Feb. 3, 1970 M. CARTA ET AL 3,493,109

PROCESS AND APPARATUS FOR ELECTROSTATICALLY SEPARATING ORES WITH CHARGING OF THE PARTICLES BY TRIBOELECTRICITY

Filed Aug. 1, 1968 3 Sheets-Sheet 1

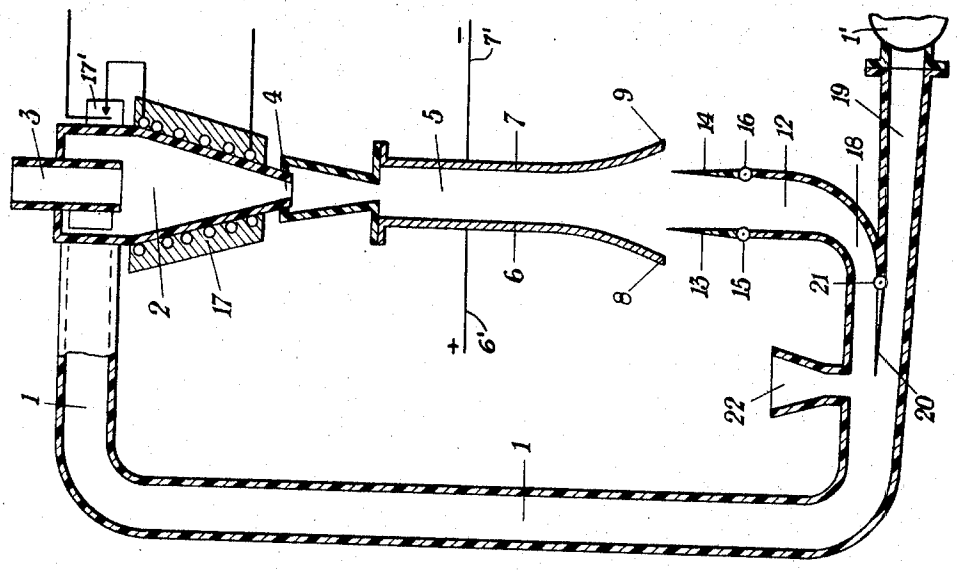


Fig. 2

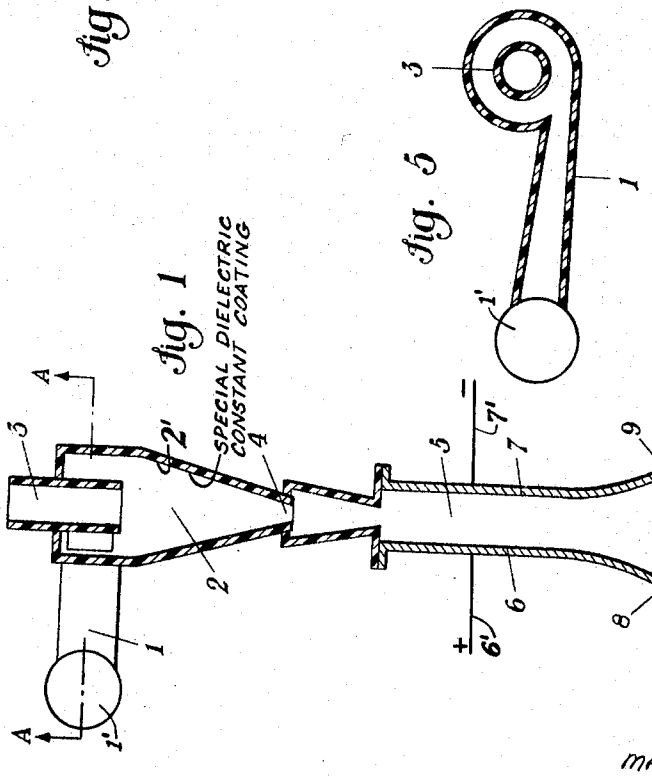


Fig. 1

Fig. 5

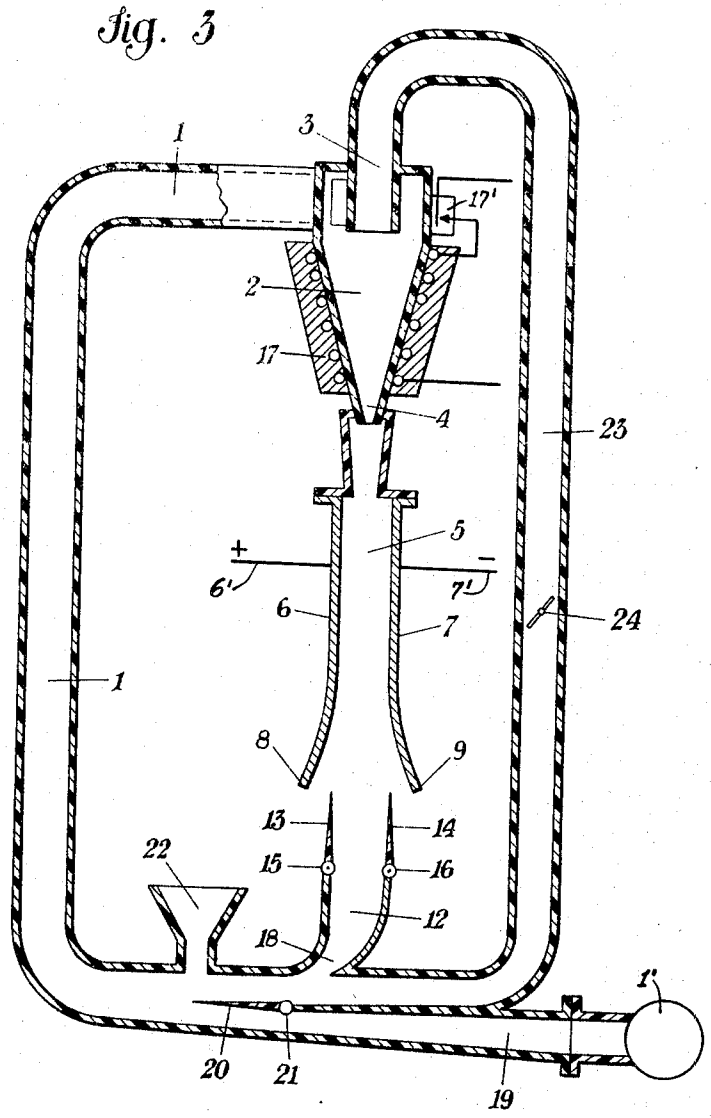
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ATTORNEYS

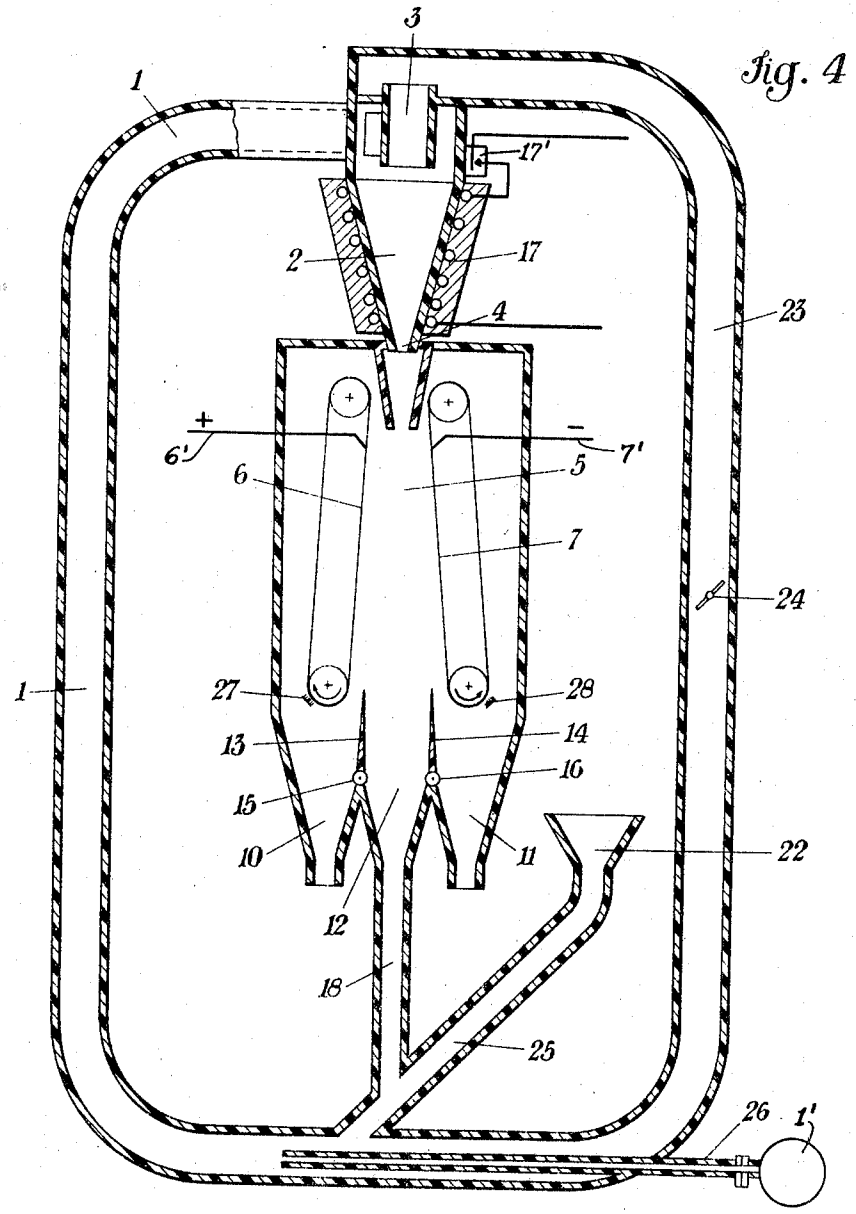
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Fig. 3



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Fig. 4



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3,493,109

PROCESS AND APPARATUS FOR ELECTROSTATICALLY SEPARATING ORES WITH CHARGING OF THE PARTICLES BY TRIBOELECTRICITY

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Int. Cl. B07b 4/02
U.S. Cl. 209—11 10 Claims

ABSTRACT OF THE DISCLOSURE

An electrostatic separator is provided wherein the charging of the ore particles takes place by triboelectricity, said separator comprising a duct fitting into a cyclone having the inner surface coated with special materials, the dielectric constant of which is intermediate that of the species to be separated or by an other means which by friction with or between the ore particles will produce charges of opposite polarity on the particles of different species to be separated.

The present invention relates to a process for electrostatically separating and recovering one or more ores from a raw ore or an ore mixture which provides the charging of the ore particles by triboelectric effect and which proves to be particularly effective for processing fine and pulverulent materials.

Electrostatic separator apparatus of different types are known in the art, in which the charging of the particles takes place by triboelectricity, that is, as the consequence of the mutual friction between the ore particles of different species or of the friction between said particles and other suitable bodies or surfaces.

The main types of separator apparatus (hereinafter called simply separators for the sake of simplicity) of this kind can be grouped in two groups, namely: the first group (which hereinafter we shall call group A) comprises separators of the gravity type on inclined surfaces, of the drum type, of the free-falling type between two substantially vertical electrodes; and the second group (that we shall call group B) comprising separators of the type carrying the material suspended in a gas stream.

In the separators belonging to group A, the charging takes place either by friction and sliding of the ore particles on inclined surfaces or on the surfaces of vibrating conveyor channels or as consequence of the friction between the particles which are caused to pass in the space between two rolls rotating in an opposite direction.

In the separators belonging to the group B, that is, of the type carrying the material in suspension in a gas stream, the charging takes place in consequence of the impacts and the friction of the particles one with another and with the walls of the duct which serves for pneumatically conveying the particles

In one illustrated embodiment of the separators of this type, a sinuous course has been imparted to the duct in order to facilitate the impacts between the particles and the wall of the duct.

In another improvement of this type of separator a curved shape has been given to the duct so as to force the ore particles, under the action of centrifugal force, to slide or roll on the concave inner surface of the duct.

In these separators, after the charging of the ore particles has taken place by triboelectric effect as above described, which charging shall be of opposite sign for the two mineralogical species to be separated, the gas stream

which holds the ore particles in suspension is caused to pass between two electrodes electrically connected to the terminals of a high-voltage generator and therefore creating an electrostatic field, and, in such a zone, the separation of the particles of different species takes place as they have an electric charge of opposite sign.

A disadvantage which is common to the separators belonging to group A is the charging of the particles by triboelectric effect, as it is provided in those apparatus, is not very effective owing to the low relative speed and therefore the limited forces involved in the friction of one particle with another and between particles and surfaces with which said particles come into contact (vibrating channel, inclined chute, etc.).

Furthermore, in such apparatus the time lapsing between the charging of the particles and their introduction in the separation zone is often too long so that, at times said particles may lose or have their charge neutralized before arriving at the separation zone.

All these disadvantages are noticeably more evident in the processing of fine and extremely fine particles and are overcome by employing the charging method applied in the separators belonging to group B, that is, the ones of the type carrying the material in suspension in a gas stream.

On the other hand, a disadvantage which is common to the separators of the B type is that sometimes the speed at which the ore suspension in the gas stream enters the separation zone, namely between the two electrodes creating the electrostatic field, is too high. This results because a minimum speed of such a gas stream is necessary to assure the pneumatic conveyance of the ore particles, as well as to assure an effective electric charging upon the impact of the ore particles one with another and between the particles and the wall of the duct.

Such a comparatively high speed of the gas stream in the separation zone, while always within certain limits, can be advantageous in many cases, as it has the function of driving the ore particles along predetermined paths and preventing that the fine particles from forming deposit on the electrodes which create the static field; however, in other cases it may give rise to inconveniences, either due to the disturbing action of whiriling motions or because the particles are held in the separation zone a time a time too short a time.

In order to overcome the aforesaid disadvantages, it is therefore an object of the invention to provide an electrostatic separator in which the charging of the particles takes place according to the principle followed in the separators of type B, that is, on material conveyed in suspension in a gas stream (by providing high speeds in the relative motion and the impacts between the particles and the walls of the duct), but also in which it is possible to adjust as necessary the amount of air to be introduced together with the particles in the separation zone between the two electrodes which create the electrostatic field, or eliminate almost entirely such air.

Another object of the invention is to provide an electrostatic separator in which the triboelectric charging takes place in a zone limited in length of the separator, so as to limit to such a zone the lining of the walls with special materials having a dielectric constant intermediate those of the two species to be separated or by any other means which by triboelectric effect will produce charges of opposite polarity on the particles of different species to be separated.

Such materials could also be advantageously formed by ore agglomerates and in particular by a mixture of the same ore species to be separated bonded by a suitable binder or material which change their dielectric constant with temperature (as is the case for the resins commer-

cially known under the name of Araldite), so that by adjusting the letter it is possible to obtain a dielectric constant intermediate the species to be separated.

Another object of the invention is to provide a separator in which, if necessary, the pneumatic conveyance of the grains can be effected according to a cycle by which those grains which have been attracted by either of the two electrodes which generate the static field are continuously separated, and the grains which have not been separated are continuously recycled in a closed cycle without being passed in contact with those grains which have been collected at the base of the two electrodes and again conveyed in the charging and subsequent separation zone, together with the fresh feed.

A still further object of the invention is to provide an electrostatic separator with triboelectric charging which permits an efficient separation of grains of different mineralogical species, with sizes lower than 200 mesh and quite lower than 400 mesh.

Such an electrostatic separator, in its essential elements, comprises a duct fitting into a cyclone having the inner surface coated with special materials having a dielectric constant intermediate those of the species to be separated or by any other means which by friction of the ore particles produces charges of opposite polarity on the particles of different species to be separated, said cyclone having the lower outlet communicating with a chamber in which two electrodes are arranged and which generate an electrostatic field, and, in the lower part of said electrodes there is provided means suitable for collecting the separated products divided in final product concentrates and tailings to be discharged from the apparatus and mixed products or grains which have not been deflected by the electrostatic field, to be recycled together with the fresh feed.

In order to make clearer the understanding of the construction of the electrostatic separator according to the invention, of its features and the advantages accruing from its use, some alternative embodiments thereof will now be described by way of examples and in no way of limitation, by reference to the attached drawings wherein:

FIGURE 1 shows diagrammatically the cross section along a vertical plane of a separator limited to its essential parts;

FIGURES 2 and 3 show, diagrammatically, vertical cross sections of two different embodiments of separators in which there is provided a closed loop of the mixed products or of the particles which have not been deflected by the electrostatic field and a closed loop of the air required for the pneumatic conveyance of the material;

FIGURE 4 shows diagrammatically an alternate embodiment in the arrangements of the ducts providing the closed loops of the material and the air and a further alternate embodiment in the construction of the electrodes creating the static field which are formed by two moving metal bands rather than by two stationary plates;

FIGURE 5 is a cross-sectional view along line A—A of FIGURE 1.

The separator shown in FIGURE 1, limited to its essential parts, comprises a duct **1** feeding a cyclone **2** (tangentially as shown in FIGURE 5) having the upper orifice **3** discharging at the outside and the lower orifice **4** (called also cyclone tip) discharging in a chamber **5** in which two electrodes **6** and **7** are arranged, one of which is connected to the negative terminal **7'** and the other one to the positive terminal **6'** of an electric generator, the connections to the generator not being shown for sake of simplicity, since they are quite obvious.

Assume for example that the electrode **6** is connected to the negative terminal and the electrode **7** to the positive terminal: the electrodes **6** and **7** are electrically insulated with respect to the remainder of the apparatus which can be made of an insulating material or at least partially of a conductive material, except, of course, the inner surface of the cyclone which, as already pointed out, must have a coating **2'** consisting of special materials having a dielectric constant intermediate those of the two species to be separated.

One of the two electrodes can be also grounded.

The electrodes **6** and **7** are formed by either flat or slightly curved surfaces and have one end thereof **8** and respectively, diverging one from another.

Below the electrodes **6** and **7**, hoppers **10**, **11** and **12** are arranged, which hoppers collect respectively the ore particles attracted by the electrodes **6**, **7** and those not deflected by the electrodes consisting of the mixed materials or the materials which have not been electrically charged. The amount and quality of the materials collected by the hoppers can be modified by turning the sectors **13** and **14** respectively on the hinges **15** and **16**.

In the separator just described, a suspension of ore particles in air is introduced through the duct **1** by a suitable blower **1'**, known in the art of the pneumatic conveyance of pulverulent materials. The ore particles are centrifugal inside the cyclone and they run along paths of circular type near and in contact with the inner surface of the outer wall of the cyclone at a very high speed.

The resultant rubbing of the particles against such a surface and the impact of the particles against each other is very intense in the proximity of the tip of the cyclone where a packing of such particles occurs.

In order to promote the charging of the particles of different species to opposite polarities, the inner surface of the cyclone is coated with a coating **2'** of special materials having a dielectric constant which is intermediate those of the two species to be separated, or by any other means which by triboelectricity produces electric charges of different polarity on the particles of different species.

Such special materials can be selected from a wide range of the commercially available plastic materials or they can be prepared purposely by means of mixture of ore particles of different species, bonded by means of a suitable binder, which can be itself a plastic material or a cement. Particularly suitable is a mixture of ore particles, formed of the same species to be separated as it has a dielectric constant intermediate those of the two species to be separated. Use can also be made of special plastic materials which change their dielectric constant with temperature, for example of the type commercially known under the name of Araldite. In such a case, it will be necessary to provide means for maintaining the walls of the cyclone at the temperature required for obtaining a dielectric constant intermediate those of the two species to be separated.

Such heating means have not been shown in FIGURE 1, since they are quite obvious and can be provided by means of a heating muff element **17**, as shown in FIGURES 2, 3, and 4 with a device **17'** for automatically controlling the temperature.

The particles after passing through the cyclone and being electrically charged in the ways before described, discharge through the orifice **4** into the chamber **5**. As the particles fall through this chamber, those charged with charges of opposite polarity are differently deflected by effect of an electric field created by electrodes **6** and **7**, and they collect in the hoppers **10** and **11**, respectively. The particles which have not been charged and therefore have not been deflected, collect in the hopper **12** wherefrom they can be sent again into the cyclone **2** together with the fresh feed.

Referring to FIGURE 2, a separator is shown similar to that illustrated in FIGURE 1 and comprises structural parts which are similar or quite equivalent to those described with reference to FIGURE 1 and which are therefore denoted for the sake of simplicity and brevity by the same reference numerals in order to avoid describing them unnecessarily. In the separator of FIGURE 2 there are also shown (in addition to those already shown in FIGURE 1) and are described merely as an ex-

ample and in no way as a limitation, the means which permit the pneumatic conveyance of the ore particles and the continuous recycling of the mixed materials or of the particles that have not been charged or have not been deflected and which must therefore be combined with the fresh feed to be again fed to the cyclone.

In the separator illustrated in FIGURE 2, the dust **1**, chamber **5**, ducts **12** and **18** form substantially a single duct forming a closed loop in which the cyclone **2** is inserted and in which the material and the air which serves for its conveyance circulate in a clockwise direction. In such a duct the spaces included between the divergent end **8** of the electrode **6** and the movable sector **13**, and the divergent end **9** of the electrode **7** and the movable sector **14** form substantially two adjustable opening orifices through which the particles deflected respectively by the elctrodes **6** and **7** are discharged, the collecting means of said particles not being shown in FIGURE 2, as they are quite obvious and can be provided for example as in FIGURE 1 or in an equivalent way, or through ducts closed to the outside environment in which the separator is installed. The particles which are not deflected by the electrostatic field recycle through the two duct portions **12** and **18** into the duct **1**, the pneumatic conveyance of the ore in the latter being assured by the introduction of a gaseous fluid under pressure through the duct **19** substantially tangentially into the duct **1** so as to generate therein a motion in the clockwise direction of the material and the gaseous fluid.

There is provided a sector **20**, pivotable on a hinge **21** to control the flow of air under pressure, said means being however not essential for the operation of the apparatus as said control can be carried out upstream or directly on the blower or compressor **1'** feeding the duct **19**, which blower and compressor are not shown in FIGURE 2. In addition a hopper **22** is provided for feeding the raw ore or the mixture to be processed into the duct **1**.

In the separator of FIGURE 2, there is also shown merely as an example and in no way as a limitation, a heating element **17**, to be used when the walls are formed by materials having dielectric constant which are variable with temperature, and when it is desired to adopt such a technique to obtain a dielectric constant intermediate those of the two species to be separated.

The separator shown in FIGURE 3 is quite similar to that shown in FIGURE 2 and comprises structural parts similar or quite equivalent to those described with reference to FIGURE 2 and which are therefore denoted by the same reference numerals. The modification introduced in the separator shown in FIGURE 3 with respect to the separator of FIGURE 2 lies in the fact that the upper discharge pipe **3** of the cyclone **2**, instead of discharging into the outside atmosphere the gaseous fluid utilized for pneumatically conveying the material, fits into a duct **23** which conveys such a gaseous fluid in such a way as to introduce it again in a closed loop in the duct **1**.

With such an expedient the gaseous fluid circulating in the ducts of the separator is separated from the outside atmosphere and therefore it can be different from air and maintained at an elevated temperature or however at strictly controlled temperature and moisture. Moreover this type structure avoids scattering into the atmosphere of the extremely fine particles which are not collected by the cyclone **2** and discharged through the orifice **4**, and therefore the alternative embodiment of the apparatus shown in FIGURE 3 is especially useful in the processing of extremely fine pulverulent materials or of mixtures comprising a considerable proportion of extremely fine particles.

In the separator shown in FIGURE 3, a valve **24** can be advantageously utilized (which valve by way of an example and in no way as a limitation, as a valve of another type can be used, is shown in FIGURE 3 as a butterfly valve) inserted in the duct **23** having the function of controlling the flow of gaseous fluid through the orifice **4** of the cyclone and consequently the separation zone **5** and the following duct section **12**. The valve **24** acts in this way: if held open, the most of the gaseous fluid which flows through the duct for the pneumatic conveyance of the material is conveyed and reintroduced in the duct **1** through the duct **23**, so that very little air together with the material passes through the separation zone **5**; if on the contrary the valve **24** is held closed, all the air which passes through the duct **1** will run through the orifice **4** of the cyclone and consequently the separation zone together with the material.

Intermediate adjustments of the opening of the valve **24** provide for precise control of the flow of gas or air passing through the separation zone **5**.

Referring now to FIGURE 4, a separator is shown similar to those illustrated in FIGURES 1, 2 and 3 and comprising structural parts which are similar or quite equivalent to those described with reference to FIGURES 1, 2 and 3 and which are therefore denoted, for the sake of simplicity and brevity, by the same reference numerals in order to avoid describing them unnecessarily.

The separator of FIGURE 4 has some variations with respect to the separator shown in FIGURE 3, namely: in place of the two stationary electrodes **6** and **7** of FIGURE 3, formed by two slightly curved metal plates, use can be made of two movable electrodes formed for example by way of an illustration and in no way of a limitation by two metal bands each traveling around two drums rotating in the direction indicated by the arrows, so that the surface of the band toward the separation zone **5** have a motion directed toward the product hoppers **10** and **11**.

Such metal bands or other equivalent system, for example the surfaces of two drums of a suitable diameter, form the electrodes, and are connected to the negative and positive terminals **6'** and **7'** of the high voltage generator, the connections to the generator not being shown since they are quite obvious.

Of course the two electordes must be insulated from the remaining parts of the separator if they are formed by a conductive metallic material. One of the two electrodes can be also grounded, as also, can the parts of the casing of the apparatus formed by conductive metallic material be grounded, and, in such a case, such grounded electrode need not be electrically insulated from such a part of the casing.

If necessary, in the separator of FIGURE 4, two brushes **27** and **28** can be also provided, which brushes have the function of causing fine particles deposited on the bands **6** and **7** to fall into the hoppers **10** and **11**.

The provision of the two movable electrodes **6** and **7** of the separator of FIGURE 4 is particularly useful in the processing of extremely fine particles which tend to deposit on the electrodes forming a thick layer which would disturb the separation of the grains subsequently entering the separator. Such extremely fine particles are thus progressively brushed away by the brushes **27** and **28**.

However, other systems could be used for the same purpose: for example the electrodes **6** and **7** of the separator of FIGURE 3 could be caused to vibrate by means of suitable vibrators so as to prevent the formation of the deposit of the particles.

In alternative or in addition to such an expedient, the partial closing of the valve **24** permits passing into the separation zone **5** a greater flow of gaseous fluid which prevents or decreases the deposition of fine particles on the electrodes.

Another modification adopted in the separator of FIGURE 4 in comparison with the separator shown in FIGURE 3 lies in the different arrangement of the duct **18** opening in the duct **25** connected to the duct **1**, rather than directly into the duct **1** as in the separator of FIGURE 3.

In the last lower section of the duct **25**, the mixed grains and all the particles which have not been deflected

in the separation zone, mix together with the fresh feed coming from the hopper **22** and are all fed into the duct.

Another modification lies in the pressurized air or gas inlet system, provided, in the separator of FIGURE 4 by means of a tube **26** fitting into the duct **1** and running through a part thereof along its axis like an injector. Such a device permits operation of the separation apparatus by feeding through the pipe **26** air or gas at a very high pressure but in a limited amount. In such a case the pipe **26** is of very small diameter, providing a considerable supply of energy in order to have a sufficient flow of gas in a closed loop in the ducts **1** and **23** and in the cyclone **2**, with the aim of an efficient pneumatic conveyance of the ore particles through, as already stated, the flow of gas in the apparatus and by consequence the flow of gas which it is necessary to remove from the apparatus together with the separated material, is in a very limited amount.

Having thus described the present invention, what is claimed is:

1. An electrostatic separator of different species of ore wherein the charging of ore particles takes place by triboelectricity, comprising a duct, a cyclone having an inlet to which said duct is connected, means for feeding ore particles in a fluid suspension through said duct into said cyclone to provide for frictional engagement between the ore particles and between the ore particles and the sides of the cyclones so as to charge the ore particles of different species with charges of opposite polarity by said friction, said cyclone having a lower outlet, a chamber communicating with said cyclone lower outlet and having two spaced electrodes therein, means for connecting said electrodes to terminals of opposite polarity of a source of electricity for generating an electrostatic field therebetween and attracting the ore particles charged with the opposite polarities to the respective electrodes of polarities opposite that of the attracted particles whereby said charged ore particles are separated according to the respective charges thereon, and means below said electrodes for separately collecting the separated ore particles and also unseparated particles.

2. A separator as defined in claim **1** having means for recycling said unseparated particles with fresh feed of ore particles by said ore feeding means.

3. A separator as defined in claim **1** wherein said cyclone is provided with a coating on the inner surface thereof formed of special materials having a dielectric constant which is intermediate those of the species of ore particles to be separated so as to charge the ore particles of different species with charges of opposite polarity by friction of the particles with said coated surface of said cyclone and with each other.

4. A separator as defined in claim **3** wherein said inner coating of said cyclone comprises a mixture of the species of ores to be separated bonded by a suitable binder.

5. A separator as defined in claim **3** wherein said inner coating of said cyclone comprises material having a dielectric constant which varies with temperature, means for heating said coating, and means for automatically controlling the temperature of said coating by said heating means to maintain said temperature at the value required to provide a dielectric constant to said coating as is required to charge the different ore species to be separated to opposite polarities by a triboelectric effect thereon.

6. A separator as defined in claim **1** wherein said means for collecting said unseparated ore particles comprises a chamber underlying space between said electrodes; said latter chamber, said duct feeding the cyclone, and said chamber in which said electrodes are arranged together forming substantially a single annular ductwork with means for continually recycling the unseparated ore particles from said underlying chamber with fresh ore particles through said feeding means; means for supplying a pressurized gaseous fluid substantially tangentially into said annular ductwork to provide pneumatic conveyance of the ore particles to said cyclone; and two openings adjacent the ends of said electrodes for discharging the particles attracted by said electrodes.

7. A separator as defined in claim **6** wherein said cyclone has an upper gas discharge opening, a duct connecting said cyclone upper opening with said annular ductwork which pneumatically conveys ore and feeds said cyclone providing a closed loop for the gas discharged from said upper opening of the cyclone with the gaseous fluid in said annular ductwork.

8. A separator as defined in claim **7** wherein a control valve is arranged in said duct connecting said cyclone upper opening with said ductwork for varying the flow of gaseous fluid passing through the separation zone between said two electrodes.

9. A separator as defined in claim **6** wherein an injector type compressed gas feed supplies gaseous fluid into said annular ductwork for pneumatically conveying ore particles to said cyclone inlet.

10. A separator as defined in claim **1** wherein said two electrodes comprise two metallic rotatably movable members turning in opposite directions and are respectively electrically connected to opposite terminals of a high voltage source and provided with brushes for removing fine particles which may adhere to said members.

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