Aug. 4, 1964 H. L. BULLOCK 3,143,492

ELECTROSTATIC SEPARATION

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Fig. 1

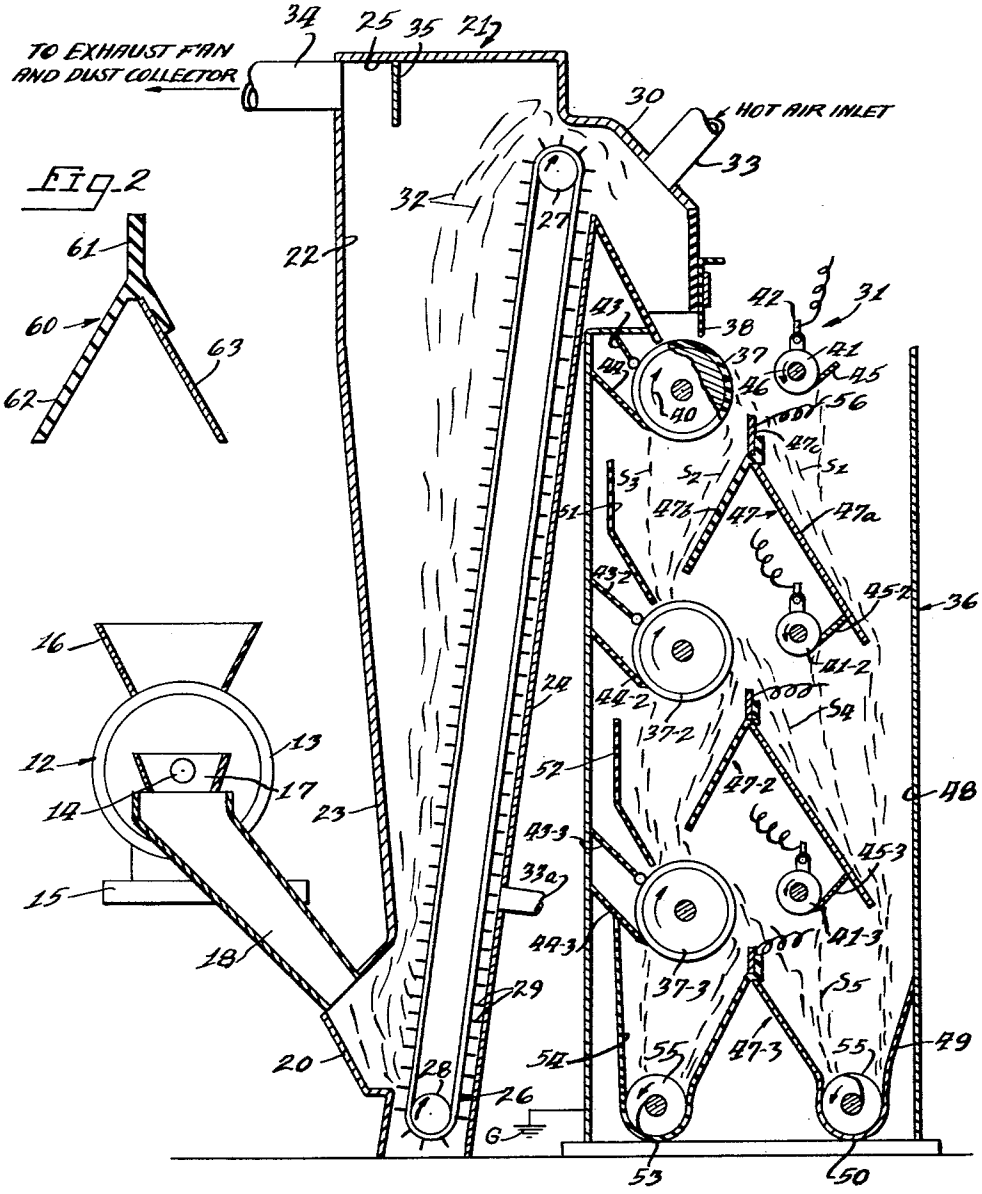


Fig. 2

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ELECTROSTATIC SEPARATION

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Fig. 3

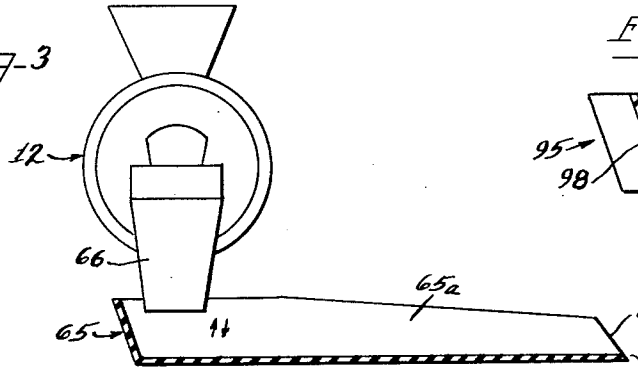
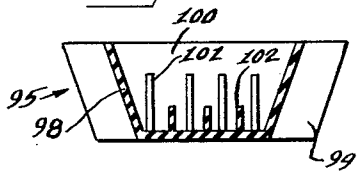


Fig. 5



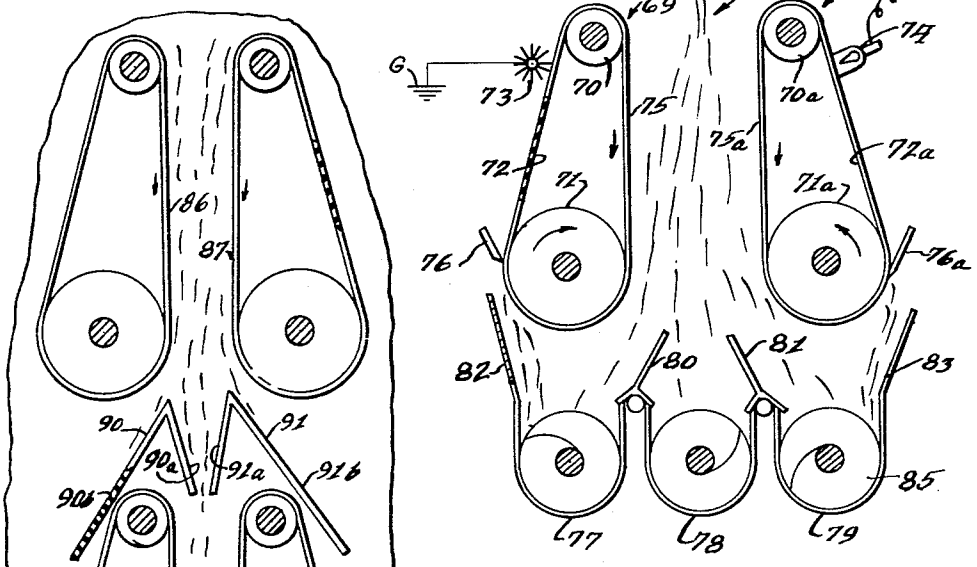


Fig. 4

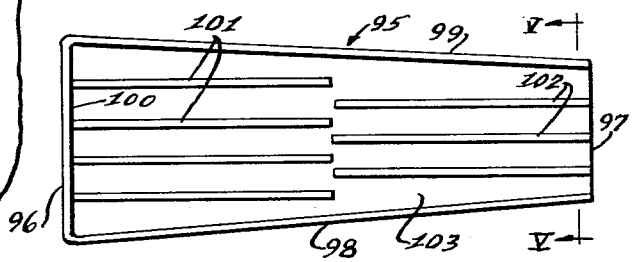


Fig. 6

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ELECTROSTATIC SEPARATION

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Fig. 7

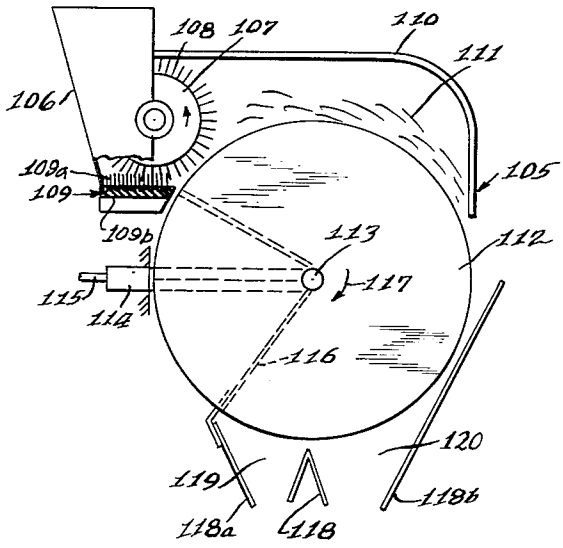


Fig. 10

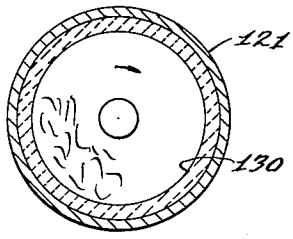


Fig. 11

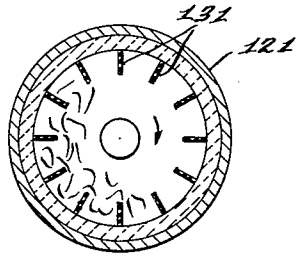


Fig. 8

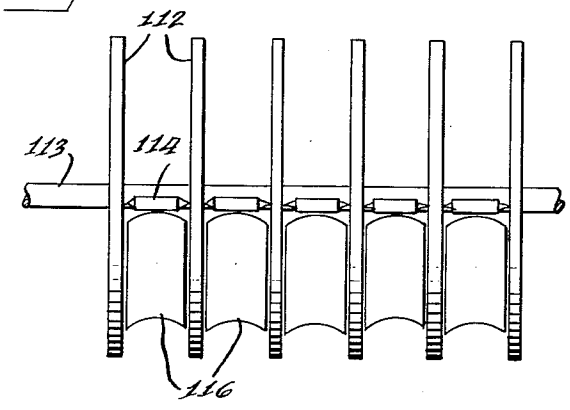
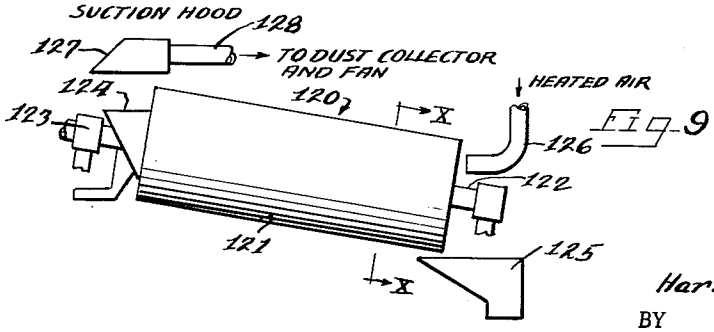


Fig. 9



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United States Patent Office

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ELECTROSTATIC SEPARATION

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Filed Nov. 17, 1961, Ser. No. 153,124
16 Claims. (Cl. 209—127)

This invention relates to electrostatic separation, and more particularly to the dry electrostatic separation of discrete, or particulate, mixtures of materials having different, or dissimilar, contact potentials. In general, the purpose of such electrostatic separation is to separate an economically more valuable constituent of a mixture from other constituents thereof, or to effect a beneficiation as to the desired constituent of a mixture, but in some cases the purpose is merely to separate the mixture into two, or more, fractions, each of enhanced purity as to a respective one constituent with consequent greater usefulness for some industrial purposes.

All methods of electrostatic separation depend upon the acquisition by the particles to be separated of different, or dissimilar, electrostatic charges. In a broad sense, particles having different dielectric constants will acquire respectively different electrostatic charges as a result of the making and breaking of contact between such particles, or between the particles and surfaces that may be used for confining or guiding the particles during movement thereof. Such charging of the particles is generally thought of as being brought about as a result of friction, but actually it is the result of contact and separation, and the extent of the differential charge acquired by the respective particles is primarily dependent upon the respective surface contact potentials of the particles. The method of the present invention will be described in connection with this contact-and-separation type of electrostatic charging of materials. Other effects may be incidental to the carrying out of this primary method, as for instance the so-called pyroelectric effect, but for best operation of my method of electrostatic separation all other techniques for imparting differential charges to the particles of a mixture are to be avoided or minimized as to their charging effect.

It is an important object, therefore, of this invention to provide an electrostatic separation system of superior efficiency and of greater applicability to a wider variety of materials to be separated than heretofore known systems.

It is a further important object of this invention to provide a method for the dry electrostatic separation of materials having different contact potentials, wherein such materials after being electrostatically charged are kept out of contact with electrically conductive surfaces until after electrostatic separation of the materials has been effected, thereby insuring the retention by the respective materials of higher proportions of the charges imparted to such materials than would be possible where neutralization of the contact charges due to shorting and/or grounding out of the charges occurs.

It is a further important object of this invention to provide for the charging and feeding of materials into an electrostatic separation zone in such a manner as to establish and maintain the highest practical differential charges on the materials to be separated from the charging stage up to and including the actual separation stage.

It is a further important object of this invention to establish differential electrostatic charges on materials and to effect the separation of said materials while the same are confined or guided as to their movement by dielectric surfaces, with little if any contact between such materials and electrically conductive surfaces from the charging to the separation stage, both inclusive.

Another object of this invention is to provide an improved method of electrostatic separation, applicable to both the contact roller type and the free-fall type of separation, wherein the high differential voltage effective for such separation is established between two relatively moving dielectric surfaces by impressing upon such surfaces the required voltages at a stage in advance of the zone in which such separation is effected, then moving the resultingly charged surfaces into such zone and thereafter removing from such charged surfaces any materials adhering thereto prior to the return of said surfaces to said voltage impressing stage.

Another object of this invention is to provide apparatus particularly adapted for the carrying out of my improved method of electrostatic separation in connection with materials of widely different physical forms and characteristics, such as mixtures of seeds, mechanically ground solids, crystals and fibrous material.

Another object of this invention is to provide an improved electrostatic separation apparatus wherein the charging and feeding zone is surfaced with dielectric material for effecting differential contact charging of the materials to be separated and the separation zone is defined by spaced moving surfaces of differentially charged dielectric material, whereby the substances to be separated are first caused to acquire optimum differential charges in accordance with their respective contact potentials and such charges are effectively maintained for most efficient separation of said substances in said separation zone.

Other and further objects of this invention will become apparent from the following description and appended claims.

Referring to the drawings:

FIGURE 1 is an elevational view, partly in section with the sections taken in several vertical planes, and somewhat diagrammatically, of apparatus, including a roll-type of electrostatic separation zone;

FIGURE 2 is a detail end elevational view of a plane type of divider for use in the electrostatic separation zone of FIGURE 1;

FIGURE 3 is a side elevational, diagrammatic view of a modified form of my invention, employing a free-fall type of electrostatic separation zone;

FIGURE 4 is a top plan view of a form of vibratory-feed mechanism for use in the apparatus of FIGURE 3;

FIGURE 5 is a sectional view taken along the line V—V of FIGURE 4;

FIGURE 6 is a side elevational, diagrammatic view of a modified form of electrostatic separation zone for use in an apparatus such as shown in FIGURE 3;

FIGURE 7 is a side elevational, diagrammatic view of a multiple disc type of separator for use in separating fibers of varying compositions, or for separating fibers from associated, foreign, non-fibrous material;

FIGURE 8 is a broken, top plan view of the multiple disc separator of FIGURE 7;

FIGURE 9 is a diagrammatic side elevational view of a modified form of dryer;

FIGURE 10 is a sectional view taken substantially along the line X—X, showing a ceramic lined dryer drum; and

FIGURE 11 is a similar sectional view of a ceramic lined drying drum with internal radial baffles, or lifts.

DEFINITIONS

Technical terms employed herein are intended to have their generally accepted meanings. Many such terms are unavoidably relative in their meaning and scope, but nevertheless have a degree of definiteness that renders their meansing clearly understandable.

By "electrical conductive" material is meant a conductor, defined as: "A class of bodies which are incapable of

supporting electric strain. A charge given to a conductor spreads to all parts of the body."

Dielectrics, insulators, or non-conductors are: "A class of bodies supporting an electric strain. A charge on one part of a non-conductor is not communicated to any other part."

Particle sizes are specified herein in accordance with Tyler Standard Screen Scale Sieves, the word "plus" indicating that the particles will stay on a sieve of the specified mesh, and the word "minus" indicating that the particles will pass through a sieve of the specified mesh. Screen mesh numbers will be understood wherever numerical limits are given for particle sizes.

GENERAL CONSIDERATIONS

With respect to conditions that are required for carrying out the method of my invention, those of temperature, relative humidity and particle size, while important, may vary within rather wide limits.

If the material to be processed is not particularly heat sensitive, it may be dried, if drying is required, at discharge temperatures ranging from 220° to 360° F., such as are produced in usual surface dryers for minerals. Dryers for foods, chemicals and organic materials usually have their discharge temperatures limited by the sensitivity of the particular material being processed. Such discharge temperatures may be as low as 140° F. However, unless the material is heat sensitive, the temperature is usually kept above the boiling point of water, or 212° F., to insure complete surface drying.

Relative humidity during electrostatic separation is only important to the extent that the material, after being dried, should not be permitted to pick up sufficient moisture to reduce substantially the ability of the material to become electrostatically charged or to retain such charge once acquired. A damp or wet surface is a conductive surface and its contact with the material to be electrostatically separated will allow shorting out or neutralization of charges on the material. Properly designed enclosures eliminate such problems where the circumambient atmosphere has a relatively high humidity.

With regard to the particle size of the materials to be separated electrostatically, extremely fine particles, or dust, are to be avoided since such particles will coat or adhere to other larger particles with resultant loss of electrical identity and impossibility of good separation. If a mixture of materials is thoroughly de-dusted, most materials capable of separation otherwise can be separated satisfactorily if not substantially finer than 200 mesh and not coarser than 6 mesh. In the case of mineral separations, satisfactory results have been obtained with a feed of minus 6 plus 200, but better results are usually possible if the feed is prescreened into fractions of minus 12 plus 40, and minus 40 plus 200 mesh. Since plastics can frequently be ground without producing a substantial proportion of fines, the feed in the case of plastics is preferably ground and screened to produce feed fractions of minus 6 plus 35, and minus 35 plus 100.

As to the materials that can be electrostatically separated, those that could be separated by prior electrostatic separation methods can generally be separated with greater facility or more efficiently by the present method. Additionally, some mixtures, not heretofore capable of separation on a practical or commercial basis, can now be electrostatically separated or beneficiated as to one or more of their constituents on an economical basis.

The prerequisite for separation of any two materials by my method is a difference in dielectric constants. Commercial separations will, of course, depend upon whether the mixtures are available in large quantities, as in the case of mineral ores, natural sands, contaminated food materials, plastic scrap, and the like. Minimum differences in dielectric constants as between materials that can or cannot be separated have not been quantitatively determined, but examples are available that indicate

satisfactory separation where there is only a single unit difference in the respective dielectric constants of the materials separated. Methyl methacrylate polymers, or resins, having a DC (dielectric constant value) of 3.5 to 4.5 have been separated from polystyrene resin having a DC of 2.45 to 2.46; a vinyl resin having a DC of 3.2 to 3.6 has been separated from rubber having a DC of 5.4, and from polyethylene resin having a DC of 2.25 to 2.35.

By actual comparative tests, my present method of separation, using dielectric surfaces in the charging and conveying, or feeding zones, and, preferably, dielectric surfaces in the drying zone, has made possible an increase in the rate of feed to the electrostatic separation zone and a reduction in the number of passes therein necessary to effect a given degree of separation or of beneficiation in a given feed material.

For example, in the separation of quartz from calcium carbonate, e.g., in the removal of "insoluble" material to obtain a product beneficiated as to its calcium carbonate content for use in making fillers in the plastics and paint industry, an old method required four passes with a feed rate of only 201 pounds per foot of feed rool length per hour, whereas with the present method, only two passes are necessary and the rate is increased to 997 pounds per foot of feed roll length per hour.

As another example, in the case of plastic scrap, under an old method, eight passes at the rate of 155 lbs./ft./hr. were required, whereas under the present method, the same or greater cleanliness of separation is obtained with two passes at the rate of 420 lbs./ft./hr.

APPARATUS FOR CARRYING OUT METHOD OF PRESENT INVENTION

Suitable apparatus for carrying out the method of my present invention is illustrated more or less diagrammatically in the drawings. The apparatus shown in FIGURE 1 illustrates a contact feed roller type of separation; while FIGURES 3 to 6 illustrate a free-fall type of separation, with details of a vibrator type of feeder therefor and modifications of the electrostatic separating and collecting devices. FIGURES 7 and 8 illustrates a multiple dielectric disc type of separator for separation of fine fibers of different composition or characteristics from each other or from foreign or contaminating substances; and FIGURES 9 to 11 illustrate various types of dryers and details thereof suitable for use in place of the dryer diagrammatically illustrated in FIGURES 1 and 3. FIGURE 2 illustrates a plain type of divider such as may be used in the apparatus of FIGURE 1 when the separation is not so delicate as to require an upper dividing edge having an adjustable potential.

A suitable source of high voltage D.C. current (not shown) is made available for the electrodes used in the electrostatic separation zones of the various types of equipment illustrated in the drawings. In general, it is preferred to operate with a total impressed difference in voltage, or potential, in the range of 3,000 to 15,000 volts per inch of distance between the separated electrodes. This voltage should be maintained at a constant high direct voltage potential substantially free of alternating current components.

AS SPECIFICALLY SHOWN ON THE DRAWINGS

In the apparatus illustrated in FIGURE 1 of the drawings, the reference numeral **12** indicates generally a conventional type of rotary dryer comprising a cylindrical metal shell **13** mounted for rotation about an axis **14** and supported upon a footing **15**. The material to be dried is introduced at one end through a metal hopper **16** and is discharged at the other end through an opening **17** into a discharge spout **18** which may be formed of metal or of dielectric material but which is preferably lined with insulation, or dielectric material. The discharge spout **18** discharges the dried particulate material to be separated into a hopper **20** at the lower end and one side of

a material-elevating and material-charging device, designated generally by the reference numeral **21**. The device **21** comprises a relatively tall, vertically arranged housing **22**, which may be of metal, and which is formed with opposed, upwardly divergent walls **23** and **24**, and a horizontal top wall **25**.

A belt type elevator, indicated generally by the reference numeral **26**, looped about upper andd lower rolls **27** and **28**, extends more or less parallel to the wall **24**. Said belt **26** is preferably formed of dielectric material, such as rubber, and is provided with spaced, transversely extending cleats **29**, which serve as flights for lifting the feed from the hopper **20** to the top of the device **21**, where some of the feed is constantly being discharged into a downwardly directed chute **30** for feeding to the electrostatic separation part of the mechanism, indicated generally by the reference numeral **31**. A proportion of the feed lifted by the cleated belt **26** falls back down to the bottom of the housing **22**, as indicated by the dash lines **32**. In order to effect a de-dusting of the feed material within the device **21**, hot air inlets **33** and **33***a* are provided to introduce hot air into the discharge chute **30** and the lower portion of the housing **22**, respectively. A pipe **34** near the top of the device **21** conducts spent air and dust from the housing to an exhaust fan and dust collector (not shown). A downwardly extending baffle **35** reduces the carryover of other than dust with the stream of hot air sweeping through the top portion of the housing **22** before its discharge through the pipe **34**.

The device **21** thus serves not only for the elevation of the material to be electrostatically separated, but also for the electrostatic charging of such material and for the de-dusting of it, prior to being fed into the electrostatic separator zone indicated at **31**. Since the charging is done primarily as a result of the friction of the particles of the material upon one another and the relative friction between the particles and the cleated elevating belt **26**, formed of dielectric material, the housing **22**, itself, may be formed of metal without substantially lessening the degree of the charges imparted to the particles of the material as a result of such mutual friction between the particles and the friction between the particles and the dielectric material of the belt. In operation, there is actually relatively little contact of the particles with the surfaces of the metal housing **22** as compared with the frictional contacts just mentioned.

The electrostatic separation zone **31** is included within a housing, generally represented by the reference numeral **36**, which may suitably be made of metal and which is merely for the purpose of protecting the electrostatic separation zone proper from the circumambient air so as to largely eliminate the effect of air temperature, relative humidity and air currents, upon the operation of the electrostatic separation zone. A driven feed roll **37** is mounted near the top of the inerior of the housing **36** directly below the open end of the chute **30** for receiving material and feeding the same into the electrostatic separation zone **31**. An adjustable feed hopper gate **38** serves to regulate the rate of feed of material to the roll **37**. The chute **30**, the adjustable portion of the gate **38** and the feed roll **37** are all formed of dielectric material, or are surfaced with dielectric material so as to preclude substantial contact of the feed material with conductive, grounded surfaces from the initial charging stage in the device **21** up to and including the actual delivery of the material as feed to the electrostatic separation zone **31**.

The feed roll **37** is driven in a direction indicated by the arrow **40**, as viewed in FIGURE 1, at a surface speed such as to give maximum through-put of material consistent with the degree of separation or beneficiation of the material that is required. A rotating dielectric electrode **41** of lesser diameter than the dielectric feed roll **37** is positioned in properly spaced relation to the surface of said roll **37** so that when the desired voltage is impressed upon said electrode **41** through the high tension lead **42** an effective voltage gradient will be set up between said electrode **41** and the feed roll **37**. Preferably, the feed roll **37** is grounded through a ground connection **43** and the metal housing **36** to ground, as at G, but it will be understood that both the feed roll **37** and the electrode **41** may be connected to sources of direct current high voltage of such difference in magnitude or sign as to give the proper potential gradient between the roll and the electrode. A scraper **44** is adjustably held against the surface of the roll **37** on the up side thereof for removing particles adhering to such surface. Similarly, a scraper **45** is associated with the rotating electrode **41** on the up or back side thereof, as indicated by the arrow **46** showing the direction of rotation of said electrode **41**, and this scraper **45** serves to remove particles adhering to the surface of said roll **41**.

A divider, indicated generally by the reference numeral **47**, is positioned beneath the gap between the roll **37** and the electrode **41** for the purpose of dividing and directing the streams of material delivered from said feed roll **37** and subjected to the effect of the high potential gradient between said roll and the electrode **41**. Due to the fact that some of the particles in the feed stream will be attracted toward the electrode **41** and others repelled therefrom, or attracted to the surface of the feed roll **37**, there will, in general, be a division of the feed stream into several branch streams. These branch streams are indicated by the dash lines and by the reference numerals S_1, S_2 and S_3, respectively. The divider **47**, which separates the main stream into the branch streams S_1 and S_2 may suitably be formed of sheets of dielectric material arranged to provide upwardly convergent surfaces **47***a* and **47***b*, with a blade-like bar **47***c* extending vertically upwardly from the convergency of said surfaces **47***a* and **47***b*.

As illustrated, the electrostatic separation zone **31** includes a second and third pass, each of which is constituted by a pair of spaced rolls similar to the feed roll **37** and the roller electrode **41** providing a high potential gradient between each of the respective pairs. The corresponding elements in the second and third pass to those in the first pass will be indicated by the use of the same reference numeral followed by **–2** or **–3** to represent the second or third pass, as the case may be.

The feed rolls **37–2** and **37–3**, in addition to being identical with the feed roll **37**, are mounted vertically beneath said feed roll **37** and are driven in the same angular direction, as indicated by the corresponding arrows. Similarly the rotating electrodes **41–2** and **41–3** are identical with the electrode **41** and are mounted vertically below said electrode. All of the rotating electrodes **41**, **41–2** and **41–3** may be connected to the same source of high voltage D.C., and all of the feed rolls **37**, **37–2** and **37–3** may be grounded, or different arrangements may be used to give different potential gradients in the respective passes. From the first pass, the stream S_1, after being divided from the stream S_2 by the blade **47***c*, is directed along the outer surface of the divider wall **47***a* and falls by gravity inside the corresponding wall **48** of the housing **36**. A downwardly inclined baffle **49** directs the falling stream S_1 into a trough-like collector **50** at the bottom of the electrostatic zone **31**.

The stream of material S_2 is directed by the wall **47***b* of the divider **47** onto the surface of the feed roll **37–2**. From said roll **37–2**, a portion of the resulting stream, indicated by the designation **S–4**, namely, particles attracted by the rotating electrode **41–2**, is conducted over the surface of the divider **47–2** to mingle and fall with the branch stream **S–1** into the collector **50**. On the other, or left-hand side of the respective dividers as viewed in FIGURE 1, the streams of material designated as S_2 and S_3, in the first pass, are guided by the downwardly sloping wall **47***b* and by a complementary downwardly directed baffle **51**, onto the surface of the feed roll **37–2**. Similarly, the streams falling from the feed roll **37–2** to

the left of the divider **47–2** are guided by the corresponding portion of said divider and by a guide **52** onto the feed roll **37–3**. From the feed roll **37–3**, the streams of material hugging or adhering to the surface of said roll are caused to drop into a collecting trough **53** and are guided therein by the left-hand wall of the divider **47–3** and the guiding wall **54**. Screw-type conveyors **55**, mounted for rotation in the troughs **50** and **53**, serve to remove the collecting fractions of the material from said troughs.

Referring more particularly to the divider **47**, with which the dividers **47–2** and **47–3** closely correspond in structure and function, the blade **47***c* is preferably formed of metal and is maintained at an adjusted potential through a high tension lead **56** that is substantially the same potential as that existing in the plane of the blade **47***c* by virtue of the potential gradient between the feed roll **40** and the roller electrode **41**. The purpose of so maintaining an adjusted potential in the divider blade **47***c* is to avoid any disturbance of the potential at this point in the high tension field between the feed roll and the rotating electrode, or, in other words, to get a uniform potential drop across the gap. This arrangement has been found to facilitate the separation of materials that are more difficult to separate electrostatically. Also, to improve the sensitivity of the separation, the left-hand walls **47***b* and corersponding walls of the dividers **47–2** and **47–3** are formed of insulation material, and so are the guiding baffles **51**, **52** and **54**, and the scrapers **44**, **44–2** and **44–3**. The right-hand side of the dividers, however, represented by the outwardly sloping wall **47***a* and the corresponding walls of the dividers **47–2** and **47–3**, and the associated electrode scrapers **45–2** and **45–3**, are formed of metal. The reason for using metal is that there is no further separation of one particle from another in the streams of particles S_1, S_4 and S_5, whereas there is further separation of particles from the combined streams S_2 and S_3, and the corresponding combined streams from the second and third passes.

FIGURE 2 shows a plain type of divider, indicated by reference numeral **60**, comprising a blade portion **61** and a left-hand downwardly sloping wall portion **62**, both made of dielectric insulation material, and a right-hand wall portion **63**, formed of metal. In this type of divider, no voltage is impressed upon the blade portion **61**. Where the electrostatic separation is not so delicate, this plain type of divider, indicated by the reference numeral **60**, may be used in place of the divider **47**, **47–2** or **47–3**, of FIGURE 1.

As in any operation of the roll type electrostatic separator, the polarity of the rotating electrode, such as the electrode **41**, is selected in accordance with the characteristics of the material of the mixture that is to be separated out, or with respect to which the mixture is to be beneficiated. In general, a polarity for the rotating electrode will be chosen such as to attract that material, or component, of the mixture that is present in a minor proportion as compared with the remaining materials, or components, in the mixture. The rotating electrode may, therefore, be either positively charged or negatively charged for greatest efficiency of separation, and the dielectric-surfaced feed roll, such as the roll **37**, may either be grounded, or oppositely charged from the roller electrode **41**. A potential gradient between the feed roll and the roller electrode is selected that is best suited to effect the desired separation, or beneficiation, of the feed material. Although three passes have been illustrated in FIGURE 1, fewer or more passes may be employed, and, if desired, a separation of middlings may be made, rather than the two fractions illustrated.

The apparatus shown in FIGURE 3, which is of the free-fall type, includes a rotary dryer **12**, similar in construction to that of FIGURE 1, and a generally horizontal vibrating feeder, indicated generally by the reference numeral **65**, on to one end of which the dried feed material is fed from the dryer **12** through a chute **66**. Vibrating means (not shown) are provided for vibrating the feeder **65** in any conventional manner. Said feeder mechanism **65** comprises an elongated trough of a width approximating that of the electrostatic separation zone, which is formed of dielectric material, or is surfaced therewith on its upper surface and sides **65***a*, to realize the advantages heretofore pointed out where the charging and feeding are effected in the substantial absence of contact with conductive surfaces.

Due to the vibration of the mechanism **65**, and/or to its slight inclination, the material fed thereon is caused to advance from the feed end toward the delivery end, indicated at **67**, from which the charged material falls by gravity into an electrostatic zone indicated by the reference numeral **68**. Said zone **68** is defined by a pair of similar belt mechanisms **69** and **69***a*, of which only one need be specifically described. The belt mechanism **69** comprises upper and lower rolls **70** and **71**, respectively, of which one of the rolls is driven to drive an endless dielectric belt **72**, as indicated by the arrows. A dielectric belt-grounding connection **73** is positioned near the top of the upper end of the run of the belt **72**, whereas a surface charging electrode **74** is positioned at a corresponding point on the upward run of the dielectric belt **72***a*. The desired potential gradient is thereby set up between the belts **72** and **72***a* across the gap between the upper rolls **70** and **70***a*. The downward runs, **75** and **75***a* of the respective belts are along generally parallel paths, although the planes of said runs **75** and **75***a* may be inclined slightly in either direction. A scraper **76** of insulation material is positioned near the lower end of the upward run of the belt **72** to scrape any adhering particles from the belt before being grounded and returned to the electrostatic zone proper. Similarly, a scraper **76***a* of insulation material is mounted near the lower end of the upwardly moving portion of the belt **75***a* to remove adhering particles before the belt is again charged by the surface charging electrode **74**.

A material-collecting zone is arranged beneath the electrostatic zone, and comprises three troughs **77**, **78** and **79** extending horizontally in parallelism and provided with dividers **80** and **81** between the central and outer troughs, and with guiding baffles **82** and **93** flared upwardly and outwardly from the outer troughs **77** and **79**, respectively. The dividers **80** and **81** are adjustable for positioning of their upper edges where best calculated to realize most efficient separation of the materials. Convolute conveyors, similar to the conveyors **55** and identified by the reference numeral **85**, are positioned in the respective troughs **77**, **78** and **79** for the removal of the separated fractions.

FIGURE 6 illustrates a modification of a free-fall type of zone for use with the vibrating mechanism of FIGURE 3. In FIGURE 6, an upper pass is provided by the driven, endless belts **86** and **87**, arranged in generally parallel spaced relationship, and a lower pass is provided by similar endless belts **88** and **89** positioned directly beneath the belts **86** and **87**, respectively. Dividers **90** and **91**, formed of dielectric material, or surfaced therewith, are interposed between the upper and lower passes of this multiple pass separator. Each of said dividers **90** and **91** is of generally inverted V-shape, the divider **90** serving to divert a portion of the stream of material falling through the electrostatic separator zone to the left, outside of the run of the belt **88**, and to divert another portion of the stream into the lower electrostatic separation zone between the downwardly running portions of said belts **88** and **89**. Similarly, the divider **91** serves to divert a portion of the falling stream of the material to the right-hand side, out of contact with the run of the belt **89**, and another portion of the stream into the lower electrostatic separation zone between the downwardly running portion of the belts **88** and **89**. The dividers **90** and **91** may be considered as a transition piece so formed as to con-

centrate the material which is not strongly attracted to either of the charged upper belts 86 or 87, and to deliver such material in the form of a thin stream between the lower charged belts 88 and 89. The dividers 90 and 91 may be made wholly of insulation material, or only the convergent inner surfaces 90*a* and 91*a* may be provided by dielectric material while the outwardly and downwardly divergent surfaces 90*b* and 91*b* may be metallic surfaces.

A modified form of vibrating mechanism is illustrated in FIGURES 4 and 5 for use where maximum charging due to extensive and repeated particle contact and separation between the various components of the feed mixture and between the feed mixture and dielectric surfaces is desired. This modified form of vibrating mechanism comprises a relatively shallow pan 95 tapering lengthwise from the feed end 96 to the discharge end 97 and provided with outwardly and upwardly flared, low side walls 98 and 99 and a connecting end wall 100 at the feed end. A plurality of spaced baffles 101 and 102 project upwardly from the bottom wall 103 of the pan 95 to increase the extent to which the material flowing over said pan 95 is agitated. The baffles 101 extend in parallel spaced relation from the end wall 100 to an intermediate portion of the pan 95, and the baffles 102 extend therebeyond to the discharge end 97 with said baffles 102 positioned in staggered relation to the baffles 101 to interrupt the flow of material toward the discharge end. The entire pan 95 is either formed of dielectric material or else all of the surfaces of the pan and of the baffles 101 and 102 that come into contact with the material are made non-conductive to impart maximum differential charges to the components of the feed material that are to be separated.

FIGURES 7 and 8 disclose a mulitiple disc type of separator, indicated generally by the reference numeral 105, for use in the separation of fine fibers of different compositions, or characteristics, or for the separation of fine fibers from foreign material associated therewith and of a different dielectric constant from that of the fibers. In FIGURE 7, there is shown a hopper 106 for receiving the fibrous material in a loosely matted or in a shredded state, but not separated as to the individual fibers. The separation of the fibers is accomplished by means of a driven, revolving brush 107 provided with bristles 108 of nylon or other suitable dielectric material projecting radially from the periphery thereof. A stationary carding cloth 109, with its pins 109*a* mounted in insulating material 109*b*, is positioned at the lower end of the interior of the hopper 106 for co-action of the carding pins with the revolving brush 107 and the bristles 108 in the separation of the fibrous material into individual, fine fibers and for throwing the separated fibers laterally within a confining housing 110, preferably formed of dielectric or insulation material. A stream of such fibers is indicated generally by the reference numeral 111.

Multiple discs 112 of dielectric material are mounted upon a shaft 113 for rotation in vertical planes within the lower open portion of the housing 110, which is of a width sufficient to accommodate the rotating brush 107 and the discs 112 on the shaft 113. Electrodes 114 connected by leads 115 to a suitable source of high tension D.C. voltage extend radially inwardly between pairs of such discs 112 to impress upon the opposed faces of each pair a high potential charge of the same sign. Alternatively, however, under some circumstances it might be feasible to charge such opposed surfaces with charges of different signs. A minimum of two discs is required for a disc-type separation with the fall of particles therebetween of particles to be separated, but any number of discs may be employed in spaced relationship along a common shaft. The number of cells is always equal to the number of discs minus one.

Radially extending scrapers 116 are stationarily mounted between the opposed faces of each pair of discs 112 to remove fibers adhering thereto ahead of the charging of the discs, the direction of rotation of which is that shown by the arrow 117 in FIGURE 7. An inverted V-shaped divider 118 is mounted for adjustable positioning below the roll 112 to cut the falling stream of material at the point of highest efficiency into two fractions, 119 and 120 and in cooperation with downwardly convergent outer baffles 118*a* and 118*b* may be formed of metal, since the desired separation has been accomplished before contact of the fibers with the surfaces of these elements.

In the operation of the multiple disc type separator of FIGURES 7 and 8, the fibers separated by the carding action of the rotating brush 107 and the carding element 109 are thrown across the rotating discs 112 for the full width of the disc assembly and fall by gravity between the several discs. In doing so, those fibers that are attracted by the charged surfaces of the discs tend to move toward such surfaces and to adhere thereto, and are scraped therefrom to fall in a stream 119 into the collecting zone provided between the guiding baffle 118*a* and the divider 118, while the unattracted fibers fall by gravity as a stream 120 into the collector defined by the other guiding baffle 118*b* and the divider 118. In cases where it might be desirable to separate those fibers attracted to and adhering to one of the charged surfaces of opposed faces of the discs 112, separate from those fibers that may be caused to adhere to the other of the opposed faces, appropriately arranged dividers, spaced lengthwise of the axis 113 of the disc assembly, would be necessary to effect such separation. In general, however, the separation will be between fibers, or between fibers and foreign components associated therewith, the separation being effected as between those components of the feed material that are attracted to the charged surfaces, and those that are not so attracted.

FIGURE 9 shows more or less diagrammaically a rotary dryer unit 120 that includes a driven, inclined, cylindrical shell 121 mounted upon a shaft 122 supported at its ends in bearing 123. Additionally, a feed hopper 124 serves for introducing the feed material into the higher end of the dryer drum 121, and a receiving hopper 125 catches the discharged, dried material from the lower end of the drum. As shown, heated air is introduced into the lower end of the drum through a duct 126 and the spent air from the feed end of the drum is drawn off through a suction hood 127 connected by means of a conduit 128 to a dust collector and fan (not shown). Such a dryer arrangement may be used in connected with the electrostatic separators of FIGURES 1 and 3.

In accordance with the principles of my present invention, the inner surface of the dryer drum 121 may be provided with a ceramic lining, indicated by the reference numeral 130 in FIGURE 10. Other non-conducting linings suitable for the purpose and relatively long-wearing may, of course, be used, but a ceramic lining is particularly adapted for the counter-current drying of granular, abrasive particles and for the concomitant charging of such particles as a result of the friction set up by the rotation of the drum. In order to increase the amout of friction that is induced, the interior of the drum 121 may be provided with radially directed, relatively narrow baffles, or lifts 131, as in FIGURE 11. The rotation of the drum thus produces a tumbling of the material upon itself and the inclination of the dryer produces a translatory movement from the feed to the discharge end. The material is thus continuously being charged as a result of the friction between the particles and between the particles and the surfaces with which they come in contact, while being dried and advanced, preparatory to being fed into an electrostatic separation zone. As previously indicated, the feed is preferably direct from the dryer to the electrostatic zone without intermediate contact with any conductive surfaces and without, of course, substantial change in the dried, charged condition of the particles as they leave the dryer.

COMPARATIVE EXAMPLES

In order to demonstrate the greater efficiency of electrostatic separation, using dielectric charging, feeding and separating surfaces, as compared with using conductive surfaces in these stages or zones, comparative separations were run on the same feed material under otherwise identical conditions of: (1) rate of feed of vibrator feeder; (2) speed of feed roll; (3) speed of rotating electrode; (4) charge on dielectric electrode, both as to sign and voltage; (5) setting of dielectric electrode; and (6) operating temperature. Operating under these conditions, all differences in results had to be due solely to the use of dielectric versus conductive surfaces in the charging, feeding and separating zones. The tests were limited to one pass to insure nearer equality of operations.

Example 1

One such comparative separation was made with a ground mixture of white Lucite (a polymethacrylate) and a red colored polystyrene plastic screened to a minus 8 plus 20 mesh fraction. With dielectric contact surfaces, 61.4% of the feed was separated as a white Lucite fraction, free from red styrene, and 38.6% of the feed was separated as a mixture of red and white plastic.

With conductive contact surfaces, under otherwise identical conditions, 79.9% of the feed was separated as a fraction that was badly contaminated with the red plastic, and 20.1% of the feed was separated as a mixture of white Lucite and red polystyrene. The separation was not satisfactory.

Example 2

In this comparative example, the feed material was a sample of calcite contaminated with natural gangue material, consisting of quartz and dark slatey mineral, probably silicates. The ground calcite was screened to give a minus 20 plus 70 mesh fraction. Before each run, the sample taken from this fraction was heated to 260° F., to surface dry the same and then allowed to cool to 130° F., to reduce the temperature gradient and to avoid rapid changes during the comparative tests.

When dielectric contact surfaces were used, as in Example 1, 95.1% of the feed was separated as a fraction that was much whiter than the feed and containing only a few fine dark specks, and 4.9% of the feed was separated as gray mixture containing quartz crystals and gangue.

With conductive contact surfaces, under otherwise identical conditions, 97.1% of the feed was separated as a fraction that was darker than the corresponding fraction, using dielectric contact surfaces, and not much improvement over the feed material; and 2.9% of the feed was separated as a fraction that was a gray mixture containing relatively fewer quartz crystals than the corresponding fraction, using dielectric contact surfaces.

While no analysis other than by visual inspection were made of the feed and separated fractions, the foregoing results demonstrated that more effective electrostatic separation can be obtained when dielectric contact surfaces, rather than conductive contact surfaces, are used in the feeding, charging and separating zones of an electrostatic separation system.

In order to obtain and maintain the maximum differential charges, based upon differences in surface contact potentials, on the materials to be separated, it is preferable to avoid not only the cancellation or diminution of any charges acquired by frictional contact in the manner herein described, but also to avoid the generation of any charges which might complicate or interfere with the separating action. To this end, infra-red dryers are to be avoided since they generate charges in a mix of dry material that may be large enough to upset the delicate balance of surface contact charges imparted to the particles by friction and thus interfere with separations being made on a contact charge basis.

Similarly, the use of spray or ion discharge electrode treatment of the feed material before it enters the separation field should be avoided, since the result of such treatment varies with the conductivity of the various components of the mix and has no direct relationship to the sign or potential of the useful contact potential charges resulting from friction alone. Consequently, straight surface potential charging utilizing the natural contact potentials of the materials to be separated, free from other methods of charging, is much to be preferred.

I claim as my invention:

1. The method of dry electrostatic separation of dissimilar substances from a particulate mixture thereof, which comprises charging said substances with differential electrostatic charges by contact with dielectric surfaces in accordance with their dissimilar contact potentials, directing said charged substances as a free falling stream through a gaseous medium into an electrostatic separation zone between electrostatically charged dielectric surfaces of differential potential for differential attraction of said substances to said surfaces, moving said surfaces with any adhering particles of said substances thereon to a point outside of said electrostatic zone and there removing such adhering particles from said respective surfaces.

2. The method of dry electrostatic separation of dissimilar substances from a particulate mixture thereof, which comprises charging said substances solely by interparticle contact and separation with differential electrostatic charges by contact with dielectric surfaces in accordance with their dissimilar contact potentials, directing said charged substances as a free falling stream into an electrostatic separation zone between electrostatically charged dielectric surfaces of differential potential for differential attraction of said substances to said surfaces, moving said surfaces with any adhering particles of said substances thereon to a point outside of said electrostatic zone and there removing such adhering particles from said respective surfaces, said substances being kept from contact with any electrically conductive surfaces from the time of initial charging to the time of removal from said dielectric surfaces.

3. The method of dry electrostatic separation of particulate substances of dissimilar contact potential from a mixture of such substances, which comprises vibrating said mixture in contact only with itself and with a dielectric surface to charge the mixture, feeding the charged mixture from such surfaces as a free falling stream of discrete particles into an electrostatic separation zone, impressing a high voltage potential upon upwardly moving spaced, generally vertical, charged dielectric surfaces and moving said charged surfaces in a downward direction in spaced relation to define said electrostatic separation zone.

4. The method of dry electrostatic separation of particulate substances of dissimilar contact potential from a mixture of such substances, which comprises vibrating said mixture in contact only with itself and with a dielectric surface to differentially charge the particles of said mixture, feeding the charged mixture from such surface as a free falling stream of discrete particles into an electrostatic separation zone defined by charged dielectric surfaces moving downwardly in spaced generally vertical planes and carrying charges of different potentials, and removing particles adhering to said last mentioned dielectric surfaces at points outside of said separation zone.

5. The method of claim 4, wherein the surfaces are endless and are moved downwardly to define said electrostatic zone therebetween and upwardly outside of said zone.

6. The method of claim 4, wherein the surfaces are endless and are moved downwardly to define said electrostatic zone therebetween and the surfaces are charged at points outside of said zones and in advance of such downward movement.

7. In an electrostatic separation apparatus, means defining a charging zone including a dielectric surface for supporting a mixture of substances to be separated, means defining a free-fall electrostatic separation zone includ-

ing spaced vertically extending differentially charged dielectric surfaces, means defining a collection zone beneath said separation zone and power means for respectively vibrating said charging zone dielectric surface to advance the mixture into said free-fall zone and for moving said spaced dielectric surfaces in a downward direction in said free-fall zone.

8. In an electrostatic separation apparatus, means defining a charging zone including a dielectric surface for supporting a mixture of substances to be separated, means including spaced movable charged dielectric surfaces defining a free-fall electrostatic separation zone, power means for respectively vibrating said charging zone dielectric surface to advance the mixture into said free-fall zone and for moving said spaced charged dielectric surfaces in a downward direction in said free-fall zone, and means for scraping off substances adhering to said downwardly moving dielectric surfaces for collection in said collection zone with corresponding portions of electrostatically diverted substances.

9. An electrostatic separation apparatus comprising: a vibratable member having a dielectric surface for supporting and charging material to be separated, means including downwardly moving portions of endless surfaces of dielectric material defining a free-fall electrostatic separation zone for receiving charged material from said vibratable member, and means including adjustable dividers defining a collection zone beneath said electrostatic separation zone.

10. An electrostatic separation apparatus comprising: a vibratable member having a dielectric surface for supporting material to be separated, means including portions of endless belts of dielectric material defining a free-fall electrostatic separation zone for receiving material from said vibratable member, means including adjustable dividers defining a collection zone beneath said electrostatic separation zone, means for vibrating said vibratable member and means for driving said belts to effect a downward movement of those portions of said belts that define said free-fall electrostatic separation zone.

11. An electrostatic separation apparatus comprising: a vibratable member having a dielectric surface for supporting material to be separated, means including portions of endless belts of dielectric material defining a free-fall electrostatic separation zone for receiving material from said vibratable member, a source of high potential electricity for differentially charging said endless belt portions, means including adjustable dividers defining a collection zone beneath said electrostatic separation zone, means for vibrating said vibratable member, means for driving said belts to effect a downward movement of those charged portions of said belts that define said free-fall electrostatic separation zone, and means outside of said separation zone for scraping off of said belts any material adhering thereto for removal to said collection zone.

12. An electrostatic separation apparatus comprising: means providing a movable dielectric surface for advancing material to be separated, means including endless belts of dielectric material having downwardly moving spaced portions defining therebetween a free-fall electrostatic separation zone for receiving material advanced by said movable dielectric surface, a source of high potential electricity for differentially charging said endless belts at points outside of and in advance of said free-fall zone and means for driving said belts.

13. An electrostatic separation apparatus comprising: vibrating means providing a movable dielectric surface for advancing material to be separated, means including endless belts of dielectric material having downwardly moving spaced portions defining therebetween a free-fall electrostatic separation zone for receiving material advanced by said movable dielectric surface, a source of high potential electricity for differentially charging said endless belts at points outside of and in advance of said free-fall zone, means for driving said belts, and scraping means for removing any material adhering to said belts at points outside said free-fall zone and beyond the lower end thereof.

14. The method of electrostatically separating substances of dissimilar contact potentials from a mixture of such substances, which comprises so moving a stream of such mixture while confined by dielectric surfaces as to effect repeated contacts and breaks between the particles of said mixture and thereby cause said substances to be charged in accordance with their respective contact potentials, delivering said mixture into an electrostatic separation zone defined by spaced endless moving dielectric surfaces having a high potential gradient between confronting portions of said surfaces, imparting a high potential charge directly to one of said dielectric surfaces in advance of said separation zone and so adjusting the charge on the other dielectric surface in advance of said separation zone as to maintain a maximum high potential gradient between said surfaces during their confronting relationship, and effecting separation of said charged substances in said separation zone.

15. In the dry electrostatic separation from a particulate mixture thereof of dielectric substances having different contact potentials, the steps of agitating said mixture in a charging zone defined by dielectric surfaces, feeding the resultingly charged mixture while supported on a moving dielectric surface for discharge in a generally downward direction into an electrostatic separation zone defined by spaced electrostatically charged dielectric surfaces of different potential to there effect a fractional separation of said substances, providing a dielectric surface for guiding at least one of the respective separated fractions into a subsequent separation zone therefor defined by charged dielectric surfaces and there effecting further separation.

16. In the dry electrostatic separation from a particulate mixture thereof of dielectric substances having different contact potentials, the steps of agitating said mixture in a charging zone defined by dielectric surfaces, feeding the resultingly charged mixture while supported on a moving dielectric surface into an electrostatic separation zone to there effect a fractional separation of said substances, providing a dielectric surface for guiding at least one of the respective separated fractions into a subsequent separation zone therefor defined by charged dielectric surfaces of differential potential and providing a conductive divider at an electrical potential favorable to optimum separation of said substances in advance of such dielectric guiding surface.

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