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[54] **ELECTROSTATIC PRECIPITATOR**

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

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[21] Appl. No.: **194,980**

Related U.S. Application Data

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

[52] **U.S. Cl.** **55/123**, 55/131, 55/138, 55/139, 55/154

[51] **Int. Cl.** **B03c 3/09**

[58] **Field of Search** 55/103, 123, 130, 55/131, 138, 139, 154, 155, 156, 127, 128, 129, 132, 136, 137

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[57] **ABSTRACT**

Covers an electrical precipitator composed of two tandem electrostatic sections arranged to eliminate dust or dirt or any form of particulate matter which may be conveyed with air or gas or any other fluid medium. The first section may, for example, include one or more pairs of positively charged vertical plates between each pair of which are positioned a plurality of negatively charged vertical wires, so that a Corona discharge may be developed between the vertical wires and the two parallel plates of each pair to electrically charge the particulate matter transmitted between the vertical plates. The second section, which is contiguous to the end of the first section and constitutes an add-on for the first section, includes a plurality of metallic grids which are parallel to each other, but perpendicular to the plates of the first section. The first and last grids of the second section may be connected to a source of voltage which does not create a corona field, and the remaining grids of the second section are "floated" between the first and last grids so as to become charged by voltage induced in such grids so that particles of matter entering the second section and traversing the opening of the various grids will respond to the electric field between adjacent grids and to the aerodynamic flow pattern developed between all of the grids, so that the particulate matter may be collected and removed from the fluid medium.

6 Claims, 2 Drawing Figures

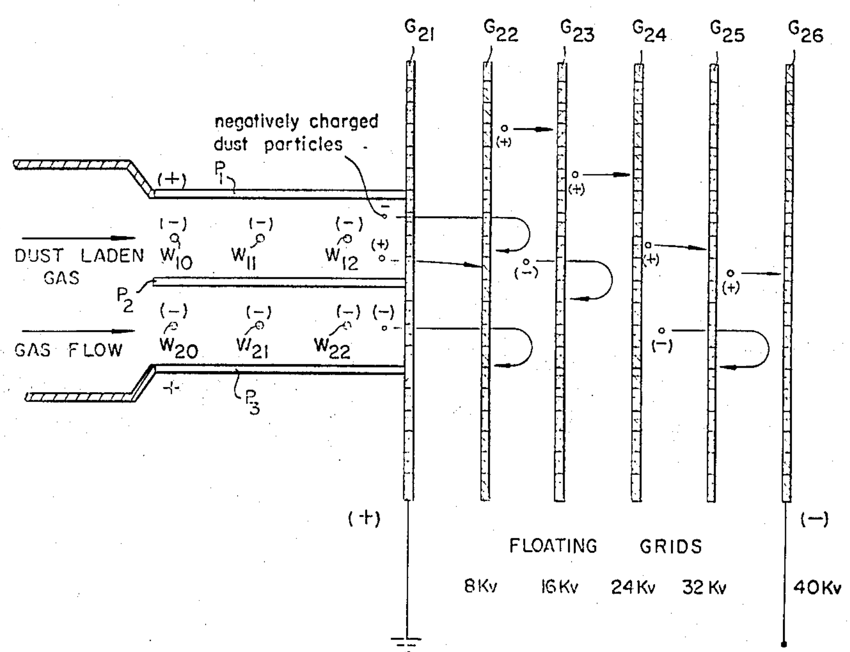


FIG. 1

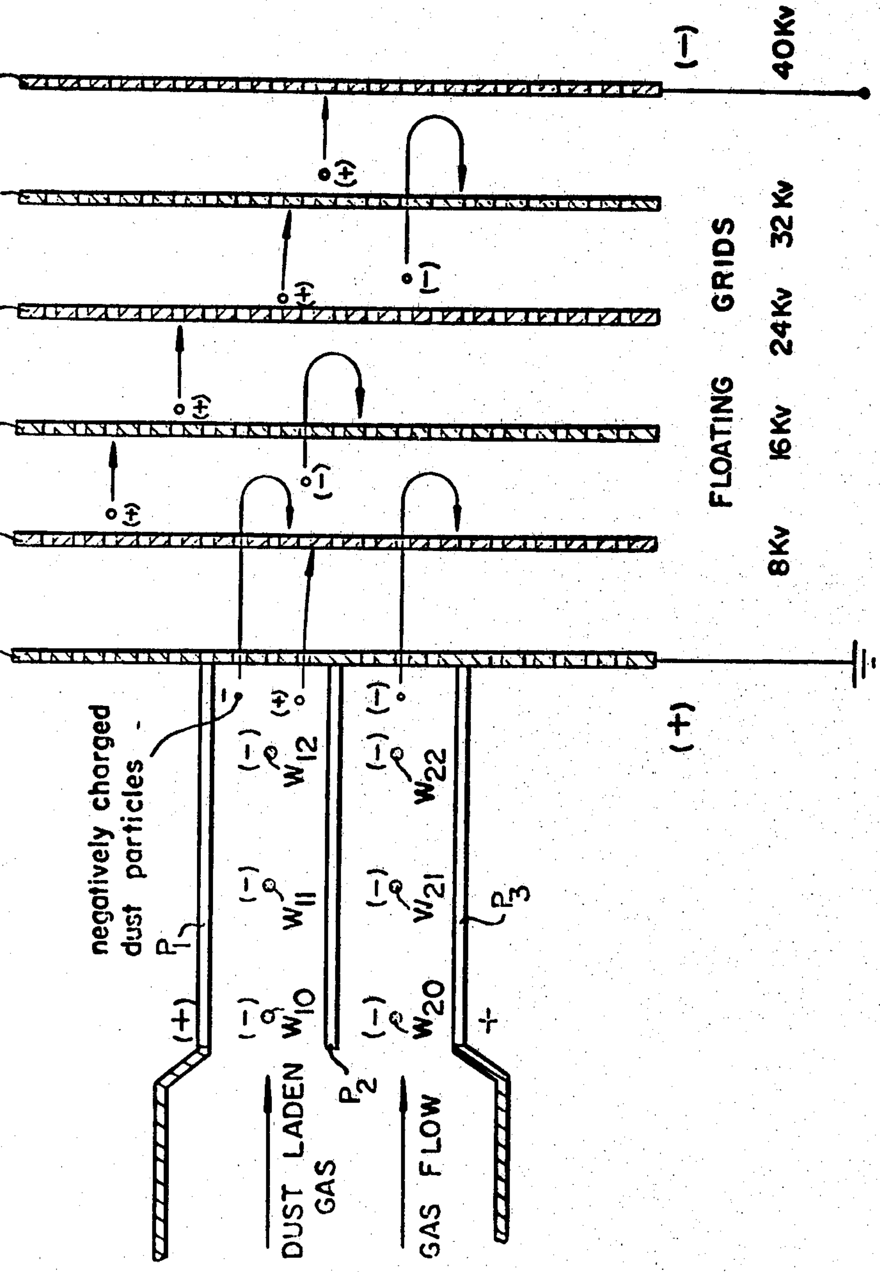
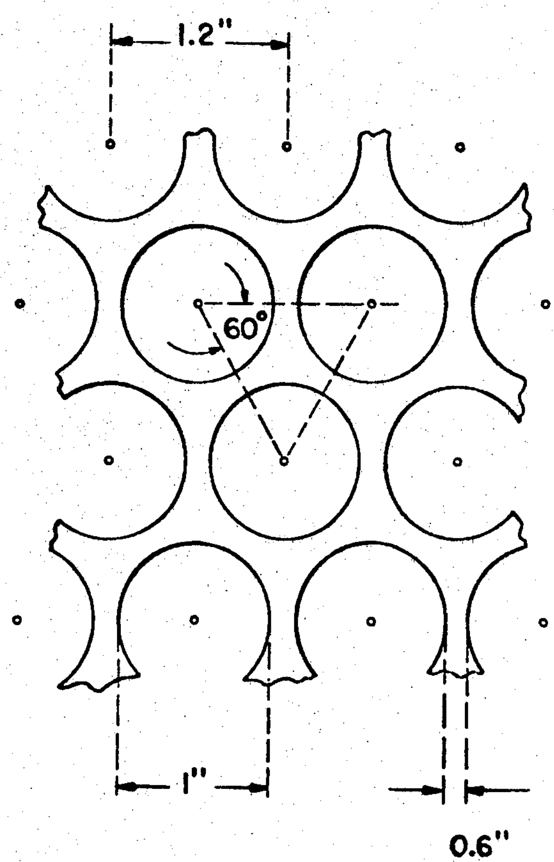

G26
G25
G24
G23
G22
G21
(−)
40Kv
FLOATING GRIDS
8Kv
16Kv
24Kv
32Kv
(+)
negatively charged dust particles
P1
P2
P3
W10
W11
W12
W20
W21
W22
DUST LADEN GAS
GAS FLOW

FIG. 2



ELECTROSTATIC PRECIPITATOR

This application is a continuation in part of my earlier application, Ser. No. 804,050, entitled "Electrostatic Precipitator," filed Feb. 25, 1969, now abandoned my earlier application, Ser. No. 869,195, entitled "Multi Stage Electrostatic Precipitator," filed Oct. 24, 1969, now U.S. Pat. No. 3,616,606 and my earlier application, Ser. No. 65,843, entitled "Multi-Grid Electrostatic Precipitator," filed Aug. 21, 1970. All of these applications are assigned to the assignee of the present patent application.

This invention relates to electrical precipitators and, more particularly, to apparatus and equipments for the precipitation of dust, dirt or other particulate matter which may be included with, or suspended in, a fluid medium such as air or gas.

The prior applications, and this application, disclose arrangements of an electrostatic precipitator for the removal of particulate matter borne by a fluid medium such as air or gas. The electrostatic precipitator embodies two series sections. The first section embodies one or more pairs of parallel metallic plates and a plurality of conductors which are parallel to each other and aligned between the two parallel plates of each pair so that, upon the application of a sufficient voltage between the parallel plates and the intervening conductors, a Corona discharge may be established between the plates of each pair and the several related conductors so that particulate matter transmitted along the path between the two parallel plates of each pair will be electrically charged and deflected toward the two plates of the first section. If the several conductors are negatively charged, the particles traversing the path may become negatively charged and, if the plates are positively charged, they will attract the charged particles so that they may be deposited on the parallel plates and then removed. Notwithstanding the intended operation, a great many charged particles will not be removed by the first section and can be, and often is a public nuisance. The second section, which may be an "add-on" section, may include two or three or more parallel grids which are parallel to each other but perpendicular to the plates of the first section and so arranged that a non-Corona electrostatic field may be established between the adjacent grids. The first grid would normally be brought to substantially the same polarity as the plates of the first section, that is, to a positive potential (which may be grounded). The third grid, and, if fifth, seventh, etc., grids are employed, would be charged to the same potential as the first grid, but the second grid, and the fourth, sixth, etc., grids would be charged to negative potential. The openings in all of the grids are rather large, and the spacings of the grids are sufficiently large, so that the air or gas will be entrained in vortices and particulate matter will be entrapped in the vortices. The electrostatic field established between the grids of the second section will act on the particles that leave the first section so that they may be attracted to and collected on the grids of the second section whereupon they will be removed from the system.

In the arrangements described in the earlier applications, the first section may be any conventional electrostatic precipitator of the plate-wire (Cottrell) type. In fact, the first section need not be restricted to the type of device referred to above, but it may consist of any precipitating device which suitably charges the dust

particles or other particulate matter electrically prior to their entry into the second (grid) section. The second section and the combination of the two sections provide the main areas of novelty and operative improvement in precipitating systems.

A fundamental novel concept is involved in the basic mechanisms by which dust or other particulate matter is collected in the second (i.e., the grid) section and it employs interaction between the electric field applied between successive grid pairs and the aerodynamic forces in the wake of the structure behind each grid. Each "grid" is in the form of a flat plate having an array of openings or holes such that air may flow through the grid in a path essentially at right angles to the grid. The air flow through such a grid will be such that, notwithstanding the flatness of the grids and the absence of circulators, recirculating flow zones or vortices will be created in the wake of the solid areas of the grid. Dust particles or other particulate matter passing through the holes in a grid may be drawn into these vortices, and the particles may reside there for a short period before continuing on their downstream paths. During the time that such a particle is thus trapped in a vortex, it is, to all intents and purposes, substantially stationary and thus temporarily removed from the downstream sweeping action of the flowing gas, and can thus be easily acted upon by an applied electric field to sweep the particle to a collecting boundry, the particle either moving back to the upstream grid through which it just passed, or moving forward to the adjacent downstream grid. By increasing the number of grids placed in parallel and perpendicular to the path of the main gas stream, the chances are substantially increased that a given particle may be trapped into an eddy or vortex, and so the chances are increased that the particle will be collected. Therefore, any increase in the number of grid stages will increase the overall particle collection efficiency. Theoretical and experimental investigations have established the conclusion that, without this vortex-enhanced electrostatic collection effect, the efficiency of the grid-type precipitator structure would be so low as to be of little value. In order to maximize the vortical formations and the particle collection effect, the grids themselves must be designed and arranged so that a maximum amount of air, and hence dust, will be entrained into the vortices, and this requires grids with an open area within a predetermined range. However, upon decreasing the open area too drastically, aerodynamic instabilities will be produced in the wake structure of the grids. It has been found that for optimum operation, the percentage of open area in the grid should lie in the range from about 60 percent to about 70 percent.

For effective utilization of the above-mentioned grid vortex-enhanced collection mechanism, the grids must be properly spaced from each other so that they do not physically interfere with one another's wake structure. Specifically, the spacing between adjacent grids must be at least as great as the mean extent of the vortices downstream from each grid. It is a general rule of thumb that, if we assign a characteristic dimension to the grid such as the mean width of the solid portions behind which the vortices are generated, then the spacing between adjacent grids should preferably be at least three times as great as that dimension. The efficiency of dust collection is not materially affected, either adversely or otherwise, by increasing the grid spacing to distances greater than this, provided that there is no loss in maximum effective electric field that can be maintained between the grids without sparkover.

One of the principal objects of the present invention is to improve the operational characteristics of a conventional electrostatic precipitator by including a plurality of charged grids so as to provide more opportunities for deflecting and removing particles of matter that enter the precipitator. Such an arrangement, if added to a conventional precipitator, such as a Cottrell structure, for example, will improve the overall efficiency. When such a multi-grid structure is joined to such a conventional first section, the first section may be reduced in length so that shorter plates may be employed along with a smaller number of parallel conductors between the plates of the first section. This, therefore, reduces the cost of the overall precipitator while at the same time achieving an increased efficiency in the removal of particulate matter from the fluid stream.

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

FIG. 1 discloses and illustrates a cross-section of a dual section electrostatic precipitator embodying a plurality of pairs of oppositely poled grids sequentially arranged in its second section, in which the second section embodies two grids which are oppositely poled, between which are interposed a plurality of additional grids, sometimes called "floating" grids; and

FIG. 2 illustrates a portion of a grid structure to exemplify the dimensional character of the structure.

Throughout the drawing the same or similar reference characters will be employed to designate the same or similar parts.

Referring to FIG. 1 of the drawing, there is illustrated a dual section electrostatic precipitator in which the first section includes three (or more) vertical parallel plate conductors such as P–1, P–2 and P–3 organized as two groups and arranged so that a plurality of vertical conductors W–10, W–11 and W–12 are typically interposed midway between a pair of the plates P–1 and P–2 and a plurality of vertical conductors W–20, W–21 and W–22 are typically interposed midway between the vertical plates P–2 and P–3, as shown. The second section includes, for illustrative purposes, six parallel grids G–21 to G–26. Plates P–1, P–2 and P–3 of the first section may be supplied, for example, with substantially equal voltages of the same polarity, for example, positive voltages as shown, while the conductors W–10, W–11 and W–12 of one path of the first section and the conductors W–20, W–21 and W–22 of the other path of the first section, have applied thereto negative voltages with respect to the several plates between which the conductors are interposed. It will be apparent that a common source of appropriately high voltage may be so arranged that its positive terminal is connected to the several plates P–1 and P–2 and its negative terminal will be connected to the conductors W–10, W–11 and W–12, as well as to conductors W–20, W–21 and W–22. Furthermore, the plates P–1, P–2 and P–3 may be connected to ground. The grids G–21 to G–26 of the second section are poled so that the same positive voltage will be applied to the grid G–21 while the corresponding negative voltage will be applied to the grid G–26. The voltages that may be employed in practice may be as high as 40 or more kilovolts as developed by a steady DC source, a pulsed DC source, an AC source or any other suitable voltage wave form. It is essential that the second section be substantially free of Corona discharge and this may require appropriate adjustment or reduced voltages between grids G–21 and G–26.

As the stream of gas or other fluid with the accompanying entrained dust, dirt or other particulate matter, which may be obtained from any source of such dust, dirt or particulate matter, such as a gas engine, or a smoke stack, or a factory, for example, and may be impelled or pressurized by a fan or other blower (not shown), the particulate matter will be driven between the two parallel paths of the first section, one path being provided by plates P–1 and P–2 and the other path by plates P–2 and P–3. Any particulate matter not removed by the first or conventional section will enter the second section which includes the several grids G–21 to G–26 which, as already noted, are equally spaced from each other and are parallel to each other and are also perpendicular to the plates P–1, P–2 and P–3 of the first section.

The electrostatic field in the first section, that is, the electrostatic field between, for example, each of the wires W–10, W–11 and W–12 and the adjacent plates P–1 and P–2 and the electrostatic field between the wires W–20, W–21 and W–22 and the adjacent plates P–2 and P–3 are substantially perpendicular to the flow path of the particulate matter transmitted through the first section. On the other hand, the electrostatic field between any pair of adjacent grids such as G–21 and G–26 of the second section is substantially parallel to the direction of movement of the particulate matter which traverses or escapes from the first section and enters the second section.

In the first section of FIG. 1, each conductor, such as W–10 or W–20, serves as a discharge electrode producing a negative Corona discharge effect so that substantially the entire space in the region of these various conductors of the first section is subjected to the Corona field. Dust particles will be charged predominantly negatively. These negatively charged wires, such as W–10 and W–20, attract any of the particles of matter which have positive charges thereon. The positively charged plates P–1, P–2 and P–3 attract and serve as collectors of the negatively charged particles. Hence, a good proportion of the particles, whether negatively charged or positively charged, are attracted to and are deposited on the surfaces of the plates P–1, P–2 and P–3, or on the conductors W–10 to W–12 and W–20 to W–22.

Any of the particles that traverse the first section, because they have not been sufficiently attracted by the positively charged plates or the negatively charged conductors of the first section and, therefore have not been deposited on the plates or conductors of that section and removed, will enter the second section. The particulate matter entering the second section may contain predominantly negatively charged particles but may also contain some positively charged particles. Both types of particles will be treated by the second section.

Negatively charged particles entering the region of the first pair of grids G–21 and G–26 of the second section will tend to be attracted by the first grid G–21 and hence turned back and collected on the first grid G–21. Those not collected there will pass to the region between the remaining grids G–22 to G–26. The collection processes outlined here are greatly assisted by the vortex effects previously mentioned. Similarly, any positively charged particles may be attracted toward and deposited on grids G-22 to G-26, and substantially assisted by the vortex effects. The overall probability of collection of particles increases with the number of grids employed. Thus, as described earlier, the overall efficiency of the system is increased.

It will be apparent that the FIG. 1 arrangement is capable of acting and removing, and does remove, both positively and negatively charged particles that may be passed by the first section of the precipitator and received by its second section. Moreover, the peak voltage in the second section need not be the same as the voltage in the first section. The voltage applied to the second section may be higher or lower than the voltage applied to the first section as may be desired, but Corona discharge in the second section should be avoided. The voltages applied to either section may be a steady d.c., pulsed d.c., or a.c. as desired. For example, the first section may have a steady or pulsed d.c. voltage while the second section may have an a.c. voltage. This type of bi-polar arrangement has been found to be quite efficient in removing a very high percentage of particulate matter which is transmitted through the filter.

Although the arrangement of FIG. 1 has been shown and described as embodying mechanism to charge incoming particles predominantly in a negative sense, reversing the voltages in the first section will cause predominantly positively charged particles to enter the second (grid) section. The same collection processes occur as described above. Furthermore, the voltages applied to the grids G-21 and G-26 may be reversed, regardless of the polarities in the first section, without basically changing the collection properties of the structure. Still further, the voltages applied to the grids may be alternating, either at 60 cycles per second or at any other frequency. In relation to the basic collection mechanism described above involving the vortices in the wake of the grids, the range of frequencies of applied voltage that can be used in the practice of this invention is limited to that where the duration of one-half cycle exceeds the mean time period that a particle is trapped in in a given vortex, which in turn is a function of grid geometry and dimensions and of the air flow velocity.

Because of the overall high efficiency due to the addition of the second section of the electrostatic precipitator of FIG. 1, the length of the plates P-1, P-2 and P-3 of the first section and the number of vertical conductors such as W-10 and W-20 in the first section may be reduced. The reduction in the length of the plates and in the number of vertical conductors materially affects the overall length of the equipment as well as the cost of the equipment and its installation and, at the same time, there is a significant improvement in the overall efficiency of the particle collecting features.

The intermediate grids G-22, G-23, G-24 and G-25 of the second section are "floating" grids in that no voltage is directly applied thereto, but voltages are induced on the several grids G-22 to G-25. Assuming that the grids G-21 and G-26 have respective positive and negative applied polarities, and the voltage is, for example, 40 KV, as shown, then the grid G-22 will have induced thereon an 8KV voltage of a negative polarity, the grid G-23 will have a negative 16KV induced voltage, and the grids G-24 and G-25 will have induced negative 24 and 32 KV voltages, as shown. And so on if additional grids or different applied voltages were employed.

In the arrangement of FIG. 1, each negative particle traversing the grid G-21 will be deflected by the induced negative voltage on grid G-22 to repel and turn back the negatively charged particle to grid G-21 where it may be collected and removed. The same particle will also be subjected to the vortical effect immediately upon entering the opening of the grid G-21 to aid in the collection process. Likewise, the increased induced voltages on the remaining downstream grids G-22 to G-25 will repel negatively charged particles that reach the regions of the respective grids and deflect and turn back such negatively charged particles to the various grids G-21 to G-25, which may attract and collect the negatively charged particles and, therefore, remove them from the air stream. Again the collection process will be aided by the vortical formations. Naturally, the number of grids interposed between the two outer grids G-21 and G-26 may be increased or decreased as desired for increasing or decreasing the trend toward reversing the path of any negatively charged particles to the first grid G-21.

Positively charged particles will be collected by the same mechanisms as already described. It will be apparent that similar collection effects will be produced by reversing the polarities on the several grids of the second section.

The several arrangements shown and illustrated in the drawing serve to improve the efficiency of collection and elimination of particles passing through the parallel and sequential paths of the conventional or other precipitator in the first section. Because of the increased efficiency due to the second section of the arrangements of this invention, the first section may be simplified so that smaller components may be employed and the number of conductors reduced, thereby reducing the cost of the overall equipment and improving the overall operation at the same time. The equipment of this invention may be made suitable for those other purposes for which electrostatic precipitators of the kind herein described are conventionally employed. Naturally, any suitable means for receiving and accumulating particles removed by the various elements of both sections may be employed in the practice of this invention.

One metallic grid configuration that has been successfully used in connection with a circularly perforated plate is shown fragmentally in FIG. 2 where adjacent holes have equally spaced centers staggered by 60°, as shown. Typically, the holes were 1 inch in diameter, with the centers spaced about 1.2 inches apart, so that the percentage open area would be about 63 percent. The plate had a thickness of one-quarter of an inch. In this instance, if the characteristic grid dimension *d* is taken to the width of the solid portion of grid between adjacent holes as measured along the line of centers, the preferable minimum spacing allowable between adjacent grids should be about 0.6 inches for a plate having 1 inch holes. The spacing between adjacent plates should be somewhere between 3*d* and 6*d* or between about 1.2 inches and 3.6 inches.

Although the elements of the first section are parallel to each other and the elements of the second section are likewise parallel to each other, their relative directions may be changed over considerable angles within the scope and spirit of this invention. Moreover, although the several elements are shown as linear or are linearly arranged, the various elements may be curved to be spherical or elliptical or of any other desired shape within the scope and spirit of this invention.

While this invention has been shown and described in certain particular arrangements merely for illustration and explanation, it will be apparent that the arrangements and operating features may be arranged in other and widely varied organizations for the purpose of carrying out the general principles and objectives of the present invention.

What is claimed is:

1. An electrostatic precipitator for removing charged particles, comprising a plurality of parallel apertured grids arranged in sequential order so that the charged particles, in travelling along a path perpendicular to said grids, will traverse the apertures of said grids, means for applying a voltage of one polarity to the first of said grids and a voltage of opposite polarity to the last of said grids, so that the only voltages impressed upon the intermediate grids will be voltages induced on the intermediate grids, whereby all of said grids will act to divert said charged particles and collect them on all of said grids.

2. An electrostatic precipitator according to claim **1**, in which the total area of the openings of each grid is about 60 to 70 percent of the effective area of said grid.

3. An electrostatic precipitator according to claim **1**, in which the apertures of all of the grids are sufficiently large so as to cause the particles to travel in vortical paths in the wake of each grid to facilitate the collection of said particles on said grids.

4. An electrostatic precipitator for upgrading a precipitator which is discharging electrically charged particles, comprising two parallel grids, a source of voltage connected between said two grids, a plurality of additional grids interposed between said first two grids so that voltages will be induced on the surfaces of said additional grids, all of said grids being arranged parallel to each other and substantially perpendicular to the path of the charged particles so that the charged particles may traverse the apertures of said grids, each of said grids having apertures which aggregate between 60 and 70 percent of the effective area of each grid, the grids being spaced from each other by a predetermined distance, whereby the particles will be vorticized in the wake of each of the grids and slowed up so as to be attracted by said grids and removed.

5. An electrostatic precipitator according to claim **4**, in which the source of voltage is of the alternating type.

6. An electrostatic precipitator according to claim **4**, including means for charging said particles before they traverse the paths through the apertures of said grids.

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