An electromagnetic separator for mineral powders.

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[Received July 25, 1930.]

THE separator here described was designed by the author some years ago in order to avoid the tedious process of hand-picking mineral powders in front of an electromagnet. It is a complete machine dealing on a laboratory scale with the less magnetic minerals, such as monazite. For research it is essential that the separation should be clean cut; in the present case a 90% separation of glauconite from monazite can be made in a single pass, while the removal of more widely differing minerals is complete. The machine must also deal with small samples down to 0·5 gram without loss; this necessitates a small scale and slow feed; the time required for more bulky samples is consequently rather long, but little or no attention is required during operation. Finally, all the moving parts should be of metal and easily cleaned.

The first model[2] of this separator was constructed by Mr. George Barrow, to whose cordial assistance the author has been indebted throughout the earlier part of the work. Shortly afterwards an improved copy was made by Mr. W. E. Fletcher, to whose skill was due a mechanical (cam) feeding device, and this machine remained in use in the Geological Survey Office until 1928, when it was replaced by the present model. In the disturbed conditions prevailing on the first publication it was thought advisable to obtain such protection as might be afforded by a patent, and the machine was originally described in the specifications to British Patent No. 109,857 (1917), where a number of alternative arrangements are indicated.

It is unnecessary to refer in detail to earlier commercial separators, of which a very full account has been given in mining textbooks.[3] Most of these are unsuited for a laboratory model, since the

[1] Communicated by permission of the Director.
[2] Exhibited at the meeting on November 9, 1915, Min. Mag., 1916, vol. 18, p. xxiv.
[3] S. J. Truscott, Textbook on ore dressing, 1923.

conveyer or belt is interposed between the pole pieces, and as soon as the scale is reduced it becomes difficult to construct a sufficiently robust conveyer without having an unduly wide gap in the magnetic circuit. For this reason it was decided to feed the material directly beneath a special form of double-poled magnet, both poles being above and close to the conveyer, and to discharge the magnetic material by interrupting the current when the magnet was above an opening in the surface of the conveyer. In principle, though not in mechanism, this recalls an early design communicated by La Rue.[1]

Fig. 1 illustrates the present machine. The sand or clean (preferably washed) mineral powder should first be roughly graded by sieves; sizes 120, 90, 60, 40 wires per inch are convenient. It is then placed in the feed-hopper, the lower end of which is closed by a valve. Beneath the small table is the conveyer disk, carried on a central upright spindle, which is rotated (clockwise) by a small motor and worm-gear. Near the outer edge of this disk is a broad groove, on the floor of which the material is conveyed. The groove is cut away at intervals, leaving six shelves with alternate gaps through which magnetic material can be discharged. As the conveyer disk rotates, the shelves pass beneath the mouth of the hopper; at a suitable time contact is made by copper bars on a commutator carried on the central spindle, so that the armature of the feed-valve is raised by the electromagnet; a small amount of material is thus deposited on each shelf. The shelf then passes in succession below (*a*) a small (single-pole) magnet which removes magnetite, (*b*) a large magnet at moderate strength, and (*c*) a large magnet at maximum strength. These magnets are connected in series to a sliding contact on a standard type of resistance (not shown in the figure), by which the strength of current can be varied. Each magnet lifts a fraction of the magnetic material from the shelf, and holds it until a gap has come below the poles. At this point the magnets are short-circuited by the commutator (or the current is otherwise interrupted) and the magnetic fractions are released through the respective gaps into glass dishes below.[2] The shelf with non-magnetic residue finally passes

[1] British Patent No. 930, 1873 (J. R. Francis).

[2] It need hardly be said that contact must be made when the magnet is above a gap. An early model was submitted direct from the maker to an independent expert, who formally reported that he had obtained a certain inadequate concentration of magnetic mineral. When, after some weeks, the present author was able to see the machine it was found that none of those concerned had realized the above essential condition: the commutator was set so that all

under a fixed brush, which sweeps the bottom of the groove and carries the tailing into a fourth glass dish. The clean shelf is then ready to receive a fresh supply of material as it again passes below the feed-hopper. The commutator is an ebonite drum with six vertical copper bars corresponding with gaps in the conveyer. Contact is

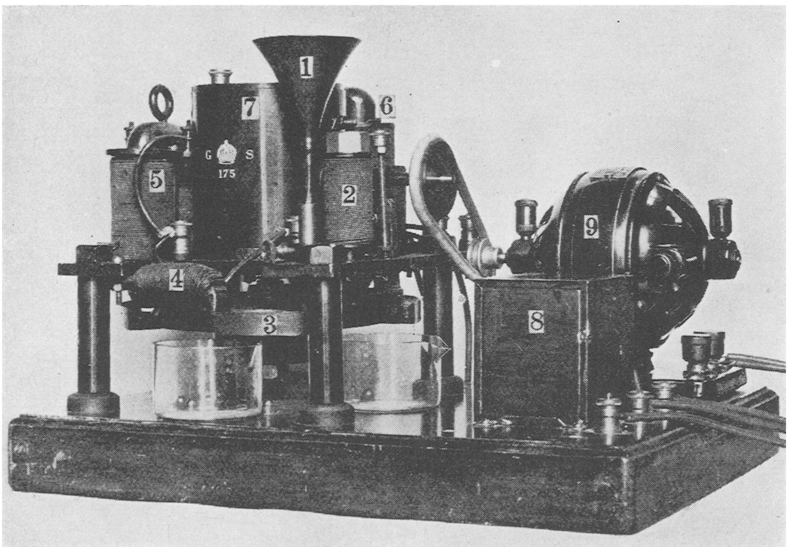

FIG. 1. Electromagnetic separator.

1, Feed-hopper. 2, Magnet operating feed-valve. 3, Conveyer disk. 4, First separating magnet. 5, Second separating magnet (for garnet). 6, Final separating magnet (for monazite). 7, Cover enclosing worm-gear and commutator. 8, Condenser across commutator. 9, Motor.

made by three spring studs which rest simultaneously upon each copper bar and thus complete circuit through the feed-magnet and at the same time short-circuit the separating magnets. A condenser (4 mf.) is connected across the contacts so as to minimize the spark at ' break '. Corrosion of the contacts is not serious and the studs are easily renewed if required. For very long service or when the margin of supply voltage does not allow short-circuiting, it would

magnetic material was redeposited on the shelves and the only mineral that had ever reached the magnetic hoppers was pushed off mechanically when the shelves were overloaded.

probably be worth while to interrupt the magnets by means of a relay mercury switch.[1]

The construction of the separating magnets will be sufficiently evident from figs. 1 and 2. Cores and poles are made from $\frac{3}{4}$-inch 'armco' iron, wound with no. 24 copper wire. A gap of about $\frac{1}{10}$ inch is left between the poles, and the working distance between poles and conveyer may vary between $\frac{1}{16}$ and $\frac{1}{8}$ inch. The pole-pieces are

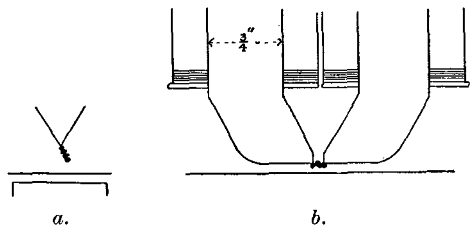

FIG. 2. (*a*) Single and (*b*) double pole-pieces of electromagnets. (The latter is the form used in the present machine.)

slightly curved to fit the groove of the conveyer, but this does not noticeably affect the uniformity of field in the gap.

Pole-pieces of magnetic separators fall into two types. The single pole (fig. 2 *a*) has the very serious defect that there is a tendency to form chains of particles which sweep the conveyer ; with the double pole (fig. 2 *b*) the chains are held up between the poles, so that the carrying power is very much greater. It might be supposed that the particles so held would short-circuit the magnetic field, but this effect is not appreciable in the case of the minerals actually in question, since their susceptibility is of the order of 0·01. Double pole-pieces have long been in use ; special reference may be made to the well-known adjustable form due to Crook[2] and to the larger magnet of the present type recently described by C. J. Ksanda.[3]

Attempts have been made to connect the theory of the double pole-piece with a diagram[4] which bears a superficial resemblance to a separating magnet, but which was actually obtained in investigating a form of magnetic balance by means of a proof-coil. This diagram

[1] A suitable switch is made by Messrs. Isenthal, Ltd., Victoria Road, London, W. 3.

[2] T. Crook, in appendix to F. H. Hatch and R. H. Rastall, Petrology (sedimentary rocks), 1st edition only, 1907, p. 366.

[3] C. J. Ksanda, Journ. Opt. Soc. Amer., 1926, vol. 13, pp. 713–715.

[4] Reproduced by B. W. Holman, Mining Magazine, 1927, vol. 37, p. 85.

is inapplicable since it relates to the force along the median line between the poles. Actually the particles are fed from one side, their rate of approach is slow (a very great advantage), and lifting takes place away from the median line. The diagram in question indicates zero lifting force at a point directly in front of the double pole; although for obvious reasons the proof-coil cannot conveniently be used in a gap of $\frac{1}{10}$ inch, an elementary experiment with an iron filing will suffice to show that this conclusion is completely erroneous. Practical trial of the present arrangement has proved that it is entirely satisfactory as regards lifting power, uniformity, and freedom from entrainment.

The magnets may be interrupted as often as every half-second. At this frequency no difficulty was experienced from delay due to the time-constant, and it is evident that the size of the magnets could be increased to any reasonable extent by arranging the windings in parallel. The small guard magnet[1] is necessary to prevent furring of the main magnet, but only one large magnet need be used. A small amount of magnetic material usually gathers between the poles of the magnets and would slightly contaminate the concentrate when the current is finally shut off; for very accurate work the dishes are best removed before the machine is stopped, or the pole-gap can be filled with a cement.

[1] If much magnetite is present, it is worth while to remove most of it first with a hand magnet.