Jan. 18, 1955 E. C. GEAR 2,699,869

ELECTROSTATIC SEPARATOR

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FIG. 1

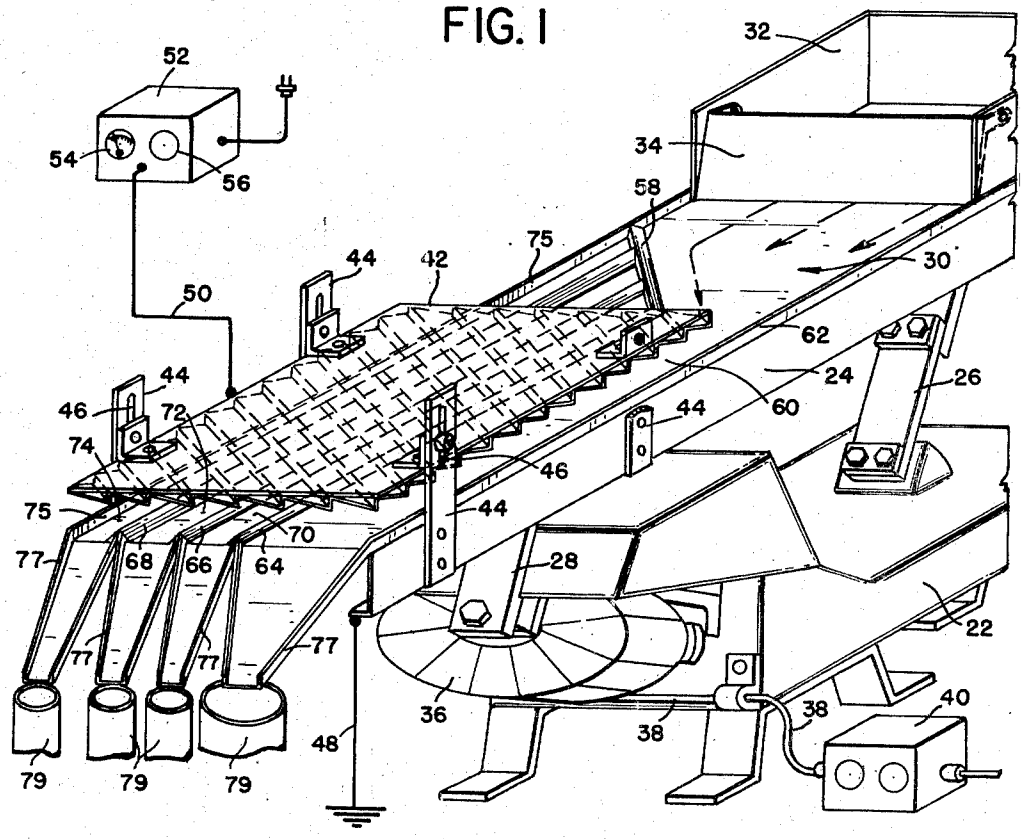


FIG. 2

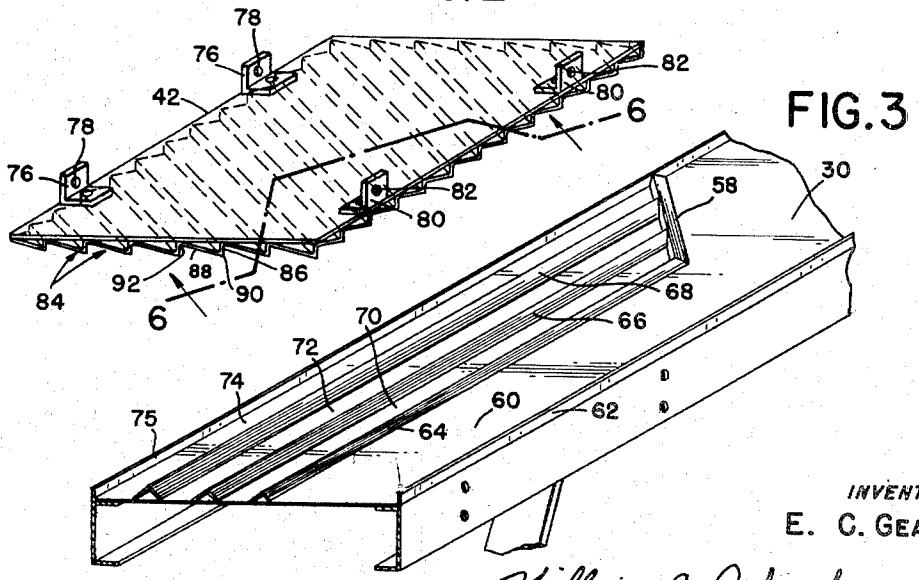


FIG. 3

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FIG. 4

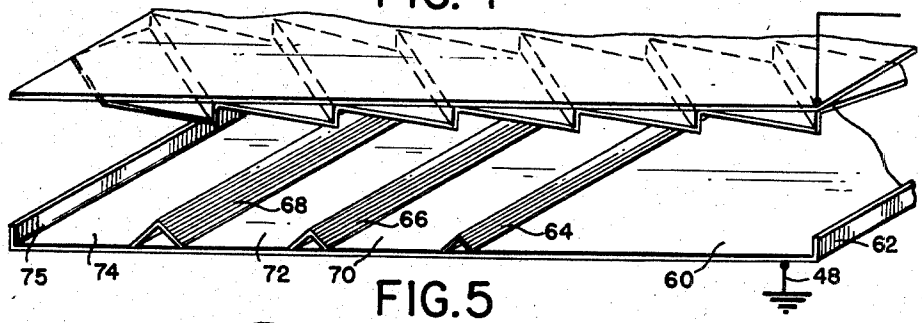


FIG. 5

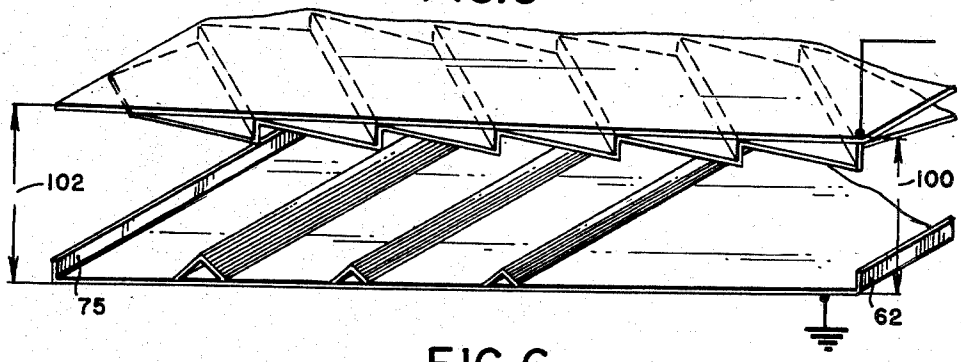


FIG. 6

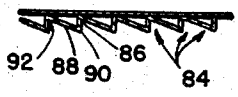
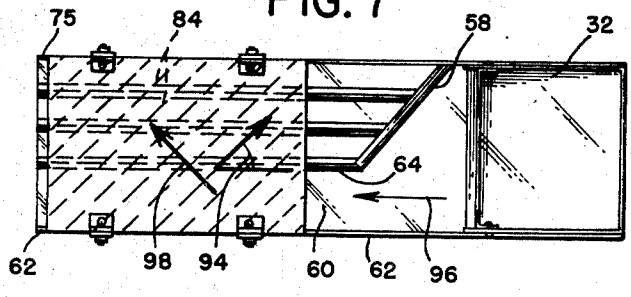


FIG. 7



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FIG. 8

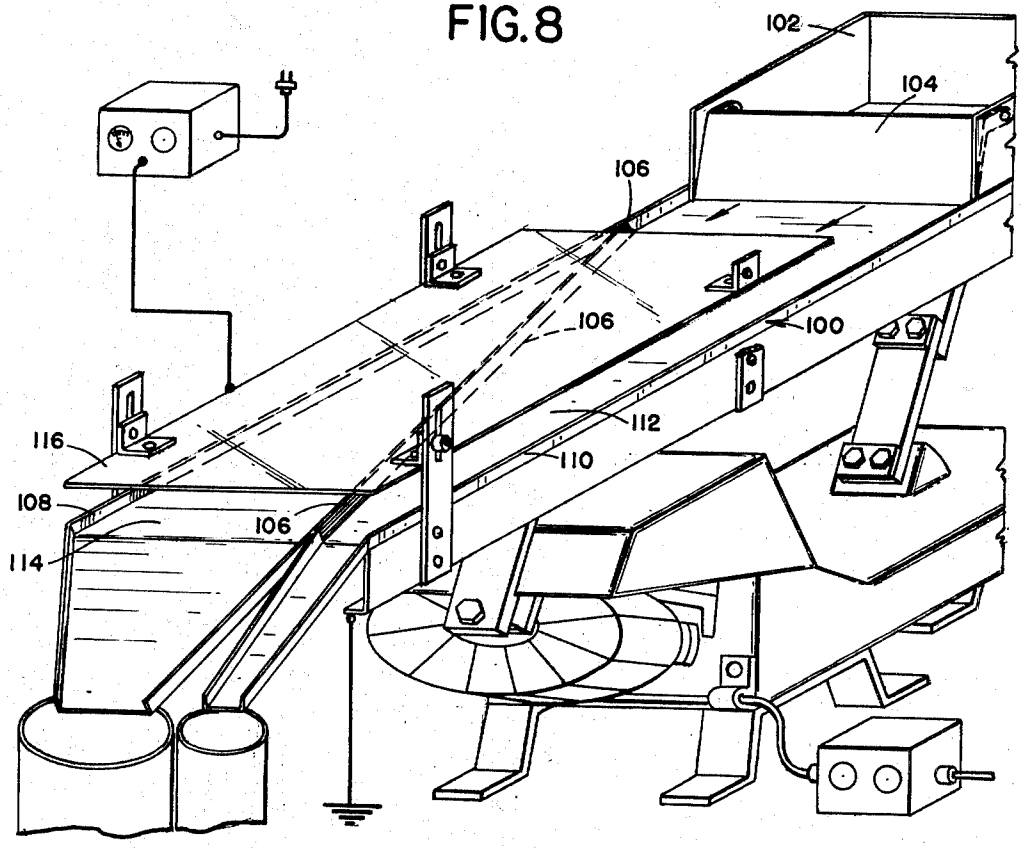


FIG. 9

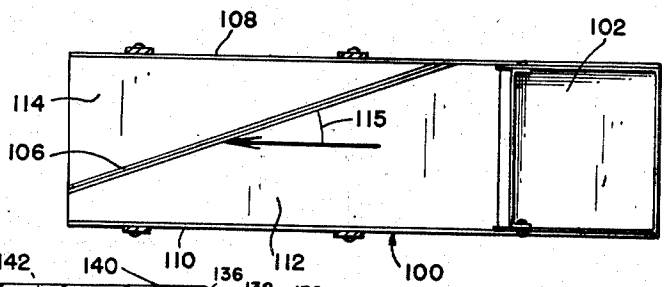
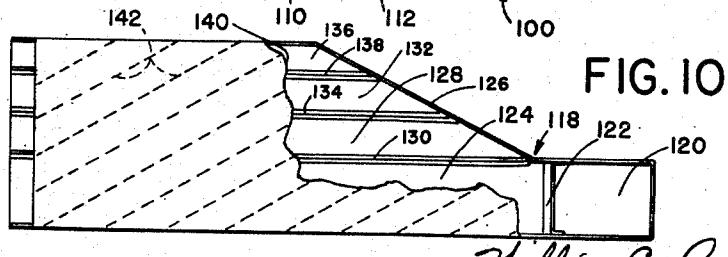


FIG. 10



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ELECTROSTATIC SEPARATOR

Eli C. Gear, Minneapolis, Minn., assignor to General Mills, Inc., a corporation of Delaware

Application April 18, 1952, Serial No. 283,021

20 Claims. (Cl. 209—127)

The present invention relates to electrostatic separation and particularly to improved apparatus for precise separation of organic stocks containing a wide range of particle types which differ only slightly one from another in their electrical characteristics.

Electrostatic separators have been proposed in the prior art in which material is fed in a given direction and an electrostatic field is produced which results in movement of selected particles transversely to said direction of feed. Such devices have worked satisfactorily with materials in which a relatively small number of particle types were included and where such types differed widely in their electrical characteristics. For example, conductors could be reasonably well separated from non-conductors by such devices. However, precise separations have not been achieved where organic particles were involved, or where a wide range of particle types of only slightly different electrical characteristics were included.

It is accordingly one object of the present invention to provide an improved electrostatic separator of the type in which material is initially fed to one area of a supporting member and in which selected types of particles are urged to another area of the supporting member under the combined influence of the electrostatic field, the feeding means, and other factors involved.

A further object is the provision of an improved means for establishing a directional electrostatic field for such a device.

Still another object is the provision of a separator of this type in which a barrier of predetermined height assists in controlling the passage of selected particles from one area to another of the supporting member.

A further object is the provision of an electrostatic separator in which at least one barrier is provided on a supporting electrode, and in which the direction of feed, the electrostatic field and other factors are correlated to give selected particles of the material repeated opportunities for attraction above and across the barrier.

Other objects and advantages will be apparent from the following specification in which certain embodiments of the invention are described with particular reference to the accompanying drawings.

In these drawings, wherein like reference characters indicate like parts,

Figure 1 is a partial perspective view of an electrostatic separator incorporating features of the present invention.

Fig. 2 is a perspective view of the upper electrode of the device of Fig. 1.

Fig. 3 is a partial perspective view of the lower electrode of the device of Fig. 1.

Fig. 4 is an enlarged partial and perspective view of the device of Fig. 1 showing one adjustment of the electrodes.

Fig. 5 is a view similar to Fig. 4 showing another adjustment of the device of Fig. 1.

Fig. 6 is a sectional view on the line 6—6 of Fig. 2.

Fig. 7 is a top view of the device of Fig. 1.

Fig. 8 is a partial perspective view similar to Fig. 1 of another embodiment of the invention.

Fig. 9 is a top view of the device of Fig. 8; and

Fig. 10 is a top view of a modified embodiment, with a portion of the upper electrode broken away for clarity.

As shown in Figs. 1 through 7, a preferred form of separator according to the present invention includes a supporting base 22 above which suitable frame members 24 are supported by means of inclined springs 26 and 28. A supporting member 30 for the material to be separated

extends substantially horizontally between the frame members 24. In the form illustrated, this supporting member 30 consists of an electrically conducting plate or lower electrode. A supply hopper 32 at one end of the device is provided with an adjustable gate 34 by means of which a thin uniform stream of material may be fed from the hopper 32 along the upper surface of the supporting electrode 30.

While it is possible in some cases to obtain the desired feeding movement along the electrode surface 30 by suitable inclination of the surface to obtain a gravity flow, the illustrated embodiment makes use of the inclined springs 26 and a suitable vibrator 36 by means of which the frame members 24 and electrode 30 may be vibrated rapidly in a direction perpendicular to the plane of the springs 26. This direction of vibration will thus include a substantial component longitudinally of the plate 30 and in the plane thereof, as well as a substantial component perpendicular to such plate.

The vibrator 36 is energized through connections 38 with a vibrator power source 40.

Located above a substantial area of the lower supporting member 30 is an upper electrode 42 which serves as a means for establishing the desired electrostatic field above the lower electrode. This upper electrode 42 is mounted on brackets 44 secured to the frame members 24. These vertical supports 44 are provided with vertical slots 46 permitting vertical adjustment of the upper electrode 42 in the manner described below. In Fig. 1 the lower electrode 30 and frame members 24 are shown as grounded at 48, while the upper electrode is maintained at a desired relative potential difference with respect to the grounded lower electrode by means of a connecting wire 50 and a voltage source 52. This electrical supply unit 52 may be provided with a volt meter or other indicator 54 and an adjusting rheostat 56 for selection of the desired voltage and field strength.

According to the present invention, the material from the supply hopper 32 is fed across a predetermined initial area of the supporting member or lower electrode 30. To guide the material to the desired first area of the plate, an inclined baffle 58 is located near the feed hopper 32 to guide the stock along a feed path which extends longitudinally of the lower electrode 30 in this particular case and adjacent one edge 62 of the device. This feed path or first area of the plate is indicated at 60 in Fig. 1. If desired, the width of hopper 32 and gate 34 may be made to correspond to the width of area 60 in which case no diagonal baffle 58 would be needed, and the flow of material to area 60 would be along a uniform straight longitudinal path. Such a modification is illustrated in Fig. 10.

In general, selected particles of the stock fed across this first area 60 of the supporting electrode 30 will be urged transversely of the electrode to one or more additional areas of the plate to obtain the desired classification. According to a further aspect of the invention, the different areas of the plate are separated by one or more barriers or baffle members as indicated at 64, 66, and 68. These barrier members are of predetermined height and require that the types of particles to be collected in the areas beyond a given barrier must be urged upwardly (by a combination of the feeding means, electrostatic field, and other factors) higher than the predetermined height of the barrier in order to reach such other areas. In this case, a second or intermediate collecting area of the plate extends longitudinally between the barriers 64 and 66 as indicated at 70. A further area of collection is indicated at 72 between the barrier 66 and the baffle member 68, while a final area of collection is shown at 74 between the baffle member 68 and the opposite or second longitudinally extending lateral edge 75 of the lower electrode 30. The fractions segregated in the different areas 60, 70, 72 and 74 may then be fed by spouts 77 to different collecting means such as receptacles or chutes 79.

As shown in Fig. 3, the baffle members 64, 66, and 68 in this particular embodiment extend longitudinally of the lower electrode 30 substantially parallel to the direction of feed of the stock. Thus the stock passing down the first area 60 of electrode 30 will have repeated opportunities for individual particles of the desired types to be pro-

jected upwardly to a sufficient height to clear the first baffle member **64** and reach at least the second area **70**. In this embodiment, the baffles are of electrically conducting material connected to the lower electrode and thus maintained at the same potential as the latter. Because they project above the lower electrode and are thus closer to the upper electrode, the electrostatic field above each baffle will be more intense than at other areas of the electrode, a factor which is believed to contribute to precision of separation in certain cases. Should a more uniform field be desired, insulating baffles may be used.

According to another aspect of the invention, the desired separations are facilitated by providing baffle members of different predetermined heights. While the relative arrangement of the different baffles may vary depending upon particular circumstances and a particular stock which is under classification, the embodiment illustrated in these drawings utilizes successively higher baffles so that the first barrier **64** is lower than the second barrier **66**, while the third baffle member **68** is higher than barrier **66**. Thus all particles which have an opportunity to be projected upwardly high enough to clear the first baffle **64** and which by the combined effect of the electrostatic field, feeding means, and other factors acquire a sufficient transverse component of motion, will be enabled to reach the second area **70** of the lower electrode.

Some of the particles reaching this area **70** will have electrical characteristics which enable them to be projected above the higher second baffle **66** and across to the next area **72**. Certain of the particles reaching the area **72** may then have electrical characteristics which permit them to be projected upwardly even higher and pass over barrier **68** into the final collecting area **74**. Thus the use of barriers of different heights can contribute effectively to the precise separation of types of particles which differ only slightly in their electrical characteristics.

Reference has been made above to the necessity of giving the selected particles of material a component of motion transverse to the original direction of feed through the combined action of the feeding means, the electrostatic field, and other factors, such as gravity. In the present embodiment of the device, since the feeding means has been described in such a manner as to provide the particles with components of motion longitudinally of the electrode **30** and perpendicularly to the plane of the electrode and since this particular embodiment is substantially horizontal, the necessary transverse component of motion must be obtained by means of the electrostatic field. The directional effect of this field is obtained by the particular construction of the electrode **42**.

Other forms of upper electrode have been proposed in the past for use in obtaining the desired selective transverse movement of certain types of particles. While such prior devcies may be used in combination with suitable barriers on the lower electrode according to certain aspects of the invention, the present invention also includes a specific improved construction for such an upper electrode. This upper electrode **42** is shown in Fig. 2 and includes brackets **76** at one edge of the electrode, provided with holes **78** through which a clamping bolt may be passed to secure the brackets **76** and corresponding electrode edge to the supports **44** at one edge of the lower electrode **30**. The other edge of the upper electrode **42** includes similar brackets **80** provided with openings **82** for a similar purpose.

To obtain the desired directional effect for the electrostatic field, the undersurface of electrode **42** is provided with a series of transversely extending substantially parallel corrugations indicated generally at **84**. As illustrated in Fig. 7, these corrugations **84** are inclined from the path of feed in the first area **60** of the lower electrode toward the opposite edge **75** of the lower electrode in a direction extending not only transversely of the device but also having a substantial component rearwardly or opposite to the original direction of feed of the material. The "inclination" referred to is measured with respect to an axis perpendicular to the plane of the upper electrode and may be indicated, for example, by the acute angle **94** in Fig. 7.

The individual corrugations themselves are preferably in the form of steps having a rear wall **86** facing back substantially toward the direction from which the feed of material originates, i. e., toward the supply hopper **32**, in combination with a forward wall **88** facing substantially in the direction toward which the material is being fed. In the form shown in Fig. 2, the front and rear walls intersect each other along transverse lines **90** representing the lowest region of each corrugation. The rear and front walls **86** and **88** preferably have different slopes or inclinations with respect to the plane of the upper electrode. It is considered important to have a much steeper slope for the rear wall **86** than for the front wall **88**.

In the embodiment shown in the drawing, the rear walls **86** are substantially vertical, while the front walls **88** are rather gently inclined and have a slant height (i. e., the distance measured from the line of intersection **90** to the surface of the upper electrode along a line perpendicular to line **90**) which is at least twice as great as the vertical depth of the rear wall **86**. The particular spacing of the corrugations is such that the gently sloping forward walls **88** reach the plane of the upper electrode just at the foot of the rear wall **86** of the next section and thus intersect the rear wall as well as the plane of the electrode along a series of transversely extending lines **92**.

The fact that the specific configuration and especially the rearward angular orientation of the corrugations with respect to the original direction of feed will produce transverse movement of selected particles from the first area **60** of the lower electrode toward the second area **70** and the farther edge **75** of the plate is particularly surprising because of the suggestion in the prior art that the material particles would tend to follow the more intense areas of the field which are presumed to lie directly beneath the lowest portions **90** of the corrugations. If this were the case, the particles which originally have a longitudinal component of motion due to the inclined springs **26** and **28** and vibrator **36** would be expected to move from the original feed path in the first area **60** toward the edge **62** of the electrode. While the particular theory of operation of the construction shown in the drawings is therefore not completely understood (but is believed to involve the relative difference in slopes of the front and rear walls of the corrugations **84**), the fact remains that the particular construction does produce movement of the particles from the region **60** toward the opposite edge **75** of the lower electrode.

In Fig. 7, the original direction of feed is indicated generally by the arrow **96** along the first area **60** of the plate. The effect of the corrugations **84** on the upper electrode thus tends to move certain selected particles generally toward a path **98** which extends transversely of the lower electrode toward the edge **75** along a line generally perpendicular to the corrugations **84**. Because the device of Figs. 1 through 7 includes barriers **64**, **66**, and **68** which are substantially parallel to the original direction of feed, indicated by arrow **96**, the corrugations of the upper electrode in this case are inclined with respect to the barriers by the same angle **94** previously referred to as defining the inclination of the baffles with respect to the direction of feed.

Certain of the stocks which can be separated by the device described above can best be handled by provision of a substantially uniform electrostatic field throughout the area above the lower electrode. For this purpose the apparatus is adjusted as shown in Fig. 4 so that all portions of the upper electrode are substantially the same distance above the lower electrode.

In other cases, with certain stocks, it may be desirable to have a field in which the general intensity is non-uniform. For this purpose the device may be adjusted as shown, for example, in Fig. 5 in which the edge of the upper electrode above the first edge **62** of the lower electrode is closer to the electrode than the opposite edge of the upper electrode which is located above edge **75** of the lower electrode. By this arrangement, the general intensity of the electrostatic field is greatest along the original path of feed and gradually decreases as one moves transversely toward the opposite edge **75**.

As pointed out above, the transverse component of motion of the particles to take them across barriers **64**, **66**, and **68** is provided primarily by means of the particular configuration of the upper electrode and the resulting directional effect of the electrostatic field, in the device of Figs. 1 through 7. It is possible in some cases, however, to practice certain aspects of the present invention by an arrangement in which the relative orientation of the barriers, the direction of feed, the feeding means, and the type of electrostatic field are somewhat different.

For example, in the device of Figs. 8 and 9, the sep-

arator includes a lower electrode or supporting plate **100** which may be mounted on inclined springs for vibration in the same manner as electrode **30** of the preceding embodiment. A hopper **102** at one end of the electrode has an adjustable feed gate **104** for starting a thin uniform stream of material across the lower electrode. In this case, a single barrier **106** of predetermined height is illustrated as extending at an angle to the longitudinal axis or direction of feed of the plate **100**.

This barrier **106** is preferably made of insulating material in order to offer the least possible interference with the uniformity of the electrostatic field to be created above plate **100**. Barrier **106** is inclined from one edge **108** of electrode **100** toward the opposite edge **110**. Thus the barrier **106** is disposed at an acute angle with respect to the direction of feed of the material along plate **100**. To state the condition another way, the path of movement of the stock under the effect of the feeding means (since it is similar to that of the device in Fig. 1) will have a very substantial component of motion parallel to the barrier, although in this case the path of feed is not exactly parallel thereto. In other words, the angle between the feed path and barrier (as shown at **115** in Fig. 9) is substantially less than 90 degrees. The net result will be to retain those particles which are not projected high enough to clear barrier **106** on the original side of the barrier in the first or initial area **112** of plate **100**.

The angular inclination of the barrier will result in movement of the particles transversely toward edge **110** of this electrode as they are fed along the latter. Barrier **106** divides the plate into a first area **112** mentioned above and a second area **114** into which selected particles may by projected by the particular combination effect of the electrostatic field, the feeding means, and the angular orientation of the barrier. Separate collecting means for the fractions segregated in the two areas are provided as in the previous embodiment.

In this case the upper electrode **116** may be in the form of a flat plate spaced substantially uniformly above the lower electrode **100** and maintained at a relative difference of potential with respect thereto by means similar to that shown in Fig. 1. Thus a substantially uniform field will be maintained between the electrodes and this field will have no particular directional effect. However, the longitudinal component of vibration of the lower electrode **100** will tend to project individual particles across the barrier **106**. The particles can not be projected, however, unless they are also urged upwardly a distance greater than the predetermined height of barrier **106**. This upward movement or urge is controlled by adjustment of the electrostatic field strength so that particles of the desired selected type will be lifted sufficiently to clear the barrier **106** while other particles will remain in the original area **112** of the lower plate.

Because the direction of longitudinal movement imparted by the feeding means has a substantial component parallel to the barrier **106**, the material which is not sufficiently charged initially to be projected above and across the barrier will have further opportunities for obtaining the necessary induced charge as the particles are fed along the plate and retained by the barrier. Thus by the time the stock has been fed from the hopper **102** to the remote end of the electrode **100**, every particle of the desired selected type should have had an adequate opportunity to acquire a sufficient induced charge to be urged upwardly a distance which will permit it to clear the barrier **106** under the combined influence of the electrostatic field and the feeding vibrations of the lower electrode.

The modified embodiment of Fig. 10 is similar in principle to the device of Figs. 1 through 7, except that here the lower electrode **118** has a hopper **120** and adjustable feed gate **122** of the same width as the first area or feed path **124**. Thus the stream of material fed from hopper **120** will not be compressed laterally as it moves along the first feed area **124**.

Electrode **118** has one edge **126** angularly inclined away from the direction of feed along area **124** in order to provide a second area **128** at one side of the first area. A barrier **130** separates the two areas **124** and **128**. Similarly, a third area **132** is separated from area **128** by a barrier **134**, while a fourth collection area **136** is separated from area **132** by a longitudinal barrier **138**.

Upper electrode **140** is provided with angular corrugations or steps **142** on its undersurface, just as in the case of electrode **42** of Figs. 1 to 7. Thus the desired particle types are segregated in the respective collecting areas as a result of selective lateral displacement across the respective barriers.

According to the foregoing description, a number of embodiments of the present invention have been disclosed which substantially accomplish the objects set forth at the beginning of this specification. Since minor variations and changes in the exact details of construction will be apparent to persons skilled in this field, it is intended that this invention shall cover all such changes and modifications as fall within the spirit and scope of the attached claims.

Now, therefore, I claim:

1. An electrostatic separator comprising an electrically conducting supporting plate, means for feeding a thin uniform stream of material along a given path across the upper surface of the plate, an upper electrode spaced above the plate and establishing an electrostatic field between the plates, said upper electrode having on its undersurface a series of parallel downwardly projecting corrugations extending across the path of feed at an acute angle with respect to such path, the angular orientation of the corrugations producing a field urging selected particles of material angularly across said path toward a direction generally perpendicular to the corrugations, and means for collecting separately a first fraction including particles which continue along the original feeding path and at least one second fraction including particles which have been urged laterally away from said path.

2. An electrostatic separator according to claim 1 in which each corrugation includes a rear wall facing back toward the portion of the path from which the material is fed and a forward wall facing in the opposite direction, said walls being angularly disposed with respect to the plane of the upper electrode.

3. An electrostatic separator according to claim 2 in which said front and rear walls intersect each other below the plane of the upper electrode and are inclined at different angles to the plane of the upper electrode.

4. An electrostatic separator according to claim 3 in which said rear wall is inclined more steeply than said first wall.

5. An electrostatic separator according to claim 4 in which said rear wall is substantially vertical and said front wall slopes gently toward the plane of the upper electrode.

6. An electrostatic separator according to claim 1 in which the upper electrode is inclined with respect to the lower electrode so that the portions of the upper electrode corrugations farthest from the original path of feed are also spaced farther from the lower electrode than those portions of the corrugations nearest the original path of feed.

7. An electrostatic separator according to claim 1 having at least one barrier of predetermined height extending across the upper surface of the lower plate and dividing the latter into a first area in which the material is originally fed and a second area which receives those particles projected over said barrier under the action of said feeding means and said field.

8. An electrostatic separator comprising an electrically conducting supporting plate having a smooth upper surface throughout its major area, means for feeding a thin uniform stream of the material along a given path across the smooth upper surface of said plate, means including the plate for establishing an electrostatic field above the plate urging selected particles upwardly from the plate, at least one barrier of predetermined height on the upper surface of the plate within said field and extending along the path of movement of said particles, said barrier dividing the material into a first fraction consisting of particles remaining on the original side of said barrier, and at least one second fraction which consists of particles which are attracted upwardly beyond said predetermined height and which thereby move across said barrier, and means for collecting separately said first and second fractions.

9. An electrostatic separator according to claim 8 having two of said barriers extending across successive portions of the path of movement of said particles, the first barrier having a height different from that of the

second barrier, and means for collecting separately the fraction which remains between the barriers and the fraction which passes both barriers.

10. An electrostatic separator according to claim 9 in which the first barrier is lower than the second barrier.

11. An electrostatic separator comprising a supporting plate having a smooth upper surface throughout its major area and an edge, means for feeding a thin uniform stream of material across a substantially smooth, unobstructed portion of the upper surface of said plate, means establishing an electrostatic field above the plate urging selected particles upwardly from the plate, said particles being moved by said feeding means along a path toward the edge of the plate under the combined influence of said feeding means and field, a barrier of predetermined height on the upper surface of the plate within the field, said barrier extending across said path of movement of the particles and dividing the plate and field into a first area containing a first fraction consisting of particles remaining on the original side of the barrier and a second area containing a second fraction consisting of particles which are projected upwardly beyond said predetermined height and which thereby move across said barrier, and means for collecting separately said first and second fractions.

12. An electrostatic separator comprising a supporting plate having a smooth upper surface throughout its major area a barrier of predetermined height extending across said plate and dividing the plate into first and second smooth-surfaced areas, means for feeding a thin uniform stream of material across the first area of the plate, means establishing an electrostatic field above said barrier and thereby urging selected particles upwardly from the plate, at least one of said feeding means and electrostatic field means urging selected particles from the first area to the second area, and means for collecting separately the particles of material which are projected upwardly above said predetermined height and thereby reach said second area of the plate.

13. An electrostatic separator according to claim 12 in which the feeding means urges the material in a direction having a substantial component parallel to said barrier.

14. An electrostatic separator according to claim 13 in which the feeding means urges the material in a direction parallel to said barrier and in which the electrostatic field urges the material transversely from said first area toward said second area.

15. An electrostatic separator according to claim 12 having a second barrier extending across the second area of the plate and dividing such second area into an intermediate portion lying between the barriers and a final portion lying beyond the second barrier, said second barrier having a height different from that of the first barrier, and means for collecting separately the fractions of material reaching said intermediate portion and said final portion.

16. An electrostatic separator according to claim 15 in which the second barrier is higher than the first barrier.

17. An electrostatic separator comprising an electrically conducting supporting plate having a smooth upper surface throughout its major area, a barrier of predetermined height extending across said plate and dividing the plate into first and second substantially smooth-surfaced, unobstructed areas, means for feeding a thin uniform stream of material in a given path across the first area of the plate, means establishing an electrostatic field above said barrier and thereby urging selected particles both upwardly from the plate and transversely across said barrier to said second area, the angle between said feed path and barrier being substantially less than 90 degrees and thereby feeding along the barrier that portion of the material which reaches the barrier but is not projected upwardly high enough to clear it, first collecting means at the end of the barrier for separate removal of the portion which remains on the original side of the barrier in said first area, and additional collecting means for separate removal of those particles which pass over the barrier and reach the second area.

18. An electrostatic separator comprising a lower electrode having a substantially smooth upper surface throughout its major area bounded by laterally spaced first and second longitudinally extending edges, means for feeding a thin uniform stream of material along a longitudinal path on the upper surface of the electrode adjacent said first edge, means establishing an electrostatic field urging selected particles of material transversely of the electrode toward said second edge during such feeding, at least two longitudinally extending barriers on the upper surface of the lower electrode between said feeding path and said second edge, said barriers being separated by an intermediate smooth-surfaced collecting area, and one of said barriers projecting farther above the electrode surface than the other, and means for collecting separately the material received in said intermediate collecting area.

19. An electrostatic separator according to claim 18 in which the barrier nearest the feeding path is lower than the barrier nearest the second edge.

20. An electrostatic separator according to claim 18 having three substantially parallel longitudinally extending barriers between the feeding path and second edge, the barrier nearest said path being lower than the intermediate barrier, and the barrier nearest the second edge being higher than the intermediate barrier.

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