

Sept. 25, 1956

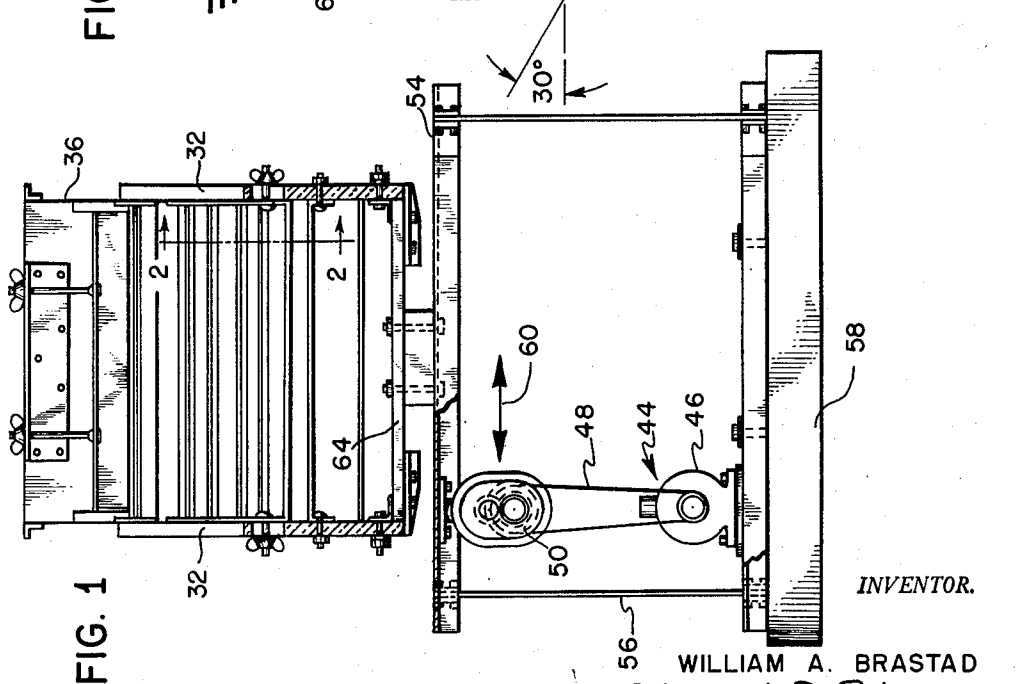
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2,764,288

SLOTTED STAIR STEP ELECTROSTATIC SEPARATOR

Filed Oct. 20, 1954

4 Sheets-Sheet 1



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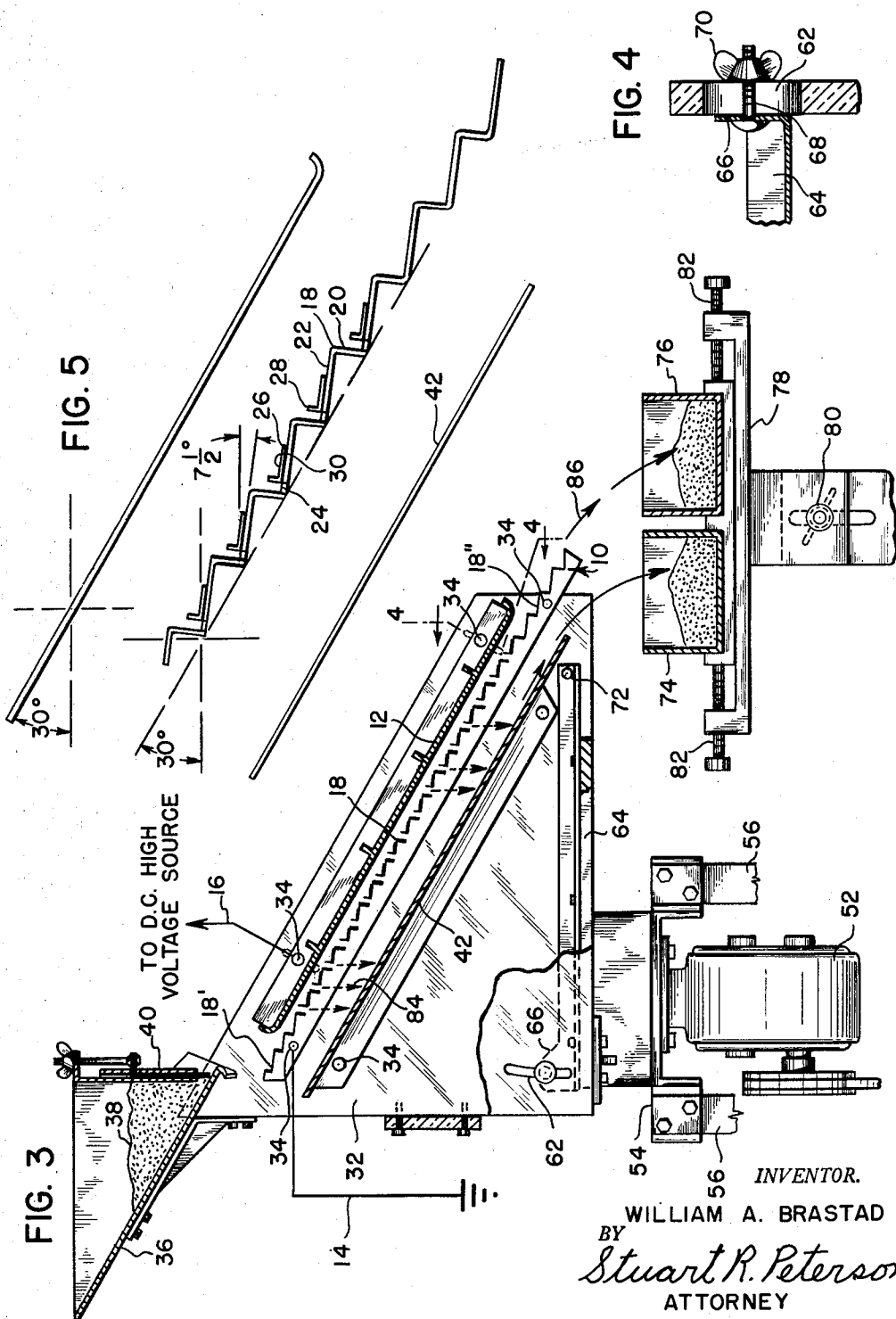
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SLOTTED STAIR STEP ELECTROSTATIC SEPARATOR

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4 Sheets-Sheet 2



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FIG. 6

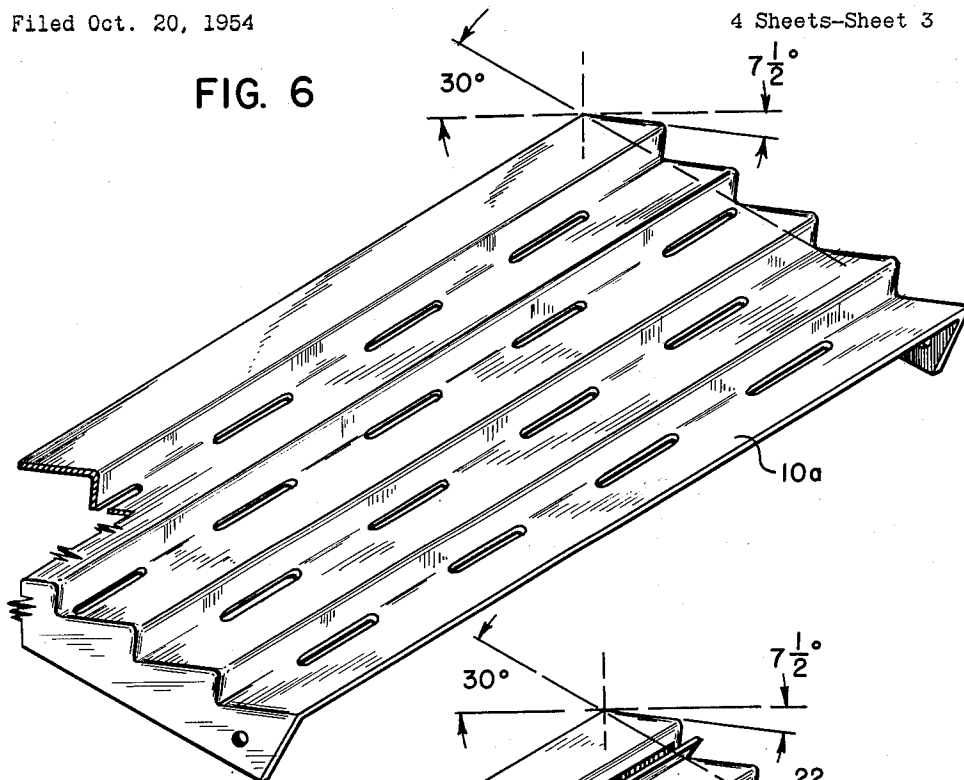
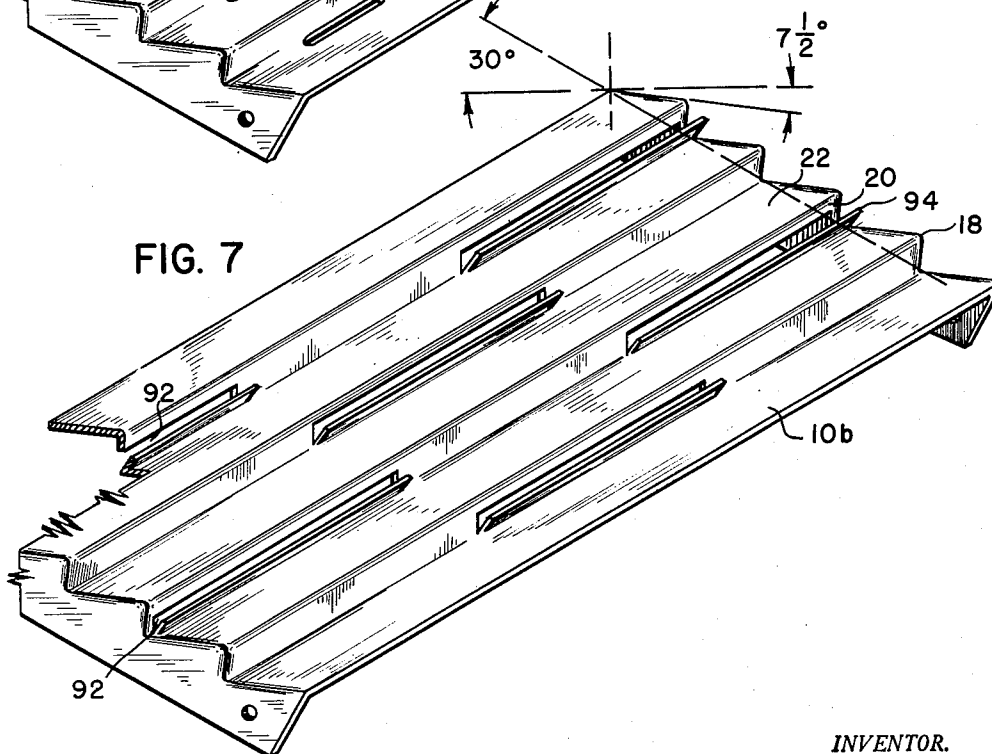


FIG. 7



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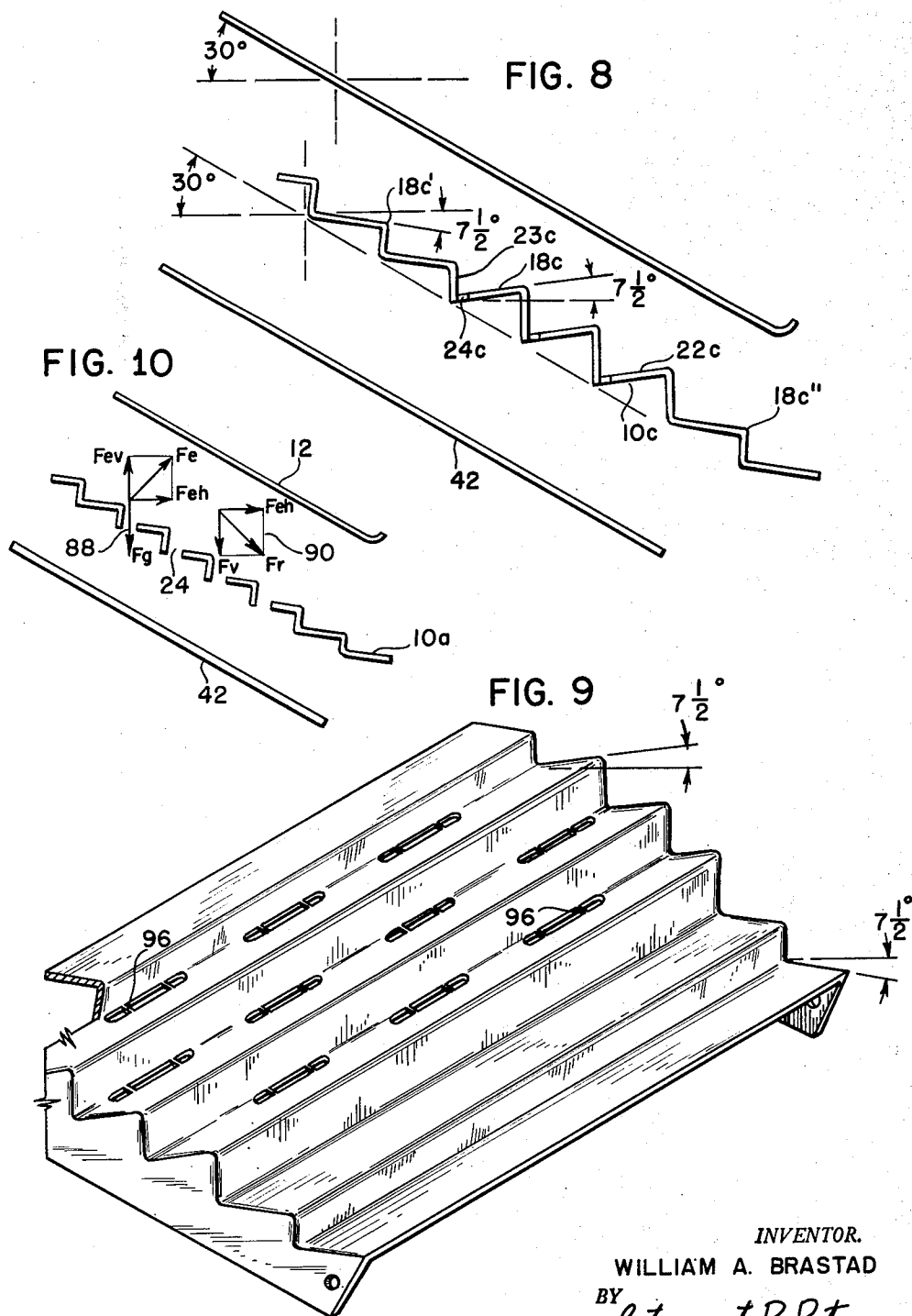
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4 Sheets-Sheet 4



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2,764,288

SLOTTED STAIR STEP ELECTROSTATIC SEPARATOR

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Application October 20, 1954, Serial No. 463,423

11 Claims. (Cl. 209—127)

This invention relates to electrostatic separators and pertain more particularly to a separator which has been found to have especial utility in the separation of cereal stocks.

Among the objects of the invention are to provide an electrostatic separator that will be of low cost construction, not apt to get out of order easily, and highly efficient in its operation with no remixing of the separated material. With these aims in mind, one outstanding feature of the invention resides in the employment of oppositely charged electrodes mounted in an inclined substantially parallel relation with each other, the lower electrode possessing what is best described as a stair step plate having strategically disposed slots therein through which a desired fraction of the material stock will escape to a locus of collection below. The electrostatic field created by the two electrodes is oriented so as to lift the remaining material over the various slots of the lower electrode and the material so elevated may either traverse the length of the said lower electrode or undergo additional classification while en route. An electrostatic field of appropriate intensity and direction causes the material to be removed to travel in close proximity to the lower electrode, whereas the remaining material is attracted away from the lower electrode to varying degrees. The fraction, which in effect hugs the lower electrode while descending the steps, encounters the strategically positioned slots and is removed via this discharge avenue. In brief, the original or mixed material introduced to the separating apparatus becomes stratified to the extent that some of the material, that influenced in a different manner or to a different degree by the electrostatic field, will fall through the above-described slots.

Other objects will be in part obvious and in part pointed out more in detail hereinafter.

The invention accordingly consists in the features of construction, combination of elements and arrangement of parts which will be exemplified in the construction hereafter set forth and the scope of the application of which will be indicated in the appended claims.

In the drawings, Figure 1 is a front elevational view, partly in section, showing the separating apparatus forming the subject of the instant invention;

Fig. 2 is an enlarged perspective view taken in the direction of line 2—2 of Fig. 1;

Fig. 3 is a side elevational view showing the apparatus of Fig. 1, portions thereof having been removed for the sake of clarity;

Fig. 4 is a sectional detail picturing the means by which the high voltage electrodes may be retained in a preferred angular relationship with the horizontal;

Fig. 5 is a somewhat schematic view presenting in greater detail the angular relationship of the electrodes shown in Fig. 3;

Fig. 6 is a perspective view of the lower stair step electrode, this electrode being a slight modification of the lower electrode depicted in Figs. 3 and 5;

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Fig. 7 is a perspective view corresponding to that of Fig. 6 but in which the electrode is further modified;

Fig. 8 corresponds closely to Fig. 5 but this figure shows what might be termed a negative angle to the stairs and therefore constitutes a still different embodiment;

Fig. 9 is a perspective view similar to the views of Figs. 6 and 7 but illustrating the modification pictured in Fig. 8; and

Fig. 10 is a somewhat schematic view of the electrode shown in Fig. 6 but with certain vector diagrams superimposed thereon.

Referring now to the drawings, and Figs. 1 through 5 in particular, it will be discerned that the separating apparatus comprises a pair of inclined electrodes 10 and 12, the lower electrode being suitably grounded by reason of a conductor 14 and the upper electrode being connected to the negative side of a source of high D. C. voltage by a conductor 16. The upper electrode 12 is of relatively simple configuration constituting, in the present instance, a substantially flat plate. However, the lower electrode 10 is of a more complex form, for this particular electrode is in the shape of a set of stairs having a plurality of steps 18 each including a riser portion 20 and a tread portion 22. In this connection the terms "riser" and "tread" are used inasmuch as such terminology is used in describing steps leading from floor to floor of ordinary buildings and the general outline of the steps 18 resemble such conventional stairs. The more centrally disposed treads of these transverse steps 18 contain elongated slots 24 for a purpose which will hereinafter be made manifest. Also in the embodiment now being described, each of the treads having a slot 24 has mounted thereon an angle member 26 extending along one side of each slot. One leg of each angle member provides an upstanding flange 28 and the other leg 30 serves as the means by which the angle member may be secured to the transverse steps 18.

Inasmuch as it is contemplated that granular material be directed along the lower electrode 10 in such fashion as to permit a certain fraction thereof to be discharged downwardly through the various slots 24, the material that is not to pass downwardly must receive appropriate electrical charges so that it will be elevated over the various slots 24 during its course of travel down the steps 18. To this end it is intended that the first few steps bearing the reference numeral 18' not have the slots which are employed in the steps designated by the numeral 18 without the addition of the prime. Also, in the region near the lower end of the electrode, to obtain the proper discharge of the remaining material, it is envisaged that these steps also be unslotted and therefore they have been distinguished by the numeral 18''.

Securing the electrodes 10 and 12 in a substantially parallel relation with each other but inclined with respect to a horizontal plane is a pair of laterally spaced, vertically arranged plate members 32 of insulating material having a fairly high dielectric strength, the electrodes being suitably fastened between these plate members such as by a plurality of bolts or rivets 34. Also supported by the plate members 32 is a hopper 36 superimposed above the upper end of the electrode 10, thereby being arranged so that material 38 contained therein will be discharged onto the lower electrode 10 in a thin uniform stream, the exiting of the material 38 from the hopper 36 taking place via a control gate labelled 40. Since the material that passes downwardly through the various slots 24 is to be collected at a preferred point, the invention also intends that an inclined plate 42 be mounted, as by additional rivets 34, between the vertical plate members 32, this plate 42 having downturned

flanges by reason of which the plate may be secured to said members 32 such as by additional rivets 34.

By virtue of the foregoing construction it will be discerned that the electrodes 10 and 12, together with the insulating side plate members 32, form a unitary structure. This unitary structure is intended to be vibrated in such a fashion so as to assure the progress or advancement of the material 38 along the electrode 10 and to this end a vibrating mechanism designated generally by the numeral 44 is employed. This vibrating mechanism may be of the solenoid type but in the present instance has been shown as including an electric motor 46, a drive belt 48, a pulley or sheave 50, the sheave 50 driving an eccentric weight member contained within the confines of a housing 52. This superstructure which includes the electrodes 10 and 12 plus the side plates 32 is secured to a platform 54 mounted at the upper ends of four spaced leaf springs 56. These leaf springs 56 are in turn anchored in an upstanding relationship with a base 58. When the vibrating mechanism 44 is placed in operation, it can be seen from a study of Fig. 1 that the platform 54 and its associated superstructure will be oscillated from side to side in the direction of the arrows 60.

Actually, it has been found from experiment that the vibration in this situation does not have to be violent in any sense of the word and that a gentle vibration which is sufficient to overcome the static friction of the material 38 resting upon the electrode 10 will give satisfactory operating results. For example, a frequency of vibration in the order of 1160 vibrations per minute with an amplitude of approximately $\frac{3}{32}$ of an inch has been found suitable with certain flour milling stocks. Of course, these specific vibration characteristics may be modified according to the characteristics of the specific material undergoing separation. The important thing, insofar as the vibration is concerned, is that it be sufficient to move the material down the steps at a rate which provides an adequate opportunity for the desired separation.

It has also been found expedient to mount the side plate members 32 so that they may be adjusted angularly with respect to a horizontal plane. With this thought in mind, each plate member 32 has been provided with an arcuate slot 62. A frame 64 which is supported by the platform 54 has a pair of laterally spaced upstanding ears 66, these ears 66 carrying a pair of outwardly directed bolt members 68. To aid in the attachment of the side members 32, the bolt members have threaded thereon a pair of wing nuts 70. Owing to this structural arrangement, there being a pivot 72 at the forward end of the apparatus, the entire superstructure which includes electrodes 10 and 12 may be tilted into an optimum angular or inclined position. Here again, the angle of inclination will depend upon the specific material to be classified or segregated and will also depend to a certain extent upon the voltage applied to the upper and lower electrodes.

In order to maintain the material leaving the apparatus in a separated condition, it is contemplated that a pair of receptacles 74 and 76 be suitably mounted for the reception of the respective fractions discharged from the apparatus. Therefore the receptacle 74 is placed subjacent the inclined plate 42 and the other receptacle 76 is disposed so as to accumulate material arriving via the unslotted steps 18'. Any appropriate means of supporting these receptacles for the reception of the respective material may be employed. As shown, a supporting bracket designated generally by the numeral 78 is utilized, such bracket mechanism being adjustable vertically by reason of a slot and bolt arrangement 80 and horizontally by virtue of a pair of adjusting bolts 82.

As hereinbefore indicated, the various inclinations of the electrodes 10 and 12 will depend in large measure upon the particular material undergoing classification. However, with reference to cereal stocks, where the invention

has been found to possess especial utility, the angular relationships depicted in Fig. 5 have been found satisfactory. However, these relationships are not to be regarded as critical for they may be varied appreciably without adversely affecting the operation of the apparatus. As indicated, the inclination is designated as 30° and the steps 18 have been disposed so that the tread portion 22 thereof are at an angle of $7\frac{1}{2}^\circ$ below the horizontal. With the steps being at right angles, this of course results in the risers being at an angle of $7\frac{1}{2}^\circ$ with the vertical. Thus the forward edge of each step will slightly overhang its respective slot 24 and the passage of the appropriate fraction of material through the slots 24 will be assured.

Describing now the operation of the apparatus as presented up to this point, it will be appreciated that the material 38, which we will assume for the sake of discussion to be comminuted wheat stock containing pure bran particles, pure endosperm particles, and particles in which both bran and endosperm are attached in varying proportions, will be discharged from the hopper 36 onto the lower electrode 10. The vibrating mechanism 52 will jostle this granular material to a certain extent and the potential impressed on the electrodes 10 and 12 will be instrumental in causing the material to be fed or advanced along the lower electrode 10. A suggested frequency and amplitude of vibration has already been given. As for a particular potential, approximately 5,000 volts per inch may be used, a specific model having employed a spacing between electrodes of one-half inch with an impressed voltage of 2,400 volts.

In order to give the material a chance to accumulate the appropriate electrical charges, the upper steps 18' as hereinbefore indicated, are not slotted. Therefore by the time the material has reached the first steps having slots 24 therein, the material will have accumulated sufficient charges and the material will have stratified sufficiently so that the endosperm particles are in close proximity to the upper surface of the steps 18'. Upon reaching the very first step 18, such step having at least one slot 24 therein, a sizeable quantity of the endosperm particles, which particles are not as greatly lifted by the electrostatic field between the two electrodes, will have gravitated to the face of the electrode 10 and will pass through this slot onto the inclined plate 42. On the one hand the brannier particles which are greatly affected by the electrostatic field will be elevated sufficiently so that they will literally hop or jump over the slots 24 and will not pass downwardly therethrough as do the endosperm particles. Of course, any endosperm particles only temporarily clinging to the bran particles will in the course of traversing the electrode 10 become dislodged and fall through some subsequent slot 24.

By adjusting the electrical potential impressed on the plates 10 and 12, the intermediate fraction, in the present instance constituting particles in which both bran and endosperm are attached in varying proportions, may be caused to move over the slots 24 in much the same manner as the pure bran particles. Consequently the apparatus may be operated so as to accumulate only pure endosperm particles in the receptacle 74. To aid in visualizing what happens, the path taken by the endosperm particles has been designated by arrows bearing the reference numeral 84 whereas the material remaining upon the electrode 10 and discharged into the receptacle 76 has been indicated by arrows carrying the numeral 86.

In some instances it has been advisable, particularly where a high degree of selectivity is desired, to use the angle members 26, for the upstanding flanges 28 thereon decrease the likelihood of any portion of the brannier fraction passing downwardly through the slots 24. Such selectivity is of course produced by the barrier effect made possible by said flanges 28. While Figures 1 to 5 show the barrier version of the apparatus, nonetheless it will be appreciated that in some instances these barriers may be

dispensed with and accordingly Fig. 6 presents an electrode 10a devoid of any barriers or angles 26. Actually, the more simplified embodiment shown in Fig. 6 facilitates an explanation of the various forces acting when the equipment is operated. Therefore an additional figure in the form of Fig. 10 has been presented which is somewhat schematic inasmuch as the electrodes 10a and 12 are only shown in outline form. Referring in detail to Fig. 10 it is to be observed that two vector diagrams 88 and 90 are pictured. The diagram 88 permits the force produced by the electrostatic field to be indicated by the arrow labeled F_e , since the electrostatic field extends perpendicularly from the electrode 12 to the electrode 10a. This force F_e may be broken down into vertical and horizontal components, the vertical component being designated by the character F_{ev} and the horizontal component by the character F_{eh} . A still further force, and this is an important one, is involved, such additional force being that due to gravity and, accordingly, this force bears the character F_g . The vector diagram 90 should now be studied and an analysis of this diagram will show that the net vertical force is the difference between the force quantities F_{ev} and F_g , such force being represented by the character F_v . Since the horizontal component F_{eh} is unaffected by the force of gravity, it remains unchanged in the diagram 90. The resultant of the F_v and F_{eh} forces has been designated F_R . F_R is the force actually utilized in moving the material along the electrode 10a. Consequently it will be appreciated that the force F_v will be instrumental in causing certain material, in the present instance the endosperm particles, to fall downwardly through the slots 24 whereas the other particles will not traverse the vertical path denoted by the character F_v and will be collected by means of the receptacle 76.

Passing now to an observation of Fig. 7, the electrode there shown has been indicated by the numeral 10b. Instead of having the slots 24 in the tread portion 22 of each of the steps 18, slots 92 are provided in the riser portions of the steps 18. One way of fabricating the electrode 10b is to form the electrode from sheet or plate material, stamping the slots 92 in such a manner that the material removed from the slot locations is not completely severed from the electrode, remaining attached along its lower edge. As will be observed from Fig. 7 which is now being referred to, the sheet material remaining constitutes an angular flange 94, being at an angle with respect to both the risers 20 and the treads 22. The utilization of the flanges 94, like the flanges 28, is instrumental in increasing the selectivity of the electrode 10b over the electrode 10a, electrode 10a having been disclosed without either flanges 28 or 94.

Although not depicted, unslotted steps corresponding in function to the steps 18' and 18'' of the first-described embodiment may be added to the structures of Figs. 6 and 7.

Still another arrangement which has been found successful in the separation of granular stocks is shown in Figs. 8 and 9. In these figures the illustrated modification includes an electrode 10c comprised of a plurality of steps 18c in which the tread portions denoted by 22c are disposed at approximately $7\frac{1}{2}^\circ$ in a negative direction with respect to the tread portions 22 which have already been described. Like the embodiment of Fig. 6, the tread portions contain a series of slots, designated 24c in the present instance, located near the riser portion 23c of the step next above. By having the tread portions 22c slope in an opposite direction from that previously considered, many of the endosperm particles will retrogress toward the slots 24c once the original stock has piled up sufficiently upon the various steps employed in this particular embodiment. Of course, the piling up of stock in a stratified manner will permit the advancement of the brannier particles down the steps, aided by the electrostatic field produced between the electrodes 10c and the electrode 12, the electrode 12, in this instance, being of

the same configuration as in the previously discussed embodiments.

Since the first several steps, designated 18c', in the embodiment pictured in Figs. 8 and 9 do not contain slots 24c, there is no need in having the tread portions 22c of such steps provided with a reverse inclination as do those containing slots. Accordingly, in the upper region of Fig. 8 it will be discerned that the slots slant or slope in a positive direction and also those steps, designated 18c'', illustrated near the lower end of the electrode slope in the same direction since they too do not contain any slots. In this way, the initial and final advancement of material along the electrode 10c is facilitated.

Also, with the reverse or negative angle utilized in the embodiment now under discussion, it is desirable to have the slots 24c substantially coextensive with the transverse length of the steps so that there will be as little obstruction to the downward flow of endosperm particles as possible. With this in mind, from Fig. 9 it will be observed that relatively small reinforcing sections 96 are employed, these sections offering little interference to the downward passage of material through the slots 24c. Of course, in this connection if design circumstances dictate, the reinforcing sections 96 can be increased in size, for the transverse vibration created by the vibrating mechanism 44 will cause the endosperm particles that have settled adjacent the rear edge of each tread portion 22c to seek the slots 24c as their avenue of downward escape.

Depending primarily upon the particular fractions and the specific material subjected to the classification process, it, at times, will be desirable to obtain more than two fractions during the separating operation. Therefore it may be that the electrode 12 should be equipped with suitable apertures (not shown herein but comparable to that pictured in U. S. Patent No. 2,615,570, issued October 28, 1952, to C. H. Morrison) so that of the brannier particles which are elevated in the assumed situation, some will pass through the upper electrode 12 for individual collection separate and distinct from the fraction that would be collected from the material that would remain on the upper surface of the electrode 10. Those particles projected onto the upperside of the electrode 12 would, of course, be those constituting the purest bran in the original unsegregated material. When so arranged it will be appreciated that the separating apparatus can separate more than the two fractions treated in detail in the foregoing description.

A further point that should be stressed as a result of experimental observations is that the vibration and slots in general should preferably be arranged so that when no voltage is applied to the electrodes 10 and 12, no stock passes all the way down the upper surface of the stairs. Thus when the proper operating voltage is applied, the electrostatic stratification helps cause selected bran particles to travel over the steps into the receptacle 76.

As many changes could be made in the above construction and many apparently widely different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the language used in the following claims is intended to cover all of the generic and specific features of the invention herein described and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

I claim:

1. An electrostatic separator comprising substantially parallel inclined upper and lower electrodes, the lower electrode including a series of transverse strips at successively different elevations over which the material to be separated may be fed and a plurality of openings subadjacent and spaced below the more advanced edge of the

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strips through which certain of said material may drop, means for feeding a thin uniform stream of the material down across said strips between the electrodes, means for maintaining a difference of potential between the electrodes, and means for collecting separately the material discharged through said openings.

2. An electrostatic separator in accordance with claim 1 in which said strips are disposed at a downwardly sloping angle in the direction in which the material is fed.

3. An electrostatic separator in accordance with claim 1 in which said strips are disposed at a downwardly sloping angle in a direction opposite to that in which the material is fed.

4. An electrostatic separator comprising substantially parallel inclined upper and lower electrodes, the lower electrode including a series of transverse strips at successively different elevations over which the material to be separated may be fed and a plurality of openings subjacent and spaced below the more advanced edge of the strips through which certain of said material may drop, members connected to the electrodes for supporting said electrodes in said substantially parallel relation, a supporting frame for said members, adjustable means interengaging the frame and members for retaining said members and the electrodes at a preferred angle with the horizontal, means for feeding a thin uniform stream of the material down across said strips between the electrodes, means for maintaining a difference of potential between the electrodes, and means for collecting separately the material discharged through said openings.

5. An electrostatic separator comprising substantially parallel inclined upper and lower electrodes, the lower electrode including a series of transverse steps down which the material to be separated may be fed, said steps having slots subjacent and spaced below the more advanced edge thereof through which certain of said material may drop, means for feeding a thin uniform stream of the material down across said steps between the electrodes, means for maintaining a difference of potential between the electrodes, and means for collecting separately the material discharged through said slots.

6. An electrostatic separator comprising substantially parallel inclined upper and lower electrodes, the lower electrode including a series of transverse steps down which the material to be separated may be fed, said steps having tread and riser portions with an elongated slot in each tread portion adjacent the riser portion of the step next above through which certain of said material may drop, means for feeding a thin uniform stream of the

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material down across said steps between the electrodes, means for maintaining a difference of potential between the electrodes, and means for collecting separately the material discharged through said slots.

7. An electrostatic separator in accordance with claim 6 in which the tread portions are equipped with an upstanding flange along the edge of each slot lying remote from the riser portion of the step next above.

8. An electrostatic separator, comprising substantially parallel inclined upper and lower electrodes including a series of transverse steps down which the material to be separated may be fed, said steps having tread and riser portions with an elongated slot in each riser portion adjacent the tread portion of the step next below through which certain of said material may drop, means for feeding a thin uniform stream of the material down across said steps between the electrodes, means for maintaining a difference of potential between the electrodes, and means for collecting separately the material discharged through said slots.

9. An electrostatic separator in accordance with claim 8 and including a flange extending upwardly from the lower edge of each slot at an angle to both the tread and riser.

10. An electrostatic separator comprising substantially parallel inclined upper and lower electrodes, the lower electrode including a series of transverse strips at successively different elevations over which the material to be separated may be fed and a plurality of openings subjacent and spaced below the more advanced edge of the strips through which certain of said material may drop, means for feeding a thin uniform stream of the material down across said strips between the electrodes, means for maintaining a difference of potential between the electrodes, means for collecting separately the material discharged through said openings, and means for rapidly vibrating the lower electrode as the material is moved along it.

11. An electrostatic separator in accordance with claim 10 in which said vibrating means causes vibration in a direction transverse to the direction in which the material is fed.

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