

May 24, 1949.

A. B. DRESCHER
METHOD AND APPARATUS FOR SEPARATING MAGNETIC
FROM NONMAGNETIC MATERIALS

2,470,889

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2 Sheets-Sheet 1

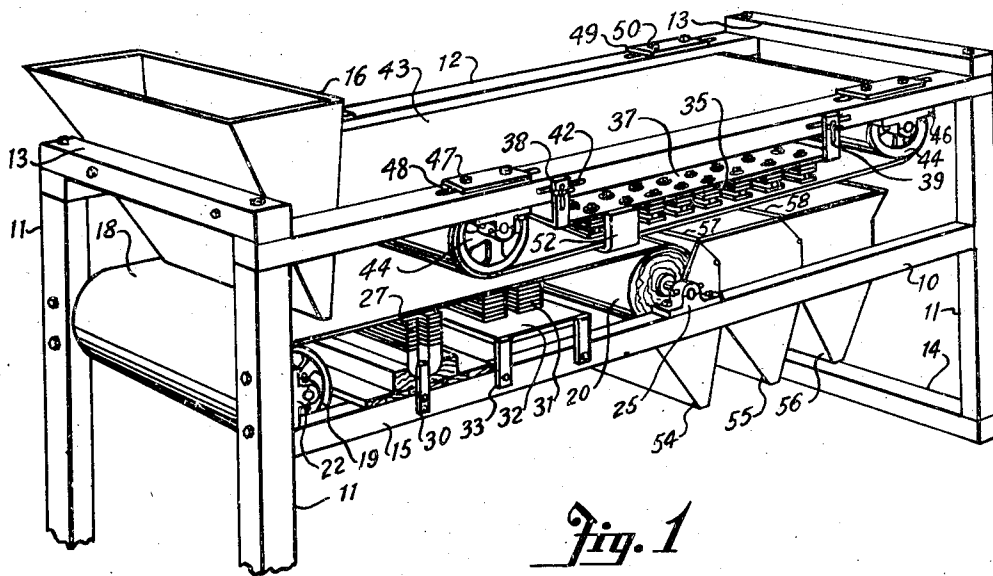


Fig. 1

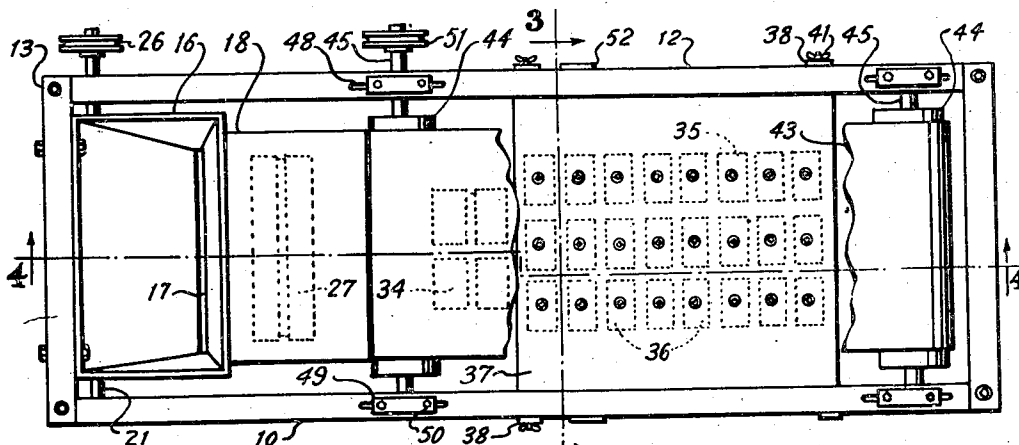


Fig. 2

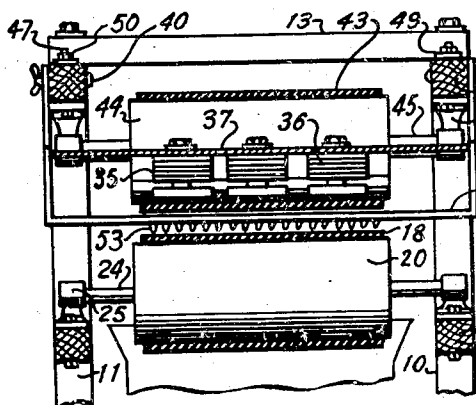


Fig. 3

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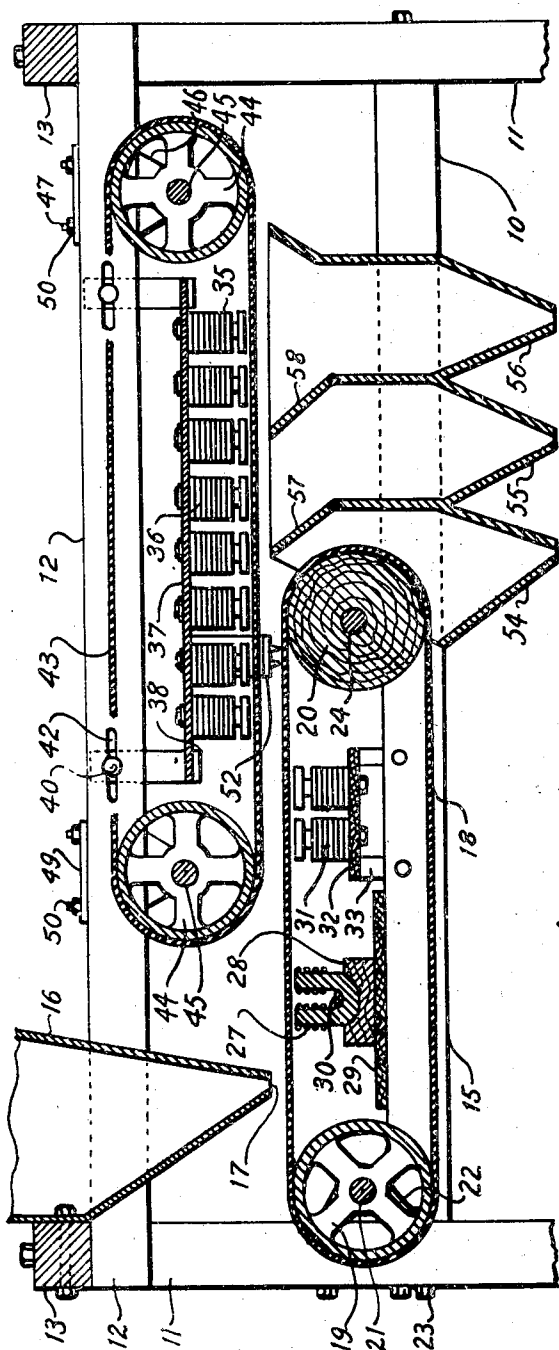


Fig. 4

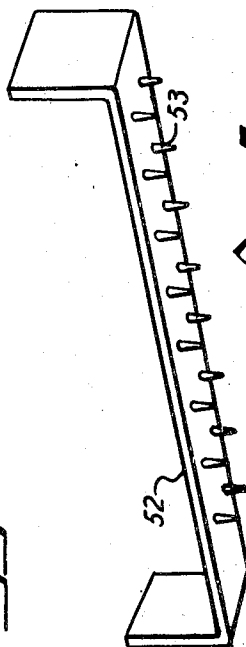


Fig. 5

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UNITED STATES PATENT OFFICE

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METHOD AND APPARATUS FOR SEPARATING MAGNETIC FROM NONMAGNETIC MATERIALS

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4 Claims. (Cl. 209-214)

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This invention relates to new and useful improvements in methods and apparatus for separating magnetic from non-magnetic materials.

As is well-known, the majority of magnetic separators are of the direct-current type which are inefficient in obtaining concentrates from fine ore uncontaminated by free gangue. This is due to the fact that, upon use of a magnetic (direct-current) field of sufficient intensity, the magnetic particles are attracted to each other as well as to the magnetic field. Thus, some of the non-magnetic waste material or gangue is inevitably entrained by the mutually-attracted magnetic particles.

Magnetic separators utilizing a series of alternate "North" and "South," or positive and negative, poles are also inefficient, because the speed of passage of the ore particles through such alternate fields is not sufficient to permit hysteretic repulsion and attraction. As the ore particles pass from, one pole to another of opposite sign, said particles merely turn end for end, often in groups with physically-entrapped gangue therein, and without actually being repulsed.

In magnetic separators utilizing an inclined or sloping surface along which the active, or activated, particles progress downwardly by gravity, an absolutely clear cut or definite separation is impossible. Due to the violent motion of the magnetic particles, a considerable quantity of the middlings as well as some of the free gangue or quartz is so physically agitated that the same progress down the inclined surface to contaminate the concentrates.

Although an alternating current magnetic field has been employed heretofore in magnetic separators, the same has been used as a "repulsion magnet" and has been located beneath the stream or path of the ore particles so as to have its force directed from underneath said particles. In this type of separation, the theory of operation is that the magnetic material and waste will be stratified with said magnetic material working to, or accumulating at, the top of the bed whereby the concentrates will be removed or separated out upon being subsequently passed through a direct-current magnetic field. The main disadvantage of this type of separation is that perfect stratification is unobtainable, since middlings and some free gangue will become admixed with the concentrates due to the rather violent agitation, especially when the material settles back to the bed upon passing from the alternating-current magnetic field. Thus, the

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stratified condition of the particles is at least partially lost by the time the same reaches the direct-current magnetic field. The alternating-current magnetic field merely prepares the particles for the actual separation step by the direct-current magnetic field and does not have any part in accomplishing such separation.

Combined direct-current and alternating-current attracting magnets have been utilized in separators in which the separation takes place under water. However, the water dampens the activity of the particles in the alternating-current magnetic field so as to reduce or impede the effectiveness of the separation. Not only does the resistance of the water retard the motion of the magnetic particles, but it also prevents the gangue from draining or dropping out as rapidly as is desirable and as it would in the free atmosphere. Manifestly, these factors limit the recovery and quality of the concentrates as well as the capacity of the separator.

By the use of an alternating-current magnetic field in a free or normal atmosphere for attracting the ore particles, the entrainment of gangue is almost entirely eliminated. Individual particles are attracted and repulsed alternately and, in general, each particle behaves or reacts more or less independently, as controlled by the direction of the magnetic field, the positions of the particles and other conditions. Thus, there is little chance for physical entrapment of waste material. During one half of the cycle, on the average, magnetic particles are repelled in an alternating current field, but are again attracted almost immediately during the other half of the cycle, thereby keeping the particles in constant activity or motion. The response of a particle at any particular moment is the result of various conditions, such as the orientation of the magnetic poles of the particle, the shape of said particle, its freedom from crowding by adjacent particles, its "locked" condition (admixture with gangue), the direction of the magnetic field at the moment, etc. The composite or total effect of these variables results in attraction of each magnetic particle during half of the cycle and repulsion thereof during the remaining half.

Therefore, one object of the invention is to provide improved means for magnetically separating materials having, or to which may be imparted, a relatively-high coercive force and a sufficiently high remanence, which means effectively overcomes the inherent drawbacks of direct-current magnetic separators and, at the same time, more efficiently utilizes the activity

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set up by an alternating-current field so as to obtain higher-grade concentrates as well as increased recoveries and capacities.

A particular object of the invention is to provide improved magnetic separation means having an alternating-current magnet through the field of which the ore, or other material to be separated, is conducted for initial activation which results in a preliminary segregation or separation of the active concentrates and inert tailings, said activated ore stream being subjected to the field of an alternating-current "attracting" magnet which physically separates said active concentrates from said inert tailings.

Another object of the invention is to provide improved magnetic separation means, of the character described, wherein the ore, or other material, is reduced in size to give the desired degree of liberation and, if necessary, properly converted to a substance of sufficiently high coercive force and remanence; said ore being passed through the field of a direct-current magnet so as to be magnetized and subsequently activated and/or repulsed by the first alternating-current magnet and separated by the alternating-current "attracting" magnet.

A further object of the invention is to provide an improved magnetic separator, of the character described, wherein a thin bed of dry ore is fed through the fields of the direct-current magnet and the activation and/or repulsion magnet by suitable conveying means disposed above said magnets, the "attracting" magnet being of greater intensity than said repulsion magnet and having concentrate conveying means associated therewith, whereby the active concentrates will be activated and segregated from the inert tailings upon the feed-conveying means by said repulsion magnet and will be transferred to and further activated along the concentrate conveying means by said attracting magnet so as to be in a state of "suspension" and thereby release entrained tailings as well as middlings.

Still another object of the invention is to provide an improved magnetic separator, of the character described, wherein the attracting magnet and concentrate-conveying means are adjustably mounted so as to permit varying of the intensity of the effect of the magnet upon the magnetic particles of the material being separated; there being means for mechanically agitating the material while the same is upon the feed-conveying means so as to permit the feeding of a thicker bed or stream of material.

An important object of the invention is to provide an improved magnetic separation method wherein the ore, or other material to be separated, is subjected to an alternating-current magnetic field of insufficient strength to demagnetize the magnetic particles of the material whereby said particles are activated and segregated or separated from the inert tailings, said material then being subjected to and attracted by an alternating-current magnetic field of greater intensity which physically removes or separates said magnetic particles from said inert tailings and suspends the same in a tenuous active mass so as to drop out entrained gangue or tailings.

Another object of the invention is to provide an improved method of magnetically separating materials, of the character described, wherein the intensity of the attracting magnetic field is not in excess of the coercive force of some of the magnetized particles, whereby said particles will maintain their respective polarity and will ad-

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just themselves by motion to the alternating-current, the activity of these particles causing the same to collide with particles having less coercive force so as to agitate the same and cause draining out of entrained gangue.

A construction designed to carry out the invention will be hereinafter described together with other features of the invention.

The invention will be more readily understood from a reading of the following specification and reference to the accompanying drawing, wherein an example of the invention is shown, and wherein:

Fig. 1 is an isometric view of a magnetic separator constructed in accordance with the invention,

Fig. 2 is a plan view of the separator,

Fig. 3 is an enlarged, transverse, vertical, sectional view, taken on the line 3—3 of Fig. 2,

Fig. 4 is an enlarged, longitudinal, vertical, sectional view, taken on the line 4—4 of Fig. 2, and

Fig. 5 is an enlarged, isometric view of the nonmagnetic rake.

In the drawings, the numeral 10 designates the frame of a magnetic separator which is substantially rectangular in cross-section and which includes a plurality of upright supporting legs or standards 11. Longitudinal beams 12 and transverse cross-heads or members 13 connect the upper ends of the legs 11 to each other, while each pair of end legs have their lower ends joined and reinforced by a suitable transverse foot member or plate 14. Below each beam 12 and in parallel, vertical alinement therewith, a reinforcing beam 15 extends longitudinally between and connects each pair of longitudinal legs. A suitable feed hopper 16, preferably of the type capable of maintaining a steady and uniform, thin-bedded feed, such as an electromagnetically-vibrating type, is secured to one of the cross-heads 13 and has its lower portion depending between and below the upper beams 12 adjacent one end of the separator frame 10. The hopper has a constricted feed slot 17 formed in its lower end, which slot terminates some distance above the beams 15.

As is clearly shown in Figs. 1 and 4, an endless conveyor or feed belt 18, of rubber or other suitable material, is disposed between the reinforcing beams 15 and is mounted upon suitable pulleys 19 and 20. The pulley 19 is of conventional construction and is supported by having its shaft 21 journaled in suitable brackets 22 which are fastened by bolts and nuts to the inner longitudinal surfaces of the legs 11 below the hopper 16. It is preferable that the pulley 20 be constructed of wood or other non-magnetic material, and has its shaft 24 journaled in suitable brackets 25 which are secured to the upper surfaces of the beams 15 at their intermediate portions. Due to the disposition of the pulleys 19 and 20, the feed belt 18 extends throughout slightly more than one-half the length of the separator frame 10 and said belt is of a width slightly greater than the length of the hopper feed slot 17 and slightly less than the distance between the beams 15 (Figs. 2 and 4). Also, the upper flight of the belt is disposed immediately below the feed slot 17 which, in turn, is positioned a slight distance forwardly of the pulley 19, whereby the dry ore, or other material to be separated, is fed from the hopper 16 through said feed slot directly upon said belt in a thin stream or bed. For driving the belt to the right or in a clock-wise direction, one end of the pulley

shaft 21 projects beyond the frame 10 and has a suitable V-pulley or sheave 26 mounted thereupon.

As is clearly shown in Figs. 1 and 4, a direct-current magnet 27, of any suitable construction, is disposed between the upper and lower flights of the belt 18 and is supported upon a suitable transverse block 28 and planks or members 29, of wood or other non-magnetic material, which rest upon and are secured to the upper surfaces of the beams 15 immediately forward of the pulley 19. The magnet 27 is illustrated as being of the conventional U-shaped construction and extends entirely across the width of the belt 18, being clamped in position upon the block 28 by an overlying strap 30 which has its ends bent downwardly and secured to the beams 15. This direct-current magnet is for the purpose of magnetizing the particles of the ore, or other material to be separated, and maximum activity is attained if said magnet is of sufficient strength to completely saturate said particles. A field strength of approximately 2700 oersteds is usually required in order to obtain complete saturation. Of course, although the use of a direct-current magnet is preferable, the same may be omitted in the event that the ore or other material is previously magnetized or possesses sufficient magnetism.

An alternating-current magnet 31 is also disposed between the flights of the feed belt 18 intermediate the nonmagnetic pulley 20 and the direct-current magnet 27, being supported upon a plate or platform 32 which is spaced above and secured to the beams 15 by a plurality of upright legs 33. As is clearly shown in Fig. 2, the magnet 31 preferably consists of a plurality of small individual magnetic elements 34 which are disposed in transverse, parallel rows at the central portion of the belt and these magnetic elements are secured to the plate 32 in the usual manner. Although the upper ends of the elements 34 are contiguous to the upper flight of the belt 18, this distance and the magnetic strength of the field created by said elements is such that the field strength is not in excess of the coercive force of the particles carried by said belt. However, this strength or intensity is sufficiently close to such coercive force to activate and repel the particles, whereby the desired activation and/or repulsion is obtained without demagnetization of said particles, as will be hereinafter more fully explained.

An attracting, alternating-current, magnet 35 depends from the beams 12 so as to be disposed above a portion of the belt 18 and its nonmagnetic pulley 20, and preferably consists of a plurality of individual magnet elements 36 arranged in transverse, parallel rows. It has been found that the magnetic elements are more effective than a single magnet and said elements as well as the rows thereof are preferably positioned in close proximity to one another, as is clearly shown in Figs. 2, 3 and 4. However, if desired, the rows may be spaced some distance apart so that each individual row will act independently and thereby increase the capacity of the magnet. Of course, this spacing should not be of sufficient distance to create a zone of weak magnetic intensity between adjacent elements. Although not illustrated, the individual magnet elements or the rows thereof may be offset relative to each other so as to force the concentrates attracted by said elements through a tortuous or circuitous path or be dropped and picked up again, as will hereinafter be more fully explained.

For supporting the magnetic elements 36, a flat plate 37 is adjustably connected to the beams 12 and said elements depend from and are secured to the plate. A plurality of vertical, depending legs or straps 38, having longitudinal slots 39 formed therein as shown in Fig. 1, project upwardly from the plate 37 along the external, lateral surfaces of the beams 12 and the slots of the straps receive bolts 40 which have wing nuts 41 screw-threaded upon the outer ends thereof. Longitudinally-extending, horizontal slots 42 are formed in the beams 12 for receiving the bolts 40, whereby the plate 37 and its attached magnetic elements may be adjusted horizontally as well as vertically of the frame 10 and belt 18. Manifestly, the vertical adjustment permits the effective intensity of the magnet 35 to be varied, while the horizontal or longitudinal adjustment makes it possible for more or less of said magnet to overlie or project beyond the end of the feed belt 18 and its pulley 20. As is clearly shown in Fig. 3, the plate 37 is of substantially the same width as the frame 10 so as to be readily suspended from the beams 12. However, each transverse row of magnetic elements 36 is of a length less than the width of the feed belt so as to be confined within the longitudinal margins thereof.

An endless conveyor belt 43 is supported by the beams 12 with its upper flight preferably above the plate and its lower flight underlying the magnetic elements and overlying the feed belt. The belt 43, which will be hereinafter referred to as the concentrate belt, is carried by means of a pair of spaced pulleys 44, each pulley having its shaft 45 journaled within suitable brackets or bearing blocks 46 which depend from the underside of each of the beams 12. As is clearly shown in Figure 1, each bracket 46 is adjustably suspended from one of the beams 12 by having its supporting bolt 47 extending through vertical, longitudinal slots 48 formed in said beam. A flat, metallic plate or strip 49 overlies each slot 48 and has an opening formed therein for receiving the bolt 47 of its respective bracket 46. A suitable nut 50 is screw-threaded upon the upper projecting end of each bolt. Thus, the brackets 46 are adjustably mounted so as to permit horizontal, longitudinal adjustments of the pulleys 44 and the concentrate belt 43. One of the latter pulleys is disposed forwardly of the attracting magnet 35 adjacent the forward end of the frame, while the other pulley is positioned in a vertical plane substantially intermediate the direct-current magnet 27 and the repulsion magnet 31 and rearwardly of said attracting magnet. As is clearly shown in Fig. 2, one end of the shaft 45 of this rearwardly-disposed pulley 44 projects beyond the frame 10 and has a suitable V-pulley or sheave 51 mounted on the outer end thereof.

By means of the pulley 51, the concentrate belt is driven in a counter-clockwise direction whereby the lower flight thereof travels in the same direction as the upper flight of the feed belt 18 or toward the forward end of the frame. The belts may be driven by the same means (not shown) at the same rate of speed or at different rates of speed. In the later event, it is usually preferable for the concentrate belt to travel at a faster rate so as to permit more rapid removal of the concentrate. For the most effective separation of the magnetic particles from the tailings, the strength of the magnetic elements 36 is less than the coercive force of the magnetic particles and this strength may be varied so as

to provide a gradual or tapered pick-up and release with an intermediate zone or plateau of maximum intensity. Thus, there is less entrainment of tailings during the pick-up of the magnetic particles by the attracting magnet 35. By tapering the strength of this magnet, or its magnetic elements, toward its forward end, middlings may be separated from the concentrate by drainage. The zone or plateau of maximum intensity is preferably located substantially in alignment with the non-magnetic pulley 20 of the feed belt so as to extend a slight distance beyond either side of said pulley and particularly beyond the forward end of said belt.

Improved results are obtained by the use of a rake or agitating member 52, of wood or other non-magnetic material, which depends from the plate 37 a slight distance rearwardly of the shaft 24 of the pulley 20 and above the belt 18. As is clearly shown in Fig. 5, a plurality of short prongs or teeth 53 are secured to the undersurface of the rake 52 so as to engage the material carried by the feed belt when said rake is properly positioned intermediate said feed belt and the concentrate belt. Manifestly, engagement of the prongs 53 with material supported by the feed belt stirs up or agitates the same so as to expose the lower or underportion of said material, whereby a somewhat thicker bed or stream of material may be employed. A plurality of hoppers 54, 55 and 56 are supported between the beams 15, below the concentrate belt and forwardly of the feed belt, and have intermediate adjustable vanes 57 and 58 at their upper ends. These hoppers are of conventional construction and the rearwardmost hopper 54 has an enlarged, open upper end for receiving a portion of the feed belt and its pulley 20 whereby the gangue or inactive tailings will drop directly into said hopper from said belt. The intermediate hopper 55 receives the middlings and is preferably disposed beneath a portion of the attracting magnet 35 which is of decreasing intensity, while the forwardmost hopper 56 projects beyond said magnet so as to receive the concentrates as they drop from the concentrate belt.

In carrying out the method, the dry ore, or other material to be separated, is reduced in size to give the desired degree of liberation and, if necessary, is properly converted, by reduction and/or oxidation, to substance having a sufficiently high coercive force and remanence. This material is fed uniformly to the feed belt 18 by the hopper 16 and is conducted by said belt to the field of the direct current magnet 27 in a relatively thin bed or stream. After being magnetized, which magnetization may be performed before the material is fed to the belt, said material travels into the field of the alternating-current repulsion magnet 31 and the material becomes very active due to the magnetization thereof or its inherent magnetism. A separation of the active concentrates and inactive tailings is accomplished by the agitation or vertical motion of the magnetic particles. Since these magnetic particles have a coercive force of greater strength than the intensity of the magnetic field, said field is of insufficient strength to demagnetize said particles and the same are repelled by the changing alternating-current. Actually, the particles are attracted and repelled alternately, but the attraction is ineffective because of the supporting surface afforded by the feed belt. Since the magnetic particles retain their polar-

ity, the repelled poles of said particles will cause the same to jump or move upwardly and the repulsion is effective. This activity or agitation of the magnetic particles continues until the material moves out of the field of the magnet 31.

The material is then conducted into the field of the alternating-current, attracting magnet 35 and its magnetic elements 36, wherein the activity of the particles is relatively complex. Upon entering this magnetic field and while still carried by the feed belt, the magnetic particles behave or react in much the same manner as when the same were under the influence of the magnet 31. This is in part due to the lower strength of the initial portion of the attracting magnetic field, or that portion of said magnetic field which is disposed rearwardly of the pulley 20, as well as the distance of the material from the magnet 35. However, the intensity of this magnetic field may exceed the coercive force of some of the magnetic particles so as to be sufficient to attract to and hold the same in engagement with the concentrate belt 43.

If the intensity of the magnet 35 is properly adjusted, either as to distance or ampere-turns, the strength or intensity of the field will not exceed the coercive force of most of the particles. The latter will retain their individual polarity and will continue to adjust themselves by motion to the alternating magnetic field so as to be acted upon by both attracting and repelling magnetic forces. Upon being repelled, the particles leave the surface of the concentrate belt and this movement will be aided by gravity, said particles again being attracted upon changing of the field. In effect, the particles are in a state of suspension and the same are carried by the underside of the concentrate belt in a tenuous active mass.

Upon reaching the zone or plateau of maximum intensity, substantially all of the magnetic particles will be so held. The particles held in engagement with the concentrate belt are not inactive as the same will be agitated by the bombardment of more active particles and said particles will themselves become more active due to a lag in magnetization which prevents a complete change of polarity of the particles.

This reduces to a minimum the entrainment of gangue. The majority of the particles are attracted more or less vertically, but will move horizontally relative to the belt to zones of denser intensity along the edges of the magnetic elements 36 or the rows thereof and, due to this horizontal travel, additional gangue drains out.

As the material, being carried along by the concentrate belt, passes from the zone of maximum intensity through the forward end zone of decreasing magnetic intensity, middlings composed of particles of locked grains and of lower remanence than the other particles drop out and are caught by the hopper 55. This material may be reground to a finer size and again passed through the separator to recover additional magnetic particles. After traveling past the middling hopper, the magnetic particles will commence to leave the belt 43 and fall into the hopper 56 due to the decreasing magnetic intensity of the magnetic elements disposed above said hopper. All of the magnetic particles will detach themselves from the belt so as to be received by this forward hopper by the time said particles are carried beyond the field of the attracting magnet. As set forth hereinbefore, the rows of magnetic elements may be offset relative to each other so

as to force the concentrates carried by the belt 43 to travel through a tortuous or curved path or are dropped and picked up again due to the alternation of the magnetic field.

This method of separation may be effectively used on any material having a high coercive force, either natural or as a result of processing, such as heat treatment. Also, a relatively high remanence is desirable so as to give amplitude to the activity of the material. Although the method and apparatus are particularly adaptable to the separation of iron ores, other minerals containing iron and some manganese ores, the same is also adaptable to materials which have or may be given a high coercive force and a sufficiently high remanence. However, materials of quite low remanence may be successfully separated. Very clean concentrates are obtainable by this method. For example, the silica of limonite and siderite ores of East Texas can be reduced 40% lower, with the same recovery, than by any other method of separation or concentration, for which other methods the ore must be ground two or three times as fine. It is pointed out that substantially all free gangue is eliminated from the concentrates by the separating method and apparatus set forth herein. The most important limitation inherent in direct-current magnetic separators has been effectively overcome and, at the same time, the activity of an alternating-current field has been more efficiently utilized so as to obtain higher-grade concentrates and increased recovery as well as increased capacity.

The foregoing description of the invention is explanatory thereof and various changes in the size, shape and materials, as well as in the details of the illustrated construction may be made, within the scope of the appended claims, without departing from the spirit of the invention.

What I claim and desire to secure by Letters Patent is:

1. The method of magnetically separating a mixture of materials certain particles of which have magnetic properties and other of which have non-magnetic properties, which consists in passing said mixture through a direct current magnetic field so as to impart to or to increase the coercive force of the particles having magnetic properties, then passing all of said mixture above an alternating current magnetic field of a strength less than the coercive force of the particles having magnetic properties so as to cause at least a partial stratification of the said mixture, and finally passing said materials below a second alternating current magnetic field of progressively increasing and diminishing force, the force of said second alternating current magnetic field being greater than the coercive force of some of the particles having magnetic properties and not greater than the coercive force of most of the magnetic particles, whereby to separate the latter from said particles of non-magnetic force.

2. The method of magnetically separating a mixture of materials certain particles of which have magnetic properties and others of which have non-magnetic properties which includes, passing the mixture above an alternating current magnetic field of a strength less than the coercive force of the particles having magnetic properties so as to cause at least a partial stratification of said mixture, and then passing said materials below a second alternating current magnetic field of a strength greater than the coercive force of some of the particles having magnetic properties and not greater than the coercive force of most of the magnetic particles so as to separate the magnetic particles from said non-magnetic particles.

3. An apparatus for magnetically separating materials having particles with magnetic and non-magnetic properties including, a material feed hopper, a conveyor disposed beneath the feed hopper, a first alternating current magnet disposed between the upper and lower runs of the conveyor and having a maximum intensity less than the coercive force of the particles having magnetic properties, a second conveyor disposed above and parallel to the first named conveyor in overlapping relation to the latter and to the first named alternating current magnet, and a second alternating current magnet disposed between the upper and lower runs of the second named conveyor having a maximum intensity greater than the coercive force of some of the magnetic particles and not greater than the coercive force of most of the magnetic particles.

4. An apparatus for magnetically separating materials in accordance with claim 3, wherein the second alternating current magnet is constructed so as to produce an alternating magnetic field of gradually increasing and diminishing zones of intensity.

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