No. 832,829.

PATENTED OCT. 9, 1906.

H. H. WAIT.

MAGNETIC SEPARATOR.

APPLICATION FILED APR. 24, 1905.

2 SHEETS—SHEET 1.

Fig. 1.

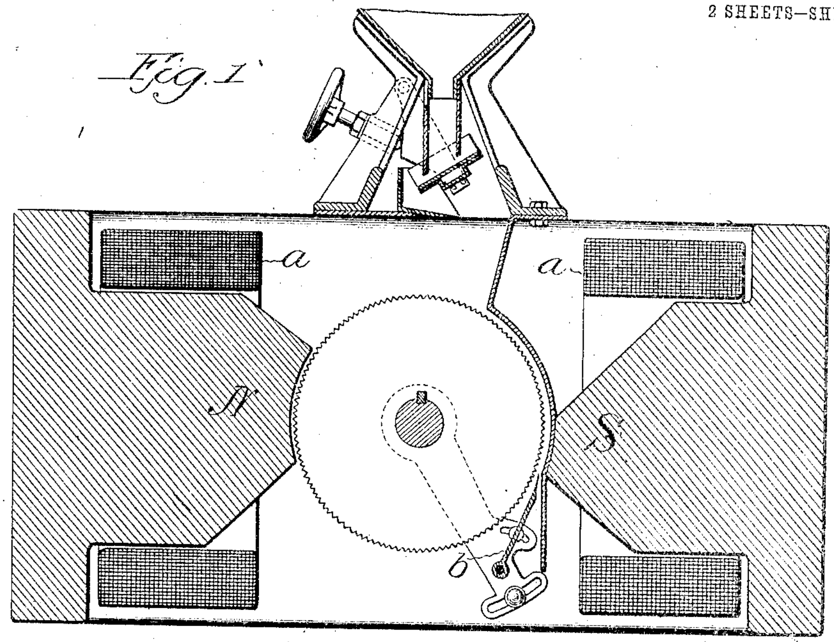


Fig 2.

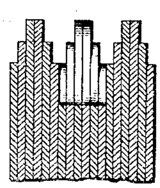


Fig 3.

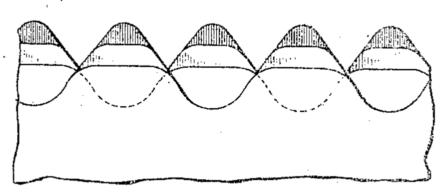


Fig. 4.

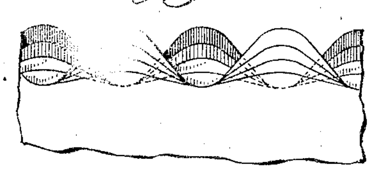
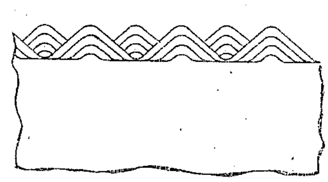


Fig 5.



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2 SHEETS—SHEET 2.

Fig. 6

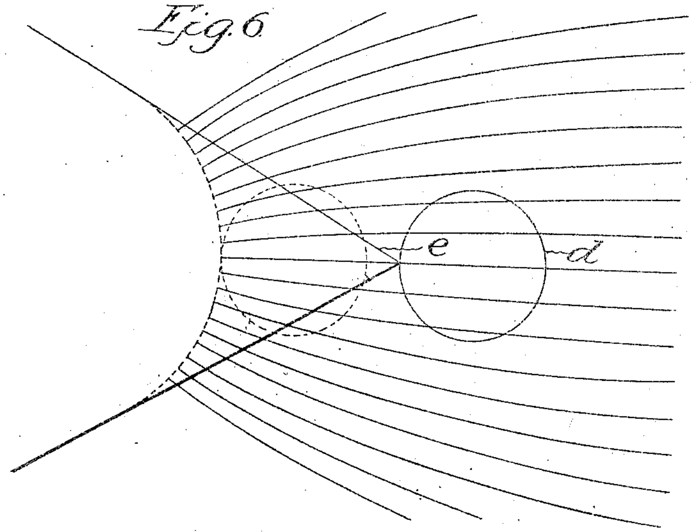


Fig. 7

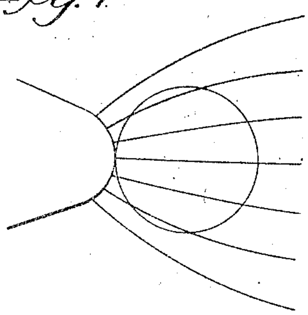


Fig. 8

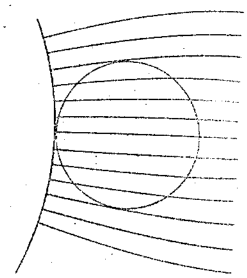
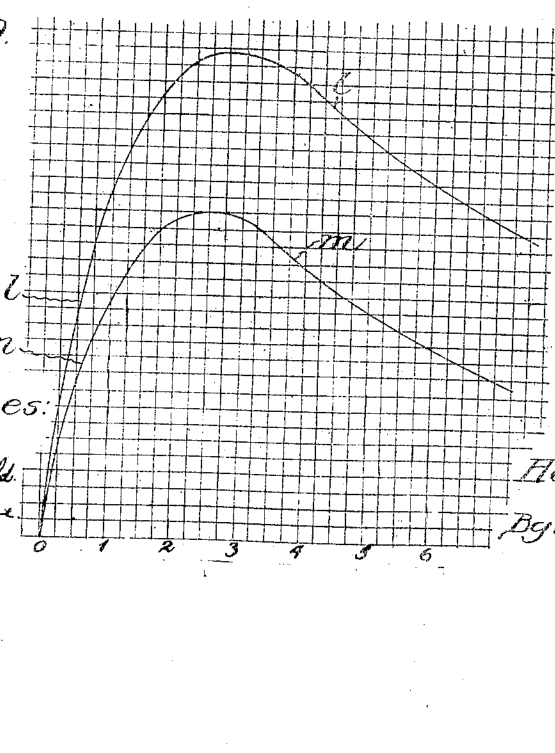


Fig. 9.



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UNITED STATES PATENT OFFICE.

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MAGNETIC SEPARATOR.

No. 832,829. Specification of Letters Patent. Patented Oct. 9, 1906.

Application filed April 24, 1905. Serial No. 257,047.

To all whom it may concern:

Be it known that I, HENRY H. WAIT, a citizen of the United States, residing at Chicago, in the county of Cook and State of Illinois, have invented a certain new and useful Improvement in Magnetic Separators, of which the following is a full, clear, concise, and exact description.

My invention relates to a magnetic separator; and its object is to improve the design of the magnetic parts so as to secure the most effective separation of materials of very low permeability with a minimum expenditure of energy.

More particularly, my invention contemplates an improved form and disposition of the magnet pole-pieces and improved forms and proportions of the armature-teeth, such as to secure the most effective magnetic attraction of the ore particles of any given size. In other words, one feature of the invention looks toward the determination of definite relations between the size of the particles to be attracted and the size and shape of the magnetic teeth to secure the best results.

I will describe my invention by reference to the accompanying drawings, in which—

Figure 1 is a sectional elevation of an ore-separator embodying said invention. Fig. 2 is a detail cross-section of the portion of the armature-surface, showing the manner in which it is built up. Fig. 3 is a detail view of a portion of the armature looking at the sides of the teeth. Figs. 4 and 5 are side views of teeth of other forms. Fig. 6 is a diagram illustrating the influence which the shape of a magnetic projection or tooth has upon the attractive force exerted upon an ore particle in contact therewith. Figs. 7 and 8 are diagrams illustrating the influence which the shape and size of the end of the tooth has upon an ore particle of given size, Fig. 7 indicating the tooth too sharp for the ore particle and Fig. 8 the tooth too blunt for the ore particle of the relative size indicated. Fig. 9 is a diagram of curves indicating the varying force of magnetic attraction produced upon an ore particle of given size by teeth, the ends of which have different radii of curvature.

The same letters of reference are used to designate the same parts wherever they are shown.

In Fig. 1 I have illustrated an ore-separating machine of the general type in which a cylindrical armature having teeth upon its periphery is arranged to rotate upon a horizontal axis between two magnet-poles of opposite polarity facing opposite sides of said armature. The machine is provided with the usual feeding mechanism for passing material to be separated onto the upper surface of the cylinder, which in its rotation carries the material through the air-gap between said cylinder and one of the magnet-poles S. The machine is provided with magnetizing-coils *a a*, through which a current is passed sufficient to set up an intense magnetic flux passing from one magnet-pole to the other through the cylinder. The air-gap between the cylinder and the magnet-pole S is the working air-gap, through which the ore to be separated is passed, while the magnet-pole N on the opposite side of the cylinder serves to establish a balancing magnetic pull upon the cylinder. The working air-gap may be of very high density—that is to say, the face of the magnet-pole S is of small area, while the face of the magnet-pole N may be of considerably greater area—and the field in the air-gap of low density. The air-gap between the pole-piece N and the armature may be of less length than the working air-gap in order to economize magnetizing force. This area is also greater than that of the working pole for the same reason. This area cannot be indefinitely increased, however; but the areas of the two opposing pole-pieces should be so adjusted with reference to the air-gaps that the pull of the pole N plus the working strain on the shaft will approximately balance the pull of the working pole S.

Referring to Fig. 1, it will be seen that the mixture of material passing between the surface of the cylinder and the magnet-pole S will be subjected to an intense magnetizing force tending to pull over the more permeable particles toward the surface of the cylinder. The cylinder is provided with teeth or permeable projections upon its periphery for the purpose of securing convergences of the lines of force toward the cylinder, so that the force of attraction, which is generally along converging lines of force, will be toward the cylinder rather than toward the stationary pole-piece. The non-magnetic material, being unaffected, will fall straight down over the edge of the cylinder, while the magnetic material will tend to follow the cylinder in its rotation through a short arc below the horizontal plane through the axis. In the case of ores of very low magnetic permeability the magnetic field, however strong, will only be sufficient to hold the attracted material to the armature through a very short arc below the horizontal plane, because as the material is carried around in the path determined by the rotation of the armature the force of attraction will act against a constantly-increasing component of gravity and in a rapidly-decreasing magnetic field. A divider-plate *b* is therefore placed in position so that its edge will be close to the under side of the cylinder and preferably just inside a vertical tangent to the cylinder. The divider, in other words, is so placed that the magnetic material will be carried beyond its edge, while the non-magnetic material will fall outside.

While the separating-cylinder is of considerable diameter, as shown, the magnetic flux through the same, which is useful for separation, must for the foregoing reasons be concentrated as much as possible along a short arc just below the horizontal plane through the axis of the cylinder; but the frame of the machine constituting the magnetic circuit should be of large cross-section in order to present the minimum reluctance to the magnetic flux, and so to require the minimum expenditure of energy for magnetization. For the foregoing reasons I therefore cut away the pole-piece S sharply just above the horizontal line through the axis of the cylinder and just below the edge of the divider-plate, leaving the polar face of restricted area facing the comparatively short arc, where separation takes place. In this way the magnetic flux is concentrated at the point where it is particularly desired for separating purposes, and the useless field is reduced to a minimum. Usually very high magnetic densities are found desirable, so that the pole-piece cannot be cut away at right angles to the surface, but must be inclined somewhat as shown in the drawings.

Coming now to the features of invention which are concerned with the size, shape, and proportions of the magnetic teeth by which the most effective attraction is secured, reference will be had to the diagrams Figs. 6, 7, and 8. The attractive force exerted upon an ore particle of slight susceptibility is dependent upon three factors: its magnetic susceptibility, the total magnetic flux through the particle, and the angles of convergence of the lines of force threading through the particle—*i. e.*, the rate of change in density of the field occupied by the particle. Fig. 6 illustrates a spherical ore particle *d* in position to be attracted by a sharp-pointed magnetic tooth *e*, and also shows in dotted lines the manner in which the tooth should be blunted in order to secure the maximum attraction of the particle. The reasons why the blunted form of tooth gives the best results may be briefly given as follows: In magnetic separators of the type under consideration the density of the magnetic flux through the teeth at the working gap is very high, the teeth being practically saturated. For such very strong fields the line of maximum attracting strength of the field lies not at the extreme point of the tooth, but some distance back, and the point of the tooth under such conditions may be rounded off to a certain extent without changing the distribution of the magnetic flux to any great extent. Now it is evident that with the sharp-pointed tooth the extreme end merely acts as a strut to hold off the attracted particle. If this point be cut away, the particle is thus permitted to move up to where the field is denser than it is at the point. In general, the outline of the end of the tooth should conform approximately in shape to the imaginary equipotential surface lying back of the real surface of the tooth. It will be evident from the foregoing, however, that the size and shape of the tooth should be proportioned to the size of the ore particle to be attracted, and that in general for small particles the tooth should be sharper than for large particles. In Fig. 7 an ore particle is indicated in position to be attracted by a comparatively sharp tooth. By reference to this diagram it will be seen that the lines of force threading the particle diverge widely, which in itself is desirable, but which in this case is accompanied by a decrease in the total flux through the particle, so that the maximum attractive force is not obtained. The opposite condition is indicated in Fig. 8, which illustrates an ore particle of the same size as that of Figs. 6 and 7 in contact with a very large blunt tooth. In this case the total flux through the particle is great; but the convergence of the lines of force is so slight that the actual attractive force tending to pull the particle toward the tooth is comparatively slight. It is evident that between the small sharp tooth indicated in Fig. 7 and the very large blunt tooth indicated by Fig. 8 there may be determined the size and shape of tooth which when magnetically saturated will exert the maximum attractive force upon the ore particle of given size.

In Fig. 9 are shown two curves which indicate the attractive forces exerted upon a particle of unit size by conical magnetic teeth having rounded blunt ends of varying curvatures. In this diagram the vertical distance indicates the relative strength of the attractive forces exerted upon the particle, while the horizontal distances from left to right indicate the radii of curvature of the magnet-pole tips in units of the radius of the particle which is attracted. The flux density at the surface of the pole-tip is the same throughout. The curve *l* indicates the re sults with hematite ore, which is of low magnetic susceptibility, and the curve *m* indicates the results with magnetite, a highly-magnetic ore. These curves represent the result of actual tests. It will be seen that in each case the maximum attractive effect is produced when the radius of curvature of the magnet-pole tip is approximately two and one-half times the radius of the ore particle. The same rule can be worked out mathematically. By applying this rule it will be evident that the constructor can at once determine the best size and shape of teeth to be used to secure the best results with any given size of ore particle, or, conversely, with a machine having magnetic teeth of given shape the size to which the ore particles should be reduced to secure the best results can be easily determined.

It will be understood that while the ideal conditions are obtained with a conical tooth having a smooth rounded end, these conditions are approximated by the use of teeth having generally pyramidal or conical shape with blunted ends slightly larger than the particle to be attracted. It may not be practicable mechanically to form the teeth in the ideal shape; but in Figs. 2 to 5, inclusive, I have indicated some forms which may be convenient in practice.

It is practically necessary that the armature or separating cylinder should be transversely laminated in structure in order that it may be turned easily in the intense magnetic field, and to avoid the heating effects of eddy-currents, and such a laminated construction lends itself readily to the formation of a toothed attracting-surface such as contemplated by this invention.

In Figs. 2 to 5 I have illustrated the surface built up of magnetizable plates having toothed edges, the teeth of adjacent plates being of progressively different heights, so that projections of generally pyramidal shape are thus built up. In the specific form shown in Figs. 2 and 3 the teeth of one set of disks are quite long with rounded ends, while the teeth of adjacent disks are cut off more and more at their ends, though coinciding in outline and position of their bases. In the form shown in Fig. 4 the teeth of adjacent disks have their edges cut at progressively different angles. In the form shown in Fig. 5 the teeth of adjacent disks going to build up the projections are progressively larger or smaller, but having their edges cut at substantially the same angles. It will be seen that in this construction the main projections built up by the teeth of a number of adjacent disks will serve to attract large particles of ore, while very small particles which may be in the mixture will be caught by the smaller teeth of individual disks.

Having thus described my invention, I claim—

1. In a magnetic separator, an element having a magnetic attracting-surface provided with a number of approximately pyramidal projections each composed of a plurality of teeth of progressively different heights.

2. A separator-cylinder having its surface formed of transversely-disposed magnetizable plates having teeth upon their edges, the teeth of adjacent plates being of progressively different heights to form approximately pyramidal projections upon the surface of the cylinder, the points of said projections being blunted, substantially as described.

3. In a magnetic separator, an element having a magnetic attracting-surface provided with a number of projections each composed of a plurality of teeth of progressively different heights, the points of said projections being blunted, and means for magnetizing said teeth to saturation.

In witness whereof I hereunto subscribe my name this 17th day of April, A. D. 1905.

HENRY H. WAIT.

Witnesses:
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