ELECTRICAL PRECIPITATOR APPARATUS OF THE LIQUID SPRAY TYPE

Original Filed Oct. 14, 1963

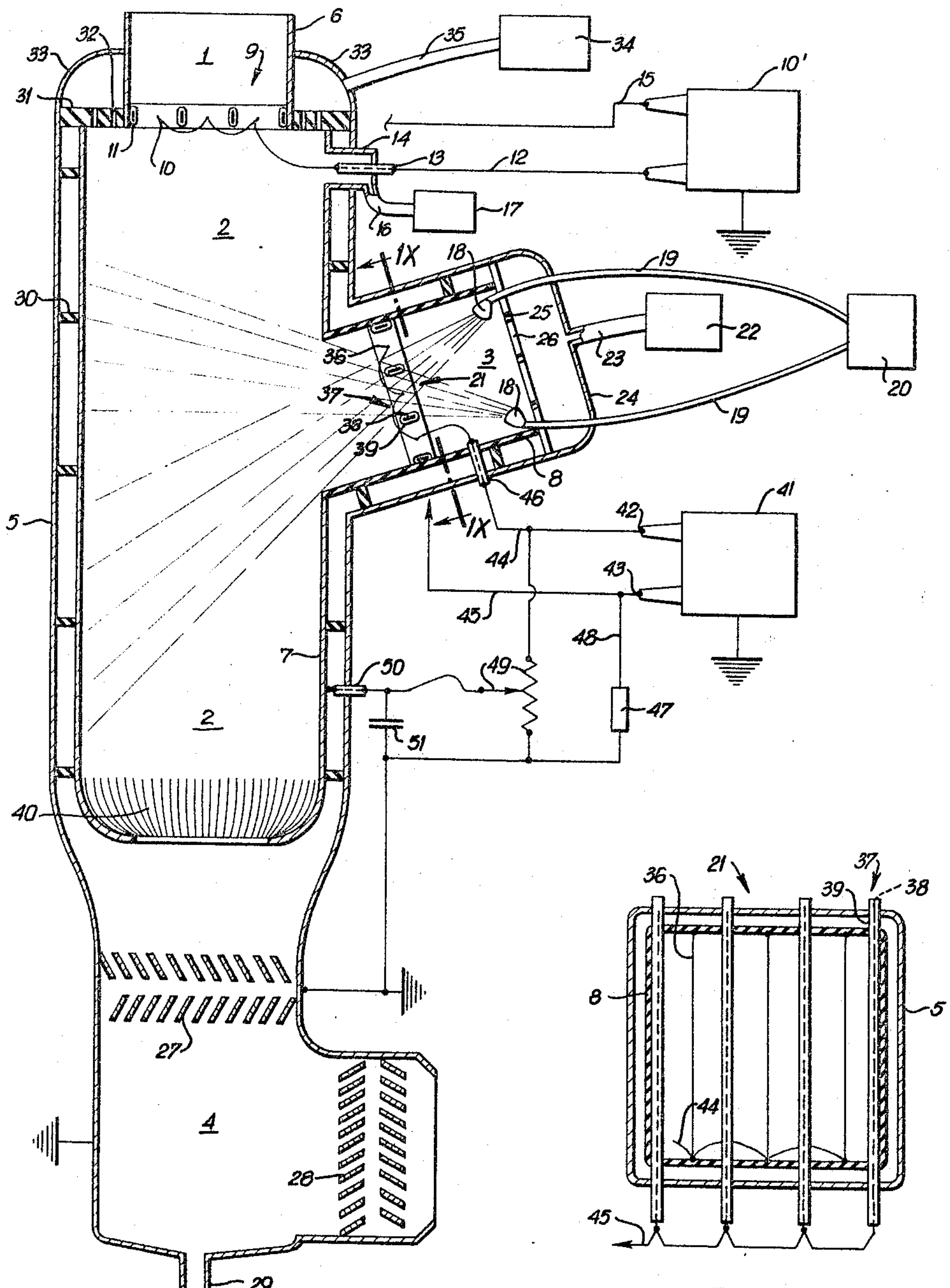

FIG. I

FIG. IX

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ELECTRICAL PRECIPITATOR APPARATUS OF THE LIQUID SPRAY TYPE

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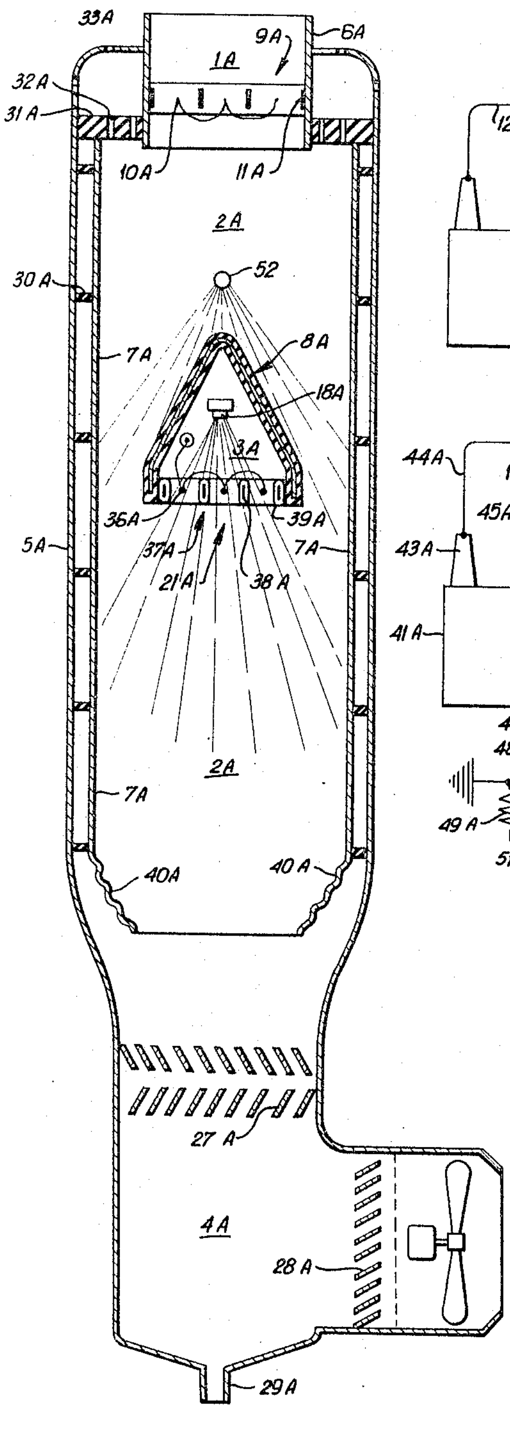

FIG. 2

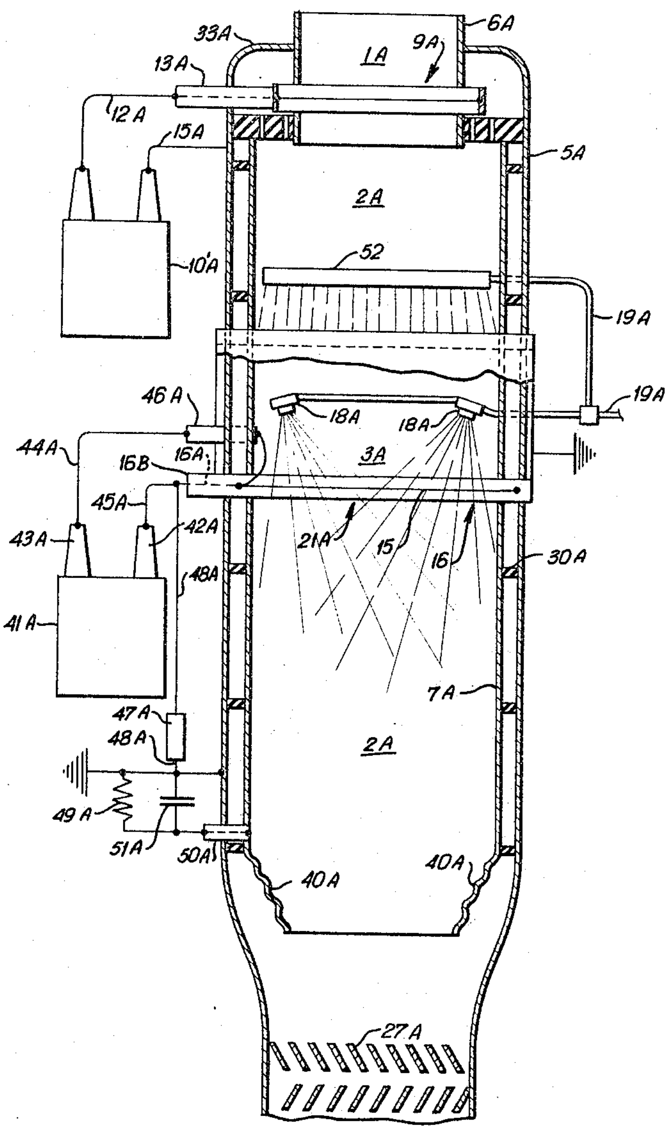

FIG. 2X

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ELECTRICAL PRECIPITATOR APPARATUS OF THE LIQUID SPRAY TYPE

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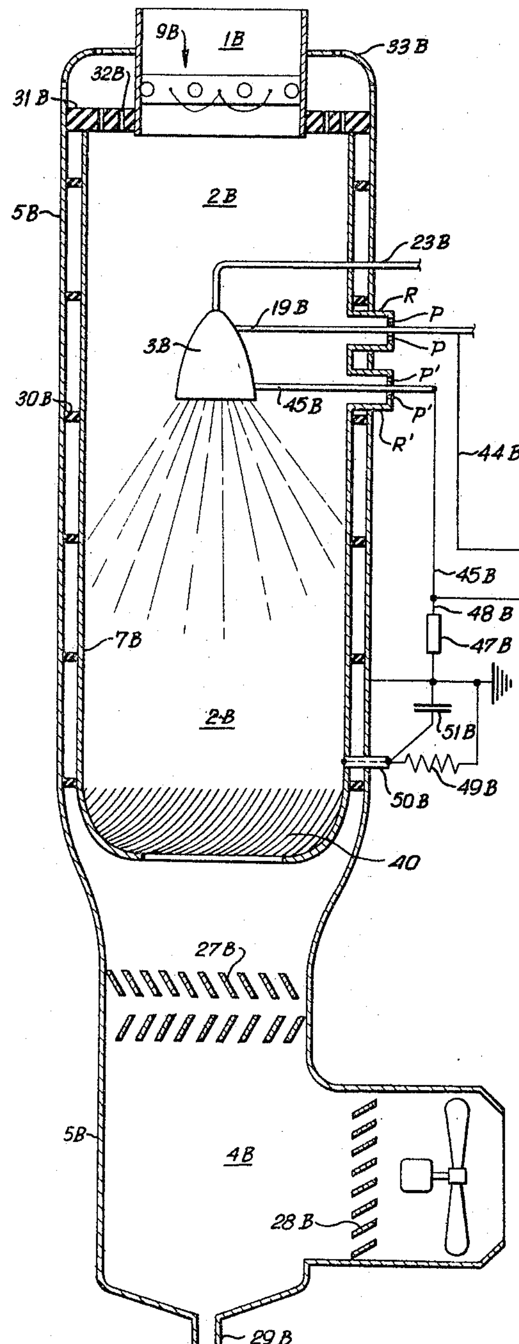

FIG. 3

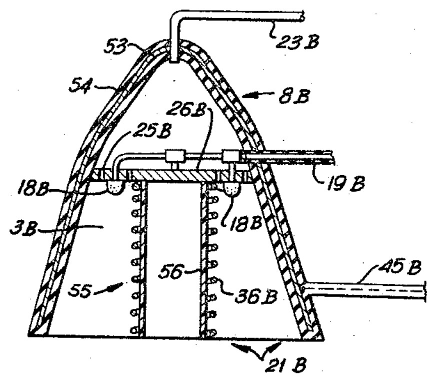

FIG. 3X

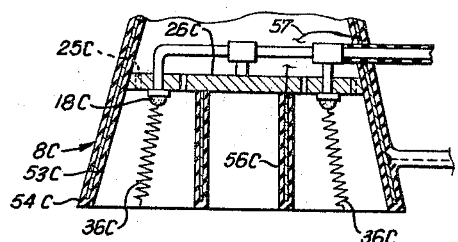

FIG. 3Z

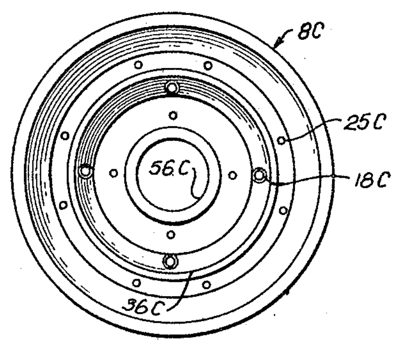

FIG. 3Y

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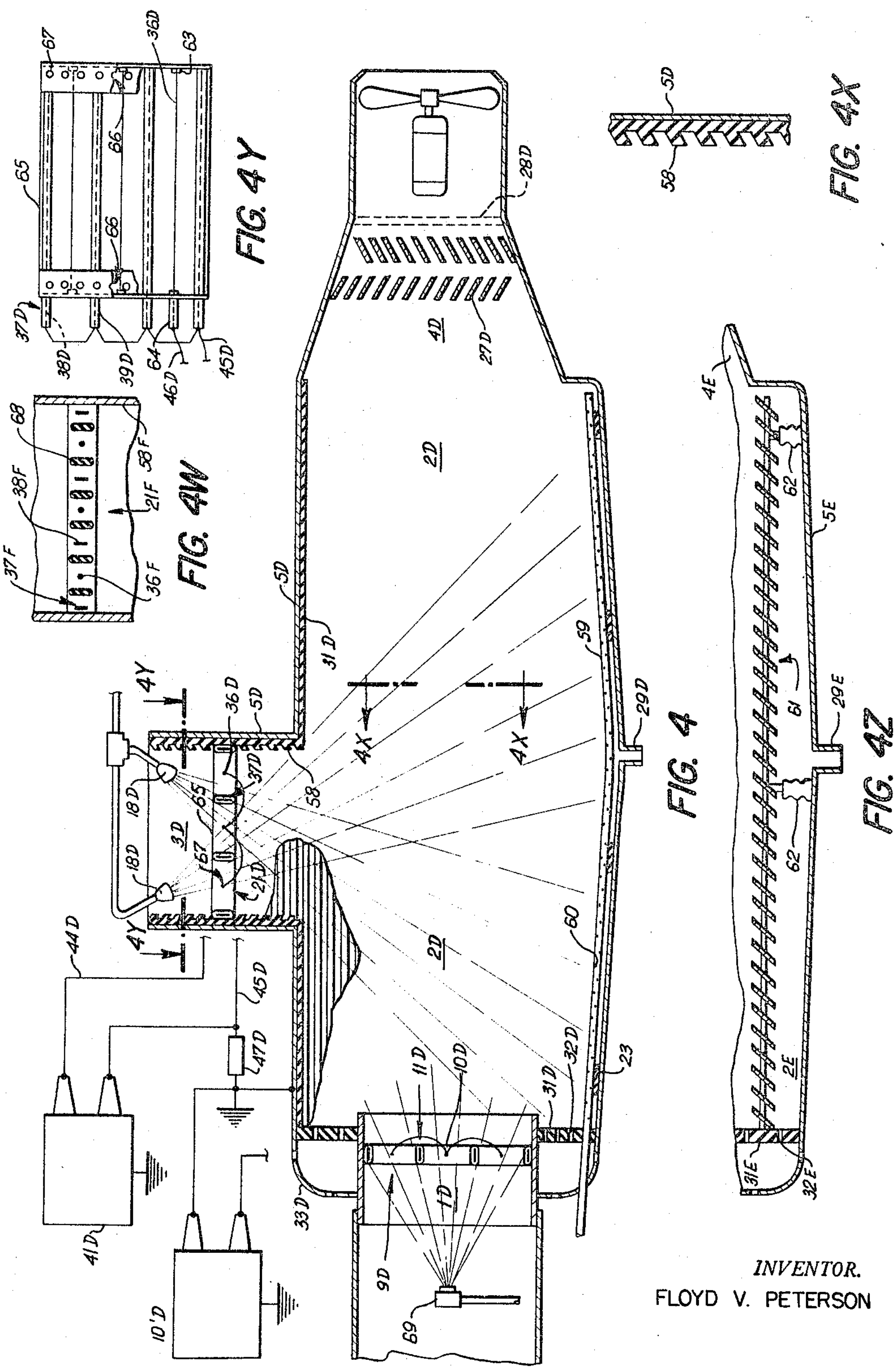

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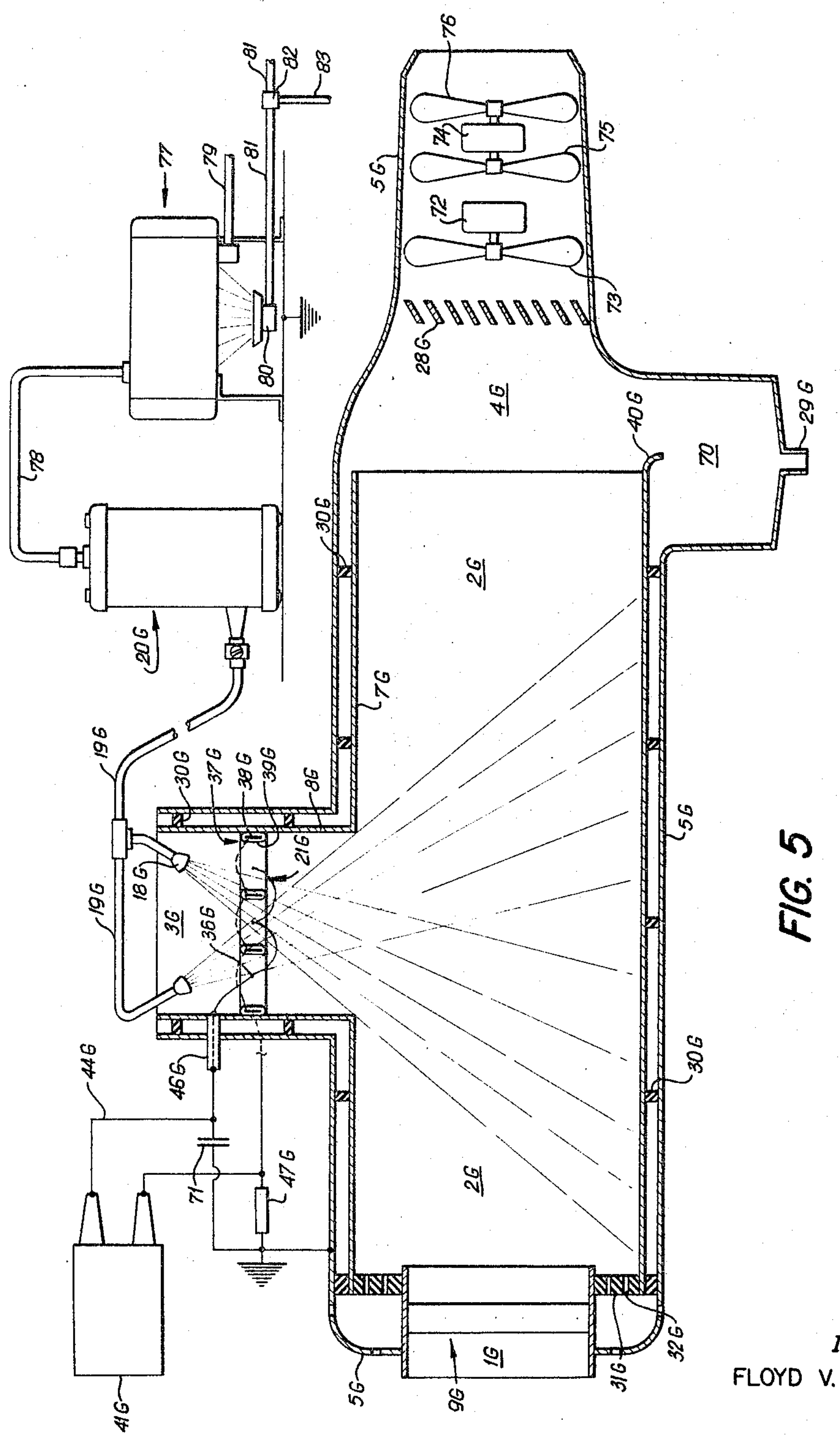

FIG. 5

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United States Patent Office

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ELECTRICAL PRECIPITATOR APPARATUS OF THE LIQUID SPRAY TYPE

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Original application Oct. 14, 1963, Ser. No. 316,097. Divided and this application Mar. 30, 1966, Ser. No. 538,845

8 Claims. (Cl. 55—107)

This application comprises a division of my co-pending patent application for Electrical Precipitator Apparatus of the Liquid Spray Type, Ser. No. 316,097, which was filed on Oct. 14, 1963, now abandoned.

Generally speaking, the present invention relates to electrical or electrostatic precipitators of the liquid spray type cooperable for removing particles of foreign or extraneous material from gas. More particularly, the present invention relates to improved precipitator apparatus of this general type adapted to remove particles of foreign or extraneous material, such as dust particles, suspended solids, foreign or undesired gases, or the like, from air or any other gas which is to be cleaned.

In a patent issued to me on Aug. 16, 1960, as U.S. Patent No. 2,949,168, covering Electrical Precipitator Apparatus of the Liquid Spray Type, I disclosed improved apparatus for the purpose of cleaning dust or other foreign or extraneous particles from gases.

In the present patent application I have disclosed apparatus which operates generally in accordance with the principles of the precipitator apparatus disclosed in my aforesaid patent and which has many of its advantages, but which also has additional advantages and certain advanced operating features.

Thus, an important object of this invention is to provide new and improved embodiments of electrical precipitator apparatus of the liquid spray type.

Another object of this invention is to provide improvements in certain of the operating features integrated with the precipitator system.

Another object of this invention is to provide for a certain degree of air cooling and controlled heating as well as air cleaning in connection with air conditioning in such precipitator apparatus.

Other and allied objects will become apparent to those skilled in the art after careful study of the present invention.

Thus this invention essentially covers improved apparatus for operation in conjunction with, or as a part of, precipitator systems which are in general comprised of the following component parts:

(1) A gas duct means cooperable to transmit gas therethrough, including an input portion, a mixing portion having special inner and outer wall construction, and an output portion.

(2) First ionizing means located at the input portion of said gas duct means for the purpose of ionizing the foreign particles in the gas to be cleaned.

(3) A liquid spray chamber of special construction, with liquid spray heads located within or upon said spray chamber and with specially constructed second ionizing means located within spray chamber for ionizing the liquid spray which is dispersed into the mixing portion of said gas duct means.

(4) A fan or other arrangement for forcing or drawing the gas to be cleaned through said gas duct means.

(5) Means for condensing and draining away the commingled liquid spray and foreign particles.

(6) Power supply sources to provide the proper voltage to each of the two ionizing means.

(7) A liquid transmissive but electric current non-

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transmissive path to ground for liquid that may be incidentally condensed in the precipitator mixing portion.

As set forth in my aforesaid Patent No. 2,949,168 referred to above, the provision of certain insulation between the discharging and non-discharging electrodes of the liquid spray ionizing means together with the specially constructed mixing portion and spray chamber, confine the power supplied to the liquid spray ionizing means to useful work within the precipitator enclosure, and precludes against undesirable voltage breakdowns and flashovers therein.

The spray liquid may be ordinary tap water which is suitable and desirable in most instances, although any spray liquid may be used unless unsuitable for such reasons as being rather explosive or too volatile.

FIGURES 1, 2, 3, 4, and 5, each show illustrative embodiments of the present invention with portions thereof in vertical section, with certain portions removed for clarity, and with certain portions in diagrammatic and/or schematic form.

FIG. 1 is a view of one exemplary embodiment of the present invention with the gas duct means and spray chamber means thereof in longitudinal central section and with other associated portions of the apparatus being shown partially in electrical schematic form and partially in block diagrammatic form.

FIG. 1X is an enlarged sectional view through the spray chamber means taken in the direction of the arrows 1X—1X of FIG. 1 showing the ionizing means in elevation and with all portions of the gas duct means behind the plane of the section removed for purposes of drawing simplification.

FIG. 2 is a fragmentary longitudinal sectional view generally similar to FIG. 1, but illustrating a modified form of the invention embodying a different type of spray chamber means.

FIG. 2X is a fragmentary longitudinal sectional view of the embodiment of the invention illustrated in FIG. 2 taken along a longitudinal plane substantially at right angles to the plane of the section comprising FIG. 2. This view also shows in fragmentary, partially block diagrammatic and partially electrical schematic form certain associated elements of this modification of the invention.

FIG. 3 is a fragmentary longitudinal sectional view very similar to FIG. 2, but shows another modification of the invention having a different type of spray chamber means.

FIG. 3X is a fragmentary, enlarged, central sectional view of the specific embodiment of the modified spray chamber means shown in FIG. 3.

FIG. 3Y is a bottom plan view of another modification of the spray chamber means shown in FIGS. 3 and 3X, this modification being shown fragmentarily and in vertical section in FIG. 3Z.

FIG. 3Z is a fragmentary, vertical sectional view of the modified form of spray chamber means illustrated in FIG. 3Y in bottom plan view.

FIG. 4 is a fragmentary longitudinal central sectional view generally similar to FIG. 1, but illustrating another modified form of the invention, and with a small portion of the channelled vertical insulating walls thereof shown in elevation and with the rest broken away for reasons of drawing simplification. This modification of the invention has a different type of spray chamber means which also has the above-mentioned liquid-transmissive but electric current non-transmissive channelled vertical insulating walls (shown in fragmentary form in this view and shown fragmentarily in cross-section in FIG. 4X).

FIG. 4X is a fragmentary cross-section of one of the channelled vertical insulating walls of the modified precipitator shown in FIG. 4 (which is shown broken away in

FIG. 4) taken in the plane indicated by the arrows 4X—4X of the precipitator embodying the complete vertically channelled walls. In other words, FIG. 4X merely indicates the plane of the section as taken in a precipitator which does not have its vertical channelled walls broken away as shown in FIG. 4 for purposes of drawing simplification.

FIG. 4Y is a view generally similar to FIG. 1X, but with the walls of the spray chamber means removed for drawing simplification purposes. This view fragmentarily shows the modified ionizing means of FIG. 4 in elevation.

FIG. 4W is a fragmentary sectional view of another modified form of ionizing means and a portion of the spray chamber means mounting same viewed from the same position as the ionizing means shown in FIG. 4.

FIG. 4Z is a fragmentary sectional view similar to the bottom portion of FIG. 4 and illustrates a modified form of means for effectively insulating the suspended spray and foreign particles in the mixing chamber from the conductive material of the drain aperture.

FIG. 5 is a longitudinal sectional view very similar to FIG. 4, but illustrates a modified form of the invention with a different type of spray chamber means, a different type of condenser-type precipitator means, and a different type of liquid transmissive but electric current non-transmissive means to allow egress of condensed liquid and foreign particles from within the interior of the precipitator.

Referring to FIG. 1, a precipitator enclosure comprises four tubular sections or chambers: An input portion **1**, a mixing portion **2**, an output portion **4**, and a spray chamber **3**. A grounded electrically conductive shield or casing **5** generally encompasses the overall precipitator and constitutes the outer wall of the same. A conduit **6** generally comprises input portion **1**. Portions **2** and **3** have inner linings **7** and **8** respectively, which are shown in FIG. 1 as being made of electrically conductive material. It should be understood that in certain forms of the invention, one of which is illustrated in FIG. 4, said inner linings may be made of electrical insulating material, as will be described more fully hereinafter.

In the FIG. 1 precipitator arrangement, the air or gas to be cleaned is forced through sections **1**, **2**, and **4** by the gas pressure at the input portion. However, said gas can also properly be drawn through the precipitator by a mechanical fan as indicated hereinafter for other embodiments of the precipitator, or drawn through the system by other suitable draft means.

The gas to be cleaned enters section **1** and passes through ionizing means **9** into mixing portion **2**. The dust or foreign particles are electrically charged as they pass through ionizing means **9**, which consists of discharging electrodes **10** alternately spaced between non-discharging electrodes **11**. A voltage is applied between electrodes **10** and **11** of about 10,000 volts D.C. or more (depending upon electrical insulating conditions and electrode spacing) by means of power supply **10'**. The power supply connection is made to electrodes **10** by lead **12** which passes through insulator **13** located in recessed chamber **14**; the other lead **15** being similarly connected (not shown in detail) between the power supply **10'** and the non-discharging electrodes **11**, which may be of the type shown in greater detail at **37** in FIG. 1X specifically illustrating the other ionizing means **21**. As indicated, one end of chamber **14** is open and extends into the interior of the precipitator. The opposite end of chamber **14** is closed except for its opening into tube **16** which is attached thereto. A small blower or other suitable air pressure means, such as is indicated diagrammatically at **17**, is used to force relatively clean air through tube **16** into container **14** and thence into mixing portion **2** at a relatively slow rate. The movement of the air around insulator **13** prevents moisture and debris from being deposited on it and thus aids in keeping said insulator clean and generally free of electrical flashovers.

Spray heads **18** located within spray chamber **3** are supplied liquid through piping **19** from a source of liquid under pressure indicated diagrammatically at **20**. The liquid spray emitted from spray heads **18** passes through ionizing means **21** where the spray droplets are electrically charged at a polarity opposite that of the dust or foreign particles, and the spray particles then pass into mixing portion **2**.

A blower or other applicable air pressure means, such as is indicated diagrammatically at **22**, is used to force air through tube **23** attached to cap **24**, through perforations **25** provided in cover plate **26**, and thence through spray chamber **3** into the mixing portion **2**. This air movement helps carry the spray particles into said mixing portion. As an alternate method, the same results could be obtained by integrating an air jet with each spray head **18**, similar to the arrangement used in the well known atomizing sprayer, in order to help disperse and carry the liquid spray into the mixing portion.

As the air or gas to be cleaned passes through section **2** the electrically charged foreign particles attach themselves to the oppositely charged spray droplets emitted from spray chamber **3**, and are carried into output section **4**. The spray droplets with the attached foreign particles strike against baffle plates **27** and **28** in section **4** and are condensed and drained away through drain pipe **29**.

Various means are provided to preclude against undesirable electrical flashovers within the precipitator enclosure, some of which are the same or similar to the means provided in the apparatus disclosed in my aforesaid Patent No. 2,949,168, referred to above. These include inner wall **7** of mixing chamber **2**, inner wall **8** of spray chamber **3**, and certain special construction features of ionizing means **21**. Inner walls **7** and **8** are insulated and isolated from other portions of the precipitator by standoff insulators **30** and insulating material **31**, which is equipped with small holes **32** for the ingress of clean air into section **2**, to aid in keeping insulator material **31** clean on the inside of the precipitator. Cap **33** fits over insulating material **31** and around input portion **1**, and the air is forced through holes **32** at a rather slow rate by means of a blower or other suitable air pressure means, such as is indicated diagrammatically at **34**, connected to the tube **35**.

Ionizing means **21** consists of alternately spaced discharging electrodes **36**, and non-discharging electrodes **37** which comprise electrically conductive strips or rods **38** with electrical insulation **39** applied to the exterior surface thereof (see the plan view of ionizing means **21** shown in FIG. IX). The electrical isolation of said inner walls and the application of insulation **39** to electrodes **38**, precludes against the ionized spray particles migrating to grounded parts of the precipitator and losing their charge thereon before they usefully perform their intended function in the precipitating action. Furthermore, the application of insulation **39** on the exterior surface of said non-discharging electrodes precludes against possible electrical flashovers in the spacial path between the discharging and non-discharging electrodes.

The lower portion of inner lining **7** is extruded and somewhat rippled, such as indicated at **40**, or otherwise arranged to provide a drip means so that whatever liquid spray is condensed on the inside surface of inner lining **7** will be fairly well broken up and will fall in droplets a moderate distance in order to offer an electric current non-transmissive path to ground for such condensed liquid.

Power supply **41** supplies D.C. voltage to ionizing means **21** at a voltage of about 10,000 volts or higher. The greater the voltage, within practical limits, the farther apart it is possible to space said discharging and non-discharging electrodes to produce an ionizing field of suitable intensity. Terminals **42** and **43** of power supply **41** are connected directly to the discharging and non-discharging electrodes of ionizing means **21** through leads **44**, **45**, and insulating bushing **46**. A current limiting means **47** is connected in series with an electrical lead **48** which connects from ground to terminal **43** of power supply **41**. With this arrangement, full operating voltage is applied across the electrodes of ionizing means **21** at all times to give best ionizing results, and at the same time the current supplied to the precipitator from power supply **41** is regulated by unit **47** to give more stable precipitator operation. Unit **47** may be a resistor, a vacuum tube current regulator or some other suitable current limiting means.

Voltage divider or potentiometer **49** is connected from terminal **42** of power supply **41** to ground, with its third terminal connected to inner lining **7** through insulating bushing **50**. By means of adjusting the movable contact arm of the potentiometer **49**, the inner lining **7** is electrically biased with respect to ground at a suitable voltage, which in general would be near or somewhat below that of discharging electrodes **36**. This arrangement will help preclude against the electrically charged spray droplets migrating to said inner lining **7**, since they bear an electrical charge of like polarity. Also, the potentiometer serves as a leakage path to ground for extraneous electrostatic charges occurring in the precipitator. Condenser **51** is a by-pass to ground for stray currents that might cause radio or video interference.

It should be noted that in cases where air or gas to be cleaned is drawn through a precipitator by suction applied to the output portion such as by a fan, or the like (such a fan being illustrated in FIGS. 2, 3, 4, and 5), the means for providing ingress of air to the ionizing means in the spray chamber means may be modified by eliminating the cap, tube, and blower or air pressure means, since air may be drawn through perforations, such as those shown at **25**, by the action of such a suction fan in the output portion of the precipitator, thereby to aid in carrying spray particles into the mixing portion.

FIGURES 2 and 2X illustrate another embodiment of the present invention, which is generally similar to the FIG. 1 arrangement except for the location and construction of the spray chamber means.

Referring to FIGS. 2 and 2X, a precipitator gas duct means comprises three tubular sections or chambers: an input portion **1A**, a mixing portion **2A**, and an output portion **4A**. A spray chamber **3A** is located within section **2A** in a manner so that chamber **3A** is accessible from the opposite sides of mixing section **2A**. A space is provided between the other two sides of spray chamber **3A** and the inner lining **7A** of mixing section **2A** for the debris laden gas to pass.

A grounded electrically conductive shield or casing **5A** generally encompasses the overall precipitator and constitutes the outer wall of the same.

As in FIGURE 1, the gas to be cleaned enters section **1A** and the foreign particles are electrically charged as they pass through ionizing means **9A** into mixing section **2A**.

Spray heads **18A** located within spray chamber **3A** emit the liquid spray through ionizing means **21A** and thence into mixing section **2A**. Said liquid spray is electrically charged at a polarity opposite that of the foreign particles as the spray passes through ionizing means **21A**, which consists of an electrode arrangement similar to that shown at **21** and described in reference to FIGS. 1 and 1X.

The electrically charged foreign particles attach themselves to the oppositely charged spray droplets in mixing section 2A and the mingled spray and foreign particles are carried into output portion 4A. Therein they strike against baffle plates 27A and 28A and are condensed and drained away through drain pipe 29A. Like means are provided to preclude against undesirable selectrical flash-overs within the precipitator enclosure of FIGS. 2 and 2X as explained in reference to FIG. 1, except for the somewhat different spray chamber arrangement. Mixing section **2A** is provided with an inner lining **7A**, and the liquid spray ionizing means **21A** comprises discharging electrodes **36A**, and non-discharging electrodes **37A** insulated on the exterior surface, similar to the FIG. 1 arrangement.

Spray chamber **3A** is provided with an open bottom wherein the spray ionizing means **21A** is located. Said spray chamber has walls **8A** comprised of electrical conductive material coated overall inside and out with electrical insulation. The conductive material of spray chamber **3A** is electrically grounded outside the precipitator enclosure, as indicated. Spray heads **18A** and spray means **52** are supplied liquid by piping **19A**, which is comprised of electrical insulating material. Spray means **52** consists of an elongated enclosure with openings along its entire length for emitting a spray to keep the top of item **8A** clean. Piping **19A** is supplied liquid through liquid transmissive but electric current non-transmissive apparatus (not shown in FIGS. 2 and 2X, but of any suitable type, such as specifically disclosed in my Patent No. 2,949,168 referred to above and in Patent No. 3,098,890, issued to me on July 29, 1963, for Liquid Transmissive and Electric Current Non-Transmissive Apparatus).

A similar spray arrangement that is supplied liquid from such a liquid transmissive but electric current non-transmissive source may be aptly used for cleaning other parts of the precipitator which are electrically isolated or which operate above ground potential. However, auxiliary cleaning means are generally not needed for most parts of the precipitator system.

The precipitator arrangement shown in FIGS. 2 and 2X has a drip means **40A** provided on the lower part of inner lining **7A**, electric power is supplied to the two ionizing means of the precipitator, and a current limiting means **47A** is provided the same as item **47** described in reference to FIG. 1.

Inner lining 7A is comprised of electrically conductive material. Resistor **49A** is connected from inner lining **7A** to ground through insulator **50A**. Resistor **49A** serves as a leakage path to ground for extraneous electrostatic charges that may occur within the precipitator. Condenser **51A** serves as a by-pass to ground for possible radio or video interference resulting from the use of resistor **49A**.

FIG. 3 shows another embodiment of the present invention wherein the gas duct means operates in the vertical position. In this embodiment, the precipitator enclosure is comprised of three sections or chambers: input portion **1B**, mixing portion **22**, and output portion **4B**. A grounded electrically conductive shield or casing **5B** generally encompasses the overall precipitator and constitutes the outer wall of the same. Mixing portion **2B** is provided with inner lining **7B** which is electrically insulated from other portions of the precipitator by means of stand-off insulators **30B** and electrical sheet insulation **31B** provided with air ingress holes **32B**.

The foreign particles in the gas stream are electrically charged by ionizing means **9B** located within input portion **1B**.

Liquid spray particles are emitted from within spray-ionizing means 3B (hereinafter described), and they are therein electrically charged at a polarity opposite to that of said foreign particles, and are thence dispersed into mixing portion 2B.

The oppositely charged spray and foreign particles combine in mixing portion 2B and the co-mingled particles are carried in the gas stream into output portion **4B**, where said particles are condensed by striking against baffle plates **27B** and **28B** and are then drained away through drain-pipe **29B**.

Spray-ionizing means 3B is a compact and effective arrangement for dispersing and electrically charging a liquid spray. FIG. 3X is an enlarged view, generally in cross-section, which depicts the various details of item 3B. Said spray-ionizing means comprises an outer shell or open end container 8B which is composed of electrical conductive material **53**, coated overall with electrical insulation **54**. A plate or support member **26B** is fastened within container 3B, as indicated. Discharging electrode assembly **55** and spray heads (or nozzles) **18B** are mounted upon said member **26B**. Container 8B serves a dual purpose of as a spray chamber and non-discharging electrode means. Discharging electrode assembly **55** consists of fine wire **36B** wound on supporting form **56**. Said fine wire **36B** is electrically connected to spray heads **18B**. Assembly **55** could also suitably comprise other types of discharging electrodes, such as a multiple arrangement of points or an array of sharp edged rings properly supported. About 10,000 volts D.C. (or more depending upon the electrode spacing and electrical insulating characteristics) is applied across electrode means **55** and container 8B from power supply **41B**, through metallic tubing **19B** and conductor **45B**, each of which is provided with electrical insulation on its exterior surface. Said applied voltage establishes an effective electrostatic ionizing field between discharging electrode means **55** and the inner wall of container 8B, which electrically charges the liquid spray particles as they are dispersed from spray heads **18B** into mixing portion **2B**. Spray liquid is supplied to spray heads **18B** under pressure through tubing **19B**, which in turn is supplied spray liquid through liquid transmissive but electric current non-transmissive apparatus (not shown, but of any suitable type, such as specifically disclosed in my above-identified patents). Tubing **23B** is provided which is composed of electrical insulating material. This tubing supplies relatively clean air from outside the precipitator, which moves through openings **25B** to the area around spray heads **18B** and into mixing section **2B**. Said air movement helps carry the spray particles into section **2B**, which is especially desirable where the spray particles are relatively minute. Said air movement may result from the draft inside mixing portion **2B** or from a blower or other pressure means applied to tubing **23B** outside the precipitator enclosure.

Recessed containers R and R′ with perforations P and P′, respectively, are provided for keeping the insulation clean on tubing **19B** and conductor **45B** where they pass through the precipitator walls.

FIGS. 3Y and 3Z illustrate a spray-ionizing means of the same general type as indicated in FIG. 3X except with a more extensive electrode arrangement. Referring to FIGS. 3Y and 3Z, discharging electrode means **36C** is spaced between the inner wall of container **8C**, which serves as one non-discharging electrode, and the outer wall of cylinder **56C**, which serves as a second non-discharging electrode. Cylinder **56C** is comprised of electrically conductive material coated overall with electrical insulation. It is electrically connected to container **8C** by means of lead **57**.

The FIG. 3 precipitator embodiment has a liquid drip means **40*b*** provided on the lower part of inner lining **7B**, and it is also provided with a current limiting means **47B**, the same as item **47** described in reference to FIG. 1.

A leakage resistor **49B** and by-pass condenser **51B** are provided, which serve the same purposes as explained above in reference to FIG. 2.

FIGURE 4 shows a precipitator system in which the gas duct means operates in the horizontal position, with the spray chamber located above said duct means. The precipitator enclosure comprises four generally tubular sections or chambers, an input portion **1D**, a mixing portion **2D**, an output portion **4D**, and a spray chamber **3D**. A grounded electrically conductive shield or casing **5D** generally encompasses the overall precipitator and serves as its outer wall.

The foreign particles in the gas to be cleaned are electrically charged as they pass through ionizing means **9D**, located within input portion **1D**, and said particles combine with the oppositely charged spray particles in mixing section **2D**. The co-mingled spray and foreign particles in the gas stream are then carried into output portion **4D**, where they are condensed and then drained away through drainpipe **29D** located in the bottom of section **2D**.

Voltage is applied to each of the ionizing means and a current limiting means **47D** is provided the same as item **47** explained in reference to FIG. 1.

The new and novel embodiments of the FIG. 4 system include the manner of insulating the interior vertical walls of mixing section **2D** and spray chamber **3D**, also the method of providing an electrical insulating means at the bottom of mixing section **2D**. There are two different methods described hereinafter for insulating the bottom of section **2D**.

The interior of the vertical walls of sections **2D** and **3D** are lined with a specially designed electrical insulating material **56** except for the front wall of section **2D**. The top and front walls of section **2D** are composed of electrical sheet insulation **31D**. Perforations **32D** are provided in said front wall for the ingress of clean air to aid in keeping the interior of the insulation clean.

As indicated best in FIG. 4X, material **58** is channelled horizontally to provide a "skirt insulator" effect. After fabrication, the overall channelled surface has a material applied to it which has little affinity for the liquid spray used, such as certain silicone paints where the spray liquid is water.

Most spray liquids that are suitable in general for spray purposes (including ordinary tap water) will break up into droplets when running a short distance down a vertical wall lined with said channelled material, and the upper part of the channels at least will stay substantially dry. Thus material **58** provides an essentially electric current non-transmissive path between vertical points on such a wall, when said points are separated by at least a few channels, even with the condensed spray liquid running down the walls.

One method of providing an insulating means at the bottom of mixing section **2D** is by laying a network of perforated pipe or closed channel **59** over the entire bottom surface if said section so relatively clean air is drawn through the perforations **60** in the pipe **59** from outside the precipitator. In case suitable draft is not available within the precipitator, a blower or other pressure means is used to force the air from the outside through said perforations in a manner similar to that described and illustrated hereinbefore.

The constant ingress of air into the bottom of mixing section **2D** will maintain a layer of air which will serve as an electrical insulating layer between the bottom of section **2D** and the gas stream which carries the suspended spray and foreign particles through the precipitator. Hence a liquid transmissive but electric current non-transmissive path is maintained between said gas stream and the bottom of section **2D**.

FIGURE 4Z depicts an alternate method for providing an insulating means at the bottom of section **2E** in lieu of controlled ingress of air. An array of baffle plates **61** is provided as indicated, and is supported somewhat above the bottom of section **2E** by insulation **31E** at one end and by pedestal insulators **62** at several other points. The gas stream with the associated spray and foreign particles suspended therein will ride over plate assembly **61** as it passes to output portion **4E** so that a liquid transmissive but electric current non-transmissive path is maintained between said gas stream and the bottom of mixing section **2E**.

The co-mingled spray and foreign particles which are condensed in output portion **4E** will drain back beneath piping **59** or plate assembly **61**, whichever is used, over to drainpipe **29D** or **29E** located in sections **2D** or **2E**, respectively, where the conglomeration is drained away.

FIG. 4Y is a sectional view through spray chamber **3D** showing a plan view of ionizing means **21D**. Said ionizing means consists of discharging electrodes **36D**, support insulators 63, through type insulator 64; non-discharging electrodes 37D consisting of conductive strips 38D provided with exterior insulation 39D; and framework 65 which has a recessed chamber 66 at each end provided with perforations 67. Said perforations allow the ingress of clean air to aid in keeping the electrode supports clean. In cases where the gas is forced through a precipitator enclosure so that the pressure is greater inside than outside the precipitator, caps may be placed over the openings such as perforations 67. Then clean air may be supplied to the caps through tubes from a blower or other suitable air pressure means and forced through said openings to aid in keeping the insulator supports clean.

FIG. 4W shows a cross-sectional view of another possible arrangement for ionizing means 21F. Discharging electrodes 36F consist of fine wires or other conventional type discharging electrodes alternately spaced between non-discharging electrodes 37F, which consist of metallic rods or plates. Strips of electrical insulation 68 are located between the discharging and non-discharging electrodes and run the full length of the same. Flow space is provided, as indicated, between the various electrodes and between the electrodes and insulating strips 68. Said strips 68 increase the length of the possibile electrical flashover path between the discharging and non-discharging electrodes, and thus help prevent flashovers between these electrodes. The insulating supports for the ends of the discharging and non-discharging electrodes and for insulating strips 68 may be kept clean by being located in recessed chambers similar to those depicted at 66 in FIG. 4Y.

Electrically charged spray particles will tend to collect upon the insulation 39D of the non-discharging electrodes 37D of the ionizing means 21D, or upon the insulating strips 68 where the alternate ionizing arrangement is used, such as shown in FIG. 4W, which will lower the ionizing efficiency of the ionizing means. There are many ways to offset this undesirable effect such as vibrating or rapping the electrodes and the insulating strip assemblies, blowing streams of air upon them, or coating said items with a material having low affinity for the liquid spray used.

FIG. 4Y, referred to above, is typical also of the ionizing means 9D, which comprises discharging electrodes 10D, and non-discharging electrodes 11D, which are also provided with electrical insulation on the exterior surface. The common lead of electrodes 11D is connected to ground.

Spray heads 18D and 69 are each supplied spray liquid through separate liquid transmissive but electric current non-transmissive apparatus.

Spray head means 69 serve to keep ionizing apparatus 9D clean.

FIG. 5 shows a further embodiment of the present invention together with certain apparatus used in connection with the system.

The FIG. 5 precipitator enclosure comprises five sections or chambers: input portion 1G, mixing portion 2G, spray chamber 3G, output portion 4G, and discharge portion 70. A grounded electrically conductive casing 50 generally encompasses the overall precipitator and serves as its outer casing.

Ionizing means 9G, located in the input portion, may be any generally suitable means for ionizing foreign particles in a gas stream. Thus it is indicated as to approximate size and location only.

The spray and foreign particles are electrically charged, intermixed, and carried within the gas stream to output portion 4G the same as explained above in reference to the FIG. 4 arrangement.

A current limiting means 47G is provided which operates the same as 47 explained in reference to FIG. 1. In the FIG. 5 embodiment, inner lining 7G of mixing section 2G and inner lining 8G of spray chamber 3G are composed of electrical conductive material. They are connected together and insulated from other portions of the precipitator by means of stand-off insulators 30G, and sheet insulation 31G which is provided with perforations 32G.

As disclosed in previously described embodiments of this invention, the liquid spray ionizing means 21G comprises discharging electrodes 36G alternately spaced between non-discharging electrodes 37G which are comprised of conductive strips 38G with exterior insulation 39G. The conductive strips 38G are electrically connected together outside of spray chamber 3G. Discharging electrodes 36G are spanned across spray chamber 3G and are connected to inner wall 8G of said chamber. Power supply 41G is connected to inner lining 8G by means of lead 44G which passes through insulator 46G. Condenser 71 is provided as a by-pass to ground for possible radio and video interference.

Since electrodes 36G, inner lining 7G, and inner lining 8G are all connected together and operate at the same applied voltage, a simplified arrangement is provided for the construction and connection of said items. This arrangement serves best where the operating voltage applied to the precipitator is not too high, such as in the neighborhood of 10,000 volts D.C.

Generally speaking, the same operating conditions can be obtained by biasing inner linings 7G and 8G at a somewhat lower voltage than is applied to discharging electrodes 36G. That is, by applying the voltage to said inner linings by some means such as a voltage divider arrangement, as described above in reference to FIG. 1. When using the lower biasing voltages, corona and extraneous electrical discharges are less liable to occur which may result from possible points, sharp edges and irregularities on inner linings 7G and 8G.

The bottom part of inner lining 7G is sloped to drain into liquid-debris discharge chamber 70. Thus the liquid which is condensed in section 2G runs along the bottom of said section and falls over drip edge 40G into chamber 70 where it is drained away through drainpipe 29G. In the process of running over edge 40G and falling to the bottom of chamber 70, the liquid is broken up sufficiently into droplets to offer an electric current non-transmissive path to ground from edge 40G to the bottom of chamber 70.

A new method is shown in output portion 4G for condensing the co-mingled spray and foreign particles from the gas stream. It consists of a multiple fan or rotating blade arrangement in which two or more sets of blades are used. As indicated, motor 72 drives blade set 73. Motor 74 drives blade sets 75 and 76. Motors 72 and 74 are connected to run in opposite directions. Blade sets 73 and 75 have blade pitches which will tend to force the gas stream back toward baffle plates 28G, or at least beat into the gas stream as they rotate. Blade set 76 is a draft fan which could be replaced by other suitable draft means. It is provided with sufficient draft action to override the opposing action of blade sets 73 and 75 and still provide sufficient draft to draw the gas through the precipitator at the desired rate.

In operation, draft means 76 will draw the gas through the open spaces between blade sets 73 and 75 which will beat into the gas stream passing therethrough which carries the co-mingled spray and foreign particles. Considerable striking and wiping action is thus obtained on the suspended particles by the rotating blades which effectively condense said co-mingled particles.

There are many possible combinations for providing a suitable condensing arrangement using a draft means and "striking blade" means as discussed above. In general, it is well to alternate the direction of rotation of every other blade set means, whether they are used for draft or striking purposes. This will prevent certain of the blade sets from more or less following around rotating gas or air currents set in motion by preceding blade sets, and consequently doing little useful work. However, reversing the direction of rotation of every other blade set calls for a separate motor or some other individual driving means for each blade set, such as gears or belts, which in brief means more complicated equipment.

Also, it should be observed that the position of draft fan **76** might be interchanged with either "striking blade set" **73** or **75** in which case fan **76** would serve to force air between the blades of a "striking fan" in the condensing operation.

The spray liquid is supplied to spray heads **18G** from liquid heating tank **77** through tubing **78** and tank assembly **20G**. Tank means **20G** provides a liquid transmissive path, but an electric current non-transmissive path from spray heads **18G** to ground.

Tank **77** is supplied liquid through pipe line **79**. The liquid is heated by means of burner **80** which is supplied fuel through pipe line **81**. The fuel supply is controlled by means of control valve **82** connected in line **81**. A temperature sensing device (not illustrated in detail since such are well known) may be connected with control valve **82** by means of line **83**. Said sensing means may be a thermostat located in a room supplied air from the output of the subject precipitator, wherein the sensing means operates to modulate or shut off valve **82** by electrical or other control means when the temperature in the room reaches a predetermined point. On the other hand, control valve **82** may be controlled by a sensing means located in tank **77**, which operates to modulate or cut off the fuel supply to burner **80** when the liquid in tank **77** reaches the required temperature.

A similar arrangement can be provided for controlling the temperature in a certain room or in tank **77** when using an electrical heating element in connection with the system instead of a fuel burner. In this case the temperature sensing means would serve to control the energy supplied to the heating element instead of controlling fuel to a burner.

The several precipitator embodiments disclosed herein by FIGS. 1, 2, 3, 4 and 5 together with the associated views, are intended to depict certain possible variations in the precipitator system as a whole. The individual features indicated on the drawings do not necessarily apply only to the embodiment of the invention in which they are shown.

For instance the condensing arrangement shown in the output portion of the FIG. 5 system could just as well be applied to the precipitator systems indicated in FIGS. 1, 2, 3, and 4. The arrangement shown in FIG. 5 for providing controlled heating of the spray liquid could aptly apply to the other precipitator embodiments. A system in which the liquid spray chamber and ionizing means are located within the mixing section as shown in FIGS. 2 and 3 could be properly integrated with the other duct means arrangement of this invention. A "spray-ionizing means" as illustrated in FIGS. 3X, 3Y, and 3Z could properly be located in the spray chamber of either the FIG. 1, 4, or 5 precipitator embodiment and thus replace ionizing means and the associated liquid spray means located in the spray chamber.

Numerous modifications and variations of the present invention will occur to those skilled in the art after a careful study thereof. All such, properly within the basic spirit and scope of the present invention are intended to be included and comprehended herein as fully as if specifically described, and illustrated and claimed herein.

The exact compositions, configurations, constructions, relative positionings, and cooperative relationships of the various component parts of the present invention are *not* critical, and can be modified substantially within the spirit of the present invention.

The embodiments of the present invention specifically described and illustrated herein are exemplary *only*, and are not intended to limit the scope of the present invention, which is to be interpreted in the light of the prior art and the appended claims only, with due consideration for the doctrine of equivalents.

It should be noted that the present invention is directed to various embodiments of electrical precipitator apparatus in complete form and also to subcombinations thereof.

I claim:

1. An electric precipitator of the liquid spray type for removing foreign particles from gas, which includes a chamber having input and output ports and inner and outer walls with at least said inner wall being made of conductive material, means to cause said gas to flow through said chamber from said input to said output port, means associated with said input port for charging said foreign particles in said gas, means for generating a spray of relatively fine particles of liquid and causing said spray to co-mingle with said gas in said chamber, means associated with said spray means for charging said particles of liquid in opposite polarity as compared to the charge of said foreign particles in said gas, electrical insulating means between said inner and outer chamber walls, and means associated with said output port for condensing and precipitating the co-mingled mixture of said spray liquid and said foreign particles and for removing said mixture from said chamber, comprising the combination of: means for locating said means for generating and charging said spray liquid particles within the air path through said chamber, whereby the gas flow space is defined between said liquid particle generating and charging means, said liquid particle generating and charging means taking the form of a hollow conductive shell substantially closed on the end facing said input port and substantially open toward said output port, said conductive shell being further fully covered by a coating of electrical insulations; and means for applying an electrical bias to said inner wall of said chamber independently of the potentials of said outer wall and said conductive shell of said liquid particle generating and charging means.

2. The invention set forth in claim **1** further defined in that said outer shell is of conductive material and is established at ground potential externally of said precipitator.

3. The invention set forth in claim **1** further defined in that said liquid particle generating and charging means has its conductive shell in the shape of a wedge within said chamber thereby to permit gas flow on two opposite sides of said wedge.

4. The invention set forth in claim **1** further defined in that means are provided for electrically biasing the said hollow conductive shell of said liquid particle generating and charging means while maintaining the electrical insulation of said shell with respect to other structural members.

5. The invention set forth in claim **1** further defined in that said inner chamber wall is truncated with respect to said outer wall in the direction in which gravity tends to make said liquid particles fall, and said inner wall is formed about the opening thereby produced in said inner wall, whereby liquid and foreign particle mixture running down said inner wall from condensed spray is broken into separated drops, on its way to said means for removing said mixture from said chamber, thereby to produce a liquid transmissive but electric current non-transmissive means.

6. The invention set forth in claim **1** further defined in that said means for generating said spray of liquid particles is fed by pumping means from the discharge of said condensing and precipitating means; heat exchanger means are provided; and means are included for passing said liquid thus returned through said heat exchanger on its way to said spray means, thereby to combine the ability to change the temperature of the said gas to be cleaned contemporaneously with the filtering action of said precipitator.

7. In an electric precipitator of the liquid spray type for removing foreign particles from gas, which includes a chamber through which gas to be cleaned is passed, means for changing said foreign particles by producing a strong electric field in an initial portion of the gas travel distance within said chamber; means for generating a spray of liquid particles and co-mingling said liquid particles with said gas to be cleaned; means for charging said liquid particles in a polarity opposite to that of the said charged foreign particles by passing said liquid particles through a second strong electric field independent of said field for charging said foreign particles; high voltage sources connected to each of said electric field producing means; and current limiting means in series

with at least one of the connections for one of said electric field producing means and its corresponding high voltage source.

8. The invention set forth in claim 7 further defined in that said current limiting means comprises a resistor.

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