March 3, 1942. E. ANDERSON 2,275,001

APPARATUS FOR ELECTRICAL PRECIPITATION

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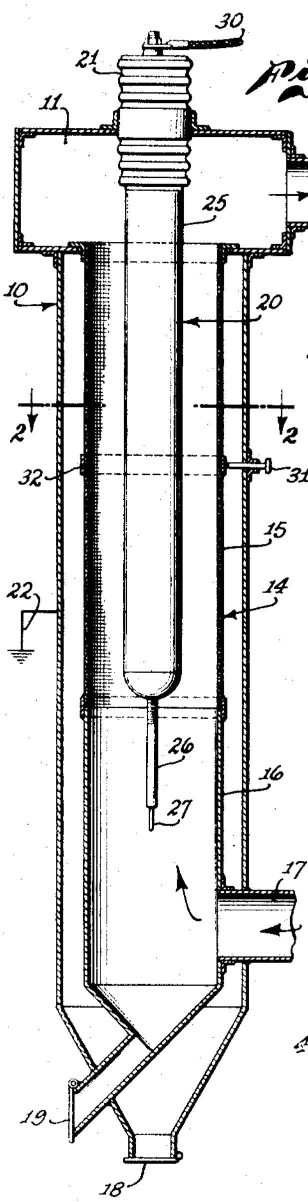

Fig. 1.

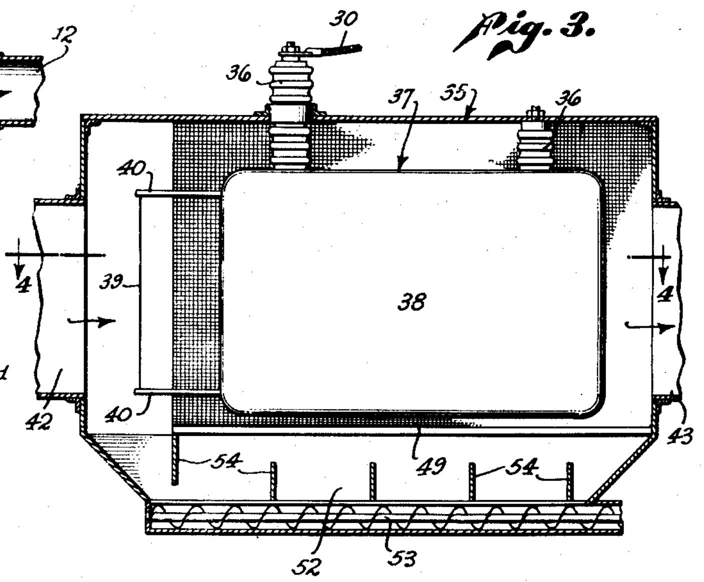

Fig. 3.

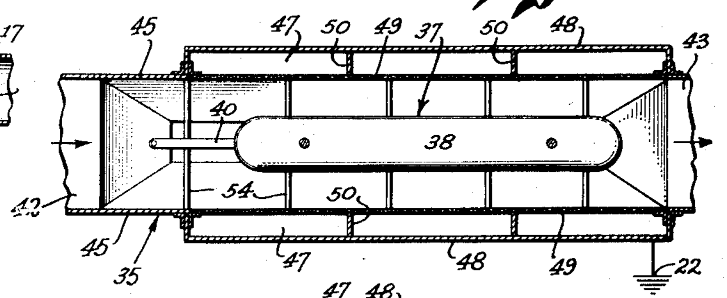

Fig. 4.

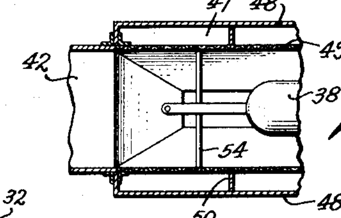

Fig. 4a.

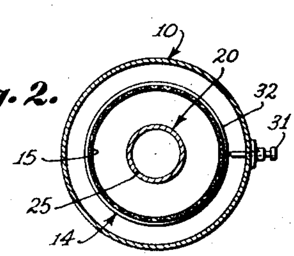

Fig. 2.

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Fig. 5.

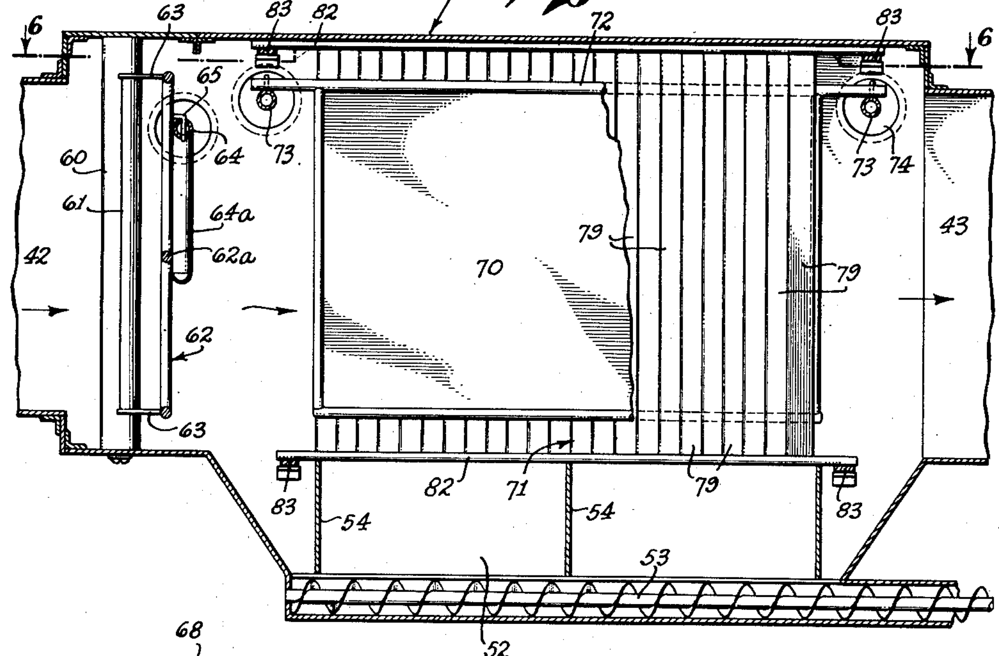


Fig. 6.

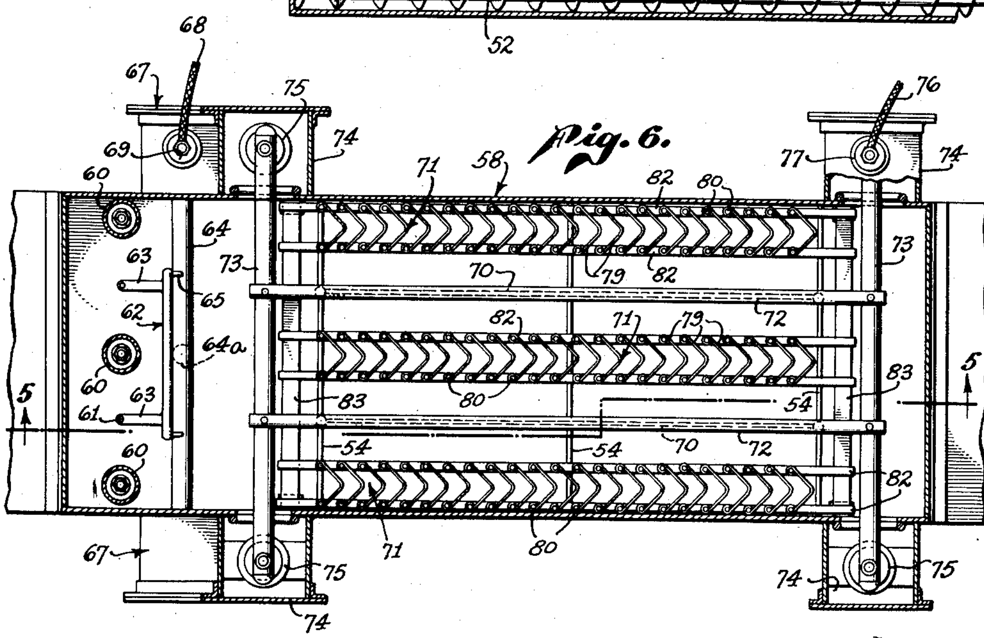
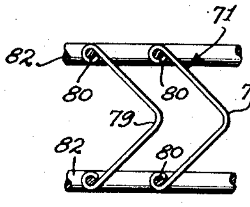


Fig. 7.



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2,275,001

UNITED STATES PATENT OFFICE

2,275,001

APPARATUS FOR ELECTRICAL PRECIPITATION

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Application July 16, 1940, Serial No. 345,850

15 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 methods and apparatus 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 its elemental form, a precipitator of this type has a first field maintained between two electrodes of which one is a discharge electrode and the other is a non-discharging electrode, and a second field maintained between two substantially non-discharging electrodes.

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 sparkover. 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 substantially to avoid ionization or corona discharge at that electrode.

The construction and advantages of an electrical precipitator of the two-stage or separated field type are discussed in Patent No. 1,343,285 granted June 15, 1920, to W. A. Schmidt and also in my co-pending application Serial No. 176,116 filed November 23, 1937 for improvements in "Electrical precipitation." Briefly, these advantages are economy of operation and installation; advantageous inherent operating characteristics with certain types of dust; a much reduced tendency to the detrimental phenomenon of "back-corona" in the collecting section; and the ability to maintain a relatively higher potential gradient between the electrodes in the collecting section, thus bringing about very effective collection.

However, two-stage precipitators have often heretofore had the disadvantage of losing dust from the collecting surface of the precipitating electrode section when the gas stream exceeds a certain velocity which is generally termed the "critical velocity." Examination of the dust blown out of the precipitator discloses that the loss is chiefly in the form of agglomerates of a number of particles originally suspended in the gas, indicating that apparently the particles have been once precipitated on the collecting electrode but have become so lightly held that, after an agglomerated mass has formed, the gas stream is able to blow the agglomerate off of the collecting surface. This loss of particles is apparently caused primarily by the absence of any corona in the precipitating field since it does not occur at comparable gas velocities in a single field precipitator, as the precipitated particles are continually subjected to a stream of ions or electrons so that the particles are charged oppositely to the precipitating electrode and adhere securely to the collecting surface. This loss from the collecting stage of the two-stage precipitator is a result of the erosive effect of the gas stream, and is herein termed the erosion loss. The quantity of particles blown from the collecting field at relatively low gas velocities is negligible, as all dust particles are adequately held; but it becomes increasingly appreciable at higher gas velocities and operates to place a definite limit on the capacity of any treater of given cross-section since the gas velocity cannot exceed the so-called critical velocity. The capacity of the treater as thus determined is very much lower than the capacity as measured by the ability of the two fields to charge and precipitate particles.

It thus becomes a general object of my invention to provide means for preventing erosion loss of precipitated particles from the precipitating section of a two-stage precipitator.

A further object of the invention is to provide a two-stage precipitator which will operate efficiently at higher gas velocity in the precipitating stage than is possible without excessive erosion loss in other types of two-stage precipitators, and to thereby provide a materially greater gas capacity in a precipitator of a given cross-sectional area.

Another object of my invention is to provide means that collects particles in the second or precipitating field of a two-stage precipitator in such a manner that the particles are not blown away by the gas stream; that is, the particles are so shielded from the main stream that they are not dislodged and re-suspended in the gas stream.

A further object of the invention is to provide an electrode of such shape that the particles are precipitated in a relatively quiet zone in which they are exposed directly only to portions of the gas stream having a relatively low velocity which is insufficient to erode the precipitated particles from the collecting electrode.

Still another object of my invention is to provide means for collecting the particles in the precipitating field of a two-stage precipitator in a dry condition.

The above objects of my invention are attained by providing, in the precipitating field of the two-stage precipitator, an electrode structure for the collecting electrode that has substantial width or thickness between its lateral boundaries which are planes or surfaces generally parallel to the direction of gas flow. The electrode has surfaces for electrical precipitation of suspended particles and has portions that define a zone between said lateral boundaries for the collection of precipitated particles and that shield said zone from the gas stream to make it relatively quiet.

An electrode having these characteristics is termed in general a "pocket-type" electrode. Broadly speaking, it is an electrode that, because of its pocket-like physical structure, reduces or prevents erosion from the electrode of particles precipitated thereon. This is accomplished by two different kinds of collecting action on the particles. In one action, the particles are precipitated directly in the relatively quiet zone from which there is little or no erosion because of the relatively low gas velocity. In the other action, the particles are precipitated on precipitating surfaces more or less exposed to the gas stream, and are subsequently directed into and collected in the quiet zone. In a given pocket-type electrode both actions may be present, though one may predominate over the other according to the design of the electrode, of which there are several.

According to my invention, the pocket-type collecting electrode is one of the pair of non-discharging electrodes forming the second complementary electrode system in a two-stage precipitator. This second electrode system is spatially separated in the direction of gas flow from the first electrode system which comprises a non-discharging electrode and a discharge electrode at which corona discharge takes place. The precipitator also includes means for directing the gas stream past the two electrode systems in succession and means for impressing a high potential between the complementary electrodes of each of the two systems. The pocket-type collecting electrode in the precipitating field is opposite in polarity to the discharge electrode in the charging field in order that the precipitating field is in a direction to attract charged particles to the pocket-type electrode.

How the above, as well as other objects and advantages of my invention, are attained will be more readily understood by reference to the following description and the annexed drawings, in which:

Fig. 1 is a vertical median section through a tubular type of two-stage precipitator constructed according to my invention;

Fig. 2 is a horizontal section on line 2—2 of Fig. 1;

Fig. 3 is a vertical longitudinal section through a horizontal flow type of two-stage precipitator, showing a variational embodiment of my invention;

Fig. 4 is a horizontal section on line 4—4 of Fig. 3;

Fig. 4*a* is a fragmentary view like Fig. 4 showing a modification therein;

Fig. 5 is a vertical longitudinal section through a horizontal flow type of precipitator on line 5—5 of Fig. 6, illustrating another variational embodiment of my invention;

Fig. 6 is a horizontal section on line 6—6 of Fig. 5; and

Fig. 7 is a fragmentary horizontal section through a collecting electrode of Fig. 6.

The precipitator illustrated in Figs. 1 and 2 is of the tubular type and comprises a tubular imperforate shell 10 with an outlet header 11 at its upper end that connects with outlet duct 12. Inside shell 10 and concentric therewith is another tubular member 14 which is made in two portions. The upper portion 15 is foraminous and preferably made of metallic screening or expanded metal or the like, while the lower portion 16 is preferably imperforate. Gas inlet duct 17 passes through the wall of tube 10 and communicates with the interior of the imperforate tubular member 16. Both tubular members 10 and 14 are provided with conical or hopper shaped bottoms in which precipitated dust is collected, the dust being removed from the interiors of the tubular members through valves 18 and 19 respectively.

The central electrode structure designated generally at 20 is located coaxially of both tubular shell 10 and member 14 and is supported from the top wall of outlet header 11 by an insulator 21 that electrically insulates the central electrode from the precipitator shell 10 which is grounded, as at 22. Central electrode 20 preferably comprises an upper non-discharging electrode section 25 of relatively large diameter in order to prevent the formation of corona discharge from this electrode. Fastened to the lower end of non-discharging electrode 25 is an intermediate member 26 which may be made of dielectric material or metal if of sufficient diameter substantially to prevent formation of corona discharge. The purpose of intermediate member 26 is to support fine wire discharge electrode 27 concentrically of shell 10 and member 14 but at a sufficient distance below non-discharging electrode 25 to insure that the field around electrode section 25 does not suppress corona discharge from electrode 27. Discharge electrode 27 is electrically connected to non-discharging electrode 25 through intermediate member 26.

Although it is possible to use other types of central electrode structures, it is preferred to use the one just described, which will be found described in greater detail in the co-pending applications of Harry J. White on "Electrode structure," filed March 1, 1940, Serial Nos.

321,784 and 321,785, now Patents Nos. 2,244,278 and 2,244,279, respectively.

The central electrode 20 is maintained at a high potential with respect to members 10 and 14 by application thereto of a high-tension current by means of electrical conductor 30 which is connected to any suitable source of current at a suitably high voltage. The current is preferably unidirectional current at a high potential; and a source is not shown as such means is well known to those skilled in the art. Annular member 14, which is intermediate central electrode 20 and shell 10, is electrically connected to the shell and is therefore also grounded.

The apparatus described provides two complementary electrode systems, each system comprising one pair of electrodes. The first complementary pair of electrodes comprises discharge electrode 27 and the surrounding tubular member 16 that acts as the opposing non-discharging electrode. Between these two electrodes, the high potential difference maintains a charging or ionizing field because of the corona discharge produced around electrode 27; and the suspended particles of dust carried upwardly in the gas stream past electrode 27 become electrically charged as a result of passage through the ionizing field.

The second complementary electrode system is spaced from the first in the direction of gas flow and comprises a pair of non-discharging electrodes, of which one is electrode 25 and the other is an opposing pocket-type collecting electrode formed by the surrounding portion of imperforate tube 10 and foraminous tube 15 spaced therefrom. Although screen 15 is interposed between shell 10 and electrode 25, the screen and shell are grounded and together act as a collecting electrode. As the charged particles are carried upwardly through the space between electrode 25 and screen 15, the electric field maintained between these two electrodes causes the charged particles to migrate toward the collecting electrode and become precipitated on screen 15 and on the inner surface of shell 10. Shell 10, and likewise member 16, serve as gas conduit means to direct the gas stream past these two electrode systems in succession.

The inner tubular member 16 may, if desired, be foraminous and a continuation of the upper portion 15; but it is preferably imperforate in order to act better as a gas directing member as well as a non-discharging electrode. It receives the incoming gas stream from inlet 17 and directs the gas stream upwardly into the annular space between the electrodes of the second system in a direction substantially parallel to the surfaces of electrodes 15 and 25, and for this purpose member 16 adjoins and is vertically aligned with the foraminous portion 15 of the annular member 14. Member 14 is foraminous throughout at least the portion that surrounds electrode 25 and extends the length of the precipitating field, thus screen 15 is preferably approximately co-extensive with electrode 25. The action of the precipitating field causes the dust particles in a large measure to pass through the screen and become precipitated on the inner surface of tube 10, although a substantial proportion of the dust is precipitated on screen 15. Some of this latter dust passes through the screen.

Screen 15 keeps the main gas stream flowing upwardly parallel to the surface of electrode 25 and acts to shield the surface of shell 10 on which dust particles are precipitated from direct impact of the gas stream. Consequently, the annular zone between screen 15 and shell 10, which defines the lateral boundaries of the electrode, is relatively quiescent, i. e., the velocity of the portion of the gas stream moving through that zone is so low that precipitated particles are not dislodged to an appreciable extent from the surface of the shell. The average gas velocity through the precipitator may be raised accordingly. The annular zone is closed at its upper end by the lower wall of outlet header 11, as shown in Fig. 1, in order to keep the gas movement within the annular zone at a relatively low velocity.

It is customary to remove the precipitated particles from the collecting electrode by rapping the collecting electrode. For this purpose, there is provided a plunger 31 which passes through the wall of shell 10 and engages an anvil ring 32 fastened to screen 15. Dust collected upon the surface of shell 10 can be dislodged by striking the external surface of the shell a few sharp blows; and dust collected on screen 15 can be dislodged by striking plunger 31 which hits anvil ring 32 and shakes the screen. The dislodged dust particles fall down into the hopper bottom of members 10 and 16 and are removed from the precipitator interior by opening valves 18 and 19. In this form of construction, it is possible to clean the electrodes without discontinuing the gas flow. The dust falling down through the annular zone outside screen 15 and tube 16, falls in a relatively quiet space in which the gas velocity is so low as to re-suspend but very little dust in the gas stream. Particles that are sufficiently small to be picked up again by the gas stream, are to some extent re-charged in the ionizing field and again precipitated.

Application of my invention to a horizontal flow type of precipitator is illustrated by the embodiment shown in Figs. 3 and 4. This precipitator comprises an imperforate shell, indicated generally at 35, having parallel vertical side walls and a horizontal top wall, the shell serving to direct the gas stream past two systems of complementary electrodes in succession. The central high tension electrode structure 37 is placed midway between the side walls and is suspended from the top wall of shell 35 by insulators 36, one of the insulators extending through the top wall in order that electrical conductor 30 may be attached to a lead-in wire passing through the insulator and connected to the electrode structure. Electrode structure 37 comprises, as before, two electrodes, a non-discharging electrode 38 and a fine wire discharge electrode 39. Non-discharging electrode 38 is a plate-like member of extended surface area having substantially plane sides with rounded edges and corners. To reduce the distance between it and the opposing electrode, electrode 38 is preferably relatively thick; and is then preferably hollow in order to reduce weight. Discharge electrode 39 is a fine wire or other member capable of producing corona discharge, and is supported from electrode 38 between a pair of horizontally projecting intermediate members 40 which, like member 26, are of such character as to prevent corona discharge from these members but to electrically connect discharge electrode 39 to non-discharging electrode 38.

Shell 35 is provided with a gas inlet 42 at one end and a gas outlet 43 at the opposite end. The initial sections 45 of the vertical side-walls adjacent gas inlet 42 form non-discharging electrodes opposing discharge electrode 39; and the discharging electrode together with the opposing electrodes form the first complementary pair of electrodes between which is maintained the charging field through which the gas stream passes in order to charge the particles of dust suspended therein.

Beyond initial wall sections 45, the shell walls are recessed outwardly, as at 47. At each side of electrode 38, section 48 of the imperforate side wall is spaced from a foraminous member 49, which is aligned in the direction of gas flow with adjoining wall section 45 to form, in effect, a continuation thereof. The foraminous member 49, which may be woven wire, expanded metal, or like material, is intermediate wall 48 and electrode 38. On opposite sides of electrode 38, a foraminous member 49 and an imperforate side wall section 48 together form a pocket-type collecting electrode having an inner quiet zone 47 between the lateral boundaries determined by the members 48 and 49. Members 48 and 49 are electrically connected together and both are grounded. The pocket-type collecting electrodes and the high tension electrode 38 form the second complementary system of non-discharging electrodes between which is maintained a substantially non-discharging electric field that causes the charged particles to migrate toward the collecting electrode and become precipitated thereon. The bulk of the dust particles are precipitated on the inner surface of wall-section 48 and in the quiet zone inside the electrode although a substantial proportion of the particles are precipitated on screen 49, and some of these are subsequently collected in the quiet zone within the electrode.

The imperforate side wall at 45 not only acts as an opposing electrode but also acts as a gas-directing means which directs the flow of the main stream of gas over and parallel to the surfaces of electrodes 38 and 49. Screen 49 shields the collecting surface of wall section 48 from the direct contact with the main gas stream and establishes in space 47 a relatively quiescent zone in which the velocity of the gas stream is sufficiently low that substantially no particles are carried away and re-suspended in the gas stream. As a result of experiments, it has been found preferable to sub-divide zone 47 into shorter lengths by providing one or more vertically extending baffles 50 that extend between screen 49 and wall member 48, as these baffles further decrease gas circulation through space 47 and increase the overall collection efficiency of the precipitator.

Quiescent zone 47 is bounded at the ends and one side by the side walls of the precipitator, on the other side by foraminous member 49, and at the top by the top wall of the shell 35. This zone is preferably open at the bottom in order that dust falling off the elements of the collecting electrode can drop down into the hopper-shaped bottom 52 of the precipitator. This hopper-shaped bottom 52 has downwardly converging walls that terminate at their lower ends in a trough in which is placed screw-conveyor 53 that, upon rotation, conveys dust from the precipitator. Obviously, any other suitable type of dust-conveying means may be employed. Dust precipitated on a collecting electrode may be removed by manually or mechanically rapping the collecting electrode, as for example, by striking a few sharp blows against the exterior of side-walls 48. Baffles 50 facilitate cleaning the electrodes since they transmit the blow to screens 49 in order to jar loose particles collected on these screens. It is preferable to place a series of transverse baffles 54 in the hopper bottom to minimize gas flow through this portion of the precipitator and instead direct the gas through the precipitating field maintained between electrodes of the second system. It will be understood that increased gas capacity of a unit may be obtained by spacing the shell side walls farther apart and by placing more than one electrode structure 37 within the shell; and in this construction an additional pocket-type electrode is located wholly within the shell between each two electrodes 38. The electrode is constructed substantially as described above. For example, the added pocket-type electrode may be like two of the previously described electrodes placed back-to-back, with a screen 49 on either side of an imperforate sheet 48; and in some instances it may be satisfactory to omit the imperforate sheet and use only the two screen sheets suitably spaced apart.

Fig. 4*a* shows a variation in the precipitator of Fig. 4. It may be desired sometimes in the interests of economy of construction to extend the pocket-type electrode into the charging field where it opposes the discharge electrode. How this is accomplished in connection with the precipitator of Figs. 3 and 4 is shown in Fig. 4*a* in which the initial wall section 45 is omitted and replaced by electrode members 48 and 49. This same change may usually be made in the other types of precipitators described herein.

Figs. 5, 6 and 7 illustrate the application of my invention to another form of horizontal flow precipitator which is arranged generally in the same manner as the precipitator just described, but employs different electrode constructions, particularly for the collecting electrode in the precipitating field. In this form of the invention, the first system of electrodes comprises a plurality of pairs of electrodes between which an ionizing field is established to charge the particles suspended in the gas stream. There is provided a plurality of spaced, parallel, non-discharging electrodes 60 with a discharge electrode 61 spaced midway between each two non-discharging electrodes. Non-discharging electrodes 60 are vertically extending cylindrical members placed in a common plane extending transversely of gas inlet 42 at one side of precipitator shell 58. Electrodes 60 are preferably hollow tubes, as may be seen from Fig. 6, as this provides a light weight construction. Non-discharging electrodes 60 are electrically connected to precipitator shell 58 and grounded through the shell, and these electrodes oppose the fine-wire discharge electrodes 61 which are maintained at a relatively high potential with respect to the grounded electrodes.

Discharge electrodes 61 are mounted on an open rectangular frame 62, each discharge electrode being mounted between a vertically spaced pair of forwardly projecting arms 63 which extend forwardly from the upper and lower transverse elements of the open frame. Discharge electrodes 61 are members capable of producing corona discharge, preferably fine wires, and are preferably, though not necessarily, located in a common transverse vertical plane which passes through the center of cylindrical electrodes 60.

Rectangular frame 62 is suspended from transverse crossbar 64, and is attached thereto by a pair of hooks 66 which slide downwardly into suitable openings in the crossbar, as may be seen from Fig. 5. Frame 62 is detached from crossbar 64 by lifting the frame vertically. Frame 62 is held in a vertical position and kept from swinging around crossbar 64 by engagement of an intermediate horizontal frame member 62*a* with a rigid depending stop member 64*a* attached to crossbar 64. Crossbar 64 is electrically insulated from precipitator shell 58 and is supported at either end on electrical insulator (not shown) which is enclosed within a separate insulator compartment 67 outside the shell 58, in order to keep the insulator out of the main gas stream and as free as possible from any accumulation of dust particles. This construction is similar to the insulator supporting arrangement of the high tension electrodes in the precipitating field, which is described below.

A high-potential difference is maintained between electrodes 61 and 60 by application of high tension current to crossbar 64 and attached electrodes 61 through cable 68 which is connected to a suitable source of unidirectional high potential current, not shown. Cable 68 is connected to a lead-in wire which passes downwardly through insulator 69 into an insulator compartment 67 where the lead-in connects to one end of the crossbar.

The second complementary system of electrodes comprises a plurality of pairs of non-discharging electrodes 70 and 71 between which substantially non-discharging precipitating fields are maintained. Although other known types of non-discharging electrode may be used instead, the high tension non-discharging electrodes 70 shown here each comprise a plate, preferably imperforate, with rounded edges which may be provided either by rolling the edges of the plate or by welding to the plate a pipe or rod of sufficient diameter to prevent corona discharge from the edges of the plate. The latter construction is employed here, and the rod 72 across the top edge of the plate has been extended beyond the ends of the plate to rest upon a horizontal crossbar 73 at each end of the precipitating section, crossbars 73 extending through the walls of precipitator shell 58 into insulator compartments 74 where the ends of the crossbars rest upon insulators 75 to electrically insulate the high-tension electrodes from the grounded shell. Insulator compartments 74, like insulator compartments 67, are provided to remove insulators 75 from the main gas stream and thus minimize collection of dust upon the surfaces of the insulator.

A high tension electrical current is applied to electrode 70 through cable 76 which is connected to a lead-in wire passing downwardly through insulator 77 into an insulator compartment 74 where the lead-in wire is attached to one end of a crossbar 73.

Each collecting electrode 71 comprises a series of V-shaped elements 79 which are aligned and spaced from one another in the direction of gas flow, as may be seen in Fig. 6. Sharp edges are removed from the open ends of each V-shaped element by rolling the end at a sufficient radius to prevent corona discharge from the element. This may be easily done by rolling the edge of a metal strip over a rod 80 as shown in Fig. 7. The ends of rods 80 are then allowed to extend beyond the ends of the sheet forming an element 79, and the ends of these vertically extending rods 80 are then secured to horizontally extending rods 82, there being two such rods 82 at the top and bottom of each assemblage of elements 79 that makes up a collecting electrode 71. As may be seen in Fig. 5, longitudinally extending rods 82 rest upon transversely extending supports 83 attached to shell 58, in order to support the collecting electrodes in place. Through this supporting structure, collecting electrodes 71 are electrically connected to shell 58 and grounded therethrough.

Broadly considered, elements 79 may be other than V-shaped; and may be arcuate or even flat, though the shape shown is preferred. In any event, elements 79 should have a substantial width transverse to the direction of stream flow in order to provide the desired shielding effect and to form a suitable space between the lateral boundaries of the electrode in which collection of the dust particles takes place. Here, the lateral boundaries are planes, parallel to the direction of gas flow, in which the lateral edges of elements 79 lie.

The operation of this form of precipitator is substantially the same as has been already described. The gas stream carries suspended particles through an ionizing field maintained between two electrodes 61 and 60 and in this region the suspended particles become electrically charged. The gas stream then flows through the spaces between electrodes 70 and 71 between which electrodes there is maintained a non-discharging precipitating field that causes the suspended particles to migrate to a collecting electrode 71. Each collecting electrode has a plurality of members 79 upon which the suspended charged particles are precipitated, and it has been found that the dust particles collect on both the front and back vertical surfaces of the V-shaped elements. Particles are precipitated not only in the quiet zone, but also on surfaces more or less exposed to the gas stream and the particles later are collected in the quiet zone. Although the gas stream is free to pass from one side of collecting electrode 71 to the other side through the spaces between two successive members 79, there is in fact very little tendency for this cross-circulation. Instead, each V-shaped element acts to shield the succeeding elements from the direct force of the gas stream. Consequently, there is established a relatively quiescent zone lying between the lateral boundaries of the collecting electrode, and within this zone the gas velocity is sufficiently low that there is very little tendency for dust particles once precipitated upon the surfaces of the collecting electrode elements to become re-suspended in the gas stream. While each element establishes a small quiescent zone of this character in the space between it and the next element 79, it may be considered that in the aggregate the several such small zones within each collecting electrode establish one large quiescent zone lying within the lateral and end boundaries of the collecting electrode.

Although this form of precipitator, as well as the forms previously described, may be provided with mechanical means for rapping or jarring the collecting electrodes to jar loose collected material, for purposes of simplicity the present form has been shown as adapted to manual rapping. Downwardly directed blows may be struck against the top wall of shell 58 at a position immediately over the rods 82, and the jar, communicated through these rods to the elements 79 of the collecting electrodes, shakes loose the material precipitated thereon. The material loosened from the collecting electrodes falls downwardly into the hopper bottom 52 from which it is removed by rotating screw conveyor 53. As before, baffles 54 are provided to prevent by-passing flow of the gas stream through the hopper 52, and to deflect the gas stream upwardly into the space between electrodes 71 and 72.

From the foregoing description of various embodiments of my invention, it will be seen that this invention comprises improvements especially applicable to a collecting electrode in a two-stage precipitator. It will be noticed that each of the collecting electrodes described has one or more portions having surfaces upon which the precipitated dust collects in a quiescent zone. In the three forms described, these collecting surfaces are respectively the inner surface of imperforate tubular shell 10, inner surface of imperforate wall section 48, and the surfaces of the V-shaped elements 79. Each of these collecting electrodes also has other portions that shield the collecting surfaces from direct impact of the gas stream; and these shielding portions, are, as may be seen by reference to the drawings, cylindrical screen 15, plane screen 49, and the V-shaped members on either side of the one providing the collecting surface. As a result of this shielding action of these portions of the collecting electrodes, there is established by each electrode one or more zones that are relatively quiescent and which are immediately adjacent and in contact with the collecting surface portions of the electrode. The portions of the electrodes which exert this shielding action prevent the direct force of the main gas stream from reaching the dust particles precipitated upon the collecting surfaces, but at the same time these portions of the electrodes do not prevent dust precipitated thereon from subsequently being collected in the quiet zone to a greater or lesser extent. While there is gas circulation over the collecting surfaces, yet the gas velocity is insufficient to cause any appreciable erosion of precipitated particles from the collecting electrodes. All these collecting electrodes having these characteristics are broadly termed "pocket-type" electrodes.

In all the improved collecting electrodes described above, it will be noticed that the electrode has considerable thickness in a direction transverse to direction of gas flow, with the lateral boundaries of the electrode lying in planes parallel to the direction of gas flow. Lateral boundaries of the electrodes are spaced apart by a substantial distance which in practice is preferably of the order of 2" or so, though it may be more or less as required by engineering design; and between these boundaries the elements of the electrode establish one or more relatively quiescent zones.

By way of example of the advantages of my invention in practice, one experimental precipitator constructed according to my invention showed a dust loss at 200 C. F. M. of about 4.5% compared with 7.8% for a conventional precipitator of the same cross-section. The dust loss was thus nearly cut in half; and it was further reduced to only 2.6%, or one-third, by installing transverse baffles in the collecting electrode, as at 50. Thus my invention enabled a given precipitator to increase its collection efficiency by reducing dust losses between one-half and two-thirds without any change in size or shape. Or, differently expressed, it enabled the same precipitator to increase its capacity from 200 C. F. M. to 275 C. F. M. without any decrease in collection efficiency.

From the above description it will be apparent that various other embodiments of my invention are possible in addition to the embodiments described, and that changes may be made in the shape and arrangement of parts without departing from the spirit and scope of my invention. Consequently, the foregoing description is to be considered as illustrative of rather than limitative upon my invention as defined by the appended claims.

I claim:

1. Electrical precipitation apparatus for removing dust particles from a stream of gas, comprising a first complementary electrode system that includes a non-discharging electrode and a discharge electrode; a second complementary electrode system including a pair of non-discharging electrodes spaced from the first system, one of the non-discharging electrodes of the second system being a pocket-type collecting electrode including means defining particle-collecting spaces open to the gas passage between the electrodes of said second system but out of the path of the gas stream; means for directing the gas stream past the electrode systems in succession; and means for impressing a high potential across the complementary electrodes of each system.

2. Electrical precipitation apparatus for removing dust particles from a stream of gas, comprising a first complementary electrode system that includes a non-discharging electrode and a discharge electrode; a second complementary electrode system including a pair of non-discharging electrodes spaced from the first system, one of the non-discharging electrodes of the second pair being a pocket-type collecting electrode having surfaces for electrical precipitation of suspended particles and having portions providing particle-collecting zones open to the gas passage between the electrodes of said second complementary electrode system and shielding said zones from the gas stream; means for directing the gas stream past the electrode systems in succession; and means for impressing a high potential across the complementary electrodes of each system.

3. Electrical precipitation apparatus for removing dust particles from a stream of gas, comprising a first complementary electrode system that includes a non-discharging electrode and a discharge electrode; a second complementary electrode system including a pair of non-discharging electrodes spaced from the first system; an outer shell directing the gas stream past the electrodes of said first and second complementary electrode systems in succession; one of the non-discharging electrodes of the second pair being a pocket-type collecting electrode of which the lateral boundaries are spaced apart by a substantial distance and are parallel to the direction of gas flow, said collecting electrode having portions providing at least one particle-collecting zone open to the gas passage between the electrodes of said second system but out of the path of the gas stream; and means for impressing a high potential across the complementary electrodes of each system.

4. In electrical precipitation apparatus for removing dust particles from a stream of gas having a first complementary electrode system that includes a non-discharging electrode and a dis-

charge electrode, the combination comprising a second complementary electrode system including a pair of non-discharging electrodes spaced from the first system, one of the non-discharging electrodes of the second system being a collecting electrode comprising a plurality of members of which one or more members have a surface on which dust collects, and of which one or more other members shield each said collecting surface from direct impact of the gas stream and form a zone of relatively low gas velocity immediately adjacent each said collecting surface open to the gas passage between the electrodes of said system but out of the path of the gas stream.

5. Electrical precipitation apparatus for removing dust particles from a stream of gas, comprising a first complementary electrode system that includes a non-discharging electrode and a discharge electrode; a second complementary electrode system including a pair of non-discharging electrodes spaced from the first system, one of the non-discharging electrodes of the second system being a collecting electrode and comprising an imperforate member and a spaced foraminous member interposed between the other electrode of the second system and the imperforate member to provide at least one particle-collecting zone open to the gas passage between the electrodes of said second system but out of the path of the gas stream; means for directing the gas stream past the electrode systems in succession and for directing the gas stream into the space between the electrodes of the second system in a direction substantially parallel to the electrode surfaces; and means impressing a high potential across the complementary electrodes of each system.

6. Electrical precipitation apparatus for removing dust particles from a stream of gas, comprising a first complementary electrode system that includes a non-discharging electrode and a discharge electrode; a second complementary electrode system including a pair of non-discharging electrodes spaced from the first system, one of the non-discharging electrodes of the second system being a collecting electrode and comprising an imperforate member and a spaced foraminous member interposed between the other electrode of the second system and the imperforate member; the non-discharging electrode of the first system and the foraminous member of the collecting electrode being aligned with each other in the direction of gas flow with the surface of one being substantially a prolongation of the surface of the other; means for directing the gas stream past the electrode systems in succession; and means impressing a high potential across the complementary electrodes of each system.

7. Electrical precipitation apparatus for removing dust particles from a stream of gas, comprising a first complementary electrode system that includes a non-discharging electrode and a discharge electrode; a second complementary electrode system including a pair of non-discharging electrodes spaced from the first system, one of the non-discharging electrodes of the second system being a collecting electrode and comprising an imperforate member and a spaced foraminous member interposed between the other electrode of the second system and the imperforate member; the discharge electrode being supported by but spaced from the electrode of the second system opposing the collecting electrode, and the non-discharging electrode of the first system being aligned in the direction of gas flow with the foraminous member of the collecting electrode; means for directing the gas stream past the electrode systems in succession; and means impressing a high potential across the complementary electrodes of each system.

8. In electrical precipitation apparatus for removing dust particles from a stream of gas, the combination comprising a tubular imperforate shell; a central electrode structure located coaxially of the shell and comprising discharge and non-discharging electrode sections; and an intermediate substantially annular member coaxial with the central electrode structure and electrically connected to but spaced from the shell, said intermediate member being foraminous throughout the portion that surrounds the non-discharging section of the central electrode structure, said foraminous portion together with the shell forming a collecting electrode.

9. In electrical precipitation apparatus for removing dust particles from a stream of gas, the combination comprising a tubular imperforate shell; a central electrode structure located coaxially of the shell and comprising discharge and non-discharge electrode sections; and an intermediate substantially annular member coaxial with the central electrode structure and electrically connected to but spaced from the shell, said intermediate member being foraminous throughout the portion that surrounds the non-discharging section of the central electrode structure, said foraminous portion together with the shell forming a collecting electrode, and the remainder of the intermediate member being imperforate and forming an electrode opposing the discharge section of the central electrode structure.

10. In electrical precipitation apparatus for removing dust particles from a stream of gas, the combination comprising an imperforate shell with a pair of substantially parallel side walls; an electrode structure located centrally of the shell and comprising discharge and non-discharge electrode sections; and an intermediate foraminous member electrically connected to but spaced from each of said side walls, said foraminous members being opposite and approximately co-extensive with the non-discharging section of the central electrode and forming, together with the shell, collecting electrodes.

11. In electrical precipitation apparatus for removing dust particles from a stream of gas, the combination comprising an imperforate shell with a pair of substantially parallel side walls; an electrode structure located within the shell and comprising discharge and non-discharge electrode sections; an intermediate foraminous member electrically connected to but spaced from one of said side walls, said foraminous member being opposite the non-discharging section of said electrode structure and forming, together with the side wall, a collecting electrode; and an initial portion of the said side wall forming an electrode opposing the discharge section of the central electrode structure.

12. In electrical precipitation apparatus for removing dust particles from a stream of gas, the combination comprising a first complementary electrode system that includes a non-discharging electrode and a discharge electrode; and a second complementary electrode system including a pair of non-discharging electrodes spaced from the first system, one of the non-discharging electrodes of the second system being a collecting electrode comprising a plurality of vertically ex-

tending elements of substantial width transverse to the direction of gas flow, the elements being aligned in the direction of gas flow and spaced from each other horizontally with the space between each two successive elements open to the gas stream in a plane substantially parallel to the direction of gas flow.

13. In electrical precipitation apparatus for removing dust particles from a stream of gas, the combination as in claim 12 in which the collecting electrode comprises a plurality of similar vertically extending V-shaped elements spaced from each other horizontally, and longitudinally extending supporting members at the top and bottom of the electrode to which the V-shaped elements are attached, the space between each two successive elements being open at its lower end to allow precipitated dust particles to fall away from the electrode.

14. Electrical precipitation apparatus for removing dust particles from a stream of gas, comprising a first complementary electrode system that includes a non-discharging electrode and a discharge electrode; a second complementary electrode system including a pair of non-discharging electrodes spaced transversely from each other and defining between them a longitudinally extending gas passage open at both ends; means for directing a gas stream past the electrodes of the first system and then longitudinally into, through, and out of the gas passage between the non-discharging electrodes of the second system; one of the non-discharging electrodes of said second system being a pocket-type collecting electrode having lateral boundaries spaced apart a substantial distance, said collecting electrode having surfaces for electrical precipitation of suspended particles and having portions that define and shield from the gas stream one or more particle-collecting zones between said lateral boundaries, and means for impressing a high potential across the complementary electrodes of each system.

15. In electrical precipitation apparatus of the separated field type for removing dust particles from a stream of gas and having two or more spatially separated systems of complementary electrodes, an electrode system that comprises a pair of opposing non-discharging electrodes spaced transversely from each other and defining between them a longitudinally extending gas passage open at both ends; means for directing a gas stream longitudinally into, through, and out of the gas passage between said non-discharging electrodes; one of said non-discharging electrodes being a pocket-type collecting electrode having lateral boundaries spaced apart a substantial distance, said collecting electrode having surfaces for electrical precipitation of suspended particles and having portions that define and shield from the gas stream one or more particle-collecting zones between said lateral boundaries; and means impressing a high potential across said non-discharging electrodes.

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