Sept. 29, 1942. C. W. WILLIAMS 2,297,601

ELECTRIC GAS CLEANER

Filed Sept. 3, 1940 3 Sheets-Sheet 1

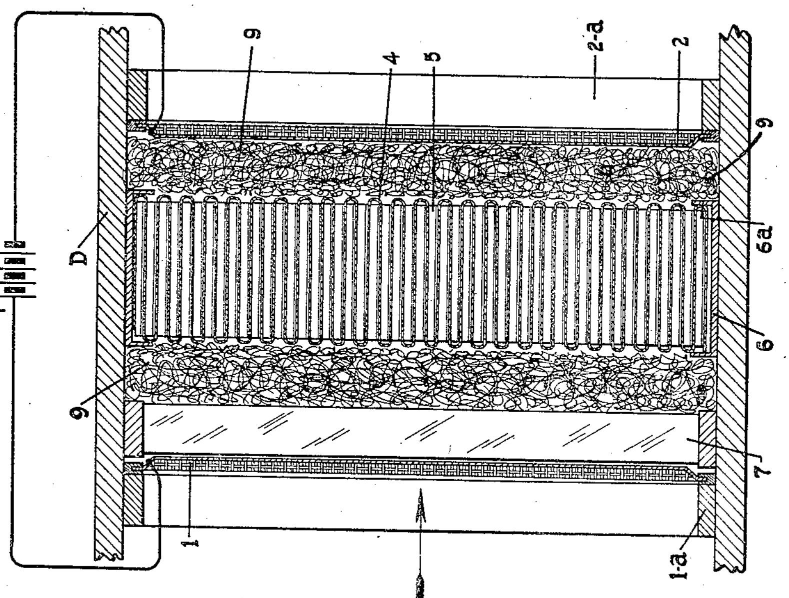

FIG. 1

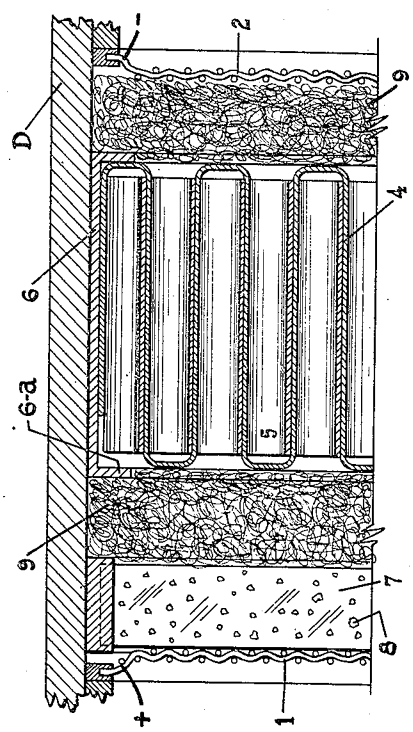

FIG. 2

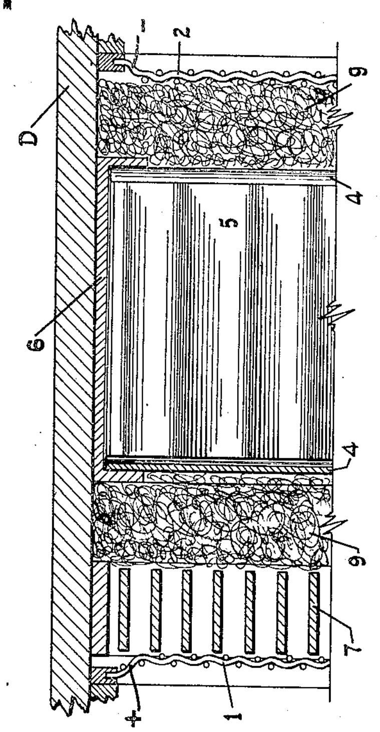

FIG. 3

CHARLES W. WILLIAMS INVENTOR

By Arthur J Robert
ATTORNEY

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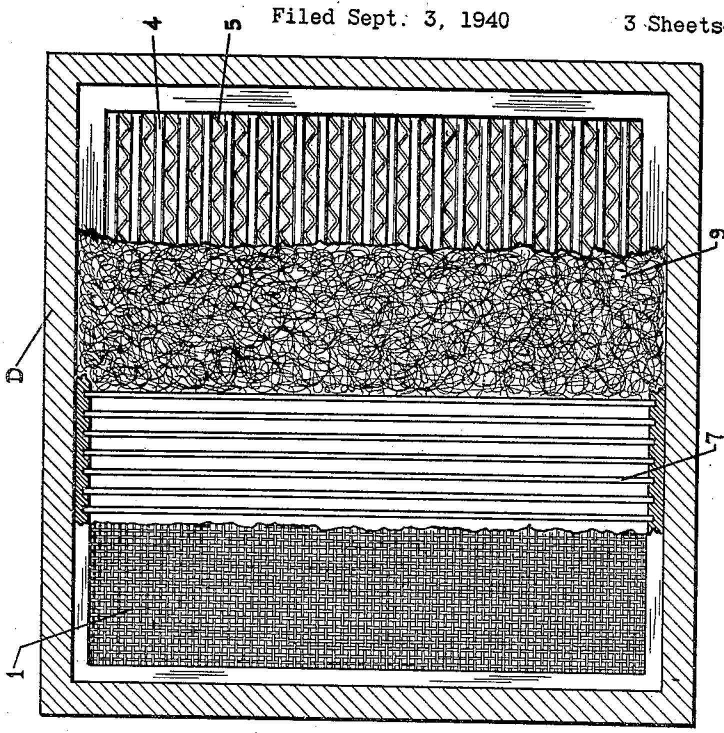

FIG. 4

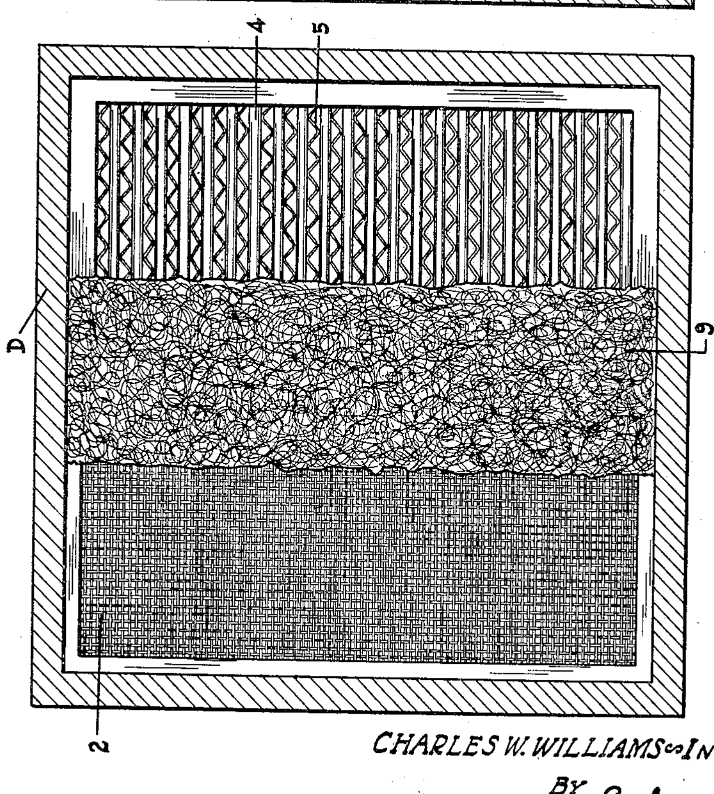

FIG. 5

CHARLES W. WILLIAMS INVENTOR

BY Arthur H. Robert
ATTORNEY

Sept. 29, 1942. C. W. WILLIAMS 2,297,601

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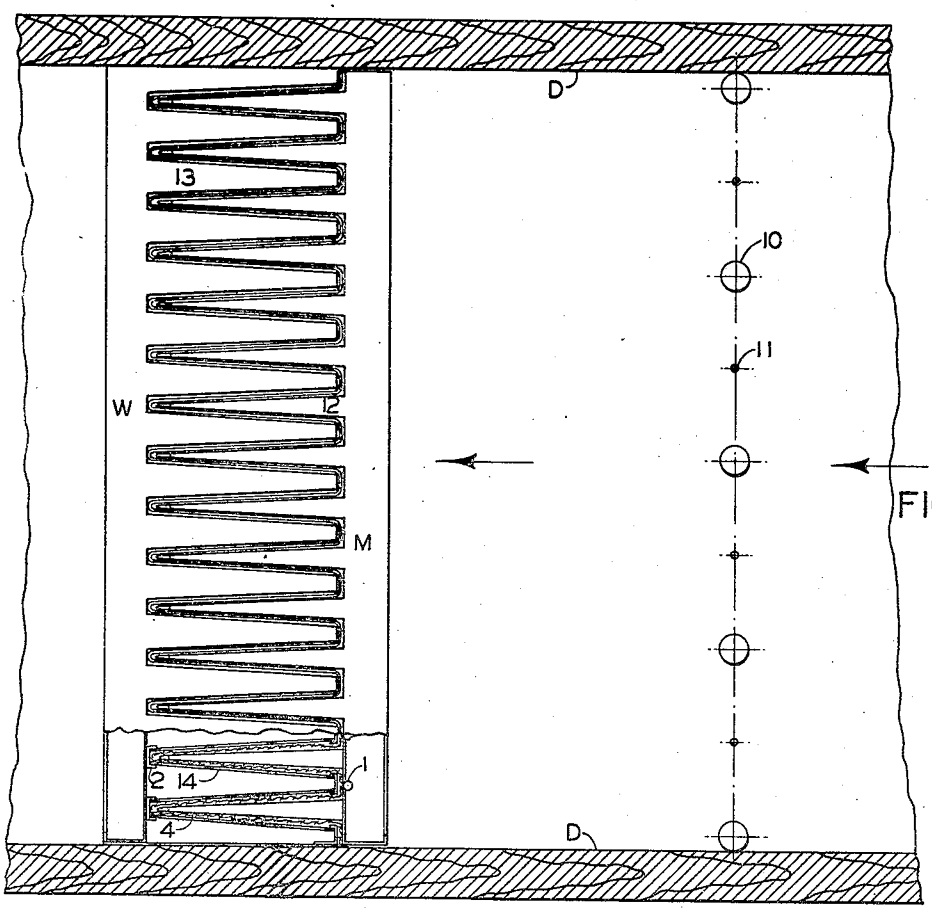

FIG. 7

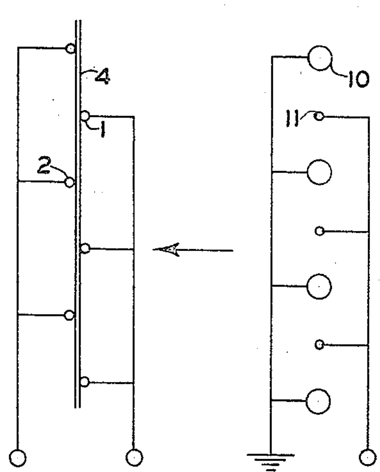

FIG. 6

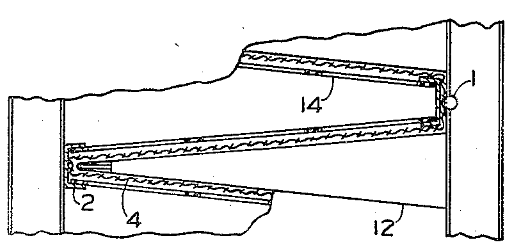

FIG. 8

CHARLES W. WILLIAMS.
INVENTOR.

BY Arthur J. Robert
ATTORNEY.

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UNITED STATES PATENT OFFICE

2,297,601

ELECTRIC GAS CLEANER

Charles W. Williams, Louisville, Ky., assignor to American Air Filter Company, Inc., Louisville, Ky., a corporation of Delaware

Application September 3, 1940, Serial No. 355,277

8 Claims. (Cl. 183—7)

This application is a continuation in part of my abandoned application Serial No. 191,421, filed February 19, 1938, which discloses an electric gas cleaner comprising: spaced up stream and down stream, the interstitial electrodes extending laterally across the gas flow space of a duct; and an interstitial dielectric separator substantially occupying the gas flow space of the duct between electrodes.

This invention relates to the art of cleaning gases electrically. In the practical application of this art, gas borne "dust" particles are electrically charged by impressing high ionizing voltages between laterally spaced electrodes to create an electrical field and passing the gas longitudinally through the field so created. Particles charged or ionized in this manner gravitate slowly across the gas flow toward oppositely charged surfaces upon which they are intended ultimately to precipitate and collect.

To create an electrical field, ionizing voltages ranging from 30,000 to more than 80,000 volts have been employed. Those high voltages necessitate wide spacing between electrodes, to avoid disruptive "flash overs," while wide spacing, coupled with slow lateral movement of charged particles, tend to maximize the contact time required between the gas and the collecting surfaces to effect cleaning. Under such conditions the use of low gas velocities and long collecting surfaces is promoted.

It has been proposed to reduce contact or cleaning time by first passing the gas through a shallow electric charging or ionizing field, created by impressing high voltages between the adjacent widely spaced short electrodes of a laterally arranged series, and then passing the charged gas through a deep electric collecting field, created by impressing a relatively low voltage (e. g. 12,000 volts) between the adjacent narrowly spaced long plate-like electrodes of a laterally arranged series. While such arrangement appears to effect a reduction in cleaning time over other arrangements in which the charging and collecting field are the same, the optimum results appear to be limited.

With the collection of dust accomplished, the problem of its removal is presented. Up to the present time this has been done largely by jarring, scraping or similarly dislodging the collected dust from the collecting surfaces or by flushing such surfaces so as to wash the dust therefrom. As indicated in Patent No. 1,800,529, cleaning methods of this general character involve many difficulties which lead to many complexities. In fact, they have been so highly unsatisfactory that a considerable part of the time and effort spent by those actively engaged in the general development of this art has necessarily been diverted to the problem of removing collected dust.

An important object of this invention is to avoid or minimize the foregoing limitations and objections, and, more particularly, to provide an improved form of device for effectively cleaning gas electrically, wherein the use of lower voltages and higher velocities are promoted and the removal of collected dust is facilitated.

A further object is to provide in a device of this character an inexpensive dust collecting medium which can be easily and quickly removed and replaced.

A still further object is to provide a compact device having desirable operating characteristics, such as low operating voltage, high gas handling capacity, low gas flow resistance and high gas cleaning efficiency, and minimum maintenance requirements, such as low power consumption and low reconditioning expense.

Another important object is to maintain an effective electrostatic charge or potential upon a dielectric filter medium through which gas is passed.

I have discovered that the foregoing objectives may be largely attained by occupying the electric field, created between suitably spaced interstitial upstream and downstream electrodes, with an interstitial dielectric separator comprising a dielectric air filter medium, and passing a gas successively through the interstices of the upstream electrode, the separator and the downstream electrode. In other words, the gas is passed through the openings of an interstitial dielectric separator, while a potential difference is maintained between the upstream and downstream faces of the separator. With an arrangement of this character, I have been able to obtain excellent cleaning results even when using operating voltages as low as 5,000 volts and gas velocities as high as 300 F. P. M. The danger of "flash overs" is substantially nil since the spacing of electrodes can be varied substantially within safe limits without appearing to affect the cleaning efficiency to any appreciable extent. Fume, smoke and other suspended particles, collected in this way have largely been deposited upon the air filter medium; hence their removal may be effected simply by removing the filter. Since the foregoing results are possible of attainment with the use of an inexpensive filter having a low gas flow resistance, it will be readily appreciated that the arrangement makes possible the attainment of excellent operating characteristics in an electric gas cleaning device having minimum maintenance requirements.

The invention is illustrated in the accompanying drawings wherein:

Figure 1 is a vertical section taken through one embodiment of the invention in its operative gas cleaning position;

Figure 2 is an enlarged fragmentary view taken from Figure 1, in which the details are exaggerated for the sake of clearness;

Figure 3 is a similarly enlarged fragmentary view taken at right angles to Figure 2;

Figure 4 is a partly broken view of the upstream end of the device;

Figure 5 is a partly broken view of the downstream end of the device;

Figure 6 is a schematic view of an alternative arrangement for carrying out the invention;

Figure 7 is a practical embodiment of the arrangement shown in Figure 6; and

Figure 8 is a detail of the air filter structure shown in Figure 7.

The embodiment, used to illustrate the invention, is shown as mounted in operative position within a gas duct D composed of wood. As shown, it includes interstitial upstream and downstream electrodes 1 and 2, which extend across the duct D and which are spaced from each other. These electrodes may be composed of any suitable material, such, for example, as ordinary metal window screening material having a mesh large enough to avoid appreciable obstruction to the gas flow. The screen electrodes 1 and 2 are mounted on shallow rectangular frames 1a and 2a and arranged for connection to a suitable source of direct current which is indicated at 3. The upstream and downstream electrodes are shown as being connected to the positive and negative sides respectively of the direct current supply 3 but this is not essential and such connections may be reversed. The experiments conducted with this device indicate that, while good cleaning results can be secured with an operating voltage of 5,000 volts, better results may possibly be obtained with higher voltages. For this reason, a higher voltage of, say, 12,000 volts, is suggested but even that may be raised or lowered if desired.

When the desired voltage is impressed on the electrodes, an electric field will be created between electrodes. Within this field the dielectric separator is placed. The dielectric separator includes an interstitial filter medium 4 which possesses dielectric properties. While various filter mediums may be used, better results appear possible of attainment with those composed of short fibers. Particularly good results have been obtained with a paper medium composed of a plurality of superimposed separable layers of sheet-like fibrous material, wherein each sheet comprises a thin matted net work of short fibered wood pulp, characterized by a multitude of fine "air strainer" openings. A highly satisfactory medium of this character is disclosed in Patent No. 1,897,976 granted February 14, 1933. The medium may be stretched straight across the gas flow with its upstream and downstream faces, either in contact with or minutely spaced from the upstream and downstream electrodes respectively. This arrangement produces excellent cleaning results, but has the disadvantage of introducing a gas flow resistance high enough to limit the gas flow velocities to values substantially under 100 feet per minute. For that reason the medium is preferably arranged in zigzag form to provide a face area large enough to insure a satisfactorily low gas flow resistance with velocities ranging as high as 300 feet per minute.

With the medium in zigzag form, a stiffener or cardboard spacer 5 is preferably arranged in each fold of the medium to support it and laterally corrugated to maintain free gas flow spaces leading to and from each fold. The medium 4 and spacers 5 may be mounted within the confines of an enclosing frame 6, having open upstream and downstream gas flow faces, and held therein by retaining flanges 6a, which extend laterally inward from the frame a short distance over the upstream and downstream margins of the filtering medium, as a whole.

The resulting filtering unit should be arranged between electrodes with its opposed faces in substantial contact therewith. As indicated before, if actual physical contact is not made, the spacing between the medium and the electrodes should be limited to minute distances in order to maintain an effective electrostatic relation between opposed surfaces. While this arrangement is capable of producing good results, I have found that equally good and possibly better results can be secured with less power consumption by interposing between one face of the unit and one of the electrodes, preferably the upstream electrode, another dielectric body.

The separator, therefore, also includes a dielectric body, preferably in the form of a series of laterally spaced parallel glass plates 7, extending in the direction of the gas flow. While I prefer the use of glass as a dielectric, it is to be understood that various other dielectric materials, including wood, have been and may be successfully used. The dielectric body 7 should have its opposed faces in contact with, or minutely spaced from both the upstream electrode and the upstream face of the filtering unit. The plates should be placed as close together as they can be without interposing any appreciable obstruction to the air flow. Ordinarily, a lateral spacing substantially under 2" and preferably around ½" will be satisfactory.

The faces of the glass plates 7 may be coated if desired with relatively small particles of a different dielectric material such, for example, as crude vermiculite i. e. a flaky micaceous mineral. A coating of particulate or discrete dielectric material while not essential is, therefore, shown as indicated at 8 in Figure 2.

The dielectric separator, as a whole, should occupy substantially the entire gas flow depth of the electric field between electrodes, and should either provide good contact throughout that depth or avoid such contact by minute clearances only. In the arrangement shown, satisfactory contact between the upstream face of the separator and the upstream electrode is easily secured. Due to surface irregularities of the filter unit, satisfactory contact or clearance between each face of the filter unit and the opposed faces of adjacent parts may not be so readily obtained. To insure good contact, a somewhat resilient, interstitial body 9 can be interposed and slightly compressed between each face of the filter unit and the adjacent faces of the dielectric 7 on one side and the downstream electrode 2 on the other. The interposed body 9 in each case may be made of material having either electrically conductive or dielectric properties. Where electrically conductive materials are used, they are preferably made in the form of a resilient pad or sheet, such for example, as a pad or sheet of steel wool or of "copper mesh" fabric, the latter material being of the character shown in Patent No. 1,676,191 granted July 3, 1928.

The gas flow depth of the foregoing arrangement may be varied widely within safe limits without appearing appreciably to affect the effectiveness of its operation. For example, with an operating voltage of 12,000 volts, the cleaning results obtained when the air flow depth of the glass plates was 1½'', of the filter unit 4'' and of the device, as a whole, 6'', were not noticeably varied even after the overall air flow depth was increased to 10'' by correspondingly increasing the depth of the plates. No attempt is herein made to explain principle governing the operation of this device. It has been noted, however, that in operation particles are effectively deposited on the filter medium, principally in the areas where it either contacts other surfaces or is minutely spaced therefrom. Particle deposits have been noted not only at the points of contact or minute spacing between the filter medium and the adjacent upstream and downstream surfaces, but also at all points of contact or minute spacing between the filter medium 4 and other material such as the spacers 5.

In the operation of this gas cleaner, it has also been observed: that ozone is not produced in noticeable amounts if at all; that current variations, ranging from one microampere to one-half milliampere, appear to produce no observable change in its effectiveness; and that the effectiveness of the device is not instantly gained or lost upon connection to or disconnection from power, but on the contrary is gradually built up or dissipated over a period of time on the order of ten minutes more or less. Consequently, although the underlying principle of operation has not been definitely ascertained, these observations may indicate that ionization is not the determining factor. It has been suggested that the effect may be due to polar or charged particles being forced from the air stream in a non-uniform electric field. It may be, and I am strongly inclined to believe that it is, due to the distribution of charges of static electricity over the surface of the filter medium. From all indications, it would appear that charges of static electricity are distributed over the medium, that dust particles are effectively precipitated when brought under the influence of such charges, and that the efficiency of separation is proportional to what I term the "electrostatic potential" of the medium, that is to say the number of charges which can be maintained upon the medium. All this is indicated by the results secured in operating the arrangements shown in Figures 6 and 7.

I have discovered that the arrangement shown in Figures 1 through 5 may be greatly improved by eliminating the material interposed between the dielectric filter medium 4 and the charging electrodes 1 and 2, and by placing such electrodes into direct contact with the filter medium or otherwise causing the medium to be charged with an effective "electrostatic potential." An arrangement of this character is schematically indicated in Figure 6.

In this arrangement, good results have been obtained with filter media such as "Airmat," the paper disclosed in Patent #1,897,976, felted wool, canton flannel, organdy, voile, rayon, matted glass, i. e. glass fibers bonded by starch into a mat, and woven glass, i. e. glass fibers spun into a thread and woven into a cloth. As before, better results appear to be obtained with materials composed wholly of short fibers or having a multitude of such fibers forming a nap over its surface. While upstream and downstream electrodes in the form of window-screen may be employed, electrodes composed of laterally spaced rods or wires are preferred and illustrated in Figure 6. These electrodes may be disposed on the same side of the medium, on opposite sides thereof, or on both sides, but, in any event, they preferably are placed in good contact with the medium along their length and laterally spaced sufficiently to prevent flash-over. A direct current charging voltage of 12,000 volts is preferred, although this may be varied up or down as desired.

I have also discovered that a conventional ionizer may be used in place of, or in combination with the charging electrodes 1 and 2 with good effect provided it is placed sufficiently close to the filter medium to charge it with an effective "electrostatic potential." In this connection, it may be noted that electrical air cleaners, having ionizers arranged in advance of cloth and other like filter mediums, have heretofore been proposed. In these cleaners, however, the ionizer operates to agglomerate fume and smoke particles to a size which facilitates their mechanical filtration from the air. So far as is known, these arrangements contemplate the use of low air-flow velocities and the provision of substantial spacing between the ionizer and filter medium in order to allow sufficient time for the agglomeration to take place. Even then, the size of the agglomerates is so small as to require a dense filter medium to effect their mechanical filtration from the air.

I have discovered that when a dielectric filter medium is placed close to the downstream side of an ionizer, a substantial number of the electrostatic charges generated by the ionizer collect upon the filter medium, thus charging it with an "electrostatic potential" which is effective to precipitate substantial quantities of smoke and fume, whereas, when it is spaced a substantial distance away from the downstream side of the ionizer, most, if not all, of the generated charges are dissipated in some way before they reach the filter medium, with the result that it is charged with little or no "electrostatic potential" and, therefore, ineffective to precipitate even small quantities of smoke and fume. Accordingly, when its use is desired, a conventional ionizer, having large and small electrodes 10 and 11, is arranged close enough to the upstream face of the filter medium to charge it with an effective electrostatic potential.

A practical embodiment of the structure schematically illustrated in Figure 6 is shown in Figures 7 and 8. In this embodiment, an air filter of the type shown in the Nutting Patent #2,211,382 granted August 13, 1940, is used, this filter comprising: a unitary open-ended air inlet frame M having outer side walls for confining the air passing through the frame, two laterally spaced side walls being serrated to form two laterally spaced series of fingers 12 extending in the direction of air flow; another unitary open-ended air outlet frame W having corresponding side walls, serrations and fingers 13, the latter being matable with the fingers 12 of the frame M and cooperating therewith, when the frames M and W are mated, to pinch the intervening portion of a filter medium 4 interposed between the frames; and a corrugated screen 14 on the frame W to support the filter medium against the force of the air flow.

Good results have been obtained with a dielectric filter medium 4 interposed between all metal frames M and W when such frames were operated in connection with an ionizer and either connected to ground or disconnected therefrom. For purposes of safety, however, a ground connection to the all metal frame is preferred.

In Figures 7 and 8, however, the filter illustrated is not an all metal filter but, on the contrary, is an insulated filter in which the fingers 12 and 13 are composed of some insulating material such as Bakelite while a Bakelite screen is placed on the air-outlet frame W in place of the metal screen normally used. Additionally, the frames M and W are respectively provided with charging electrodes 1 and 2. With this arrangement, good results have been obtained when either set or both sets of electrodes were energized with direct current at 12,000 volts. For example, with a filter 24″ x 24″ in cross section, fitted within a wooden duct D and positioned with its upstream face spaced 4″ from the downstream face of the ionizer (or 9″ from a vertical plane passing through the longitudinal axes of the ionizing electrodes 10 and 11), and with both sets of electrodes energized by a direct current of 12,000 volts, cleaning-efficiency tests were conducted with various dielectric filter mediums using atmospheric air as the medium to be cleaned. The cleaning efficiencies obtained were measured by the discoloration method which is published in the August 1938 edition of the "Journal Section" of the "Heating, Piping and Air conditioning" magazine. These results follow:

Filter medium	Per cent cleaning efficiencies	
	Initial	Subsequent
Woven glass	Below 40	40
1/16″ ply of matted glass	43	44
Rayon	50	50
Voile	60	60
Organdy	60	60
14 oz. felted wool	65	65
Same with surface roughened	80	82.5
Same with surface resmoothed	75	75
12 oz. canton flannel	65	90
Same with surface singed	65	80
10 ply "Airmat"	85	85

It will be understood that the efficiencies shown by the discoloration method indicate the ability of the filter medium to remove smoke, fume and other extremely fine particles which cannot be effectively removed from air by mechanical filtration. When the same test method is employed to measure the cleaning efficiencies of any of the mediums above noted, such as Airmat, under conditions in which it is not subjected to an electrostatic charge or potential, the efficiencies obtained are substantially under 20%.

In the foregoing arrangement, with the upstream face of the insulated filter spaced 2″ from the downstream face of the ionizer, with the charging electrodes disconnected from power and with the ionizing electrodes energized with direct current at 10,000 volts, a leakage current of 1.0 micro-amperes was observed in the ground connection leading from the charging electrode 2 to ground, whereas this current dropped to 0.1 micro-amperes when such spacing was increased to 9″. Again with an all metal filter connected to ground and having its upstream face spaced 3″, 6″ and 9″ from a vertical plane passing through the longitudinal axes of ionizing electrodes 10 and 11 energized at 20,000 volts, leakage currents of 100, 10 and 5 micro-amperes respectively were observed in the ground connection of the filter. The amount of current in such ground connections appears to be an indication of the electrostatic potential of the filter medium, and, as such, shows that such potential decreases rapidly with increases in the spacing between the filter and the ionizer. Nevertheless, while this is true, a small leakage current should not be taken as an absolute indication that the electrostatic potential of the filter medium is ineffective, because the magnitude of the leakage current not only depends upon the magnitude of the electrostatic potential but upon the resistance afforded to the flow of current. In this connection, it has been noted that the amount of leakage current normally increases with an increase in the humidity of the atmosphere, although, at the same time, the efficiencies of the filter medium, and, no doubt, the magnitude of the electrostatic potential, decreases.

Generally speaking, it may be said that good results will always be obtained when an effective electrostatic potential is maintained on the filter medium, and that the maintenance of an effective electrostatic potential will be promoted by using short-fibered or napped filter mediums, by using the highest practical voltage or by increasing the dryness of the air or gas being cleaned, where this is possible, and by decreasing the spacing between the filter medium and the ionizer when the latter is used. Since the maximum permissible spacing between the ionizer and filter medium will depend upon various factors which affect the dissipation of the generated charge and since such factors will vary in different installations, it is difficult accurately to define the maximum spacing limit; hence, in each particular installation, it may be necessary to determine such limit experimentally should conditions require the use of maximum spacing. In this connection, it may be noted that the generated charge apparently was entirely dissipated when a spacing of 15 feet was employed between an ionizer and filter medium in a metal duct having an area 24″ x 24″. It should suffice to say that the smaller spacings are recommended, that a minimum of metal be interposed between the ionizer and filter medium in order to minimize the dissipation of the charge and that, to promote safety, all interposed metal be grounded.

Having described my invention, I claim:

1. An electric gas cleaner comprising: spaced upstream and downstream interstitial electrodes; an interstitial dielectric body arranged within the electric field space between electrodes and substantially in contact with the upstream electrode; and an interstitial dielectric air filter medium interposed between and in electrical contact with said dielectric body and said downstream electrode.

2. An electric gas cleaner comprising: spaced upstream and downstream interstitial electrodes; a series of laterally spaced substantially parallel dielectric plates extending from the upstream electrode toward the downstream electrode; and a dielectric air filter medium arranged between

and in contact with the downstream electrode and the downstream edges of said plates.

3. A device as claimed in claim 2, wherein said medium is composed of fibrous material.

4. A device as claimed in claim 2, wherein said medium is composed of short fibred material matted to form a highly porous net work.

5. The combination with a gas flow duct of an electrical gas cleaning device comprising: spaced upstream and downstream interstitial electrodes, each electrode extending laterally across the gas flow space of said duct; and an interstitial dielectric separator substantially occupying the gas flow space of the duct between electrodes.

6. The combination with a gas flow duct of an electrical gas cleaning device comprising: an interstitial dielectric filter medium with upstream and downstream air-flow faces extending across said duct to filter the gas passing therethrough, and means to establish and maintain an electrostatic potential on said filter medium to substantially increase the collecting ability of said filter medium for relatively fine particles including particles of smaller size than the interstices in said filter medium.

7. The combination defined in claim 6 wherein: said means include charging electrodes in physical contact with said dielectric filter medium.

8. The combination defined in claim 6 wherein: said means includes an ionizer in said gas-flow duct positioned upstream of said dielectric filter medium and sufficiently close to the upstream face of said dielectric filter medium to prevent the dissipation of charges imposed on the particles in the gas flow by said ionizer prior to their reaching said dielectric filter medium.

CHARLES W. WILLIAMS