

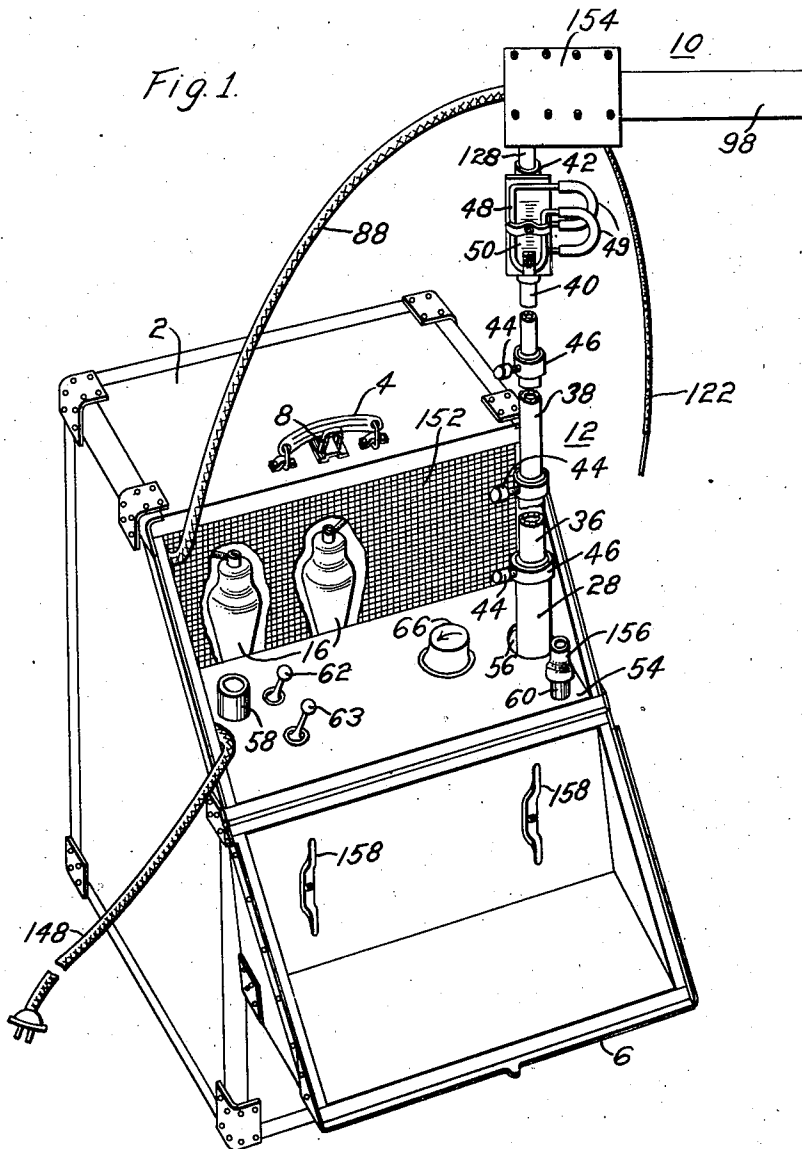
Jan. 5, 1943.

G. W. PENNEY ET AL
ELECTROSTATIC DUST SAMPLER

2,307,602

Filed Oct. 20, 1938

3 Sheets-Sheet 1



WITNESSES:

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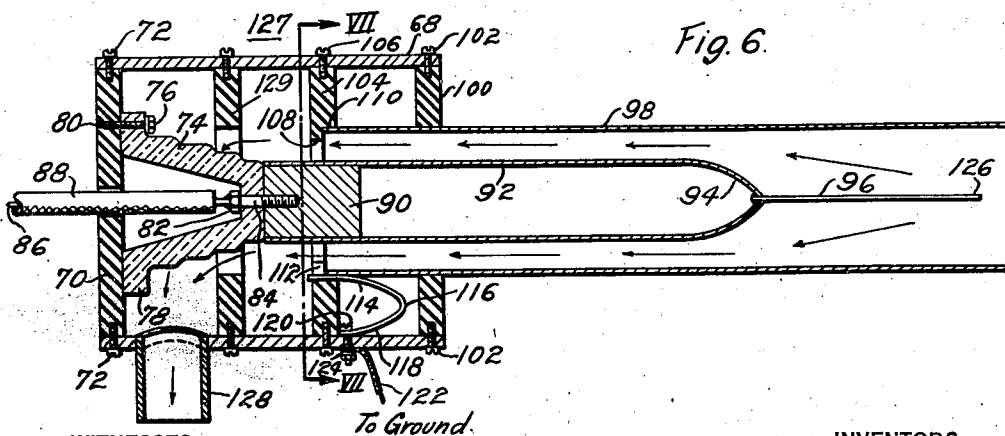
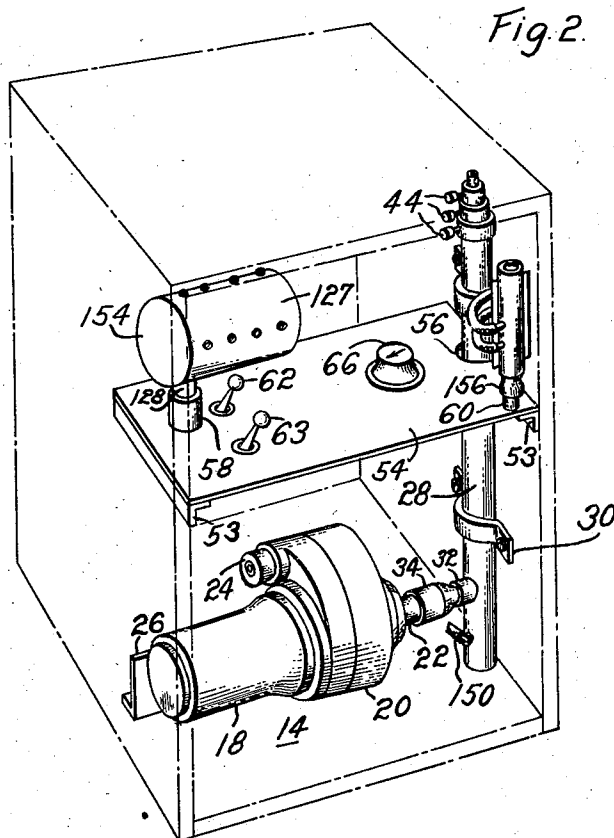
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ELECTROSTATIC DUST SAMPLER

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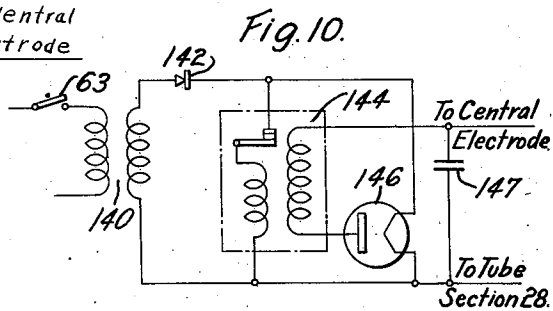
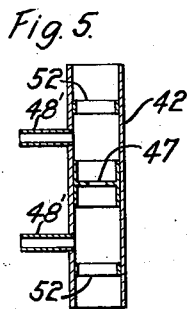
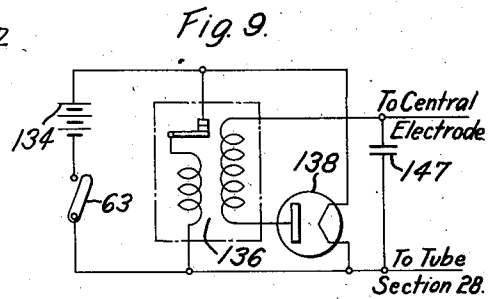
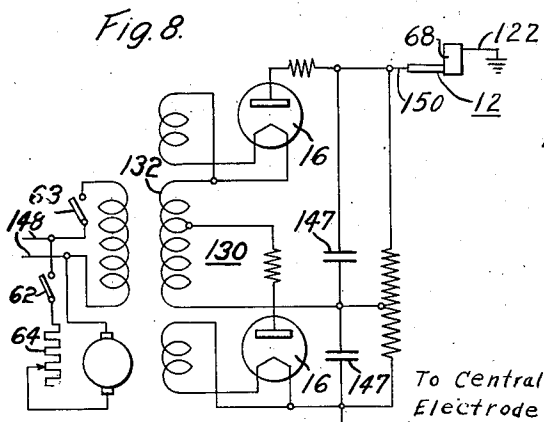
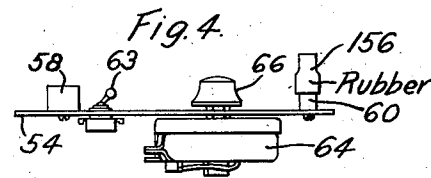
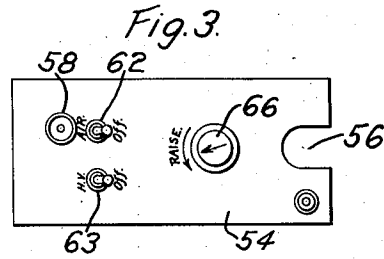
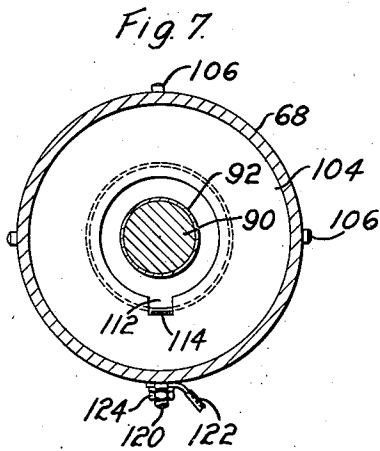
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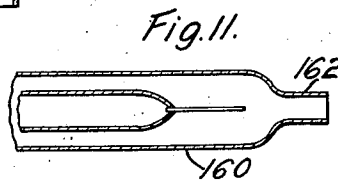
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UNITED STATES PATENT OFFICE

2,307,602

ELECTROSTATIC DUST SAMPLER

Gaylord W. Penney, Wilkinsburg, and Edgar C. Barnes, Edgewood, Pa., assignors to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application October 20, 1938, Serial No. 236,022

22 Claims. (Cl. 73-21)

Our invention relates generally to a device or apparatus for electrostatically precipitating particles of dust, fumes, smoke and the like from a gaseous atmosphere, and more particularly to a device or apparatus capable of being employed as an instrument for qualitatively or quantitatively determining the particulate matter in the atmosphere, a process more commonly known as dust sampling, the term "dust" including any and all kinds of particulate matter that may be present in the atmosphere being analyzed.

Our invention has application for the sampling of the dust content of the atmospheres encountered in different localities or in diverse industrial fields of which foundries, mines and pottery works are outstanding examples, but is of general application wherever some accurate analysis of the dust content in the gaseous atmosphere is desired. It is a primary purpose of our invention to design a dust sampler of general utility, and capable of use with practically any gaseous atmosphere, as for example, atmospheres in smelters or brass foundries containing lead fumes, mine atmospheres, sooty atmospheres, foundry atmospheres containing mixtures of silica and iron oxide. Atmospheres in many localities and of many kinds have been successfully sampled with our novel instrument with consistent results with repeated tests. Since gaseous atmospheres vary greatly in composition and constituents, for the sake of brevity and simplicity, the term "air" is hereinafter employed as a general designation for any gaseous atmosphere, but it should be understood that such terminology is not to be deemed a limitation, except where required to a specific end.

In general, our invention comprises apparatus for moving air or the like through an electrostatic precipitator head unit which has ionizing electrodes for ionizing the dust in the air, and collecting or depositing electrodes by which the ionized dust is made to deposit upon one or more of the collecting electrodes. The precipitator head is designed with the collecting electrodes easily removable so that they may be weighed before and after each assay. A means for measuring the flow or volume of air passing through the precipitator head is also provided, so that by simple calculations the dust weight per unit volume of air can be readily ascertained. Moreover, the deposited matter can be removed from the electrodes in any easy manner for the purpose of making counts of the number of particles or for determining their size or general composition in accordance with known dust analyzing methods.

Our invention is, therefore, also an important adjunct for complete dust sampling and analysis.

One of the main accomplishments of our invention is a simply and economically constructed dust sampler which is self-contained in a compact unit that can be easily transported from place to place, and to this end the essential parts of the dust sampler are built into or contained in a small case having a handle by which it may be easily carried. Inasmuch as electrical precipitation requires high voltage, the case includes a built-in, appropriately-designed power-pack, and to further make the dust sampler complete in itself, a blower, comprising a fan and motor, for moving air through the precipitator head, is also built into the container case. Additionally, a collapsible tube upon which the precipitator head may be mounted extends from the fan inlet, and includes a flow-measuring instrument of any suitable form by which the flow of air through the collector head may be measured.

The case compactly accommodates the voltage transforming means, that is, the power-pack and the blower means, and is also suitably designed to provide compartments into which the precipitator head and collapsible tube may be disposed or fitted when the apparatus is not in use. All the working parts of the dust sampler, therefore, are accommodated in the case for ready portability. In one practical embodiment of our invention, a case containing all the necessary elements for a complete dust sampler weighs approximately but 25 pounds.

A very important feature of our invention lies in the construction of the precipitator head which comprises a relatively-elongated, outer, electricity-conducting tube, preferably of metal and cylindrical, concentrically disposed about an insulated, inner central electrode consisting of two sections. One section comprises an electricity-conducting tube somewhat over a half length of outer tube, and the other section comprises a wire of somewhat less than half the length of the outer tube. In operation, with a high potential applied between the outer and inner electrodes, with the outer tube grounded and of a polarity to act as a collector for the dust, the zone between the central wire and outer tube serves for ionizing whatever dust may be in the air flowing through the precipitator head, while that between the outer and inner tubes serves as a dust depositing or collecting zone. The outer tube, and preferably the inner electrode also, are mounted as part of the precipitator head in such manner that they may be easily removed so that they

may be weighed and cleaned or otherwise utilized in accordance with the method of dust sampling being employed.

Since the composition or constituents of air may vary in different localities or industries, the particular substance for making the electrodes must be carefully selected. We have found that the tubes made of aluminum are exceptionally satisfactory for dust sampling in most environments and under most conditions. However, our novel construction of the precipitator head permits tubes of other substances to be interchangeably used so that where a dust sampling of air would not yield satisfactory results with aluminum either because the constituents of the air would chemically react therewith or where the use of aluminum would not yield results of the accuracy desired, other tubes made of proper substances can be substituted. Moreover, our novel construction also permits a hose to be connected to the precipitator head for sampling air in normally inaccessible air ducts or in other places in which it would be difficult to place our dust sampler. By these expedients our dust sampler is adapted to practically universal usage in its field.

After much experiment, we have found a relationship of parts in the precipitator head, and voltages to be applied thereto for dust sampling which will not yield any measurable amount of generated ozone or oxides of nitrogen such as are usually created in high potential electrostatic fields. The absence of these gases is extremely important for accurate dust analyses inasmuch as all possible chemical reactions between the gases and the dust should be eliminated. To achieve this result, we have employed, in general, the principles disclosed in Patent No. 2,129,783, granted September 13, 1938, to G. W. Penney, a co-inventor of the invention described in this application, and assigned to the Westinghouse Electric & Manufacturing Company. In the dust sampler, as in the precipitator of the patent, positive ionization of the dust particles is preferably utilized and the functions of charging the particles and collecting them are separated.

Other novel features, objects, elements and combinations of our invention will be apparent from the following description thereof taken in conjunction with the drawings in which:

Figure 1 is a perspective view of one specific embodiment of our dust sampler in operative position;

Fig. 2 is a partial, phantom view of the case, showing certain features of construction and certain parts and their position in the case for transportation;

Fig. 3 is a top view of the control panel in the case;

Fig. 4 is a side view of the control panel;

Fig. 5 is a sectional view of a section of the collapsible tube connecting the blower to the precipitator head, which section is employed as part of the flow measuring device;

Fig. 6 is an axial section through the precipitator head;

Fig. 7 is a sectional view on the line VII—VII of Fig. 6;

Figs. 8, 9 and 10 are schematic wiring diagrams showing different forms of power-packs for obtaining the high voltages to be applied to the electrode of the precipitator head; and,

Fig. 11 is a sectional view, on a smaller scale, showing a modified form of outer electrode.

As aforesaid, it is a primary object of our invention to have the essential parts of the dust sampler instrument contained in a small portable case, and to this end a case 2 is provided having a handle 4, by means of which it may be carried, and a hinged cover 6 which may be opened, as shown in Fig. 1, when the dust sampler is to be used as such, or which may be closed and locked by means of a latch 8.

The essential parts of the dust sampler may be contained in the case 2 and comprise the complete precipitator head 10, shown more in detail in Fig. 6, a collapsible tube 12, a blower 14 and a suitable power-pack, together with circuit controlling devices. Generally, the blower draws the air to be sampled through the head 10 and down the collapsible tube system, in its extended position, to an inlet of the blower from whence it is subsequently discharged within the case 2. The power-pack serves to supply the necessary voltage to establish the electrostatic field between the electrodes of the precipitator head, so that the dust will be deposited upon the collecting electrodes during the flow of air through the precipitator head.

The blower and power-pack are preferably permanently built into the case 2, and may be arranged therein in any suitable manner which will yield a compact assembly whereby the case 2 may be kept to a minimum size. The embodiment of Fig. 1 is constructed with a power-pack shown schematically in Fig. 8 which requires two rectifier tubes 16, and other appurtenances in the form of transformers, condensers and resistances, and which will later be described in somewhat greater detail. Whatever form the power-pack assumes, it is obvious that the parts may be compactly arranged in the lower part of the case 2 and also on the back-side thereof.

The blower 14 comprises an electric motor 18 driving an air moving means such as a fan, and generally indicated by the reference numeral 20. The blower has an intake 22 and a discharge outlet 24. The blower is preferably secured in the lower, forward portion of the case 2 by any suitable number of securing means, such as brackets 26.

The collapsible pipe system by which air is conducted from the precipitator head 10 to the blower 14 comprises a plurality of telescoping sections, the lower one 28 of which is permanently secured to a side of the case 2 by means of brackets 30. The tube section 28 has a protruding stub 32 at right angles thereto aligned with the inlet 22 of the blower and an adapter connection 34 completes the passage for the air flow from the pipe 28 to the blower. The lower end of the tube 28 rests on the bottom of the case, and is preferably closed by a plug, or otherwise, to prevent air from being sucked into the blower from this end.

The collapsible tube system 12 also comprises a number of tube sections 36, 38, 40 and 42, respectively, with the tube sections 36, 38 and 40 of decreasing size so as to be capable of nesting in a telescopic manner, and these last three sections completely nest in the section 28 except for fastening screws 44 by means of which the tube system may be secured in extended form, in an obvious manner. In Fig. 1 the tube system is shown extended with the lower end of the section 36 nesting in the upper end of the section 28, the lower end of the section 38 nesting in the upper end of the section 36, and the lower end of the section 40 nesting in the upper end of

the section 38, and all maintained in position by the screws 44 suitably tightened and extending through appropriate rings 46 at the upper ends of the respective sections, and which serve to provide a necessary length of threaded aperture for adequately resisting the screws 44.

It is quite obvious that any number of telescopic sections may be provided for the tube system 12, or any other form of collapsible construction employed wherein the different tube sections are appropriately fitted together, and, as a matter of fact, in one embodiment, instead of using telescopic tube sections, sections are employed that can be interlocked by suitable threaded portions at each of their ends. The whole purpose of the collapsible tube system is merely to enable the collector head to be disposed at a suitable height above the case 2 so that the air discharge by the blower will not recirculate through the collector head and so that the collector head can be conveniently placed at a suitable location for sampling. Manifestly, many expedients may be employed to accomplish this result which is achieved by separating the intake of the collector head from the discharge of the blower.

The collapsible tube system 12 also includes, in this embodiment, an air flow measuring means comprising the tube section 42, which has a central orifice 47. During air flow the differential pressure between both sides of the orifice is measured by a manometer 48, the legs of which are connected by means of tubes 49 to the stub pipes 48' which communicate with the chambers at each side of the orifice 47 in accordance with well known practice. The manometer includes a suitable scale 50 which can be calibrated either in terms of the differential pressure or, as will subsequently be described, directly in terms of cubic feet of air flow per unit time. The tube section 42 is of such diameter that its lower end will fit around the upper section 40 of the collapsible tube system, and its upper end will fit around a protruding stub pipe extending from the precipitator head. Rings 52 may be brazed or force-fitted or otherwise suitably positioned inside the section 42 at a proper distance from its ends to provide stopping means in the nature of shoulders against which the inserted pipe sections abut.

Resting upon angular ledges 53 secured to the sides of the case, and somewhat from the top, is a control panel 54 which extends the length of the case and for a fraction of its width. The panel is apertured as at 56 to partially encompass the pipe 28 when the panel is in its operative position. Upon this panel are mounted control devices for starting the blower and energizing the power-pack, and also to control the speed of the motor of the blower. The panel also has appurtenances in the form of a stub tube 58, and an additional stub shaft 60, secured to the panel by any appropriate means, and serving as a confining means for a portion of the precipitator head and the flow measuring device comprising the tube section 42, respectively, when they are to be stored in the case.

As shown more particularly in Figs. 3 and 4, a switch 62 is mounted to the panel 54 and controls the supply of electrical energy to the motor 18 of the blower 14, and a switch 63 controls the low potential input side of the power-pack. The motor 18 is of the type whose speed may be controlled by a variable resistance, and this variable resistance 64 is mounted on the underneath side of the panel 54 with its control knob 66

above the panel, in a well known manner. By means of this resistance 64 the speed of the motor 18 and therefore the air flow through the precipitator head 10 can be controlled.

The precipitator head 10 which forms an essential part of our invention is shown with greater detail in Fig. 6, and generally comprises an outer, tubular shell 68, which is preferably of metal. One end of the tube is substantially closed by a disk 70 of insulating material, the disk being held in position by a plurality of circumferentially spaced screws 72. An insulator 74 is centrally secured to the disk 70 by a plurality of screws 76 extending through suitable holes in the base flange 78 of the insulator and threading into suitably tapped apertures 80 in the disk 70. The insulator 74 is hollow and has a flat plane apex perforated with a central aperture into which a bolt snugly fits with its head 82 abutting the flat underneath surface of the apex of the insulator and its threaded shank 84 protruding beyond the outside surface. The disk 70 and insulator 74 completely block the one end of the shell 68 against air flow.

Conductively secured to the head 82 is the high voltage lead 86 of an insulating cable 88 coming from the power-pack, and screwed onto the shank 84 is a solid metallic cylinder 90. It may be observed in Fig. 6 that the cylinder 90 is substantially centrally disposed in the shell 68 and is conductively connected to the high potential lead 86 through the bolt upon which it is threaded. The cylinder is of some length with its outer diameter accurately machined so that the central electrode comprising a tube 92 may slidably and snugly fit thereover, and be maintained in position thereby.

The tube 92 has its end 94 spun to a symmetrical bullet-nose shape, and a wire 96 extends from the tip thereof, being sealed thereto in a gas-tight manner. The tube 92 and the wire 96 comprise the central electrode which is encompassed by an outer tubular electrode 98 of somewhat larger diameter.

The electrode 98 is also removably mounted with respect to the remaining parts of the precipitator head, and for this purpose the other end of the shell 68 is snugly fitted with an annular sleeve or closure 100, maintained in position by circumferentially spaced screws 102. A second annular sleeve member 104 is spaced inwardly of the sleeve 100 and is secured to the shell 68 by circumferentially spaced screws 106. This sleeve member 104 is formed with a shoulder having a flat bottom side 108 and a cylindrical side 110 extending outwardly therefrom. The diameter of the central aperture in the sleeve 100 and of the cylinder formed by the side 110, are preferably equal, and are of a size to snugly fit the outer tubular diameter of the electrode 98, so that the latter may be slid into position with its end abutting the side 108, as shown in Fig. 6, or may be readily removed by sliding action.

The tubular electrodes 92 and 98 are always in set relation with respect to each other during operation of the device, since the cylinder 90 maintains the inner tubular electrode 92 in position, and the sleeve 100 and sleeve member 104 maintain the outer tubular electrode in position.

The sleeve member 104 is also formed with a groove 112 into which may seat a side 114 of a U-shaped spring 116, the other side 118 of which is secured to the shell 68 by means of a metallic screw 120. The spring 116 is disposed with its V directed outward in the direction of the pro-

truding parts of the electrode 98 and has sufficient flexibility so that when the electrode 98 is withdrawn the side 114 will contact the tube 92 of the central electrode, and if the latter be withdrawn, will contact the metallic cylinder 90 for a purpose to be later described.

A ground connection 122 is conductively contacted with the shell 68 and, therefore, with the spring 116, by wrapping one of its ends around the screw 120 and suitably tightening it against the shell 68 by a nut and washer on the screw, and collectively indicated by the reference numeral 124.

In accordance with our invention the inside extremities of the tubes 92 and 98 are placed with that of the tube 92 extending somewhat inwardly beyond that of the tube 98. Similarly the other free extremities of the central electrode and the tube 98 are displaced with the end 126 of the wire 96 inward of the outer end of the tube 98.

In the operation of the collector head, air is drawn through the space between the central and outer electrodes into the rear of the body portion 127 of the precipitator head, from whence it flows, either directly or around the insulator 74, to an outlet from the body portion which comprises a stub tube 128. For most successful operation, the flow of air through the precipitator head should be approximately the same about the central electrode. With the particular embodiment shown we have found that an air-flow equalizer, in the form of an annular plate 129 placed about the insulator 74, and before the outlet 128 prevents a concentration of air at the lower portion with reference to Fig. 6 of the precipitator head, that is, the portions in a more direct line with the outlet 128.

Since electrical precipitation as a rule requires a source of high potential which is very seldom available, a power-pack forms an integral part of our dust sampler and can convert ordinary commercial alternating-current voltages to constant or pulsating direct-current, or for even greater utility the power-pack may be designed with batteries as a primary source of energy, and, in Figs. 8, 9 and 10, we show different power-packs, any one of which may be structurally built into the case 2, and which will yield a substantially constant direct current voltage, Fig. 9 employing a battery as a primary source of power and Fig. 10 being adapted for connection to any available commercial alternating current source of either 25 or 60 cycles, or thereabouts.

The power-pack of Fig. 8 comprises a step-up transformer 130 with separate low voltage secondaries for energizing the filaments of the rectifier tubes 16 and the high voltage secondary 132 for connection to the electrodes of these tubes. The circuit of Fig. 8 is well known and corresponds substantially to that shown in the afore-said Penney Patent No. 2,129,783 and need not therefore be described in any great detail, it being sufficient to state that this circuit is designed to yield a voltage in the neighborhood of 10,000 volts direct current between the ground 122 and the high potential lead 86. The connections shown in Fig. 8 energize the ionizing wire 96 positively; but for negative ionization the connections can be changed, along the lines taught in the afore-said Penney patent.

The power-pack of Fig. 9 is preferably employed in units which will be used in localities or places where no ready easily accessible source of commercial electric power is available, and is therefore designed to derive its energy from

batteries 134 which supply energy to a voltage step-up induction coil 136 whose high voltage output is rectified by means of a rectifier tube 138.

The power-pack of Fig. 10 is somewhat more economical than that of Fig. 8 and contains fewer parts so that the total weight of the dust sampler can be somewhat decreased. The power-pack employs a step-down transformer 140, the secondary output of which passes through a dry rectifier 142 and is fed to the primary of a step-up induction coil 144, the output of which is made unidirectional for application to the collector head by means of a rectifier tube 146. The circuits of Figs. 9 and 10 charge the ionizing wire 96 for negative ionization, but the output connections can obviously be reversed for positive ionization.

Many electrical circuits are well-known by which high-voltage direct-current, either constant or pulsating, can be obtained from commercial power sources or from batteries. We do not claim any particular novelty in the connections of our power-pack, but do consider the power-pack as a unit to be an important element of our invention. However, whatever type of power-pack is employed the high voltage transformer or induction coil is preferably of the type which can withstand a short-circuit across its secondary, such transformers being well known, and usually of the high-leakage type. We prefer to use our dust sampler with substantially constant direct-current voltage between the electrodes, and to this end condensers 147 are connected across the output leads of the power-packs and are of a capacity to smooth out the voltage ripples sufficiently for our purpose.

The operative position of our dust sampler is shown generally in Fig. 1. An elongated cord 148 is adapted to plug into any suitable outlet of a commercial frequency source, and conveys electrical power to a power-pack of the type shown in Fig. 8 whose parts are suitably mounted in the case 2, the switch 63 controlling the application of power thereto. The output of the power-pack is either constant voltage or pulsating voltage direct-current, with one output terminal or conductor preferably directed to the wire 86 of the insulated cable 88 while the other output terminal or conductor is directly connected to the tube system 12, as, for example, by a conductor 150 soldered or otherwise conductively secured to the tube section 28 of the tube system 12.

The cable 88 extends through a central aperture in the insulating disk 70 and the wire 86 charges the central electrode parts comprising the tube 92 and the wire 96. The other output terminal of the power-pack is conductively connected to the other electrode 98 through the metallic tube system 12, metallic stub pipe 128, metallic outer shell 68 and spring 116. The precipitator head is now charged for use with the zone between the wire 96 and outer electrode 98 forming an ionizing chamber and the zone between the central tube 92 and the outer electrode 98 forming a dust precipitating or collecting chamber.

The blower 14 may now be started by means of the switch 62, the speed of the motor being controlled by the variable resistance 64. Air will accordingly be drawn through the precipitator head in accordance with the arrows shown and will pass down through the extended tube system 12, through the blower, and will be dis-

charged in the case through blower outlet 24 where it will diffuse and flow outward partly through the aperture 56, but mostly around the back end of the panel 54. A screen 152 may be disposed to cover the open portion of the case above the panel 54 to prevent the ingress of foreign matter.

Inasmuch as the parts of the precipitator head are carefully designed as to dimensions and the flow measuring device disposed directly at its air flow outlet, it is possible to calibrate the scale of the manometer directly in cubic feet per hour, and any desired velocity of air may be obtained by turning the knob 66 for controlling the speed of the motor 18, and observing the reading of the air-flow measuring means.

After a suitable run, the sampler may be disassembled for transportation. This is accomplished by first deenergizing all electrical circuits and pulling the plug on the cord 148, and then removing the two electrodes from the precipitator head, leaving the remaining body portion 127. This body portion may be placed inside the case 2 by inserting its stub tube 128 into the stub tube 58 on the panel 54. The tube section 42 including the manometer may then be removed and placed upon an extension of a rubber cap 156 which fits the stub shaft 60. The remaining tube sections 36, 38 and 40 of the pipe system may then be collapsed into one another and fall into the tube section 28.

The cable 88 is relatively short and can be folded in back of the body portion 154, while the cable 148 which is of considerable length, may be wound around cleats 158 secured to the cover 6. The electrodes may be wrapped in a cloth, or may be inserted in a small container designed for the purpose, which can be disposed in the remaining space above the panel 54, and by closing cover 6 the dust sampler is ready for transportation to any other locality where sampling of dust may be desired.

The foregoing describes only the physical steps for setting up and disassembling the dust sampler for use. In a practical design of our invention the outer, grounded, metallic tube electrode 98 has an outside diameter of $1\frac{1}{2}$ inches, is $7\frac{1}{2}$ inches long, and has a wall thickness of .035 inch, while the central tube has a $\frac{7}{8}$ inch outside diameter, is approximately 5 inches long, and of the same wall thickness as the outer electrode. The wire 96, protruding from the central tube, is 2 inches long and of .020 inch diameter. We have found that such proportions, when employed with a direct current potential of approximately 10,000 volts and a current of 100 microamperes and over are exceptionally satisfactory for depositing dust upon the outer electrode only, and without the creation of measurable amounts of either ozone or compounds of nitrogen. We have tried different sizes, both of length and diameter, for the different elements, but have finally arrived at the foregoing dimensions as the most satisfactory for accurate readings.

By means of the ground wire 122, all outside parts of the supporting head and the outer electrode are at ground potential, and when the outer electrode is removed, the spring 116 flexes to automatically ground the central electrode, and even when the central electrode is removed the spring further flexes to automatically ground the cylinder 90. Thus, there is practically no shock hazard in using our dust sampler. It should be noted, however, that the tip of the central elec-

trode is at high potential when the sampler is in operation, and should not be touched. The disposition of the end 126 of the wire 96 inward of the extremity of the outer electrode makes accidental touching of the high potential parts less likely. However, this construction has further more important functions tending for accurate measurements with practically all types of dust. We have found that if the tip 126 is placed near or beyond the plane of the end of the electrode 98 dust may sometimes be deposited on the outside surface of the electrode 98, or particles of dust may sometimes be repelled through the air away from the collecting electrode.

While the depositing of dust on the electrode 98 is the aim of the dust sampler, nevertheless it is preferred to have the dust deposited on the interior surface thereof and in the collecting zone which is about the inner tube 92. If the dust is permitted to deposit on the outside of the electrode 98, it may be brushed off or otherwise lost when the outer electrode is removed to be weighed, so that inaccurate results might sometimes result. In addition, if any particles of dust are permitted to be repelled beyond the collecting range of the electrodes, results may be obtained for weight, count or size sampling, or the like, of doubtful value.

Placing the other end of the tube 92 beyond that of the tube 98 is also a precautionary measure, and will discourage arcing or any breakdown between any rough points on the edges of the electrodes.

We have found that electrodes made of aluminum and a wire of platinum-rhodium are satisfactory for most purposes, since most dusts or atmospheres encountered will not react chemically with either of these elements. Slight changes in weight, due to temperature differences, are the greatest objection to aluminum tubes, but with care these weight changes can be kept below 1.5 milligrams, plus or minus. The tubes, when new, should be cleaned with a fine rouge paper to remove any scale or rough places, and then washed with a soap powder that contains a non-scratching abrasive to clean them thoroughly. In order to take a dust sample in accordance with our invention, it is necessary to first thoroughly clean the electrodes and to dry them at least for one hour preferably at a temperature in the neighborhood of the boiling point of water. However, for most accurate results the weight of each of the electrodes before a dust sample is taken should not be determined until the electrodes are absolutely at the same temperature as the surrounding atmosphere, for with each one-tenth of a degree centigrade difference in temperature the error in weight may approximate one-tenth milligram. Such change in weight can be accounted for by assuming that the air within the tube and a film of air on the outside of the tube tend to take the temperature of the tube and the buoyant effect due to the change in the density of this air reacts on the tube to increase or decrease its apparent weight, depending upon whether the tube is cooler or warmer than the ambient air.

The tubes must at all times be carefully handled and preferably by tongs or a clean cloth. After the desired run for a measured length of time the outer electrode is carefully removed and weighed, the difference in weight before and after the run being a measure of the dust precipitated upon the electrode. With some dusts such as soot, a deposit sometimes occurs on the tube 92 of

the central electrode. In such case both electrodes should be weighed before and after each run for greatest accuracy. We desire it to be distinctly understood, however, that with the properties disclosed and potential gradients employed, we have found that dust is deposited on the central electrode only on rare occasions in spite of the fact that our dust sampler has been used with many different atmospheres containing many different types of dust.

We have found that with the dimensions previously described, and with an air flow of about 3 cubic feet per minute through the collector head, all the dust in the air is precipitated, usually entirely on the inside surface of the outer electrode and only rarely will dust be found on the central electrode. Moreover, dust will not blow off the outer electrode at the relatively low velocity employed. However, the speed of the motor of the blower and the total amount of sample may be controlled in cases where the deposited dust builds up in a light fluffy layer such as some kinds of soot may do and there is a likelihood of it being blown off by higher air velocities.

For sampling where dust or fume concentration is very low, so that a small change in weight of the aluminum tubes may result in a considerable error, or for sampling atmospheres which might react with aluminum, glass tubes with a conducting glaze on them have been found to yield more accurate results. In any event, because of the construction of our precipitator head, it is possible to replace any of the electrodes by electrodes made of some other substance more suitable for a particular purpose.

For sampling of air from ducts or places inaccessible to the sampler, a hose connection can be made to the outer electrode. Here again the connection must be carefully made to avoid any possible errors in the determined results. A satisfactory connection may be had by wrapping a small sheet of paper tightly around the outer end of the electrode 98 and then slipping a closely fitting adapter over the paper. A good seal can be had between the adapter and paper with adhesive tape without causing a change in the weight of the outer electrode. If the hose is clean, we have found that the foregoing precautions are not altogether essential and may on proper occasions be dispensed with. As another alternative, the outer collector electrode may be formed purposely with an extension over which a rubber tube can be slipped or fitted. An electrode for this purpose is shown in Fig. 11 and has a body portion 160, similar in size to the electrode 98, and which is provided with an extension 162 spun or otherwise formed to a contracted cylindrical end of a diameter more in accordance with common hose sizes.

It is, of course, imperative in our invention that the air flow measuring device measure only the actual flow between the electrodes, and to this end the seals between the enclosures and the body sleeve 68 should be made air-tight, either by the use of sealing compound or gaskets at the joints. The disposition of the air measuring means immediately at the outlet of the body portion of the precipitator head is a further feature tending for accurate measurements, and although we have described an orifice and manometer for the purpose, it is obvious that any other air-flow measuring means may be employed.

In accordance with the foregoing we have described a dust sampler which, for all practical

purposes, is self-contained within a small portable case, so that samples of dust may be taken in any locality, and with a degree of accuracy which we believe has seldom been obtained except in laboratories. Manifestly, the amount of dust in a unit volume of air can be computed by weighing the outer electrode in most cases, or both electrodes in some cases, before and after a run of predetermined time at a predetermined air flow. If other determinations of the quality or the characteristics of the dust are required, the deposited dust may be carefully removed from the electrode and subjected to methods for determining dust count, or size, or composition in accordance with known practices.

While we have described our invention in a preferred embodiment, and have suggested certain limits in accordance with our best understanding of the same at the present time, we desire it to be distinctly understood that these limits are described for the purpose of depicting one particular form of our embodiment and not by way of limitation upon our invention. We desire, therefore, that the appended claims be accorded the broadest construction and limited only by the prior art.

We claim as our invention:

1. In a device of the class described, a precipitator head comprising a pair of substantially concentrically formed and arranged inner and outer electrodes, the inner electrode being of less length than the outer electrode and having one end protruding slightly beyond the corresponding end of the outer electrode, said outer electrode having opening means permitting the passage of atmosphere through said outer electrode, said inner electrode having a closed end against the atmosphere flow, and an ionizing wire extending from said closed end but not quite to the end of the outer electrode; said head also comprising a hollow body portion having means for removably mounting said inner electrode, said body portion having means for removably mounting said outer electrode in substantially gas-tight relation therewith so that any atmosphere flowing between said outer and inner electrodes discharges into said body portion, and atmosphere outlet means from said body portion.

2. In a device of the class described, a precipitator head comprising a tubular body portion having an end closure including an insulator secured inside said body portion, a second closure for the other end of said body portion, having an enlarged opening, a tubular electrode removably secured in said body portion, closely fitting said opening, and extending beyond both sides of said second closure; a central electrode within said tubular electrode, comprising a closed tubular member provided with an extending ionizing wire, means for securing said central electrode to said insulator, said body portion having a gas outlet, and insulated means extending through said body portion for conveying a potential to said central electrode.

3. The device of claim 2 including automatic means for grounding said central electrode upon removal of said removable electrode.

4. A precipitator unit of the type described comprising a tubular outer shell, an end closure therefor, a first tubular electrode of lesser diameter than said shell, means to removably mount said electrode with a part thereof within the said shell, said means providing a gas-tight seal between the said shell and the outer surface of said electrode, a second tubular elec-

trode within said first electrode, means to hold said second electrode to said shell substantially concentric with said first electrode, said electrodes being constructed and arranged so that when air or the like passes through the unit, none will flow directly through the inside of said second electrode, and a grounding means contacting said first electrode but automatically contacting said second electrode upon removal of said first electrode.

5. A dust sampler comprising a precipitator head having outer and inner tubular electrodes with contiguous dust-ionizing and dust-collecting zones operable with different potential gradients, means to apply a single direct-current potential between said electrodes whereby one of said electrodes is a collecting electrode, means to create a flow of a sample of air through said zones at a relatively low velocity, said electrodes having dimensions and said potential being such that there is practically no generation of ozone or gaseous oxides of nitrogen when air or the like is passed through said head, said electrodes being of a length to collect substantially all the dust contained in the air flowing through the said head, said head having provisions for removably supporting said collecting electrode whereby it may be removed for weighing or other manipulation.

6. A portable, self-contained dust sampling instrument of the class described comprising a case having a cover, a blower comprising a motor and fan secured in the bottom of said case, an up-standing conduit connected to said blower, said conduit being of lower height than the interior of said case and secured therein, a control panel removably mounted in said case above said blower and below the top of said case thereby leaving a space thereat, a power-pack built in said case primarily below said panel, motor speed-control means mounted on said panel, comprising manually-operable means on the upper side of said panel, a dust precipitator head element having a stub pipe at one end thereof, a stub pipe secured to the top of said panel interfitting the first said stub pipe whereby said collector head may be stored in the aforesaid space, collapsible conduit means having one extremity fitting an extremity of the first said conduit and the opposite extremity fitting the first said stub pipe, a gas-flow measuring means in said conduit means, said gas-flow measuring means having a removable indicator, and means on the top of said panel for mounting said indicator in the aforesaid space, said head having means removably holding said outer electrode in position.

7. A unit of the type described comprising an ionizing chamber and a contiguous dust-collector chamber, and means for causing a gas-flow successively therethrough, said ionizing chamber comprising at least one fine wire substantially spaced from a removable grounded electrode also forming part of said ionizing chamber; said dust-collector chamber comprising said grounded electrode, and a second spaced electrode substantially parallel to the direction of gas-flow, said wire and second electrode being insulatedly supported; relatively low-voltage power-supply leads for the unit; limited-energy, voltage-conversion, relatively high-voltage output means for unidirectionally charging said wire and said inner second electrode relatively to said grounded electrode, said limited-energy means having such a limited wattage-output that it will withstand a short circuit, and means connecting ground

to said tubular electrode and to one side of said high-voltage output means, said last means automatically completing a ground to said insulated parts upon removal of said grounded electrode.

8. A precipitator unit of the type described, comprising a tubular, outer shell, an insulating end closure therefor having a relatively small, conducting member secured thereto and projecting inwardly into said shell, a tubular electrode slidably and tightly fitting said member, said electrode being considerably smaller diametrically than said shell but of a length protruding outwardly therefrom, the outward end of said electrode being closed and having an ionizing wire, extending outward, a closure for the other end of said shell, the last said closure having a bore larger than said electrode, a second tubular electrode slidably and tightly fitting said bore, means cooperating with the last said closure for removably maintaining said second electrode substantially concentric with said first electrode, and a gas outlet from said shell.

9. A precipitator unit of the type described, comprising a tubular, outer shell, an insulating end closure therefor having a relatively small, conducting member secured thereto and projecting into said shell, a tubular electrode slidably and tightly fitting said member, said electrode being considerably smaller diametrically than said shell but of a length protruding outwardly therefrom, the outward end of said electrode being closed and having an ionizing wire extending outward, a closure for the other end of said shell, the last said closure having a bore larger than said electrode, a second tubular electrode slidably and tightly fitting said bore, means cooperating with the last said closure for removably maintaining said second electrode substantially concentric with said first electrode, a gas outlet from said shell, and grounded safety-means which normally makes contact with said second electrode, and with said first electrode when said second electrode is removed.

10. The structure of claim 9 wherein said shell is metallic and is connected to said grounded safety-means.

11. A precipitator unit of the type described, comprising a tubular outer shell, an insulating end closure therefor having a relatively small, conducting member secured thereto and extending into said shell, a tubular electrode slidably and tightly fitting said member, said electrode being considerably smaller diametrically than said shell but of a length protruding outwardly therefrom, the outer end of said electrode being closed and having an ionizing wire extending outward, a closure for the other end of said shell, the last said closure having a bore larger than said electrode, a second tubular electrode slidably and tightly fitting said bore, means cooperating with the last said closure for removably maintaining said second electrode substantially concentric with said first electrode, a gas outlet from said shell, and grounded safety means which makes contact with said conducting member when both said electrodes are removed.

12. A precipitator unit of the type described, comprising a metal, tubular, outer shell, an insulating end closure therefor having a relatively small, conducting member secured thereto and extending into said shell, a tubular electrode slidably and tightly fitting said member, said electrode being considerably smaller diametrically than said shell but of a length protruding out-

wardly therefrom, the outward end of said electrode being closed and having an ionizing wire extending outward, a closure for the other end of said shell, the last said closure having a bore larger than said electrode, a second tubular electrode slidably and tightly fitting said bore, means cooperating with the last said closure for removably maintaining said second electrode substantially concentric with said first electrode, a gas outlet from said shell, a ground lead to said shell, means to electrically connect said shell and said second electrode, and a high-potential lead for applying high-potential to said inner electrode and wire.

13. A portable, self-contained dust sampling instrument of the class described comprising a case having a hinged cover, a blower comprising a motor and fan secured in the bottom of said case, an upstanding conduit connected to said blower, said conduit being of lower height than the interior of said case and secured therein, a control panel removably mounted in said case above said blower and below the top of said case thereby leaving a space thereat, a power-pack built in said case primarily below said panel, motor speed-control means mounted on said panel with manually-operable means on the upper side of said panel, a dust precipitator head element having a stub pipe at one end thereof, a stub pipe secured to the top of said panel interfitting the first said stub pipe whereby said collector head may be stored in the aforesaid space, collapsible conduit means having one extremity fitting an extremity of the first said conduit and the opposite extremity fitting the first said stub pipe, a gas-flow measuring means in said conduit means, having a removable indicator, and means on the top of the said panel for mounting said indicator in the aforesaid space.

14. A portable self-contained dust-sampling instrument of the class described comprising a case and hinged cover, a blower secured in said case, a pipe secured in said case and connected to said blower, a dust precipitator head having a hollow cylindrical body portion, an insulating means closing one end of said body portion and including an insulator attached within said body portion, of a size to leave free gas-passages between said disc and body portion, said body portion having an opening at said passages, a stub pipe secured in said opening, a collapsible tube with means for maintaining it rigidly extended, attached at one end to an end of the first said pipe, and a section of pipe including a flow-measuring device attached to said stub pipe and the other end of said tube.

15. A precipitator unit comprising a metallic, tubular body portion having an opening in one end thereof, a tubular cylindrical electrode provided with a gas inlet, secured in said opening and extending outwardly from said body portion, a closure for the end of said body portion opposite the first said end, an insulator secured to said closure and axially disposed within said body portion, a relatively short tubular member of smaller diameter than said electrode secured to said insulator, a second electrode comprising a tubular element having a closed end, an ionizing wire secured to said closed end, said second electrode being smaller diametrically than said first electrode and disposed therein, the other end of said second electrode being hollow and fitting said tubular member whereby said second electrode is maintained in position within said first electrode.

16. The structure of claim 15 characterized by said body portion having an air-outlet, and insulated, conducting-means for conveying electric potential to said second electrode.

17. An electrical dust-sampling instrument of the class described of general application for sampling different kinds of air-borne dust, comprising an electrical precipitating device having a path for the flow of a sample of air, said device including in said air-flow path successively, an electrical dust-ionizing means and an electrical dust-collecting means, the said dust-ionizing means being of the type for producing ionization, with the production of inappreciable ozone in the presence of oxygen, said dust-collecting means including a pair of spaced electrode means for precipitating charged dust particles, said device including supporting means for individually removably supporting both said electrode means, said supporting means having aligning means for consistently supporting said electrode means in reproducible preset spaced relation, said device including means for creating an air-flow through said path, and means for controlling said air-flow, whereby the air-flow can be adjusted to a sufficiently low value to prevent collected dust from blowing off said electrode means.

18. An electrical dust-sampling instrument of the class described of general application for sampling different kinds of air-borne dust, comprising an electrical precipitating device having a path for the flow of a sample of air, said device including in said air-flow path successively, an electrical dust-ionizing means and an electrical dust-collecting means, the said dust-ionizing means being of the type for producing ionization, with the production of inappreciable ozone in the presence of oxygen, said dust-collecting means including a pair of spaced electrode means for precipitating charged dust particles, said device including supporting means for individually removably supporting both said electrode means by frictional engagement, said supporting means having aligning means for consistently supporting said electrode means in reproducible preset spaced relation, said device including means for creating an air-flow through said path, and means for controlling said air-flow, whereby the air-flow can be adjusted to a sufficiently low value to prevent collected dust from blowing off said electrode means.

19. A self-contained dust-sampling instrument comprising a portable case, a relatively small dust-precipitator head comprising an outer relatively low-voltage tubular electrode and an inner insulated high-voltage tubular electrode, said electrodes being substantially concentric, and forming contiguous ionizing and dust-collecting zones, with a gas outlet connection near the end of said dust-collecting zone, said gas outlet connection being conductively connected to said low-voltage electrode, a blower secured in said case having an intake, a relatively high-voltage-output power-pack built into said case, having an extended, insulated, high-voltage, conductive connection to the said high-voltage electrode, collapsible supporting means for supporting said dust-precipitator head outside said case, said supporting means comprising conducting gas-conduit means connecting said gas outlet to said blower intake, said blower-pack having a low-voltage lead connected to said gas-conduit means whereby said electrodes can be oppositely charged by said high-voltage connection and low-voltage lead.

20. A device of a class described comprising dust-charging and dust-precipitating means for removing dust from a flowing gas, said means comprising relatively insulated, inner and outer electrodes; the outer electrode being a tubular electrode provided with a gas-inlet opening at one end thereof, the gas flowing through said outer electrode; the inner electrode having a tubular portion inside said outer electrode, which is of less length than said outer electrode and cooperable therewith for providing a dust-precipitating electrostatic field, said inner electrode comprising a closed end for said tubular portion, directed against the gas flow, and an ionizing wire before said closed end in a direction counter to the direction of the gas flow; said outer electrode being about said ionizing wire and cooperable therewith for providing a dust-charging ionized field; and supporting means for supporting said inner electrode with said tubular portion of said inner electrode substantially rigid with respect to said supporting means, in substantially coaxial, insulated fixed spaced relation with said outer tubular electrode during dust-removing operation of the device.

21. A device of a class described comprising a dust-charging and dust-precipitating means for removing dust from a flowing gas, said means comprising relatively insulated, inner and outer electrodes; said outer electrode being a tubular electrode provided with a gas-inlet opening at one end thereof, the gas flowing through said outer electrode; said inner electrode having a tubular portion inside said outer electrode, which is of less length than said outer electrode and cooperable therewith for providing a dust-precipitating electrostatic field, said inner electrode comprising a closed end for said tubular portion, directed against the gas flow, and an ionizing wire before said closed end in a direction counter to the direction of the gas flow; said outer electrode being about said ionizing wire and cooperable therewith for providing a dust-charging ionized field; and supporting means for supporting said inner electrode with said tubular portion of said inner electrode substantially rigid with

respect to said supporting means, in substantially coaxial, insulated fixed spaced relation with said outer tubular electrode during dust-removing operation of the device, said supporting means comprising means for supporting said inner electrode only by a part of said inner electrode which is away from said ionizing wire.

22. A device of a class described comprising a dust-charging and dust-precipitating means for removing dust from a flowing gas, said means comprising a pair of relatively insulated, inner and outer electrodes; said outer electrode being a tubular electrode provided with a gas-inlet opening at one end thereof, the gas flowing through said outer electrode; said inner electrode having a tubular portion inside said outer electrode, which is of less length than said outer electrode and cooperable therewith for providing a dust-precipitating electrostatic field, said inner electrode comprising a closed end for said tubular portion, directed against the gas flow, and an ionizing wire before said closed end in a direction counter to the direction of the gas flow; said outer electrode being about said ionizing wire and cooperable therewith for providing a dust-charging ionized field; supporting means for supporting said inner electrode with said tubular portion of said inner electrode substantially rigid with respect to said supporting means, in substantially coaxial, insulated fixed spaced relation with said outer electrode during dust-removing operation of the device, said supporting means comprising means for supporting said inner electrode only by a part of said inner electrode which is away from said ionizing wire; said device having a gas-outlet opening for gas which has passed through said dust-precipitating electrostatic field, said gas-outlet opening being disposed near the gas-flow exit of said dust-precipitating electrostatic field and so disposed as to cause the gas flow to curve; and gas-flow equalizing means before said gas-outlet opening for causing the gas flow through the dust-charging field and dust-precipitating field to be substantially unidirectional.

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