An electromagnetic separator for mineral powders.

By R. C. EVANS, M.A., Ph.D., B.Sc.
Department of Mineralogy and Petrology, University of Cambridge.

[Exhibited June 8, 1939.]

THE use of a magnetic separator for the separation of certain ores has long been a standard commercial practice and a laboratory scale instrument applying the same principles to the separation of mineral grains from a powdered rock has been designed by Hallimond.[1] In this apparatus the mineral grains are spread on a rotating pan which carries them below the pole pieces of one or more electromagnets, the pole pieces being so designed that the grains pass through a strongly diverging magnetic field and so are subjected to a force proportional to their susceptibility. If this force exceeds the weight of the grains they are attracted and adhere to the pole pieces. The material thus collected is periodically discharged by interrupting the magnetic field and the grains then fall through a slot in the rotating pan into a receptacle below.

The instrument here described resembles in principle that designed by Hallimond, but incorporates a number of modifications which experience has shown to be desirable. In particular, attention has been given to the following general points:

(1) The mechanical design has been made very robust in order to ensure trouble-free operation over long periods of time, so that if necessary the apparatus may be allowed to run for hours on end when large quantities of material are to be handled.

(2) As far as possible the apparatus has been made dust-proof and easy to clean. Thus all connecting wires are concealed and exposed surfaces are smooth and free from encumbrance.

(3) Trouble from electrical contacts has been eliminated by the use of a mercury switch to control the magnets and of a brushless induction motor for the drive.

A general view of the apparatus is shown in fig. 1. The pans (1) are turned from a heavy brass disk and are carried on a vertical steel shaft

[1] A. F. Hallimond, Min. Mag., 1930, vol. 22, p. 377.

mounted on ball-bearings. This shaft is driven at six revolutions per minute through a gear train by an electric motor, both the motor and gears being housed in the aluminium casting (2) which forms the base of the machine. The mineral grains are deposited on the pans by the hopper system situated under the cover (3) and described in more detail below. They are carried beneath the pole pieces (4) of the two magnets and any grains which are unattracted are finally swept from

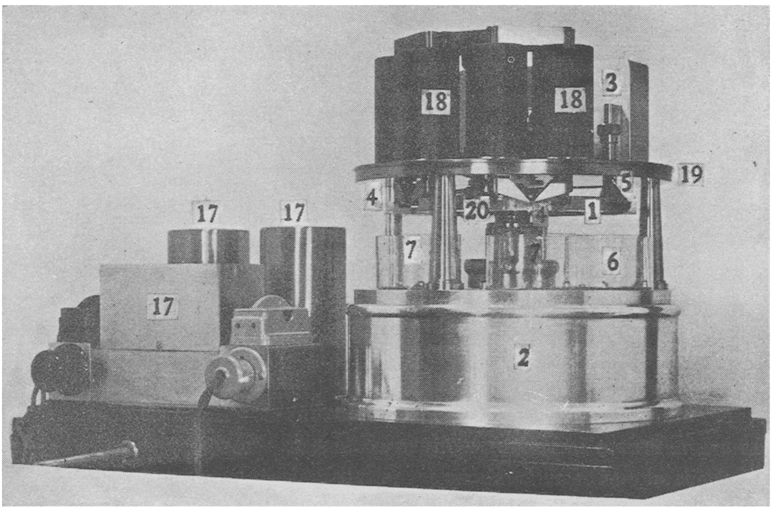

FIG. 1. Electromagnetic separator.

the pans by the brush (5) and fall into the glass receptacle (6). The other receptacles (7) receive the material dropped from the two magnets when the magnetic field is interrupted. Other special features of the machine are best described separately.

The hopper system is shown in fig. 2 and is designed to spread the mineral grains in a uniform layer over the full length of each pan, thus permitting a much faster rate of delivery than if the grains were dropped at one point only. The grains are placed in the hopper (8), the bottom of which is closed by the door (9). This door is carried on a steel spring (10) and is opened momentarily by a magnetic impulse obtained by discharging a condenser through the electromagnet (11). This magnet is carried on a lever (12), and by means of the screw (13) the opening of the door (9), and therefore the quantity of powder delivered, can be delicately regulated. From (9) the powder falls on to the upper end of the sloping tray (14), which is also mounted on a spring (15) and is tuned to resonance with an alternating current passed through the electromagnet (16), being thus maintained in a state of continuous vibration. The powder is in this way gradually shaken from the tray on to the rotating pans (1) below. The amplitude of the vibrations of this

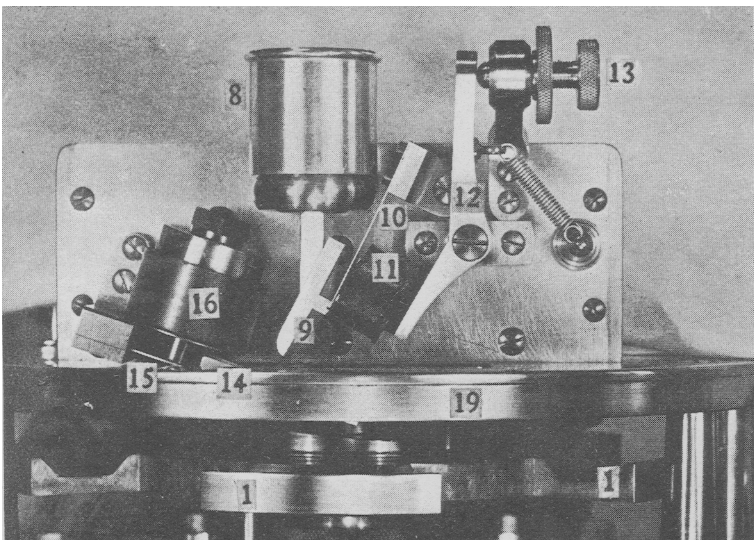

FIG. 2. Hopper system of electromagnetic separator.

tray can be adjusted by withdrawing the pole piece of the electromagnet (16), but in practice it is not found necessary to make use of this adjustment once a suitable setting has been found. In order to handle powders of different grain-sizes, which travel down the vibrating tray at different speeds, provision is made for adjusting electrically the instant of operation of the door (9) relative to the arrival of a pan below the end of (14). For ease of cleaning, the hopper (8) can be removed, and it, the door (9), and the tray (14) are all rhodium plated to provide an untarnishable and virtually unscratchable surface. During operation the whole of the hopper system is enclosed in the brass box (3) (fig. 1). The condenser and other electrical apparatus for the operation of the hopper are contained in the boxes (17) seen to the left of the apparatus in fig. 1.

The magnets (18) are made of a special high permeability mild steel which is easy to machine and yet has a low retentivity, and the two are identical. All the pole pieces (4) were machined together in one operation to ensure that the magnets are at exactly the same height above the pans. The magnets are rigidly fixed in the heavy brass plate (19).

The current for the magnets is drawn from the direct-current mains using banks of lamps as regulating resistances. Switches enable the strengths of the magnets to be varied independently by the selection of any combination of these lamps. If desired, both magnets can be of the same strength and it is sometimes convenient to operate under these conditions, for then the material collected on the second magnet gives some indication of the efficiency of separation at the first magnet by showing the amount of material which it has failed to collect. In addition to the provision for varying the strength of the magnets, arrangement is made for adjusting the height of the pans relative to the pole pieces. In practice, however, it has been found that it is not normally necessary to make use of this adjustment once the optimum setting has been discovered.

No weak magnet is provided to remove magnetite or other very strongly magnetic minerals, and if these are present in any considerable quantity they are best removed first with a hand magnet.

The magnets are switched on and off by a mercury switch mounted on a lever in the aluminium base of the apparatus and tripped by a cam driven directly from the gearbox. The cam mechanism is designed to give a very abrupt operation of the switch in both directions. Experiments with a cathode ray oscillograph showed that the magnetic field practically reaches its final value in 1/70 second after the operation of the switch, so that no difficulty is to be anticipated due to delay arising from the time constant of the magnet.

In order to eliminate trouble due to material continuing to adhere to the magnets after the current has been cut off, due to the retentivity of the steel, the circuit is so arranged that a small reverse current then passes through the coils of the magnets and demagnetizes them completely. At the same time small hammers (20), operated by a castellated head mounted on the central spindle above the pans, drop on to the pole pieces to dislodge the adhering particles.

During operation the pans and collecting receptacles are protected from dust and draughts by a cellophane shield, not shown in fig. 1, which spans the gap between the top of the aluminium casting (2) and the plate (19). When not in use the whole apparatus is protected by a wooden cover.

Preliminary tests of the instrument have shown that it is capable of giving a good separation of mineral powders over a wide range of particle size. It is normally not possible to achieve a complete separation in a single operation except in rather favourable cases of minerals of widely different susceptibilities, since with an anisotropic material the force with which the particles are attracted must always depend upon their chance orientation relative to the magnetic field. For this reason it is generally most satisfactory to subject the material to several successive fractional separations with a fast rate of delivery from the hopper and with one or both magnets of strength only just sufficient to attract the mineral required. Details of technique must, however, depend upon the particular circumstances of each individual case and experience soon teaches the most profitable method of operation.

It is a great pleasure to express my thanks to Mr. H. C. G. Vincent who suggested several features of the apparatus and from whose considerable experience of separators I was able to profit in its design. The instrument was constructed in the workshops of the Department of Mineralogy and Petrology, Cambridge, by Mr. A. N. Lanham, to whom also I am much indebted not only for the quality of his workmanship, to which the successful operation of the apparatus is largely due, but also for the many detailed points of the design for which he is responsible. In its present form the commercial manufacture of such a separator would necessarily be rather expensive, but in the light of the experience gained it might be possible to design a somewhat simplified form of the apparatus, incorporating, however, all the essential features of the present machine, which could be manufactured at a moderate price, provided a demand for several instruments could be anticipated. If any readers are sufficiently interested in this proposition I shall be glad to give the matter further consideration.