United States Patent [19]

Trump et al.

[11] **3,912,467**

[45] **Oct. 14, 1975**

[54] **MOVING ELECTRODE ELECTROSTATIC PARTICLE PRECIPITATOR**

[75] Inventors: **John G. Trump,** Winchester; **Helmut I. Milde,** Andover, both of Mass.

[73] Assignee: **High Voltage Engineering Corporation,** Burlington, Mass.

[22] Filed: **Apr. 6, 1973**

[21] Appl. No.: **348,743**

[52] **U.S. Cl.** **55/149;** 55/112; 55/114; 55/154

[51] **Int. Cl.**[2] **B03C 3/10**

[58] **Field of Search** 55/113, 114, 115, 116, 55/149, 121, 14, 13, 112, 117, 118, 119, 120, 154

[56] **References Cited**

UNITED STATES PATENTS

2,212,885	8/1940	Pound et al.	55/116
2,383,111	8/1945	Dahlman	55/138 X
2,625,238	1/1953	Roper	55/114 X
2,786,575	3/1957	Roberts	209/127
2,946,400	7/1960	Gustafsson	55/156
3,008,541	11/1961	Wachter	55/149 X
3,028,714	4/1962	Mayer	55/114
3,362,135	1/1968	Steuernagel	55/154
3,375,638	4/1968	Dungler	55/131 X
3,581,468	6/1971	Gourdine et al.	55/129 X
3,701,236	10/1971	Rotsky et al.	55/121 X
3,740,925	6/1973	Gothard	55/113 X

FOREIGN PATENTS OR APPLICATIONS

513,836	11/1920	France	55/149
377,788	7/1964	Switzerland	55/149

OTHER PUBLICATIONS

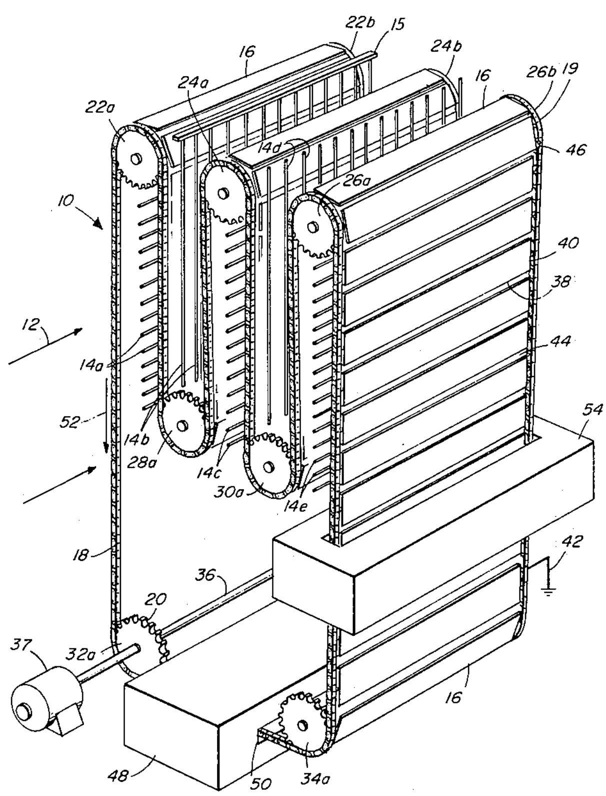
German Printed Application No. 1,001,973, printed 2-7-57, 1 sheet drawing, 2 pages specification.

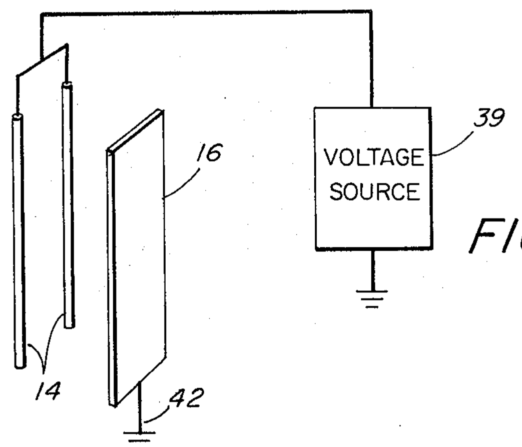
Primary Examiner—Bernard Nozick
Attorney, Agent, or Firm—Russell & Nields

[57] **ABSTRACT**

An electrostatic particle precipitator includes a plurality of planar arrays of wire positioned in a stream of gas containing particles, the arrays of wire forming one electrode of a corona discharge device. A pair of endless roller chains supported by a plurality of sprocket wheels pass between the wire arrays. A plurality of grounded metallic plates that are generally rectangular in shape are detachably mounted on the roller chains such that the longer dimension is parallel to the gas stream and the shorter dimension is parallel to the direction of the motion of the chains. The plurality of plates form a moving collecting electrode. The moving electrode passes out of the gas stream and through a region wherein the individual plates are cleaned. The surface of the plates may include a plurality of depressed and raised areas to assist in collecting the particles.

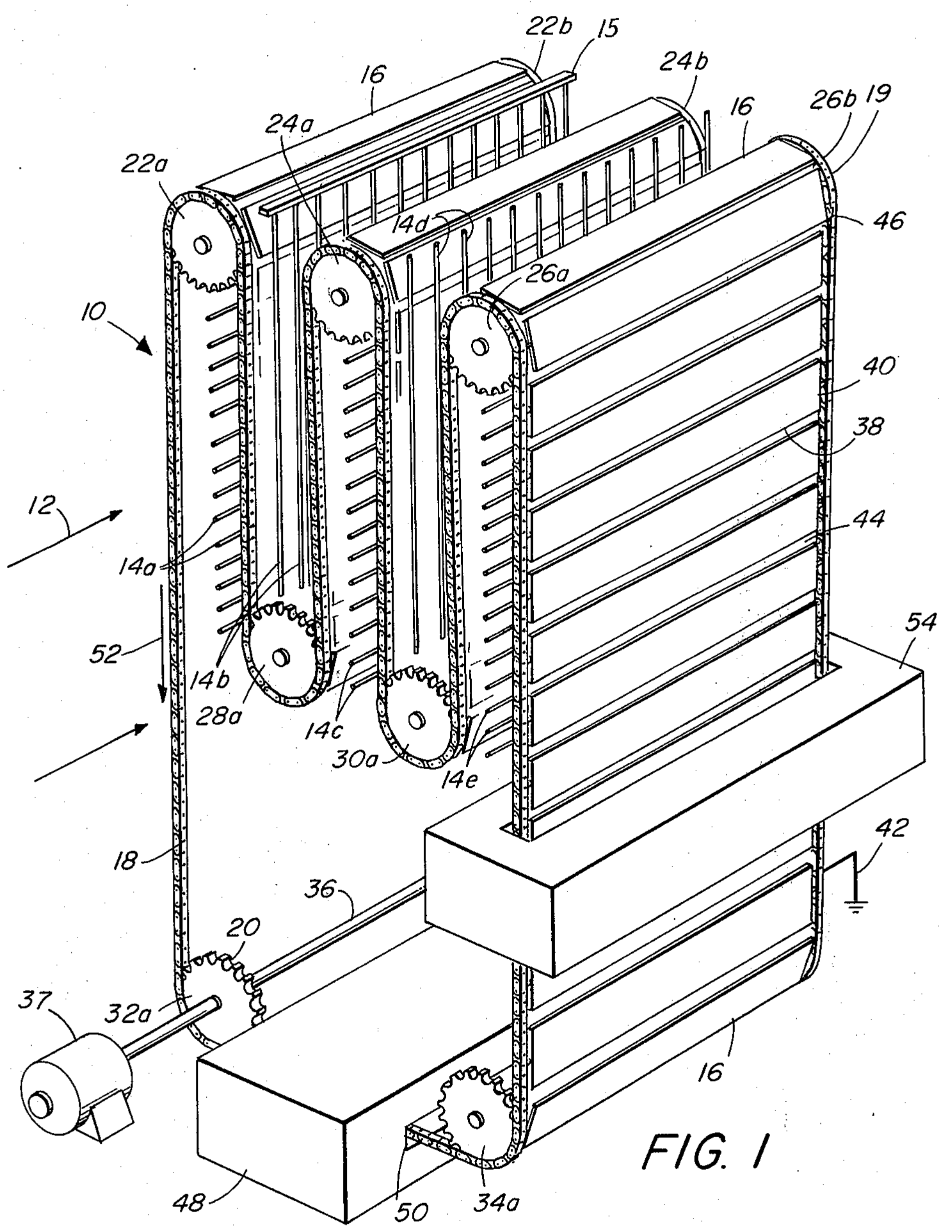
7 Claims, 17 Drawing Figures





39
VOLTAGE
SOURCE
16
14
42

FIG. 7



22b
15
16
24b
16
26b
19
24a
22a
14d
46
26a
10
40
38
12
44
14a
54
52
14b
28a
14c
30a
14e
42
18
36
20
37
32a
16
48
50
34a

FIG. 1

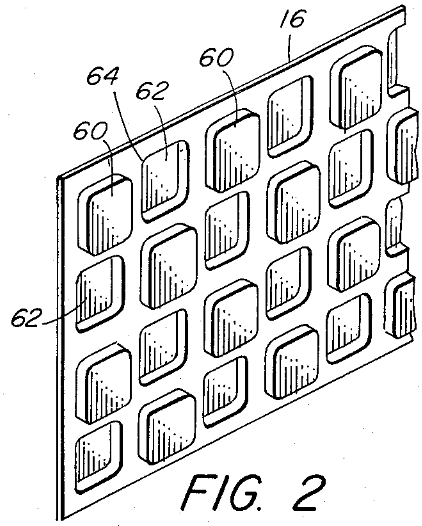


FIG. 2

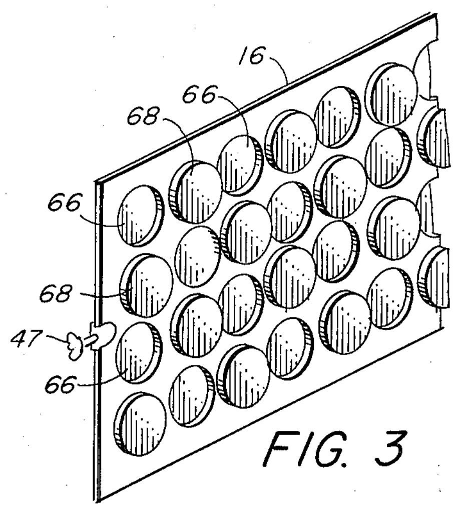


FIG. 3

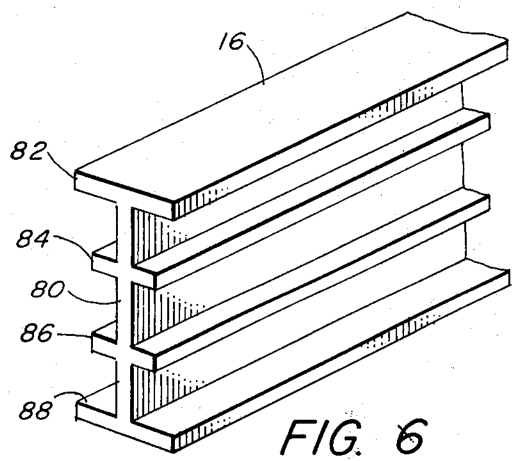


FIG. 6

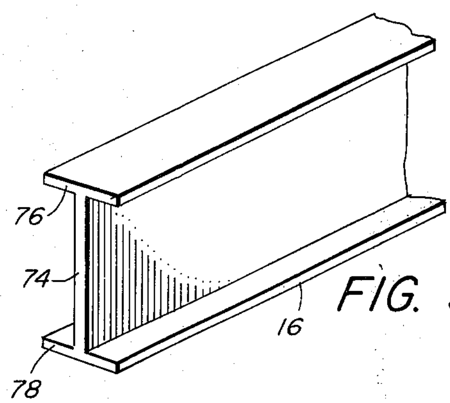


FIG. 5

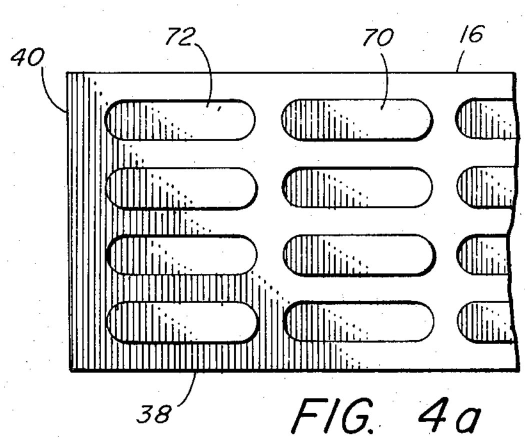


FIG. 4a

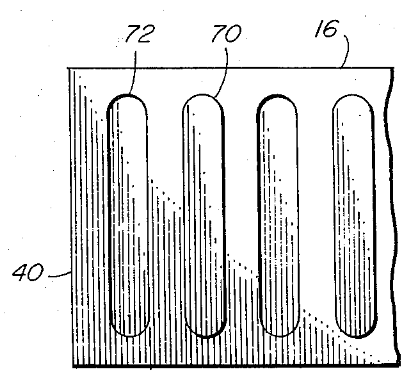


FIG. 4b

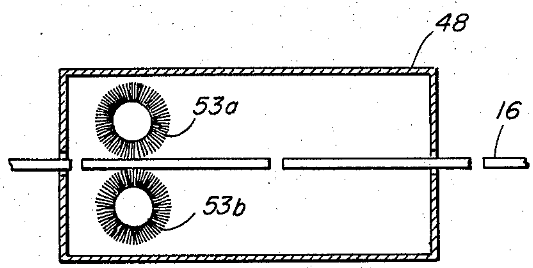


FIG. 8a

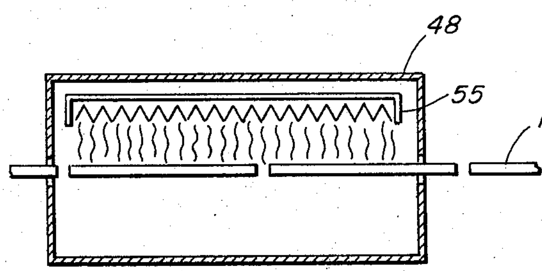


FIG. 8b

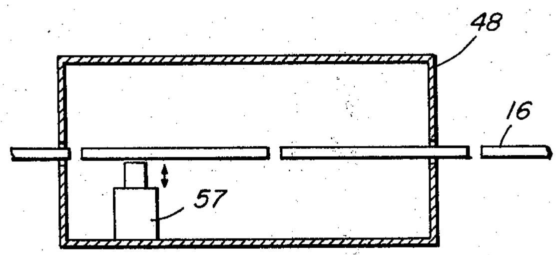


FIG. 8c

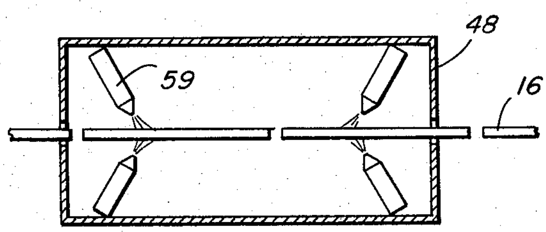


FIG. 8d

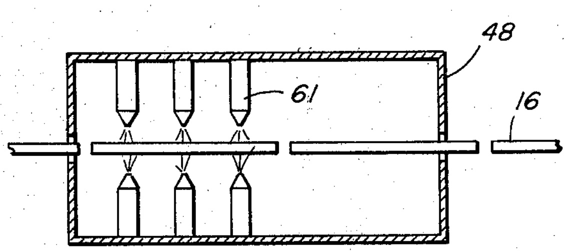


FIG. 8e

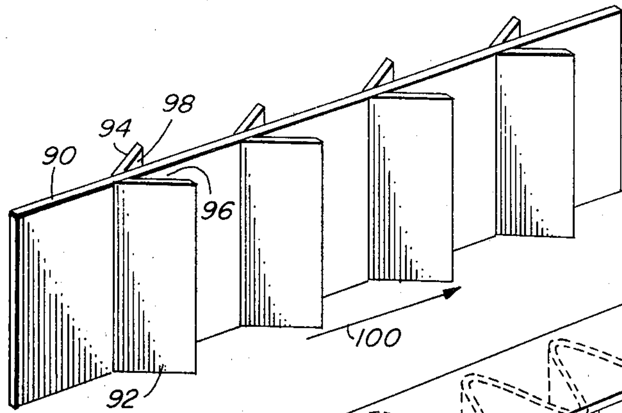


FIG. 9

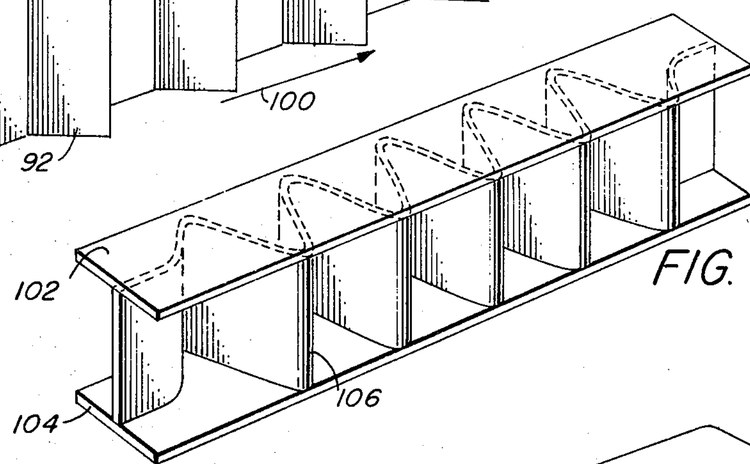
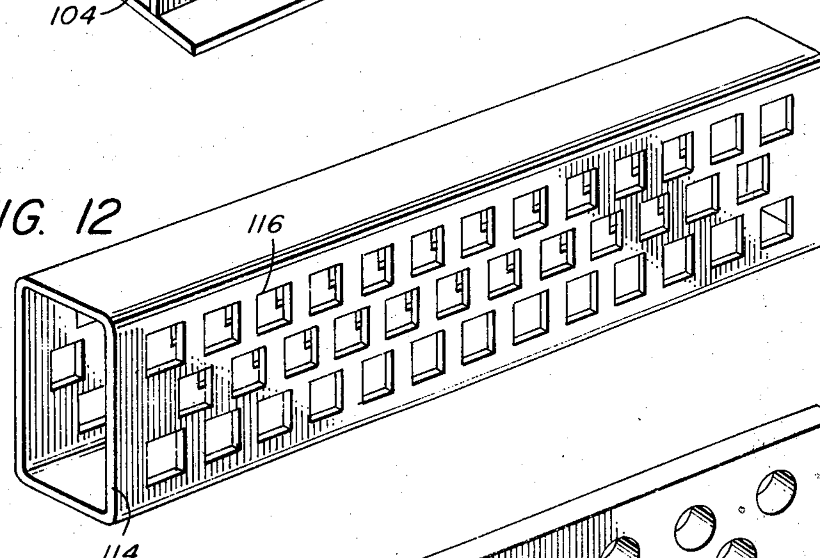


FIG. 10

FIG. 12



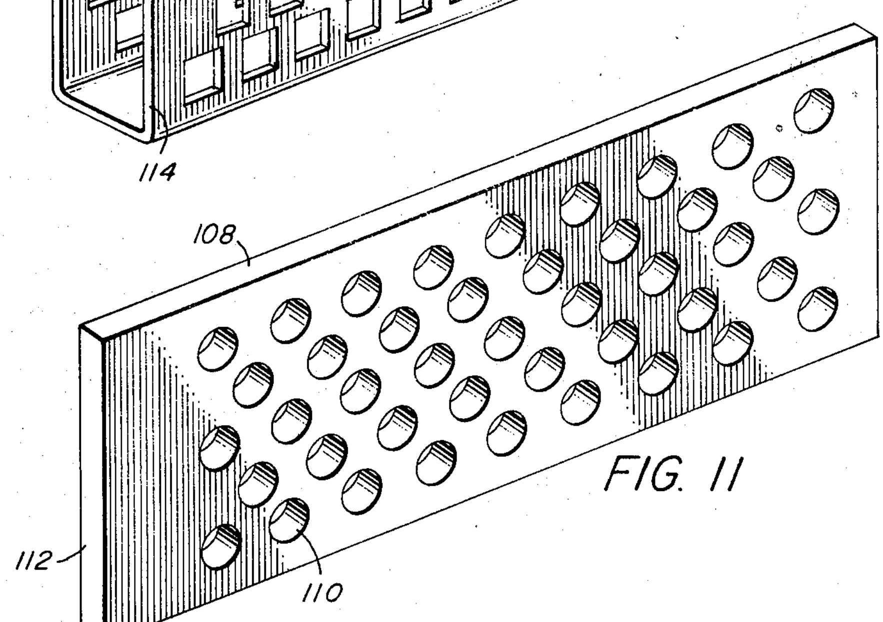


FIG. 11

MOVING ELECTRODE ELECTROSTATIC PARTICLE PRECIPITATOR

BACKGROUND OF THE INVENTION

The present invention relates to electrostatic particle precipitators and more particularly, to a precipitator having a moving collecting electrode.

Electrostatic precipitators have long been used for removing particles from a gas. Basically, a corona discharge between a corona and a collecting electrode creates ions that adhere to the particles, thereby charging them. The forces resulting from the presence of charged particles in an electric field propel the particles to the collecting electrode.

Those skilled in the art of electrostatic particle precipitators have long struggled with the problem of removing and collecting the solid materials accumulated on the collecting electrode without causing the material to be re-entrained in the gas. Stationary collecting electrodes that are mechanically vibrated have been tried, but they have a serious re-entrainment limitation because not all the material falls due to gravity into a collecting vessel. Since the electrode is in the region of the gas, a significant quantity of the material becomes entrained in the gas, thereby seriously degrading precipitator efficiency.

Concern over re-entrainment has led to efforts to have a moving collecting electrode that is cleaned in a region outside the gas stream. Particle re-entrainment is thus reduced because the materials removed from the electrodes may not be swept into the gas stream.

One conventional moving electrode precipitator includes an endless metallic band that passes over vertically disposed sprockets to permit the band to have approximately sinuous motion. The corona electrodes are disposed adjacent the band. The band moves through a region outside the gas stream that applies a cleaning fluid to the band, brushes the band, dries the band and finally applies an adhesive to the band.

While this moving electrode precipitator was generally successful in reducing the re-entrainment problem, several problems arose due to the nature of the moving electrode. Because of the presence of moving parts, there was greater chance of mechanical breakdown. Since the band was a single entity, the entire precipitator had to be shut down if any part of the band required maintenance. Furthermore, the flexibility of the band can cause the particles to become loose where the band passes over the sprockets. The smoothness of the band also necessitates the application of an adhesive to assist in securing the particle to the electrode.

Thus, a particle precipitator that would reduce re-entrainment, while at the same time would eliminate the disadvantages of known moving electrode precipitators, would be a valuable contribution to the art of precipitators.

SUMMARY OF THE INVENTION

There is provided in accordance with the present invention an electrostatic particle precipitator that overcomes the problems previously mentioned. More particularly, the precipitator of the type with which the invention is concerned includes a plurality of planar arrays of wire positioned in a stream of a fluid containing particles, a plurality of plates positioned adjacent one another and adapted to be positioned between the arrays of wire, the plates forming the collecting electrode, a device for producing a corona discharge and a device for moving the electrode around an endless path. Preferably, an apparatus is provided for cleaning the plates in a region outside the gas stream. The plates may then be separately and successionally cleaned.

There are several advantages to the collecting electrode being formed of a plurality of plates following an endless path. The collecting electrode may be cleaned more efficiently because each plate is separately and successionally cleaned. The plates are preferably separated by a small space in the direction of movement to avoid contact of the plates with each other. Thus, the plates do not cause particles to become loose when the belt passes around the sprocket wheels. The plates are detachably mounted on a roller chain to allow rapid repair of the collecting electrode.

The plates may have depressed and raised areas on the collecting surface to enhance the collecting of the particles. The combined effect of the areas is to create in the depressed areas a zone that is protected from the forces of the moving gas stream and that has a low electric field. Charged particles tend to steer into low field regions. The plates may be formed with rows and columns of alternately raised and lowered areas, the areas being circular, generally rectangular or square. Additionally, plates may have a plurality of flanges mounted thereon. The collecting plate may also have vectored or undulating sides or be formed as a solid material or as a hollow tube, the solid or hollow configuration being formed with holes through the thickness of the plate.

The cleaning device may include brushes, a heater, a vibrator, air jets or liquid jets.

BRIEF DESCRIPTION OF THE DRAWINGS

In the Drawings:

FIG. **1** is a perspective view of an electrostatic particle precipitator arranged according to the present invention;

FIG. **2** is a perspective view of a modified form of a collecting electrode plate having raised and depressed areas of square shape;

FIG. **3** is a perspective view of another form of a collecting electrode plate having raised and depressed areas of circular shape;

FIG. **4*a*** is an elevational view of another form of a collecting electrode plate having raised and depressed areas of generally rectangular shape;

FIG. **4*b*** is an alternative form of the collecting electrode plate shown in FIG. **4*a*;**

FIG. **5** is a perspective view of another form of a collecting electrode plate having end flanges;

FIG. **6** is a perspective view of another form of a collecting electrode plate having a plurality of flanges;

FIG. **7** is a diagram showing the connection of the wire electrodes to a voltage source;

FIG. **8*a*** is a diagram of a brush for cleaning the plates;

FIG. **8*b*** is a diagram of a heating device for cleaning the plates;

FIG. **8*c*** is a diagram of a vibrator for cleaning the plates;

FIG. **8*d*** is a diagram of air jets for cleaning the plates;

FIG. **8*e*** is a diagram of liquid jets for cleaning the plates;

FIG. **9** is a view of an alternate form of collecting plate having vectored sides;

FIG. 10 is a view of another alternate form of collecting plate having undulating side portions;

FIG. 11 is a view of another form of collecting plate having holes formed therethrough;

FIG. 12 is a view of a collecting plate formed into a hollow tube with holes formed therein.

DESCRIPTION OF PREFERRED EMBODIMENTS

In an exemplary embodiment of an electrostatic particle precipitator arranged accordingly to the present invention, as shown in FIG. **1**, a precipitator, represented generally by the reference numeral **10**, is disposed in the path of a stream of gas flowing in the direction of an arrow **12**. The precipitator **10** is suited for removing particles from waste gases from coal and fuel power generating stations but it may also be used for many other applications where it is necessary to remove minute particles from a gas.

The precipitator **10** comprises generally a pair of electrodes **14** and **16** disposed in the stream of the gas, the electrodes being connected to a suitable high potential source **39** as shown in FIG. **7**. The high potential between the electrodes creates a corona discharge that places an electrical charge on the particles passing between the electrodes. Due to the electric field established by electrodes, forces are exerted on the particles that accelerate them to one of the electrodes, usually termed the collecting electrode. Once in contact with the collecting electrode, which is usually grounded, the particles discharge and remain on the surface of the electrode.

While in FIG. **1** the precipitator **10** is the Cottrell or single stage type, the present invention is equally applicable to the two stage precipitator. In the single stage precipitator the same electrodes create the corona discharge and the electric field that accelerates the particles to the electrode. On the otherhand, in a two stage precipitator, separate electrodes create the corona discharge and the electric field.

The precipitator **10** includes a plurality of corona electrodes **14** and a plurality of collecting electrodes **16**. The corona electrodes **14** are arranged in groups of planar arrays **14***a*, 14*b*, 14*c*, 14*d* and **14***e*. Preferably, planar arrays **14***a*, 14*c* and **14***e* are disposed horizontally in the stream of the gas, while planar arrays **14***b* and **14***d* are disposed vertically. Each of the wires **14** is connected to a high potential source shown in FIG. **7**. A conductive strip **15** provides a common electrical connection to the wires of the array **14***b* and like strips (not shown) are similarly used for the other arrays. Also the arrays are held rigid in their positions by supports (not shown). The wires **14** are preferably of small diameter so that each wire has a relatively small surface area.

A plurality of collecting plates **16** pass through the midplane between adjacent arrays of wire. The plates **16** are mounted at their ends to a pair of roller chains **18** and **19**. The roller chains in turn mesh with teeth **20** of a plurality of sprocket wheels. Roller chain **18** is supported by upper sprocket wheels **22***a*, 24*a* and **26***a*, middle sprocket wheels **28***a* and **30***a* and lower sprocket wheels **32***a* and **34***a*. In similar manner, roller chain **19** is supported by upper sprocket wheels **22***b*, 24*b* and **26***b*, a pair of middle sprocket wheels (not shown in FIG. **1**) and a pair of lower sprocket wheels (not shown in FIG. **1**). The sprocket wheels are in turn mounted on a support rod, such as a rod **36**. A drive mechanism, such as a motor **37**, imparts motion to the plates **16** around and between the arrays of wire **14** by imparting rotary motion to the sprocket wheels.

The plates **16** are preferably rectangular in shape. The longest dimension **38** extends parallel to the direction of gas flow and the shorter dimension **40** is parallel to the direction of movement of the plates **16**. The surface area of the plates **16** is preferably substantially larger than the surface area of the wires **14**. The plates **16** are metallic and preferably grounded as shown functionally at **42**. Each of the plates **16** is separated from adjacent plates by a spacing **44**. Additionally, the plates **16** are preferably rigid, and therefore, when the plates pass around the sprocket wheels, as at **46**, the plates maintain their flat surface unlike the known unitary metallic sheet electrodes. Both sides of the collecting plates **16** collect the particles.

Preferably, the plates **16** are fastened to the roller chains **18** and **19** at a point approximately midway between the dimension **40** of the plates **16** to permit the ends of the plates **16** to spread out a distance from the roller chain during rotation about the sprockets as at **46**. One suitable fastener is the assembly shown in FIG. 3 at **47**. The fastener should permit the plates to be readily assembled and removed.

The optimum size of the plates **16** and the spacing therebetween is a function of several factors. First, it is desirable to make the overall surface area on one hand as close as possible to that of a continuous metallic belt to provide maximum surface area for collecting particles. Thus, the dimension **38** is relatively large to accommodate this feature. The spacing **44** need be no larger than is necessary to prevent the plates **16** from contacting each other, especially as the sprockets pass over the sprocket wheels. The size of the dimension **40** is related somewhat to the diameter of the sprocket wheels; the dimension should not be so small as to deviate too far from the feature of maximizing surface area and yet should not be so large as to cause the plate to undergo extreme, erratic motion as the plate passes around the sprocket wheel. Preferably, the dimension is approximately the size of the radius of the sprocket wheel.

In keeping with one of the desirable features of a moving collecting electrode, the electrode passes out of the gas stream and into a region, represented generally by a housing **48**, where the electrode is cleaned. Thus, this arrangement permits the particles that are removed from the electrode from becoming re-entrained in the gas. In the present invention, each plate **16** is individually cleaned by any of several cleaning arrangements, shown in FIGS. **8***a* to **8***e*. The plates **16** enter the housing **48** through a slot (not shown in FIG. **1**) and leave through a slotted opening **50** for a belt movement shown by an arrow **52**.

Several cleaning arrangements may be used either alone or in combination. Referring now to FIG. **8***a*, the plates **16** may be individually cleaned by a pair of rotating brushes **53***a* and **53***b* that come into contact with the plates as they pass through the housing **48**. In FIG. **8***b* a heating device **55** heats the plates **16** to assist in removing the particles from the plates. In FIG. **8***c* a mechanical vibrator **57** imparts vibratory motion to the plates. Referring to FIG. **8***d*, a plurality of jets **59** direct air under pressure to the surface of the plates. Preferably, the jets **59** are in combination with the brushes **53***a* and **53***b*. Lastly, FIG. **8***e* shows a plurality of devices **61** that direct liquid in turbulent, active or sonic motion against the plate surfaces.

Another feature of the present invention resides in the ease of repair or replacement of the plates **16.** A maintenance section, represented in FIG. **1** by a housing **54,** permits access to any of the plates **16.** The housing **54** has a removable cover (not shown) whereby access may be permitted to the plates within the housing. Thus, the precipitator need be shut down only while the defective plate is removed and replaced by another. With precipitators having a unitary belt, the precipitator must be shut down until the belt is repaired.

Preferable, the surfaces of the collecting plates are provided with raised and depressed areas as shown in FIGS. **2** to **6** and FIGS. **9** to **12.** These areas assist the particle collection process in several ways. The depressed areas form shields or shadow zones where the particles may collect without being re-entrained by the scouring action of the gas stream. In addition, the raised and depressed areas produce a region in the depressed areas where the electric field for particle collection is low. Charged particles tend to steer into low field regions.

In FIG. **2,** rows and columns of alternate, square raised and depressed areas **60** and **62,** respectively, are formed on the surface of the plate **16.** The corners of the areas are preferably rounded, as at **64,** to facilitate cleaning the plates.

Similarly, in FIG. **3** the surface of the plate **16** has circular depressed areas **66** and circular raised areas **68.**

In FIG. **4***a* raised and depressed areas **70** and **72,** respectively, are rectangular shaped with rounded corners. The longer dimension is parallel to the longer side **38** of the plate **16.** The rectangular shaped areas may however be formed with the longer dimension parallel to the shorter side **40** of the plate **16** as shown in FIG. **4***b*.

Referring now to FIG. **5,** the plate **16** comprises a web **74** with a pair of end flanges **76** and **78** formed generally perpendicular to the web **74.** Preferably, the plate **16** is affixed to the roller chains **18** and **19** at the midpoint of the web **74** by a suitable fastener.

Similarly, FIG. **6** has a web **80** with flanges **82, 84, 86** and **88** disposed at a right angle to the web **80.**

The collecting plate in FIG. **9** includes a plate **90** and a series of side members **92** and **94.** The side members **92** and **94** extend from the plate **90** at an acute angle to form a region **96** and a region **98** that is protected form the moving gas stream represented by an arrow **100.** These regions **96** and **98** also have a low electric field, and thus, the charged particles are attracted to them.

In FIG. **10** the collecting plate includes a flange **102,** a flange **104** and an undulated web **106.** The undulated web **106** increases the anode area for collecting particles in addition to creating collecting regions removed from high gas flow and from high collecting electric fields.

In FIG. **11** a collecting plate **108** is formed with a series of holes **110** extending through the thickness of the plate. Preferably, the diameter of the holes ranges from 1 to 3 times the plate thickness shown at **112.**

Lastly, the collecting plate of FIG. **12** is formed as a hollow tube **114** with a plurality of holes **116.** The holes **116** pass through the thickness of the sides of the tube **114.** As shown in FIG. **12** the holes **110** are present on each active side of the tube. The total hole area ranges from 25% to 75% of the plate area on that side and preferably is 50% of the plate area on that side. Also, in FIG. **12,** the holes on opposite sides of the tube **114** do not line up.

The advantages of the present invention are realized in all of the embodiments herein described. The primary advantage resides in the reduction of reentrainment of the particles in the gas flow once they are accumulated on the collecting electrode. One feature which permits this advantage is that the collecting electrode moves to a separate electrode cleaning area and is formed as a series of separate plates that are individually cleaned. Furthermore, the collecting plates have surface geometries that have areas that are removed from the gas flow, thereby further reducing reentrainment. In addition, these areas have generally weak electrostatic fields which cause the particles to migrate toward them.

The embodiments of the present invention are intended to be merely exemplary and those skilled in the art shall be able to make numerous variations and modifications to them without departing from the spirit of the invention. All such variations and modifications are intended to be within the scope of the invention as defined by the claims.

We claim:

1. An electrostatic precipitator including a housing having fluid inlet and outlet means, electrode inlet and outlet means, a plurality of planar arrays of wire positioned in the stream of fluid containing particles within said housing, a plurality of metallic plates of generally rectangular shape, the shorter dimension of which being disposed parallel to the direction of movement of the plates, the longer dimension of which being disposed perpendicular to the direction of movement of the plates, positioned adjacent to one another and adapted to be positioned between the arrays of wire, the plates forming a collecting electrode having multiple raised and depressed portions on the surface of the plates forming alternately open topped, open bottom enclosed areas for creating regions of dimension smaller than those of the plate which have reduced electric fields to enhance particle collection therein and which are shielded from the fluid stream to reduce re-entrainment of the collected particles, means for producing a corona discharge between the arrays of the wire and the collecting electrode, and means connected successively to the shorter dimension of each of the plates of the collecting electrode for moving the plates around an endless path formed by said electrode between successive arrays of wire and extending outside said housing through said electrode inlet and said electrode outlet means provided therein.

2. The precipitator according to claim **1** wherein the plates are separated from adjacent plates so that they do not touch.

3. The precipitator according to claim **1** including means associated directly with said plates and said means for moving said plates connecting said plates to said moving means such that said plates may be replaced individually.

4. In an electrostatic particle precipitator of the type having a housing containing a fluid inlet and a fluid outlet, a plurality of metallic planar electrodes of relatively large surface area at ground potential positioned parallel to each other and parallel to the fluid flow within said housing, a plurality of planar arrays of wire of relatively small surface area positioned in the respective midplanes between adjacent planar electrodes, and means connected to the arrays for subjecting the same to high corona-producing potentials, whereby particles entrained in the gasses flowing between the arrays of the electrodes are electro-mechanically deposited upon said planar electrodes, an improvement wherein the planar electrodes are formed into an articulated endless belt, the belt including a plurality of separates metal strips of extended length in the direction of gas flow and of short width in the direction of belt travel, each strip having multiple raised and depressed portions of dimension smaller than those of the surface of the strip on the surface of the strip forming alternately open topped, open bottom enclosed areas for creating regions which have reduced electric field to enhance particle collection therein and which are shielded from the gas flow, each strip being mechanically connected at each short end thereof to an endless, linked roller chain to form an almost closed surface, said chains being engaged by an arrangement of supported lower sprockets, means for moving the strips successively between at least three planar wire arrays at high potential and thence to a region separated from said corona and said flowing gasses, and means in said region for removing successively from each strip the particles adherent to its surface, whereby re-entrainment in the gas flow of particle accumulations from the grounded electrodes is reduced.

5. The precipitator according to claim **1** wherein each strip has a fixed alignment with respect to the portion of the chain to which it is attached.

6. An electrostatic particle precipitator including a housing having fluid inlet and outlet means, electrode inlet and outlet means, a plurality of planar arrays of wire positioned in the stream of fluid containing particles within said housing, a plurality of metallic plates of generally rectangular shape, the shorter dimension of which being disposed parallel to the direction of movement of the plates, the longer dimension of which being disposed perpendicular to the direction of movement of the plates, positioned adjacent to one another and adapted to be positioned between the arrays of wire, the plates forming a collecting electrode and having multiple raised and depressed areas of alternately open top, open bottom rectangular box shape on the surface of the plates for creating regions of dimensions smaller than those of the plates which have reduced electric fields to enhance particle collection therein and which are shielded from the fluid stream to reduce reentrainment of the collected particles, means for producing a corona discharge between the arrays of wire and the collecting electrode, and means connected successively to the shorter dimension each of the plates of the collecting electrode for moving the plates around an endless path formed by said electrode between successive arrays of wire and extending outside said housing through said electrode inlet and electrode outlet means provided therein.

7. The precipitator according to claim **6** wherein said multiple raised and depressed areas are of alternately open top, open bottom cylindrical shape.

* * * * *