

March 5, 1940.

E. ANDERSON

2,192,172

CLEANING OF GASES

Filed June 1, 1938

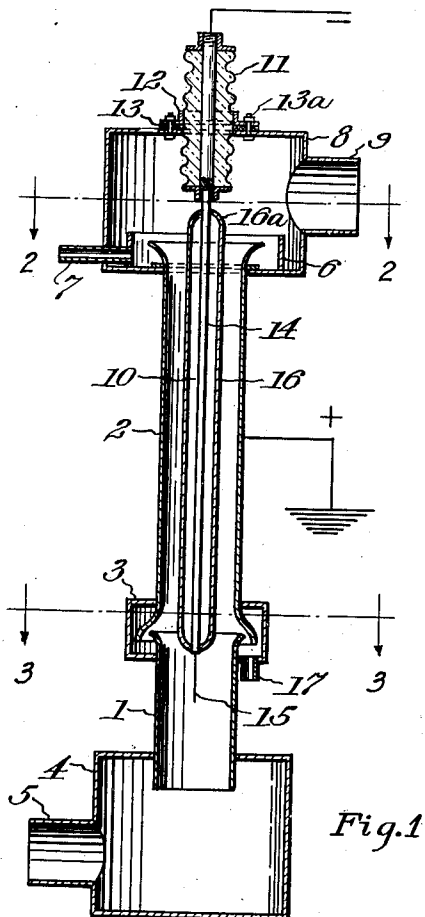


Fig. 1

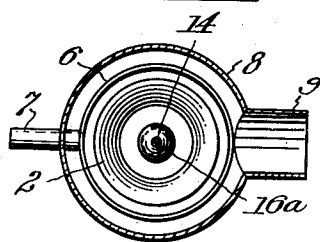


Fig. 2

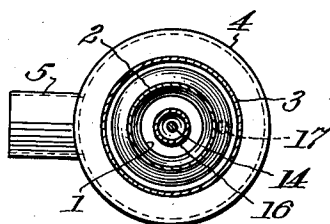


Fig. 3

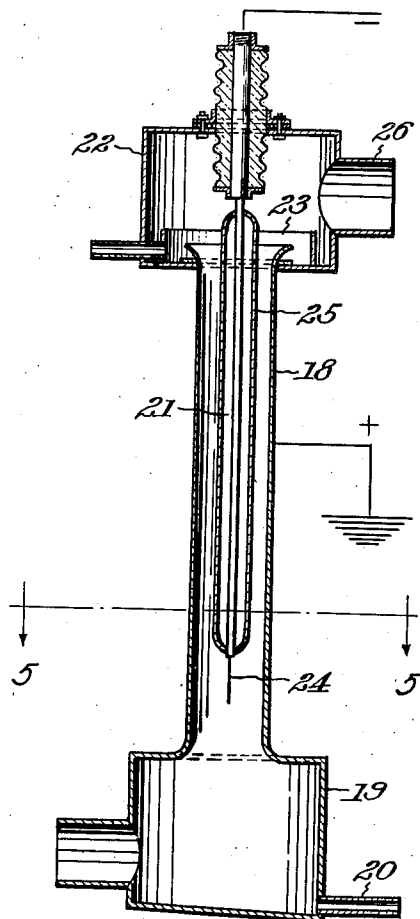


Fig. 4

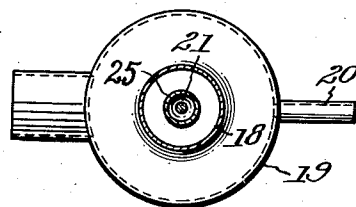


Fig. 5

INVENTOR.
Evald Anderson,
BY *Potter, Pierce & Scheffler*
ATTORNEYS

UNITED STATES PATENT OFFICE

2,192,172

CLEANING OF GASES

Evald Anderson, San Marino, Calif., assignor to
Western Precipitation Corporation, Los Angeles,
Calif., a corporation of California

Application June 1, 1938, Serial No. 211,306

5 Claims. (Cl. 183—7)

This invention relates broadly to cleaning gases, and more specifically to an apparatus for electrically precipitating suspended particles from gases, comprising a two-stage precipitator including a collecting electrode which may be kept covered with a liquid film. The invention also includes a method for precipitating suspended particles from a stream of gas.

In the following description and in the 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 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 below the voltage required for disruptive discharge or spark-over. For this purpose, a non-discharging electrode usually is 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.

A patent to W. A. Schmidt 1,343,285, granted June 15, 1920, discloses an electrical precipitator of the two-stage or separated field type. In the apparatus shown therein, two spacially separate fields are used. In the first of these electric fields, commonly called the charging field, a silent electrical discharge is maintained between a discharge electrode and a non-discharging electrode. The gas bearing fine particles of matter to be precipitated is passed between the electrodes where the particles adsorb ions or electrons and acquire electrical charges of the same sign as the attached ions or electrons, and consequently of the same sign as the discharge electrode. From the charging field the gas is led through a precipitating field between two non-discharging electrodes maintained at a high potential difference. One of these electrodes is kept charged

at a sign opposite to the sign of the charges upon the particles, and acts as a collecting electrode. In the precipitating field, the charged particles in the gas migrate to the surface of the collecting electrode, where they give up their charges, become neutralized, and adhere to the surface of said electrode. From this electrode the precipitated material may be removed by rapping the electrode so as to cause the adhering material to fall away from the collecting surface into a collecting box from which it may be removed from time to time. It is necessary to divert or discontinue passing the stream of gas to be treated during the clean-out periods which occur more or less frequently depending upon the quantity of material removed from the gas.

In the Schmidt type two-stage precipitator, it has not been possible for collection efficiency and gas capacity both to reach simultaneously the highest possible values. As was pointed out, the precipitated particles are neutralized at the collecting electrode, which is not opposed by a discharging electrode, and consequently no appreciable force tends to hold the precipitated material in continued contact with the collecting electrode. In fact, some of the precipitated particles pick up a charge from the collecting electrode and are repelled therefrom because of the similarity of the charges. Since the material adheres only very loosely to the collecting electrode, some of it is redispersed into the gas stream due in part to erosion of the built-up cake by the currents of gas passing thereby and carrying away agglomerated masses of precipitated particles, and in part to the projection of particles from the collecting electrode into the gas stream because of electrical forces, in which case the particles deposit on the opposing electrode. The redispersed particles carried away by gas erosion are not again precipitated, but are carried out of the treating apparatus into the zone where purified gas is desired. In order to increase efficiency, it is necessary to cut down erosion in the precipitating chamber; and this is accomplished by lowering the gas velocity through the chamber which results in a severe loss in capacity. Efficiency and capacity are sacrificed one for the other; high efficiency has formerly been obtained at the expense of capacity, or high capacity at the expense of efficiency.

This disadvantage of the Schmidt type precipitator is not found in a single stage precipitator, wherein both charging and precipitation take place in the same field, or in a series of like fields. It has been common practice to effect

charging of the suspended particles by passing them between two opposed electrodes between which a high potential difference is maintained, one of the electrodes being of a type to produce therefrom silent or corona electrical discharge that causes suspended particles to become charged with the same electrical sign as the discharging electrode. This is termed charging or ionizing action. The charged particles migrate, under the influence of the electric field between the electrodes, toward the other electrode which is a non-discharging electrode of extended surface, and collect or become precipitated upon the second electrode which is consequently termed the collecting electrode. A precipitator of this type using only two electrodes for the complete operation uses but a single electric field in which both charging and precipitation take place.

In this single-field type of precipitator the continuous impingement of the corona current on the dust layer on the collecting electrode maintains an electrical charge on the precipitated particles so that the particles are held to the collecting electrode by the electrostatic field, and particles which become redispersed in the air stream after precipitation are immediately recharged and reprecipitated upon the collecting electrode; consequently the single stage precipitator allows much higher gas velocities than a two-stage precipitator of corresponding size. However, the ordinary single stage precipitator is open to the disadvantage that optimum conditions for charging are not identical with optimum conditions for precipitation, and a compromise must be effected so that neither ionization nor precipitation are carried out under the most favorable conditions.

There has been observed in electric precipitators a phenomenon termed "back corona" that greatly interferes with proper collection of particles and so reduces the collection efficiency. Without discussing the various theoretical aspects of back corona, it is sufficient to say that it appears when collecting solid particles that are relatively poor conductors. After a thin layer of these high resistance particles covers the collecting electrode, the layer usually punctures at some point, and at this point there first occurs a corona discharge from the collecting electrode and later, if the potential is sufficient, an arcing over to the ionizing electrode. The back corona or arc prevents proper charging and precipitation of the particles which are allowed to pass on out of the precipitator. The subsequent reduction in collection efficiency is sometimes very great. Back corona phenomena are characteristic of the single-field precipitator and are not found usually in the precipitating field of the separated field type because the collection electrode is opposed only by another non-discharging electrode; and under ordinary conditions there is much less tendency to form a corona or arc even at a puncture in the precipitated dust layer. Consequently, the latter type gives greatly improved performances under certain circumstances, as it is free from back corona in the precipitating field. The separated field precipitator offers other marked advantages over the single-field precipitator because it can be more compactly built and uses less current, so that it is more economical to install and operate.

Another advantage of the separated field type of electrical precipitator results from the fact that, for a given spacing between two opposing electrodes, a materially higher potential difference

may be maintained, without causing disruptive discharge or arcing therebetween, when both electrodes are of the non-discharging type than when one of the electrodes is a discharging electrode. Consequently, by carrying out the precipitation between opposing non-discharging electrodes it is possible to maintain a higher potential gradient per unit distance in a direction from one electrode to the other, and therefore to cause more rapid movement of the charged particles in that direction, than in the single field type of precipitator. For this reason, the time required to effect precipitation of a given percentage of charged particles is materially reduced, resulting in an increased efficiency of collection or an increased capacity in terms of volume of gas treated per unit time, or both increased efficiency and increased capacity, in an apparatus of a given size. Additional advantages by way of more rapid precipitation are also made possible by the fact that the opposing non-discharging electrodes may be placed much closer together than has been found practical when one of the electrodes is a discharging electrode, thus decreasing the mean distance through which the charged particles must be moved by the electric field in order to reach a collecting surface. The quantitative value of these advantages is greatly diminished when a poorly conductive or highly resistant dust is collected. A thin layer of such highly resistant material on the face of the collecting electrode causes a disproportionately large fraction of the total potential drop between the two opposed electrodes to exist across the dust layer. The result is that the effective potential remaining for precipitation is greatly decreased, and a corresponding decrease in collection efficiency takes place. This situation does not occur when the electrodes are kept continually clean or the dust is highly conducting. The physical conditions causing this are analogous to those creating back corona, but the results are not as detrimental though they are definitely undesirable.

Electric precipitators of all types have been used chiefly for industrial purposes, and in this field it has been generally immaterial whether or not any new compounds or gases have been formed by the action of the electric field. But with the present trend toward air conditioned offices and homes electrical precipitating units are being designed to clean air used for ventilation; and in this type of use it is of prime importance that the precipitator not produce any substances that are either annoying because of their odor or dangerous to health. Consequently, production of ozone and oxides of nitrogen, formerly of little significance in industrial installations, has now become a factor of importance in air conditioning units, since these gases are distinctly irritating to many people, and ozone, according to some medical authorities, is potentially harmful in excessive concentrations. What upper limit of ozone concentration is permissible is not definitely established though it is now set at various points approximately averaging one part per ten million parts of air, a concentration that is only a small fraction of that produced by most conventional precipitators.

Thus it becomes a general object of my invention to provide an improved separated field type of electric precipitator in which higher velocities can be used than heretofore, thus securing greater capacity for a treater of a given size because the precipitated particles are effectively trapped against blowing out of the treater.

A further object is to provide a precipitator in which conditions that reduce the effective voltage of the precipitation field are prevented from arising, thus keeping the precipitator always at a relatively high precipitation efficiency.

An additional object of my invention is to provide an electrical precipitator that does not introduce into the air physiologically objectionable products in quantities above established tolerance limits, so that the precipitator may be adapted to clean air for ventilating purposes.

These and other objects which will be pointed out hereinafter are attained according to my invention by passing a stream of gas containing suspended particles to be precipitated through successive electric fields. In one of these fields the particles are electrically charged, and in another of the fields substantially all the charged particles entering the field are precipitated and simultaneously trapped against redispersion into the gas stream, and continually removed from the collecting surface.

In apparatus for carrying out my novel method of electrically precipitating suspended particles, I provide two successive spacially separate electrode arrangements, each of which is adapted to maintain an electric field, the first of these fields being an ionizing or charging field, and the second being a substantially non-discharging precipitating field. In the second of these fields redispersion of particles into the gas stream after precipitation is successfully prevented by maintaining the collecting electrode wetted with a film of suitable liquid, for example, water, and preferably keeping this surface film of fluid in uniform unidirectional motion so as to continuously wash the collecting electrode free of precipitated material.

The attainment of the above objects and advantages of this invention, as well as others which will appear hereinafter, will be more particularly described and pointed out with reference to the accompanying drawing in which:

Fig. 1 is a vertical sectional view, partly in perspective, of a unit of one form of apparatus for carrying out the method of this invention;

Fig. 2 is a horizontal section along the plane 2—2 of Fig. 1;

Fig. 3 is a horizontal section along the plane 3—3 of Fig. 1;

Fig. 4 is a modified form of apparatus for accomplishing the objects of this invention; and

Fig. 5 is a horizontal section, partly in plan, along the plane 5—5 of Fig. 4.

In Figs. 1, 2 and 3, there is shown a tubular electrical precipitating unit in which the tube is divided into two sections 1 and 2 which are interconnected electrically through the medium of the liquid sump 3. These parts are preferably made of sheet metal or like conducting material, since the parts may conveniently be joined by welding. With a water film, non-conducting material may be used if desired. At the bottom of tube 1 is an inlet header 4 fitted with an inlet pipe 5. The top of tube 2 is flared outwardly and rises into a liquid feeding basin designated by the numeral 6, the top of said basin being slightly above the top of the flared portion of tube 2. The feeding basin is supplied with water, or other suitable liquid, through a pipe 7. Containing the feeding basin and surrounding the tube 2 is a gas receiving means comprising a header 8, similar to the inlet header 4 above referred to. A gas outlet pipe 9 welded to the receiving header leads the treated gas to the location of use or disposal. The tube sections, head-

ers, liquid feeding basin, sump and cooperating pipes are joined in any suitable manner, but preferably are welded together for mechanical strength.

Located centrally and coaxially of tubes 1 and 2 is the rigid central electrode generally indicated at 10. Electrode 10 is mounted at its upper end in insulator bushing 11 which passes through the top wall of receiving header 8, the opening being somewhat larger in diameter than the bushing. The central electrode and bushing are mounted on the top wall of the receiving header in a flanged ring 12 which rests upon a flexible gasket 13 supported by the top wall. Suitable bolts 13a hold the electrode mounting assembly in position. The electrode assembly may be moved bodily in a direction radial of the tube to the extent of the clearance between bushing 11 and the top wall of the header, and the electrode may be adjusted angularly with respect to the tube axis by tightening bolts 14 at one side of the bushing more than at the opposite side so as to compress gasket 13 unequally.

The electrode assembly 10 may have any one of a number of different forms but preferably comprises a length of rod 14 at the lower end of which is attached a short length of smooth steel wire 15 of smaller diameter serving as a discharge electrode. The rod 14 commencing just above the point of attachment of the small steel wire 15, is surrounded by a smooth-walled cylindrical jacket or shield 16 of larger diameter than the rod, said shield being secured to or supported on the rod 14 in any suitable manner, as by welding, and forming in effect an integral part of the electrode. The shield 16 preferably is formed as a hollow tube for the sake of lightness in weight, and is closed at both ends, preferably by rounded end portions 16a. As will be well understood by persons skilled in the art, electrode sections having exposed surfaces of relatively small radius of curvature, such as is provided in this case by the steel wire 15, bring about silent or corona discharge when a high potential is applied to the central electrode. However, shielded section 16 has no such outer surface of small radius and consequently there is substantially no corona discharge from this portion of the electrode. Thus, the parts 1, 2 and 16 constitute non-discharging electrodes. When using flexible electrodes, such as wire, it has been necessary to attach them at their lower ends to weights or fixed members in order to keep them taut and centered in the tube. However, the wire section 15 of the electrode assembly herein described is sufficiently short and rigid to prevent undue flexing thereof. The steel wire section 15 of the electrode assembly extends below the level of the flanged top of tube section 1, and in cooperation with tube section 1 as non-discharging complementary electrode, comprises the charging or ionizing section of the apparatus. The shielded portion 16 of the electrode in cooperation with tube section 2 comprises the precipitation and collecting section of the apparatus, and the shield 16 extends throughout at least the major portion of the height of said tube section.

A high electrical potential difference is applied between the central electrode assembly and the tube comprising sections 1 and 2, preferably by connecting the central electrode assembly to the negative terminal of a source of unidirectional current, not shown, such as a transformer and rectifier assembly familiar to those skilled in the art, the positive terminal of the current source

either being directly connected with the tube or indirectly so connected through ground. The current source is adapted to create a potential between the electrodes sufficiently high to cause corona or silent discharge from the discharge electrode 15 but not high enough to cause arcing or disruptive discharge. The same potential difference establishes and maintains a substantially static precipitating electrical field between non-discharging electrode sections 16 and 2. A potential difference of the order of 25 kilovolts times the number of inches between the electrodes in the precipitating zone has been found to be advantageous in many cases.

In operation, gas bearing suspended matter to be precipitated enters the inlet header 4 through the pipe 5 from a source, not shown, of gas to be cleaned. The gas flows upwardly from the header 4 into the ionizing zone in tube section 1 where it is acted upon by the corona discharge to charge the particles of suspended matter with an electrical sign like that upon the discharge electrode 15. The ionizing zone is preferably made as short as possible and the gas velocity is kept as high as possible so that no excess current above the minimum required for substantially complete charging of suspended particles is used. In this way the most efficient charging conditions are maintained. From the charging zone, the gas flows through the precipitation zone within tube section 2 where the previously charged particles migrate to the walls of the tube and are precipitated thereupon under the influence of the electrostatic field maintained between electrodes 16 and 2. The length of the precipitation zone depends on the type of particles collected and their rate of travel toward the collecting electrode surface, but is comparatively short because substantially all the suspended charged particles are precipitated in the minimum length of chamber under optimum conditions of precipitation. In some cases it may be desirable to increase the length of the charging zone or the precipitation zone in order to take care of overloading conditions or the like.

In general, the charging zone may be substantially shorter than the precipitating zone and may advantageously have a length of the order of one-tenth the length of the precipitating zone. From the precipitation zone the treated gas enters receiving header 8 and thence by way of pipe 9 is led to the point of delivery.

During precipitation, the inner walls of tube 2 are covered continuously with a film of liquid which flows from top to bottom. The electric precipitating field is maintained between the electrode member 16 and this continuous film of liquid, and thus may be described as terminating upon the liquid film. The liquid enters the feeding basin 6 through pipe 7 from a source, not shown. The liquid rises within the basin to the lip of the flared portion at the top of tube 2 whence it overflows uniformly along the periphery into the tube, continuously flowing down the inside of the tube in an unbroken smooth film. As particles are precipitated on the collecting electrode, the moving film of water entraps them, carrying them downward and maintaining the collecting electrode always in a clean condition. The bottom of tube 2 is flared out to form a bell-like portion which leads the liquid bearing precipitated matter into a quiescent zone in the sump 3 where it is collected and drawn off to a reservoir, not shown, through pipe 17. The liquid

may be filtered or otherwise cleaned and recirculated, if desired.

The liquid for wetting the electrode preferably is water which is universally available at low cost and which has the property of high surface tension and therefore is adapted to maintain a smooth-surfaced film and to resist the tendency for portions thereof to be torn away and carried along by the passing gas stream, which permits satisfactory operation at relatively high gas velocities. However, other liquids may be employed, if desired, for special reasons. For instance, oil or some other organic liquid may be used where the precipitated particles are not readily wetted by water, or an aqueous or other liquid solvent may be used where it is desired to dissolve some constituent of the precipitated material or of the gas itself.

It will be seen that the tubular collecting electrode member 2 and the film of liquid thereon are charged oppositely, that is, of opposite sign or polarity, with respect to the discharge electrode member 15 and the charged particles entering the precipitating field, and that the direction of the precipitating field is such as to cause precipitation of such charged particles upon the liquid film on electrode member 2.

A modification of the above-described apparatus is shown in Figs. 4 and 5. The only essential difference between the two treaters is that in the modified form the extended surface electrode of the ionizing zone and the collecting electrode of the precipitation zone comprise one continuous tube 18, while in the previously described apparatus these two electrodes, although specially located in corresponding positions, are physically separate and distinct. Due to the construction of the modified apparatus, the liquid film flows not only upon the surface of the collecting electrode, but also upon the extended surface electrode of the charging zone. The sump intermediate the charging and the precipitation zones is eliminated, and the inlet header 19, provided with a drain pipe 20, performs the added function of a sump. It is apparent that this construction is considerably cheaper to make than the construction of Fig. 1, since the straight tube 18 replaces the tube sections 1 and 2. The central electrode assembly 21 is the same as the corresponding electrode assembly 10 in Fig. 1, and is adjustably mounted in similar fashion. The headers 19 and 22 and their inlet and outlet pipes, the feed-basin 23 and its supply pipe, and the electrical fittings and connections functionally correspond to analogous members in Fig. 1. For the sake of structural rigidity the parts of the apparatus preferably are welded together where possible.

The fact that the extended surface electrode of the ionizing zone is wetted in the apparatus of Fig. 4, does not change the operation, and creates added advantages in some cases, as pointed out hereinafter. The portion of tube 18 surrounding the steel wire electrode 24 and the steel wire electrode comprise means for ionizing the gas and charging the particles, and the rest of tube 18, in cooperation with the shielded portion 25 of the central electrode, comprises means for precipitating the previously charged particles.

The operation of the modified apparatus is similar to the operation of the first described treater. Gas bearing suspended particles is conducted into inlet header 19, and passed through the tube 18 in an upwardly direction, where the particles receive a charge in the ionizing zone and are pre-

precipitated and collected in the precipitation zone. The cleaned gas is led to the receiving header 22 and thence by means of pipe 26 to the point of destination.

A liquid wetting medium is caused to flow from feeding basin 23 in a continuous film downwardly through tube 18 into the bottom of inlet header 19, from which it is withdrawn, and if desired, cleaned and recirculated.

Broadly, this invention includes a method of removing suspended particles from gases by subjecting the gas to the action of corona or silent discharge in a high tension electric field wherein the particles are charged electrically and subsequently passing the gas through a second high tension electric field substantially free from corona discharge, the latter of said fields, or alternatively, each of said fields, terminating on a substantially continuous film of liquid.

An electrical precipitation apparatus for carrying out the method of this invention comprises a complementary electrode system including a discharge electrode element adapted to create an ionizing field and an opposing non-discharging electrode, a second complementary electrode system comprising spaced non-discharging electrode elements, means for directing a gas to be treated successively between the complementary members of said electrode systems, means for impressing a high potential across the complementary electrodes of each of said electrode systems, and means for maintaining a liquid film on that one of the complementary electrodes of the second of said electrode systems, whose sign or polarity is opposite to that of the discharge electrode, or upon said electrode element and also upon the non-discharging electrode of the first complementary electrode system.

The invention is not limited to the two types of precipitators described above by way of illustration. The principles of the invention may be applied to other forms of two-stage precipitators, including precipitators in which either or both the charging and the precipitation zones have plate collecting electrodes. A plurality of tube units embodying the principles of the invention may be combined in a single apparatus having common gas and liquid headers for a number of ionizing and collecting units.

Furthermore, the invention may include construction in which the electrodes of the precipitating field are not electrically or mechanically connected to the electrodes of the charging field, as is the case in the specific embodiments shown in the drawing. Thus, the electrode system of the charging field may be entirely separate from the electrode system of the precipitating field, and the two electrode systems may be separately supported, and any electrode of either system may be insulated from any one of the other electrodes. Also, different electrical potentials, obtained either from a common source or from separate sources, may be maintained between the complementary electrodes of the charging field and between the complementary electrodes of the precipitating field.

The forms of both Figs. 1 and 4 have the marked advantage of preventing particle loss from the precipitating stage because the precipitated particles are held and carried away by the liquid film. This condition permits full realization of the advantages resulting from higher field strength in the precipitating stage, and increased velocity without any loss in efficiency. Consequently, a unit of a given size can operate at a

much larger capacity than has previously been the case. This is true whether the material collected is a good conductor or a poor conductor.

Poorly conducting material tends to form an insulating layer over the electrode surface that requires a large potential drop across the layer for the electric field to penetrate to the electrode surface. Since the potential difference between the two electrodes is assumed to be constant, the potential between the high tension electrode and the surface of the deposit, which is the effective precipitation voltage, is proportionately decreased. But both forms of treater eliminate this cause of decreasing field strength in the precipitating stage by continually washing the collecting electrode surface clean and preventing the formation of detrimental deposits. Thus full field strength for precipitation is always assured, even with poorly conducting dusts or fumes.

The poorly conducting dusts also are apt to cause serious trouble as a result of back corona discharge in the initial or charging field, since it is impossible to prevent some precipitation on the surface of the non-discharging electrode in the first field. In the prevention of this condition, the apparatus of Fig. 4 has particular advantages since the non-discharging electrode in the charging field (i. e., the portion of tube 18 opposite wire 24) is continually washed by the liquid film and the precipitated particles are carried away before any harmful quantity can be deposited. Keeping the non-discharging electrode 18 clean eliminates formation of positive ions in the charging field and secures maximum degree of negative charging of the dust particles in the gas stream. Any positive ionization reduces or may even neutralize the negative charge on the dust particles, thus reducing the precipitation efficiency. In some cases positive ionization, if it occurs to an excessive extent, may even create positive charges on some particles which are then precipitated on the high tension electrode in the precipitating stage, where they are not removed by the liquid film.

The novel step of providing a liquid film trapping means in the precipitating zone of a two-stage precipitator allows operation of the apparatus at higher gas velocities than could otherwise be used were such a trapping means not provided.

The novel characteristics of my improved apparatus have unsuspected influences on the production of ozone and nitric oxide, as the precipitator operates now with only negligible formation of these undesirable products. Formation of ozone and nitric oxide occurs in fields having corona discharge and the rate of formation of each gas is roughly proportional to both the current consumed and the length of discharging electrode. Since a decrease in electrode length decreases the current, it also decreases the quantity of ozone and nitric oxide formed in proportion to the second power of the change in length. Ozone is formed at a relatively constant rate independently of the gas velocity past the electrodes within the range of velocities used in practice, but of course the concentration varies inversely as the velocity so that the increased velocity at which this novel precipitator can operate further reduces the unit concentration of ozone or nitric oxide. Tests have shown that conventional single-field precipitators as now constructed and operated are usually unsatis-

factory in ventilating units since they produce ozone considerably in excess of the upper limit of tolerance now adopted which is about .1 p. p. m. By comparison, the treaters above described have been found to produce only .02 to .1 p. p. m. of ozone with about .04 p. p. m. regularly obtainable under favorable conditions. Thus the ozone concentration is materially less than that produced by a single-field precipitator of equal capacity and the production of nitric oxide shows a similar decrease.

The liquid film has the particular advantage that the liquid may be used to absorb to some extent the gaseous products of the electric discharge. Water alone, or an alkaline aqueous solution may be used to absorb oxides of nitrogen, and a solution of potassium iodide may be used to absorb the ozone. This absorbing action is increased in the form of Fig. 4 having a liquid film in the first stage where the electric wind promotes contact of gas with the liquid on the electrode walls.

From the foregoing description it will be apparent that various other shapes and arrangements of electrodes may be used in conjunction with a water film without departing from the spirit and scope of my invention, and consequently it is to be understood that the foregoing disclosure is to be considered as illustrative of, rather than restrictive upon, the appended claims.

I claim:

1. The method of removing suspended particles from gases which comprises subjecting the gas to the action of corona discharge in a high tension electric field wherein the suspended particles are charged, subsequently passing the gas through a second high tension electric field substantially free of corona discharge, and maintaining in said second field a substantially continuous film of liquid, said second field being maintained in a direction to force the charged particles toward the liquid film.

2. Electrical precipitation apparatus comprising a complementary electrode system including a discharge electrode element adapted to create an ionizing field, a second complementary electrode system comprising spaced non-discharging electrode elements, means for directing a gas to be treated successively between the complementary members of said electrode systems, means for impressing a high potential across the complementary electrodes of each of said electrode systems, and means for maintaining a liquid film on the electrode of the second of said electrode systems which is of opposite sign with respect to said discharge electrode element.

3. An electric precipitator comprising two electrode tube sections having their axes in alignment and connected electrically, means for establishing a flow of gas serially through said sections, means for flowing a film of liquid over

the inside surface of the electrode section which is second in the direction of gas flow and sump means exterior to said sections for collecting the film of liquid as it leaves said second electrode section, a central electrode disposed coaxially of the tube sections, the extreme end portion of which is of a character to bring about corona discharge in a high tension electric field, said end portion projecting into the first electrode tube section from the portion of the central electrode which is surrounded by the second electrode tube section, a hollow shield forming part of the central electrode which lies within the second electrode tube section, which shield is adapted to prevent corona discharge between the central electrode assembly and the second tube section, and means for impressing a high potential between the central electrode and said electrode tube sections.

4. An electric precipitator comprising a hollow tubular electrode member, gas inlet and outlet means at opposite ends of the tubular electrode, a central electrode assembly disposed coaxially of the tubular electrode, the extreme end portion of said central electrode being shaped to produce corona discharge in cooperation with a section of the tubular electrode under the influence of a high tension electric field, the remaining portion of the central electrode surrounded by the tubular electrode being provided with a tubular shielding member which forms an integral part of the central assembly and is adapted to eliminate corona discharge between the shielded portion of the central electrode and the surrounding portion of the tubular electrode, means for causing a film of liquid to continuously wet at least a portion of the inside surface of the tubular electrode, and means for impressing a high potential between the central electrode and the tubular electrode.

5. In a method of removing suspended particles from gas wherein the suspended particles are precipitated from the gas by subjecting a stream of the gas to the action of a corona discharge in a high tension electric field wherein the suspended particles are charged and subsequently passing the gas through a second field substantially free from corona discharge to cause the charged particles to move under the influence of said field to a boundary of said field, the improvement which comprises passing the gas through the second field at a velocity sufficient to normally cause substantial re-dispersion of precipitated material from a dry surface at said boundary and maintaining in said second field a substantially continuous film of liquid at said boundary thereof to intercept the charged particles moving under the influence of said field and thereby substantially prevent the occurrence of such re-dispersion.

EVALD ANDERSON.