

C. Q. PAYNE.
METHOD OF SEPARATING ORES.
APPLICATION FILED MAR. 15, 1911.

994,870.

Patented June 13, 1911.

2 SHEETS—SHEET 1.

Fig. 1

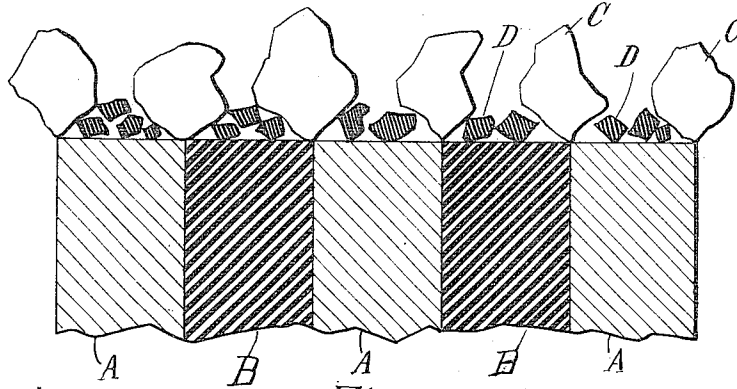


Fig. 2

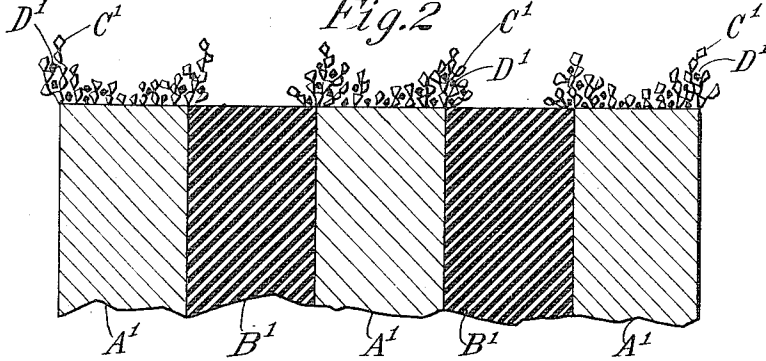


Fig. 3

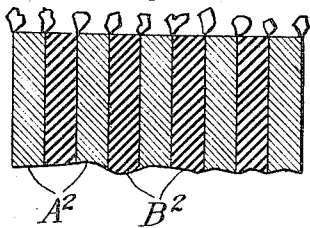


Fig. 4

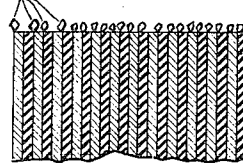


Fig. 5



Fig. 6

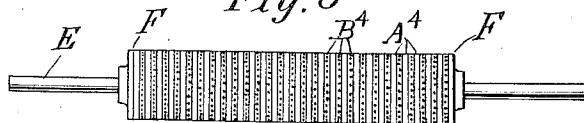


Fig. 7



Witnesses:

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2 SHEETS—SHEET 2.

Fig. 8.

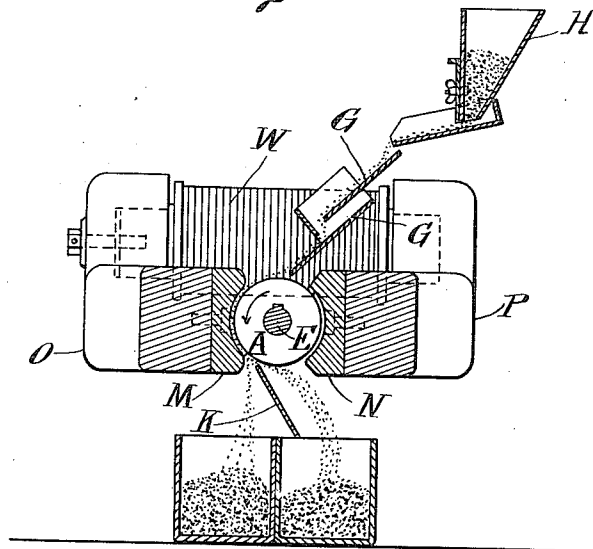
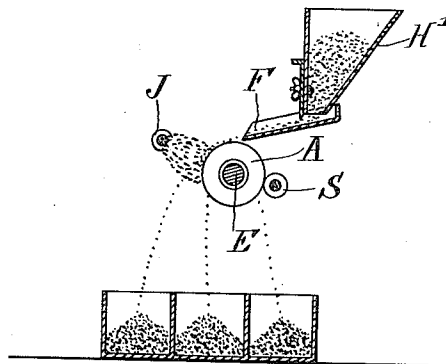


Fig. 9.



WITNESSES

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UNITED STATES PATENT OFFICE.

CLARENCE Q. PAYNE, OF NEW YORK, N. Y.

METHOD OF SEPARATING ORES.

994,870.

Specification of Letters Patent. Patented June 13, 1911.

Application filed March 15, 1911. Serial No. 614,585.

To all whom it may concern:

Be it known that I, CLARENCE Q. PAYNE, a citizen of the United States of America, residing in the borough of Manhattan, city, county, and State of New York, have invented a certain new and useful Improvement in Methods of Separating Ores, of which the following is a full and true description.

My invention relates especially to improvements in the method of separating those ore mixtures which contain minerals which can be distinguished by their permeability to magnetic induction, or by their conductivity of electricity.

It consists broadly in a method of overcoming the mechanical interference or entanglement of the various particles of an ore mixture with each other when acted on by magnetic or electrostatic fields, thus aiding their more efficient separation.

I have found that mechanical entanglement is due to two principal causes: first, to the presence of particles differing greatly in size in an ore mixture, whereby the large particles, when acted on by a field charge, wedge and hold the smaller particles not so acted upon, and prevent their free motion; and, secondly, to the unequal action of the field charge, especially upon the smaller particles, when they are afforded areal rather than lineal positions of attachment upon the separating surface. I have also found that the efficiency of certain types of magnetic separators, as well as of electrostatic separators, is seriously reduced by the interference or mechanical entanglement of the various particles of an ore mixture with each other while they are undergoing separation. It has become a matter of importance to prevent this mechanical entanglement, since in the above types of apparatus, unlike that depending upon the principle of gravity separation, the period of time during which the separation can take place is exceedingly short. Defective separation resulting from mechanical entanglement can, therefore, with the methods now in use, only be overcome by re-passing the partly separated products several times through similar apparatus. This involves considerable expense for separating machines, as well as losses in handling, and from abrasion of the ore particles, dust, etc.

In case of magnetic separation of ore mixtures, I have previously sought as shown

in my Patent Number 791,494, dated June 6th, 1905, as well as in other patents granted to me, to so control the positions of the lines of force in a magnetic field as to procure what may be called a "unipolar" field, *i. e.*, one in which the lines of force all pass in the same direction and do not reverse at any point. This I accomplish by causing the separation to take place in an air gap of a magnetic circuit between two opposing pole pieces. In this way a large amount of mechanical interference or entanglement of the particles undergoing separation is prevented as compared with the use of a bipolar field, in which loops or bridges of attracted particles are permitted to span the space between the adjacent poles, and thus surround and inclose a considerable amount of non-magnetic material. Notwithstanding the use of the unipolar field, a considerable amount of mechanical entanglement has heretofore still persisted.

It is the object of my present invention to overcome this remaining amount of mechanical entanglement, while retaining at the same time the advantages of the unipolar field already set forth.

My invention also has important advantages in electrostatic separation of ore mixtures for the removal of good conductors of electricity from poor or non-conductors. This applies especially to that type of machine in which the poorer conductors are made to cling tenaciously to the separating cylinder, while the better conductors are repelled or drop off.

In place of a continuous cylinder having an areal electrostatic charge, I employ in my invention one which is provided with a series of charged disk edges. These edges permit the attractions and repulsions of the various particles of an ore mixture to be much better localized and controlled, and when the thickness of these disks is properly proportioned to the size of the ore particles to be separated, in accordance with the principle involved in my invention, the mechanical interference or entanglement of one set of particles with another in an electric field, can be largely prevented.

I have succeeded in overcoming mechanical entanglement by dividing the ore mixture to be separated into groups by sizing it, so that the particles in each group shall be as nearly uniform in size as possible, and then treating each group independently

upon a separating surface, so formed that the particles are permitted lineal or independent positions instead of areal or massed positions of attachment, and are free to respond to gravity and centrifugal force while acted upon by electrical or magnetic attraction.

Since different properties of certain minerals of an ore mixture may be availed of, such as their magnetic susceptibility or their electrical conductivity, in affecting a separation from certain other minerals associated with them, my invention covers a general method of ore separation.

In the drawings accompanying and forming a part of this specification, Figures 1, 2, 3 and 4 illustrate the principle of my invention, and show upon an enlarged scale sections of cylindrical disks, whose thickness bears a certain ratio or size relation to the diameter of the particles which they are respectively designed to act upon. Fig. 6 shows a separating cylinder made up of a series of disks having smooth edges, mounted upon a shaft. Figs. 5 and 7 show disks having various projecting or exposed edges, and which may be employed in certain cases in place of disks having smooth edges. Fig. 8 shows a sectional view through a magnetic ore separator, and Fig. 9 is a similar view through an electrostatic ore separator. These illustrate the application of my invention to the separation of various ore mixtures by means of different field charges.

Referring in detail to these drawings in order to illustrate more clearly what is sought to be accomplished by my invention, Fig. 1 shows in section, upon a much enlarged scale, a series of disks A A, whose edge faces can be charged either with magnetic or electrical density. These disks alternate with a series of disks B B, whose edge faces cannot be so charged, or else to a much less degree. If we convey upon these disk edges a series of particles which differ greatly in size, such as C C and D D, and assume that the particles C C respond to the field charge, and are attracted and held to the charged edges of the disks while the particles D D do not so respond, and are hence free to be removed by other forces, it is evident that in the positions in which the particles D D are placed, they are held or blocked by the irregular shape of the attracted particles C C, and their separation from the latter is thus prevented. This interference or mechanical entanglement of a certain percentage of one set of particles D D by another set C C, has the obvious disadvantage that the entangled particles are caused to pursue the same path of movement as the particles C C, when the latter are finally released and discharged from their separating cylinder, instead of a differ-

ent path of movement, thus causing a defective or inefficient separation. It is evident that if the smaller particles D D are removed from the larger ones C C by screening them out before the mixture is fed upon the separating cylinder, their mechanical entanglement would be prevented. Since the more highly charged edges of the disk faces largely determine the position of the impressed particles, it is evident that the thickness of the disks should not be disproportionately great as compared with the diameter of the particles to be separated. For illustration, if in Fig. 1 only particles of the size C C be treated on the disks A B, whose thickness bears to the diameter of the particles C C approximately the ratio 2:1, there will then be little or no entanglement between particles of such relative size while they are undergoing separation, and an efficient separation can be made. The ideal condition for sized particles may be assumed to be realized when the thickness of the disks is just equal to the diameter of the particles to be separated. Each impressed article then almost instantly finds a point of attachment when fed upon the cylinder made up of such disks, and the free distribution of the impressed particles is thus aided. Such a size relation, however, is not feasible in practical work, and I have found that the ratio of the thickness of the disks to the diameter of the particles of 3:1, 4:1, or even somewhat greater, will give practical and efficient results, especially when the ore mixture is properly fed upon the separating cylinder.

In Fig. 2 is illustrated the effect of a disproportionate size relation between the thickness of charged disks, and the diameter of the sized particles to be separated. Since the magnetic density and also the electrical density is much greater upon a sharp edge or corner than upon a flat surface, the edges of the disks A' A' become more highly charged than their centers where they are acted on by a magnetic or an electrostatic field. The attracted particles are thus acted on by a difference of potential and tend to move away from the centers of the edge faces and to crowd toward the edges of the disks A' A', as shown in Fig. 2. In such positions they form column like attachments, especially toward the extreme edges, and among these attachments considerable mechanical entanglement of the non-attracted particles D' D' occurs. This can be largely prevented by using thinner disks for the smaller particles, as shown in Fig. 3 by A² A² and B² B² in order to avoid a great inequality in the distribution of the magnetic or electrical density upon the disk faces,—and also by carefully feeding the ore mixture upon the separating cylinders. In Fig. 4 is illustrated an appropriate size rela-

tion in the case of still smaller particles $C^3 C^3$.

I have found that the best results are obtained when thin disks are used for separating small particles, medium thick disks for medium sized particles, and thick disks for coarser particles; in other words, an approximate similar size relation should exist between the thickness of the disks and the average diameter of the particles of each group treated upon them respectively. The number of the group divisions of an ore mixture, likewise the number of the separating cylinders employed, and the precise ratio of the thickness of the disks of each cylinder to the average size of the ore particles of each group division will vary with different ore mixtures, but it is evident that the sizing and disk variations may be carried to as great a limit of refinement as the value of a given ore, and the resulting gain in efficiency will warrant.

Fig. 6 shows a complete separating cylinder such as may be used in carrying out my invention, either in magnetic or electrostatic separation. Here the separating surface consists of two series of disks mounted upon a shaft E, and held in place by compression flanges F F. These disks have smooth edge faces. One series $A^4 A^4$ is made of iron or steel when employed in magnetic separation, or of any other electrically conducting material as well, such as brass, aluminum, etc., when used in electrostatic separation. The disks of the other series are alternately interleaved with the disks A^4 , and are made of a suitably non-permeable or non-conducting substance, such as fiber, etc. In place of the interleaved disks B^4 , it is also possible to employ the permeable or conducting disks A^4 alone, and to construct them with alternately projecting edges, as shown in Fig. 5, or else to give their edges toothed outlines, as shown in Fig. 7. The latter construction permits, in such cases where it is desirable, especially when the disks are so assembled that the teeth are staggered or are out of alinement, a somewhat more intense localization of the field charges than in the case of the interleaved disks with smooth edges.

In the different constructions of the separating cylinder herein described, it is sought to present in all cases disk edges which are so exposed to the field-charges that the ore particles may be attracted and held in approximately lineal positions along the cylinder surface in carrying out the purpose of my invention. Where all the disks are metallic, *i. e.*, permeable to the lines of force of the field charge, this exposure of the disk edges may be accomplished by making the alternate disks of larger diameter, as shown in Fig. 5, or by giving them toothed outlines, as shown in Fig. 7, and preferably placing the teeth of alternate disks out of

alinement. Where alternately permeable and non-permeable disks are employed of the same diameter, as shown in Fig. 6, the edges of the metallic disks are, for the purpose of ore separation, permeably exposed, although they are physically in contact with the edges of the non-permeable interleaved disks. Other combinations of disks not shown in Figs. 5, 6 and 7 may also be made, such as alternating non-permeable disks with permeable disks of larger diameter, having smooth edges or toothed edges, etc. In all cases the object aimed at is the same; viz., to secure permeably exposed disk edges along the surface of the separating cylinder.

In Fig. 8 I have shown a sectional view of a magnetic separator adapted to be used in practicing my invention. In this arrangement W represents the coil of an electro-magnet, which, when energized by an electric current, establishes a magnetic field between the pole pieces M N. The edges of the permeable disks which wholly or partly make up the armature cylinder A then become charged or impressed with local condensations of magnetic lines of force when it is revolved through the field formed between the pole pieces M N. Those particles of the ore mixture fed upon the cylinder A from a convenient hopper H, and guide plates G G, which are susceptible to magnetic attraction, are held to the charged edges of the disks while they are being conveyed through the magnetic field, and are discharged from the cylinder at the end of the field in a different path of movement from those particles of the ore mixture which are not acted on by magnetic attraction, thus effecting a separation between them.

In using my improved method, each ore mixture is first divided into separate groups, preferably by screening it, so that the average diameters of the particles of the different groups differ respectively among themselves. These groups are then treated upon several separators of the type which I have shown in Fig. 8, and which differ among themselves in the thickness of the disks, which are used respectively in the separating cylinder. The group containing the coarsest ore particles is then separated upon the cylinder containing the thickest disks, while the group containing the finest ore particles is treated upon the cylinder containing the thinnest disks. The greater the number of the groups into which an ore mixture is divided, and the more closely the thickness of the disks approximates to the size of the ore particles in each group, the more perfectly can the mechanical entanglement of one set of particles with another set, during separation be overcome, and the more perfect will the separating action between them become.

While practical considerations based upon the value of a given ore, and the expense involved in its treatment, will necessarily modify the ideal conditions already referred to in connection with over-coming mechanical entanglement, it is evident that there must be at least two groups of particles into which an ore mixture must be divided, and at least two separating cylinders must be employed having disks of different thicknesses, in order to apply my method of separation in accomplishing the purpose of my invention.

In the electrostatic ore separator shown in Fig. 9, which may also be used in carrying out my invention, the separating cylinder A may be provided with disks of any conducting material, have smooth edges and interleaved with those of non-conducting material, or else the disks may have projecting or toothed edges, as already explained. The sized portion of an ore mixture is fed upon the cylinder from a convenient hopper H and feed plate F. The electrode J conveys an electric charge of high voltage to the opposing surface of the disk edges, either from a static-electric generator, or an alternating dynamo having a proper transformer and rectifier in circuit, so as to supply uni-directional charges of static-electricity. The shaft E, upon which the disks are mounted, may be insulated or grounded, depending upon the nature of the impressed charge desired, and the character of the mineral separation to be made. Those particles of the ore mixture which are good conductors of electricity, upon falling upon the charged areas of the disks, assume at once a charge of electricity of the same polarity, and are promptly repelled, or else drop off. Those particles of a less electrical conductivity are removed less promptly, while the non-conducting particles are held tenaciously to the surface of the disk edges by the attraction of charges of unlike polarity, until they are removed by the brush drum S, or other device. By causing the particles to pursue different paths of movement, as they pass through an electrostatic field, a separation may thus be made between the minerals of an ore mixture which are of unequal electrical conductivity. By sizing an ore mixture, and then providing several separating cylinders having disks of different thicknesses adjusted to the different sizes of the ore particles of the different groups to be separated, it is thus possible to overcome the effects of mechanical entanglement of one set of particles with another, while undergoing electrostatic separation in accordance with the principle of my invention, as already explained.

This application is intended to cover the general method of ore separation herein described, and also the specific method herein

described as the electrostatic method. I do not claim herein that species of my general method described as the magnetic method, but have described and claimed the same in my pending application, Serial No. 614,587, filed March 15, 1911. In my pending application, Serial No. 614,586, filed March 15, 1911, I have described and claimed an apparatus especially adapted for carrying out the electrostatic method described herein.

I am aware that the sizing of ore mixtures as a preliminary step to their treatment by various methods of separation, is not uncommonly practiced, but it will be seen that the main feature of my invention consists in providing unobstructed positions of attachment for those particles in an ore mixture which are acted on by an impressed force, and as a further aid in thus overcoming mechanical entanglement I have found that a preliminary sizing of the ore particles is of assistance.

I claim as my invention:

1. The method of ore separation, which consists in dividing an ore mixture into a plurality of groups which differ respectively in the average diameter of their component particles and subjecting each of said groups independently to the action of field-charges at the edges of disks arranged in series, the thickness of which disks varies with the average diameter of the particles treated thereon.

2. The method of ore separation, consisting in dividing ore into a plurality of groups differing respectively in the average diameter of their particles, and subjecting each of said groups independently to the separating action of a series of field charges spaced proportionately to the average diameter of the particles of the field group treated, substantially as described.

3. The method of separating substances of all degrees of susceptibility to the action of field charges from one another or from inert substances with which they may be mixed, which consists in dividing a mixture into a plurality of groups which differ respectively in the average diameter of their particles; feeding each group separately upon one of a plurality of cylinders, each of which is provided with a series of disks which differ in their thickness, each series with respect to the others, and whose edges are impressed with a field charge; acting upon each group by means of said field charge, as well as by gravity and centrifugal force, and then discharging two or more sets of the separated particles of each group mixture from each cylinder along diverging paths of movement.

4. The method of ore separation which consists in dividing an ore mixture into a plurality of groups which differ respectively in the average diameter of their particles, and then acting upon each of said

groups independently by the electrostatically charged edges of disks arranged in series, which disks vary in thickness with the average diameter of the particles acted on.

5 5. The method of separating substances of all degrees of electrical conductivity from one another, and from non-conducting substances with which they may be mixed, which consists in dividing a mixture of such
10 substances into a plurality of groups which differ respectively in the average diameter of their particles; feeding each group separately upon one of a plurality of cylinders
15 each of which is provided with a series of disks which differ in their thickness, each series with respect to the others, and whose edges are charged with static-electricity; acting upon each group by means of said electro-static charges as well as by means

of gravity and centrifugal force, and then 20 discharging two or more sets of the separated particles of each group mixture from each cylinder along diverging paths of movement.

6. The method of ore separation, consist- 25 ing in dividing ore into a plurality of groups differing respectively in the average diameter of their particles and subjecting each of said groups independently to the separating action of a series of electrostatic 30 charges spaced proportionately to the average diameter of the particles of the group treated, substantially as described.

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Witnesses:

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