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METHOD AND APPARATUS FOR SEPARATING MAGNETIC ORES.

APPLICATION FILED JUNE 12, 1915.

1,218,916.

Patented Mar. 13, 1917.

2 SHEETS—SHEET 1.

Fig. 1.

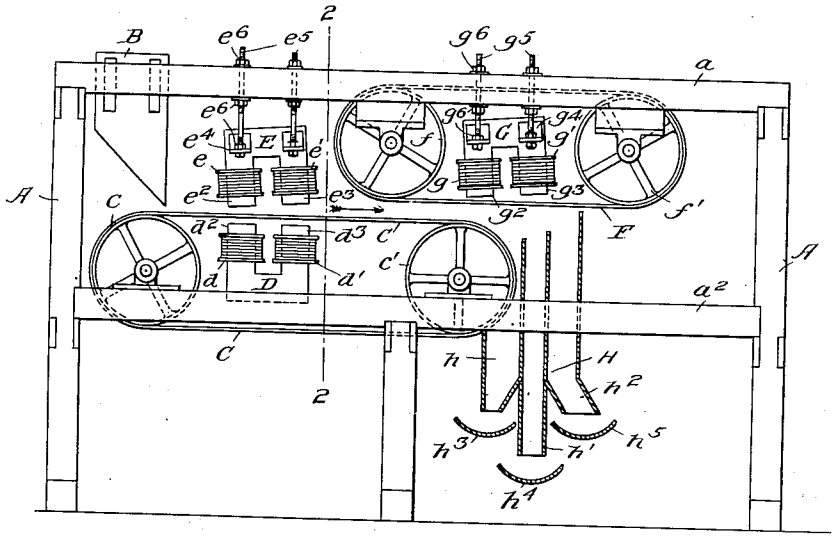


Fig. 2.

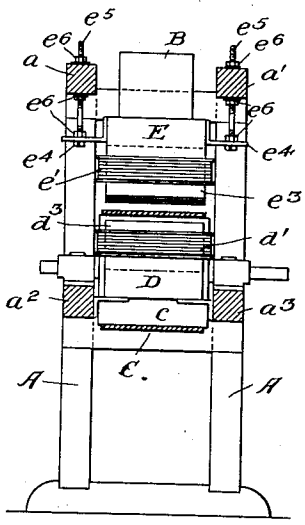


Fig. 3.



Witnesses

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2 SHEETS—SHEET 2.

Fig. 4.

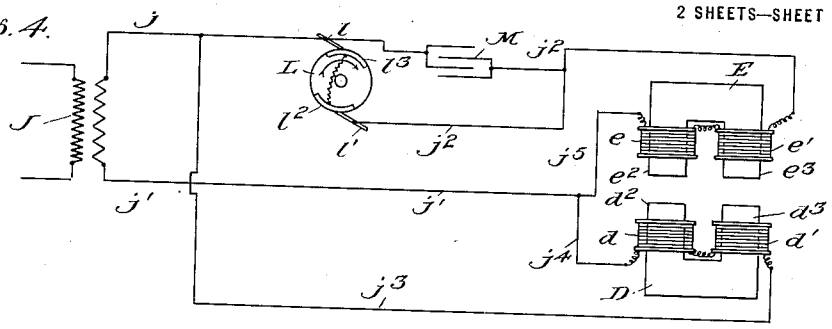


Fig. 5.

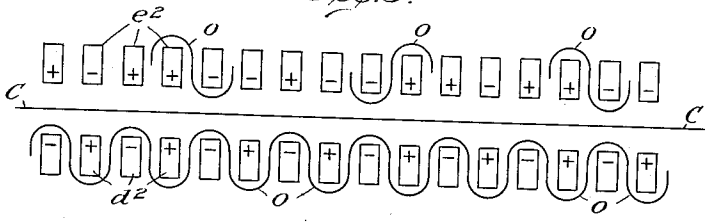


Fig. 6.

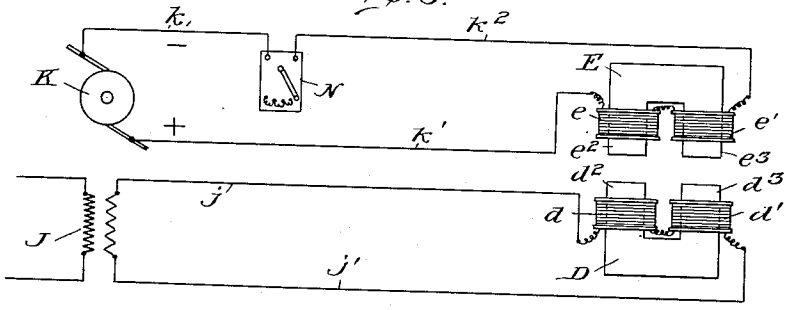
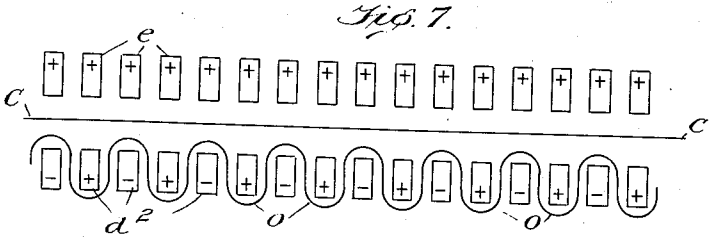


Fig. 7.



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UNITED STATES PATENT OFFICE.

JOSEPH WEATHERBY, OF NEW CUMBERLAND, PENNSYLVANIA, ASSIGNOR, BY DIRECT AND MESNE ASSIGNMENTS, TO ELECTRIC ORE SEPARATOR COMPANY, OF NEW CUMBERLAND, PENNSYLVANIA, A CORPORATION OF DELAWARE.

METHOD AND APPARATUS FOR SEPARATING MAGNETIC ORES.

1,218,916. Specification of Letters Patent. Patented Mar. 13, 1917.

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To all whom it may concern:

Be it known that I, JOSEPH WEATHERBY, a citizen of the United States, residing at New Cumberland, in the county of Cumberland and State of Pennsylvania, have invented certain new and useful Improvements in Methods and Apparatus for Separating Magnetic Ores; and I do hereby declare the following to be a full, clear, and exact description of the same, reference being had to the accompanying drawings, forming part of this specification, and to the figures and letters of reference marked thereon.

This invention relates to improvements in the treatment of magnetic ores in a subdivided mixture consisting of particles having different degrees of magnetic permeability.

In magnetic separators heretofore designed for the separation of magnetic ore particles from gangue materials, it has been found that the magnetic particles on entering the magnetic field will form into thick groups or clusters incidentally entangling within the clusters such gangue materials as might be between the magnetic particles before entering the magnetic field; thus the gangue material is carried mechanically to the discharge, and a clean separation of the magnetic from the non-magnetic particles cannot be obtained.

Many methods have been tried to overcome this fault, among these, feeding the ore one grain thick, which in very fine ore particles result in small capacity per machine. A comparatively weak magnetic field is sometimes used, which results in great loss of values to the gangue, with little improvement in the magnetic concentrate. Another method used with more success is the placing of many magnetic poles adjacent to one another, but of opposite sign, the ore being conveyed over or under the magnet poles by a suitable carrier. The magnetic particles leap to the first pole in clusters as before described, thence are thrown or carried to the following poles in regular order. Since the magnetic particles have magnetic polarity, they are compelled to turn over and expose their pole of opposite sign to that of the magnet pole in whose influence they are progressed. This method shakes out considerable of the gangue that is close to the surface of the clusters and causes the particles to arrange themselves in layers or stratas in accordance with their magnetic permeability, but since the clusters turn over in masses or sheets, the gangue that is held deeper in the mass is progressed mechanically to the concentrate discharge.

One object of the present invention is to preliminarily effect a practically complete stratification of the ore particles with the magnetic portion superposed or in the form of a sheet which may be readily separated or lifted away from the underlying gangue.

Another object is to prevent the formation of fingers or clusters of magnetic material during stratification, whereby entanglement of gangue particles is prevented.

Another object is to provide a cheap and effective form of magnetic separator which will effectively stratify and separate the ore in a thick layer or stream and at high speed, whereby the capacity of the apparatus is greatly augmented.

When magnetic ore is brought within the influence of a rapidly alternating magnetic field, and especially when carried through an air gap between oppositely located pole pieces, the magnetic particles tend to revolve at great speed, due to the reversals of the current, and the fact that each particle has magnetic polarity. Each magnetic particle tries to adjust itself parallel with the lines of magnetic force with its poles in proper relation to the magnet. Each individual magnetic particle tries to lock itself in contact with its neighbor, but is prevented from doing so by the surrounding gangue material and its violent revolution. This agitation which takes on the characteristics of a violent ebullition of the magnetic particles brings the magnetic particles to the surface of the gangue for freedom of action and repels such gangue as interferes with their movement.

I have discovered that should the current be suddenly reversed in one of the magnets so that the magnets become opposed to one another in improper magnetic relation so that the magnetic circuit in the air gap between the magnets become neutral, the magnetic ore particles will be violently repelled one from the other and from magnet poles, thus preventing the formation of fingers or clusters in the magnetic field and by pe-

riodically subjecting the traveling sheet or stream of ore to the influence of the rapidly alternating field and to the opposed magnetic fields the ore will be stratified with the magnetic content in the form of a top layer which as it recedes from the field of magnetic action will be practically quiescent and in condition to be readily separated or lifted off of the underlying gangue content.

The invention may be carried into effect in various forms of apparatus and a simple easily understood form is shown in the accompanying drawings, in which:

Figure 1 is a side elevation of a magnetic ore separator for carrying out the improved method, well known parts being omitted or indicated in general outline only.

Fig. 2 is a transverse section taken in a plane indicated by the line 2—2 of Fig. 1, looking in the opposite direction to that indicated by the arrow.

Fig. 3 is an enlarged transverse section of a conveyer belt showing the mixture after it has been stratified into layers.

Fig. 4 is a diagram showing one form of apparatus for obtaining alternate attractive and repulsive magnetic fields.

Fig. 5 is a diagrammatic representation of the changes in polarity of the magnetic fields when the apparatus shown in Fig. 4 is in operation.

Fig. 6 is a diagram showing a modified form of apparatus for obtaining alternate attractive and repulsive magnetic fields.

Fig. 7 is a diagrammatic representation of the changes in polarity of the fields when the apparatus shown in Fig. 6 is in operation.

Like reference characters in the several figures indicate the same parts.

As shown in Fig. 1, the principal parts of a magnetic separator embodying the present improvements are supported in a suitable framework A having at one end thereof a hopper B of any well known construction and suspended from upper longitudinal frame members a and a'. Located in position to receive material discharged from the hopper B is a conveyer, consisting preferably of an endless belt C made of the usual rubber covered fabric and mounted on pulleys c and c'. The pulleys are suitably journaled on the frame members a^2, a^3 and the belt is arranged to be driven in the direction indicated by the arrow in Fig. 1.

Securely mounted between frame members a^2, a^3 and located below the conveyer belt C is an electro-magnet D having coils d, d' and pole pieces d^2, d^3. Adjustably suspended above the belt is a second electro-magnet E having coils e, e' and pole pieces e^2, e^3. Magnet E is arranged directly over magnet D in such manner that when either magnet E or D is energized, a magnetic circuit will be completed through the air gap located between the magnets. Magnet E is preferably so suspended from the framework that adjustment is provided of the air gap between the magnets. For this purpose magnet E is provided with lugs e^4 in which are screwed bolts e^5. The bolts e^5 are screwed into the upper longitudinal frame members a, a', and are provided with lock nuts e^6 which permit each end of magnet E to be raised or lowered as desired. Suspended above the discharge end of conveyer belt C, *i. e.*, the end beyond magnets E, D, is a separator belt F mounted at its ends on pulleys f, f' suitably journaled on frame members a, a'. The belt F is driven to move in the same general direction as belt C. Adjustably suspended from frame members a, a' in the same manner as magnet E is a lifting magnet G having coils g, g' and poles g^2, g^3. The magnet G is suspended from lugs g^4 in which are screwed bolts g^5 adjustably mounted in the frame by nuts g^6. It will be noted that magnet G is so arranged that the lower run of separator belt F is interposed between it and conveyer belt C and pole g^2 is located above the discharge end of conveyer belt C.

Suitably mounted within the frame members a^2, a^3 and located approximate the discharge end of conveyer belt C and under magnet G are discharge bins or chutes H consisting of a chute h for gangue materials, a chute h' for middlings or magnetic particles of ore that are mechanically connected or embedded in gangue material, and compartment h^2 for the magnetic particles of greatest magnetic permeability or the magnetic concentrate. Below the discharge ends of the chute are conveyer or carrier belts h^3, h^4, h^5, respectively, these being arranged to carry away the separated layers to their proper destination.

Referring now particularly to Figs. 4 and 5, a source of alternating current supply is indicated at J having main circuit wires j and j'. Leading from a main circuit wire j to a coil d' of electromagnet D is a conducting wire j^3 and leading from main circuit wire j' to a coil d of electro-magnet D is a conducting wire j^4. A conducting wire j^5 connects coil e of electro-magnet E with main circuit wire j' and a conducting wire j^2 connects coil e' of electro-magnet E with a brush l' of a rotary make-and-break L. The other brush l of rotary make-and-break L is provided with oppositely disposed contact surfaces l^2, l^3 electrically connected as shown for the purpose of intermittently connecting the coils of electro-magnet E with the source of alternating current supply J. Interposed between brush l and conducting wire j^2 is a condenser M of sufficient capacity to absorb the counter-electromotive force or back-kick from the coils of electro-magnet E when the circuit is broken by rotary make-

and-break L, and to prevent a heavy arcing discharge at the brushes l, l'.

In Fig. 5 the changes in polarity of pole pieces e^2 and d^2 are represented, the signs plus and minus denoting magnetic polarity. The sinuous line O' indicates the alternating current passing through pole piece d^2 of electro-magnet D and the broken sinuous lines O denote the alternating current as it intermittently passes through pole pieces e^2 of electro-magnet E.

It will be noted that magnet D is continuously connected with the source of alternating current supply through connecting wires j, j', and magnet E is only connected with the source of alternating current supply when the contact surfaces l^2, l^3 are in engagement with brushes l, l'. Magnet E is so arranged with respect to magnet D that when an alternating current is flowing through the coils of magnet E pole pieces e^2, e^3 of magnet E are in improper relation to the magnet poles d^2, d^3 of magnet D, thus causing the lines of magnetic force from each magnet to oppose each other. When the current is disconnected from magnet E energized magnet D induces magnetic action in magnet E, causing lines of magnetic force to flow across the air gap between the magnets through magnet E, completing its magnetic circuit, and energizing both magnets in proper relation with respect to each other.

When, however, electro-magnet E is connected to the source of alternating current supply J through rotary make-and-break L, a magnetic field is created about the poles e^2, e^3 of magnet E which magnetic field is opposed to the magnetic field of electro-magnet D, thus causing the lines of magnetic force in the air gap between the two magnets to flow in opposite directions from the direction of flow when magnet E is not connected with the source of alternating current supply J. This action is best represented by the series of oblong blocks e^2 denoting changes in polarity of magnetic pole e^2 and the series of oblong blocks d^2 representing the changes in polarity of pole d^2, when the rotary make-and-break L is in operation and electro-magnet E is being intermittently connected with the source of alternating current supply J. In the said diagram it will be noted that when magnet E is disconnected from the source of current supply, pole e^2 is in proper magnetic relation with respect to pole d^2, pole e^2 being shown as of positive polarity and pole d^2 of minus polarity, the changes in polarity of the two poles taking place in accord with the oscillations of the alternating current flowing through the coils of electro-magnet D and the induced magnetic field created in the air gap between the two electro-magnets E and D. At the times when an alternating current O is passing through the coils of electro-magnet E the pole piece e^2 is in improper relation with respect to pole piece d^2, it being of positive polarity at the same time that pole piece d^2 is of positive polarity. In this manner when electro-magnet E is connected by the rotary make-and-break L with the source of alternating current supply J the magnetic field of electro-magnet E is opposed to the magnetic field of electro-magnet D. C is a diagrammatic representation of the conveyer belt carrying the mixture of particles of different degrees of magnetic permeability through the air gap of the magnets when the rotary make-and-break L is in operation.

The operation is as follows:

Assuming that the rotating connecting device L has been started to revolve at a fairly high speed, and at the present instant the current is temporarily disconnected from magnet E. The magnetic lines of force are flowing to complete their proper circuit from magnet D to and through the air gaps and ore, and through magnet E. The ore particles on the belt are now within a rapidly alternating magnetic field and the magnetic particles are compelled to revolve or whirl in proportion to the alternations, to present their respective poles parallel with the magnetic lines of force. They also want to group together in proper magnetic relation with one another and in contact, but are prevented from doing so by the surrounding gangue particles. In their violent agitation they throw the gangue aside and leap to the surface of the ore mass and thence many of them getting into contact with one another leap in a whirling mass toward pole e^2. Before, or after they arrive in contact with pole piece e^2, the rotating connecting device connects magnet E in circuit; the magnetic circuit is distorted and opposed and the magnetic particles are violently thrown back on the top of the progressing gangue material, only to be again attracted and repelled many times before they finally travel through the field between the pole pieces of the magnets. Magnet E is tilted as shown to gradually weaken the attraction so the action will not be so violent as the ore progresses out of the field.

The ore on leaving the alternating zone is spread out on the belt in layers or stratas as shown in Fig. 3 of the drawing, where c represents the non-magnetic gangue layer next to the conveyer belt. c' represents the sluggish middlings or mechanically combined particles on top of the gangue layer, and c^2 represents the high grade magnetic ore particles or concentrate as a top layer. The ore progresses in this condition to the discharge end of the conveyer belt where it comes under the influence of pole g^2 of a powerful direct current magnet G. The top magnetic layer of ore, together with the

lesser magnetic middlings underneath, leap in a sheet or mass to get into contact with pole g^2, the front edge of which is adjusted close to the inner side of the discharge belt F. The outer side of the rapidly moving belt F is interposed between the ore and the poles of the magnet G, the magnet G being adjusted on an angle to weaken the attraction of pole g^3 and to taper off the magnetic strength. The ore particles coming into contact with the rapidly moving belt under pole g^2 are thrown toward pole g^3 and owing to the weakening magnetic strength of the field, the lesser magnetic middlings product drop into receptacle h' and thence fall to conveyer belt h^4. The magnetic concentrate particles are thrown into receptacle h^2 and drop to conveyer belt h^5, while the non-magnetic gangue material falls off the conveyer belt C into receptacle h and drop to conveyer belt h^3.

In Figs. 6 and 7 of the drawing are shown diagrammatic representations of a modified arrangement for obtaining alternate attractive and repulsive magnetic fields. Magnet D is supplied with an alternating current through main circuit wires j, j', and the source of alternating current supply J. Magnet E, however, is continuously supplied with a direct current. A direct current generator is indicated at K having a main circuit wire k' connected with the coil e of electro-magnet E, and a main circuit wire k connected with a rheostat N. The rheostat N in turn is connected by a conducting wire k^2 with the other coil e' of the electro-magnet E. The current in magnet E may be adjusted by rheostat N to obtain equal magnetic strength in both magnets. When current is turned on in both magnets, the polarity of a pole piece e^2 of electro-magnet E (see Fig. 7) is constant because of the fact that electro-magnet E is being supplied with a direct or continuous current. Electro-magnet D, however, is supplied with an alternating current, and the oscillation of the alternating current changes the polarity of pole piece d of electro-magnet D. In this way the respective magnets D, E, are in proper magnetic relation during one half the cycle of alternating current O as shown in Fig. 7 and in improper magnetic relation during the other half of the cycle of the alternating current. According to this arrangement the attractive and repulsive magnetic fields created alternate with great speed, and the magnetic particles will be attracted and repelled in accordance with the frequency of the alternating current passing through electromagnet D.

What is claimed is:—

1. The process of separating a mixture of magnetic and non-magnetic ore particles, which consists in subjecting the mass first to the influence of a magnetic field, the polarity of which is rapidly alternated and secondly, to the influence of magnetic fields of similar polarity located above and below the mass whereby the magnetic particles are alternately set into violent agitation or ebullition and caused to repel each other and settle in a surface layer on the non-magnetic particles.

2. The process of separating a mixture of magnetic and non-magnetic ore particles, which consists in supporting the mass and subjecting it first to the influence of a magnetic field between pole pieces of opposite sign the polarity of which is rapidly alternated and, secondly to the influence of a magnetic field between pole pieces of similar sign, whereby the magnetic particles are alternately agitated in the mass and caused to rise to the surface and are caused to repel and lie inert as a surface layer on the non-magnetic particles.

3. The process of separating a mixture of magnetic and non-magnetic ore particles, which consists in supporting the mass and subjecting it to the influence of a constantly and rapidly alternating magnetic field between oppositely located pole pieces which are periodically of opposite sign and similar sign.

4. A method of separating a mixture of magnetic and non-magnetic particles which consists in bringing the mixture under the influence of a magnetic field of constantly and rapidly alternating polarity, the characteristics of which are such that a magnetic condition is induced in the magnetic particles to impart a spinning motion thereto causing them to free themselves from the non-magnetic particles and intermittently subjecting them to the influence of a repulsive magnetic field adapted to cause the particles to repel one another whereby the magnetic particles are alternately under the influence of alternating and repulsive magnetic fields.

5. A method of separating a mixture of magnetic and non-magnetic particles which consists in bringing the mixture under the influence of a magnetic field of constantly and rapidly alternating polarity, the characteristics of which are such that a magnetic condition is induced in the magnetic particles causing them to revolve and free themselves from the non-magnetic particles, and then, while the magnetic particles are still in the area sensitive to the magnetic forces, subjecting them to the influence of a repulsive magnetic field of constantly and rapidly alternating polarity.

6. A method of separating a mixture of magnetic and non-magnetic particles which consists in bringing the mixture under the influence of a magnetic field of constantly and rapidly alternating polarity, the characteristics of which are such that a mag-

netic condition is induced in the magnetic particles to impart a rotary motion thereto causing them to free themselves from the non-magnetic particles, and, while the magnetic particles are still in the area sensitive to the magnetic forces intermittently subjecting them to the influence of a repulsive magnetic field of constantly and rapidly alternating polarity whereby the magnetic particles are alternately under the influence of alternating and repulsive magnetic fields.

7. A method of separating a mixture of magnetic and non-magnetic particles which consists in bringing the mixture under the influence of a magnetic field induced by the flow of an alternating current, whereby a magnetic condition is induced in the magnetic particles, causing them to free themselves from the non-magnetic particles and then, while the magnetic particles are still in the area sensitive to the magnetic forces subjecting them to the influence of a repulsive magnetic field.

8. A method of separating a mixture of magnetic and non-magnetic particles which consists in bringing the mixture under the influence of a magnetic field induced by the flow of an alternating current, whereby a magnetic condition is induced in the magnetic particles causing them to revolve and free themselves from the non-magnetic particles and, while the magnetic particles are still in the area sensitive to the magnetic forces, intermittently subjecting them to the influence of a repulsive magnetic field whereby the magnetic particles are alternately under the influence of an alternating and a repulsive magnetic field.

9. A method of separating a mixture of particles whose characteristics are different degrees of magnetic permeability, which consists in bringing the mixture under the influence of a magnetic field the polarity of which is rapidly alternated whereby a magnetic condition is induced in the magnetic particles causing them to revolve, then, while the particles are still in the area sensitive to the magnetic forces subjecting them to the influence of a repulsive magnetic field, the polarity of which is rapidly alternated, and, finally, bringing the stratified mixture under the influence of a magnetic field of gradually decreasing intensity, whereby the stratified layers of particles are separated in the order of their magnetic characteristics.

10. A method of separating a mixture of particles whose characteristics are different degrees of magnetic permeability which consists in bringing the mixture under the influence of an intermittent magnetic field whereby a magnetic condition is induced in the magnetic particles, causing them to revolve and free themselves from the non-magnetic particles, then, while the particles are still in the area sensitive to the magnetic forces, intermittently subjecting them to the influence of an intermittent repulsive magnetic field, and, finally, bringing the stratified mixture under the influence of a magnetic field of gradually decreasing intensity whereby the stratified layers of particles are separated in the order of their magnetic characteristics.

11. In an apparatus for separating a mixture of magnetic and non-magnetic particles, the combination of means for creating a magnetic field the polarity of which is constantly and rapidly alternated to cause the magnetic particles of the mixture to revolve and free themselves from the non-magnetic particles, means for advancing the mixture into said magnetic field, and means, operative while the mixture is still in the field, for subjecting the mixture to a repulsive magnetic action.

12. In an apparatus for separating a mixture of magnetic and non-magnetic particles, the combination of means for creating an alternating magnetic field to cause the magnetic particles of the mixture to revolve and free themselves from the non-magnetic particles, means for advancing the mixture into the said alternating magnetic field and means, operative while the mixture is still in the area sensitive to the magnetic forces for intermittently subjecting the mixture to a repulsive magnetic action causing said particles to repel one another, whereby the mixture is alternately under the influence of alternating and repulsive magnetic fields.

13. In an apparatus for separating a mixture of magnetic and non-magnetic particles, the combination of means for creating a magnetic field of constantly and rapidly alternating polarity to cause the magnetic particles of the mixture to revolve and free themselves from the non-magnetic particles, means for advancing the mixture into the field and means, operative while the mixture is still in the area sensitive to the magnetic forces to change the field into a repulsive magnetic field of constantly and rapidly alternating polarity to cause the magnetic particles to repel one another.

14. In an apparatus for separating a mixture of magnetic and non-magnetic particles, the combination of means for creating a magnetic field of constantly and rapidly alternating polarity to cause the magnetic particles of the mixture to revolve and free themselves from the non-magnetic particles, means for advancing the mixture into said magnetic field, and means, operative while the mixture is still in the area sensitive to the magnetic forces for intermittently changing the field into a repulsive magnetic field of constantly and rapidly alternating polarity adapted to cause the magnetic particles to repel one another whereby the mixture is under the influence of a magnetic

field whose characteristics are intermittently changed to cause the magnetic particles to first revolve and then repel one another.

15. In an apparatus for separating a mixture of magnetic and non-magnetic particles, the combination of means for creating alternately attractive repulsive magnetic fields adapted to stratify the material, means for passing the mixture through said fields and means for magnetically separating the material so stratified.

16. In an apparatus for separating a mixture of magnetic and non-magnetic particles, the combination of means for creating alternately attractive and repulsive magnetic fields of constantly changing polarity adapted to stratify the material, means for passing the mixture through said fields and means for magnetically separating the material so stratified.

17. In an apparatus for separating a mixture of magnetic and non-magnetic particles, the combination of means for creating alternately alternating and repulsive magnetic fields of gradually decreasing intensity, and means for passing the mixture through said fields.

18. In an apparatus for separating a mixture of magnetic and non-magnetic particles, the combination of means for creating alternately alternating and repulsive magnetic fields each of constantly changing polarity and of gradually decreasing intensity, and means for passing the mixture through said fields.

19. In an apparatus for separating a mixture of particles whose characteristics are different degrees of magnetic permeability, the combination of means for creating alternately attractive and repulsive magnetic fields, means for advancing the mixture through said fields whereby the stratification of the mixture into layers of particles in accord with their magnetic permeability characteristics is effected, means for creating another magnetic field of gradually decreasing intensity, and means for advancing the stratified mixture into the last named magnetic field whereby the stratified layers of particles are separated in the order of their magnetic characteristics.

20. An apparatus for separating ore mixtures consisting of particles whose characteristics are different degrees of magnetic permeability, comprising a movable support for the ore mixture, an electro-magnet beneath the support, an electro-magnet above the support, with its poles in proper magnetic relation with respect to the first named magnet whereby a magnetic field is created between the poles of both magnets having lines of magnetic force approximately parallel with the poles of the magnets, and means for intermittently energizing said second-named magnet in such manner that its poles are in improper relation to the poles of the first named magnet and opposing magnetic fields are created.

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