June 3, 1941. H. J. WHITE 2,244,278

ELECTRODE FOR ELECTRIC PRECIPITATORS

Filed March 1, 1940

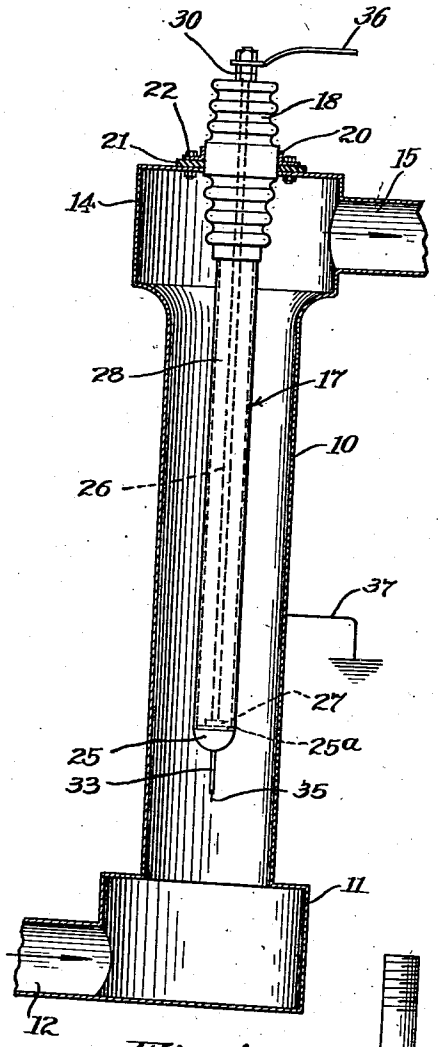


Fig. 1.

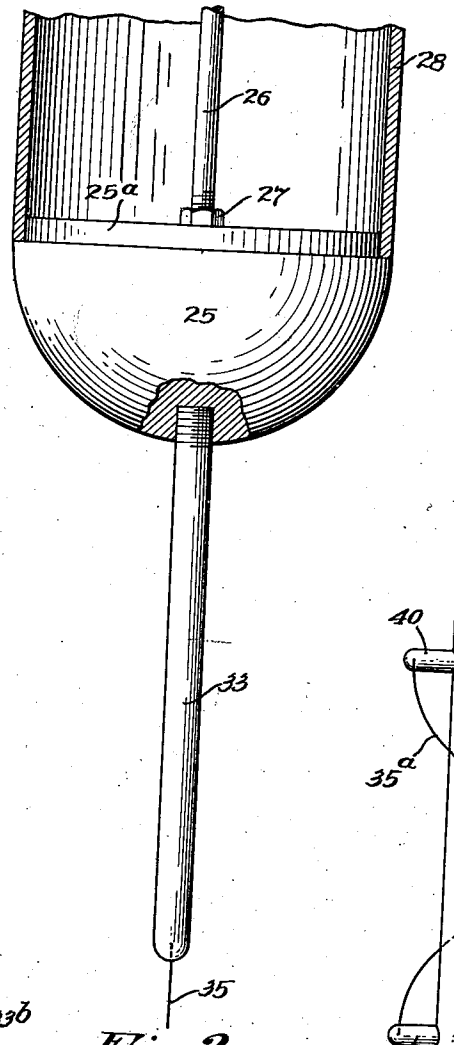


Fig. 2.

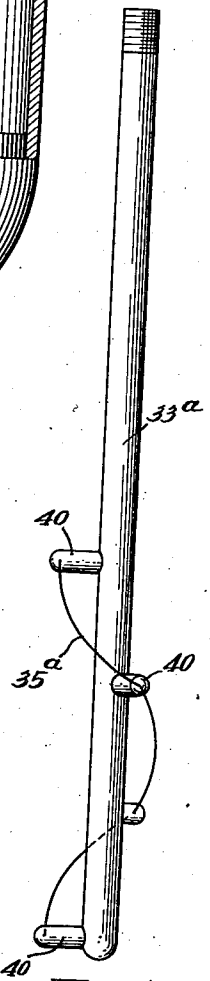


Fig. 3.

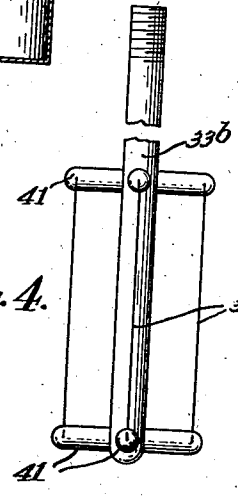


Fig. 4.

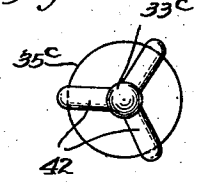


Fig. 5.

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ELECTRODE FOR ELECTRIC PRECIPITATORS

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Application March 1, 1940, Serial No. 321,784

5 Claims. (Cl. 183—7)

The present invention is generally concerned with the art of electrically precipitating suspended particles from a stream of gas; and it is more particularly concerned with improvements in electrodes for precipitators of the type in which the particle-laden gas is first passed through a charging field in which corona discharge is produced, in order to electrically charge the suspended particles, and is then passed through a spatially separate electrostatic precipitating field which is substantially free from corona discharge, in order to precipitate the charged particles. The gas is subjected successively to two functionally distinct fields, and for this reason a precipitator of this type has been termed a "two-stage" or "separated field" precipitator.

In the following description and appended claims, the term "discharge electrode" will be understood to designate an electrode that facilitates corona discharge therefrom, because it has a configuration that establishes a sufficiently high potential gradient at or near its surface to create corona discharge before there is a disruptive discharge or spark-over. For this purpose, the discharge electrode usually takes the form of a member of small surface area, such as a small diameter wire or a rod provided with sharp edges or points, whereby there may be created in the immediate vicinity thereof a sufficiently high electric field intensity to cause ionization and corona discharge. The term "non-discharging electrode" will be understood to designate an electrode that minimizes or prevents corona discharge therefrom because it has a configuration that establishes a sufficiently low field concentration at or near the surface to suppress corona discharge at elevated potentials lower than the voltage required for disruptive discharge or sparkover. For this purpose, a non-discharging electrode is usually one of extended surface area, substantially free from sharp corners or other parts of sharp surface curvature at all portions which are located within the electric field, so as to substantially avoid ionization or corona discharge at that electrode.

Electric precipitators of various types have in the past been used chiefly for industrial purposes, and in this field it has been immaterial that small amounts of ozone or oxides of nitrogen are formed by the corona discharge and introduced into the stream of gas flowing through the precipitator. But electric precipitators are now coming into extensive use for the purpose of cleaning air that is used for ventilation in homes, offices and the like; and in this type of use it is of prime importance that the precipitator not produce substances that are objectionable because of their odor or possible danger to health. Consequently, production of ozone and oxides of nitrogen, formerly of little significance, has now become a factor of very considerable importance in designing an electrical precipitator for cleaning ventilating air, because both these gases are distinctly irritating to many people, and, according to some medical authorities, ozone may be harmful in excessive concentrations. The permissible upper limit of ozone concentration has not been definitely established although various arbitrary limits have been established at approximately one part per 10 million parts of air, a concentration that has been greatly exceeded by precipitators of conventional type used for industrial purposes. Since ozone is the chief product of interest, it will be particularly referred to, but it will be understood that reference to ozone includes also the oxides of nitrogen since conditions which bring about a decrease in the production of ozone also reduce the production of oxides of nitrogen.

Ozone is generated in the field of corona discharge at the discharge electrode. It has been shown experimentally that the rate of production is roughly proportional to the current consumed and to the length of the discharge electrode, and it decreases rapidly with decreasing electrode diameter for electrodes smaller than about 60 mils. Consequently all of these factors should be kept at a minimum in order to reduce the rate of ozone production; but it is to be kept in mind that various other factors also influence the net rate of production, such as applied voltage, ozone concentration, configuration of electrodes, etc.

In separated field precipitators of the tubular type, one form of precipitator has comprised a tube through which the gas stream flows and which acts as a non-discharging electrode that opposes a central electrode placed co-axially of the tube, the central electrode having both discharge and non-discharging sections. The upper section of the central electrode is generally cylindrical of relatively large diameter to prevent discharge therefrom, while the lower section is a wire or rod of relatively small diameter that acts as a discharge electrode and around which the corona discharge takes place. A precipitator of this construction is disclosed in my co-pending application filed July 6, 1938, Serial No. 217,748

entitled "Apparatus and method for cleaning gases," now Pat. No. 2,192,249 issued Mar. 5, 1940.

A central electrode structure of the conventional type described usually has an upper non-discharging section of a diameter of two inches or more, while the lower discharge section is usually of the order of 50 mils or less in diameter. The two sections are joined directly together and consequently the fields set up by each portion of the electrode are to some extent super-imposed upon each other. This physical overlapping of the electric fields of the non-discharging section and the discharge section of the electrode creates conditions which tend to increase the amount of ozone generated by this conventional type of electrode structure.

The very close proximity of the two adjoining electrodes causes the electric field in the neighborhood of the discharge electrode to be reduced and consequently the corona discharge current at a given applied potential is reduced, that is, the non-discharging electrode partially shields, in an electrical sense, the discharge electrode and thereby reduces the corona current from it. To increase the corona current to the desired value for charging suspended particles, the applied potential must be increased. But a more important result of the electrical shielding effect is that the shielding increases the rate of ozone production per unit corona current. The net result is that in the conventional electrode structure, the rate of ozone production is comparable to the production rate of an unshielded discharge electrode of larger diameter, and the benefits of small diameter electrodes are impossible of full realization.

It thus becomes a general object of my invention to provide a discharge electrode with a minimum rate of ozone production.

It is also an object of my invention to provide an electrode structure comprising both discharge and non-discharging sections in which the discharge electrode is supported from the non-discharging electrode of relatively large diameter in such a way that the discharge electrode is substantially uninfluenced by the electric field produced by the non-discharging electrode.

A further object of my invention is to provide an electrode structure comprising both discharge and non-discharging sections in which the discharge electrode is a very fine wire.

These objects have been accomplished in my invention by spacing the discharge electrode from the non-discharging electrode in the direction of gas flow by means of an intermediate member which supports the discharge electrode on the non-discharging electrode. This construction provides a unitary electrode structure around which the gas flow is, in general, parallel to the electrode surfaces. In a preferred embodiment of my invention adapted to upward gas flow, a cylindrical intermediate member is attached at its upper end to a cylindrical non-discharging electrode of relatively large diameter and at its lower end carries the discharge electrode which is a very fine wire. The intermediate member may be made of metal and is of such character that no corona discharge is produced around it, but it is materially smaller in diameter than the non-discharging electrode so that the field around it does not appreciably influence the action of the discharge electrode by reducing corona discharge therefrom. The minimum length of the intermediate electrode is approximately equal to the diameter of the non-discharging electrode, measured in a plane transverse to the direction of gas flow, as a member of this length removes the discharge electrode from the influence of the non-discharging field sufficiently that there is no material shielding effect or reduction in corona discharge. Although in the subsequent description of a preferred embodiment of my invention I show and describe an electrode structure having a cylindrical non-discharging section, it will be understood that my invention is not necessarily limited thereto; and it is within the scope of my invention to use non-discharging electrodes that are not circular in cross-section, as for example, oval, and in this case the minimum diameter in a plane transverse to the direction of gas flow determines the spacing between the discharge electrode and the non-discharging electrode.

According to the present invention, this intermediate supporting member is made of metal or other electrically conducting material, which construction offers important advantages from the standpoint of economy and cost of manufacture as well as durability of the structure. Reference should also be made to my co-pending application entitled "Electrode for electric precipitator" filed concurrently herewith in which is described and claimed an intermediate member embodying non-conducting or dielectric material; and the present application contains generic claims as well as specific claims to a metallic member.

How the above objects and advantages of my invention, as well as other objects and advantages not specifically mentioned, are attained, will become more readily apparent by reference to the following description and the annexed drawing, in which:

Fig. 1 is a vertical median section through a simplified form of tubular, separated field precipitator with an electrode constructed according to my invention;

Fig. 2 is a fragmentary elevation, partially in vertical section, of the lower end of a preferred form of central electrode structure;

Fig. 3 is a side elevation of a modified form of intermediate member with a spiral discharge electrode;

Fig. 4 is a side elevation of another modified form of discharge electrode and support therefor; and

Fig. 5 is a plan view of another modified form of discharge electrode and support therefor.

There is shown in Fig. 1 a tubular type of precipitator comprising a single tube 10 of substantially circular cross-section and preferably of uniform diameter, or nearly so, throughout its entire length. At the lower end of tube 10 is gas inlet means in the form of housing 11 which is connected to a conduit 12 that communicates with some source, not shown, of gas containing dust or other suspended particles to be removed. Gas flows upwardly within tube 10, and at the upper end of tube 10 is gas outlet means in the form of housing 14 that is connected to conduit 15 which either may open to the atmosphere or may communicate with some space to which it is desired to conduct the cleaned gas. Although a uniform diameter of tube 10 is not necessary, yet it is much preferred, because it is much easier and less expensive to make a straight tube of uniform diameter throughout its entire length than to construct a tube with varying diameter or with two or more different diameters.

The rigid central electrode, generally indicated at 17, is mounted at its upper end on insulator

bushing 18 which passes through an opening in the top wall of housing 14, the opening being slightly larger in diameter than the bushing. The bushing and electrode assembly are supported on the top wall of housing 14 by flanged ring 20 which engages the periphery of the insulator bushing and rests upon gasket 21 made of rubber or similar compressible material. Gasket 21 is between ring 20 and the top of housing 14. This construction is preferred because it permits adjustment of electrode 17 to accurately align this electrode with the axis of tube 10, since the central electrode can be moved laterally to the extent of the clearance between bushing 18 and the top wall of housing 14, and the electrode also can be moved angularly, as a result of the compressibility of gasket 21, by tightening selected ones of bolts 22 which hold the central electrode and ring 20 in place.

Although electrode 17 may be constructed in other ways than shown and described here, the present form illustrates the general principles of construction as well as certain preferred details. Electrode 17 comprises a hemispherical body 25 into the upper side of which vertically extending rod 26 is screwed and held in position by locknut 27, as may be seen in Fig. 2. The hemisphere 25 closes the lower end of cylindrical sleeve 28, the two members being of the same diameter to provide a smooth joint. The upper end of hemisphere 25 is preferably provided with a shoulder 25*a*, as shown in Fig. 2, in order to hold cylinder 28 and hemisphere 25 in proper position with respect to each other. The upper end of sleeve 28 rests against the lower face of insulator bushing 18, which also may have a shoulder to position the cylinder. Central rod 26 passes upwardly through the insulator, and locknuts 30 are screwed on to the upper end of rod 26 to hold the parts assembled in the position shown in Fig. 1. Hemisphere 25 serves to eliminate corners or edges that would produce corona discharge from sleeve 28.

Into the lower end of hemisphere 25, there is screwed rod-like intermediate member 33 which is co-axial with sleeve 28 and carries at its lower end a very fine wire which serves as a discharge electrode 35. The wire is preferably secured to rod 33 by drilling an axially extending hole in the lower end of rod 33, inserting wire 35 in the drilled hole, and then filling the hole with metallic solder.

From the standpoint of function, wire 35 is a discharge electrode, and sleeve 28 together with hemisphere 25 is a non-discharging electrode, the two electrodes being separated by an intermediate member 33 which has no function as an electrode. From the standpoint of construction, these same parts are but sections of a single, continuous electrode structure.

Electrode support 33 is a metallic rod and is preferably cylindrical in order to eliminate any portions of sharp surface curvature which might produce corona discharge. The largest diameter of the rod which will produce corona discharge depends on various factors, but for any given set of conditions it can be determined and it is preferable that the minimum diameter actually used be somewhat in excess of this diameter, as by say 25%, in order to provide some factor of safety. As typical of a diameter satisfactory in actual use, rod 33 will have a diameter of not less than about one-fourth inch. Since it is desirable that the field exerted by intermediate member 33 be kept at a minimum, the maximum diameter of rod 33 should not greatly exceed the minimum diameter, as above described; and for this reason the maximum diameter of rod 33 will ordinarily not exceed about one-half inch.

The diameter of sleeve 28 is considerably larger than that of rod 33, and usually is of the order of 2" to 4", though the size depends on the diameter of tube 10 and a larger or smaller diameter for the electrode can be used as may be found suitable under circumstances encountered. The diameter of sleeve 28 serves as a measure of the distance from the electrode that the non-discharging field is particularly active and beyond which it is desired to place discharge electrode 35. The lines of force in the electric field maintained between electrodes 28 and 10, do not extend radially outward from the bottom of hemisphere 25 for a long distance, but soon bend toward the opposing electrode 10. For this reason, the field strength decreases rapidly in the direction of the axis of sleeve 28, and beyond about one diameter from member 25 in the direction of gas flow the field is so reduced in strength that it exerts relatively little adverse effect on a discharge electrode. In order to be definitely in a position at which the discharge electrode is substantially unaffected from a practical standpoint by the non-discharging field, it is preferred that the length of the intermediate section 33 between hemisphere 25 and the upper end of electrode 35, be approximately one and one-half times the diameter of sleeve 28. It has been found by experiment that this length should not be less than the diameter of sleeve 28, and that little advantage is gained by increasing it to more than twice the diameter of sleeve 28. It is not to be inferred that there is necessarily no part of the field from the non-discharging electrode in this vicinity, at or near the axis of tube 10, where the discharge electrode is placed; but rather that the existing field is so weakened because of the path followed by the lines of force that the field exerts substantially no diminishing influence on the corona discharge.

With the foregoing description of a specific non-discharging section in mind, it will be understood that the non-discharging electrode section may be non-circular in cross-section, e. g. oval or elongated. In this case, the minimum diameter, as measured in a plane transverse to the gas flow, is used to determine the length of intermediate member 33 in the same manner as already described.

Discharge electrode 35 may be described as a very fine wire, which term is used to include a wire of such small diameter that a length equal to about one and one-half or two times the diameter of sleeve 28 is not sufficiently rigid to project from the non-discharging electrode without support at its lower end, as in the conventional construction described. From a quantitative standpoint, a wire of the order of about 50 mils or larger possesses this amount of rigidity; but a wire of a diameter substantially less than 50 mils is so flexible that, when say three or four inches long and supported only at the upper end, the gas stream blows it away from the axis of tube 10, with a resultant uneven distribution of the discharge and frequently a sparkover. Of course the flexibility of a piece of wire depends on the physical characteristics of the particular wire, as well as the ratio of length to diameter, so that no hard and fast limits can be set to the diameter, and my invention is not limited to any specific size of wire. In practice, I use a very

small diameter to minimize ozone, and preferably use a discharge electrode of approximately 5 to 15 mils diameter and of a length to project beyond the lower end of electrode support 33 for a distance of about one-half inch. It has been found by experiment that an electrode of this length gives an adequate amount of corona discharge when substantially free from the influence of the non-discharging electrode section. In general, it is desirable to keep both the diameter and the length of electrode 35 as small as possible in order to minimize the production of ozone; and the length is also then kept to a minimum in order to keep the electrode sufficiently rigid that it need be supported at only one end.

It is preferred that wire electrode 35 be made of tungsten or other refractory material having similar characteristics. Another suitable metal is tantalum. Materials of this character are used in order that the electrode may not be completely destroyed in the event of a sparkover from the electrode to opposing electrode 10 because, when such a sparkover occurs, the heat generated is sufficient to melt the more common metals.

In operation, a high potential is applied to the central electrode by conductor 36 which is connected to the upper end of rod 26 and is ordinarily connected to the negative terminal of a suitable source of uni-directional current at high potential, such as a transformer and mechanical rectifier or like equipment familiar to persons skilled in the art, adapted to create a high potential between the central electrode and tube 10 which is suitably grounded, as indicated diagrammatically at 37. Instead, tube 10 may be connected to the positive terminal of the power source. Fine wire 35 and the surrounding section of the opposing electrode 10 form one pair of electrodes; and the high potential applied to the discharge electrode is sufficient to create corona discharge at and in the vicinity of discharge electrode 35, but is not sufficient to cause arcing or disruptive discharge between the two electrodes of this pair. The upper non-discharging electrode section formed by sleeve 28 and hemisphere 25, and the surrounding portion of opposing electrode 10 form a second electrode pair; and the applied high potential maintains between these two electrodes a non-discharging electric field.

The gas stream enters housing 11 through conduit 12 and flows upwardly within tube 10. The gas stream first passes through the ionizing or charging field surrounding discharge electrode 35 when the suspended particles in the gas stream become electrically charged with the same polarity as the discharge electrode. The gas next passes through the non-discharging field around the non-discharging electrode 28; and this field is of sufficient length in the direction of gas flow to effect precipitation of substantially all the charged particles entering the field. These precipitated particles collect on the interior wall of tube 10. The precipitated particles may be removed from tube 10 by any suitable means, as, for example, by mechanically rapping the tube with suitable hammers, which are not shown as they are familiar to those skilled in the art. According to my invention, discharge section 35 and non-discharging section 28 of the central electrode 17 are separated by the length of the intermediate section 33, thus removing the discharge electrode and the ionizing field around it from active or substantial influence by the non-discharging field maintained around electrode 28. Because of this spacing between electrodes, the discharge electrode functions with maximum efficiency, i. e., it maintains a given corona discharge or corona current flowing to the opposing electrode 10 with a minimum current consumption and at a lower voltage than is possible when the discharge electrode immediately adjoins the non-discharging section. My improved construction permits the use of a shorter discharge electrode and operation with lower voltage and less current; and in the preferred form described the length of discharge electrode is reduced to a minimum consistent with minimum charging of particles in the gas stream. All of these factors control the production of ozone, and when reduced to a minimum, as they are with my improved type of discharge electrode, the production of ozone is substantially reduced compared with production rates of conventional types of electrodes. An electrode constructed according to my invention can keep ozone concentration at about one part per hundred million parts of air, even less. A further advantage is the economy of operation resulting from decreased power consumption.

When it is desired to have a longer discharge electrode to provide a longer charging field, it is necessary that a wire as small as the wire used here be supported at short intervals, and such an embodiment is shown in Fig. 3. In this form, the intermediate electrode section 33*a* that supports discharge electrode 35*a*, is the same as described except that it is longer and is provided with four short radial arms 40 on which the wire electrode 35*a* is mounted. Arms 40 are both angularly and axially spaced to hold the discharge electrode in the form of a spiral of one complete turn. The upper end of the discharge electrode is spaced from the hemispherical end of the non-discharging electrode by an interval of about one and one-half times the diameter of sleeve 28, a distance that is determined by the considerations above described in connection with electrode 35 of Fig. 2.

The spiral form of discharge electrode 35*a* provides a longer and more intensive charging field, thus not only bringing about more nearly complete charging of all particles in the gas stream but allowing a higher gas velocity through the charging field. The higher gas velocity to some extent offsets a higher rate of ozone production, as the ozone concentration is inversely proportional to the rate of flow; but even without a higher gas velocity, the rate of ozone production is still so low as to be well under generally accepted tolerance limits, because the full advantage of a very small diameter electrode is secured. One factor contributing to the high charging efficiency of the spiral electrode is that the supporting member 33*a* is inside the spiral and does not appreciably shield the electrode with respect to the opposing electrode 10, either by the rod 33*a* setting up a field or by being interposed between the wire and electrode 10.

Fig. 4 illustrates another embodiment designed to provide a longer charging field, and having much the same characteristics as the form of Fig. 3. Here, intermediate section 33*b* supports a plurality of lengths of discharge electrode 35*b*; and though four wires 35*b* are here shown, a larger or smaller member may be used. Each electrode wire 35*b* is held in a vertical position by a radial arm 41 on rod 33*b* at either end of the wires. The intermediate member 33*b* is preferably sufficiently long that the closest part

of each discharge electrode 35b is spaced from the non-discharging electrode by at least one and one-half times the diameter of the latter. It will be appreciated that in the forms of Figs. 3 and 4 the minimum spacing from the non-discharging electrode is not so critical since with the longer electrode the lower end is well beyond the minimum spacing and therefore more certain to be substantially unaffected by the non-discharging field.

Fig. 5 shows an inverted plan view of a modified form in which the discharge electrode 35c is in the shape of a circle mounted on three spaced radial arms 42 at the lower end of intermediate member 33c.

It will be understood from the foregoing description that various changes in the form and arrangement of parts may be made without departing from the spirit and scope of my invention and that the specific embodiments disclosed are but typical and illustrative forms of the invention. Consequently, it is to be understood that the foregoing description is to be construed as illustrative of rather than limitative upon the claims appended hereto.

I claim:

1. An electrode for a separated field type of electrical precipitator comprising a cylindrical non-discharging electrode section terminating in a rounded portion, the entire surface of said section having a radius of curvature not substantially less than about one inch; an intermediate section carried by said non-discharging section comprising a rod-like member extending from said non-discharging section to a distance at least equal to the smallest diameter of said non-discharging section, the entire surface of said intermediate section having a radius of curvature not substantially less than about one-eighth inch; and a very fine wire discharge electrode section mounted on the intermediate section and spaced from the non-discharging section at a distance at least equal to the smallest diameter of the non-discharging section.

2. An electrode for a separated field type of electrical precipitator comprising a cylindrical non-discharging electrode section terminating in a rounded portion, the entire surface of said section having a radius of curvature not substantially less than about one inch; an intermediate section carried by said non-discharging section comprising a rod-like member extending from said non-discharging section to a distance at least equal to the smallest diameter of said non-discharging section, the entire surface of said intermediate section having a radius of curvature not substantially less than about one-eighth inch; and a very fine wire discharge electrode section mounted on the intermediate section and spaced from the non-discharging section at a distance at least equal to the smallest diameter of the non-discharging section, all of said electrode sections being substantially coaxial.

3. An electrode for a separated field type of electrical precipitator comprising a cylindrical non-discharging electrode section terminating in a rounded portion, the entire surface of said section having a radius of curvature not substantially less than about one inch; an intermediate section carried by said non-discharging section comprising a rod-like member extending from said non-discharging section to a distance at least equal to the smallest diameter of said non-discharging section, the entire surface of said intermediate section having a radius of curvature not substantially less than about one-eighth inch; and a very fine wire discharge electrode section mounted on the intermediate section and spaced from the non-discharging section at a distance at least equal to the smallest diameter of the non-discharging section, said discharge electrode section comprising a wire of about five to fifteen mils diameter.

4. An electrode for a separated field type of electrical precipitator comprising a cylindrical non-discharging electrode section terminating in a rounded portion, the entire surface of said section having a radius of curvature not substantially less than about one inch; an intermediate section carried by said non-discharging section comprising a rod-like member extending from said non-discharging section to a distance at least equal to the smallest diameter of said non-discharging section, the entire surface of said intermediate section having a radius of curvature not substantially less than about one-eighth inch; and a very fine wire discharge electrode section in the shape of a spiral mounted on the intermediate section and spaced from the non-discharging section at a distance at least equal to the smallest diameter of the non-discharging section.

5. An electrode for a separated field type of electrical precipitator comprising a cylindrical non-discharging electrode section terminating in a rounded portion, the entire surface of said section having a radius of curvature not substantially less than about one inch; an intermediate section carried by said non-discharging section comprising a rod-like member extending from said non-discharging section to a distance at least equal to the smallest diameter of said non-discharging section, the entire surface of said intermediate section having a radius of curvature not substantially less than about one-eighth inch; and a very fine wire discharge electrode section in the shape of a circle mounted on the intermediate section and spaced from the non-discharging section at a distance at least equal to the smallest diameter of the non-discharging section.

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