(No Model.) 2 Sheets—Sheet 1.

R. R. MOFFATT & S. CHICHESTER.

ELECTRO MAGNETIC SEPARATOR.

No. 462,321. Patented Nov. 3, 1891.

Fig. 1.

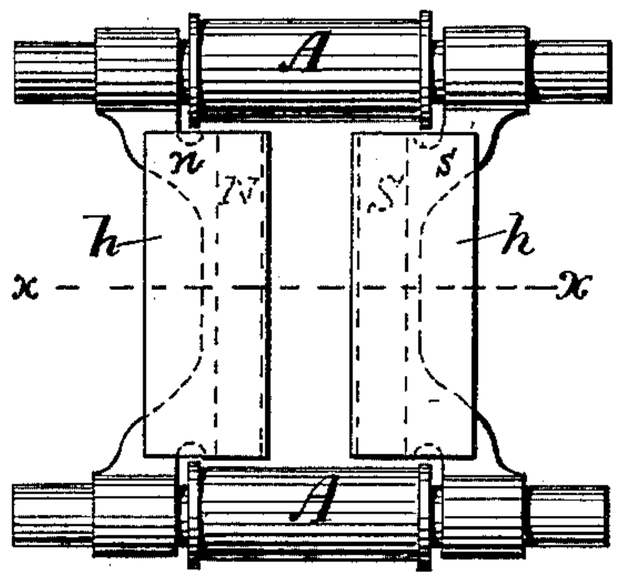

Fig. 2.

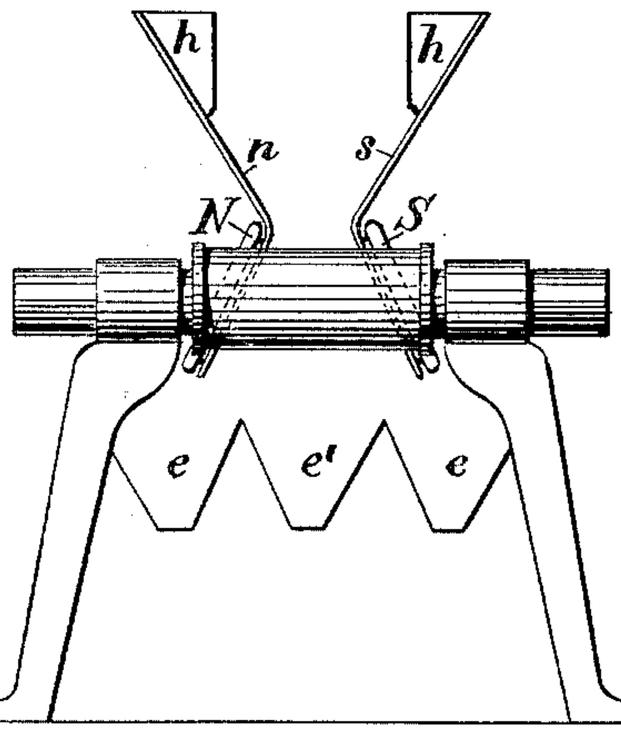

Fig. 3.

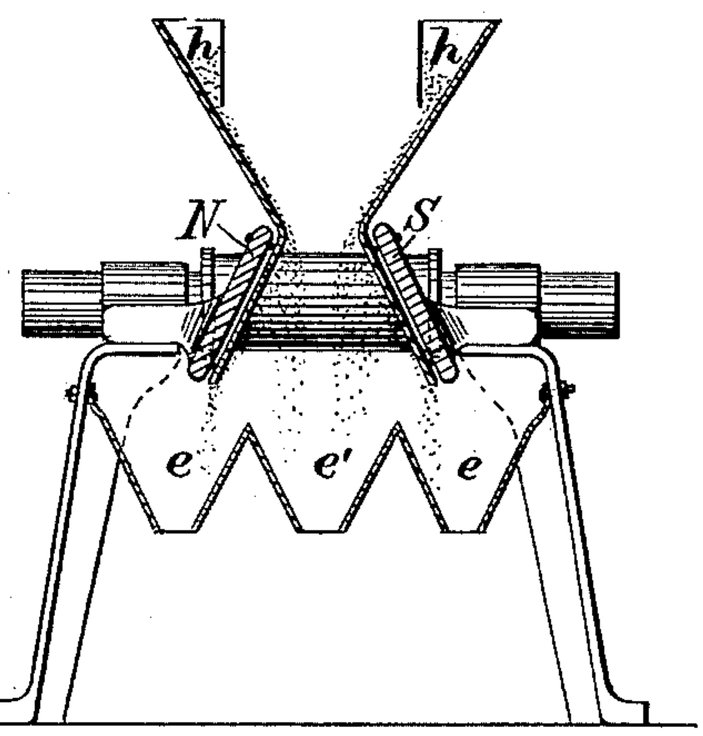

Fig 4

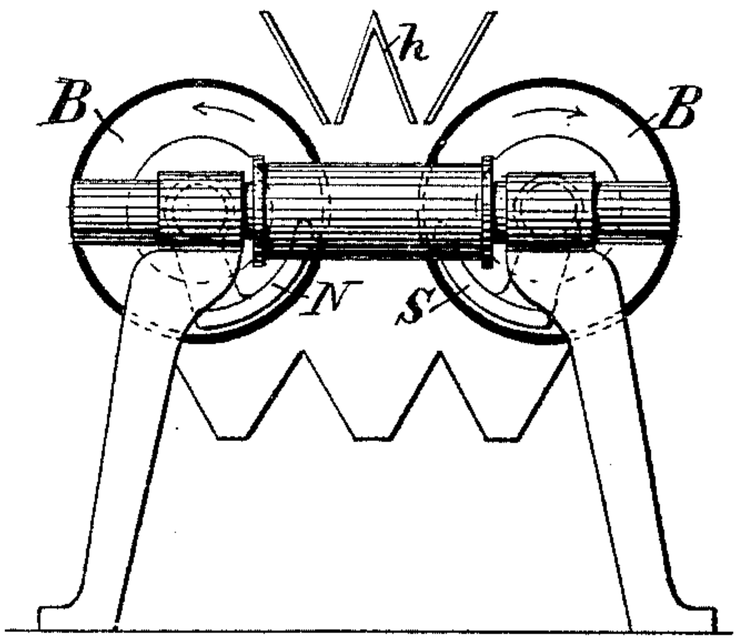

Fig. 5.

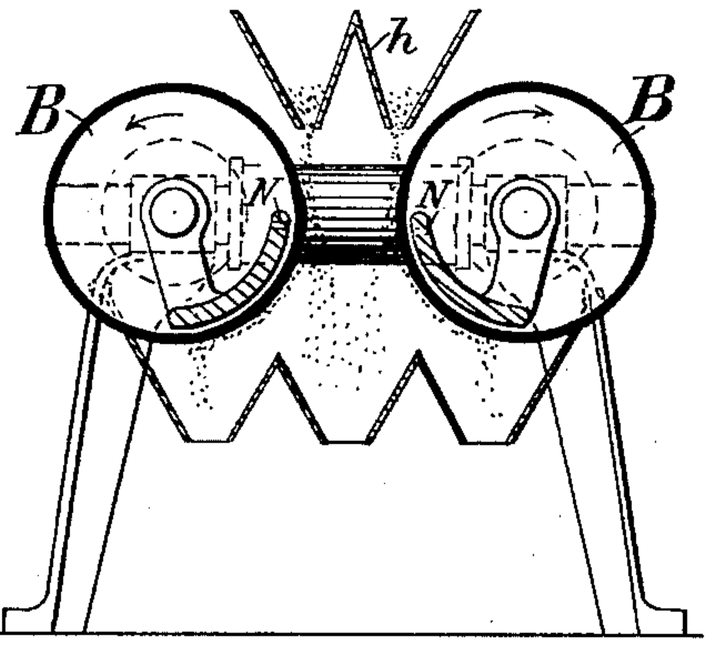

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Fig. 6.

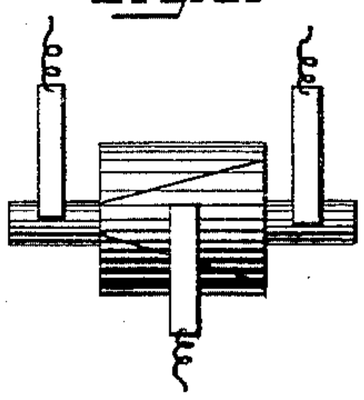


Fig. 7.

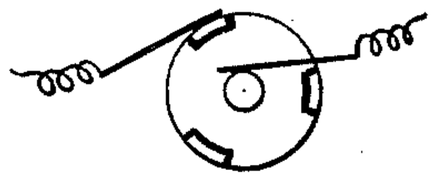


Fig. 8.

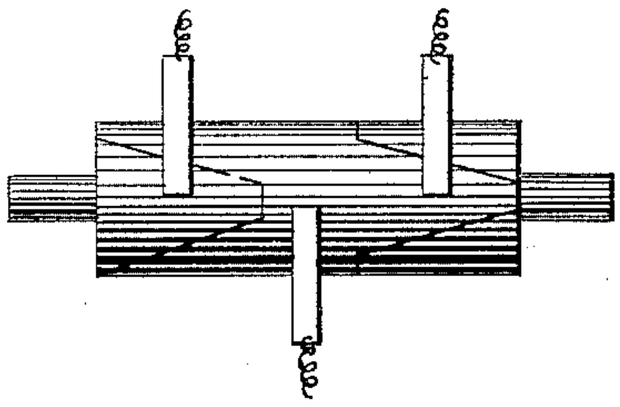


Fig. 9.

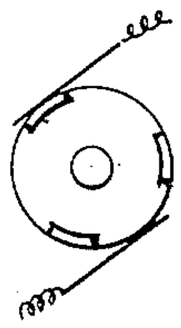


Fig. 10.

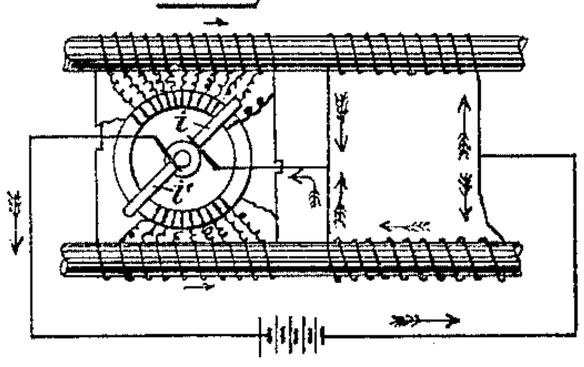


Fig. 11.

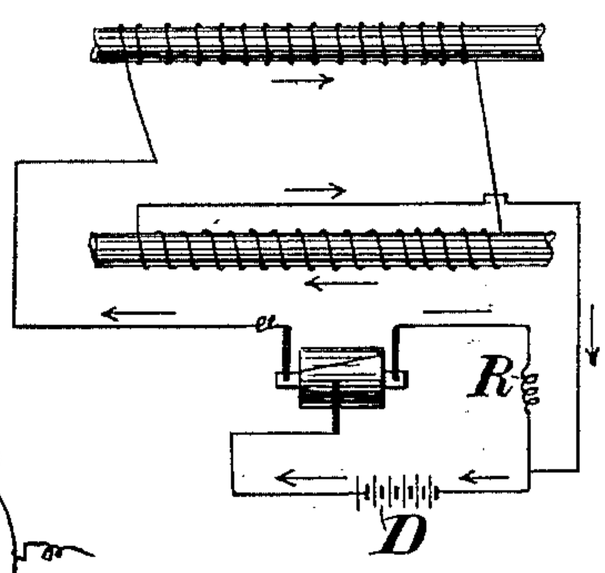
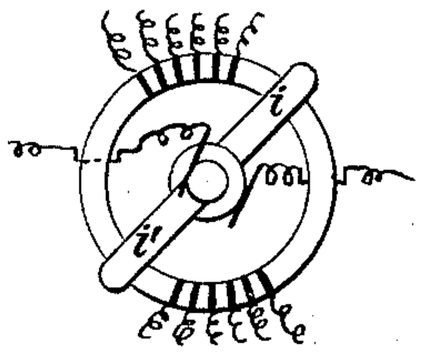


Fig. 12.



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UNITED STATES PATENT OFFICE.

RICHARD R. MOFFATT, OF NEW YORK, AND SYLVESTER CHICHESTER, OF BROOKLYN, NEW YORK.

ELECTRO-MAGNETIC SEPARATOR.

SPECIFICATION forming part of Letters Patent No. 462,321, dated November 3, 1891.

Application filed January 20, 1891. Serial No. 378,407. (No model.)

To all whom it may concern:

Be it known that we, RICHARD R. MOFFATT, a citizen of the United States, residing in the city, county, and State of New York, and SYLVESTER CHICHESTER, a citizen of the United States, residing in the city of Brooklyn, in the county of Kings and State of New York, have invented new and useful Improvements in Electro-Magnetic Separators, of which the following is a specification.

The object of our invention is to separate magnetic from non-magnetic particles that are mingled together in a free state, such as finely-granulated magnetic iron ore associated with non-magnetic matter, as lime phosphates, silicon, &c.

To this end our invention consists in a novel process of agitating the ore, &c., while in a magnetic field of force by causing the magnetic circuit to be successively interrupted, thus producing magnetic pulsations with sufficient duration of time between them to permit the magnetic particles to fall by their gravitation from the poles a desired distance. Then they are drawn back again by the magnetic attraction, which alternating action, being continuous, agitates and separates the free magnetic particles from the non-magnetic particles.

It further consists in the employment of automatic means for producing an intermittent or pulsatory action of the electric current in the magnet-coils for the purpose of causing a similar magnetic action in the field of force.

It also consists in a novel arrangement of the magnetic poles, combined with means for producing intermittent or pulsatory magnetic action in the field of force for the purpose of causing a feed movement of the magnetic particles while in the field, at the same time agitating the same and conveying them to a point where they will pass into a receiver separate from that into which the non-magnetic particles fall.

It further consists in other features hereinafter described, and detailed in the claims.

In the accompanying drawings, which form a part of this specification, our invention is illustrated embodied in apparatus of various designs.

Figure 1 is a plan or top view of one form of apparatus embodying our invention, the hopper being removed. Fig. 2 is an end view of the same, showing hoppers in place. Fig. 3 is a section taken on line X X, Fig. 1. Fig. 4 is an end view of a differently-designed apparatus. Fig. 5 is a sectional view of the same. Figs. 6 and 7 are detail views illustrating a rotary circuit interrupting or changing device. Figs. 8 and 9 illustrate in similar manner a rotating circuit-reversing device. Fig. 10 shows another method for reversing the circuit. Fig. 11 is a diagram showing a preferred manner of exciting the helix-coils of the magnets, and Fig. 12 is a diagram showing another method for a like purpose.

Similar letters of reference in the several figures indicate like or corresponding parts.

In the apparatus illustrated in Figs. 1, 2, and 3, A A designate the helix-coils of the compound electro-magnet, the cores of which are connected with pole-pieces N S, which are provided with inclined pole-faces that extend in a direction, as shown, toward each other, with a space or opening between them, which space may be varied to any desired distance by adjusting the pole-pieces upon the magnet-core extensions, thus forming a strong field of force, in which the maximum number of lines are where the poles are nearest each other and the minimum number are at the points that are farthest apart. Preferably the pole-faces are inclined, as shown in Fig. 3; but they may be curved, as in Fig. 5, or made in other desired forms.

n s are inclined plates, preferably made of thin annealed sheet-iron, which becomes magnetized by induction through the poles. Preferably we insulate these plates from the pole-pieces for the purpose of insuring a more perfect demagnetizing effect. By this means the pole-pieces can be constructed of cast-iron, which retains residual magnetism without producing in the plates *n s* sufficient attractive force to retain magnetic particles against the force of gravitation when the circuit is open. At the upper parts of the upper inclines are located hoppers *h*, from which the material passes to the inclines and is fed into the field of force.

e e are receptacles into which the magnetic

particles pass, while the non-magnetic particles fall by gravitation into the receptacle *e'*.

In Figs. 6 and 7 is shown a rotary circuit-changing device made in two parts, each provided with fingers or projections that interlock. These parts are properly insulated from each other. Preferably we make the interlocking fingers or projections tapering, as shown, by which means the durations of time that the current flows in the helix-coils can be varied as desired, as also the time that the circuit therein is open, by locating the contacts thereon. The circuit-changing device may be connected to any suitable rotating motor.

In Figs. 8 and 9 is shown a rotating current-reversing device made in three interlocking parts, each properly insulated from the others. Preferably we make the interlocking parts or projections tapering, as in the device shown in Figs. 6 and 7, for the same purpose of regulation.

In Figs. 4 and 5 is shown an apparatus in which there is a stationary (compound) electro-magnet, the helix-coils of which are connected in such a manner that a current active thereon will produce consequent poles in the pieces N S which connect the magnet-cores. These pole-pieces are made with cylindrical portions near their junction with the magnet-cores to receive rotating hubs, which carry drums B. These drums are preferably made of sheet-iron and revolve without magnetic contact with the pole-pieces. They become magnetic by induction, being strongest where the lines of force are most condensed between the pole pieces, which are arranged as shown in Fig. 5—*i. e.*, having projecting portions that occupy the lower quarters of the drums nearest each other. Similar means are employed for conveying the material to the field and for receiving the assorted particles as are described in the apparatus shown in Fig. 1, as also the manner of producing an intermittent or pulsatory action in the field of force. The drums are rotated by any suitable means, preferably in the direction indicated by the arrows, in which case the speed should be such as to simply retain the magnetic particles a longer time within the field of force to receive more agitation, but not to prevent the particles from passing through, as will be understood.

If desired, all particles composed of magnetic and non-magnetic matter in a fixed or united state may be collected in a separate receiver located between those into which the wholly magnetic or the non-magnetic particles fall.

For the purpose of producing intermittent or pulsatory action in the magnetic field of force, we employ a novel circuit-changer (shown in Figs. 6 and 7) or a circuit-reversing device. (Shown in Figs. 8 and 9.) These differ from other known apparatus for like purpose in having the interlocking portions or fingers tapering, by which means the durations of time of electric action within the helix-coils of the field-magnets may be varied, as desired, by properly locating or adjusting the circuit-contacts, as will be understood by those skilled in the art.

The field-magnet coils may be connected in multiple arc or in series, as shown in Fig. 10, in which case the circuit-changer shown in Figs. 6 and 7 may be used, together with a resistance R, located in the by-pass circuit, (which should be the same as the resistance of the magnet-coils;) but we prefer to connect the magnet-coils as shown in Fig. 11, each half forming a closed or multiple-arc circuit independent of the other, using the circuit-reversing device shown in Figs. 8 and 9, by which means the current in one half is made to pass in a direction that will cause all the coils to act in unison with those in the other half to produce maximum magnetic effect in the field of force, or, in an opposite direction, to oppose each other by their counter electro-motive force, thus destroying magnetic polarity and attractive power in the field of force. Preferably the helix-coils forming one-half of the field-magnets are arranged in bobbins, each connected to the other in continuous or closed circuits like the coils on the Gramme ring armature, with connections from each bobbin to a series of insulated contacts, which are arranged, preferably, in a circle to form a rotating circuit-reversing device, as shown in Fig. 12. These contacts are arranged to occupy limited portion of the circular space, excepting those contacts which produce maximum and minimum magnetic effect, which are made to occupy a greater space in the circle to produce a proper period of time for the alternating action of gravitation and magnetic attraction upon the magnetic particles for effective agitation in the field. By this means the extra or counter current produced by breaking the current that includes an electro-magnet having many coils is reduced, so that no sparking or but little will occur at the contacts in reversing the current. In this device the contacts are stationary and the contact strips or brushes *i i'* are arranged to rotate. These are insulated from each other, forming terminals, through which the current enters and leaves the helix-coils, in which the current is reversing. In the diagrams, Figs. 11 and 12, the large arrows indicate the continuous circuit, while the small ones indicate the circuit that is interrupted or reversed. The circuit includes an electric source, such as a dynamo D.

The operation of our invention as embodied in the device shown in Figs. 1 and 2 is as follows: The circuit being closed with an electric source—such as a dynamo—and the circuit changing or reversing device properly rotated, the current will flow as indicated by the arrows on the diagrams 11 and 12, passing in an alternating manner through one-half of the magnet-coils, the durations of time between each reversal being determined by

the speed given to the rotating circuit-changer. This produces magnetic pulsation in the field of force. The ore, (or other material to be separated,) in a fine granulated or pulverized condition, is fed into the hoppers in a regulated manner, from the lower part of which it passes onto the upper surface of the magnetic inclines to which the magnetic particles are attracted and are held when the poles are magnetized. When the poles are demagnetized, the particles move down the inclined surface by their gravity, stopping and moving in their course as the magnetic field of force becomes active or non-active. This movement of the particles continues intermittently until they reach the turning-points on the inclines where the lines of force are most numerous, and the attractive force is strongest. Then when the magnets become non-active the particles fall away from their contact with the inverted incline, (by their gravitation,) to be drawn back again before they have reached a distance that is beyond the attractive influence of the magnet. In returning they will move in the same direction as the magnetic lines of force, which direction is at right angles (or nearly so) to that in which they moved when falling from the incline. This action produces a feed movement of the magnetic particles along the surface of the lower inverted incline. This conveys them in a lateral direction out of the field of force to a point where the magnetic attractive force is weak. Then they pass into a receiver separate from that into which the non-magnetic particles fall. This novel movement of the magnetic particles through the field of force produces an effective agitation, with beneficial results in separating the magnetic from the non-magnetic particles. When the feed-openings in the lower part of the hoppers are located near the upper inclines, the material therein cannot pass out therefrom while the magnetic field is active, as the magnetic particles become magnetized and are held thereby together as also to the incline.

The operation of the device shown in Figs. 4 and 5 is the same as that described in Fig. 1 when the drums are not rotated. When the drums are rotated in the direction indicated by the arrows, the magnetic particles are retained a longer time within the influence of the field of force and are subjected to more agitating action. In this case the speed of rotation should be such as not to interfere materially with the ultimate passing of the magnetic particles into their receptacles. When the drums are rotated in the opposite direction to that indicated by the arrows, the feed movement is increased, but the agitating action is reduced.

If desired, an extra separator could be substituted for the resistance R, (shown in Fig. 11,) in which case the contact, on the circuit-changing device should be so located that the magnetic pulsation in each should be the same in duration of time.

Suitable means may be employed for producing air-currents by exhaust, which can be used advantageously in conveying fine non-magnetic dust away from the magnetic particles in their passage through the field of force.

The general elements of our invention can be embodied in apparatus of various design without departing from the principle, and we do not confine our invention to the specific apparatus herein described, as it is evident from the foregoing description that some of our improvements may be applied to and carried out by machines of different type and that some may, if desired, be used independent of the others.

Having thus described our invention and the method of its operation, what we claim as new, and desire to secure by Letters Patent, is—

1. The process of separating magnetic from non-magnetic particles, which consists in agitating the mixed materials in a magnetic field of force by the attractive forces of gravitation and pulsatory magnetism, substantially as specified.

2. The process of separating magnetic from non-magnetic particles, which consists in agitating the mixed materials in a magnetic field of force by the attractive forces of gravitation and pulsatory electro-magnetism, substantially as specified.

3. In an electro-magnetic separator, the combination of the field-magnet coils with an electric switch or circuit-changing device to produce magnetic interruptions or pulsations in the field of force of such periods of duration as to allow the magnetic particles to fall away from the magnetic poles to be again attracted thereto, and thus thoroughly agitated by the attractive forces of gravity and magnetism.

4. In a method of separating magnetic from non-magnetic particles in a pulverized condition, the improvements which consist of feeding the magnetic particles through a magnetic field of force by the action of gravity and the intermittent magnetic impulses, substantially as described.

5. The process of separating magnetic from non-magnetic particles, which consists in subjecting the mixed materials in a magnetic field to intermittent magnetic action recurring at periods of sufficient duration to produce a vibratory movement of such materials, substantially as specified.

6. In an electro-magnetic separator, the field-magnet having half of its coils connected in closed or multiple-arc circuit, combined with means for reversing the current therein to cause their unison of action with the other half of the magnet-coils for producing maximum magnetic effect in the field or to act in opposition to them by counter electro-motive force for producing minimum mag-

netic effect in the field, substantially as and for the purpose specified.

7. In a magnetic separator, the field-magnets having all or a portion of the helix-coils connected in closed or multiple-arc circuit, combined with means for alternately reversing the flow of current in half of the coils to produce intermittent magnetic pulsation in the field of force, substantially as specified.

8. In a magnetic separator, the field-magnet having coils arranged in bobbins or layers connected together in closed or multiple-arc circuit, combined with means for reversing the flow of current therein, which will switch the circuit through the several bobbins or layers successively in reversing the current, substantially as and for the purpose specified.

9. In a magnetic separator, the field-magnet coils wound in bobbins or layers connected in closed or multiple-arc circuit, combined with a switch provision having connections with said bobbins or layers, arranged so that the circuit may be changed therein for varying the magnetic field of force, substantially as specified.

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