Sept. 17, 1968 D. A. BERGSTROM 3,401,503

ELECTROSTATIC PRECIPITATOR

Filed Oct. 19, 1967

FIG 1

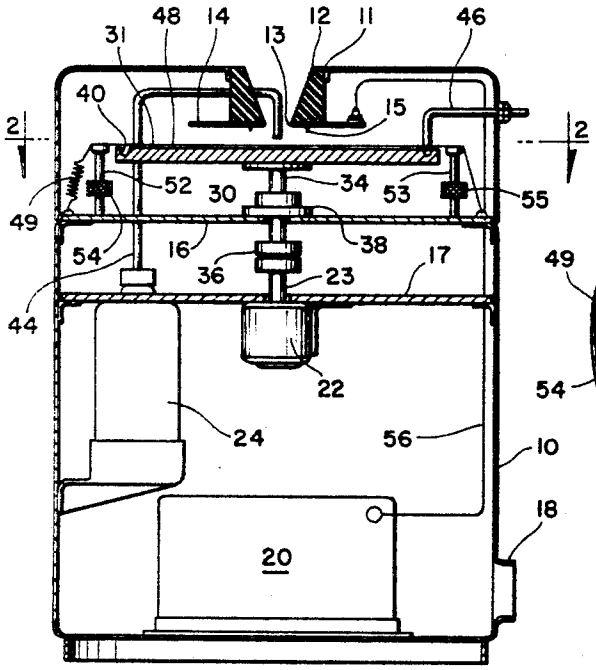


FIG 2

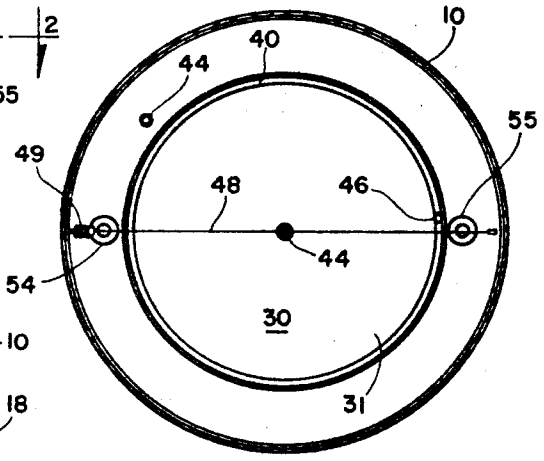


FIG 3

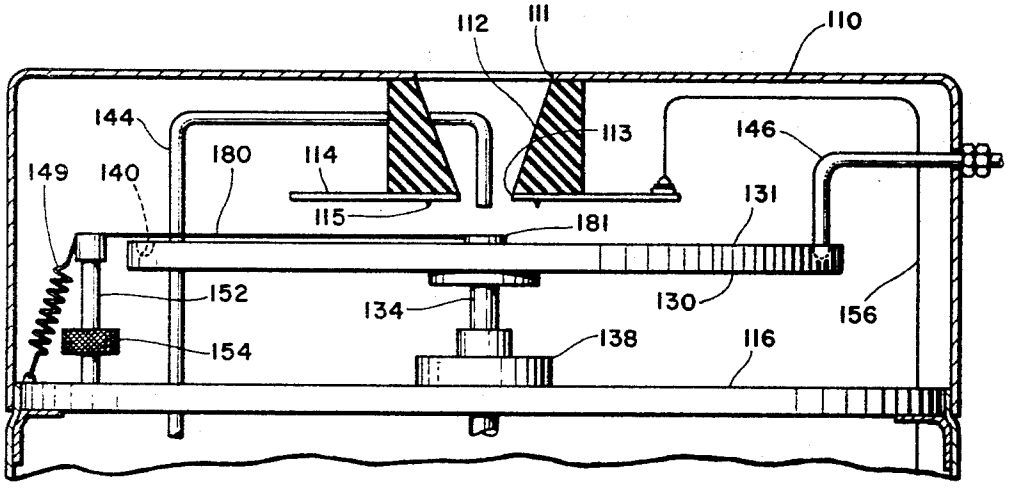
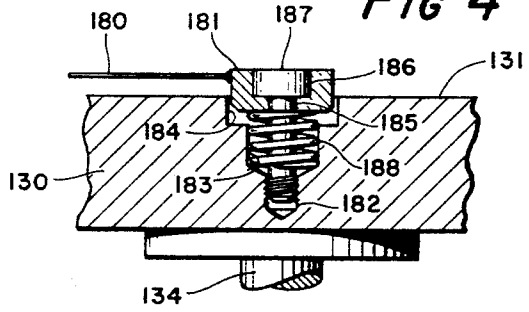


FIG 4



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ELECTROSTATIC PRECIPITATOR

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ABSTRACT OF THE DISCLOSURE

An electrostatic precipitator in which particle laden air is first passed through an electric field where the particles receive an electric charge of one polarity and then passed through another electric field where the charged particles are attracted to an electrode having the opposite polarity. The attracting or collector electrode is a slowly rotating disk over which a film of liquid flows thereon outwardly from the center thereof. The charged particles are electrically precipitated into the moving film of collector liquid and are thereby collected. A stationary wire or line extends across the top surface of the disc in closely spaced relation thereto and at least substantially covers the collector disc with a film of liquid. The collector electrode is provided with an irregular or slightly rough surface.

Background of the invention

This invention relates to improved apparatus for electrostatically precipitating particles from a particle laden air or gas stream into a continuously flowing liquid.

Electrostatic precipitators of the type to which the present invention pertains are common and well known in the art. These precipitators have a mode of operation in which a particle laden air stream or aerosol is passed through a corona field so that the particles receive an electric charge and thereafter the aerosol is passed through an electrostatic field where the charged particles are caused to be electrostatically precipitated onto the surface of a liquid film which flows continuously over the surface of an appropriately charged collector electrode.

In prior art devices, as in the present invention, the collector electrode is in the form of a rotating disk and the collector liquid is applied to the center of the disk from where it flows in a generally radially outward direction over the surface of the disk. In the prior art devices, as distinguished from the present invention, the collector disks are rotated at relatively high speeds on the order of 300 to 2500 r.p.m. and it is the substantial centrifugal force thereby created which is the primary force in causing the radially outwardly flow of the liquid. In those devices having high speed collector disks the surface of the collector disk is made smooth and highly polished to facilitate or insure the complete wetting of the disk and maintenance of a liquid film by the action of the centrifugal force. If the high speed disks have rough or textured surfaces the wetting is not complete because the protrusions cause the liquid to be carried in a tangential instead of radial direction and dry areas result in the downstream areas from the protrusions. A prior art improvement which improved the wetting efficiency consisted of adding a wetting agent to the collector liquid. The collector liquid is normally a liquid such as water, glycerine or inert normal tissue culture media. Polyoxyethylene laurel ether is an example of a wetting agent.

A disadvantage of using a wetting agent occurs when an electrostatic precipitator is used as an air sampler for collecting microorganisms from the air which particles are to be subsequently analyzed and processed. An ideal wetting agent would be chemically of a nature that it would not affect the viability of the collected microorganisms and would effectively perform the wetting function.

As no chemical agent is known which has both of these characteristics to a satisfactory degree, it is highly advantageous if the use of a wetting agent in connection with collecting microorganisms can be avoided.

In the present invention a line, referred to as a distributor line, is stretched partially or wholly across the collector disk of an electrostatic precipitator in closely spaced relation to the disk. The distributor line, which is preferably made of a nonmetallic material such as nylon, functions to spread a collector type liquid such as water or glycerine evenly over the disk without the necessity of adding a wetting agent to the collector liquid. The use of the distributor wire permits the collector disk to be operated at a relatively slow speed such as 25 r.p.m. as compared to 300 to 2500 r.p.m. in prior art devices. The complete wetting of the collector disk is desirable in the precipitator of the present invention, as well as prior art devices, to insure the transport of collected particles to the edge of the disk where the particle laden liquid is collected. It was found that the use of a highly polished collector disk surface in combination with a distributor line and a slowly rotating collector disk gave improved results over the prior art with regard to wetting the surface. It was found, however, that a slightly irregular or textured surface for the collector disk gives even better results than a very smooth, highly polished surface. Thus, in effect, the combination of a distributor line with an irregular collector disk surface permits the collector disk to be operated at a small fraction of the speed of a highly polished disk without the use of a distributor line.

Advantages resulting from the use of a slow speed collector disk are that a smaller motor may be used for driving the disk and the elimination of the splashing that accompanies the use of a high speed disk. The splashing is undesirable because it is conducive to arcing between the electrodes and it tends to cause a particle residue buildup in various parts of the machine including the region of the corona needles which will be referred to further on.

Summary of the invention

A main object of the invention is to provide a new and improved electrostatic precipitator in which particles collected by the collector disk are efficiently transported to the peripheral edge of the disk.

Another object of the invention is to provide an electrostatic precipitator which includes novel means for effecting the efficient transport of collected particles to the peripheral edge of the collector disk while permitting the collector disk to be operated at a relatively slow speed. Related objects of the invention based on satisfactory performance and effective operation being attained with a relatively slowly rotating collector disk are the facilitation of the use of a correspondingly smaller motor for driving the collector disk, the elimination of splashing of the collector liquid caused by the substantial centrifugal force imparted to the collector liquid by a high speed collector disk, and the elimination of arcing between the electrodes and the elimination of particle residue buildup which are associated with a splashing collector liquid.

Another object of the invention is to provide a new and improved electrostatic precipitator having novel means associated therewith which facilitates satisfactory performance while operating the collector disk at a speed on the order of ten percent or less of the speed of collector disks in comparable prior art precipitators.

Another object of the invention is to provide an electrostatic precipitator having novel means for distributing a collector liquid over the collector disk which includes a distributor wire and a textured or roughened surface for the collector disk. Related objects based on the above

mentioned novel means are the facilitation of a relatively small motor for driving the collector disk, a quiescent or non-splashing flow of collector liquid over the collector disk, the effective wetting of the collector disk surface without the addition of a wetting agent to the collector liquid, and the avoidance of contamination of the particles collected by reason of eliminating the use of a wetting agent and hence the avoidance of adversely affecting the viability of microorganisms collected by reason of exposure to a wetting agent in the collector liquid.

Other objects and advantages of the invention will become apparent from the following specification, drawings and appended claims.

Description of the drawings

In the drawings:

FIG. 1 is an elevational sectional view of an electrostatic precipitator which incorporates a first embodiment of the invention;

FIG. 2 is a sectional view taken on line 2—2 of FIG. 1;

FIG. 3 is a fragmentary elevational sectional view of an electrostatic precipitator which incorporates a second embodiment of the invention; and

FIG. 4 is an enlarged fragmentary sectional view of a portion of the apparatus shown in FIG. 3.

Description of the disclosed embodiment

Referring to the drawings, FIGS. 1 and 2 show an electrostatic precipitator in which one embodiment of the invention incorporated therein is illustrated. The precipitator has a housing which comprises a cylindrically shaped container **10** which may be made of a metal such as aluminum or from some other suitable material. The top of container **10** has a central opening **11** and an inwardly converging nozzle **12**, having a lower circular opening **13**, is attached to the container for admitting a particle laden air stream or aerosol into the container through the nozzle. Although a particle laden "air" stream is referred to herein for convenience, it will be understood that the invention is applicable to the separating of particles from a stream of any kind of gas admitted through the nozzle **12**.

An annularly shaped metal plate **14** for receiving an electrostatic charge is attached to the bottom of the nozzle **12** with the plate opening being aligned with the nozzle **13** to permit an air stream to flow therethrough. Nozzle **12** is illustrated as being made of an electrical insulating material but may be made from a conducting material if insulating means is provided to either insulate the nozzle from the container **10** or insulate the conducting plate **14** from the nozzle. A number of needles **15** are attached to the lower side of plate **14** with the needles being symmetrically arranged in surrounding relation to the nozzle opening **13**. The ring of needles **15** emits a corona sheath and particles in the air stream passing through this corona sheath are electrically charged.

Disposed within container **10** are two spaced apart platforms **16** and **17** which divide the container generally into upper, middle and lower chambers and which are utilized for mounting various parts of the apparatus. An outlet **18** for container **10** is provided in the region of the lower chamber to which a suction pump or fan (not shown) may be attached. The withdrawal or suction of air or other gas from the lower chamber of the container **10** creates a suction which will cause a particle laden air stream to be drawn into the container through the nozzle opening **13**. Suitable holes or perforations, not shown, are provided in the platforms **16** and **17** so as to not appreciably impede the flow of air or other gas from the nozzle opening **13** to the outlet **18**.

In the lower chamber of container **10** there is disposed and mounted a high voltage rectifier which constitutes a direct current power supply unit **20**. Mounted in a central location to and under the platform **17**, on one side of the motor **22**, is a collector fluid reservoir **24**.

A rotatable collector plate or disk **30** having a generally flat upper surface **31** in spaced relation to conductor plate **14** and the ring of needles **15** is disposed in the upper chamber of the container and is supported by a shaft **34** attached thereto. The spacing between conductor plate **14** and collector plate **30** may be in the range of about one-half to three-fourths of an inch but this dimension has to do with design considerations which are not material or related to the theory of the present invention. Motor **22** functions to rotate the collector disk **30** through a disk shaft **34** which is coupled to motor shaft **23** with a flexible coupling **36**. A radial thrust bearing **38** mounted on platform **16** is provided for maintaining disk shaft **34** in radial alignment. Motor **22** is provided with suitable axial thrust bearings (not shown) to provide adequate vertical support for the collector disk **30**. Collector disk **30** has an annularly shaped, recessed trough **40** extending around the periphery thereof for a purpose explained further on herein.

It will be understood that although disk surface **31** is illustrated as being in a plane, it is within the scope of the invention that surface **31** may also be conically shaped with the apex thereof extending in either an upwardly or downwardly direction.

A conduit **44** is provided which extends from the collector fluid reservoir through platforms **16** and **17**, around disk **30** and through nozzle **12** to a terminal or exhaust point centrally located above disk **30**. A motor and pump unit, not shown, is provided in the interior of reservoir **24** for pumping fluid therein through conduit **44** to the terminal end thereof above disk **30**. Another conduit **46**, referred to as an aspirating conduit, is provided in the upper chamber of container **10** which extends out of the container through the container wall and which extends down into the disk trough **40** where the terminal portion thereof lies in spaced and tangential relation to the confines of the trough **40**. The terminal portion of the conduit **46** which lies in the trough **40** is referred to as an aspirating probe. External suction producing means such as a pump (not shown) may be connected to conduit **46** to effect a withdrawal of a particle laden liquid from the trough **40** which rotates with the disk **30**.

Stretched substantially diametrically across collector disk **30** in precisely spaced relation to the flat surface **31** of disk **30** is a line **48** which is made of a suitable material and is referred to as a liquid distributor. Line **48** is effectively attached at opposite ends thereof to the platform **16** and at one end of the line there is interposed, between the line and the platform **16**, a spring **49** for resiliently tensioning the line. Vertical columns **52** and **53** are provided on diametrically opposite sides of disk **30** in alignment with line **48** for vertically supporting the line in spaced relation to disk surface **31**. The lower ends of columns **52** and **53** are threaded and threaded bores are provided in platform **16** for threadedly receiving the threaded ends of the columns. Columns **52** and **53** are provided with adjustment collars **54** and **55** to effect the individual raising and lowering of the columns and thereby effect a positional adjustment of the line **48** so that it may be precisely positioned in spaced and parallel relation to disk surface **31**.

Collector disk **30** is grounded to the container **10** through disk shaft **34**, bearing **38** and platform **16** as well as through the coupling **36**, the motor shaft **22** and the platform **17**. An insulated conductor **56** extends from the direct current power supply unit **20** to conducting plate **14** for establishing an electrostatic potential in the range of 15,000 volts for establishing the electrostatic field between the plate **14** and the collector disk **30**. The plate **14** and the disk **30** constitute electrodes which may be oppositely charged, or the charge may be on one electrode **14** and the other electrode **30** grounded as illustrated.

In the operation of the precipitator a collector liquid from the reservoir **24** is continuously pumped through the conduit **44** onto the center of the surface **31** of the rotating collector disk **30**. As will be described more in detail fur-

ther on, the liquid flows radially outwardly on the surface **31** in a thin film into the trough **40** of the disk. At the same time, aerosol is drawn into the container **10** through the nozzle **12** and through the center of the high voltage conducting plate **14**. By reason of the suction created at outlet **18**, the aerosol flows radially outwardly between the conducting plate **14** and the collector disk **30**. The electric potential maintained between the plate **14** and the disk **30** has the effect of causing (1) a corona to be emitted from the ring of needles **15** which ionizes the air and thereby imparts an electrical charge to the particles carried by the air, and (2) creates an electrical force which precipitates the charged particles onto the radially outwardly flowing liquid film on the rotating collector disk **30**. Particles collected on or in the liquid film on the collector disk **30** float or are carried to the annular trough **40**, which rotates by reason of being associated with the collector disk **30**, and the particle laden liquid is withdrawn from the trough by the suction effect of the aspirating probe of the aspirating conduit **46**. The present invention is not concerned with any subsequent operations involving the treatment of the particle laden liquid after it leaves the container **10** through the conduit **46**.

It has been found that better results are obtained when the surface **31** of the disk **30** is slightly irregular or textured as distinguished from being a ground and highly polished surface. A highly polished stainless steel surface having a roughness index of 17 microinches was considered unsatisfactory in view of results obtained with textured surfaces.

An etched stainless steel surface having a roughness index of 25 microinches, etched with a ferric chloride solution, proved successful from the mechanical standpoint. Other material for the disk surface **31** had to be investigated, however, because certain solutions which are desirable as collector liquids from the standpoint of not affecting the viability of the microorganisms collected have a deteriorative effect on the etched stainless steel surface. Thus, an etched stainless steel surface is satisfactory within the scope of the invention if a collector liquid which causes deterioration is avoided.

An etched aluminum surface having a roughness index of 70 microinches, etched with a sodium hydroxide solution, gave reasonably satisfactory results from the mechanical standpoint but also has the disadvantage that it is subject to chemical deterioration with the use of certain collector liquids.

An anodized aluminum surface having a roughness index of 45 microinches gave fair results from the mechanical standpoint, but has the disadvantage that it is subject to chemical deterioration.

A textured Mylar film, having a roughness index of 40 microinches, affixed to a collector disk was found satisfactory from the mechanical standpoint, but was also subject to deterioration when collector liquids having certain solvents were used. Mylar film is a product of the Kueffel and Esser Company and the particular film used is identified as "Herculean Polyester Drafting Film," 191153.

Two collector disk coatings which have proved satisfactory from both the mechanical standpoint and from the standpoint of resistance to chemical deterioration are a ceramic coating and a porcelain coating. The porcelain coating gives the better results of the two and had a roughness index of 32 microinches. The ceramic coating had a roughness index of 200 microinches.

The roughness indices referred to above were obtained with a machine having the trademark Surfindicator (model BL–110), manufactured by the Brush Insturments Division of the Clevite Corporation, Cleveland, Ohio. The machine is of the type which has a diamond tipped stylus for sensing surface irregularities.

The surface roughness indices referred to above indicate generally that a certain degree of roughness for the disk surface **31** provides optimum wetting characteristics. The type of material used also appears to be a factor, however, in that good results are obtained with porcelain and ceramic surfaces having indices of 32 and 200 microinches, respectively, whereas anodized aluminum having an intermediate index of 45 microinches gave only fair results.

In the actual construction of a collector disk for an electrostatic precipitator embodying the invention, the collector disk comprised two parts which were a circular aluminum base having a surrounding trough and a porcelain coated disk of 16-gauge low carbon steel attached to the aluminum base with a screw. It is contemplated that the porcelain coated disk could also be attached to the aluminum base with an adhesive cement.

The spacing of the distributor line **48** relative to the disk surface **31** is adjustable as shown and described. In practice, the line **48** is positioned as close to the disk surface **31** as possible without touching it. The precipitator would be completely operative with line **48** touching surface **31** but the collection and subsequent analyzing of the collected particles is sometimes a delicate and demanding operation and in those cases the contamination of the sample collected by even the few minute particles which would be produced by the gentle abrasive contact between the line **48** and the disk surface **31** could not be tolerated.

The line **48** may be made of vraious materials and a single strand, nylon fishing line having a diameter of about .020" has been found to be satisfactory. The line **48** could also be made of metal from the standpoint of its function as a liquid distributor but its use involves certain electrical problems such as arcing and for that reason a non-metallic line is deemed preferable.

In operation, the air stream admitted through the nozzle **12** is a primary factor in causing the collector liquid flowing to the center of the disk **30** to flow radially to the periphery of the disk. With the disk rotating slowly at only about 25 r.p.m. the resulting centrifugal force is so small that its effect is negligible. The air stream has the effect of causing the collector liquid depth to be shallow at the center of the disk and substantially thicker at the periphery. By way of example and without inferring any limitations, the liquid depth may be on the order of .010" at the center and .060" at the periphery. The height of the line **48** is adjusted to a sufficiently low level that it engages the liquid and functions to cause a wetting of substantially all of the disk surface by a form of wiping action. If the disk surface is too smooth, the wiping action is not quite as effective and undesired rivulets are formed instead of a complete wetting of the surface.

A second embodiment of the invention is illustrated in FIGS. 3 and 4. FIG. 3 shows the upper portion of a precipitator which is identical to the precipitator illustrated in FIGS. 1 and 2 except that a different form of distributor line is illustrated. Parts in the second embodiment which are identical to parts in the first embodiment are identified by corresponding numbers in the 100 series such that, for example, an element **150** in the second embodiment would correspond to element **50** in the first embodiment. It is thus not necessary to describe the construction or operation of the second embodiment in any detail except with respect to the modified distributor line thereof.

In the second embodiment of the invention a distributor line **180** extends radially across the collector disk **130** instead of diametrically across the disk as in the first embodiment. Line **180** is stationary relative to the rotatable disk **130** and means are provided for attaching the line to the center of the disk which permits the disk to rotate relative to the line. These means include a cylindrically shaped anchor or anchoring means **181** which is attached centrally of the disk **130** in a manner such that it is rotatable relative to the disk and its height relative to the disk is vertically adjustable. The mounting of anchor **181** is facilitated by a threaded bore **182** in the disk and two counterbores **183** and **184**. Anchor **181** has a bore **185** and counterbore **186** and has the same effective outer diameter as the counterbore **184** of disk **130** in which it is rotatably disposed. A self-holding Allen head screw

187 is provided as a spindle for journalling the anchor 181 and limiting its movements in a vertical direction. A coil spring 188 is disposed in counterbore 183 for resiliently biasing the anchor 181 in the vertical direction against the head of the screw 187. The line 180 is attached to the top of anchor 181 and, by reason of the line being moored at the other end thereof in the same manner as in the first embodiment, the disk 130 is rotatable relative to the anchor 181 and the line 180 as is evident from the construction described and shown. The spacing of the line 180 relative to the disk surface 131 is adjustable by adjusting the height of anchor 181 relative to the disk 130 and the height of support member 152 relative to the platform 116.

While two embodiments of the invention are described here, it will be understood that they are capable of modification, and that such modification, including a reversal of parts, may be made without departure from the spirit and scope of the invention as defined in the claims.

What is claimed is:

1. An electrostatic precipitator comprising a container having an inlet opening for admitting an aerosol to the container, means for drawing aerosol into said container, means for imparting electrical charges to particles of said aerosol, an oppositely chargeable rotatable collector disk to which said particles are electrostatically precipitated, said disk having a top surface which is symmetrical relative to the axis of rotation of said disk, means for supplying a flow of collector liquid to said surface, means for guiding said aerosol over said disk surface for moving said collector liquid to the periphery of said disk, and a distributor line extending over said disk surface in closely spaced relation thereto for engaging said collector liquid to effect a substantial wetting of said disk surface.

2. Apparatus in accordance with claim 1 wherein said disk surface is in a plane.

3. Apparatus in accordance with claim 2 wherein said distributor line extends substantially diametrically across the top of said disk surface.

4. Apparatus in accordance with claim 1 wherein said distributor line is operatvely attached to the center of said disk and extends radially therefrom.

5. Apparatus in accordance with claim 2 wherein said distributor line is operatively attached to the center of said disk and extends radially therefrom.

6. Apparatus in accordance with claim 1 wherein the spacing of said distributor line is adjustable relative to said disk surface.

7. Apparatus in accordance with claim 1 wherein said distributor line is resiliently tensioned.

8. Apparatus in accordance with claim 1 wherein said distributor line is of a non-metallic material.

9. Apparatus in accordance with claim 1 wherein said disk surface has a textured finish.

10. Apparatus in accordance with claim 2 wherein said disk surface has a textured finish.

11. Apparatus in accordance with claim 9 wherein said surface is etched stainless steel.

12. Apparatus in accordance with claim 9 wherein said surface is a textured Mylar film.

13. Apparatus in accordance with claim 9 wherein said surface is etched aluminum.

14. Apparatus in accordance with claim 9 wherein said surface is anodized aluminum.

15. Apparatus in accordance with claim 9 wherein said surface is ceramic coating.

16. Apparatus in accordance with claim 9 wherein said surface is porcelain coating.

17. An electrostatic precipitator comprising a container having an inlet opening for admitting an aerosol to the container, means for drawing aerosol into said container, means for imparting electrical charges to particles of said aerosol, an oppositely chargeable rotatable collector disk to which said particles are electrostatically precipitated, said disk having a top surface which is symmetrical relative to the axis of rotation of said disk, said top surface having a textured finish, means for supplying a flow of collector liquid to said surface, means for guiding said aerosol over said disk surface for moving said collector liquid to the periphery of said disk, and liquid distributor means extending over said disk surface in closely spaced relation thereto for engaging said collector liquid to effect a substantial wetting of said disk surface.

18. Apparatus in accordance with claim 17 wherein said disk surface is in a plane.

19. Apparatus in accordance with claim 18 wherein said surface is etched stainless steel having a roughness index on the order of 25 microinches.

20. Apparatus in accordance with claim 18 wherein said surface is a textured Mylar film having a roughness index on the order of 40 microinches.

21. Apparatus in accordance with claim 18 wherein said surface is etched aluminum having a roughness index on the order of 70 microinches.

22. Apparatus in accordance with claim 18 wherein said surface is anodized aluminum having a roughness index on the order of 45 microinches.

23. Apparatus in accordance with claim 18 wherein said surface is ceramic coating having a roughness index on the order of 32 microinches.

24. Apparatus in accordance with claim 18 wherein said surface is porcelain coating having a roughness index on the order of 200 microinches.

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