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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO ATTN OF: GP

JUN 5 1979

TO: NST-44
XXX/Scientific & Technical Information Division
Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,387,218

Government or Corporate Employee : TRW, Inc. Redondo Beach, CA

Supplementary Corporate Source (if applicable) :

NASA Patent Case No. : NPO-10,151

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

YES [✓] NO [ ]

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "...with respect to an invention of ..."

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Enclosure

(NASA-Case-NPO-10151) APPARATUS FOR HANDLING MICRON SIZE RANGE PARTICULATE MATERIAL Patent (NASA) 6 p CSCL 13I

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NPO-10,151

June 4, 1968 J. F. FRIICHTENICHT ETAL 3,387,218

APPARATUS FOR HANDLING MICRON SIZE RANGE PARTICULATE MATERIAL

Filed May 6, 1964

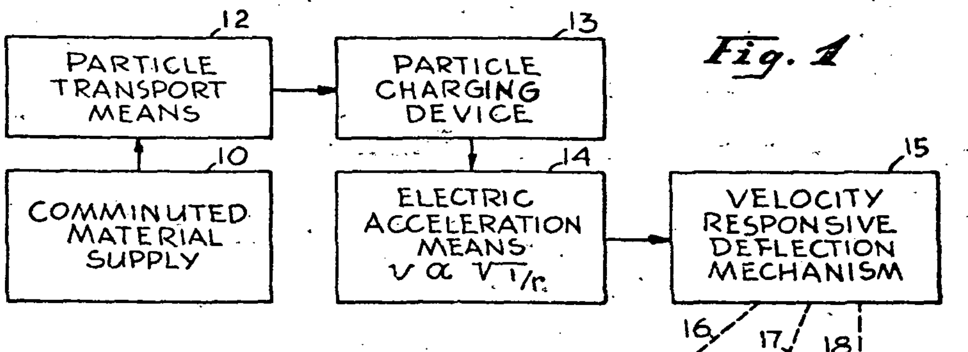

Fig. 1

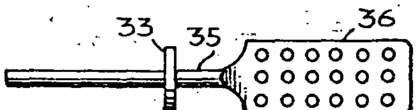

Fig. 3

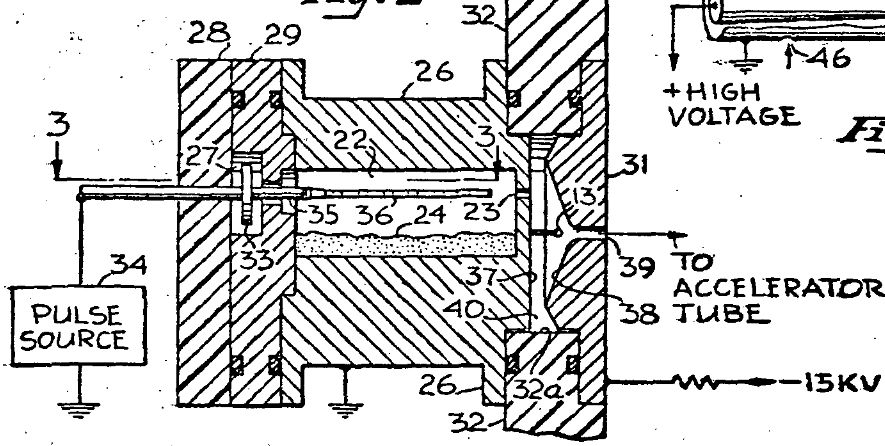

Fig. 2

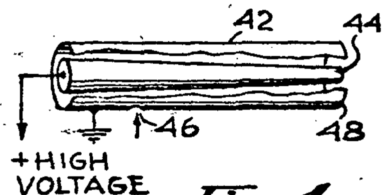

Fig. 4

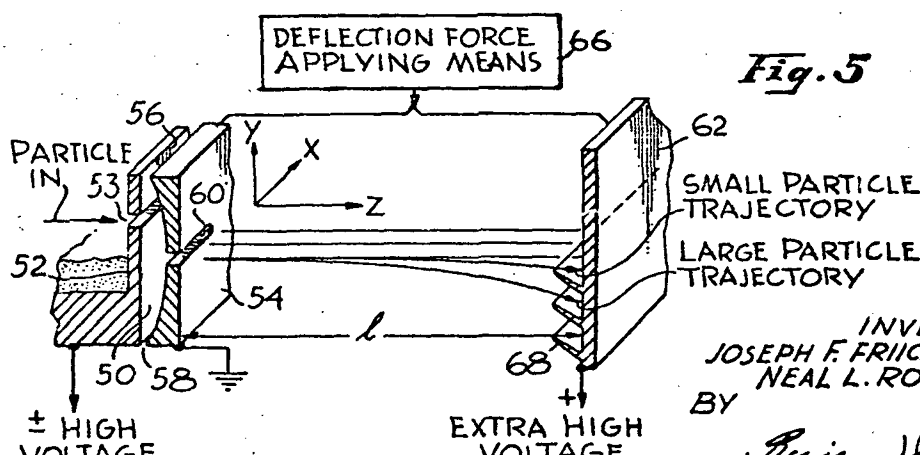

Fig. 5

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United States Patent Office 3,387,218
Patented June 4, 1968

1

3,387,218
APPARATUS FOR HANDLING MICRON SIZE RANGE PARTICULATE MATERIAL

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Filed May 6, 1964, Ser. No. 365,244
7 Claims. (Cl. 328—233)

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85–568 (72 Stat. 435; 42 U.S.C. 2457).

Our invention relates to apparatus for handling, transporting or size classifying comminuted material and more particularly to apparatus employing electrostatic acceleration techniques for classifying particles as to size in the particle size range from about 0.1 to about 100 microns diameter. More specifically, the invention relates to improvements in apparatus of the general type disclosed in U.S. Patent No. 3,018,399 issued Jan. 23, 1962 to H. Shelton.

In the industrial arts, there is an increasing demand for finally divided materials in which the particle sizes are quality controlled to be within predetermined size ranges. For example, in research concerning phenomena associated with particles having meteoric velocities, it is advantageous to have a supply of metallic particles all of which have substantially the same diameters or the same mass. Conventional prior art techniques for grading particulate material are relatively unsatisfactory in that particles smaller than a few microns cannot be satisfactorily separated from a supply which includes larger particles. Thus, in the manufacture of tungsten elements for electron guns or ion emitters there has been no practical way to remove, from a supply of comminuted tungsten, all those dust particles having diameters less than about 10 microns.

Accordingly, it is an object of the present invention to provide an improved apparatus for separating or classifying minute particles in accordance with their respective sizes.

It is a further object of the invention to provide apparatus of the above mentioned type which depends, for its operation, on electrostatic acceleration of charged particles and in which the arrangements for charging and accelerating the particles are relatively immune to accumulation of conductive particles on insulating surfaces.

The above mentioned Shelton patent illustrates in FIGURE 3 thereof an apparatus for individually ejecting into an electrostatic field extremely fine particles which are electrically charged so that they may be accelerated by the electrostatic field. The apparatus described by Shelton includes a reservoir for containing a supply of particulate material, an arrangement for subjecting the particles in the reservoir to an electric field in order to disturb the particles and electrically transport some of them into a desired area, positively charged electrode means for contact charging one particle at a time and electrostatically ejecting the charged particle into the acceleration tube of a conventional Van de Graaff generator or other type of electric accelerator.

One apparatus generally similar to that disclosed by Shelton is considered in a technical article entitled "Two-Million-Volt Electrostatic Accelerator for Hypervelocity Research," by J. F. Friichtenicht in the Review of Scientific Instruments, volume 33, Number 1 (February 1962).

2

In that article, it is shown that the particle velocity obtainable by electrostatic acceleration techniques is:

$$v=\left(\frac{6VE\epsilon_0}{r\rho}\right)^{1/2} \text{ meters/sec.} \qquad (1)$$

where:

v is the particle velocity in meters per/second;
V is the potential difference through which the particle falls;
E is the electric field intensity at the particle surface in volts per meter;
ϵ_0 is the permittivity of free space ($\frac{1}{36\pi}\times10^{-9}$ farads per meter);
r is the radius of the particle in meters; and
ρ is the particle density in kilograms per cubic meter.

In apparatus of the general type to which the subject invention relates, the electric field E at the surface of a particle is substantially constant for the reason that the maximum obtainable is generally used. Thus the factor E in Equation 1 can be regarded as constant, as can the material density ρ so long as all particles used are of the same material. Accordingly, in a given apparatus with fixed voltages, the obtainable particle velocity varies as the square root of the reciprocal of the particle radius, i.e.

$$v=K\left(\frac{1}{r}\right)^{1/2} \text{ meters/second} \qquad (2)$$

where K is a constant taking into account the accelerating voltage used, the particle density and the field intensity E at the surface of the particle.

Thus, it is clear that apparatus of the general type disclosed by the Shelton patent may be used to give different particles different velocities which depend respectively on their different sizes. As will be discussed in more detail hereinafter, such different velocities may be used for size classifying the particles.

When an apparatus such as that disclosed by the Shelton patent is used for size classifying particulate material certain difficulties are encountered. Firstly, the apparatus which he discloses is very inefficient in the sense of particle utilization. That is, a large percentage of the particles which his apparatus transports from the supply reservoir fail to contact the final charging electrode and escape from the system through apertures other than that which would direct them into the accelerating field. Secondly, when apparatus such as that disclosed by the Shelton patent is used continuously to process a large volume of material, misdirected particles tend to accumulate on the surfaces of insulators inside his ejection structure, with such accumulation periodically resulting in short circuits which render the system inoperable so that frequent maintenance is necessary.

Accordingly, it is an additional object of the present invention to provide an improved charged particle ejection apparatus in which the fouling of insulating surface by misdirected particles is substantially avoided.

It is a general object of the present invention to overcome the above mentioned disadvantages of prior art particle charging and accelerating apparatus.

Other objects, purposes and characteristic features of our invention will become more apparent as the description of particular embodiments proceeds.

One embodiment of our invention is particularly useful for accelerating particles to meteoric velocities, or for size classifying particles according to size. In this specific embodiment, a reservoir of particles is arranged in conjunction with a means for disturbing the particles and causing them to move into an adjacent particle manipulation chamber. The particle manipulation chamber comprises first and second oppositely biased conductive members which are spaced apart and insulated from one another with the first conductive member having a substantially planar inner surface and with the second conductive member having a concave inner surface so that the chamber defined between the two members has a region of minimum electric field intensity near its center and a region of maximum electric field intensity peripherally encompassing the low field intensity region. In the preferred embodiments, the concave conductive member is provided with a particle exit aperture near the center of its concave surface portion through which charged particles are ejected from the particle manipulation chamber. In a different embodiment of the invention, the substantially planar conductive member supports a positively biased charging electrode. The charging electrode comprises a sphere of tungsten having a diameter of about 25 microns which is supported on the end of a tungsten wire having a diameter of a few microns and extending from the planar surface toward the center of the particle manipulation chamber.

FIGURE 1 illustrates in block diagram form a particulate material size classifying system in accordance with our invention;

FIGURE 2 is a cross-sectional view of one charged particle ejection apparatus;

FIGURE 3 is a cross-sectional view taken along the lines 3—3 of FIGURE 2;

FIGURE 4 illustrates diagrammatically, the mechanism by which small particles may be transported from one place to another by means of electrostatic fields; and

FIGURE 5 illustrates in diagrammatic form a further embodiment of a charged particle ejection apparatus and a system utilizing the same to classify particles according to their sizes.

In the block diagram illustration of FIGURE 1, there is shown a particle classifying system which comprises a material supply 10, a particle transport mechanism or device 12 and a particle charging device 13 to which the transport means 12 carries particles from the supply 10. From the charging device 13, the assembly ejects or propels individual particles into an electrical acceleration means 14. As the particles individually fall through the electric field of acceleration means 14, a transverse force is applied to each particle by a deflection mechanism 15 so that the particles travel along different exit trajectories indicated by the dotted lines 16, 17 and 18. The function of the acceleration means 14 is to impart motion to the particle in a given direction. Substantially any one of various types of electrical accelerators may be used. Particles having the highest velocity will be deflected least and hence will travel along the trajectory 18 and be caught by section *g* of the particle segregating means 20. Particles having the lowest velocity emerge from the electric accelerating field along the trajectory indicated by line 16 and therefore fall into section *b* of the segregating means 20. Particles having intermediate velocities will obviously be segregated by bins *c*, *d*, *e* and *f* according to their respective velocities.

In FIGURE 2, there is illustrated, by way of example, one form of particle manipulation and ejection apparatus in accordance with our invention. The apparatus shown in FIGURE 2 encompasses the functions indicated by the components 10, 12 and 13 in the block diagram apparatus of FIGURE 1. In FIGURE 2, the particle manipulation and ejection assembly comprises a main body portion 26 whch includes therewithin a particle reservoir cavity 22. The body 26 preferably is generally cylindrical as are the adjacent elements 28, 29, 31 and 32. The cavity formed within the member 26 is rectangular, having a depth normal to the plane of FIGURE 2 approximately equal to its height as shown in FIGURE 2. The particle reservoir 22 contains a supply of particulate material 24 and has inserted therein a means for electrically disturbing the supply of material so that when desired, one or more particles may be induced to pass out of the cavity 22 by way of a hole 23 formed in the right hand end thereof. In a preferred form the means for electrically disturbing the particle supply comprises a tongue-like member 36 which is best illustrated in FIGURE 3. The tongue-like member 36 is a relatively flat metallic member supported by a neck portion 35 which projects through a conductive disc 33 and is supported in position by a cylindrical Teflon insulator 28. The outer end of the tongue-like member 36 is connected at its outer end to an electrical pulse source 34 for selectively applying high voltage pulses to the tongue 36 relatively to the main body 26 and the material 24 contained therein. The conductive disc 33 is affixed to the portion 35 of the tongue-like member and is carried within a cylindrical aperture 27 formed in the outer face of metallic member 29. Disc 33 and the member 29 cooperate to provide a labyrinth-like path along which particles from the supply 24 must travel to reach the inner surface of insulator 28. More importantly, conductive disc 33 provides a region of high field intensity at its peripheral edges. That region of high field intensity tends to trap particles which are travelling toward the insulator 28 and forces such particles back into the reservoir cavity 22. Accordingly, such particles have no access to the insulating surface 28 and fouling of that insulating surface is avoided or at least advantageously diminished. It should be understood that the disc 33 and the cavity 27 in metallic member 29 are shown by way of example only. Persons skilled in the art will appreciate that a plurality of spaced discs similar to the disc 33 may be provided with interstitial inwardly projecting discs connected to the member 29 to provide a serpentine path of any desired length between the cavity 22 and the insulator 28.

At its right hand end, the main body member 26 has an exterior surface 37 which preferably is substantially planar and is highly polished. Since the member 26 is exteriorly cylindrical, it will be recognized that the surface 37 is circular in this embodiment. From the center of the circular surface 37, there is supported a tungsten wire carrying at its outer end a tungsten sphere 13 for electrically charging particles which come into contact with the sphere. Spaced apart from and facing the surface 37 is a cylindrical electrode 31 having a generally cone-shaped inner surface 38 and having a particle exit aperture 39 extending axially therethrough preferably in alignment with the charging sphere 13. The cylindrical electrode 31 is supported in spaced alignment relative to the main body member 26 by means of a generally cylindrical insulator 32 which is clamped between the electrode 31 and the body 26 and is sealed thereto by means of conventional O-ring gaskets.

When particles within the reservoir cavity 22 are electrically disturbed by pulse energization of the tongue 36, at least a few such particles pass out of the cavity 22 through the aperture 23 and into the particle manipulation chamber 40 defined between surfaces 37 and 38. The innermost edge of electrode 31, where the surface 38 most closely approaches the surface 37, provides a circular region of relatively high electric field intensity. Centrally within that region, there is a second region of relatively low field intensity between the surfaces 37 and 38. Particles which enter the cavity 40 first impinge on the surface 38 and acquire a negative charge. The now negatively charged particle is attracted by surface 37 and repelled by surface 38. The electric field lines between the two surfaces are curved so that as the particle travels toward the surface 37 it has a force exerted on it which is directed toward the axis of symmetry of the chamber 40. Because of the low velocities which are obtained within the chamber 40, the particles impinge on the surfaces 37 and 38 in a nearly elastic manner so that the particle makes several bounces within the chamber. Each time the particle strikes one of the two surfaces, it acquires a charge of the same polarity as that surface and is accelerated towards the opposite surface. When so accelerated, it gains an increment of kinetic energy corresponding to the product of its charge and the potential difference through which it falls. The energy gained through each inter-surface transit is sufficient to overcome the energy loss of the particle when it impinges on a surface. Thus, the average velocity of the particle increases until an equilibrium value of kinetic energy is achieved by the particle. The actual behavior of a particular particle within the particle manipulation chamber is not readily determined. The particles no doubt bounce around in a somewhat random manner. However, we have found that apparatus constructed in accordance with FIGURE 2 quite effectively "traps" all particles between the surfaces 37 and 38 with the electrical forces being sufficient to keep the particles from escaping radially outward to the inner surface 32a of the insulator 32. Most of the particles which enter the chamber 40 eventually strike the charging electrode 13, are positively charged to a high value thereby and are ejected out of the assembly through the exit aperture 39. In actual practice, the structure shown in FIGURE 2 is coupled to the acceleration tube of a Van de Graaff generator (not shown) so that particles emanating from the aperture 39 pass into the accelerating electrostatic field of the Van de Graaff. The conical shape of the surface 38 in conjunction with the substantially planar surface 37 provides a particle manipulation cavity 40 therebetween which operates to control the motion of all particles which enter it and eventually direct such particles to the charging electrode 13. Only about 1% of the particles which enter the chamber 40 ever reach the peripheral insulating surface 32a. Thus the structural arrangement illustrated in FIGURE 2 improves the efficiency of apparatus of the type described by forcing substantially all of the particles into the immediate vicinity of the charging electrode 13. In addition, that structural arrangement provides an important reduction of insulator fouling. Since the particles are trapped within the central low field intensity region of the chamber 40, they have no access to the insulating surface 32a. Accordingly, it is seen that the insulating surface 32a is protected from fouling in much the same manner as described heretofore in connection with the inner surface of insulator 28.

The concept of transporting particles from one place to another by means of curved electric field lines may be better understood by considering the diagram of FIGURE 4. Here, a substantially cylindrical tube 42 formed of conductive material has a tapered or conical metallic member 44 supported coaxially therewithin. The outer tube 42 is shown as being grounded with the inner electrode 44 being connected to a positive high voltage source. Since the electric field intensity between the members 42 and 44 decreases from left to right in FIGURE 4, a particle injected into the space between the members 42 and 44 (as, for example, through the hole 46) will bounce back and forth between the members 42 and 44 and will tend to travel along the curved electric field lines so that the particle is gradually forced toward the right or the low field intensity region of the assembly. That is, particles injected at 46 are forced toward the end portion 48 and only a negligible percentage will exit from the other end.

In FIGURE 5, there is shown in diagrammatic form a further embodiment of apparatus in accordance with the invention which takes a variant structural form but utilizes the same basic concepts and principles. Here a particle manipulation cavity 50, is defined by first and second oppositely biased conductive members 52 and 54. As indicated by the cut away edge of the member 54 the members 52 and 54 may be of any desired length in the X-axis direction. The first conductive member 52 has an inner surface facing the manipulation chamber 50 which is substantially planar and preferably is highly polished. It will be appreciated that the member 52 in the diagrammatic illustration of FIGURE 5 corresponds to the right hand end of the member 26 of the apparatus illustrated in FIGURE 2, the only important difference being that in FIGURE 5 the elements are rectangular and elongated in the X-axis direction rather than being cylindrical. Particles enter the manipulation chamber 50 through one or more apertures 53 corresponding to the aperture 23 in the apparatus of FIGURE 2. The second conductive member 54 has a cylindrically concave inner surface disposed oppositely to and facing the member 52. The particle manipulation chamber 50 has a region of minimum field intensity near its center and has regions 56 and 58 of high electric field intensity adjacent the upper and lower edges of the member 54. As described in detail heretofore in connection with the apparatus in FIGURE 2, this configuration forces all particles which enter the cavity 50 toward the center thereof and prevents particles from escaping to the insulating surface (not shown) adjacent the upper and lower edges of the manipulation cavity. The second conductive member 54 has an elongated slot 60 through which particles are ejected from the cavity 50 into an adjacent electric field gradient. Thus the arrangement illustrated in FIGURE 5 provides a sheet-like beam of particles emanating from the cavity 50 through the slot 60 and falling through a potential gradient toward the positively biased target 62.

When an apparatus in accordance with FIGURE 5 is used for size classification of particles the system is preferably oriented with the Z-axis horizontal so that the earth's gravitational field provides a region of transverse force acting on all of the high velocity particles as they travel from the member 54 toward the target 62. It should be understood however, that the present invention is not limited to the use of gravity for providing the Y direction deflection force. The Y direction or transverse force can be provided in several ways, the only requirement being that the Y-force must be of a different form than the Z direction force. The gravitational force is of the correct form and is a convenient choice. Time varying electric fields will also suffice. One example of apparatus for providing time varying electrical deflection forces is that disclosed in U.S. Patent No. 2,939,952 issued to Wolfgang Paul. Another similar apparatus which may be used for providing a deflection force in the system of FIGURE 5 is specifically disclosed and claimed in copending application Ser. No. 146,642 of R. V. Langmuir and R. F. Wuerker filed Oct. 20, 1961 and assigned to the assignee of the present invention. Accordingly, in the system of FIGURE 5, the deflection force applying means 66 is shown in block diagram form. The block 66 will be understood as encompassing any of the various known arrangements for applying a downward force in the Y direction to a particle during the entire time required for that particle to traverse the distance L from the member 54 to the target 62.

In the system illustrated in FIGURE 5, the particles are segregated in accordance with their sizes by falling into the spaces between a plurality of shelf-like members 68. These longitudinally extending shelf-like members correspond to the different sections *a*, *b*, *c*,—of the size classifying means 20 of the system illustrated in FIGURE 1. It will be understood that the target member 62 taken with the shelf-like member 68 operates to terminate the flight of all particles and segregates the particles according to their respective sizes. The principles of this segregation function have been described more particularly heretofore in connection with FIGURE 1. Thus for present purposes, it is only necessary to note that gravity for example provides a deflection force $F=mg$, where g is the gravitational constant and m is the mass of the particular particles. Accordingly, the gravitational force creates a vertical displacement S of horizontal travelling particles which is given by

$$S=1/2\,gt^2$$

Over a given travel distance L as shown in FIGURE 5 the travel time of a given particle depends on its velocity; that is

$$t=L/v$$

The length of time spent in traversing the distance L may be adjusted by varying the magnitude of the post-ejection accelerating voltage. For particle classification, it is desirable under some circumstances to electrically retard the particles, after initial acceleration, to thereby increase the lateral deflection.

therefore

$$S=1/2\ g\times(L/v)^2 \quad (3)$$

This last Equation 3 demonstrates that in an apparatus conforming to FIGURE 5, all particles comprised of the same material are laterally displaced different distances in inverse proportion to their respective velocities. In Equation 2 heretofore, it was shown that the velocity of particles ejected by apparatus in accordance with the present invention varies inversely as their radii. Accordingly, the displacement of a given particle in traversing the distance L in the system of FIGURE 5 is directly proportional to its radius or size. Thus the apparatus operates as a system for classifying particles according to their sizes.

It should be understood that the particle ejection assembly illustrated in FIGURE 2 (or the assembly comprising members 52 and 54 in FIGURE 5) may be operated with a number of possible electrical connections. The particles emanating from aperture 23 (or 60) may be accelerated to any required velocity by suitable choice of the accelerating potential. Either the target or the injector may be located at ground potential. It is to be understood that the present invention contemplates either arrangement and the specific arrangements herein described are not to be considered as limited in this respect. In one form of apparatus which we have used with considerable success the acceleration means 14 (FIGURE 1) has comprised a well known Van de Graaff generator such as that shown in FIGURE 6 of the above mentioned Shelton patent. In that apparatus the structure shown in FIGURE 2 is coupled directly to the end of the accelerator tube of the Van de Graaff generator. Again it is to be understood that the invention is not limited in this respect. Substantially any of various known arrangements and structures for providing electric acceleration of charged particles may be employed to provide the function indicated by block 14 (FIGURE 1) and the invention is not to be construed as being limited to any particular type of electric accelerating mechanism.

It should be understood that the apparatus described is operable for size classification of substantially any kind of particulate material whether conductive or dielectric and that the invention is not to be construed as being limited to the particular materials mentioned or to any one of them.

While the present invention has been described with reference to certain specific embodiments only, it will be clear to those skilled in the art that it is not so limited but is susceptible of various changes and modifications without departing from the spirit and scope of the concepts thereof.

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

1. In a system for electrostatic acceleration of particles:

a particle reservoir for containing a supply of comminuted material, with one wall portion thereof having a particle exit passage communicating therethrough;

means associated with said reservoir for disturbing said material and inducing a plurality of said particles to exit through said passage;

first and second oppositely biased conductive members spaced apart in a manner to define a particle manipulation cavity therebetween, with said members being located to receive particles which exit from said reservoir by way of said exit passage;

said first conductive member having a substantially planar first surface portion adjacent said manipulation cavity;

said second conductive member having a concave second surface portion disposed opposite to and facing said first surface portion and having a particle beam aperture extending therethrough for expulsion of particles from said cavity;

at least one substantially spherical charging electrode disposed, between said first and second surface portions, on a particle projection axis which extends normal to said first surface portion and through said particle beam aperture,

with said charging electrode being positioned approximately at the point of minimum electric field intensity between said first and second surface portions so that material particles received within said cavity are electrostatically propelled back and forth between said first and second members along trajectories which become more nearly parallel to the particle beam axis as the particles move toward the region of minimum field intensity.

2. In a system for electrostatic acceleration of particles:

first and second oppositely biased conductive members spaced apart in a manner to define a particle manipulation chamber therebetween;

particle injection means for introducing a plurality of particles of a comminuted material into said chamber;

said first conductive member having a substantially planar first surface portion adjacent said chamber;

said second conductive member having a concave second surface portion disposed opposite to and facing said first surface portion and having a particle exit aperture extending through said concave portion for expulsion of particles from said chamber;

said particle exit aperture being located approximately at the point of minimum electric field intensity between said first and second surface portions and in alignment with a particle projection pathway which extends normal to said first surface portion and outwardly beyond said second member;

and means for applying a sufficient differential bias potential between said conductive members to induce electrostatic propulsion of particles back and forth between said first and second surface portions along trajectories which become more nearly parallel to the axis of said particle projection pathway as the particles move toward the region of minimum field intensity within said chamber.

3. An apparatus in accordance with claim 2 in which misdirected particles are trapped within the particle charging cavity by the provision of relatively high field intensity regions near the peripheral portions of said cavity and a relatively low electric field intensity region near the center of said cavity.

4. In a micron-size particle classifying system:

first and second oppositely biased conductive members spaced apart in a manner to define a particle manipulation chamber therebetween;

means for providing a supply of heterogeneously-sized particles and introducing a plurality of said particles into said chamber;

at least one of said conductive members having a curved active surface facing said chamber with the radius of curvature of said surface being at least several times larger than the spacing between said members for causing an average displacement of particles toward the region of minimum electric field intensity within said cavity;

said conductive member facing said chamber being apertured to define a particle ejection passageway extending therethrough;

acceleration means for accelerating positively charged particles out through said passageway and to respectively different velocities substantially proportional to the square root of the reciprocals of the different particle radii;

deflection means for applying a force to said particles, in a direction transverse to their direction of flight, and substantially in proportion to the respective particle masses so that over a given flight distance particles of different velocities are differently laterally displaced inversely as their respective velocities; and

classification means for terminating the flight of said particles and segregating the same in accordance with their different lateral displacements.

5. An apparatus in accordance with claim 4 in which said acceleration means projects a substantially horizontal beam of charged particles, and in which said deflection means comprises an arrangement for subjecting said particles to the earth's gravitational field over a flight distance of at least several inches.

6. A high velocity particle ejection device comprising:

a particle reservoir means;

a plurality of particles in said reservoir;

positively charged electrode means having a predetermined longitudinal axis;

particle transport means for providing an electric field for charging said particles to cause repetitive electrostatic displacement of a portion of said particles from said reservoir into an area adjacent said electrode means;

each of said particles being positively charged on contact with said positively charged electrode means;

said transport means including a negatively charged electrode having a concave active surface with the radius of curvature thereof being at least several orders of magnitude larger than the diameter of said positively charged electrode so that as the particles are repetitively electrostatically displaced toward the area adjacent said positively charged electrode their trajectories approach parallelism with said axis;

with said negatively charged electrode including means defining an exit aperture extending therethrough in alignment with said axis; and

accelerator means for providing an accelerating potential for positively charged particles which have exited through said aperture.

7. A high velocity particle ejection device comprising:

a particle reservoir means;

a plurality of particles in said reservoir;

positively charged electrode means having a predetermined axis of symmetry;

particle transport means providing an electric field for charging said particles to cause repetitive electrostatic displacement of a portion of said particles toward said axis of symmetry;

each of said particles being positively charged on contact with said positively charged electrode means;

said particle transport means including a negatively biased electrode having a concave active surface with the radius of curvature thereof being at least several orders of magnitude larger than the spacing between said concave surface and said charging electrode so that as the particles are repetitively electrostatically displaced toward said axis of symmetry their trajectories approach parallelism with said axis;

with said negatively charged electrode being apertured to provide a particle ejection aperture extending therethrough in alignment with said axis of symmetry;

means for subsequent electrostatic acceleration of particles which are ejected through said aperture to respectively differential final velocities which vary inversely as the sizes of the different particles.

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