of a combination of a discharging plate 2c for applying a high voltage and the collecting electrode 1b.

Operation of the electrostatic precipitator of the embodiment having the above electrode construction will now be described.

In accordance with the layout of electrodes shown in the embodiment, the collecting electrode 1a or 1b forms the very uniform current density $I\rho_2$ on the surface of the round collecting electrode 1a as shown in the current density distribution characteristic of FIG. 14(A) as compared with the current density $I\rho_1$ of the prior art electrode combination (1b and 2b) shown in FIG. 14(B). This is conformed by the theoretical calculation and the experimental measurement of the inventor.

On the other hand, FIGS. 15(A) and (C) show equal electric field strength lines for the discharging electrode and the collecting electrode, and FIGS. 15(B) and (D) show the electric field strength distribution at the shortest distance. The prior are electrode structure shown in (C) and (D) has high electric field portions Pb only near the discharging electrodes 2b. However, the electrode structure of the embodiment shown in (A) and (B) has the high electric field portions Pa not only near the discharging electrodes 2a but also near the collecting electrode 1a. This is conformed by the theoretical calculation and the experimental measurement.

Description is now be made to the function of the charging unit of the two-stage EP, that is, the improvement of the function of charging dust.

Dust handled by the EP is charged by the electric field charging mainly, that is, by energizing single-pole ions produced by the corona discharge by the electric field to collide the ions against the dust. The charged quantity q of the dust is given by

$$q = q_\infty \frac{t/\tau}{1 + \tau/t} \qquad \ldots\ldots (1)$$

where q_∞ (charged saturation quantity) is proportional to the electric field strength E of the charging unit and τ (charge time constant) is proportional to the electric field strength E and is inversely proportional to the current density i. Accordingly, in order to increase the charged quantity, it is necessary to increase the electric field strength E. Further, it is necessary to increase the current density in order to increase the charged quantity in a short time.

As shown in FIG. 14, in the embodiment, since the current density is uniform as compared with the prior art electrode, the dust is charged uniformly and the high operating electric field is obtained for the high resistance dust, so that the charging function is improved.

More, particularly, in the case of the high resistance dust, the operating voltage is determined by the starting point of the inverse ionization and the starting point of the inverse ionization is determined on the basis of time when the product id x ρd of the current id flowing through the dust layer and the resistance ρd of dust exceeds the breakdown voltage Edc of the dust layer. The fact that the density of current flowing from the surface of the dust collecting electrode is uniform produces the effect that the operation can be maintained without generation of the inverse ionization until high current and voltage condition and hence the charging function can be improved.

As shown in FIG. 15, in the embodiment, an area in which a high electric field is formed as shown by Pa of FIG. 15(A) exists in the collecting electrode side. An area in which dust is highly charged is limited to the vicinity of the discharging electrode in the prior art, whereas an area in which dust is highly charged is enlarged. Accordingly, dust carried by the flowing gas G almost passes through the area having a high electric field, that is, the area in which dust is highly charged and hence the charging function of the electrostatic precipitator is improved.

Further, even when the DC high voltage is supplied to the electrodes as shown in FIGS. 12(A) and (B) by the DC high voltage generator 3, it is effective as compared with the prior art electrode construction. Accordingly, when the high voltage pulse is applied by the high voltage pulse generator 8 connected through the coupling condenser 9, it is confirmed by a test that the effect is more remarkable.

The electrode structure of the embodiment also possesses the dust collecting function. The dust collection efficiency per the same surface area of the dust collecting electrode is large as compared with the prior art electrode structure and hence the electrode structure can be used as the ordinary one-stage EP. However, if pipes are disposed in square at spaced intervals of the electrode of the discharging electrode and the dust collecting electrode for the general industry, it is necessary to enlarge the diameter of the pipes or increase the number of pipes along the gas flowing direction in order to make equal the dust collecting area per the same capacity to the prior art electrode and hence it is not practical since the above merit is not utilized. Accordingly, the embodiment is particularly effective for the two-stage EP.

As described above, the electrical characteristic formed by the combination of the polygon layout (ordinarily square) formed of the round or similar shaped dust collecting electrodes and the discharging electrodes disposed in the substantially center of the polygon is excellent in only the characteristic of charging dust differently from the prior art combination of the plate-like dust collecting electrode parallel with the gas flowing direction and the discharging electrode line disposed in the center thereof.

Summerizing the novel point of the present invention as described above, the round or similar shaped dust collecting electrodes is used instead of the parallel plate-like dust collecting electrode used as the charging unit of the prior art two-stage EP and the discharging electrodes are disposed at the substantially equal distance from each apex of the polygon formed by the center of the collecting electrodes, so that the charging function for dust is enhanced and hence the dust collection efficiency of the two-stage EP is increased.

A further embodiment of the present invention will now be described with reference to FIGS. 18 to 22.

FIG. 18 is a side view of the electrostatic precipitator showing a further embodiment of the present invention. In the figure, numeral 31 denotes a body of the precipitator, in which charging units 32 for charging dust in gas and dust collecting units 33 for collecting dust charged by the charging units 32 by the coulomb force are disposed in two stages along the gas flowing direction G. As shown in FIG. 19, the charging unit 32 is composed of a plurality of discharging electrodes 32a disposed in parallel with the gas flowing direction and opposite to each other and a plurality of opposed electrodes 32b disposed between the discharging electrodes 32a. The dust collecting unit 33 is composed of a plurality of dust collecting electrodes 33a disposed in parallel with the gas flowing direction and opposite to each other and a plurality of opposed electrodes 33b disposed between the collecting electrodes 33a. The discharging electrodes 32a and the opposed electrodes 32b of the charging unit 32 are connected to the negative side and the positive side of a DC high voltage generator 41, respectively. The collecting electrordes 33a and the opposed electrodes 33b of the collecting unit 33 are connected to the negative side and the positive side of a DC high voltage generator 42, respectively. In other words, the charging unit 32 is constructed so that dust in gas is charged by the voltage supplied from the DC high voltage generator 41 and the collecting unit 33 is constructed so that the dust charged by the charging unit 32 is collected by the voltage supplied from the DC high voltage generator 42.

In the embodiment, a small sectional damper 34 for cutting off the flow of gas is provided downstream of the latter stage collecting unit 33. The damper 34 is constructed for example as shown in FIG. 20 and serves to prevent scattering of dust when dust collected by the collecting unit 33 is shaken down into hoppers 35. In other words, in FIG. 20, numeral 51 denotes a movable closing plate for sequentially closing a plurality of gas passages 52 formed by the plurality of dust collecting electrodes 33a one by one. The movable closing plate 52 moves perpendicularly to the gas flowing direction by a chain 55 wound between sprockets 53 and 54. A drive motor 57 is coupled with the sprocket 53 through a transmission mechanism 56. The movable closing plate 51 moves along guide rails 59 and 60 provided at upper and lower end of partition plates 58 disposed at the rear side of the collecting electrodes 33a. Limit switches 61 which detect the position of the movable closing plate 51 are disposed at the lower end of the partition plates 58. In other words, the small section damper 34 is constructed so that the movable closing plate 51 closes the gas passage of the collecting electrode 33a to be hit to cut off the gas flow so that the re-scattering of dust is prevented.

Operation of the embodiment constructed above will now be described. As described above, the iverse ionization phenomenon is generated in the prior art electrostatic precipitator when the electric resistance of dust is high. This is because the dust layer deposited on the collecting electrode 21 is isolation brokendown when a certain value or more corona current flows. In the prior art, the corona current must be reduced in order to prevent the phenomenon. In this case, since the applied voltage is also reduced, the performance is not improved. On the contrary, in the embodiment, the electrode structure which sufficiently charges dust by the charging unit 32 or the charge technique is applied to maintain the corona current in the latter stage collecting unit 33 low and to form the high electric field so that an obstacle due to the inverse ionization phenomenon is avoided. Accordingly, a previously charging device, for example, already disclosed in a general literature may be applied to the charging unit 32. The charging device contains, for example, a manner of maintaining cleaner the surface of the electrode, improvement of the electrode structure including an electrode cooling manner of reducing the electric resistance of dust, and a manner of applying the charging pulse of a short and sharp waveform. By using such a manner, the high resistance dust can be charged sufficiently while suppressing the inverse ionization phenomenon in the charging unit 32. On the other hand, the collecting electrode 33a of the collecting unit 33 uses, for example, a plate or a similar member to the plate. The opposed electrode 33b uses a uniform section member without a sharp projection or edge such as a round wire having a diameter of 6 mm or a square wire having an area of 8 mm^2 or more so that a high electric field strength can be formed under a low corona current.

In the embodiment, when the dust collected by the collecting unit 33 is shaken down into the hopper 35 by hitting by a hammer, only the collecting electrode 33a having the gas passage closed by the small section damper 34 is hit so that the re-scattering of dust can be prevented.

As described above, according to the embodiment, the dust charged by the charging unit 32 is collected by the formation of the high electric field of the collecting unit 33. Hence, even if dust has a high resistance, the reduction of collection performance due to the inverse ionization can be prevented. Further, since the collecting electrode 33 having the gas passage closed by the small section damper 34 is hit to shake down the dust collected by the collecting unit 33, the reduction of the collection performance due to the re-scattering of dust can be prevented. In the embodiment, while description has been made to the two-stage electrostatic precipitator having the charging unit 32 and the collecting unit 33, one stage of the charging unit 32 and the collecting unit 33 or three or more stages as shown in FIG. 21 can attain the same effects. Further, the electrostatic precipitator according to the present invention may be combined with the prior art collecting unit 12 as shown by the modification shown in FIG. 22.

CLAIMS:

1. A two-stage electrostatic precipitator including a charging unit for mainly charging dust and a dust collecting unit for mainly collecting the dust, wherein said charging unit includes a discharging electrode having a substantially uniform cross section and which is applied with a high voltage pulse superimposed on a DC high voltage.

2. A two-stage electrostatic precipitator including a charging unit for mainly charging dust and a dust collecting unit for mainly collecting the dust, wherein said charging unit includes a discharging electrode having a substantially uniform cross section and a plate-like or round dust collecting electrode, a high voltage pulse superimposed on a DC high voltage being applied between both the electrodes.

3. A two-stage electrostatic precipitator according to Claim 1 or 2, wherein said discharging electrode has a uniform cross section of a round wire of 3 to 10 mm or an equivalent radius of curvature.

4. A two-stage electrostatic precipitator according to Claim 1 or 2, wherein said discharging electrode has a uniform cross section of a square wire of diagonal width 4 to 10 mm or an equivalent square wire.

5. A two-stage electrostatic precipitator according to Claim 1 or 2, wherein said discharging electrode has a uniform cross section of a round wire having same shaped

projection on both side thereof.

6. A two-stage electrostatic precipitator according to Claim 1 or 2, wherein said discharging electrode has a uniform cross section in the form of a cross.

7. A two-stage electrostatic precipitator including a charging unit for mainly charging dust and a dust collecting unit for mainly collecting the dust, wherein said charging unit comprises dust collecting electrodes in the form of a rod in the direction substantially perpendicular of gas flow and having a substantially uniform cross section, said collecting electrodes being disposed to form a polygon, and a discharging electrode disposed at a substantially equally spaced position from each apex of the polygon formed by said collecting electrodes.

8. A two-stage electrostatic precipitator including a charging unit for mainly charging dust and a dust collecting unit for mainly collecting the dust, wherein said charging unit comprises dust collecting electrodes in the form of a rod in the direction substantially perpendicular of gas flow and having a substantially uniform cross section, said collecting electrodes being disposed to form a polygon, and a discharging electrode disposed at a substantially equally spaced position from each apex of the polygon formed by said collecting electrodes, a high voltage pulse superimposed on a DC high voltage being applied between said discharging

electrodes and said collecting electrodes.

9. A two-stage electrostatic precipitator according to Claim 7 or 8, wherein said collecting electrodes are disposed to form a regular polygon.

10. A two-stage electrostatic precipitator according to Claim 7 or 8, wherein said collecting electrodes are disposed to form an isosceles triangle containing equilateral triangle.

11. A two-stage electrostatic precipitator according to Claim 7 or 8, wherein said collecting electrodes are disposed to form a square containing a regular square.

12. A two-stage electrostatic precipitator including a charging unit for mainly charging dust and a dust collecting unit for mainly collecting the dust, wherein said charging unit and said collecting unit are disposed along a gas flow, and said electrostatic precipitator comprises a small section damper disposed downstream of said collecting unit for cutting off the gas flow.

FIG. 1

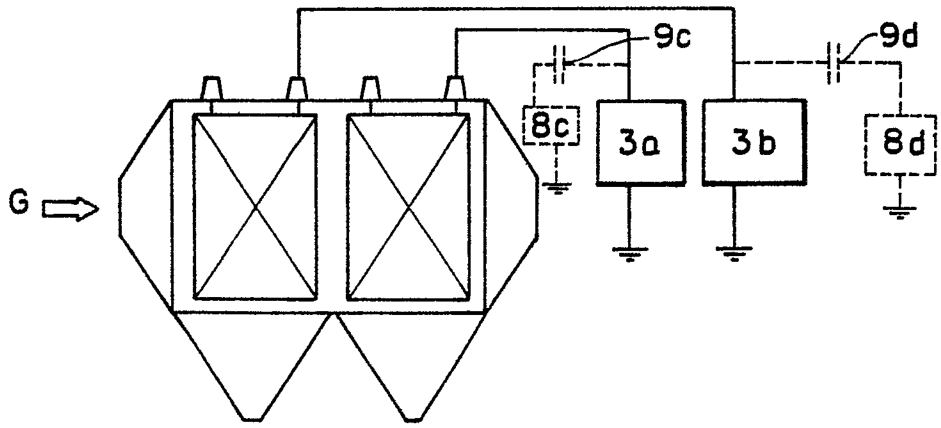


FIG. 2

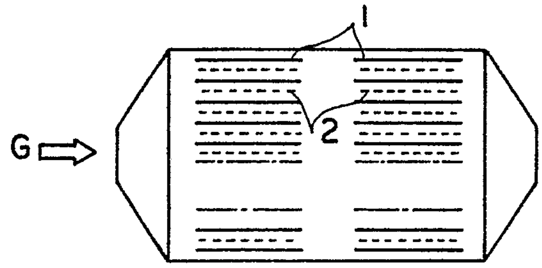


FIG. 3

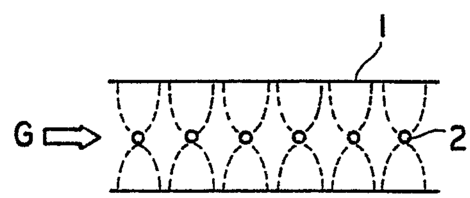


FIG. 4

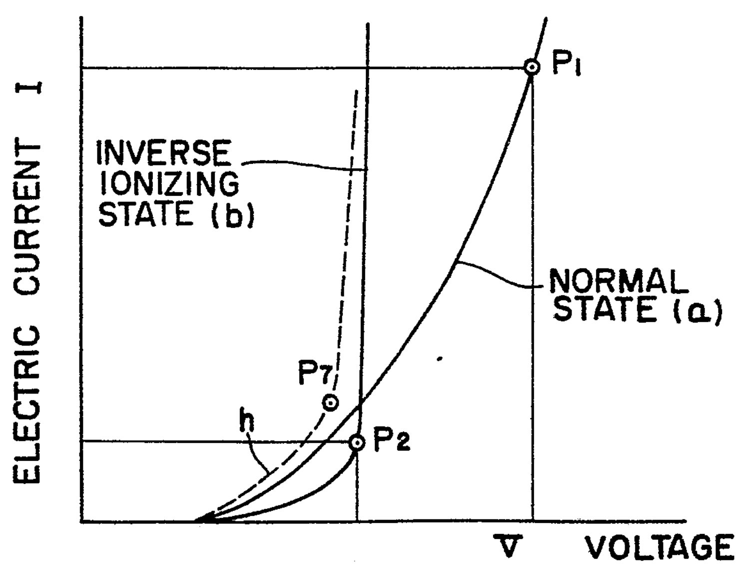


FIG.5(A)

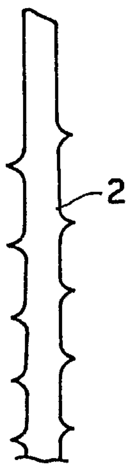


FIG.5(B)

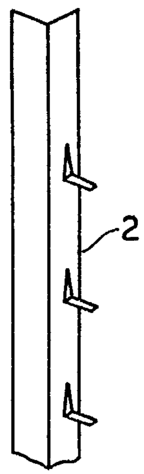


FIG.5(C)

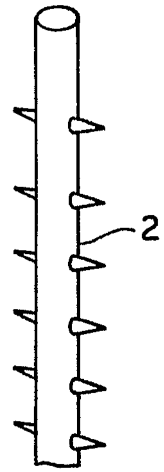
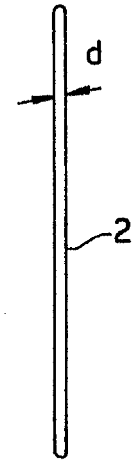
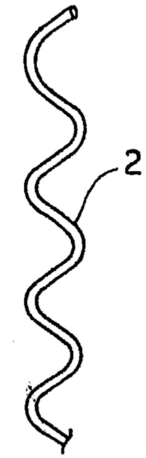


FIG.5(D)

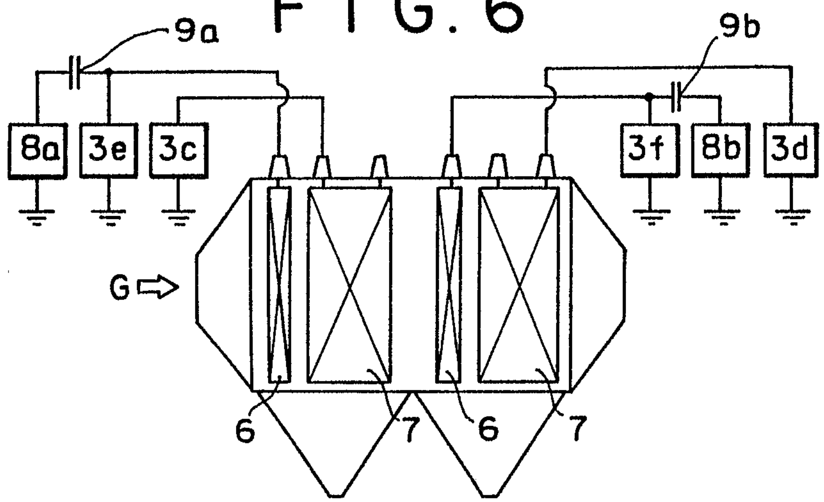


d = 1~3mm φ

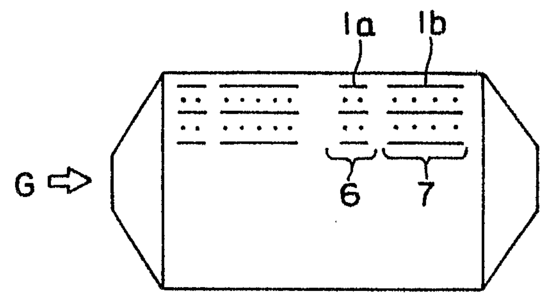
FIG.5(E)



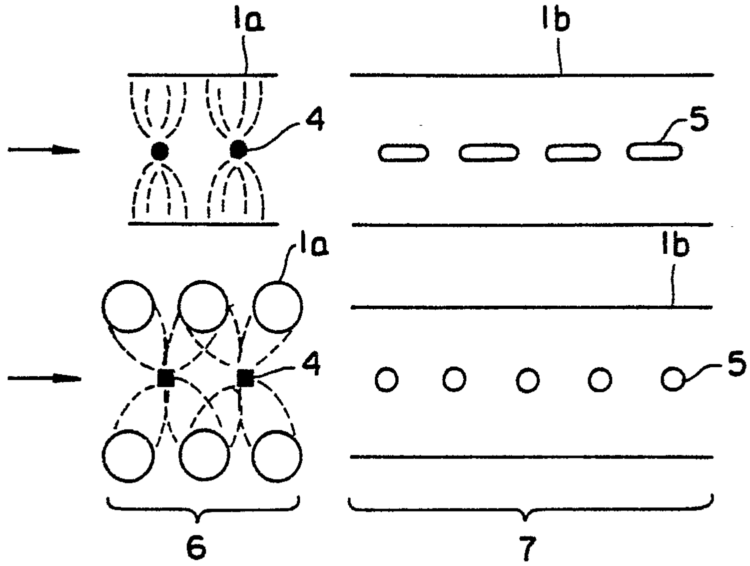
F I G. 6



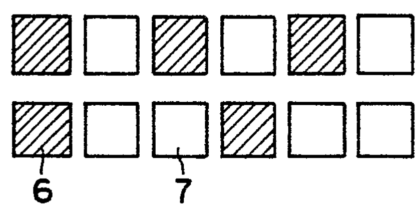
F I G. 7



F I G. 8



F I G. 9



F I G. 10

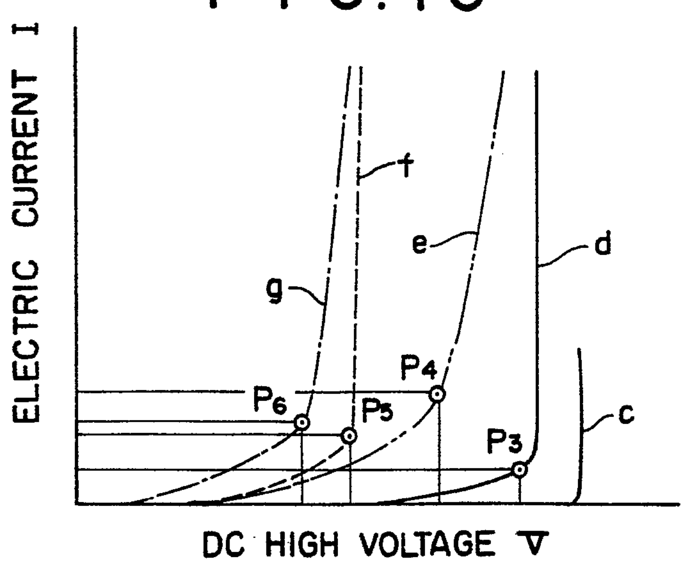


FIG. 12(A)

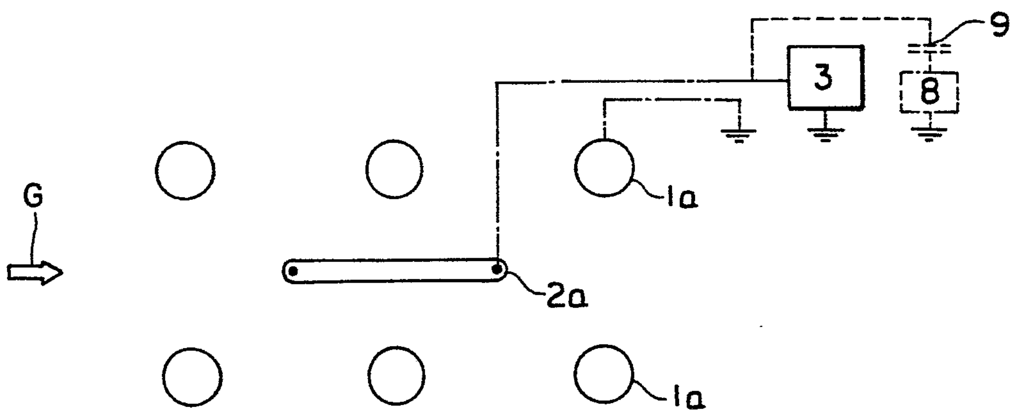


FIG. 12(B)

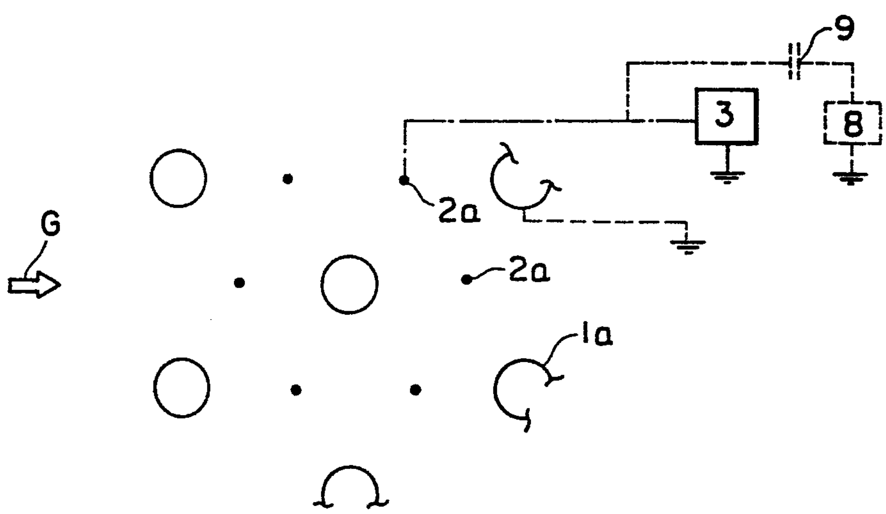


FIG.11(A)

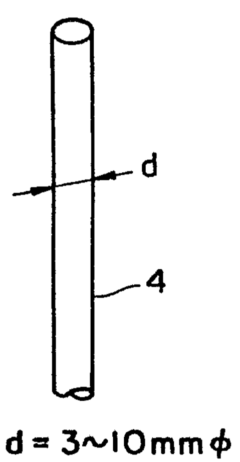


FIG.11(B)

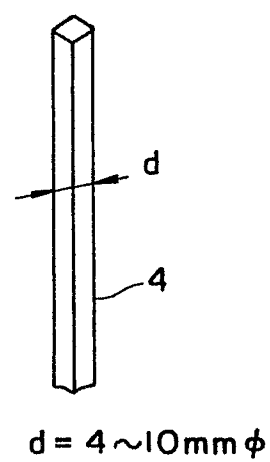


FIG.11(C)

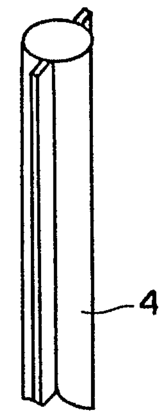


FIG.11(D)

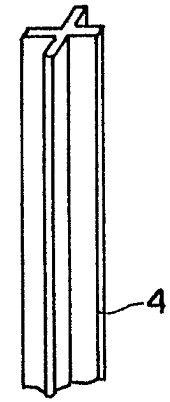


FIG.13

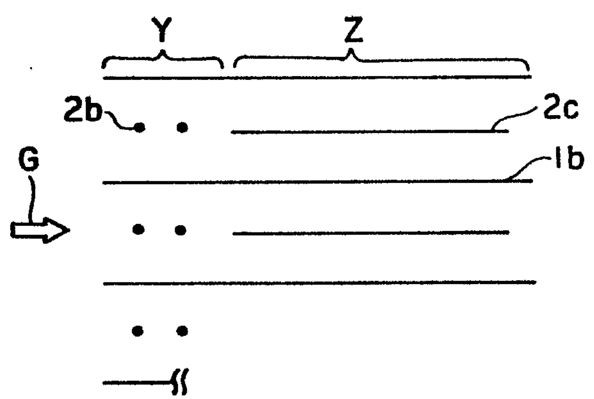


FIG.14(A)

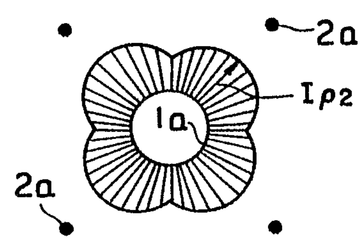
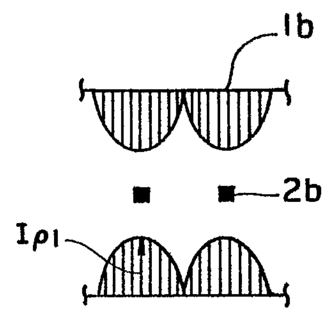


FIG.14(B)



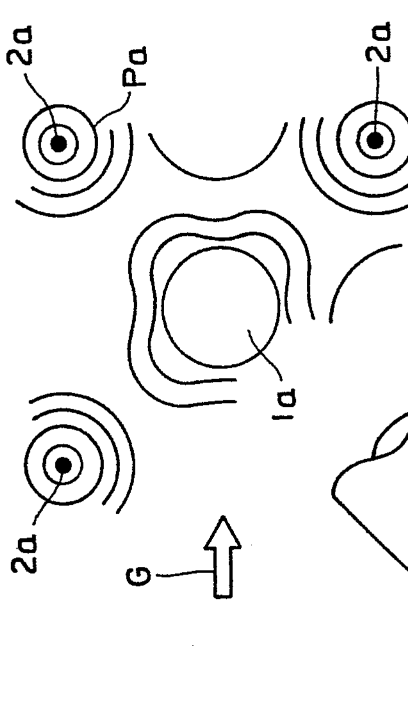


FIG.15(A)

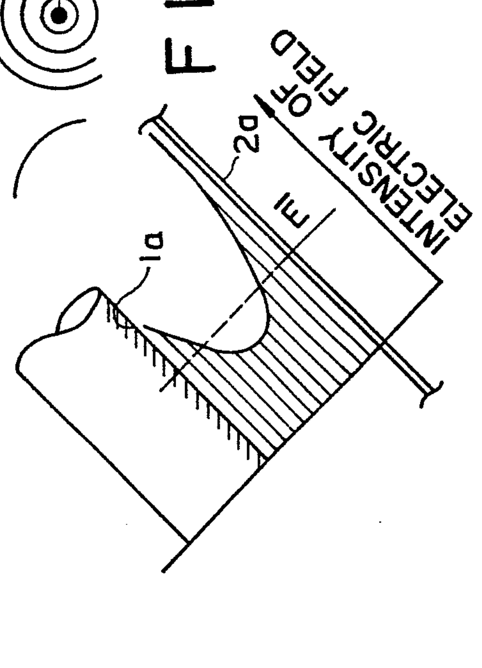


FIG.15(B)

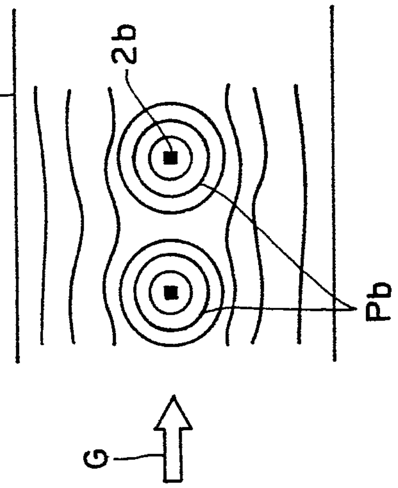


FIG.15(C)

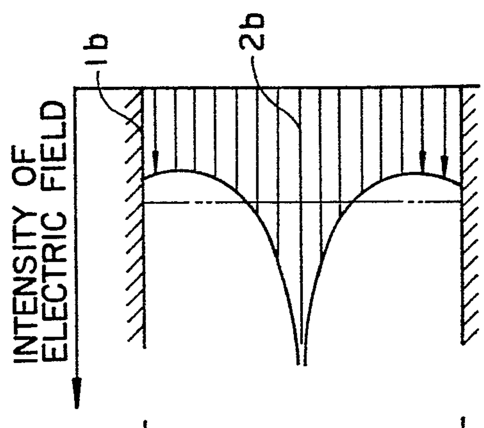


FIG.15(D)

FIG.16

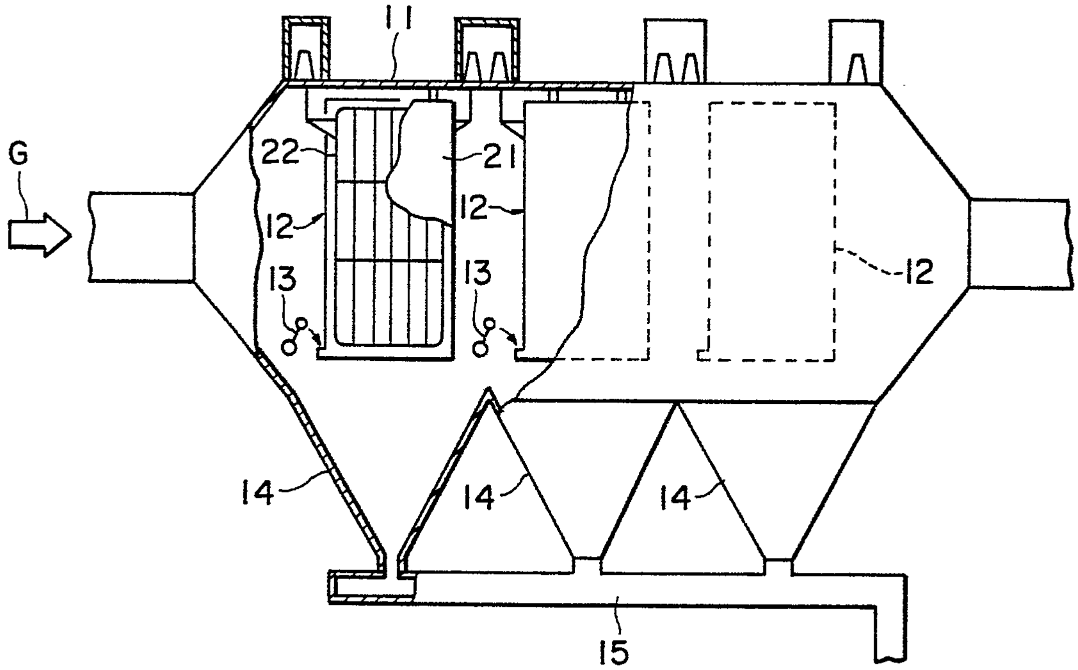


FIG.17

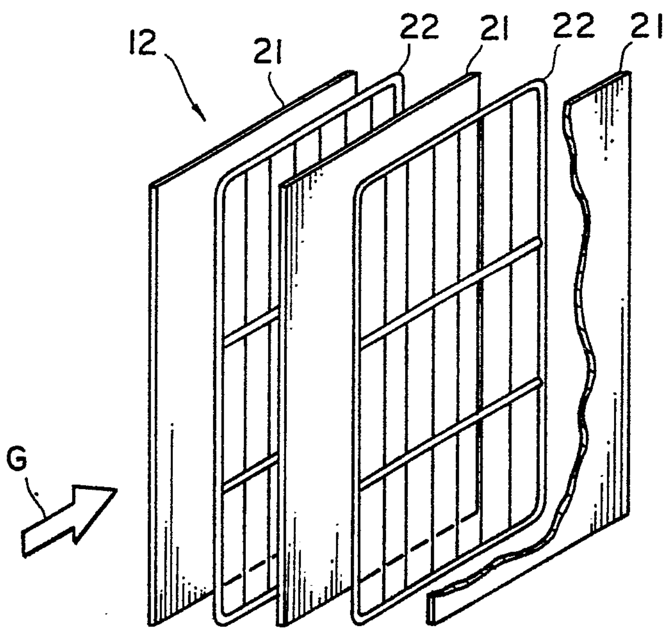


FIG. 18

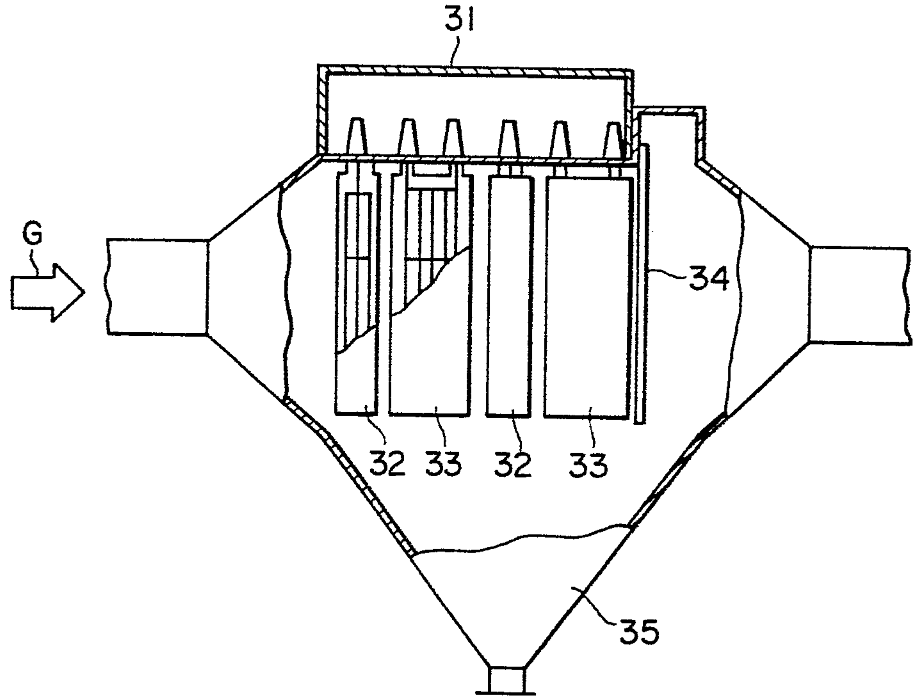

31
G
34
32
33
32
33
35

FIG. 19

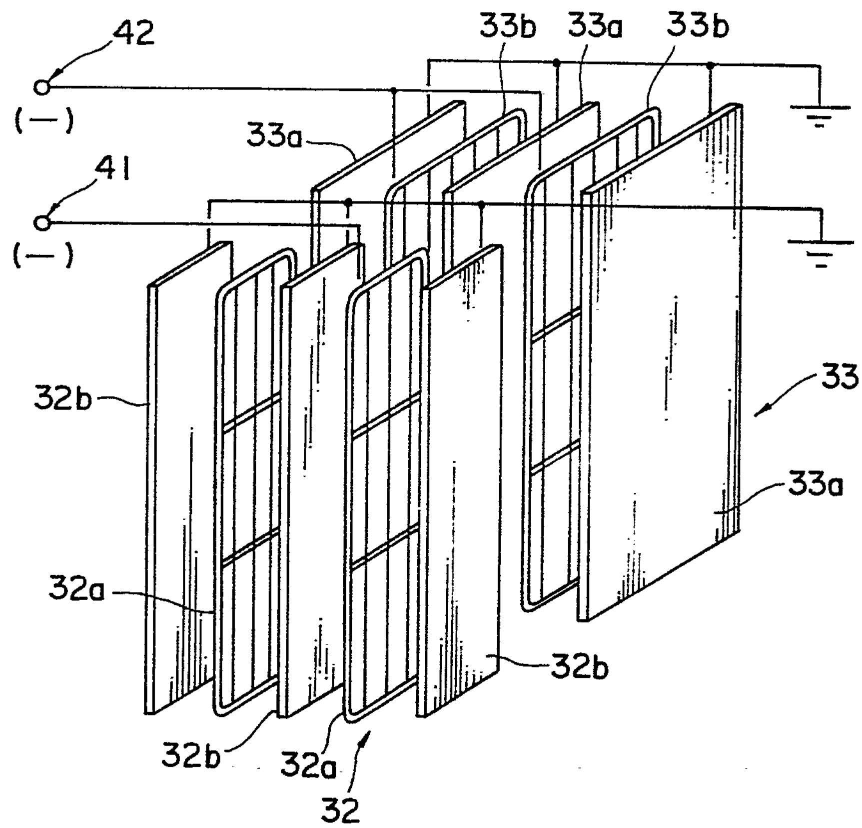

42
(−)
41
(−)
33b
33a
33b
33a
32b
32a
33
33a
32b
32b
32a
32

FIG. 20

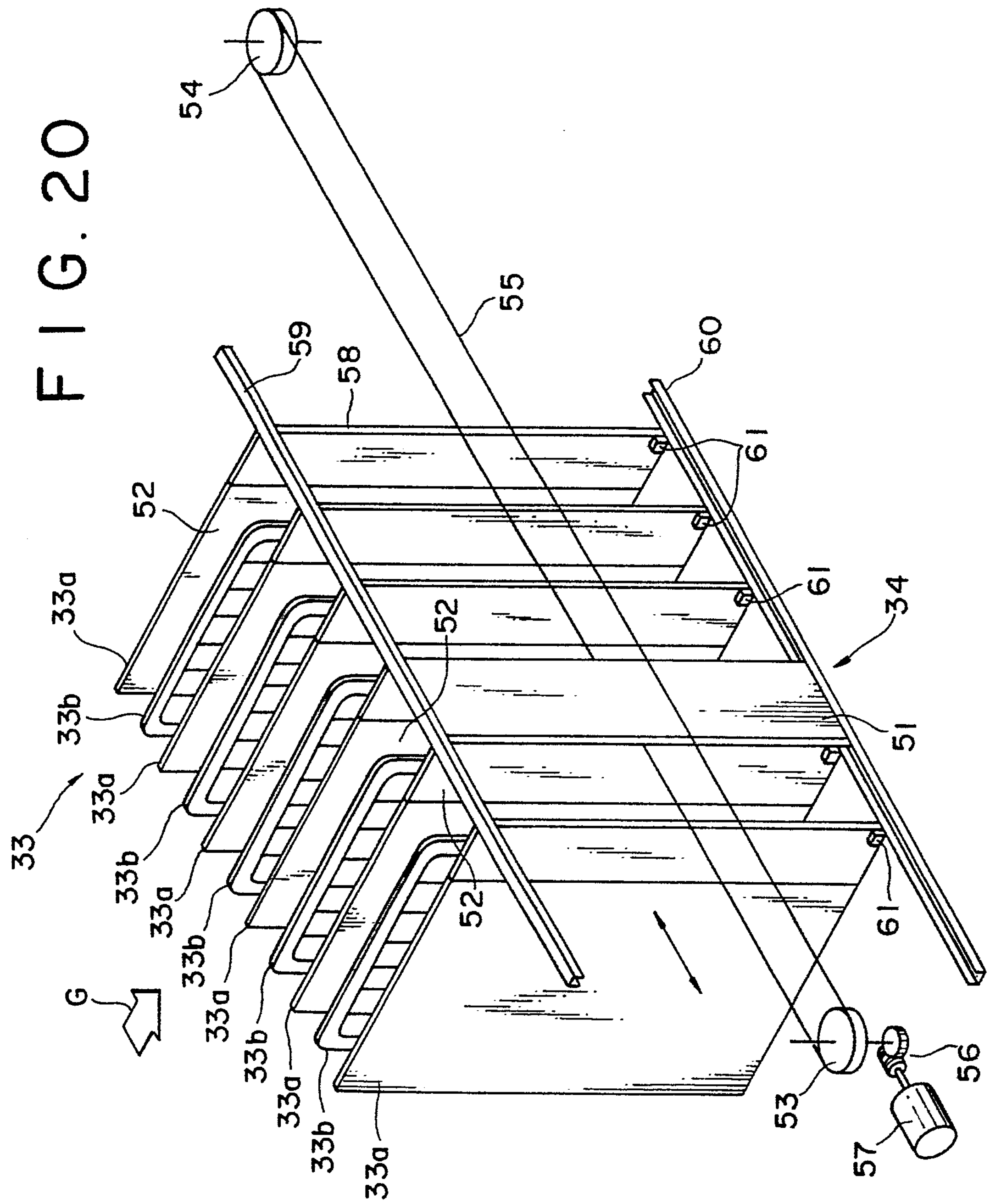


FIG.21

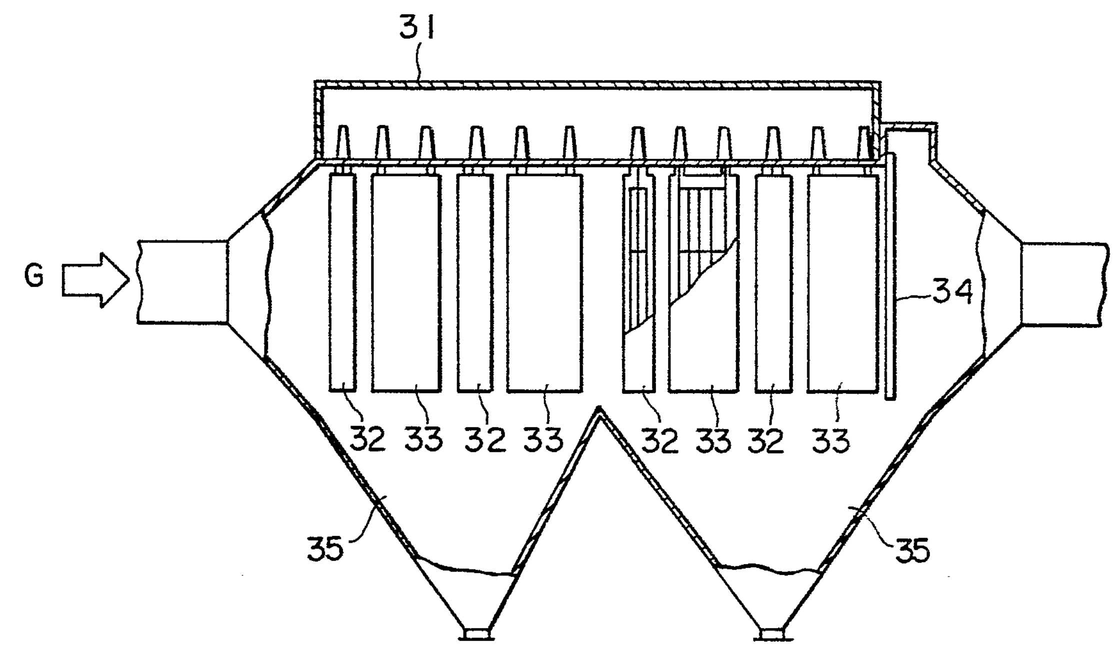


FIG.22