Feb. 20, 1973 A. P. DE SEVERSKY **3,716,966**

WET ELECTROSTATIC PRECIPITATOR

Filed Aug. 31, 1960 5 Sheets-Sheet 1

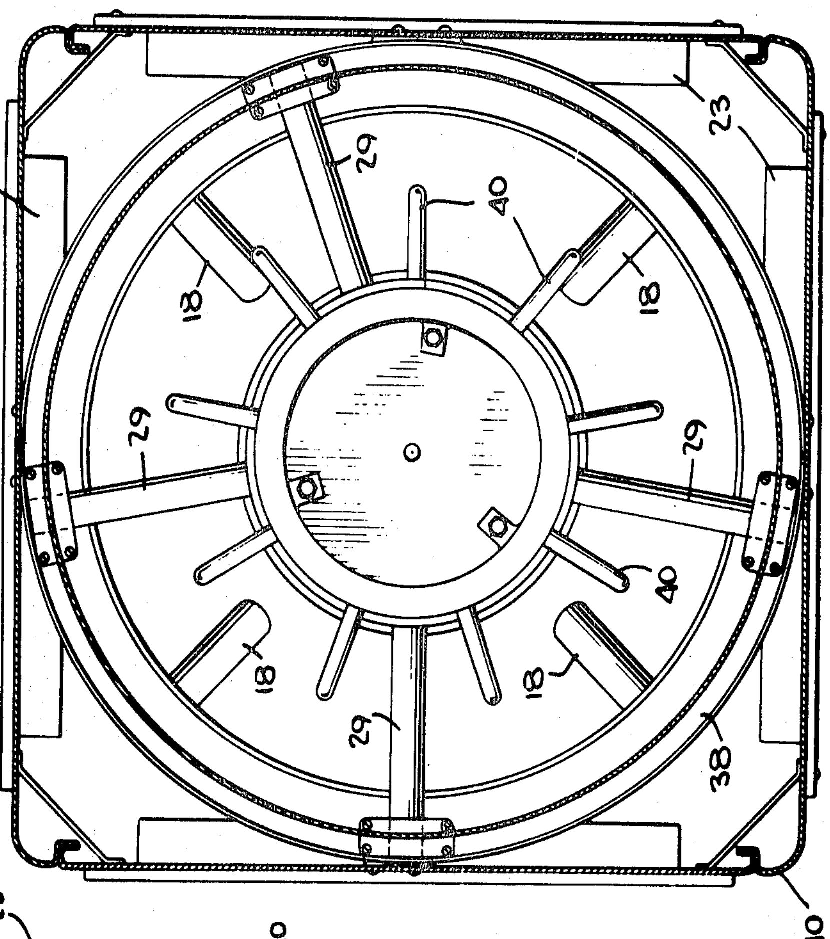

Fig. 3.

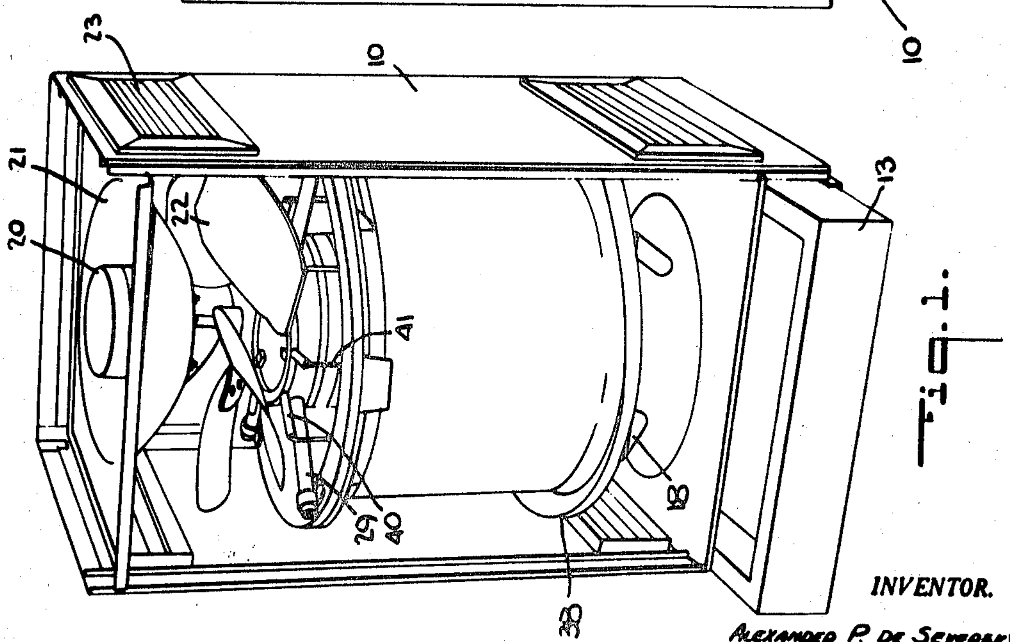

Fig. 1.

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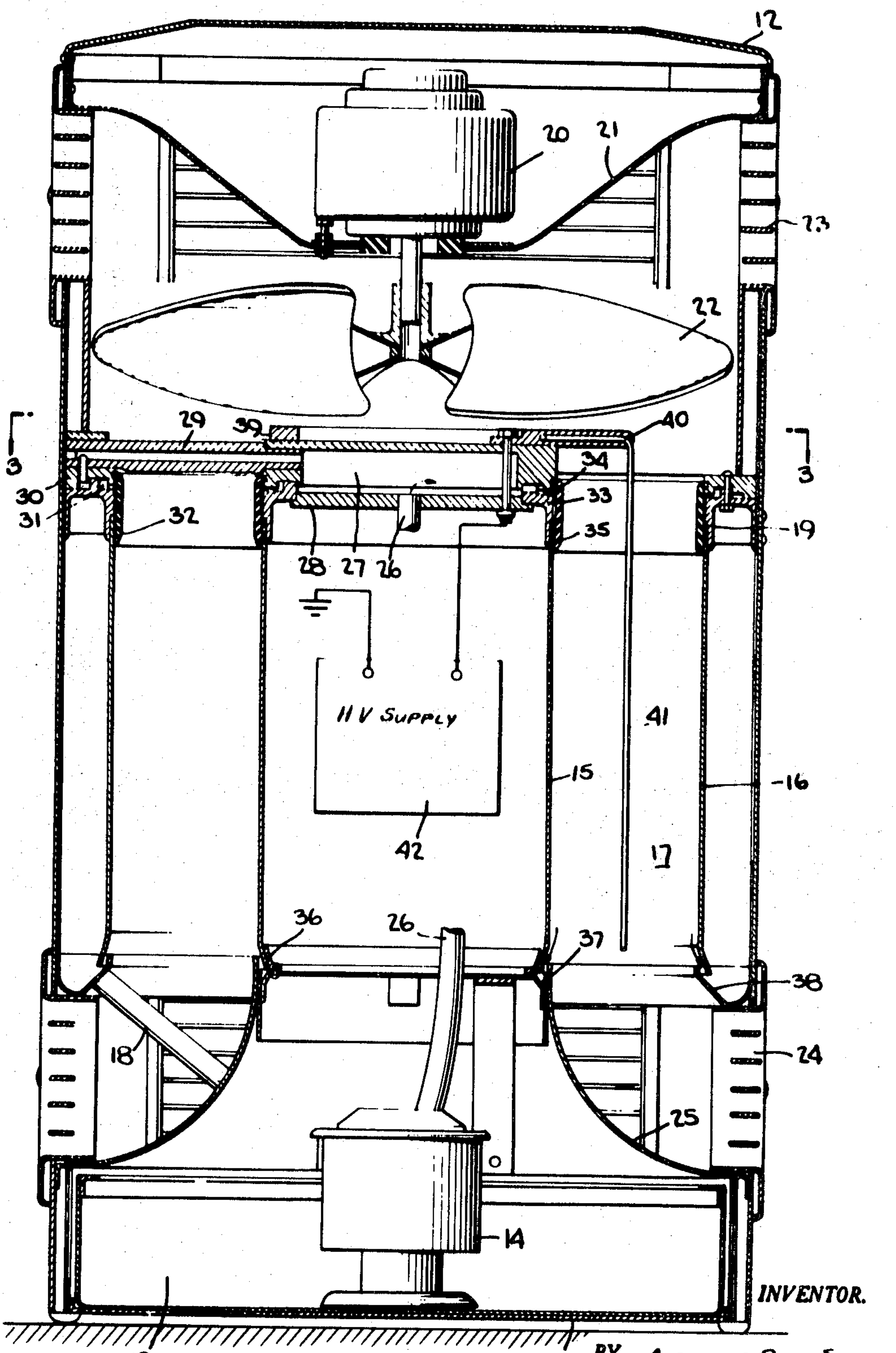

Fig. 2.

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Fig. 4.

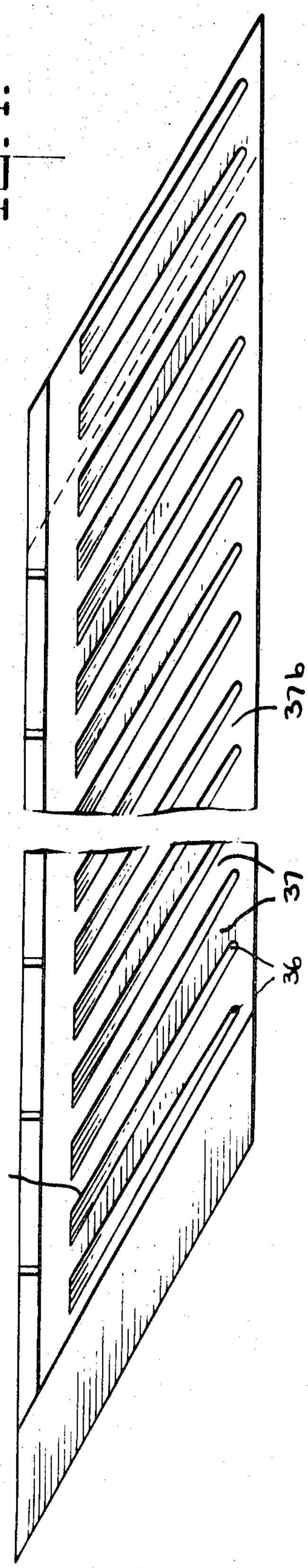
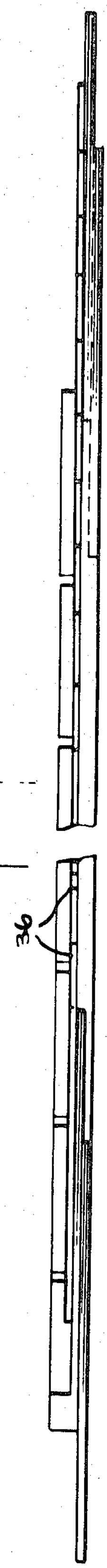


Fig. 5.



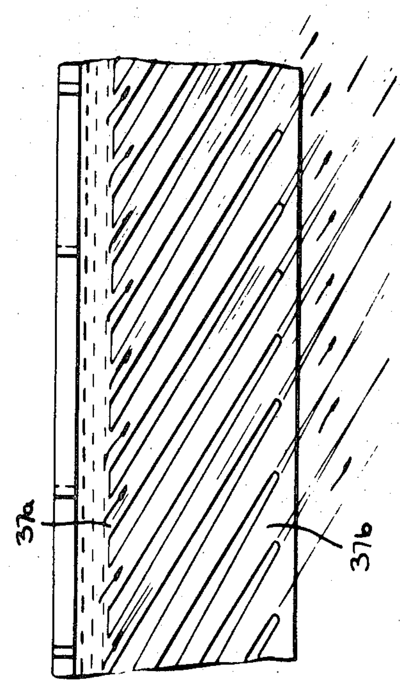


Fig. 7.

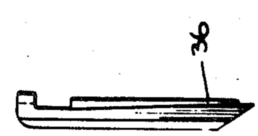


Fig. 6.

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Fig. 8.

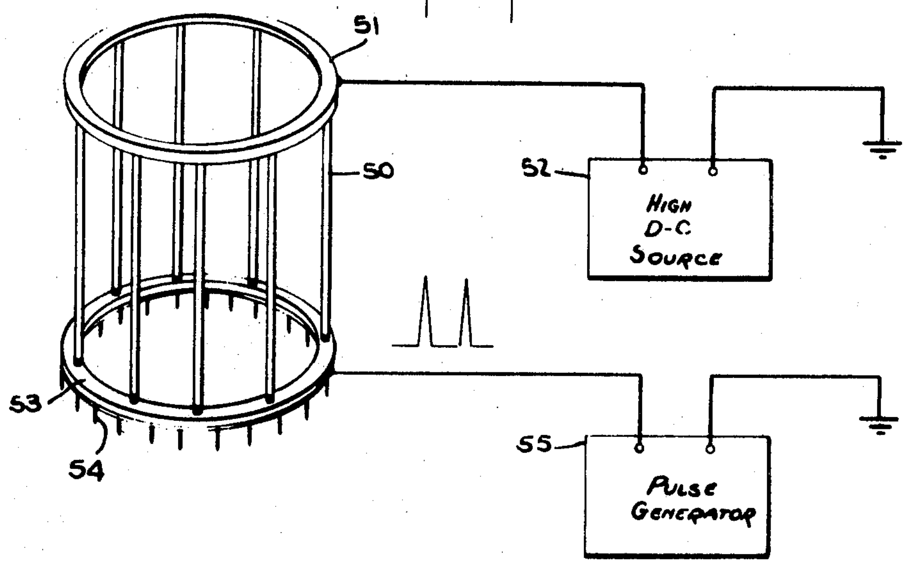
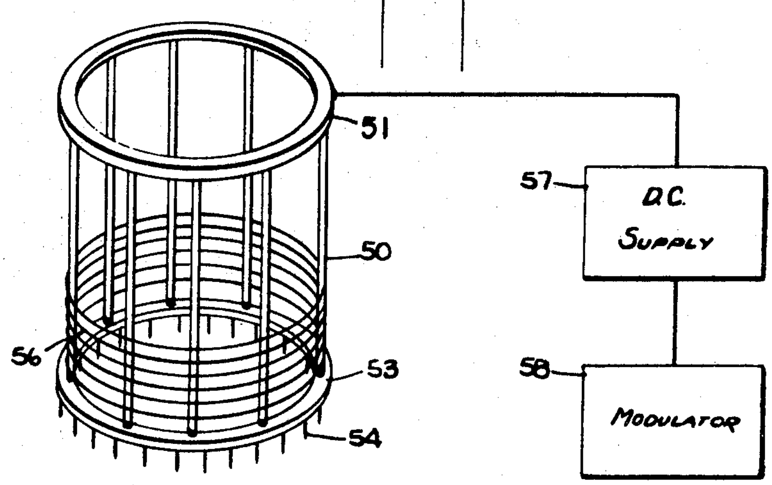


Fig. 9.



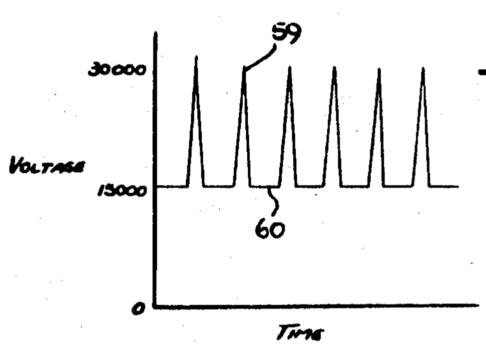


Fig. 10.

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Fig. 11.

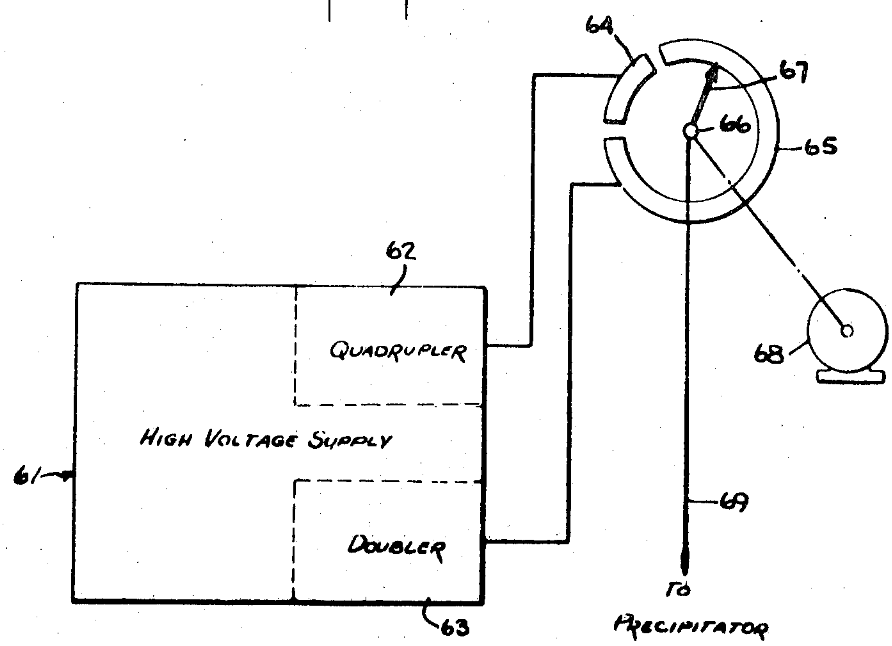
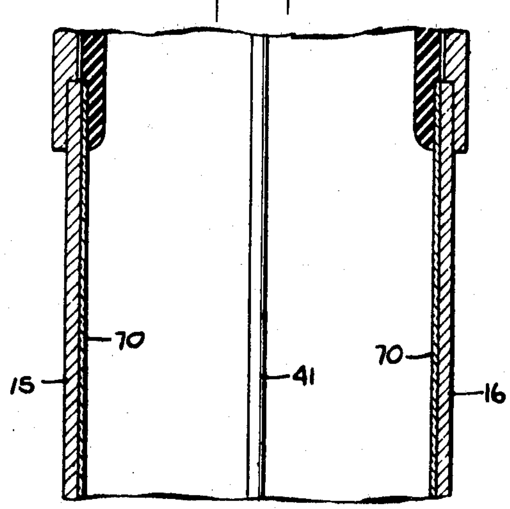


Fig. 12.



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United States Patent Office

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Patented Feb. 20, 1973

3,716,966

WET ELECTROSTATIC PRECIPITATOR

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Continuation-in-part of application Ser. No. 855,369, Nov. 25, 1959. This application Aug. 31, 1960, Ser. No. 53,255

Int. Cl. B03c 3/41, 3/78, 3/49

U.S. Cl. 55—118 4 Claims

This invention relates generally to apparatus for cleaning contaminated gases and more particularly to a wet electrostatic precipitator of exceptional efficiency.

This application is a continuation-in-part of my copending application Ser. No. 855,369, filed Nov. 25, 1959, and issued Sept. 11, 1962 as Pat. 3,053,029, which copending application is a division of my original application Ser. No. 479,909, filed Jan. 5, 1955, and issued as Pat. 2,937,709 on May 24, 1960.

The increase in atmospheric pollution and smog in modern communities has created a health hazard of major proportions and has become a matter of grave social concern. Air pollution is imputable to many factors among which are the use of incinerators to burn household waste and various industrial operations which discharge combustion products into the atmosphere.

Electrostatic precipitators, both of the dry and wet type, have been used for cleaning contaminated gases, but such use has been limited mainly to industrial applications. There has not heretofore been available an inexpensive, efficient and reliable precipitator for non-industrial users, to be installed for example in apartment houses so as to prevent the discharge into the atmosphere of particles emanating from incinerator and heating systems.

The present invention deals with a precipitator of the wet type wherein the contaminated gases are conveyed through an electrostatic field between electrode surfaces. Particles in the gas are precipitated onto a collecting surface constituted by a film of water flowing over a collector. Since the water carries the particles away continuously, a precipitator of this type is self-cleaning and is therefore particularly suited to non-industrial uses. This wet type of precipitator is also advantageously used for extracting radio-active particles from the atmosphere in case of fallout. The dry type of precipitator would accumulate the extracted particles and become so highly radioactive that it would become a hazard itself. By using the wet type of precipitator, the radioactive material is carried away by the liquid which may then be stored or treated to decontaminate. While the present invention will be described in connection with a wet precipitator, it will become apparent that certain features of the invention are also applicable to dry precipitators.

One of the characteristic defects in existing wet precipitators arises from the fact that the liquid film is generally uneven and does not fully coat the collector surface. If the water is merely poured into the vertical collector tube of the precipitator, it tends to trickle down in separate streams and it is difficult to ensure that it will spread over the interior surface without an excessive flow of incoming water. As a result, dry patches appear on the collector and certain particles, such as carbon black, on reaching a dry area tend to give up their charge. These particles acquire an opposite charge by induction and may experience sufficient force in a strong field to be moved back toward the other electrode into the gas stream. As a consequence, the particles pass out of the cleaner and are discharged into the atmosphere.

Accordingly, it is one object of the invention to provide an electrostatic precipitator of the water film type wherein water is caused to flow uniformly and smoothly on the walls of the collector tubes, and wherein dry patches are obviated. A significant feature of the invention resides in the fact that a water distributor is provided which discharges multiple streams tangentially against the surface of the collector, the streams being divergent and intersecting.

Another factor which militates against the use of wet precipitators in non-industrial applications is the relatively high power requirements for the precipitator. It is the usual practice to pass the contaminated gas initially through a charging field in which a corona discharge is produced in order to ionize the suspended particles. The gas then passes through an electrostatic precipitating field which is free of corona discharge, this field acting to cause migration of the particles toward the collecting electrode. The use of a pre-ionization field involves a relatively high voltage and in conventional precipitators brings about a substantial current flow. The power requirements of the pre-ionization field when added to that of the precipitating field are considerable and make the operation of the standard precipitator costly.

It is therefore another object of the invention to provide a wet electrostatic precipitator of high efficiency which requires substantially less power to operate than conventional gas cleaners.

A further object of the invention is to provide a power supply for a precipitator which generates pulsed voltages of high amplitude to produce an ionizing field.

Also an object of the invention is to provide a wet electrostatic precipitator which is of compact design and yet has a large gas cleaning capacity.

The wet precipitator in accordance with the invention is constituted by two concentric collector tubes, a water film being formed uniformly both on the outer surface of the inner tube and the inner surface of the outer tube by means of distributors producing multiple diverging streams of water which are introduced tangentially to the collector surface and intersect thereon. Precipitator and corona discharge electrodes are suspended in the annular passage between the two tubes to remove particles from the gas conveyed vertically thereon. Corona discharge voltages are applied in pulsatory form, whereas the lower precipitation voltage is maintained at a constant level.

For a better understanding of the invention as well as other features and objects thereof, reference is made to the following detailed description to be read in conjunction with the accompanying drawing wherein like components in the several views are identified by like reference numerals.

In the drawings:

FIG. 1 is a perspective view of the precipitator cabinet.

FIG. 2 is a section taken through the precipitator structure in the vertical plane.

FIG. 3 is a transverse section taken in the plane indicated by line 3—3 in FIG. 2.

FIG. 4 is a linear projection of the flange water distributor.

FIG. 5 is a plan view of the flange.

FIG. 6 is an end view of the flange.

FIG. 7 shows the water distribution pattern produced by the flange.

FIG. 8 schematically shows one preferred form of pre-ionization and collector electrode structure in accordance with the invention.

FIG. 9 schematically shows another form of pre-ionization and collector electrode structure in accordance with the invention.

FIG. 10 shows the waveform of voltage applied to the structure shown in FIG. 9.

FIG. 11 is a schematic view of a pulsating high voltage supply suitable for use in conjunction with the present invention.

FIG. 12 is a sectional view of a preferred form of a portion of the two shells forming the collector assembly.

Referring now to the drawings and more particularly to FIGS. 1 to 3, a preferred embodiment of the wet precipitator in accordance with the invention is shown housed in a metal cabinet constituted by side panels **10**, a base plate **11** and a cover **12**. The water supply for the precipitator is contained in a sliding tray **13** disposed at the bottom of the cabinet, and serving as a well. Mounted in the tray is a water pump **14**, which may be electrically driven.

Vertically mounted within the cabinet is a collector assembly including a cylindrical inner collector shell **15**. Concentrically disposed about the inner shell is an outer collector shell **16**, an annular air passage **17** being defined between the shells. The outer shell is supported within the cabinet by means of a mounting ring **19**.

Supported above the collector assembly at the top of the cabinet is a fan motor **20**, the motor being positioned centrally within an inverted conical deflector **21**. Positioned in the space between the deflector **21** and the collector assembly is a fan **22**, the fan being attached to the shaft of motor **20**. Air drawn by the fan **22** through the air passage **17** is exhausted through a set of louvered grills **23** mounted on the panels of the cabinet. Air enters the cabinet through a set of intake grills **24**, the air being deflected upwardly into the air passage **17** by means of a truncated conical deflector **25**.

Water sucked from tray **13** by the pump **14** is supplied through a flexible tube **26** to a water distributor **27** mounted atop the inner collector shell **15**, the upper end of the shell being closed by a sealing disc **28**. Water from the distributor is supplied through radially extending pipes **29** to an outer water ring **30** lying above the mounting ring **19** and provided with passages **31** which conduct the water to distribution channels formed in a circular flange **32**. Flange **32** lies against the inner surface of the outer shell **16** and acts to supply water therein in a manner producing thereon an evenly distributed film of downwardly flowing water.

Water from the distributor **27** is also fed to a water ring **33** connected to the upper end of the inner shell **15** and having a passage **34** therein which supplies the water to the distribution channels formed in a circular flange **35** which lies against the outer surface of the inner shell **15** in a manner also producing an evenly distributed film of downwardly flowing water.

The structure of the water distribution flanges can best be seen in FIGS. 4, 5 and 6 which show the circular flange **35** for the inner shell in a straight line projection. It will be seen that formed on the surface of the flange is an array of equi-spaced tapered ribs **36** which are all inclined relative to the vertical to define a series of diverging or flared water channels **37**. Water enters the flange from the associated ring at the channel entrances **37*a*** and is discharged against the surface of the collector shell at the channel exits **37*b***.

As best seen diagrammatically in FIG. 7, the flow of water through the divergent channels **37** causes the water at the exits thereof to fan outwardly. The diverging patterns from the various channels intersect at a point slightly beyond the exits and the resulting interference prevents build-up of the film and tends to produce an even water distribution along the collector surface. This action is further aided by the whirling motion imparted to the water by reason of the incline of the flange channels, the water thereby entering tangentially and spirally along the collector surface. The combined action of the diverging multiple streams of water and the whirling motion of the stream has been found to result in a uniform water film which adheres to the surface of the collector and avoids the presence of dry spots thereon. The flanges may in practice be made of rubber, nylon or similar material.

Attached to the lower end of inner collector shell **15** is a base ring **36** and attached thereto is a circular gutter **38A**, the gutter being interposed between the upper end of conical deflector **25** and the lower end of the inner shell **15** so as to receive the downwardly flowing water therefrom. Positioned at lower end of shell **16** is an annular trough **38**, the inner wall of the trough extending above and being spaced from the lower end of the outer shell **16** to receive the water flowing downwardly thereon. Suitable pipes **18** are provided (not shown) to return the water received in gutter **37** and trough **38** to the tray well **13** for recirculation. Thus continuous water films are produced in both collector shells.

Supported above the water distributor **27** and insulated therefrom is a conductive spider ring **39** from whose radially extending horizontal arms **40** are vertically suspended a group of wire precipitator or discharge electrodes **41**, the wire electrodes lying midway between the inner and outer shell in the air passage **17**. Pre-ionization electrodes (not shown) may be attached to the lower end of the precipitator electrodes. A suitable high-voltage power supply **42** may be housed within the space provided within the inner shell, or it may be mounted adjacent the motor **20** at the top of the cabinet.

The high voltage supply is constituted by any known high voltage generator whose negative terminal is connected to the water pool and whose positive terminal is connected to the precipitator electrodes. As the water is pumped continually by the pump and allowed to fall uniformly down the collector surfaces, the potential applied to the pool by the supply will also be applied to the water films or curtains on the collectors. Thus an electrostatic field is established between the electrodes and the two fluid collector surfaces on the walls defining the annular passage **15**.

The precipitator shown is capable of cleaning the air in a large enclosure, the air being drawn in through the intake grills and being conveyed through the air passage between the collector electrodes. Water sucked up from the pool is caused to flow in a tubular curtain down the collector shells, the contaminating particles being precipitated and washed down the collectors and being received in the pool. Suitable filters are provided in conjunction with the pump to prevent the return of the particles to the collectors. The air is expelled horizontally and omnidirectionally through the exit grills. It will be obvious that essentially the same system may be used for any cleaning application and the intake may be any form of contaminated gas.

In the electrode system shown in the above-noted figures, the precipitator electrodes may be provided with discharge needles or points to effect pre-ionization of the gas entering the passage. The electrodes are of relatively large diameter whereas the needles are of smaller diameter and have sharp edges to provide a sufficiently high voltage gradient to cause ionization and corona discharge. The corona discharge acts to ionize the particles, such that when they enter the electrostatic field they will be caused to migrate toward the collectors.

To effect power economy, there is provided an electrode arrangement as shown in FIG. 8, wherein precipitator electrodes **50** supported from a ring **51** are connected to a source of direct-voltage **52** which generates a constant voltage, say in the order of 15,000 volts. Suspended below the electrodes **50** by a ring **53**, and insulated from the electrodes **50**, are circumferentially-arranged corona producing discharge points **54** to which are applied periodic pulses having a magnitude in the order of 30,000 volts. The periodicity of the pulses may be in the audio range or higher.

Since the duty cycle of the pulses is relatively brief, the integrated amount of current drawn is fairly low despite the high voltage. Thus the particles in the air entering the structure are first ionized by the high potential pulses and the ionized particles are then caused to migrate by the precipitator electrodes which need not operate at so high a potential. For purposes of ionization, a constant voltage is not essential since once ionization occurs no useful purpose is served by the ionization field.

The pulse generator **55** may be of any known design, such as is used in radar techniques, and may include differentiating networks or other pulse shaping means.

An alternative electrode structure is shown in FIG. 9, wherein the discharge electrode for creating corona effects is constituted by a series of rings **56** of relatively fine wire which girdles the group of precipitator electrodes **50**. In practice, the electrodes **50** may be of a 1/16 inch diameter and the rings of much finer diameter, such as 8 mil wire. The corona producing discharge points employed in the structure of FIG. 8 may be used in conjunction with the wire rings for increased effectiveness. In this case, the same voltage is applied to both sets of electrodes and for this purpose a D.C. supply **57** is provided which is modulated by a modulator **58** to provide pulses superimposed over a constant voltage of the D.C. supply. Thus, as shown in FIG. 10, the pulses **59** are developed above the D.C. level **60**, the pulse peak being twice the D.C. level.

In the embodiment shown in FIG. 9, the number of rings used and the spacing thereof are dependent on the velocity of the gas stream and the frequency of the high voltage pulses in the power supply. Thus, as the frequency of the high voltage pulses increases, the number of rings may be decreased, one ring being sufficient at frequencies of the order of 1000 cycles and greater. Increasing the gas handling capacity of the precipitator by increasing the velocity of the gases passing therethrough will necessitate using a larger number of rings to ensure the ionization of substantially all of the particles carried by the gas stream.

FIG. 11 depicts a schematic diagram of a high voltage pulse generator suitable for use with the precipitators herein described. High voltage supply **61** is employed to produce two D.C. voltages of different magnitudes. Supply **61** embodies a quadrupler **62** and a doubler **63** produced outputs which are related by a factor of two.

The output of doubler **62** is connected to curved contact **64**. The output of quadrupler **63** is connected to curved contact **65**. The inner surfaces of contacts **64** and **65** lie along an imaginary circle whose center is at point **66**. Wiper **67** is rotated about point **66** by variable speed motor **68**. Wiper **67** may be connected by lead wire **69** to an electrical device utilizing pulsating high voltage, such as for example the electrostatic precipitators of this invention.

The rotation of wiper **67** produces essentially a square wave voltage which fluctuates between the level of the output of the doubler **62** and the level of the output of the quadrupler **63**. It is necessary to confine contacts **64** and **65** and wiper **67** in such a manner as to prevent sparking. This may be accomplished by submerging the parts in a high dielectric liquid, or, alternatively by enclosing the parts in a chamber which may be maintained at a high gas pressure.

The frequency of the output voltage is controlled by the speed of rotation of wiper **67**. The duty cycle is fixed by appropriately choosing the relative circumferential lengths of contacts **64** and **65**.

Other pulsating high voltage systems may also be employed in conjunction with the electrostatic precipitators of the present invention. Thus for example, instead of the contact and wiper arrangement shown in FIG. 11, either a mechanical chopper or an electronic control utilizing gas tubes as electronic gate selectors are suitable.

FIG. 12 shows a sectional view of a portion of inner collector shell **15** and outer collector shell **16**. In the preferred embodiment shown in FIG. 12 the outer surface of shell **15** and the inner surface of shell **16** are coated with a porous ceramic, such as, for example, alumina. It has been determined that use of such a porous coating **70** facilitates the formation of a thin, uniform liquid film which is essential in order to achieve high efficiency.

While there has been shown what are considered to be embodiments of the invention, it will be manifest that many changes and modifications may be made therein without departing from the essential spirit of the invention. It is intended, therefore, in the annexed claims to cover all such changes and modifications as fall within the true scope of the invention.

What is claimed is:

1. An electrostatic precipitator for cleaning contaminated gas comprising:

(a) concentrically-arranged inner and outer collector tubes defining a vertically-disposed annular gas passage,

(b) means coupled to a well to draw liquid therefrom and to feed the liquid to the upper ends of said tubes to produce a downwardly-flowing and substantially uniform liquid film on those surfaces of said inner and outer tubes which line said passage,

(c) concentrically-arranged troughs at the lower ends of said tubes to receive the downwardly-flowing liquid therefrom and to discharge the liquid into said well,

(d) inlet means to introduce said contaminated gas into the lower end of said annular passage between said troughs, said inlet means including means to admit said gas in a horizontal plane and further including a frusto-conical deflector in axial alignment with said tubes to direct contaminated gas entering in the horizontal plane upwardly through the vertically-disposed annular passage,

(e) a discharge electrode structure supported within said passage,

(f) means to apply a high voltage between said discharge electrode structure and both of said tubes to cause migration of particles in said gas toward the films on said tubes and thereby produce a clean gas, and

(g) outlet means at the upper end of said annular passage to discharge the clean gas into the atmosphere, said outlet means including an inverted frusto-conical deflector in axial alignment with said tubes to direct the clean gas from said passage outwardly in the horizontal plane.

2. An electrostatic precipitator for cleaning contaminated gas comprising:

(a) concentrically-arranged inner and outer collector tubes defining a vertically-disposed annular gas passage,

(b) means coupled to a well to draw liquid therefrom and to feed the liquid to the upper ends of said tubes to produce a downwardly-flowing and substantially uniform liquid film on those surfaces of said inner and outer tubes which line said passage,

(c) concentrically-arranged troughs at the lower ends of said tubes to receive the downwardly-flowing liquid therefrom and to discharge the liquid into said well,

(d) inlet means to introduce said contaminated gas into the lower end of said annular passage between said troughs,

(e) a discharge electrode structure supported within said passage,

(f) means to apply a high voltage between said discharge electrode structure and both of said tubes to cause migration of particles in said gas toward the films on said tubes and thereby produce a clean gas,

(g) outlet means at the upper end of said annular passage to discharge the clean gas into the atmosphere, and

(h) a high-voltage supply disposed within said inner tube to produce said high voltage.

3. An electrostatic precipitator for cleaning contaminated gas comprising:

(a) concentrically-arranged inner and outer collector tubes defining a vertically-disposed annular gas passage,

(b) means coupled to a well to draw liquid therefrom and to feed the liquid to the upper ends of said tubes to produce a downwardly-flowing and substantially uniform liquid film on those surfaces of said inner and outer tubes which line said passage, said means to produce a downwardly-flowing liquid film on said inner and outer tubes including a distributor flange coupled to the upper end of each tube and provided with diverging water channels inclined to direct water in a plurality of diverging streams tangentially against the tube surface, which streams intersect on the surface to form said substantially uniform water film thereon,

(c) concentrically-arranged troughs at the lower ends of said tubes to receive the downwardly-flowing liquid therefrom and to discharge the liquid into said well,

(d) inlet means to introduce said contaminated gas into the lower end of said annular passage between said troughs,

(e) a discharge electrode structure supported within said passage,

(f) means to apply a high voltage between said discharge electrode structure and both of said tubes to cause migration of particles in said gas toward the films on said tubes and thereby produce a clean gas, and

(g) outlet means at the upper end of said annular passage to discharge the clean gas into the atmosphere.

4. An electrostatic precipitator as set forth in claim **3**, wherein said distributor flange is provided with ribs which bear against the surface of the tube to produce said inclined water channels.

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U.S. Cl. X.R.

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