

July 14, 1970

B. Y. H. LIU ETAL

3,520,172

AEROSOL SAMPLER

Filed May 29, 1967

2 Sheets-Sheet 1

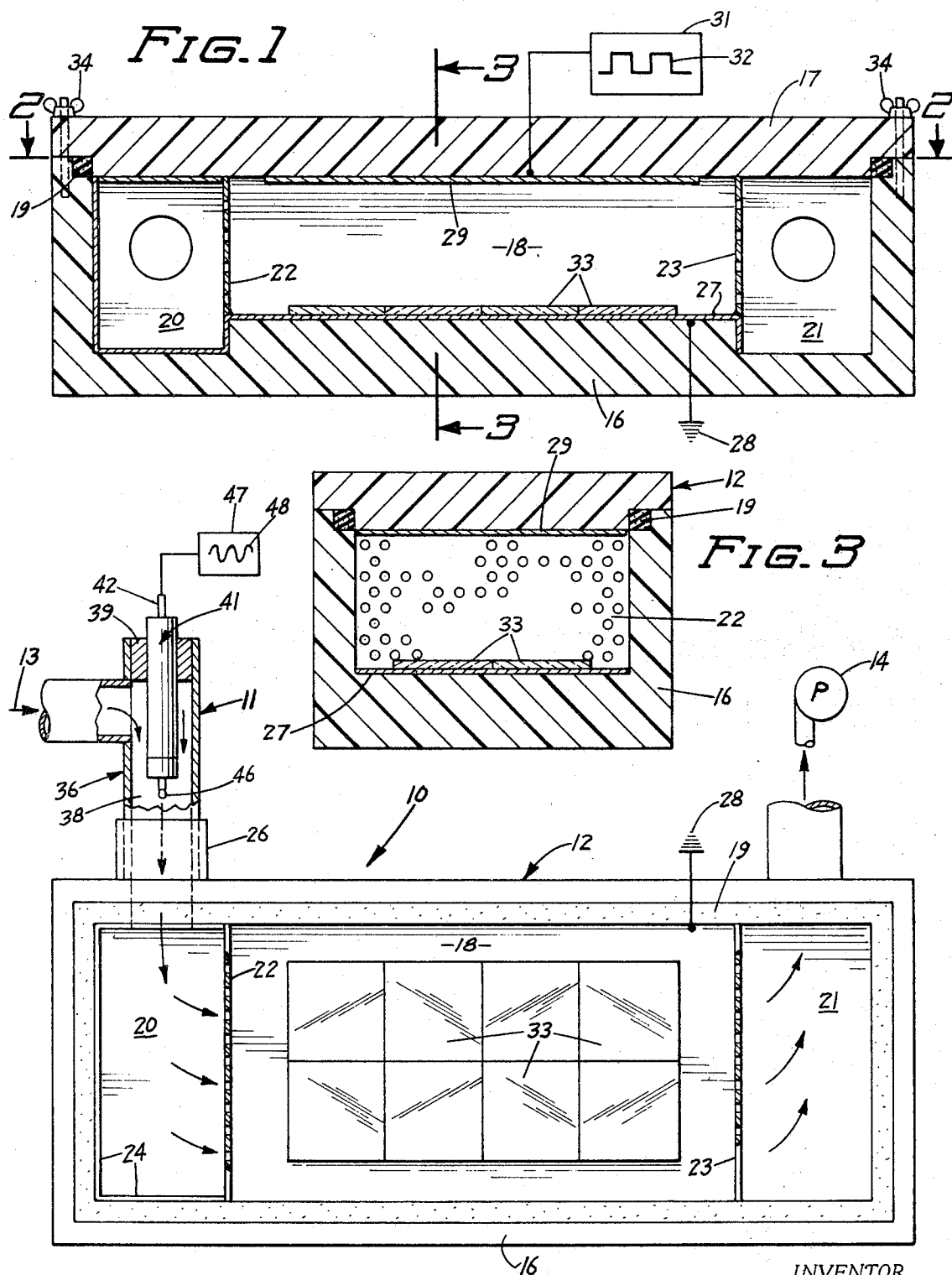


FIG. 2

INVENTOR.
BENJAMIN Y. H. LIU
KENNETH T. WHITBY
BY
Burd, MacEachron, Braddock,
Bart & Schwartz
ATTORNEYS

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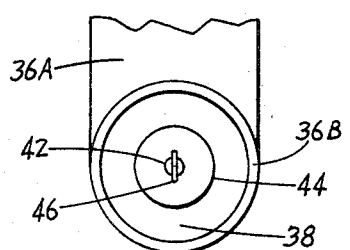


FIG. 5

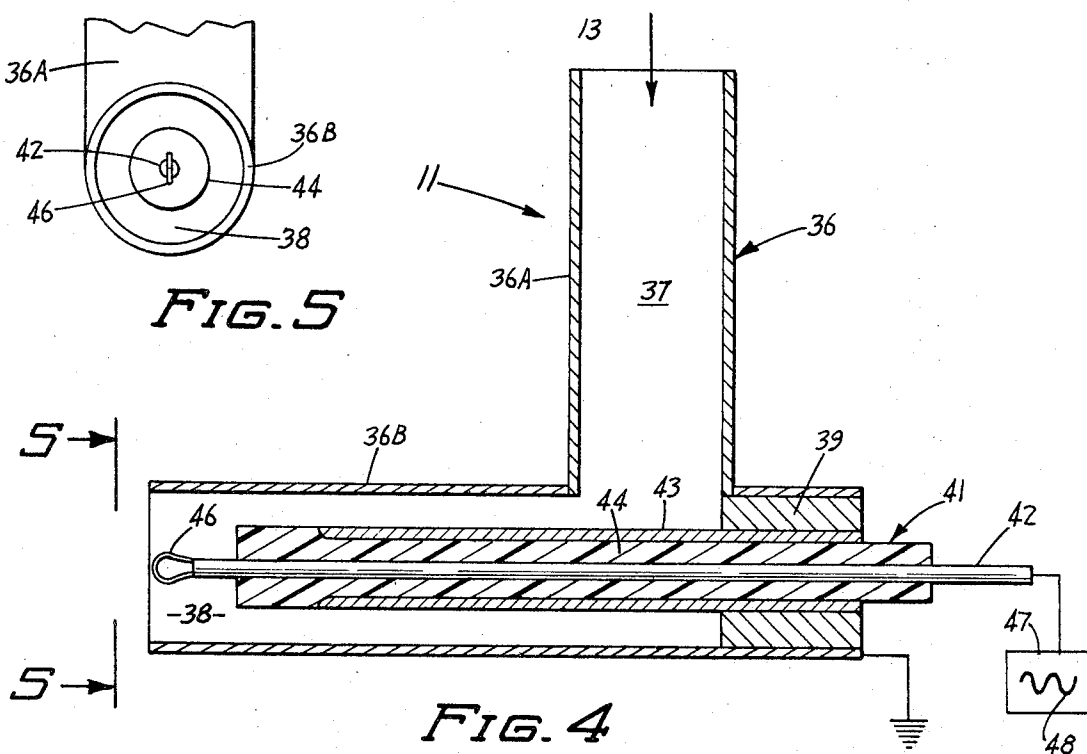


FIG. 4

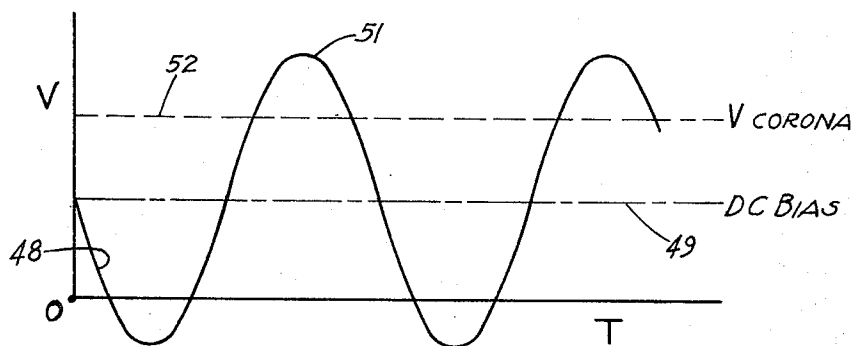


FIG. 6

INVENTOR.
BENJAMIN Y. H. LIU
KENNETH T. WHITBY
 BY
Burd, MacEachron, Braddock,
Bart & Schwartz
 ATTORNEYS

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AEROSOL SAMPLER

Benjamin Y. H. Liu and Kenneth T. Whitby, Minneapolis, Minn., assignors to The Regents of the University of Minnesota, Minneapolis, Minn., a corporation of Minnesota

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Int. Cl. G01n 31/00

U.S. Cl. 73—28

17 Claims

ABSTRACT OF THE DISCLOSURE

A two stage electrostatic aerosol sampler having a charger and a separate precipitator for collecting micron and sub-micron sized aerosol particles on any flat collecting surface. The charger has a looped corona tungsten wire located in the aerosol passage leading to the precipitator. A DC biased alternating voltage is applied to the wire to provide pulses of positive ions to impart an electrical charge to the aerosol particles without precipitating the aerosol particles. The precipitator is a non-conductive box having a removable cover forming a channel in which the charged aerosol particles flow under the influence of a suction pump. The collecting surface, as microscope slides, are located on the bottom of the channel over a plate on the bottom of the cover. A pulsed voltage is applied to the plate. The voltage is of a magnitude so that the precipitating velocity of the aerosol particles is in a direction perpendicular to the direction of air flow through the channel whereby all of the particles are collected uniformly on the collecting surface.

BACKGROUND OF INVENTION

Aerosol samplers of conventional design, as the inertia impactor, electrostatic precipitator or thermoprecipitator have severe limitations when used to obtain samples of aerosols for sizing and counting in light or electron microscopes where quantitative data is required. The limitations of these samplers stems from the fact that the aerosol sample collected is usually not distributed uniformly over the collecting surface and the presence of a considerable amount of size classification of particles over the collecting surface. When size classification is present, the measured size distribution of the aerosol particles may not be representative of the aerosol particles in their original suspended state. In conventional electrostatic precipitators where particles are simultaneously charged and precipitated in a corona field, the collecting surface for particles must also conduct the large corona current. Under these conditions a non-conductive collecting surface would acquire sufficient electrical charge to repel the ions as well as the charged aerosol particles. The result is that aerosol particle precipitation becomes impossible.

SUMMARY OF INVENTION

The invention relates to an apparatus and method for obtaining a uniform deposit of aerosol particles on any flat collecting surface that is particularly suitable for use with electron microscope grids, microscope slides, cover slips, glass slides and other surfaces with high electrical resistivity. The sampler is a two stage electrostatic apparatus capable of sampling aerosol particles and depositing them uniformly over a relatively large area onto any type of flat collecting surface. The deposit is quantitative so that absolute particle concentration of the aerosol particles can be determined. The sampler comprises a combination charger and precipitator having connecting flow passages. A steady aerosol flow is maintained through the passages by a suction pump attached to the discharge outlet of the precipitator passage. The inlet end of the charging

passage receives the aerosol particles for delivery to a charging region. In the charging region, the aerosol particles are exposed to positive ions for imparting an electrical charge on the aerosol particles. The positive ions are produced by an ion generator located in the charging passage. The ion generator has a corona wire to which an AC charging voltage is applied to intermittently obtain a corona producing pulses of positive ions. The charged aerosol particles are distributed uniformly in the entire volume of the precipitating region of the channel where they are subjected to a pulse voltage applied for a short duration of time during which time all charged particles are deposited uniformly over the collecting surface. During the time when the electric field is zero, another volume of charged aerosol particles move into the precipitating region. A second pulse voltage deposits these particles. This cycle is repeated until the desired number of deposits have been collected on the collecting surfaces.

IN THE DRAWINGS

FIG. 1 is a longitudinal sectional view of the precipitator of the aerosol sampler;

FIG. 2 is a plan view taken along line 2—2 of FIG. 1 with the top member removed and the charger shown in section;

FIG. 3 is a sectional view taken along the line 3—3 of FIG. 1;

FIG. 4 is an enlarged sectional view of the charger shown in FIG. 2;

FIG. 5 is an end view taken along line 5—5 of FIG. 4; and

FIG. 6 is a voltage diagram of the voltage applied to the charger.

Referring to the drawings, there is shown in FIG. 2 the two stage electrostatic aerosol sampler of this invention indicated generally at 10. The sampler has a charger 11 and a precipitator 12 providing separate charging and precipitating regions permitting the use of collecting surfaces with high electric resistivity, as glass microscope slides. The aerosol indicated by arrows 13 flows into charger 11 where it is charged with positive ions. The charger 11 is of a type capable of charging aerosol particles without collecting or precipitating the charged particles. The charged aerosol particles flow into the precipitator along with air carrying the aerosol particles. A suction pump 14 coupled to the outlet of the precipitator draws the aerosol particles at a steady rate through the charger and into the precipitator.

Precipitator 12 has a box-shaped body 16 closed with a cover 17 forming an elongated flow channel 18. The volume of channel 18 is the precipitating region of the sampler. A seal 19 around the periphery of the walls of the body cooperates with the cover to prevent the entrance of foreign material into channel 18. Thumb screws 34 threaded on upright studs hold the cover on the body. The body 16 and cover 17 may be formed of material having high electrical resistivity, as a plastic. Channel 18 extends between an entrance chamber 20 and an exit chamber 21. An upright perforated metal plate 22 separates the entrance chamber from the entrance of channel 18. In a similar manner, an upright metal perforated plate 23 separates the exit of channel 18 from exit chamber 21. The metal plates function to maintain a uniform flow and even distribution of the aerosol particles in channel 18. To minimize the accumulation of charged particles in entrance chamber 20, the chamber is lined with metal walls 24 maintained at zero potential. The upright plates 22 and 23 are also maintained at zero potential. A connector 26, as a flexible tube, couples charger 11 to body 12 so that the charged aerosol particles are delivered to entrance chamber 20.

The bottom of channel 18 has a flat metal plate 27

connected to a ground 28. Plate 27 functions as an electrode and a support for the sampling surface 33, as electron microscope grids, microscope slides and cover slips. Located above plate 27 and secured to the bottom of cover 17 is an electrically conductive plate 29 connected by a suitable line to a power source 31 capable of generating a pulse signal 32. Plate 29 covers the entire width of channel 18 and is spaced from upright plates 22 and 23. The pulse signal or voltage has a square wave form illustrated at 32. As an example of the pulse signal 32, the electric field is zero for a 3 second period during which time the entire volume of the precipitating volume of channel 18 is filled with charged aerosol particles. A 4200 volt pulse is then applied for 1.5 seconds during which time all the charged aerosol particles are deposited uniformly over the lower collecting surface 33. Under these conditions, the aerosol flow rate in channel 18 is sufficiently high to permit the precipitating region to be completely filled with charged aerosol particles during the 3 second filling period. The total aerosol sample is dependent on the number of cycles of operation and the volume of chamber 18 over the area of the collecting surface 33. The sample volume is independent of the aerosol flow rate since it depends only on the area of the collecting surface, the height of channel 18 above the collecting surface and the number of sampling cycles.

Referring to FIGS. 4 and 5, there is shown charger 11 for charging the aerosol particles without collecting or precipitating the particles. Sampler 11 has a body 36 comprised of tubular members 36A and 36B secured together at a right angular relationship forming an inlet passage 37 and a charging passage 38. Members 36A and 36B are one-half inch copper fittings. One end of charging passage 38 is closed with a collar 39 slidably supporting a cylindrical support 41 for an electrode rod 42. Support 41 has an outer metal tube 43 slidably supported in collar 39 and a non-conductive cylindrical member 44 within metal tube 43. The electrode rod 42 extends longitudinally through member 44. The forward end of rod 42 projects from member 44 and carries a looped corona wire 46. The wire 46 is a fine wire having a loop shape capable of taking large currents. Wire 46 is 0.0025 cm. diameter tungsten wire. The opposite end of rod 42 is coupled to a power source 47 generating a charging voltage 48. An example of the charging voltage is an AC voltage in the form of a 60 c.p.s. sine wave with a peak amplitude of 800 v. FIG. 6 shows the wave form for the charging voltage 48 having a shifted base line. The AC voltage is subjected to a DC bias 49 sufficient to move the peaks 51 of the voltage wave above the voltage necessary to accomplish corona in the area of wire 46. This causes pulsed or intermittent corona.

In use, with the charging voltage 48 applied to the charger 11, the aerosol particles 13 move into the charger through the inlet passage 37 and forms a moving annular sleeve of aerosol particles about cylindrical support 41. As the sleeve of aerosol particles move past corona wire 46, the particles are subjected to positive ions. The result is that a charge is imposed to the aerosol particles. An AC charging voltage is used in order to charge the aerosol particles during a limited portion of the cycle with a pulse or burst of ions. This mode of charging minimizes the loss of aerosol particles which would otherwise occur in the charging process. The charged particles flow into the entrance chamber 20 through the perforations in upright plate 22 which uniformly distributes the charged aerosol particles in the precipitating region of the sampler. With the application of the pulse voltage to plate 29, all charged particles are deposited uniformly over the lower collecting surface 33. The precipitating voltage is of such a magnitude that the precipitating velocity of the aerosol particles is in a direction perpendicular to the direction of air flow through channel 18 so that all the charged aerosol particles are collected over the bottom area of the channel. During the time

when the electric field is zero, the entire volume of channel 18 is filled with another volume of charged aerosol particles. The next voltage pulse precipitates these charged aerosol particles on the collecting surface 33. The total aerosol particle sample is taken after a desired number of cycles have been completed.

In terms of the method of sampling aerosol particles, the invention comprises the steps of providing a steady flow of aerosol particles in a passage having a charging region separated from a precipitating region. During the flow of the aerosol particles they are first exposed to positive ions in a charging region. The aerosol particles are subjected to pulses or bursts of positive ions to provide the aerosol particles with a charge without collecting or precipitating the particles. The charged particles then move into a precipitating region above a particle collecting surface 33. The charged particles are then precipitated onto the collecting surface by subjecting the aerosol particles to a pulsed voltage of a square wave form. This procedure is repeated until the total aerosol particle sample is taken.

This invention is based at least in part upon work done under a contract or grant from the United States Government.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A two stage aerosol sampler comprising in combination an aerosol particle charger having a charging passage for exposing aerosol particles to ions to impart an electrical charge to the particles, a precipitator coupled to the charger for receiving charged aerosol particles, said precipitator having a channel forming a separate precipitating chamber for charged aerosol particles and a support adapted to hold at least one member having a particles collecting surface, an inlet chamber at one end of the precipitating chamber and an outlet at the other end of the precipitating chamber, said charger connected to the precipitator with the charging passage connected to the inlet chamber whereby the charging passage is separate and spaced from the precipitating chamber, an electrode means spaced from and located over said support, and means for applying a pulse precipitating voltage to the electrode means to deposit said charged aerosol particles in the precipitating chamber on the collecting surface.

2. The sampler of claim 1 wherein said charger has a corona wire located in the charging passage and means for applying a voltage to said wire of a magnitude to cause corona.

3. The sampler of claim 2 wherein said voltage is an AC voltage of a magnitude to cause intermittent corona.

4. The sampler of claim 3 wherein said voltage has an additional DC bias.

5. The sampler of claim 1 including means for uniformly distributing the charged aerosol particles in the precipitating chamber.

6. The aerosol sampler of claim 1 wherein said electrode means for applying the pulse precipitating voltage to the charged aerosol particles comprises a plate along the top of the precipitating chamber of said channel and circuit means for applying the pulse precipitating voltage to said plate whereby the charged aerosol particles are uniformly deposited on the collecting surface.

7. The aerosol sampler of claim 6 wherein said precipitating voltage is a pulsed voltage to uniformly deposit the charged aerosol particles on the collecting surface.

8. The aerosol sampler of claim 6 wherein said pulsed voltage has a square wave form.

9. The aerosol sampler of claim 6 wherein said precipitating voltage is a DC voltage.

10. A method of sampling aerosol particles comprising the steps of: providing a steady flow of aerosol particles through a first passage, exposing the flowing aerosol

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particles to ions in the first passage to place an electrical charge on the aerosol particles moving the charged particles from the first passage through an inlet chamber into a separate precipitating chamber spaced from the first passage, maintaining the walls of the inlet chamber at zero electrical potential, precipitating the charged aerosol particles in the precipitating chamber onto a collecting surface on one wall of the chamber by subjecting the charged aerosol particles in the precipitating chamber of the passage to a pulse precipitating voltage.

11. The method of claim 10 including: intermittently producing ions in the first passage with an AC charging voltage.

12. The method of claim 10 wherein the charged aerosol particles in the precipitating chamber are subjected to a pulse DC precipitating voltage.

13. The method of claim 10 wherein the aerosol particles in the precipitating chamber are subjected to a single voltage pulse to uniformly deposit the charged aerosol particles on the collecting surface.

14. An ionizer comprising a body having a passage with an inlet opening and outlet opening directing flowing fluid, an elongated cylindrical member having an electrical conductor located in said passage, means located outside of said passage mounting said cylindrical member on said body along the longitudinal axis of said passage, said conductor having corona wire loop means at said end located entirely in said passage between the inlet opening and outlet opening, and circuit means for applying an AC voltage of a magnitude to cause intermittent corona at said wire loop means thereby subjecting said flowing fluid to pulses of ions.

15. The ionizer of claim 14 wherein said poltage has an additional DC bias.

16. The aerosol sampler of claim 6 including a removable cover, said plate secured to said cover whereby the member having the particle collecting surface can be removed from the sampler.

17. An aerosol sampler comprising in combination: an aerosol particle charger having a body, a passage in said body, an inlet opening and an outlet opening in communication with said passage, for directing aerosol particles through said passage, and an elongated electrical conductor located in said passage between the inlet opening and the outlet opening, means mounting said conductor on said body, said conductor having a corona wire means located in said passage between the inlet opening and the outlet opening, means for applying a DC biased AC voltage of a magnitude to cause intermittent corona to said corona wire means to expose the aerosol particles flowing through the passage to ions to impart an electrical charge to the aerosol particles, a precipitator comprising

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a body having side walls, bottom wall and cover around a channel forming a separate precipitating region, means for removably securing the cover to the body thereby enclosing the precipitating region, said channel having an entrance chamber and an exit chamber on opposite ends of the precipitating region, an inlet opening into the entrance chamber, an exit opening into the exit chamber, means for separating the entrance chamber and the exit chamber from the precipitating region for uniformly distributing the charged aerosol particles in the precipitating region, electrically conductive walls in said entrance chamber, said exit opening of the charger being connected with the inlet passage of the precipitator, means in fluid communication with the exit opening of the precipitator to move the aerosol particles through the charger and the precipitator, an electrode plate means on the cover along the top of the precipitating region, and circuit means for applying a pulsed DC square wave precipitating voltage to said plate whereby the charged aerosol particles are deposited on a collecting surface supported on the bottom wall.

References Cited

UNITED STATES PATENTS

768,450	8/1904	Hardie	55—155 X
1,358,031	11/1920	Smith	55—150 X
1,358,032	11/1920	Smith	55—123
1,934,923	11/1933	Heinrich	55—139 X
2,097,233	10/1937	Meston	55—152 X
2,336,625	12/1943	Milton	55—139 X
2,484,202	10/1949	Wintermute	73—28
2,857,978	10/1958	Lenger	55—151 X
2,868,318	1/1959	Perkins et al.	55—151
2,949,168	8/1960	Bergstedt	55—152
3,027,970	4/1962	Mueller	55—129 X
3,035,445	5/1962	Evans et al.	73—421.5
3,157,479	11/1964	Boles	55—154 X
3,181,285	5/1965	Tepolt et al.	55—138

FOREIGN PATENTS

287,648	9/1915	Germany.
657,376	3/1938	Germany.
145,477	5/1921	Great Britain.
381,631	10/1932	Great Britain.
546,617	7/1942	Great Britain.
795,006	5/1958	Great Britain.

HARRY B. THORNTON, Primary Examiner

D. E. TALBERT, Jr., Assistant Examiner

U.S. Cl. X.R.

55—2, 123, 129, 138, 139, 146, 151, 155, 270

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,520,172 Dated July 14, 1970

Inventor(s) Benjamin Y. H. Liu and Kenneth T. Whitby

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, Line 10, "pullse" should be--pulse--;

Column 3, Line 28, "areosol" should be--aerosol--;

Column 4, Line 36, "particles" should be--particle--;

Column 5, Line 33, "poltage" should be--voltage--;

Column 6, under References Cited United States Patents,
"2,949,168" should be--2,949,167--.

SIGNED AND
SEALED
OCT 13 1970

(SEAL)

Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents