ELECTRICAL PRECIPITATOR AND OPERATING METHOD

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Fig. 1

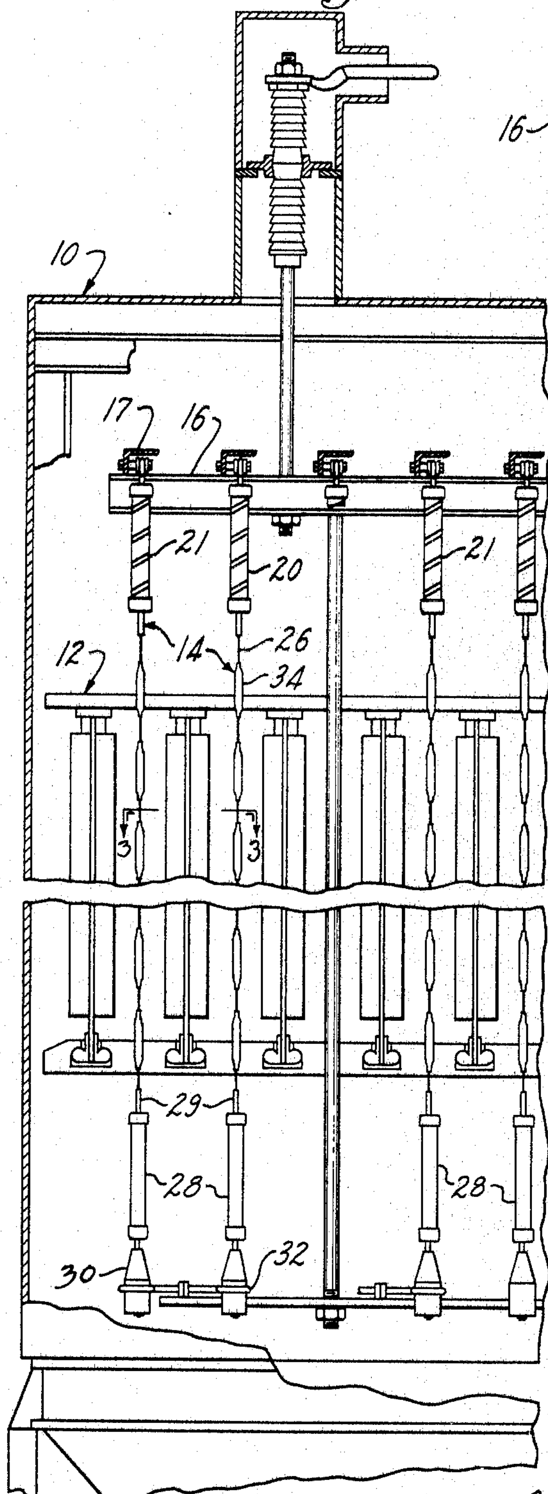


Fig. 2

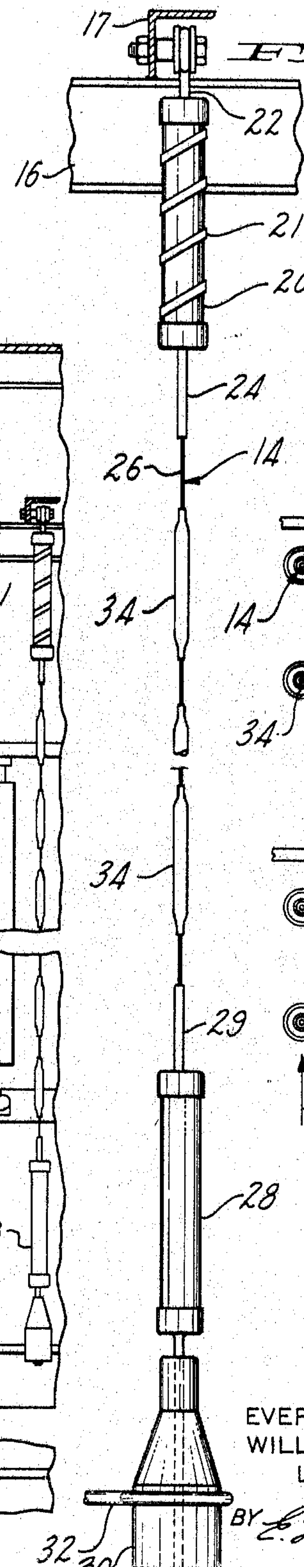
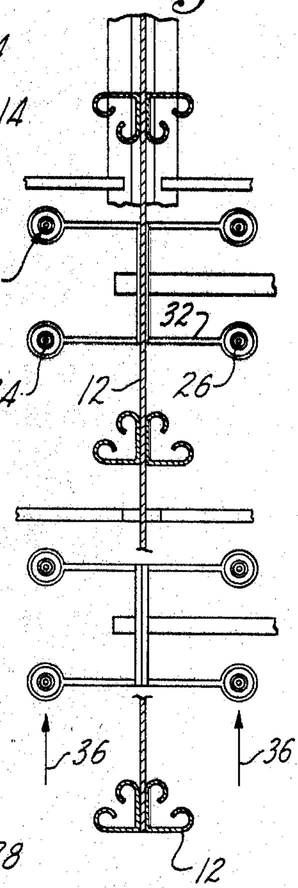


Fig. 3



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ELECTRICAL PRECIPITATOR AND OPERATING METHOD

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Fig. 4

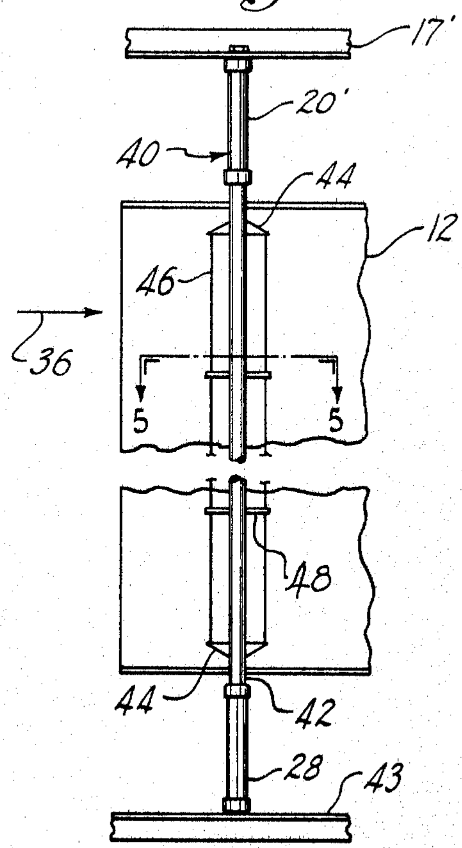


Fig. 6

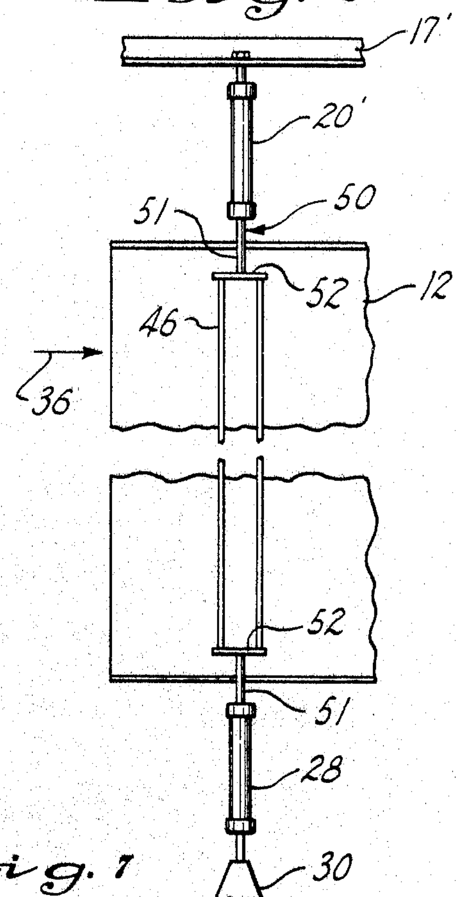


Fig. 7

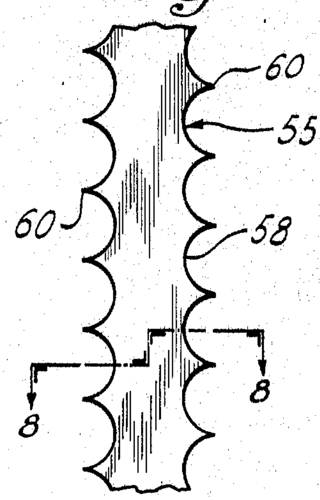


Fig. 5

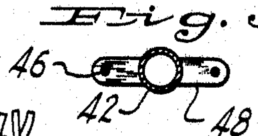


Fig. 9

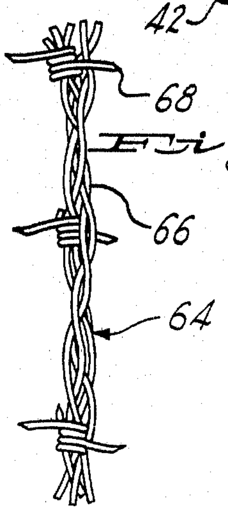
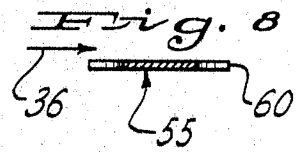


Fig. 8



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ELECTRICAL PRECIPITATOR AND OPERATING METHOD

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Continuation-in-part of application Ser. No. 407,968, Nov. 2, 1964. This application Oct. 21, 1966, Ser. No. 600,310

Int. Cl. B03c 3/40

U.S. Cl. 55—2 13 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus for and method of operating a multiple electrode precipitator which provides isolating resistance between the power supply and each charging electrode individually and further provides sufficient capacitance in each electrode set to prevent prolonged electrical breakdown.

This application is a continuation-in-part of application Ser. No. 407,968 filed Nov. 2, 1964 now abandoned.

Experiments with resistors in series with the discharge electrodes of electrostatic precipitators as taught by Wintermute (U.S. Patent 1,968,330) reveal that when resistance values are high enough to achieve the necessary electrical isolation of one electrode wire from another, undesirable prolonged electrical discharges between the emitting and grounded collecting electrodes take place with an accompanying undesirable voltage breakdown causing an interruption of the desired collecting action of the precipitator. These discharges are probably a localized glow type and are nonoscillatory in the usual sense of spark oscillation but are probably more on the order of a brush discharge as a result of spark prevention by the damping effect of high resistance. To this extent the use of a resistor in series with each discharge electrode can be said to prevent sparking in the usual sense of the word; however, such prolonged electrical voltage breakdowns are undesirable in that they remove the affected electrodes from operation for relatively long periods of time thereby substantially reducing the average voltage between the electrodes of the precipitator.

To convert these relatively prolonged electrical breakdowns into short duration breakdowns and maintain the maximum average voltage between the electrodes of the precipitator, it has been found necessary to add to the normal capacitance of the emitting electrode. Such added capacitance provides that, simultaneously with a spark current flow between a pair of electrodes, capacitor current flow is added to the spark current flow to produce a voltage reduction in the spark current path sufficient to prevent any further discharge between this pair of electrodes and thus, quench the above described nonoscillatory discharge.

Theoretically and experimentally, the capacitance of a set of electrodes comprising a single 0.105″ diameter wire between a pair of long flat plates on 9″ centers is about 3 picofarads (3×10^{-12} farads) per foot. Experiments have proven that the above described prolonged breakdowns can be prevented by the presence of approximately 70 picofarads of capacitance in a single electrode and with the theoretical value of 3 picofarads per foot a set of such electrodes 24 feet long should have the necessary capacitance to prevent such prolonged breakdowns. However, when such a wire is being operated as an emitting electrode at or above the corona threshold voltage, in a dusty gas environment, the effective capacitance of the wire drops to less than half of this value. This drop in

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capacitance is reasoned to be due to the space charge of ions and charged dust particles which has been formed in the space around the electrode with a consequent reduction in the apparent amount of energy storage in the stress of the gaseous dielectric.

The discovery that the use of isolating resistors in series with the respective discharge electrodes, while preventing sparking, resulted in the above described prolonged voltage breakdowns gave rise to a series of theoretical studies and practical experiments demonstrating the reduction of effective capacitance of a wire operating under corona producing conditions. The result was the invention of means for restoring such lost effective capacitance so that such prolonged voltage breakdowns were transformed into short duration breakdowns from which recovery to normal voltage was achieved in an interval of 5 to 10 milli-seconds so that interruption in the charging function of an individual electrode was held to a minimum. It was further observed that less than 50 picofarads of capacitance, per set of electrodes (one discharge electrode between two collecting electrodes) under corona producing conditions, was insufficient to produce enough capacitor current to increase the current to produce a voltage reduction to the value necessary to have the desired effect on the voltage breakdowns and that additional capacitance above 70 picofarads was unnecessary but not detrimental to the operation of the precipitator.

We have found that a number of ways can be devised to achieve the normal emitting function of the electrode while preserving its effective capacitance at corona threshold voltages or above. Specifically, passive areas (non-corona producing) must be provided which do not go into corona at these voltages.

The following geometries of charging electrodes forming sets of electrodes with spaced flat plate collecting electrodes have been tested and found to develop adequate capacitance under corona producing conditions for use with isolating electrode resistors:

(1) Barbed wire; the corona is concentrated at the barbs, and the main strand is thereby shielded and non-emitting.

(2) Segmented wire; sections of wire alternating with larger diameter tube spaced along the length of a 24 foot wire with 6 inches of .105″ diameter wire exposed between 6″ lengths of ⅜″ tube (totaling 12 feet of tube or substantially one half the length of the wire) produced the necessary 70 picofarads under corona producing conditions.

(3) Paired wires; two wires on 2″ centers parallel to each other so that the shielding effect of each wire on the other allowed one half of the surface of the wire to act as corona producing and the other half of the surface of each wire to provide capacitance.

(4) Large diameter rod or cable; such as ⅜″ rod or ½″ aircraft cable produced the necessary capacitance for good operation with the series resistor while the addition of surface irregularities to either the rod or the aircraft cable would be necessary to control the number and location of corona points.

Other forms of electrodes which were not tested but which are envisioned as effective embodiments of this invention are:

(1) Flate plate discharge electrodes with controlled corona emitting points such as a wire grid, a perforated plate, or the like, having a controlled amount of emitting surface and enough non-emitting surface to provide the needed capacitance. In this configuration the amount of corona current per unit surface area can be controlled as a very desirable additional benefit.

(2) Paired active and passive electrodes wherein a wire for producing the corona would be paired with a rela-

tively large diameter non-corona producing member, the diameter of the non-corona producing member being such that said member has a radius of curvature greater than the maximum radius at which corona will be produced under the conditions of voltage and dust load prevailing in the precipitator equipped with this electrode.

It has been found that a resistance of approximately 4 megohms is desirable to isolate one electrode from the other electrodes but that this amount of resistance overdamps the electrical circuit represented by one emitting electrode and one collecting electrode so that when a breakdown of the resistance in the path between such pair of electrodes occurs, the above described prolonged nonoscillatory breakdown takes place with the result that this particular emitting electrode is out of service for a relatively long period of time with a resultant decrease in the average precipitator voltage. Such prolonged breakdowns can be transmuted into single short duration breakdowns by the addition of capacitance to the emitting electrode. The total capacitance necessary for such change in the character of the breakdown is of the order of 70 picofarads of which about 30 picofarads would be furnished by a single .105″ diameter wire 24 feet long under corona producing conditions while another 40 to 50 picofarads can be supplied by the use of approximately 12 feet of ⅜″ tubing cut into lengths of perhaps 6″ each and strung along the wire at equal intervals.

With the above described conditions of 4 megohms isolating resistance and 70 picofarads capacitance each emitting electrode operating at corona producing voltages is isolated from every other emitting electrode and when a spark current flow results in a breakdown in the resistance of the path between an emitting electrode and a collecting electrode the capacitor current assures that the breakdown is of short duration (approximately five to ten milliseconds in length) and is of such low energy that no damage occurs to the electrode and of course because of the isolating resistance none of the other electrodes is affected by this particular breakdown.

In summary, the advantages inherent in the electrical precipitator of this invention over prior art structures are: Prevention of a localized discharge or spark current on one electrode from affecting other electrodes in the precipitator with the result that the charging function is interrupted only on one electrode for a given spark current; the elimination of spark damage to the electrode since the energy dissipated in any one spark current flow is the energy associated with only one electrode rather than all of the electrodes of the precipitator; an increase in the permissible peak voltage for a given electrode configuration since more sparking can be tolerated without damage to the precipitator; and a relatively large increase in the average electrode voltage of the precipitator because a single spark current produces a voltage drop in only one electrode rather than in all of the electrodes of a precipitator, together with the fact that such a voltage breakdown is of very short duration.

It is therefore an object of this invention to provide a new and improved electrical precipitator.

It is another object of this invention to provide a new and improved electrical precipitator having a resistance in series with each emitting electrode.

It is a further object of this invention to provide a new and improved electrical precipitator wherein each emitting electrode is provided with an isolating resistance and has a configuration which, in conjunction with a pair of collecting electrodes, provides sufficient capacitance to produce short duration electrical breakdowns.

It is a still further object of this invention to provide a new and improved electrical precipitator wherein maximum average voltage between the electrodes is maintained by providing that each emitting electrode incorporates an isolating resistance and is of a configuration which, in conjunction with a pair of collecting electrodes, has adequate capacitance to provide sufficient capacitor

current to be added to a spark current flow between electrodes so that a total current flow will induce a large enough voltage reduction along the spark current path to produce short duration electrical breakdowns.

It is yet another object of this invention to provide a new and improved method of maintaining the maximum average voltage between the electrodes of an electrostatic precipitator, having a plurality of electrode sets in which each of the electrode sets consists of at least one collecting electrode and one cooperating discharge electrode, by maintaining an energy level of capacitance between the discharge and collecting electrodes of each of the electrode sets during normal operating current flow through the discharge electrode to provide capacitor current flow simultaneously with the occurrence of a spark between the discharge electrode and a collecting electrode of a given electrode set to increase the flow of current between the electrodes of the electrode set to lower the voltage between the last mentioned electrodes to a value below the voltage required to maintain any discharge between the electrodes of said given set.

It is yet a further object of this invention to provide a new and improved electrical precipitator wherein each emitting electrode is provided with an isolating resistance and comprises an elongated small diameter wire having short portions of relatively large diameter tubing spaced apart, longitudinally, therealong.

These and other objects and advantages of this invention will become more readily apparent upon consideration of the following description and drawings in which:

FIG. 1 is a fragmentary sectional view of a precipitator constructed according to the principles of this invention;

FIG. 2 is a front elevational view of an electrode and an associated resistor such as those shown in FIG. 1; and

FIG. 3 is a sectional view taken substantially on line 3—3 of FIGURE 1;

FIG. 4 is a fragmentary sectional view of a precipitator constructed according to the principles of this invention showing a second embodiment of such principles;

FIG. 5 is a sectional view taken substantially on line 5—5 of FIG. 4;

FIG. 6 is a view similar to FIG. 4 showing a third embodiment of the principles of this invention;

FIG. 7 is a fragmentary sectional view of an electrode wherein the principles of this invention are incorporated in a fifth embodiment;

FIG. 8 is a sectional view taken substantially on line 8—8 of FIG. 7;

FIG. 9 is a fragmentary elevational view of an electrode wherein the principles of this invention are incorporated in a sixth embodiment.

In FIGURE 1 there is shown an electrical precipitator **10** of a type well known in the art, provided with a set of collecting electrodes **12** such as those described and illustrated in U.S. Patent No. 3,125,426 and also having a set of emitting or charging electrodes **14** spaced and positioned with respect to the collecting electrodes **12** as described in that patent, so that one emitting electrode **14** and portions of two collecting electrodes **12**, adjacent thereto, form a set of electrodes. The electrodes **14** are constructed according to the principles of this invention and constitute a preferred embodiment thereof as more fully described hereinafter. However, such description of the electrodes **14** should not be taken as limitative upon this invention as the principles herein embodied and described can be applied in various ways to the construction of precipitators as earlier described. Each of the electrodes **14** is suitably suspended from an angle iron **17** supported by an electrode support frame **16** suspended below the roof of the precipitator **10** and insulated therefrom in a manner well known in the art. Each electrode **14** comprises an elongated generally cylindrical electrical resistance element **20** which in this embodiment comprises a ceramic insulating tube having on its surface a thin stripe **21** of conducting material connected at its upper end to an attachment means such as an eyebolt **22** and at its lower end to a short length of metallic tubing **24** rigidly secured to the ceramic tube. An elongated small diameter wire **26** is secured to or within the lower end of the tubing **24** and extends downwardly within the precipitator to an elongated hollow cylindrical ceramic insulator **28** secured to the bottom end of the wire **26** as by a short length of tubing **29**. Suspended from the bottom end of the insulator **28** is a suitable weight **30** suitably held in position but not supported by a locating frame **32** so that the weight **30** maintains tension on the wire **26** to hold it straight and vertical. The wire **26** extends through a plurality of longitudinally spaced tubing elements **34** secured in the desired spaced relationship along the wire **26** by reduced end portions closely engaging the wire **26** as the result of a swaging operation or by any other suitable means which will maintain the desired spacing of the tubing elements **34** from each other along the wire **26**.

It is to be noted that the electrical resistance value of the resistance element **20** must be large enough to achieve effective isolation of each electrode from all the others as regards sudden change in potential, i.e. substantially greater than the ohmic value of the impendance inherent in the supply of power to the electrical precipitator, it has been found that the valve of this resistance needs to be in the neighborhood of 4 megohms although this value may be anywhere in the range from 3 megohms up to the maximum value which will allow normal corona current to flow. In one embodiment of this invention the electrode wire **26** has a diameter of approximately .105 inch and a total length of 24 feet while the tubing elements are of ⅜ inch diameter and 6 inches long with a total length of the tubing elements on a given electrode being approximately 12 feet. It has been found that this electrode configuration when used in conjunction with the electrodes **12** produces the desired 70 picofarads of capacitance per set of electrodes under corona producing conditions. It is to be realized, however, that variations in the amount and electrical nature of the dust to be precipitated and in the spacing and length of the emitting and collecting electrodes could require a different number and spacing of the tubing elements **34**. It is further to be noted that the amount of capacitance per set of electrodes is not critical as long as it is greater than 55 picofarads under corona producing conditions.

Normal operation of the precipitator **10** is the same as that of prior art structures with the electrode support frame being maintained at a corona producing voltage of 35 to 50 kilo-volts while the collecting electrodes **12** are grounded and dusty gas flows through between the collecting electrodes and around the emitting electrodes **14** in a direction indicated by the arrows **36** (see FIGURE 3). The value of the resistances **20** although high is such as to allow the passage of normal corona current to maintain the normal charging function of the emitting electrodes **14**. When, however, a spark current occurs or flashover takes place between one of the emitting electrodes **14** and one of the grounded collecting electrodes **12**, the resistance **20** is of a value that almost completely isolates the rest of the electrodes **14** from the effect of the sparkover on any one of them with the result that only a single electrode **14** is discharged by the spark and normal operation of the rest of the electrodes continues during the sparking period of any one of them. The effect of the electrode configuration as before described is to produce a total capacitance for each electrode set of approximately 70 picofarads under corona producing conditions. This capacitance is sufficient to provide a capacitor current to be added to the spark current flow between the electrodes so that the total current flow will induce a large enough voltage reduction along the spark current path to produce a spark current of short duration with recovery to normal voltage achieved within approximately five to ten milliseconds after the biginning of the flashover.

FIGS. 4–9 show additional embodiments of the principles of the invention wherein elements of the precipitator which are the same as those shown in FIGS. 1–3 are identified by the same reference numerals, respectively, while those of similar structure and function are denoted by the same reference numeral primed.

FIG. 4 shows an angle iron **17′** adapted to rest upon or be otherwise supported by an electrode support frame such as frame **16** shown in FIG. 1 and having suspended therefrom a charging electrode **40** comprising an elongated cylindrical resistance element **20′** removably secured to the angle iron **17′** as by a cap screw and extending downwardly therefrom to a point slightly higher than the upper edges of a pair of collecting electrodes **12** such as those shown in FIGS. 1 and 3 (only one of which is shown in FIG. 4). Extending downwardly from and supported by the resistance element **20′** is an elongated, electrically conducting tubular element **42** having a length somewhat greater than the vertical dimension of the collecting electrodes **12** and secured at its lower end to an insulating element **28** in turn secured to a support bar **43** rigidly mounted in a lower portion of the precipitator. Downwardly spaced from the upper end of the tubular element **42** and extending outwardly therefrom in opposite directions parallel to the collecting electrodes **12** is a pair of support arms **44** triangular in shape, electrically conducting and rigidly secured to the outer surface of the tubular element **42**. Near the bottom of the element **42** similarly spaced upwardly from the insulator **28** and similarly oriented is a second pair of the support arms **44**. A pair of elongated small diameter conducting elements such as wires **46** are secured to the outer ends of the upper support arms **44** and extending downwardly therefrom are secured to the outer ends of the bottom support arms **44** with some tension applied to the wires **46** to hold them in alignment with diametrically opposite sides of the tubular elements **42** and spaced outwardly therefrom.

At a plurality of intermediate points pairs of outwardly extending spacer elements **48** rigidly secured to opposite sides of the tubular element **42** provide lateral stability for the wires **46** which pass through bores in the ends of the spacer elements **48**.

The diameters of the wires **46** (on the order of ⅛ inch or smaller) is small enough to provide a radius of curvature for the wires **46** such that there will be corona emission from the wires **46** at the operating voltage and dust load of the precipitator in which they are installed. Conversely the diameter of the tubular element **42** is large enough to provide a radius of curvature above the maximum radius at which corona emission will be produced under the operating conditions of the precipitator in which it is installed. With such dimensions the tubular element **42** then becomes the passive portion of the electrode **40** to provide the necessary capacitance while the wires **46** become the emitters of the electrode **40** with the resistance **20′** of approximately the same electrical resistance value as hereinbefore described for resistance **20** for performing the isolating function so that a spark current flow from one of the wires **46** to one of the collecting electrodes **12** will not draw electrical current from the rest of the precipitator while the capacitance of the electrode set provides sufficient current to reduce the voltage along the spark current path and stop the flow of current from the wire **46** to the collecting electrode **12**, preventing the long continued glow type discharge in the same manner as such discharge was prevented in the embodiment of FIGS. 1–3.

It is to be realized that with the rigid mast type electrode **40** of FIGS. 4 and 5 the weight **30** is unnecessary and the bottom end of the insulator **38** may be rigidly secured to a support bar or other portion of the precipitator frame with the tensioning effect of the weight **30** assumed by the tubular element **42**.

FIG. 6 illustrates a third embodiment of the principles of this invention in a charging electrode **50** similarly comprising a resistant element **20′** depending from and supported by an angle iron **17′** resting upon and otherwise supported by the support frame **16** (not shown), in a manner similar to that of the above described embodiments. Extending downwardly from the resistance element **20′**, supported by and electrically communicating therewith, is an elongated tube or rod **51** ending at a point slightly lower than the top edge of the collecting electrodes **12** at which point the rod **51** is rigidly secured to a horizontally disposed cross bar **52** extending transversely of the rod **51** and parallel to the collecting electrodes **12**. At points equally distant from the rod **51** in opposite directions a pair of elongated cylindrical electrical conducting elements such as the wires **46** extend downwardly from and are supported by the cross bar **52**. At a point slightly upwardly spaced from the bottom edge of the collecting electrodes **12** the bottom ends of the wires **46** are secured to a second cross bar **52** and a second similarly spaced and connected rod **51** extending downwardly from the lower cross bar **52** to connection with the insulator **28** and the weight **30** as described for the embodiment of FIGS. 1–3. The wires **46** are parallel to each other and spaced apart a relatively small distance compared to their length from a minimum of approximately ½ inch to a maximum of approximately 2 inches.

With the above arrangement of the wires **46** each one of the wires will be an emitter on the side opposite that which faces the other of the two wires while on the side facing the other wire it will be shielded by the second wire and being a non-emitting surface will provide capacitance in conjunction with the collecting electrodes in the same manner as the non-emitting surface of the first two embodiments with the same results as regards operation of the precipitator.

It is to be noted that in the case of the third embodiment shown in FIG. 6 the non-emitting portion of the wires **46** is of no greater radius of curvature than the emitting portions thereof, but, that the non-emitting character of this portion of the surface is entirely due to the shielding provided by its companion wire.

FIGS. 7 and 8 illustrate a fourth embodiment of the principles of this invention in an electrode **55** comprising the angle iron **17** or **17′**, a resistor element such as **20** or **20′**, a pair of the rods **51**, the insulator **28** and the weight **30** (none of which are shown in FIGS. 7 and 8) but with a thin elongated, narrow metallic emitter element **58** extending from the upper rod **51** to the lower rod **51** and rigidly secured in electrical communication therewith. The emitter element **58** has scalloped edges with outturned points **60** and is oriented parallel to the collecting electrodes **12** so that non-emitting flat surfaces of the emitter element **58** face the flat surfaces of the collecting electrodes **12** to provide the required capacitance of the electrode **58** in conjunction with the collecting electrodes **12** as required by operation of the precipitator in the above described manner. It is to be noted that the shape of the scallops is unimportant as long as the points **60** have a radius of curvature below the maximum radius at which corona emission will occur under the conditions at which the precipitator is operating.

FIG. 9 illustrates a charging electrode **64** in which a length of barbed wire **66** replaces the emitter element **58** of the above described embodiment to provide a fifth embodiment of the principles of this invention. A plurality of barbs **68** provide the emitting points of the required small radius while the braided strands of wire have a body portion with a radius of curvature great enough to prevent corona emission under precipitator operating conditions and thus provide non-emitting areas sufficient to develop the requisite capacitance for operation as hereinbefore described.

Preferred embodiments of this invention having been herein described and illustrated, it is to be realized that still other embodiments of these principles are envisioned especially those hereinbefore mentioned. It is further to be realized that various impedance means such as vacuum tube resistances and inductive resistances are recognized in the art as functional equivalents of the resistors recited herein.

What we claim is:

1. A charging electrode for an electrical precipitator comprising; a resistance element; an elongated emitting member of a given diameter and given length in series with said resistance element; and a plurality of tubular elements having a diameter at least two and one half times said given diameter said elements having an individual length equal to more than ten times said given diameter and a total length equal to substantially one half said given length, longitudinally spaced apart at substantially equal intervals along said emitting member.

2. A charging electrode for an electrical precipitator as specified in claim **1** wherein said tubular elements are at least thirty times as long as said given diameter and each said interval is substantially equal to the length of one of said tubular elements.

3. In an electrical precipitator: a plurality of spaced collecting electrodes; a plurality of spaced charging electrodes; said charging electrodes being positioned intermediate said collecting electrodes to form electrode sets therewith, each of said charging electrodes comprising an isolating impedance means; an elongated emitter member in series with said impedance means; said emitter member having non-emitter portions of an area to have electrical capacitance under corona producing conditions in conjunction with said collecting electrodes, said electrical capacitance being of a magnitude to produce a short duration electrical voltage reduction upon the occurrence of a spark between one of said charging electrodes and one of said collecting electrodes.

4. The combination as specified in claim **3** wherein said non-emitter portions have a radius of curvature greater than the maximum radius at which corona emission will occur under precipitator operating conditions.

5. The combination as specified in claim **4** wherein said non-emitter portions comprise on elongated given diameter tubular element located between, parallel to, and at equal distance from elongated emitter elements having a diameter giving said emitter elements a radius of curvature less than said maximum radius; said given diameter being more than twice said maximum radius of curvature.

6. The combination as specified in claim **5** wherein said equal distance is within the range of ½ inch to 2 inches.

7. The combination as specified in claim **3** wherein said non-emitter portions are flat surfaces.

8. The combination as specified in claim **3** wherein said emitter member is a length of barbed wire having braided body portions, said body portions being said non-emitter portions.

9. The combination as specified in claim **3** wherein said magnitude is at least 55 picofarads.

10. The combination as specified in claim **3** wherein said impedance means has more than 3 megohms of electrical resistance.

11. A method of maintaining the maximum average voltage between the electrodes of an electrostatic precipitator having a plurality of electrode sets in which each of said electrode sets consists of at least one collecting electrode and one cooperating discharge electrode with said discharge electrode comprising an elongated conducting portion having a conductivity such that essentially no voltage drop occurs along the length thereof when normal operating current flows therethrough and which conducting portion is connected to an isolating impedance means, the improvement consisting of: maintaining an energy level of capacitance between the discharge and collecting electrodes of each of said sets during normal operating current flow through said discharge electrode; providing a capacitor current flow simultaneously with the occurrence of a spark between the discharge electrode and a collecting electrode of a given electrode set which capacitor current flow increases the flow of current between the electrodes of said given set to lower the voltage between the last mentioned electrodes to a value below the voltage required to maintain any glow type discharge between the electrodes of said given set.

12. A method of maintaining the maximum average voltage between the electrodes of a precipitator as specified in claim **11** wherein said capacitance is maintained by forming said electrode sets to have at least 55 picofarads of capacitance under corona producing conditions.

13. A method of maintaining the maximum average voltage between the electrodes of a precipitator as specified in claim **11** wherein said capacitance is maintained by electrostatically shielding portions of said discharge electrode.

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U.S. Cl. X.R.

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