ELECTROMAGNETIC SEPARATION OR CONCENTRATION OF MINERALS

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Fig. 1.

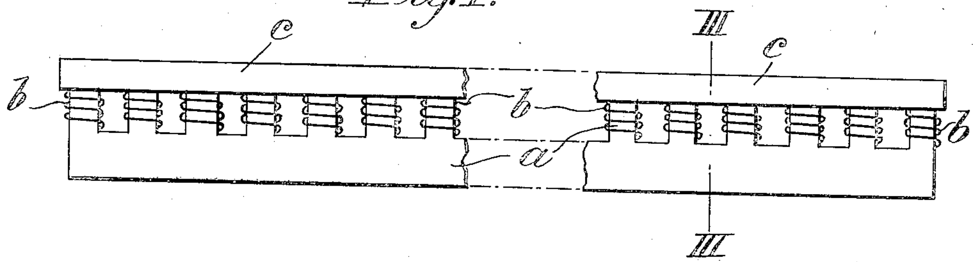


Fig. 2.

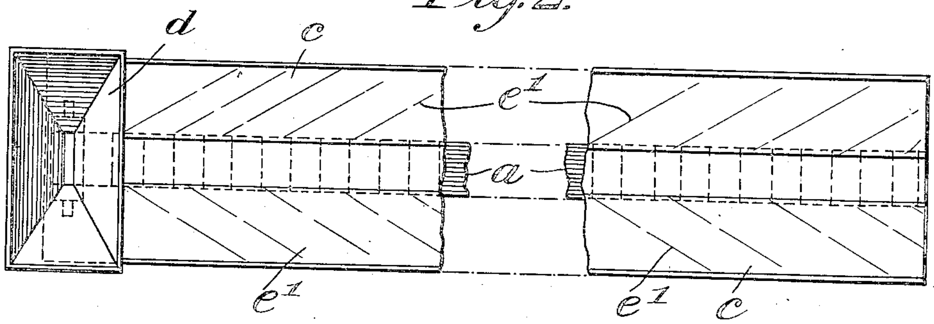


Fig. 4.

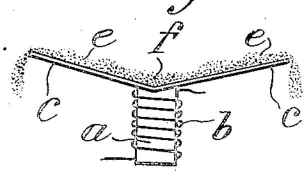


Fig. 10.

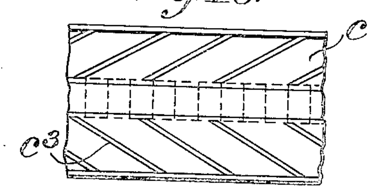
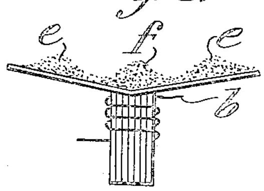


Fig. 3.



Inventor:

William Morris Mordey

By Dowell and Dowell

Attorneys

Sept. 24, 1929. W. M. MORDEY 1,729,589

ELECTROMAGNETIC SEPARATION OR CONCENTRATION OF MINERALS

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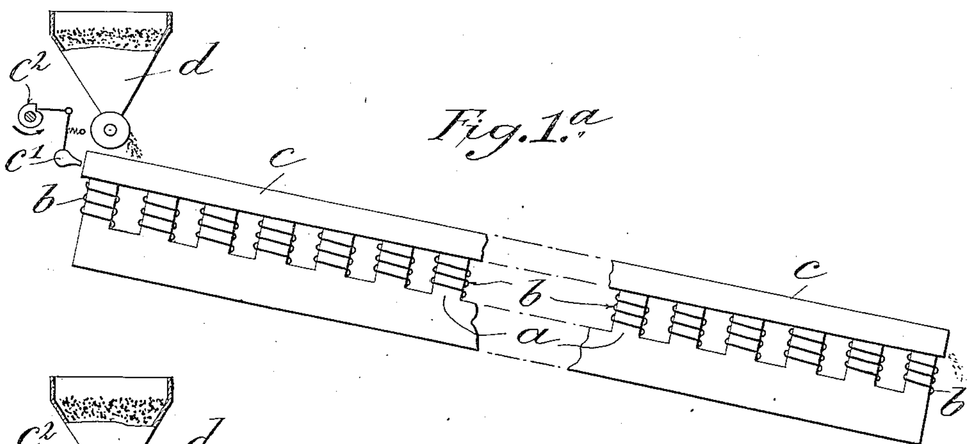

Fig. 1a.

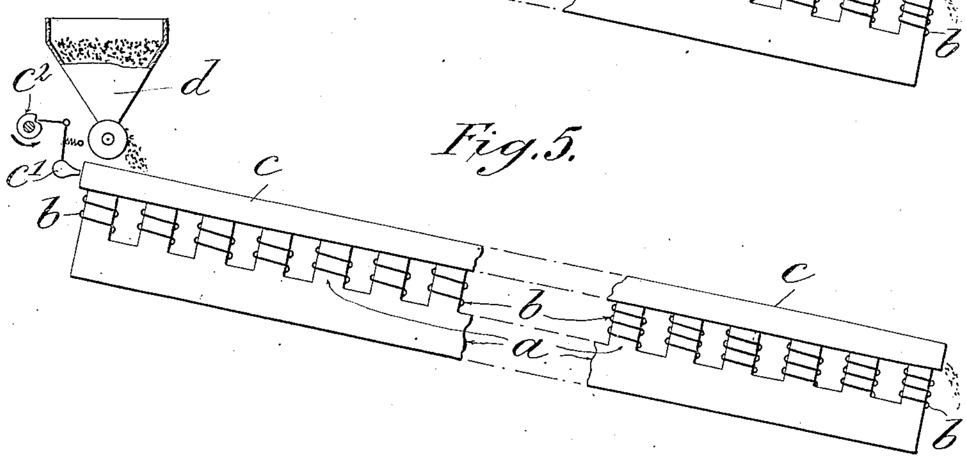

Fig. 5.

INVENTOR

William Morris Mordey

By Dowell & Dowell

his Attorneys

ELECTROMAGNETIC SEPARATION OR CONCENTRATION OF MINERALS

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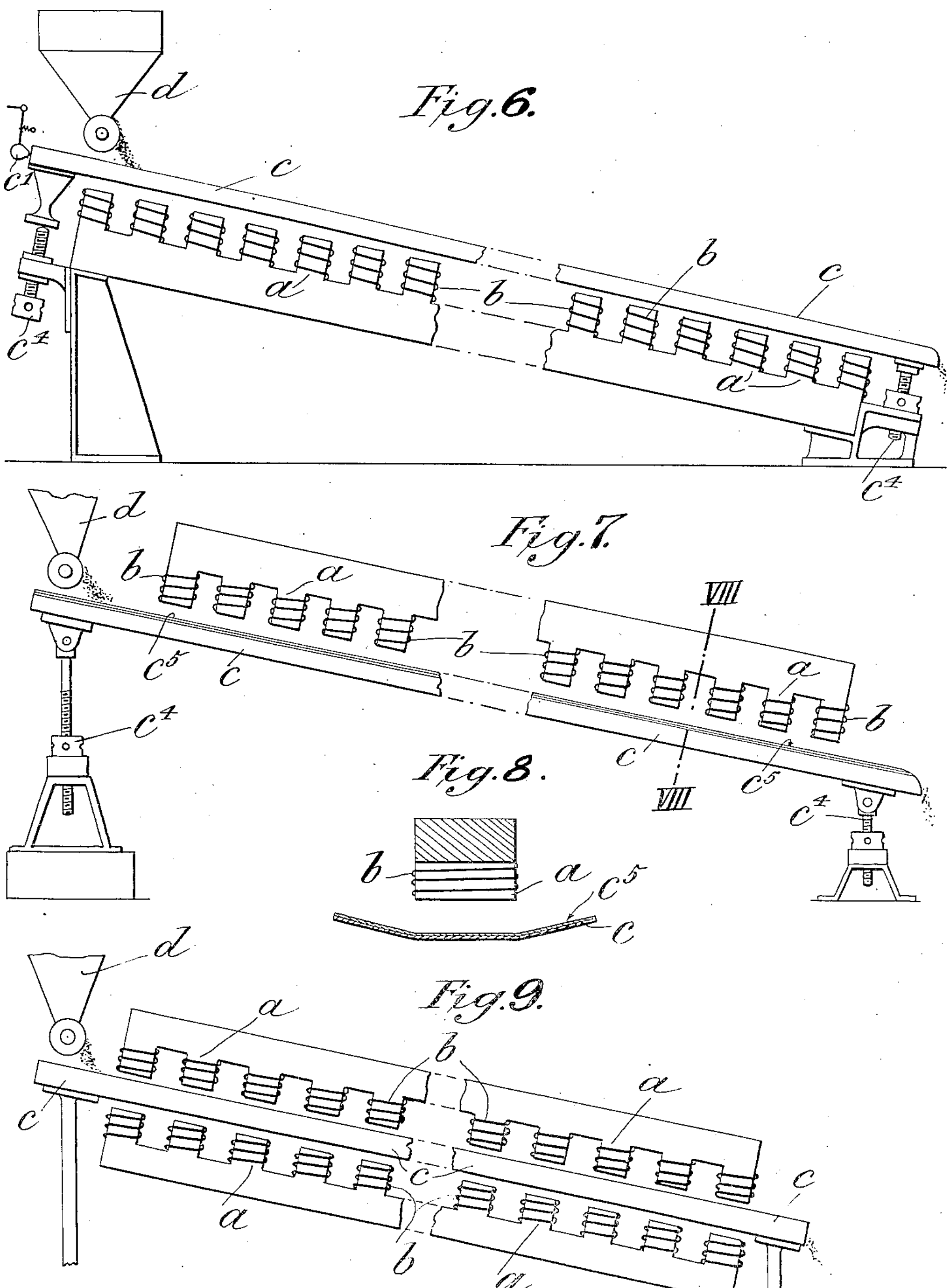

INVENTOR
William Morris Mordey
By Dowell and Dowell
his Attorneys

Sept. 24, 1929. W. M. MORDEY 1,729,589
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Fig. 11.

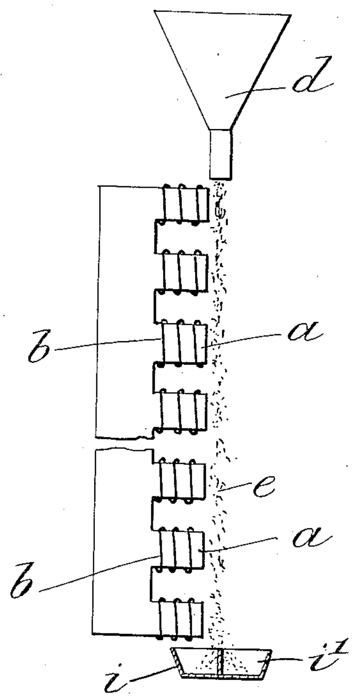


Fig. 12.

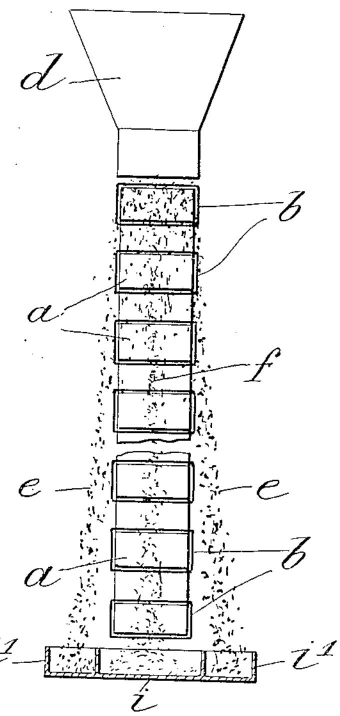
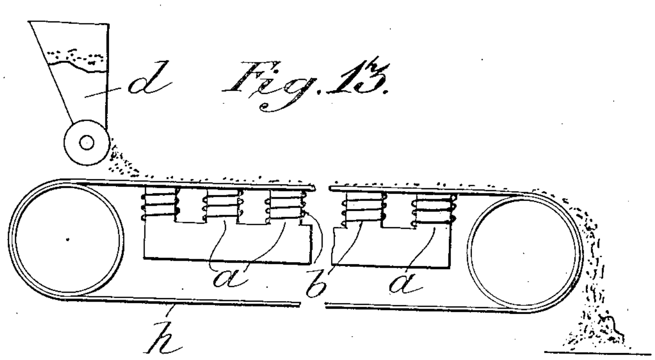


Fig. 13.



INVENTOR
William Morris Mordey
By Dowell & Dowell
his Attorneys

Patented Sept. 24, 1929

1,729,589

UNITED STATES PATENT OFFICE

WILLIAM MORRIS MORDEY, OF LONDON, ENGLAND

ELECTROMAGNETIC SEPARATION OR CONCENTRATION OF MINERALS

Application filed May 8, 1924, Serial No. 711,888, and in Great Britain May 17, 1923.

This invention has reference to improvements in connection with the electro-magnetic separation or concentration of minerals that are responsive to the action of a multiphase magnetic field from other material that is not responsive or not so responsive to such field, and it has for its object to enable such separation or concentration to be carried out in a rapid, effective and economical manner.

For this purpose, the mineral material or ore to be treated, whilst in a finely divided condition, is caused to move through a relatively long and narrow multiphase electromagnetic field arranged to travel in the line of flow of material and set up by a multiphase electro-magnetic system in such manner, that matter which is responsive to such field and which is hereinafter called for brevity and distinction responsive matter, will be repelled by such elongated field laterally in opposite directions, and also longitudinally in relation to the general direction of the stream and thereby become separated from gangue or other material, (hereinafter called for brevity and distinction, inert matter) which is unaffected, or less affected, by such field and which will flow onward unaffected through the central portion of the magnetic field.

The electro-magnetic system comprises a relatively long and narrow row of successive magnetic poles, extending longitudinally in the direction of the pathway for the stream of mineral material to be treated and energized by a multiphase winding, preferably a two-phase winding, each magnetic pole and the energizing winding between successive poles, extending transversely of the said pathway for the stream of material. The longitudinal row of poles may be of any desired width relatively to the width of the pathway for the finely divided mineral material to be treated.

The finely divided material may be in the form of pulp, or in a dry condition, and be caused to pass in the form of a thin layer longitudinally through the longitudinal moving multiphase magnetic field in various ways.

The invention can be carried into practice in various ways.

In the accompanying illustrative and diagrammatic drawings, Fig. 1 shows in side elevation, Fig. 2 in plan and Fig. 3 in cross section on the line III—III of Fig. 1, one construction of apparatus suitable for carrying out the invention. Fig. 1[a] is a similar view to Fig. 1, but showing the apparatus inclined in the longitudinal direction. Fig. 4 is a similar view to Fig. 3, showing a modified construction. Figs. 5, 6, 7 and 9 show, in side elevation, other modified arrangements. Fig. 8 is a cross section on the line VIII—VIII of Fig. 7. Fig. 10 is a detail view. Figs. 11 and 12 are elevations at right angles to one another, showing a further modified construction of apparatus for carrying out the invention in another way. Fig. 13 shows, in side elevation, a further modified arrangement.

According to the example shown in Figs. 1, 2 and 3, the iron magnet core, which is laminated longitudinally, is shaped like a long rack having a succession of vertical teeth or poles *a* on the upper side, the teeth or poles being wound with coils or windings *b* appropriately arranged to be traversed by a multiphase current, preferably two-phase current, whereby a moving field will pass in one direction or the other along the magnet the length of which may be many feet, and of any desired width relatively to the launder *c*.

The long, narrow magnet is placed under a non-conducting launder *c* on to which a stream of the material to be treated, is delivered from a hopper *d* and by which such stream will be supported during its movement through the longitudinally moving multiphase magnetic field produced by the electro-magnet *a*—*b*. The launder may be inclined in the longitudinal direction (see Fig. 1[a]) at such an angle that when the magnet is not excited, the stream of material will flow freely down it by the action of gravity alone. Or, the launder may be inclined to a less degree and the material be caused to move along it by imparting a succession of shocks to it in an endways direction, or by jigging the launder, as for instance by a spring and gravity actuated pivoted striker c^1 controlled by a rotary cam c^2. Or the launder may be horizontal (Fig. 1) and the material caused to move along it by imparting to it a succession of shocks or a jigging motion by means such as shown in Fig. 1^a.

The launder, which is made long and narrow, is made slightly concave, or, as shown in Fig. 3, flat-bottomed in the middle with sides slightly sloping upwards in opposite lateral directions, or each side may slightly slope upwards from a middle line, as shown in Fig. 4, the formation in each case, having for its object to ensure that by gravitation, the inert material, shall tend to move to the middle portion of the launder. The upper surface of the magnet, especially when of considerable width, may advantageously be formed to correspond to the underside of the launder. Usually, the launder will rest, as shown in Figs. 3 and 4, against, or be as closely adjacent to the magnet poles as is practicable but the distance between them may be increased or varied to suit requirement, as hereinafter explained.

This arrangement of the apparatus is suitable for the treatment of finely divided material whether the same be mixed with water to form a pump, or be in the dry condition. When a thin stream of suitable finely divided mineral material is moved along the launder *c*, the magnet *a*—*b* (Figs. 1, 2, and 3) being suitably excited by a multiphase current the responsive material *e* will have the following directions of movement imparted to it. It will be repelled laterally in opposite directions from the middle of the space above the elongated magnet poles *a* and it will also be driven lengthwise along the launder, as indicated in dotted lines at e^1 in Fig. 2 and travel along the launder *c*. Thus, the resultant motion will be longitudinal, either downward or upward in the launder *c*, according to the relation of the phases. In other words, the concentrate or responsive matter *e* will, in addition to the opposite lateral motions of repulsion, be propelled either in the direction of the flow of the stream, or in the opposite direction. In the latter case, the tendency of the stream will be to delay or hold back the concentrate or responsive matter and thus to ensure a more complete separation thereof from the gangue or inert matter *f* than in the former case. The responsive matter will also be repelled upward from the face of the poles and thus facilitate its separation from the inert matter.

Assuming the launder to be suitably inclined, the repelled responsive matter will be carried down the two sides of the launder by gravity whilst the inert matter will gravitate towards and flow down the middle portion of the launder, also by gravity, and be discharged at the lower end thereof as tailings. Or the responsive matter *e* may be repelled over the sides or edges of the launder *c*, as shown in Fig. 4 whilst the inert matter *f* flows downward over the central portion of the row of poles *a* to the bottom of the launder and will be discharged therefrom by gravity. Thus a separation of the concentrate or responsive matter from the nonresponsive matter will take place.

If the stream of material is not sufficiently rapid, the concentrate or responsive matter will form a continuous bank or deposit on each side of the launder from which it can periodically be removed, as for example by interrupting the supply of material to the launder, switching off the exciting current from the electro-magnet and, after the inert matter then remaining in the launder has been discharged therefrom by gravity, passing a stream of water down the launder, whereby the concentrate will be washed down the middle of the launder into a suitable receptacle. Obviously, two parallel launders and magnets may be used to enable the flow of pulp or dry material to be continuous, each launder alternately being traversed by a stream of material and by a stream of water.

The length of the magnet *a*—*b* and of the launder *c* will depend on the strength of the magnetic field, or the distance between the launder and the magnet, or the speed of flow of the steam of material and on the degree of concentration required in a single passage of the material down the launder. The launder is made narrow in order that the particles of responsive matter *e* and inert matter *f* shall have only a short distance to travel transversely.

The strength of the magnetic field acting on the material in the launder may in each case be graduated. Thus, less excitation of the magnet core may be produced below the upper end portion of the launder and greater excitation of the magnet core below the lower end portion of the magnet core, as for example by providing the poles *a* towards the upper portion of the magnet with fewer effective convolutions of the winding *b* than the poles towards the lower end portion of the magnet core, as shown in Fig. 5. Or a greater depth of air space may be provided for between the upper end portions of the magnet *a*—*b*, and launder *c* than between the lower end portions of the electro-magnet and launder, as shown in Fig. 6, as for example by adjusting the inclination of the launders relatively to the electro-magnet by screw jacks c^4. In this way the material being treated can be subjected to a weaker magnetic field whilst passing through the upper portion of the launder than that to which it is subjected whilst passing through the lower portion of the launder so that the more susceptible or responsive matter in the material will be separated from such material in the upper portion of the launder and thus be prevented from being entrained with the remainder of the material so as to enable the less susceptible or responsive matter the better to be separated from the inert matter when passing through the stronger magnetic field at the lower portion of the launder.

The magnet *a*, *b* may as shown in Fig. 7 be arranged above the launder *c* instead of below it. In this case the launder may be constructed of laminated iron with the stream of pulp or dry material in contact with the iron. Or it may, as shown in Fig. 8 be provided with a non-conducting lining or cover c^5. Or the launder *c* may be placed between upper and lower electro-magnets *a*—*b* as shown in Fig. 9.

The upper side of the launder may, in each case, be formed with grooves, or riffles c^3 (Fig. 10), extending in an outward direction but inclined to the longitudinal edges of the launder in order to assist separation of the responsive matter from the inert matter.

Instead of causing a thin stream of the material to be treated, to flow through a launder whilst subjected to a multiphase magnetic field as hereinbefore described, it may be caused to fall through a vertical path, say through the air, from a feed opening in the bottom of a raised chute or hopper, the multiphase magnetic system being then arranged vertically below the chute or hopper and adapted to repel the responsive matter outward from the inert matter so as ultimately to divide the stream into four streams, the outer two lateral ones and the front one being composed wholly or mainly of responsive matter and the inner central one of inert matter the separated responsive matter and inert matter being collected in separate receptacles below.

In Figs. 11 and 12, the vertically arranged multiphase electro-magnet *a*—*b* is similar to that shown in Figs. 1 and 2. With this arrangement, the responsive matter or concentrate *e*, repelled in opposite lateral directions and from the face of the magnet, can be collected at the bottom in two side receptacles i^1, i^1 and a front receptacle i^2 whilst the inert matter or gangue *f* will fall and be collected in a central receptacle *i*. The material to be treated falls in front of the central portion of the electro-magnet in the form of a thin narrow stream or screen. The vertical arrangement shown may be regarded as a unit. For the treatment of larger quantities of material, it may be made wider, or it may be repeated, as for example by placing a number of them side by side below a suitable supply hopper.

Or, the finely divided mineral material, in a dry condition, may, as shown in Fig. 13, be carried through the longitudinal multiphase magnetic field of the electro-magnet *a* *b* by the upper portion of an endless movable band conveyor *h*.

The invention is specially applicable for the separation and concentration of specular hæmatite and other like feebly magnetic substance from ores and like material containing the same, as well as for the separation and concentration of magnetite and other substances that are more susceptible to magnetic action.

In the treatment of material containing specular hæmatite, it will be advantageous to use a powerful field and a small air gap between the electro-magnet and launder. Under these conditions the specular hæmatite is acted upon and repulsion takes place from the field. In the case of magnetite however, associated with other material, attraction of the magnetite to the magnet takes place and the magnetite will tend to collect or adhere near the magnet pole or poles, but if the field of the electro-magnet be weakened, or the air gap or space between the face of the magnet and stream of material be increased, the magnetic attraction will be lessened and with a still greater increase in the air gap or space, or weakening of the field will be overcome and repulsion of the magnetite from the field will take place, this repulsion being attributed to the magnetic attraction being overcome by repulsion, due to hysteresis. By varying the depth of the air gap or space between the magnet and launder, or the excitation, the degree of repulsion can be varied at will to suit the material to be treated. In this way it is possible to cause the repulsion or propulsion of magnetite to take place, using an air gap of a depth of several inches, and thus avoid the difficulties of polar attraction which would otherwise make the treatment of this material difficult or impracticable.

The invention can, without departing from its principle, be applied in connection with the treatment of powdered ores or minerals in the form of pulp, or in the dry condition, in various forms of ore-dressing machines.

What I claim is:—

1. A method of effecting the electro-magnetic separation or concentration of mineral material, said method consisting in causing the material, in a finely divided condition, to move through a multiphase magnetic field arranged to move in the direction of movement of the material, causing matter in the said material that is responsive to such magnetic field to be repelled thereby laterally to opposite sides of the longitudinal central portion of said field and also longitudinally, and in a direction vertical to said moving field, and causing the matter that is not repelled or not so strongly repelled by such field to move longitudinally through the central portion of said field.

2. In the method of effecting the electro-magnetic separation or concentration of mineral matter according to claim 1, causing the responsive material that is repelled in op-

posite lateral directions and also longitudinally, to move longitudinally in two outer separated streams and causing matter that is not responsive or not so strongly responsive to the multiphase magnetic field to move longitudinally as a separate stream located between the said outer streams.

3. A method of effecting the electro-magnetic separation or concentration of mineral material, said method consisting in causing the material, in a finely divided condition, to move in a downward direction through a downwardly extending relatively long and narrow multiphase magnetic field arranged to move in the direction of movement of the material, causing matter in the said material that is responsive to said multiphases magnetic field to be repelled thereby to opposite sides of the longitudinal central portion thereof and also longitudinally and in a direction vertical to said moving field, and causing matter that is not repelled or not so strongly repelled by said field, to move longitudinally as a separate stream through the longitudinal central portion of said field.

4. A method of effecting the electro-magnetic separation or concentration of mineral material, said method consisting in causing the material, in a finely divided condition, and whilst supported by a relatively long and narrow support, to move through a relatively long and narrow multiphase magnetic field arranged to move in the longitudinal direction of movement of the material, thereby causing matter in the said material that is responsive to such multiphase magnetic field to be repelled thereby to opposite sides of the longitudinal central portion of said field and also longitudinally and in a direction vertical to said moving field, and causing matter that is not repelled or not so strongly repelled, by such field, to move longitudinally as a separate stream through the longitudinal central portion of said field.

5. A method of effecting the electro-magnetic separation or concentration of mineral material, said method consisting in causing the material, in a finely divided condition and whilst supported by a relatively long and narrow support, to move through a relatively long and narrow multiphase magnetic field arranged to move in the longitudinal direction of movement of the material, thereby causing matter in the said material that is responsive to such multiphase magnetic field to be repelled thereby to opposite sides of the longitudinal central portion of said field and in upwardly and outwardly inclined directions and also longitudinally, and in a direction vertical to said moving field, and causing matter that is not repelled or not so strongly repelled by such field, to gravitate in opposite directions towards the longitudinal central portion of said field and to move longitudinally through the said longitudinal central portion of said field.

6. A method of separating or concentrating mineral material, said method consisting in causing the material, in a finely divided condition, to move through a relatively long and narrow multiphase magnetic field arranged to move in the direction of movement of the material, and adjusting the strength of said multiphase magnetic field so that, metalliferous matter in the said material can be rendered responsive to the said field in such manner that it will be repelled thereby to opposite sides of the longitudinal central portion of said field and also longitudinally and in a direction vertical to said moving field, and causing matter that is not repelled or not so strongly repelled, by such field, to move longitudinally through the central portion of said field.

7. A method of separating or concentrating mineral material, said method consisting in causing the material, in a finely divided condition, to move through a relatively long and narrow multiphase magnetic field arranged to move in the direction of movement of the material and which is of different strengths at different parts of its length, causing matter that is responsive to such multiphase magnetic field to be repelled thereby to opposite sides of the longitudinal central portion of said field and also longitudinally and in a direction vertical to said magnetic field and causing matter that is not repelled or not so strongly repelled, by such field, to move longitudinally through the said longitudinal portion of said field.

8. The herein described method of separating feebly magnetic matter, in a finely divided condition, from finely divided material containing it, said method consisting in repelling the finely divided feebly magnetic matter in opposite lateral and longitudinal directions and also vertically, from a relatively long and narrow moving stream of the said material by causing the stream to move longitudinally through a relatively long and narrow longitudinally moving multiphase magnetic field co-incident with the said stream, and causing matter that is not repelled or not so strongly repelled by said field to travel longitudinally through the central portion of said field.

9. For carrying out the method of separating or concentrating mineral material hereinbefore described, apparatus comprising a relatively long and narrow multiphase electro-magnet arranged to produce a longitudinally extending multiphase magnetic field, and a relatively long and narrow launder arranged to extend longitudinally through said longitudinally extending multiphase magnetic field and through which the material to be treated can be caused to pass,

said launder having upwardly and outwardly extending side portions.

10. For carrying out the method of separating or concentrating mineral material hereinbefore described, apparatus comprising a relatively long and narrow multiphase electro-magnet arranged to produce a longitudinally moving multiphase magnetic field, and a relatively long and narrow downwardly inclined launder having opposite outwardly and upwardly inclined sides and arranged to extend longitudinally through said longitudinally extending multiphase magnetic field and through which the material to be treated can be caused to flow.

11. For carrying out the method of separating or concentrating mineral material herein described, apparatus comprising a relatively long and narrow multiphase electro-magnet adapted to produce a longitudinally moving multiphase magnetic field, means adapted to enable the material to be treated to move longitudinally through the said longitudinally moving field and of matter responsive to said field to be repelled to opposite sides thereof and also longitudinally and at right angles thereto, and means adapted to deliver said material into the central portion of said moving field at one end thereof.

12. For carrying out the method of separating or concentrating mineral material herein described, apparatus comprising a relatively long and narrow multiphase electro-magnet adapted to produce a longitudinally moving multiphase magnetic field, relatively long and narrow supporting means arranged longitudinally above and extending laterally in opposite directions from said electro-magnet and adapted to enable the material to be treated to move longitudinally through said magnetic field so that matter responsive to said field will be repelled to opposite sides thereof and also longitudinally and vertically, and to permit other matter to move through the longitudinal central portion of said field and means for delivering material on to one end portion of said supporting means.

13. For carrying out the method of separating and concentrating mineral material hereinbefore described, apparatus comprising a relatively long and narrow multiphase electro-magnet arranged to produce a longitudinally moving multiphase magnetic field, a relatively long and narrow launder arranged longitudinally above said electro-magnet so as to extend longitudinally through said moving field and through which the material to be treated can be caused to pass, said launder extending laterally in opposite directions relatively to the opposite sides of said electro-magnet, and means for delivering the material to be treated on to the central portion of said launder, at one end thereof.

14. For carrying out the method of separating and concentrating mineral material hereinbefore described, apparatus comprising a relatively long and narrow downwardly inclined multiphase electro-magnet arranged to produce a longitudinally moving multiphase magnetic field, a relatively long and narrow downwardly inclined launder arranged above said electro-magnet and extending laterally beyond opposite sides thereof and means for delivering the material to be treated on to the central portion of said launder at one end thereof.

15. For separating or concentrating mineral material, apparatus comprising a relatively long and narrow multiphase electro-magnet adapted to produce a longitudinally moving multiphase magnetic field, a relatively long and narrow launder arranged longitudinally above said electro-magnet and extending laterally from the sides thereof, means for varying the action of said field at different parts of the length of said field on said material, and means for delivering the material to be treated on to the central portion of said launder at one end thereof.

16. For separating or concentrating mineral material, apparatus comprising a relatively long and narrow multiphase electro-magnet adapted to produce a longitudinally moving multiphase magnetic field, a relatively long and narrow launder arranged longitudinally above said electro-magnet and having its opposite longitudinal edges at a higher level than its longitudinal central portion, and means for delivering material to be treated, on to the central portion of said launder and moving magnetic field at one end thereof.

Signed at London, England, this twenty-fifth day of April, 1924.

WILLIAM MORRIS MORDEY.