(No Model.) 3 Sheets—Sheet 1.

R. H. SANDERS & C. T. THOMPSON.

PROCESS OF AND MACHINE FOR MAGNETIC SEPARATION.

No. 573,485. Patented Dec. 22, 1896.

FIG. 1.

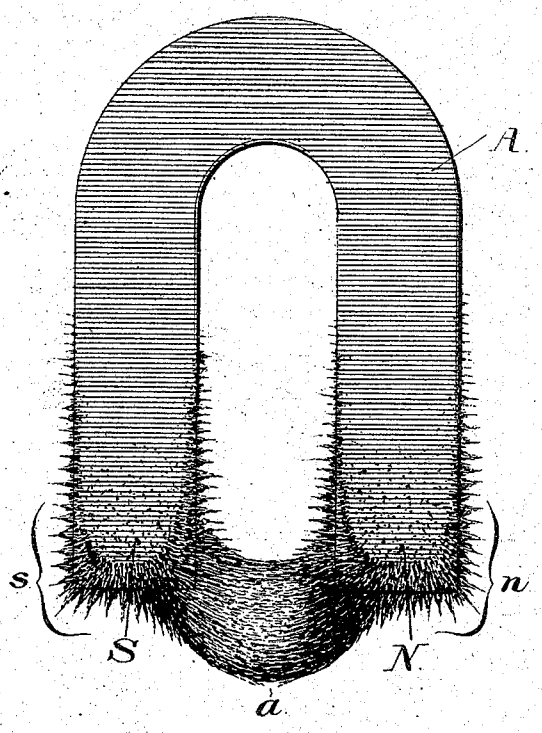
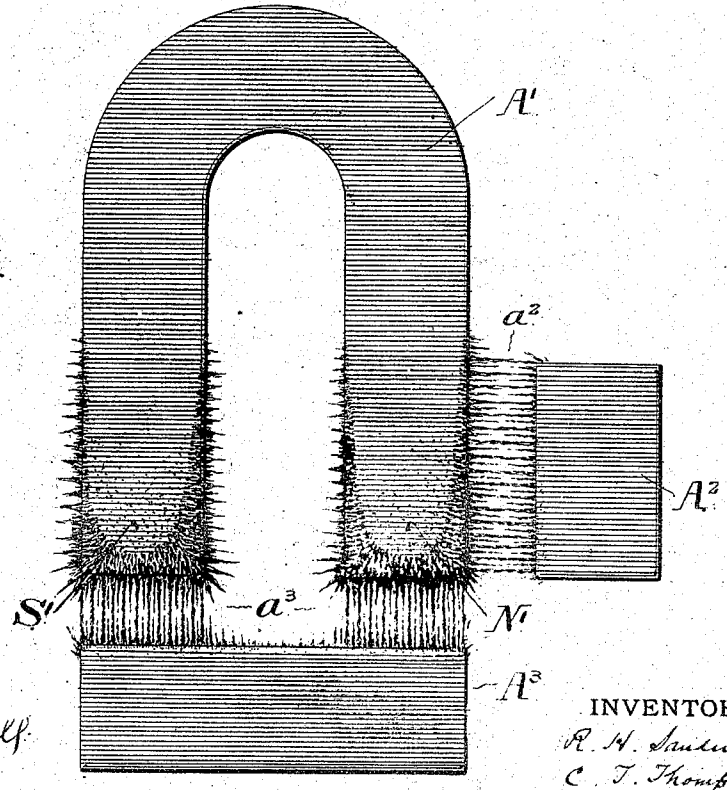


FIG. 2.



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(No Model.) 3 Sheets—Sheet 2

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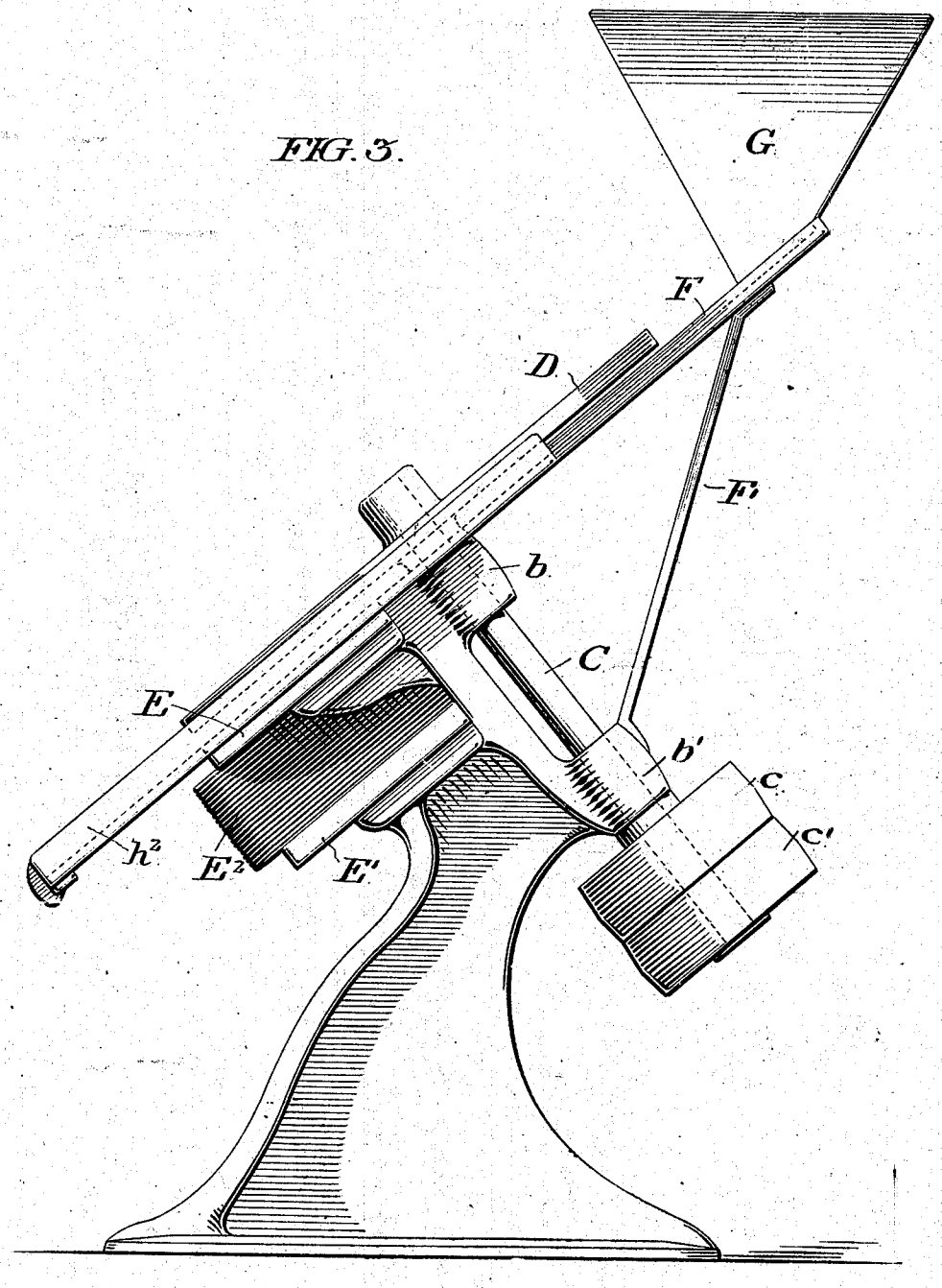
FIG. 3.



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(No Model.) 3 Sheets—Sheet 3.

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PROCESS OF AND MACHINE FOR MAGNETIC SEPARATION.

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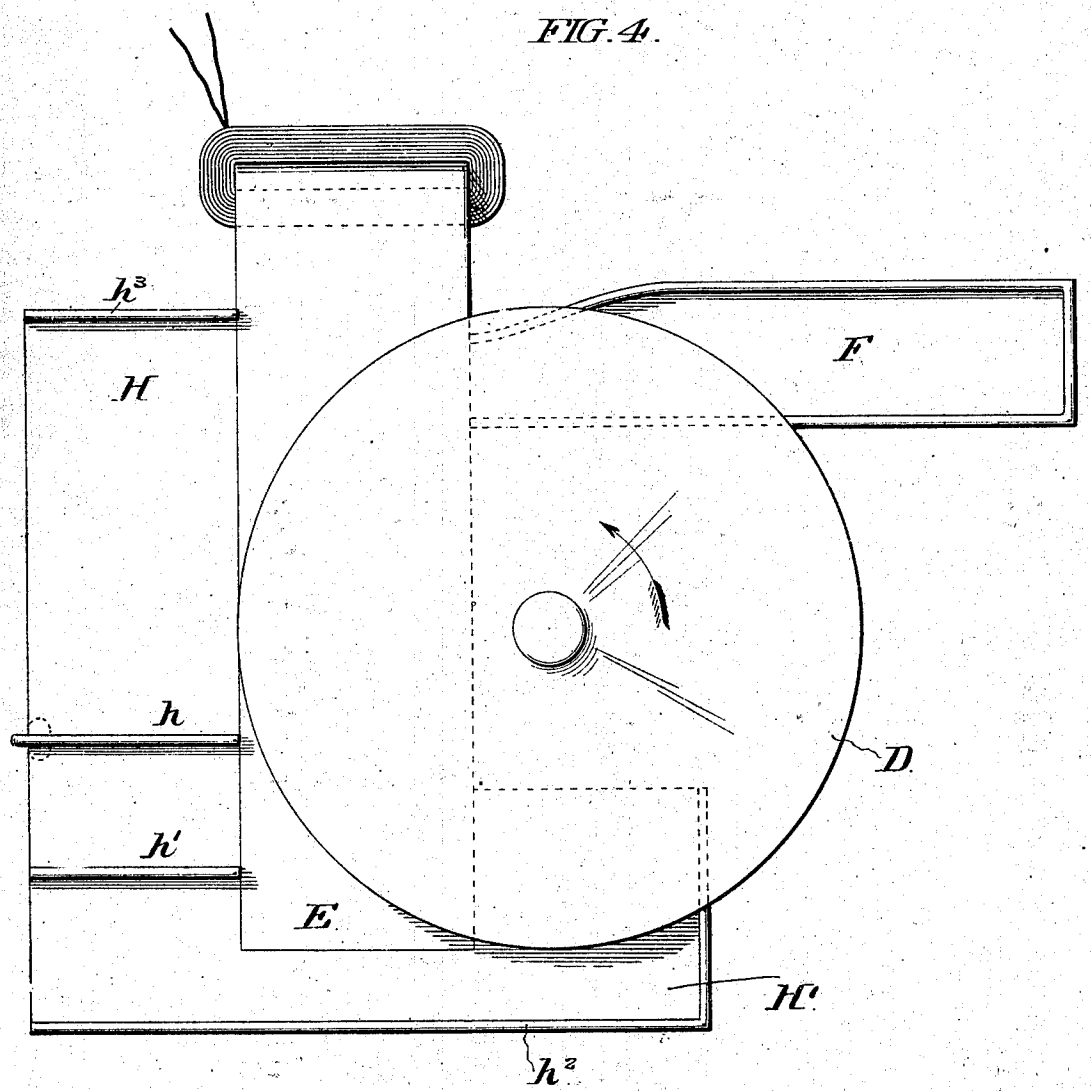
FIG. 4.



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UNITED STATES PATENT OFFICE.

RICHARD H. SANDERS AND CHARLES T. THOMPSON, OF PHILADELPHIA, PENNSYLVANIA.

PROCESS OF AND MACHINE FOR MAGNETIC SEPARATION.

SPECIFICATION forming part of Letters Patent No. 573,485, dated December 22, 1896.

Application filed August 10, 1892. Serial No. 442,709. (No model.)

To all whom it may concern:

Be it known that we, RICHARD H. SANDERS and CHARLES T. THOMPSON, of Philadelphia, Pennsylvania, have invented a certain new and useful Process of and Machine for Magnetic Separation, whereof the following is a specification.

Although our process is of course adapted to separate and remove particles of paramagnetic material generally from a mixed mass, we shall, to avoid prolixity of description, use the term "ore" as typical of said particles, the term "gangue" as typical of the non-paramagnetic material, and the term "stock" as indicating the admixture of the two which is to be subjected to treatment.

Our invention is based upon the discovery that when an armature of proper efficiency is placed in proximity to a magnetic pole in such manner as to leave a limited space or gap between, which gap is not the direct path of the maximum flow of lines of force under normal conditions, the magnetic field formed across said gap possesses a character peculiarly adapted for the separation of ore from gangue and for the removal of the separated ore to an isolated point of discharge.

Before proceeding to describe our invention in detail we will, to facilitate the explanation thereof, compare the behavior of paramagnetic particles in an ordinary magnetic field (or one whose lines of force flow without abnormal diversion through the air-space between the two poles of a magnet) with the behavior of such particles in a field whose lines of force are shunted and without undue condensation are definitely directed through an air-space or other gap by means of an efficient armature placed at a short distance from the poles of a magnet.

By the term "efficient" we mean that the armature (which, of course, is composed of material having a high conducting power for lines of magnetic force) shall have a sufficient mass to concentrate upon and conduct through itself a large percentage of the lines of force which pass near it; otherwise the lines which it fails to conduct will find a path through the air independent of the armature and will not be diverted in such manner as to produce the best results.

Figures 1 and 2 of the accompanying drawings illustrate diagrammatically the characteristics of the two kinds of fields referred to with sufficient clearness for the purposes of such comparison.

Referring to Fig. 1, A represents an ordinary horseshoe-magnet having poles N S, respectively, between and around which a magnetic field extends. If iron filings or other paramagnetic material in particles be introduced into said field, so as to be arrested therein against the action of gravity, the particles will cling to the poles and bridge the interspace substantially in the manner indicated in said figure. In the gap directly between the poles the particles will be densely crowded together, as indicated at *a*, around a line of maximum magnetic density, or greatest number of lines of force per unit of area of cross-section. At other points in the region of smaller magnetic density they will cling to the surface of the magnet in substantially pyramidal heaps, as indicated at *n s*, respectively. Although this arrangement of the particles has a quasi-structural character, in that the particles are polarized and cling to one another in masses of little chains, yet their close aggregation or agglomeration affords conditions highly unfavorable for the separation of ore from gangue, since, when a mixed stock is fed into said field, a large amount of the gangue will be mechanically entangled and detained within the mass of closely-interlocked particles of ore.

Referring now to Fig. 2, the behavior of paramagnetic particles in a field which has been shunted and definitely directed by an armature will be described. In said figure, A′ represents a horseshoe-magnet having poles N′ S′, respectively. Parallel to one leg of the magnet is an armature A^2, and parallel to the under surface of the poles is another armature A^3, the intervening gap in each instance being such as to be readily traversed by the lines of force from the proximate surface of the magnet. If now paramagnetic particles be introduced into the fields between the magnet and the armatures, it will be noted that said particles build themselves up naturally into diffused striæ suspended or resting not only upon the surface of the mag-

net, but upon the surface of the armatures as well, many of the opposing striæ meeting and bridging across the gap in complete chains, substantially as indicated at a^2 a^3, respectively.

As compared with the arrangement of particles in an ordinary field, and still more as compared with the arrangement of particles in a field whose lines of force are condensed to a greater degree than is found in the region of greatest intensity in a normal field, these striæ of polarized particles are highly attenuated and are, moreover, diffusedly arranged in substantial parallelism. The conditions thus obtained are in the highest degree favorable for the separation of ore from the gangue, since if a mixed stock be fed into the fields the particles of ore are at once suspended in the attenuated striæ just described, while the gangue is permitted to readily drop out through the substantially-regular interstices between them, so that a minimum amount of gangue is mechanically detained in the interior of the striæ.

As thus far described, the peculiar value of the shunted field as compared with a normal one has only been pointed out with reference to part of the work essential in magnetic separation.

In a practical process it is not only necessary to separate the ore from the gangue and permit the latter to escape, but it is also necessary to remove the ore from the region where separation has taken place to a region of discharge isolated from the path of outgoing gangue.

Our discovery of the properties of a shunted field embraces also certain features which are peculiarly available for effecting the removal and discharge of the separated ore.

If after the striation of the particles in the gap between the pole and the armature the latter be moved away from the pole, (or vice versa,) a very large percentage of the striated material will cling in pendulous lines to the armature and be carried bodily away from the magnet, not falling at the instant of removal, but remaining for an appreciable time sufficient to carry it to a point relatively distant.

We will now proceed to describe means whereby the properties of such a field, with respect to the separation and removal of ore, can be made available in a practically-working process.

In Figs. 3 and 4 we have shown a type of apparatus adapted for the conduct of such process, Fig. 3 being a side elevation of said apparatus and Fig. 4 a top or plan view thereof.

B represents the base or standard, provided with bearings b b' for a shaft C, rotatably mounted therein at an angle of about forty-five degrees to the horizon. Said shaft has at its lower end fast and loose pulleys c c', respectively, and carries at its upper end a rigidly-attached disk D, preferably of soft iron.

E E' represent the two legs of a horseshoe-magnet, energized by means of a coil E^2 upon the transverse portion which connects them and which in Fig. 3 is supposed to be situated at the rear or side farthest from the observer.

The magnet is supported upon the base-plate B in such relation to the disk that the outer surface of the uppermost leg E is substantially parallel to the plane of the disk and at a short distance therefrom, the outside edge of the leg being in a plane substantially tangential to the periphery of the disk. That portion of the disk which at any given time is directly opposite to the surface of the leg E constitutes the armature, and to have the highest efficiency for the purposes of our invention the disk should be of such thickness that said portion shall be capable of conducting within itself substantially all the lines of force which it intersects. Should the metal of the disk be too thin, some of the lines of force will fail to be intercepted thereby and will find paths through the air or through other portions of the disk not at the time in immediate proximity to the magnet-leg, thus to a degree interfering with efficient action. As the disk is rotated successive portions thereof become temporarily the armature during their passage by the region of immediate proximity to the magnet-leg, thus obtaining an effect equivalent to that which would be produced by an absolutely-continuous series of individual armatures successively moved through the field, but without the variation in direction and intensity of the shunted field which would occur if there were intervals between the armatures.

The feed-chute F is supported at an inclination upon an arm F' and leads at one side of the apparatus into the gap between the disk and the upper surface of the leg E, the plane of said chute being preferably coincident with the plane of the upper surface of said leg. A hopper G is arranged above the upper end of said feed-chute to supply stock thereto.

The delivery-chutes are conveniently formed by dividing the surface of an inclined diaphragm or plate H, which extends down from the lower edge of the leg E, also projecting beyond thereof and extending upward, as indicated at H', on that side of the figure which is nearest the observer in Fig. 3 and which is at the bottom in Fig. 4. Partitions h h', one or both of which may be adjustable, divide the surface of the diaphragm into distinct chutes, and a raised side or rim h^2 extends along the extreme edge of the upwardly-projecting portion H' of said diaphragm. In the instance shown three distinct chutes are thus formed, the first of which is subjacent to the region where the stock is fed into the apparatus, extending, however, somewhat beyond said region, and constitutes the discharge for the gangue. The second chute comprises that portion of

the surface of the diaphragm H which is between the partitions $h\,h'$, while the third chute comprises that portion of said surface which is between the partition h' and the outside rim h^2.

The conduct of the process by means of the apparatus just described is as follows: The magnet is energized by a current from any suitable source, and the shaft C is rotated in the direction of the arrow, Fig. 4, at a speed which is of course to be regulated in accordance with the feed and character of stock and the intensity of the magnet. The stock is introduced into the hopper G, and is fed at a proper rate upon the feed-chute F, down which it is carried by gravity and discharged upon the surface of the magnet-leg. As soon as it reaches the shunted field intermediate between the leg E and the disk D the particles of ore are detained and commence to build themselves up in the striated structure above described, the gangue falling between the striæ or at temporary breaks therein and passing out into the chute provided for it. The greater number of the striæ, under favorable conditions, will extend in continuity across from surface to surface, being supported at one end upon the magnet-leg and at the other end upon the proximate surface of the disk, but even when not thus continuous they are greatly attenuated and the opposite ends approach closely. As the disk rotates it carries the striæ with it, agitating or moving them, and in some instances bending them like the bristles of a brush moving in contact with a surface. During this period of their detention and movement along the surface of the magnet-leg any particles of gangue which have theretofore failed to escape are disengaged and fall into the chute between the partitions $h\,h'$, together with any small percentage of the ore which may be accidentally knocked off before reaching the point of final discharge. In some cases this intermediate chute will not be found necessary, but we mention it as a convenient arrangement, since the tailings collected thereby may be of sufficient value to be subjected to a repetition of the process. Nearly all the separated ore is, however, carried in suspension entirely through the shunted field, and when that portion of the armature to which the striæ cling emerges from said field their continuity with the particles clinging to the magnet is broken. A very large percentage of the particles, however, continue to cling to the surface of the disk until after it has completely emerged from said field, not being dislodged or dropping off until they are so far from the region of force that when they fall they do not return thereto, but are received into the ore-chute, which is between the partition h' and rim h^2, whence they are discharged by gravity into any suitable receptacle. The feed being continuous, new portions of ore particles are constantly being carried in to take the place of those which are discharged, said new portions in many instances building themselves up upon the ends of those striæ which have been left within the field clinging to the surface of the magnet-leg after disruption from the striæ carried away by the armature. Thus the process is a continuous one.

Having thus described our invention, we wish, in order to avoid confusion, to point out certain distinctions which exist between our process and the processes carried on by apparatus heretofore constructed.

Where, as in some cases, the stock has been directly fed into the ordinary or normal field between two poles, (either of the same magnetic circuit or opposing poles of different circuits,) the process lacks the advantages of our invention by reason of the fact that such intermediate field is not shunted so as to dispose its lines of force in the proper manner to form attenuated and regularly-arranged striæ of polarized particles, and of the further fact that the conditions interfere with the removal of the ore. Thus in the apparatus of Letters Patent No. 264,620 and others of its type the ore particles are suspended in a closely-condensed mass directly across the path of the outgoing gangue, and when the outside layers of suspended ore are broken they break along a line which is over the gangue-chute, thus facilitating the accidental discharge of ore particles along with the gangue. In our process, on the contrary, there is no tendency to condense the striæ across the path of the outgoing gangue. The movement of the striæ in leaving said path is transverse thereto instead of in a line therewith, and the striæ are not separated from one of their supports until they have passed to a comparatively remote point. These distinctions are even more marked when the comparison is made between our invention and the mode of operation of devices which tend to condense or compact the lines of force to a degree beyond the normal maximum intensity of condensation by means of an armature placed directly in the path of maximum flow. Again; in apparatus which separates the ore in a diffused or expanded ordinary field between two stationary poles moving plates and scrapers or equivalent devices are employed to carry the separated ore to a point of discharge.

Our discovery that the armature not only has the power to shunt and definitely direct the field, but also to carry away therefrom the striated material still in suspension, enables us to accomplish the removal of the ore upon an entirely different principle, simpler and much more effective than where such intermediate carrying and dislodging devices are employed.

A still more obvious difference exists between our process and the method of separation indicated in Letters Patent No. 400,317 and others of its class, wherein the ore is not detained within the field, but is merely de-

flected from its normal trajectory as it falls through a magnetic field. No striation and suspension of ore particles of course could occur under such conditions.

In the foregoing specification we have pointed out an elementary though typical form of apparatus as adapted to the conduct of our process, but we wish it to be understood that we do not restrict our claim to the exact conditions found in the use of the apparatus specified. Thus instead of relying upon gravity to effect the introduction of stock and removal of the gangue and ore other means used in this class of machines may be substituted, such as, for instance, currents of air or water, &c. The form of the magnet and of the armature may also be varied and the surfaces of both or either may be covered or protected without departing from the spirit of our invention, all these being details which are not essential to the underlying principles upon which our process depends. Furthermore, in using the term "armature" to designate the element of the apparatus which shunts the field and removes the ore therefrom after separation we do not necessarily restrict ourselves to an armature which is *per se* absolutely devoid of polarity. Although we prefer that the magnetism of said armature should be only due to induction from the magnet whose field it is intended to shunt, such condition is not essential to the operation.

To the extent that the armature possesses individual polarity its efficiency is impaired until a point may be reached where it practically ceases to act as an armature and becomes a second magnet, whereupon the operation will present the objections heretofore pointed out.

In our claim, hereinafter made, we use the term "diffusedly" to characterize the shunting of the field utilized by our invention and to distinguish such field from those wherein the lines of force are unduly condensed about an axis of maximum intensity, whether such undue condensation be merely the normal one of said field or whether it be enhanced by so placing an armature as to cause the convergence of more than the normal number of lines toward and about the axis of maximum density. It must of course be understood that we do not by the use of such word imply that the lines of force in our shunted field are dispersed. On the contrary, it will be seen by reference to the foregoing description of our process that they are definitely directed into substantial parallelism and that no "dispersion," properly so called, takes place.

We claim—

1. The hereinbefore-described process of magnetic separation, which consists in feeding stock into a diffusedly-shunted field between a magnet and a moving armature of substantially continuous mass; conducting the ore through said field suspended in striæ supported at the end farthest from the magnet, and thereby delaying the passage of the ore through the field; permitting the gangue to escape during the period of delayed conveyance; removing the ore from the field still supported as aforesaid, and finally discharging it, substantially as set forth.

2. In a magnetic separator, the combination of a stationary magnet; a movable conductor of lines of force, arranged in the described relation to the magnet to produce a diffusedly-shunted field of substantially unvarying intensity and direction, and thereby adapted to convey ore through said field while delaying the passage of such ore through the same; means substantially as set forth for presenting in continuity successive portions of the mass of said conductor to said field; a feeding device arranged in the described relation to said field; a delivery-chute for gangue arranged in relation to said field substantially as set forth; and a delivery-chute for ore leading from a point beyond the limit of said field; whereby the stock is definitely delayed but conveyed through said field, the escape of the gangue is permitted during the period of delayed conveyance, and the ore is removed from the field, substantially as set forth.

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