United States Patent [19]

Vincent

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[54] **ELECTROSTATIC PRECIPITATOR EMPLOYING DIELECTRIC GRIDS**

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[73] Assignee: **American Standard, Inc.,** New York, N.Y.

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[21] Appl. No.: **194,983**

Related U.S. Application Data

[63] Continuation-in-part of Ser. Nos. 869,195, Oct. 24, 1969, Pat. No. 3,616,606, and Ser. No. 65,843, Aug. 21, 1970, each is a continuation-in-part of Ser. No. 804,050, Feb. 25, 1969, abandoned.

[52] **U.S. Cl.** **55/123,** 55/127, 55/131, 55/136, 55/155

[51] **Int. Cl.** **B03c 3/04**

[58] **Field of Search** 55/155, 154, 146, 138, 55/137, 136, 131, 130, 123, 128, 129, 127

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[57] **ABSTRACT**

Covers an electrical precipitator composed of a plurality of similar apertured plates, called "grids", which are vertically arranged so that particles of matter may be transmitted through the apertures of any or all of the grids. The grids may comprise two or more apertured metallic plates, between any two of which there may be one or more dielectric plates which are also apertures so that the particles of matter may also be transmitted therethrough. Such dielectric plates will receive induced potentials and hence engage in the process of precipitation of such particles. If a single apertured dielectric plate is arranged between two apertured metallic plates, it may be equally spaced from and between the two metallic plates. If two apertured dielectric plates are positioned between two apertured metallic plates, the two dielectric plates may be spaced from each other by a distance which is about equal to the spacing of either of the dielectric plates from the respective adjacent metallic plates.

19 Claims, 3 Drawing Figures

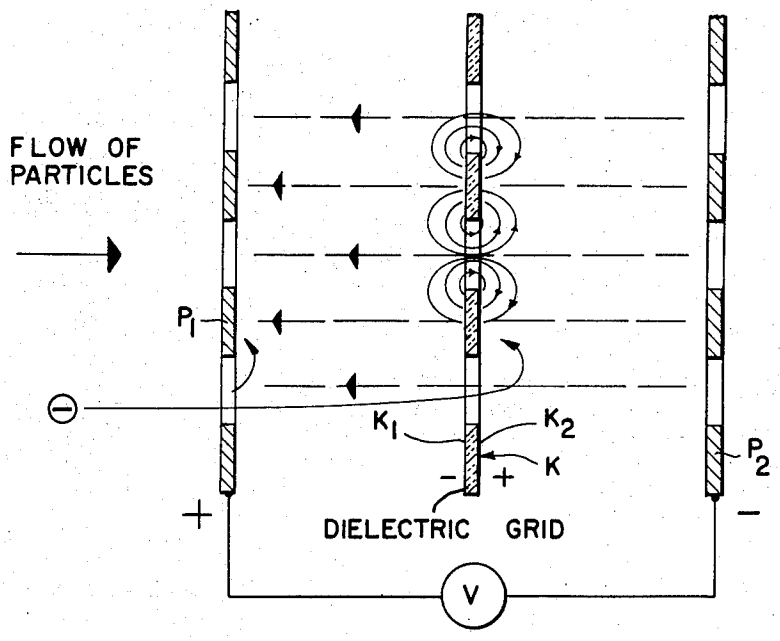


FIG. 1

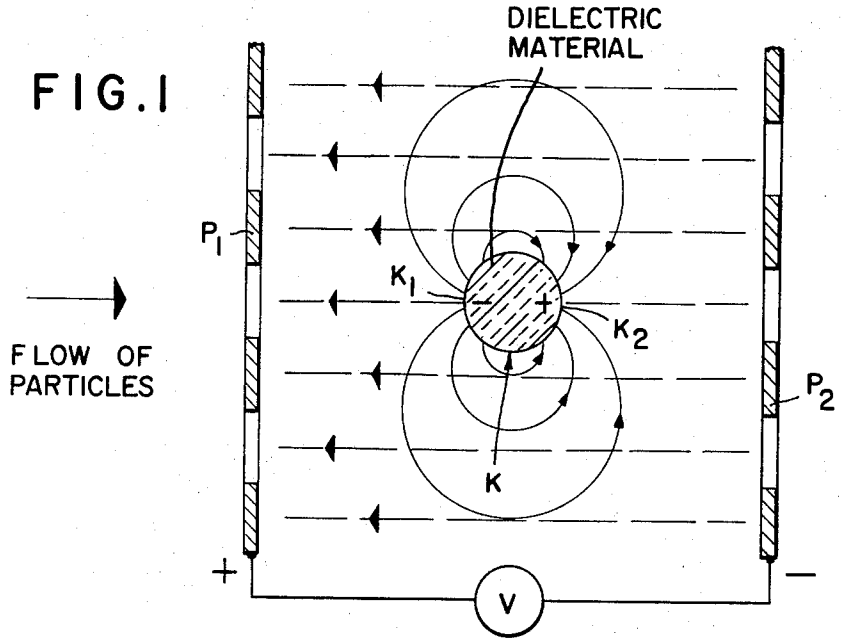

DIELECTRIC MATERIAL
P1
K1
K2
K
P2
FLOW OF PARTICLES
+
−
V

FIG. 2

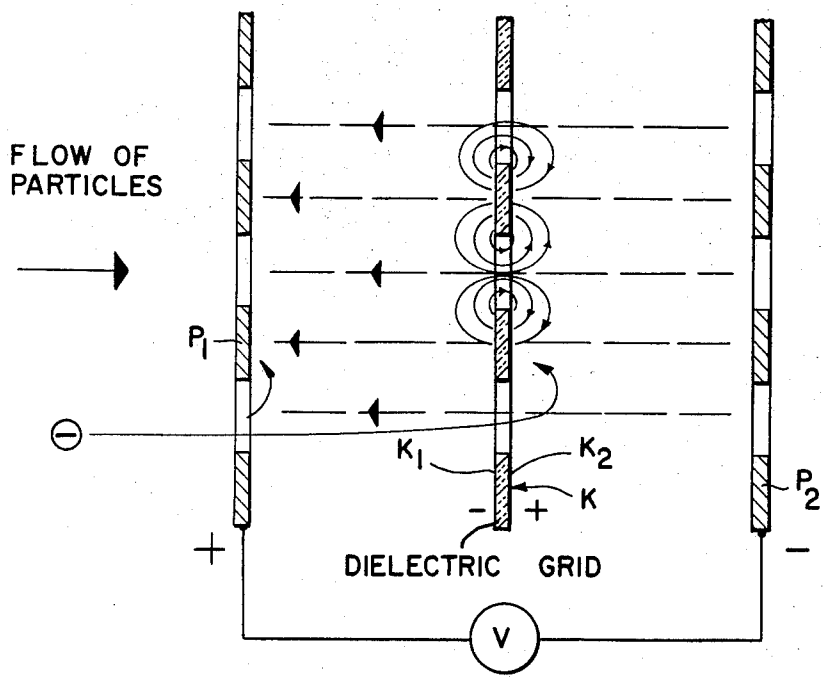
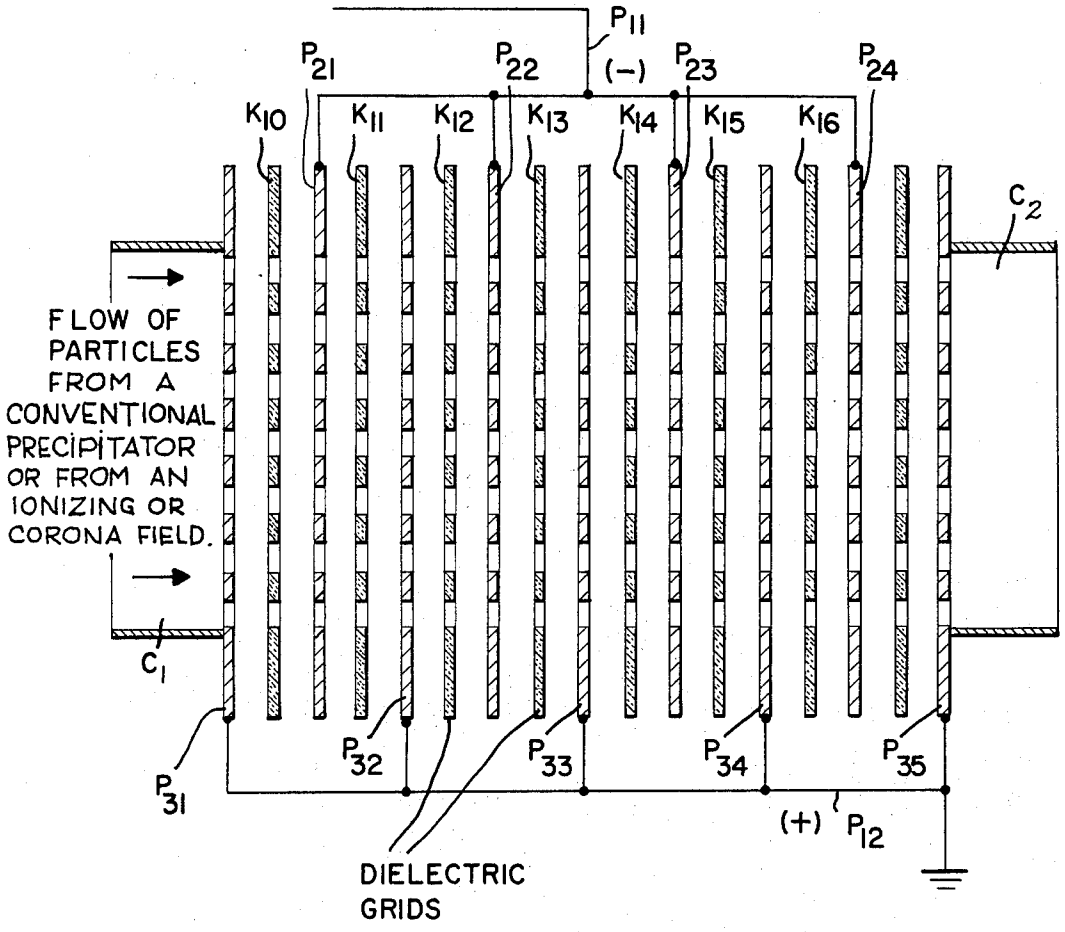

FLOW OF PARTICLES
P1
K1
K2
K
P2
DIELECTRIC GRID
+
−
V

FIG. 3


P11
(−)
P21
P22
P23
P24
K10
K11
K12
K13
K14
K15
K16
C2
FLOW OF PARTICLES FROM A CONVENTIONAL PRECIPITATOR OR FROM AN IONIZING OR CORONA FIELD.
C1
P31
P32
P33
P34
P35
(+)
P12
DIELECTRIC GRIDS

ELECTROSTATIC PRECIPITATOR EMPLOYING DIELECTRIC GRIDS

This application is a continuation-in-part of patent application Ser. Nos. 869,195, filed Oct. 24, 1969 now U.S. Pat. No. 3,616,606 and Ser. No. 65,843 filed 8-21-70, which in turn are continuations in part of Ser. No. 804050, filed 2-25-69, now abandoned.

This invention relates to electrical precipitators and especially to such precipitators for the precipitation of dust, dirt or any other material which may be included with, or suspended in, air, gas or any other fluid medium. In the above referred to applications there are shown various forms of electrostatic precipitators employing a plurality of metallic plate electrodes which are apertured (sometimes called "grids") so that gas or any other fluid medium bearing particulate matter which has been electrically charged may be moved or otherwise transported under pressure through the apertures of the various plate electrodes for precipitation thereon. The particulate matter may be entrained into the vortices which are formed in the wakes of the solid portions of the grids, and a voltage may be applied between the metallic grids of sufficient magnitude to establish an electrostatic field to direct the thus trapped particulate matter toward one or the other of the two adjacent grids and be deposited thereon and thereby removed from the fluid stream.

It is well known that such metallic electrodes, especially those metallic electrodes employed in commerical establishments such as power plants or extensive factories, are large and heavy and, because of their size and weight, such electrodes may be installed in the plant or factory only with considerable difficulty and expense. Moreover, metallic electrodes, such as, for example, steel electrodes, readily submit to various chemical reactions especially in chemical plants and, in many types of operational atomspheres, such electrodes readily deteriorate and hence require repair or replacement. It is, therefore, important to minimize the employment of such metallic electrodes. If possible or feasible, it would be preferable to replace such metallic electrodes with other forms of electrodes which are lighter and put less stress on the supporting structure, and are not readily subjected to chemical reactions. Furthermore, metallic electrodes are oftentimes subjected to spark discharges or arc-over and such electrical phenomena are destructive of the metals. Hence, to the extent that metallic electrodes are replaced by non-metallic or dielectric electrodes, the likelihood of arc-over and possible chemical reactions may be substantially reduced or eliminated. The equipment then becomes safer to use and its operation more efficient.

According to one embodiment of the present invention, non-metallic or plastic or other dielectric plate electrodes are added to metallic plate electrode installations. Hence, in such an arrangement, a metallic electrode will be followed by one or more non-metallic or dielectric electrodes and finally supplemented by a second metallic electrode. In such an arrangement, a relatively high voltage may be applied between the two metallic electrodes to establish an electrostatic field therebetween. The intermediate non-metallic or dielectric electrode may be equally spaced from the two metallic electrodes and have induced on its surface a potential which may be about one-half of the total voltage applied between the metallic electrodes. If two dielectric

electrodes are interspersed between the two metallic electrodes, the two intermediate non-metallic or dielectric electrodes will be appropriately spaced from each other and appropriately spaced also from the metallic electrodes. The two intermediate dielectric electrodes will have induced therein intermediate potentials corresponding to the spacings, and such induced potentials will act substantially the same as metallic electrodes. In essence, there will be an electrostatic field between any adjacent pair of apertured plates, whether they be metallic or dielectric, closely similar to that between the two extreme metallic plates if the dielectric plates were not interposed. However, the presence of the dielectric plates will cause a certain amount of distortion of the electrostatic field, which can be used to considerable advantage as will become apparent from the following description. Thus, each metallic electrode and each non-metallic or dielectric electrode will serve to attract the particulate matter transmitted through the apertures of any of the various metallic and non-metallic electrodes and remove the particulate matter from the fluid path.

This invention will be better and more clearly understood from the more detailed description and explanation hereinafter following when read in connection with the accompanying drawing in which:

FIG. 1 illustrates a schematic diagram, shown in cross-section, of a cylindrical fiber inserted in a substantially uniform electric field between two metallic grid electrodes;

FIG. 2 illustrates schematically a three-electrode arrangement employing two metallic apertured electrodes and one dielectric apertured electrode interposed between the two metallic electrodes; and

FIG. 3 schematically illustrates an arrangement employing nine metallic apertured electrodes and eight apertured dielectric or non-metallic electrodes, each of the dielectric electrodes being interposed between two adjacent spaced metallic electrodes.

Throughout the drawings, the same or similar reference characters will be employed to designate the same or similar parts wherever they may occur throughout the drawings.

FIG. 1 shows an elemental form of dielectric cylindrical member K inserted midway between two apertured metallic electrodes P1 and P2 which may be made of steel or other metal. This drawing serves to provide an understanding of the basic physical mechanisms which cause the collection of particulate matter in the device. A source of voltage V, which may be an alternating or direct voltage, is connected between the two metallic electrodes P1 and P2. If the source V is d.c. voltage, the electrodes P1 may be at a positive potential with respect to plate P2, which is at a negative potential, but, if the source V is of an a.c. type, then at each alternate half cycle the electrode P1 will be positive with respect to the electrode P2 which will be negative, etc. The cylinder K may be considered, for example, to be a dielectric fiber inserted into a uniform electric field between the metallic electrodes P1 and P2 as shown by the horizontal arrows of the Drawing.

Both of the electrodes P1 and P2 are, as already noted, of the apertured or grid type, as shown in applicant's earlier filed applications, preferably embodying circular apertures which may have, for example, an aggregate open area of some 63 percent of the total active area of each respective electrode. It follows, therefore,

that the dielectric cylinder K will be polarized by the established electric field between conductors P1 and P2 so that its left side K1 will obtain a negative potential as shown and its right terminal K2 a positive potential. The negative potential on side K1 of dielectric cylinder K will face the positive electrode K1, while the positive side K2 of the dielectric cylinder K will face the negative electrode P2. The voltage induced in the dielectric cylinder K is developed therein notwithstanding the absence of any voltage directly applied to any portion of the dielectric cylinder K.

Thus, dielectric cylinder K may be regarded as polarized by the electrostatic field between metallic electrodes P1 and P2 so that the electric field surrounding the cylinder K may be regarded as being the sum of two separate components. One component is the uniform electric field produced between the two metallic plates by means of the voltage difference applied between them shown in FIG. 1 by the straight arrows. Because also of the opposite polarities induced upon the two sides K1 and K2 of the cylinder K, there will be an electric field due to the induced potentials on opposite sides of the cylinder K represented by the curved arrows of FIG. 1. Hence, there will be two fields simultaneously co-acting and cooperating with respect to the dielectric cylinder K, the uniform field shown by the horizontal lines, and the non-uniform field represented by the curved arrows of the figure.

Assume that a negatively charged particle or particles exhausted, for example, by a Cottrell precipitator or any conventional precipitator, are moving from left to right as indicated and that the particles are superimposed upon or otherwise transported by gas or air or any other fluid in the usual way. Negatively charged particles, influenced and moved by a blower, will move through the apertures of the metallic grid electrodes P1 and, if unobstructed, the particles will move further along through the space between electrodes P1 and P2 and exit through the apertures of the second metallic grid electrode P2. However, such particles will, if they move close to the fiber or cylinder K, experience an electrical force tending to precipitate them on the downstream side of the cylindrical fiber K, that is, the right side K2 of the fiber K. The positive voltage induced in the side K2 of fiber K will cause the attraction of the negatively charged particles in motion. The force acting on the polarized or charged particles will be the total or resultant force produced by the externally applied field developed between electrodes P1 and P2 and the force due to the induced field arising from the interposition of the dielectric fiber K between the two metallic electrodes P1 and P2.

If the Reynolds number for the air flow around and adjacent to the cylindrical fiber K is sufficiently high, particles will be entrained into vortical paths as they pass close to the fiber. This will tend to slow up the particles and facilitate their precipitation on the right side K2 of the intermediate dielectric cylinder K under the action of the combined electrostatic field components.

Thus, the dielectric fiber K will act as a means for attracting, holding and removing particulate matter. Fiber K will provide an additional means for removing particulate matter.

FIG. 2 schematically illustrates an arrangement in which the two grid electrodes P1 and P2, both of which may be metallic, have a dielectric apertured plate K interposed midway between the two metallic grid electrodes P1 and P2. The dielectric grid K may be formed of substantially the same dimensions as the two metallic electrodes P1 and P2, so that it will have apertures or openings which correspond to the apertures or openings in the metallic grids P1 and P2. Moreover, the apertures in the dielectric grid K may be lined up with the corresponding apertures in metallic electrodes P1 and P2. It may be assumed that the dielectric grid K is positioned midway between the two metallic electrodes P1 and P2 so that the applied voltage of source V between electrodes P1 and P2, creating an electrostatic field represented by the horizontal lines in the figure, is divided into two substantially equal electrostatic fields, one developed between plate P1 and the left side K1 of the dielectric grid K, and the second field developed between the metallic grid electrode P2 and the right side K2 of the dielectric grid K. There will also be an induced electrostatic field caused by polarization of the dielectric grid plate K by the externally applied electrostatic field between plates P1 and P2. This induced field is shown by the curved arrows in FIG. 2. The two fields, the externally applied field between P1 and P2 and the fields induced by polarization of the dielectric grid K, are vectorially additive in the regions of the openings of the intermediate dielectric grid K. Thus, the electrostatic field is more intense close to the openings than it is at other points between plates P1 and P2. Naturally, the fields change direction when the polarities of electrodes P1 and P2 are reversed.

It follows, therefore, that a particle which is charged negatively and moving from left to right may undergo an aerodynamic vortical path formation in the wake of its passage through one of the openings of the metallic grid P1. The particle thus trapped becomes subjected to the electrical force caused by the electrostatic field between P1 and P2, this force acting so as to drive the negative particle against the right side of the grid P1. If the force of attraction is sufficiently great, the negatively charged particle will be collected on the downstream surface of the grid P1 and removed from the path of the gas. On the other hand, if the negatively charged particle remains in motion and passes through an aperture of the dielectric grid K, it will again be subjected to an aerodynamic vortical force as it exits from the opening and it will likewise be subjected to another electrostatic field, this time being the sum of the externally applied electrostatic field and the electrostatic field induced by polarization of the dielectric medium of the dielectric grid plate. This field is poled in such a direction that the particle will again be directed to move upstream against the normal path of the air and be attracted to the right side K2 of the dielectric grid K which has a positive polarity. If the field is sufficiently great so as to drive the particle against the right side of grid K, the particle will be collected on the downstream side of grid K and be removed from the path of the airflow. This total electrostatic force due to this field is clearly greater than that which was acting on the particles in the wake of the first metallic grid where there was only the externally applied electrostatic field acting.

On the other hand, if the particle remains in motion, it will remain under the influence of the electrostatic field until it is driven through an aperture of the second metallic grid electrode P2 and consequently becomes subjected to the aerodynamic vortices again. Such a

particle may be collected on still another electrode if one were positioned downstream of the metallic grid P2.

Thus, each negatively charged particle may be collected on either of the two grid electrodes P1 or K as it moves with the airstream from left to right.

When the electric field established by source V is reversed, as would be the case if the source V were an alternating voltage, then the applied voltages would be opposite to those shown in FIG. 2. A negative particle of dust or other matter may then be collected on the upstream side of the intermediate dielectric grid K or on either of the surfaces of the second metallic electrode P2.

The arrangement of FIG. 2 represents an "add-on" structure for any conventional or other means for establishing a corona field or other field for charging the incoming particles. Such a corona generator is illustrated and described in my earlier filed applications above noted. In such event, the electric field between the metallic electrodes P1 and P2 will be, preferably, at a voltage which is not sufficient to establish a corona discharge between electrodes P1 and P2. In other words, the electrodes P1 and P2, as well as the intermediate dielectric electrode K, are positioned in an electrostatic field which is uniform enough to prevent the onset of a corona discharge.

Moreover, the arrangement of FIG. 2, when subjected to a source of a.c. voltage, will apply opposing fields during each successive half cycle to render the charged particle subject to attraction by each of the three electrodes P1, K and P2 as the particle moves downstream during the reversal of the applied voltage.

From the preceding discussion, it is obvious that the efficiency for collecting particulate matter in the electrostatic precipitator can be materially increased by increasing the number of chances that a given particle has of undergoing the described collection mechanisms. This may be achieved by increasing the total number of collecting grids employed, whether they be metallic or dielectric. It is an important feature for electrostatic precipitators of this type.

FIG. 3 shows another schematic arrangement showing a housing C1 providing an input terminal through which a fluid is admitted which may have superimposed thereon particles of material to be precipitated and a housing C2 providing an output terminal for receiving the gas and any particles which remain uncollected by the precipitator. The precipitator includes a high voltage power supply with one terminal P11 which may be negative and the other terminal P12 which may be positive and grounded as shown.

The terminal P11 is connected to metallic grids P21, P22, P23 and P24, all of which may be similar grids having similar apertures of a relative size previously mentioned. The other terminal P12 is connected to metallic grids P31, P32, P33, P34 and P35, as shown, and all of these grids may be equal in structure as noted. However, dielectric electrodes K10 to K17 are interspersed between the metallic electrodes as shown in the drawing. One dielectric electrode, such as K10, is interposed between metallic electrodes P21 and P31 but, if desired, two or more such dielectric electrodes may be interposed between the two metallic electrodes P11 and P31. In any case, a single dielectric electrode, such as K10, interposed between two metallic electrodes, such as P21 and P31, will have a potential induced thereon which is approximately midway between the potentials applied to metallic electrodes P21 and P31. A similar or identical potential will be induced on each of the other dielectric electrodes K11 to K17.

Hence, each dielectric electrode will serve to break up each field between two adjacent metallic electrodes into two electrostatic fields to effectively double the particle attractive capability and double the particle collecting capacity of the arrangement.

A precipitator of the kind shown in FIG. 3, for example, will be more efficient than a corresponding precipitator without dielectric grid electrodes owing to the added electrostatic field component due to polarization of the dielectric grids. The precipitator, such as that shown in FIG. 3, may be an added-on structure for a conventional precipitator which may not have sufficient precipitating ability and the add-on structure will increase the overall efficiency to almost 100 percent.

The interposition of the floating dielectric grid electrodes serves to considerably reduce the electrical stress and strain placed on the supporting structure. The use of dielectric grid electrodes will materially alleviate the problems of insulating the equipments against the necessary high voltages and ground voltages of the metallic electrodes.

Furthermore, a grid network employing dielectric grids will occupy a smaller overall space for a given precipitating capacity and still remain just as efficient in the removal of dust particles. The material of which the dielectric electrodes is composed may be fiberglass or any plastic composition and non-corrosive and unaffected by the chemical characteristics of the particulate matter and the gas transmitted through the precipitator. Dielectric electrodes made of fiberglass, for example, may be employed in atmospheres where it might be impractical or impossible to employ metallic electrodes. A medium of sulphuric acid or other acids might be highly destructive of metallic electrodes but non-destructive to selected dielectric materials employed for the intermediate grids.

The openings in all of the grid electrodes P1, P2, K, etc. whether metallic or dielectric, should preferably aggregate somewhere between 60 and 70 percent of the total area of the grid electrodes. The openings in all of the grid electrodes should preferably be staggered along 60° angles, as shown and described in my earlier filed patent applications. Furthermore, the grid electrodes should be properly spaced from each other. If the spacing between two adjacent openings is designated *d*, the spacing between adjacent grid electrodes should preferably be somewhere between 3*d* and 6*d*. Openings of one inch in a grid electrode would preferably embody a spacing d between adjacent openings of 0.18 inch in the same grid electrode. The spacing between adjacent grids would be somewhere between 0.54 and 1.08 inches. Such a geometry would be suitable for particles having a maximum size of about 10 microns. These proportions would be changed with any change in the areas of the openings.

While this invention has been shown and described in certain particular arrangements merely for illustration and explanation, it will be apparent that the arrangement of this invention may be set forth in many and widely varied formations all within the scope of this invention.

What is claimed is:

1. An electrostatic precipitator for precipitating charged particles conveyed by a fluid medium, comprising a pair of metallic plates each having substantial apertures therein through which the charged particles are transmitted, a dielectric plate having similar apertures which are aligned with the apertures of the metallic plates and interposed between and spaced from each of the metallic plates and insulated from the metallic plates, a source of voltage which is connected across the metallic plates to apply voltage directly to the metallic plates and to establish an electrostatic field between the metallic plates and to induce electrical charge on the opposite surfaces of the dielectric plate, whereby the charged particles may traverse the apertures of all three plants and may be attracted to and collected by all three plates.

2. An electrostatic precipitator according to claim 1 in which the apertures of the metallic plates and the apertures of the dielectric plate occupy about 60 to 70 percent of the effective area of each of the plates and the plates are spaced from each other by a predetermined distance so that the particulate matter will be vorticized in the wake of its passage through each of the plate apertures, whereby the particulate matter will be slowed up to facilitate the attraction of the particulate matter by said plates.

3. An electrostatic precipitator comprising three parallel plates which are positioned transverse to the path of charged particles and are parallel to and spaced from each other and have substantially aligned apertures so that particulate matter may be transmitted through the apertures of all of said plates, a source of voltage connected to the outer plates to establish an electrostatic non-ionizing field therebetween, the intermediate plate being made of dielectric material and being disconnected from the source of voltage so as to receive an induced voltage, all of the plates being collectors of particulate matter transmitted through the apertures.

4. An electrostatic precipitator according to claim 3 in which the apertures occupy more than half of the active collecting surface of the respective plates and spaced from each other by a predetermined distance so that particulate matter will be vorticized in the wake of its passage through any aperture so that it may be slowed down and collected on the surface of said plates.

5. An electrostatic precipitator comprising a conventional precipitating structure, and an add-on precipitating structure coupled to the conventional structure, the add-on structure including two parallel apertured metallic plates between which a voltage is directly applied to produce a non-corona field therebetween and an intermediate substantially identical parallel apertured plate made of dielectric material which is spaced from and insulated from the metallic plates to receive an induced voltage due to its position between the metallic plates, so that ionized particulate matter received from the conventional precipitator may be transmitted through the apertures of all of said plates and collected on the surfaces of all of said plates.

6. An electrostatic precipitator according to claim 5 in which the plates are spaced from each other by at least a predetermined minimal distance and the apertures occupy at least 60 percent of the effective surface areas of the plates, whereby particulate matter will be vorticized and slowed down so as to be attracted by and collectable on the charge surfaces of said plates.

7. An electrostatic precipitator for collecting charged particulate matter, comprising a first plurality of interconnected metallic plates, a second plurality of interconnected metallic plates, a source of voltage connected between the first and second pluralities of plates to establish a non-corona electrostatic field therebetween, and a plurality of dielectric plates so arranged that one of said dielectric plates is interposed between one of the first plurality of metallic plates and one of the second plurality of metallic plates so that an individual dielectric plate is interposed between two metallic plates of said two pluralities of plates to receive an induced electrostatic charge due to its interposition, all of said metallic and dielectric plates being positioned parallel to each other and having substantially aligned apertures so that charged particulate matter may be borne through the apertures of said metallic and dielectric plates and vorticized and collected thereon.

8. An electrostatic precipitator according to claim 7 in which the source of voltage is of the d.c. type.

9. An electrostatic precipitator according to claim 7 in which the source of voltage is of the alternating type.

10. An electrostatic precipitator according to claim 7 in which the apertures of the metallic and dielectric plates are circular and aligned so that they are optically transparent to permit the free flow of the particulate matter therethrough without substantial pressure loss.

11. An electrostatic precipitator according to claim 10 in which the dielectric plate is made of a plastic material.

12. An electrostatic precipitator according to claim 10 in which the dielectric plate is made of fiberglass.

13. An electrostatic precipitator for improving an existing precipitator for removing charged particles, comprising a pair of apertured metallic plates, an apertured dielectric plate interposed between and insulated from the metallic plates, and means for applying a voltage between the metallic plates so as to induce a voltage on the interposed dielectric plate, the apertures of all of the plates being of substantially the same size and aligned with each other and the spacings between said plates being substantially uniform so that charged particles will be vorticized as they exit an aperture and slowed up to facilitate their attraction by said plates.

14. An electrostatic precipitator according to claim 13 in which a plurality of spaced substantially identical apertured dielectric plates are inserted between the metallic plates.

15. An electrostatic precipitator comprising a plurality of apertured metallic plates spaced from each other, a plurality of apertured dielectric plates spaced from each other and interspersed between said metallic plates so that each dielectric plate is interposed between a pair of adjacent metallic plates, a source of voltage having one terminal connected to certain of said metallic plates and its other terminal connected to the remaining metallic plates so that opposing voltages appear on adjacent metallic plates but no voltage is directly applied to the dielectric plates and yet a voltage is induced upon each dielectric plate, the apertures of all said metallic and dielectric plates being substantially coaxially aligned with each other so that particulate

matter traversing said apertures may be attracted to and collected by said metallic and dielectric plates.

16. An electrostatic precipitator according to claim **15**, including a source of pressurized air for moving the particulate matter through the apertures of said metallic and dielectric plates.

17. An electrostatic precipitator according to claim **16** in which the apertures of the metallic and dielectric plates occupy 60 to 70 percent of the total effective area of each of said plates.

18. An electrostatic precipitator including a pair of spaced metallic plates, a dielectric plate interposed between the metallic plates, a source of voltage connected to the metallic plates but are not connected to the dielectric plate, said source of voltage inducing an electrical charge of a substantial voltage on the dielectric plate, said metallic plates and said dielectric plate each having a plurality of apertures, all of which are substantially coaxially aligned with each other to provide direct through paths through said apertures, particulate matter being vorticized in traversing the apertures of said metallic and dielectric plates and slowed down so as to be attracted by and collected on the surfaces of all of said metallic and dielectric plates.

19. An electrostatic precipitator according to claim **18** in which the sum total of the areas of said apertures of each plate occupy at least 60 percent of the total active surfaces of said plates.

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