No. 653,345. Patented July 10, 1900.

# E. GATES.

## DIAMAGNETIC SEPARATION.

(Application filed Dec. 2, 1899.)

(No Model.)

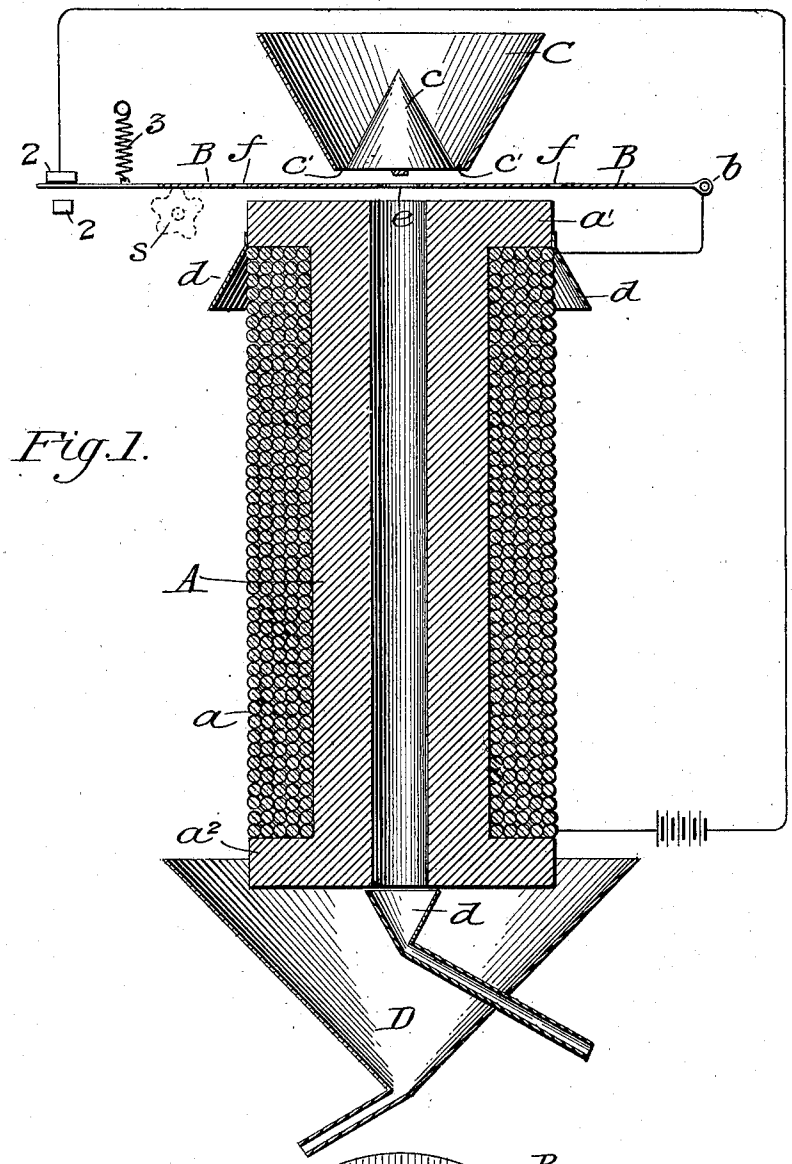



Fig. 1.

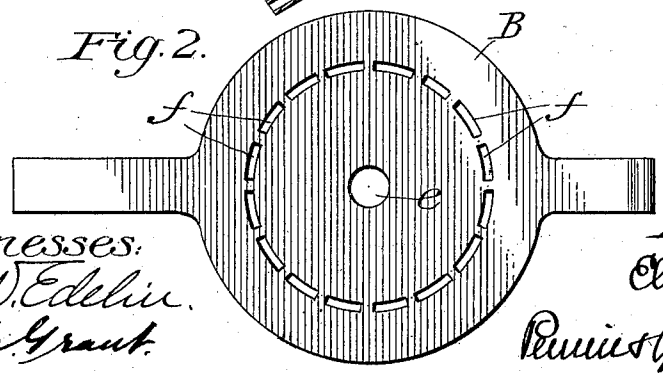



Fig. 2.

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# UNITED STATES PATENT OFFICE.

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## DIAMAGNETIC SEPARATION.

SPECIFICATION forming part of Letters Patent No. 653,345, dated July 10, 1900.

Application filed December 2, 1899. Serial No. 739,008. (No specimens.)

*To all whom it may concern:*

Be it known that I, ELMER GATES, a citizen of the United States, residing at Chevy Chase, in the county of Montgomery, State of Maryland, have invented certain new and useful Improvements in Diamagnetic Separation; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

In an application for Letters Patent of the United States filed September 26, 1899, Serial No. 731,762, I have described and claimed a method of separating diamagnetic substances from the other constituents of granular mixtures in which they are to be found, the characteristic feature of which consisted in feeding the mixture in regulated amount into the intense part of a magnetic field and prolonging the period during which the same while in a freely-movable condition was subjected to the influence of said field until the slight initial tendency of the diamagnetic particles to separate became sufficient to effect their actual and practical separation from the remaining constituents of the mass. The present invention has to do with the same general subject, and besides having for its object to provide an improved method of separating diamagnetic substances of varying degrees of susceptibility contemplates also the separation of the paramagnetic constituents of the mixture from those constituents that are diamagnetic or from the remaining constituents without regard to their classification according to magnetic susceptibility. It is based upon the principle that when freely-movable granular materials or mixtures containing diamagnetic particles of varying degrees of susceptibility or diamagnetic particles of uniform susceptibility combined with paramagnetic particles are introduced into a circle or zone of median magnetic intensity the diamagnetic particles and the paramagnetic particles of weakest susceptibility tend to seek the center of the zone, while the paramagnetic particles and the diamagnetic particles of least susceptibility tend to move away from the center toward the outer edges of the zone. I avail myself of this known property of these substances for the purpose of securing a practicable separation thereof, and in the accompanying drawings I show a convenient form of apparatus for carrying out this method.

In the drawings, Figure 1 is a central vertical section of the complete apparatus; and Fig. 2 is a plan view of a vibrating plate onto which the granular mixture is fed and which constitutes the means for maintaining the freedom of motion between the constituents thereof, as well as their detention for the desired period within the borders of the zone of diamagnetic intensity.

Referring to the views, A denotes a hollow tubular soft-iron core having the requisite number of turns of wire *a* to develop a magnetic force of the desired intensity. The heads $a'$ $a^2$ of this core are circular, and when the magnet is energized an annular zone or field of electromagnetic force is developed, which for the practical purposes of magnetic separation is bounded by the inner and outer peripheries of the heads.

Located centrally over the above-described magnet is a hopper C, from which the material to be treated is allowed to flow continuously in a regulated amount. There is a cone *c* arranged within this hopper near the bottom, and the discharge-orifice for the material is an annular space $c'$ between the outer periphery of the base of the cone and the inner periphery of the bottom wall of the hopper. Below the magnet two receivers D *d* are located, with appropriate spouts for conducting away the separated constituents of the material received from the hopper C.

The feeding-hopper is located above the magnet, so that its annular discharge-orifice $c'$ is preferably concentric with the base of the magnet and also with the outer edge of the head $a'$, and this arrangement is important, for the reason that the material to be treated is thus conveniently introduced into a zone of median magnetic intensity, or, in other words, is delivered into the magnetic field midway between its practical boundary-lines and allowed to separate according to the law above stated, the diamagnetic particles gradually working toward the center of the field and the paramagnetic particles mak-

ing their way toward the circumference or outer edge of the zone.

The large receiver D is for the purpose of catching the "tailings," as those constituents of the mixture which are paramagnetic or of least diamagnetic susceptibility are herein termed. It is therefore arranged with its upper edge outside and preferably slightly above the lower head $a^2$ of the magnet. The small inner receiver $d$ is located immediately below the tubular central opening of the magnet and catches those constituents of the mixture as are herein classified as "heads."

Around the periphery of the upper head $a'$ there is located an apron or deflector $d$, whose purpose is to deflect the material falling over the outer edge of the head slightly away from the body of the magnet and to direct its course into the large receiver at the bottom.

For the purpose of obtaining the requisite freedom of motion of the particles while in the magnetic field, as well as to detain them within said field and allow them to arrange themselves in accordance with the law of their relative diamagnetic susceptibility and the natural slight initial tendency to separate out has been reinforced by gradual increments of magnetic repulsion, I provide a plate B, between the upper surface of the head $a'$ and the discharge-orifice of the hopper C. This plate preferably conforms in shape to the outline of the head of the magnet and is pivoted at $b$, so as to be rapidly reciprocated in the direction of the axis of the magnet. The material is received upon its upper surface directly from the hopper, and corresponding in location to the inner and outer boundaries of the magnetic field or zone it is provided with holes $e$ $f$, the former being coincident with the hollow bore of the magnet and the latter in proximity to and concentric with the outer edge of the head. The plate may be vibrated mechanically or by being connected up in the circuit of the magnet-windings. Its outer end vibrates between the points 2 2, and when electrically operated is normally held against the upper point by a spring 3, and when the magnet is energized will vibrate rapidly in a manner well understood. As a convenient means for operating it mechanically I show in dotted lines a star-wheel $s$, located under it and down upon which it will preferably be found best to hold it lightly by a spring acting in the opposite direction to the one shown in full lines.

The plate B may be made out of material that is in itself diamagnetic or paramagnetic, as circumstances may require or make desirable, and instead of vibrating the plate I may fix it in position and obtain wholly or partially the effect of such vibration on the mixture by vibrating the magnet.

With the apparatus organized as above described the operation of separating out the diamagnetic substances of varying degrees of susceptibility or the paramagnetic substances from those of opposite susceptibility proceeds as already explained, the former moving gradually while on the plate B toward the center, where on reaching the hole $e$ they fall through the hollow magnet and are received as heads by the receiver $d$ and conducted away, and the paramagnetic substances or those of diamagnetic susceptibility in the least degree gradually working their way under the constant agitation of the plate toward the outer openings $f$, through which they fall and are received as tailings in the receptacle D.

For the purpose of further facilitating the separation of the described constituents of the mixture a small ridge or elevation might be arranged concentrically around the opening $e$, with its apex arranged with respect to the discharge-orifice of the hopper, so as to give the whole mass a tendency toward the openings $f$ independently of any diamagnetic action. The material would then tend to move outward rather than inward and the diamagnetic substances of least susceptibility would follow the tendency of the mass outward and only those of greatest diamagnetic susceptibility would find their way to the center.

Having thus described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. The method of diamagnetic separation which consists in introducing the mixture into a zone of median magnetic intensity, agitating the mixture while detained in said zone until the particles of varying susceptibility move in opposite directions, and collecting the separated particles and conducting them away separately.

2. The method of diamagnetic separation which consists in feeding the mixture onto a support midway between the boundaries of a belt or zone of magnetic intensity, agitating the support until the substances of different susceptibility move laterally in opposite directions across said belt or zone, and collecting the separated substances at different points and conducting them away separately.

In testimony whereof I affix my signature in presence of two witnesses.

ELMER GATES.

Witnesses:
THEODORE J. MAYER,
HUGH M. STERLING.