

March 28, 1961

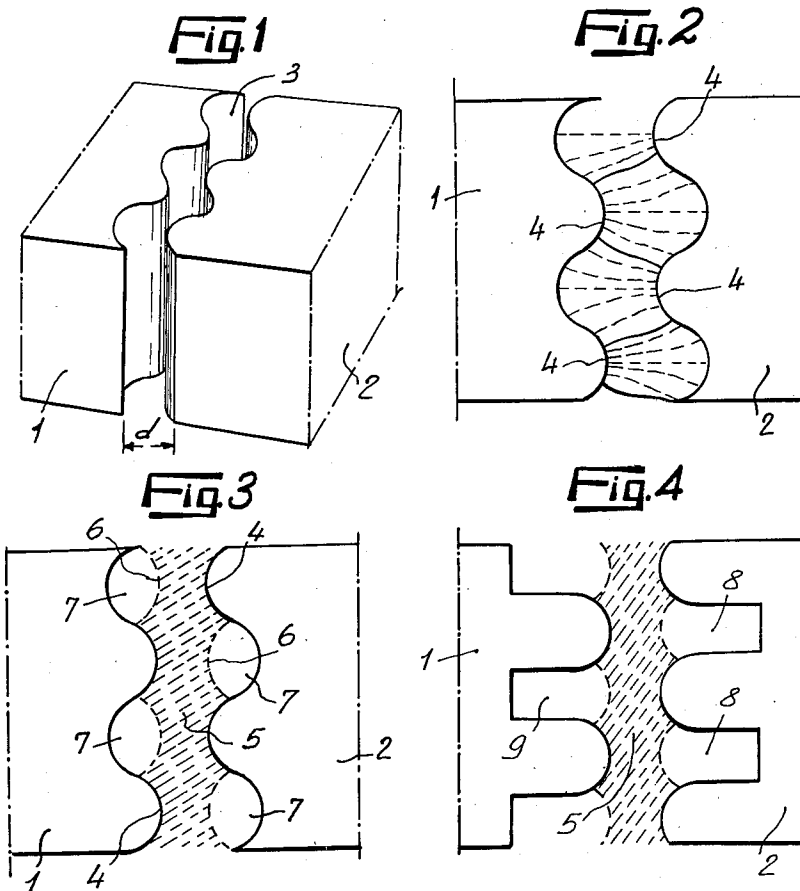
R. C. FORRER

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MAGNETIC SEPARATOR OPERATING IN AN AQUEOUS MEDIUM

Filed Jan. 10, 1957

4 Sheets-Sheet 1



INVENTOR
ROBERT CHARLES FORRER
By *A. John Michel*
ATTORNEY

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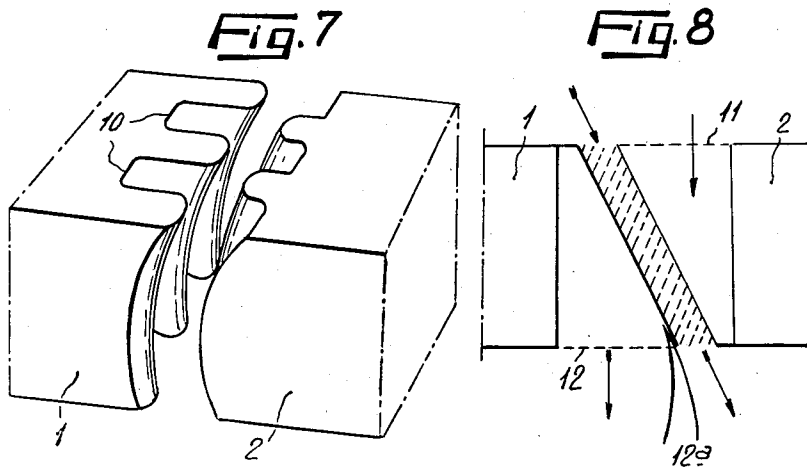
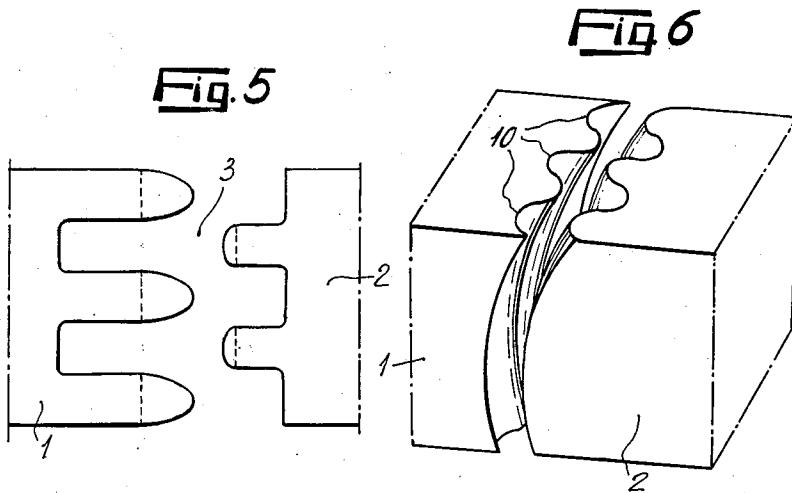
R. C. FORRER

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INVENTOR
ROBERT CHARLES FORRER
By *A. John Michel*
ATTORNEY

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R. C. FORRER

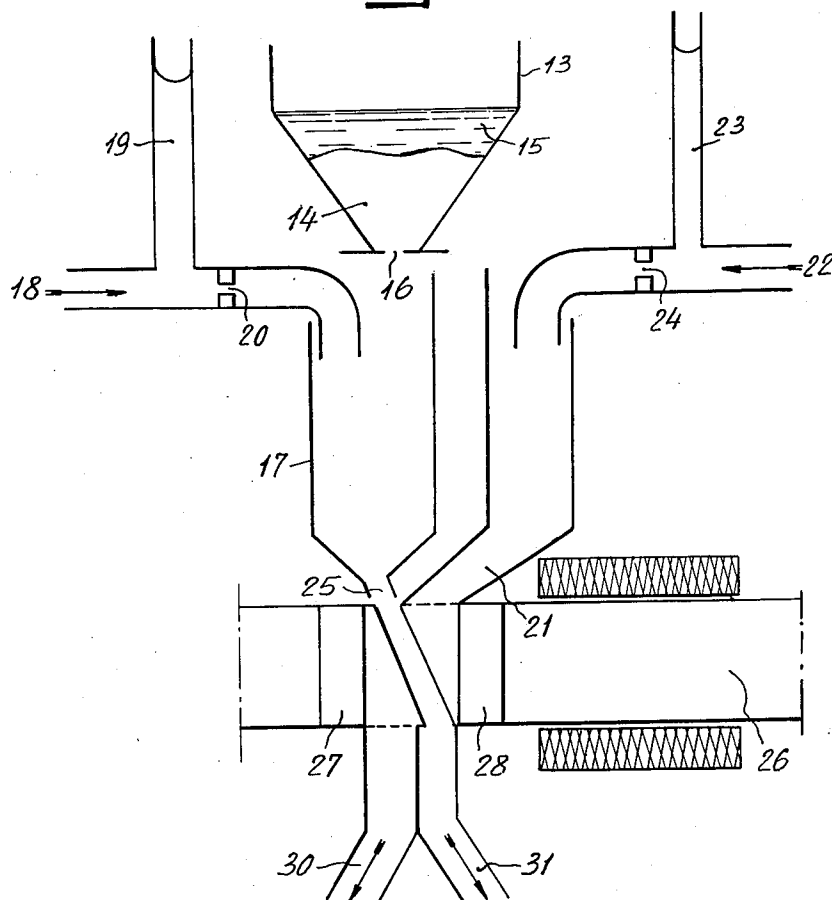
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Fig. 9



INVENTOR

ROBERT CHARLES FORRER

By *A. John Michel*
ATTORNEY

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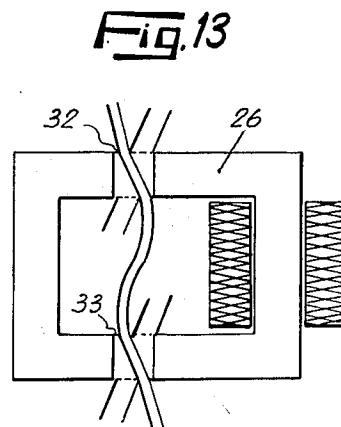
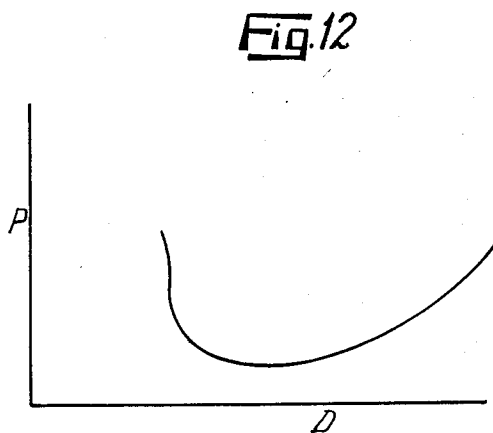
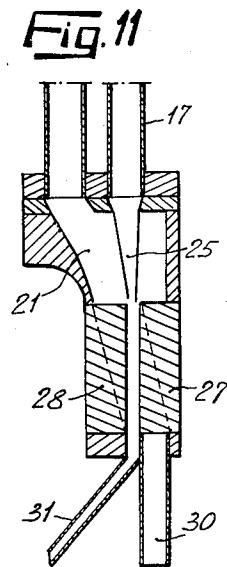
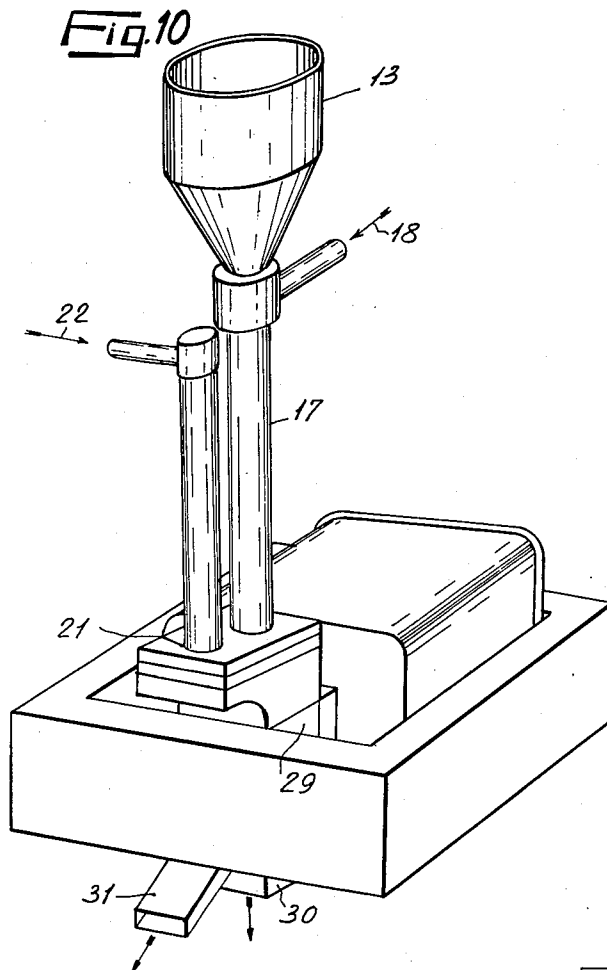
R. C. FORRER

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4 Sheets-Sheet 4



INVENTOR
ROBERT CHARLES FORRER
By *A. John Michel*
ATTORNEY

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MAGNETIC SEPARATOR OPERATING IN AN AQUEOUS MEDIUM

Robert Charles Forrer, 4 Rue de l'Universite,
Strasbourg, France

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4 Claims. (Cl. 209—223)

Numerous ores serving for metallurgical purposes are paramagnetic and this is the case for instance with ores containing iron or manganese. In their natural state, these ores are often associated with non-magnetic components, the so-called deads. It is of advantage to separate and remove these deads which often detrimentally affect the subsequent operations or make them more expensive.

The above-mentioned ores are often wet either in their natural state or as a consequence of a preliminary treatment. The separators existing at the present time and for instance the separators with a rotary armature do not operate correctly otherwise than on carefully dried ores. But such a drying makes their operation expensive.

My invention has for its object the provision of a magnetic separator operating in an aqueous medium, which allows cutting out the drying step and obtaining a more economical separation.

To this end, my invention provides a magnetic separator for aqueous media containing in suspension substances which behave in a different manner from a magnetic standpoint, said separator including in principle two pole-pieces, the operative surfaces of which extend at a short distance from each other so as to produce a field of a high intensity and the transverse outline of which is such that the magnetic fields generated are not uniform at any point, the magnetic attraction being directed alternately towards either pole-piece surface without any discontinuity while in certain areas of the gap the magnetic field has an intensity and a non-uniformity which are smaller so that, during the separation, the apparent specific weight of the magnetic substance is lower therein and thus a sort of magnetic channel is formed between said pole-pieces on the inside of a magnetic barrier formed by the areas in which the lack of uniformity of the field multiplied by its intensity reaches its maximum value, such a channel retaining the magnetic substances while the pole-pieces thus designed and shaped are furthermore associated with mechanical means for constraining an aqueous medium to flow between them so that the paramagnetic and weakly ferromagnetic particles may follow the magnetic channel in contradistinction with the non-magnetic particles which are removed outside said channel.

According to a further feature of my invention, the above-mentioned mechanical means are constituted by eddies arising suddenly through the circulation of the aqueous medium between the pole-pieces.

According to a further feature of my invention, the above mentioned mechanical means are such as will produce a centrifugal force which develops inside the aqueous current as a consequence of the special shape given to the pole-pieces.

According to a further feature of my invention, the mechanical means referred to are constituted by a stream of water flowing obliquely from the top to the bottom of the magnetic channel.

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According to yet a further feature of my invention, the pole-pieces are made of alloys having a very high mechanical hardness together with a high magnetic saturating capacity.

5 Still further features and advantages of my invention will appear in the reading of the following description of a number of embodiments given by way of example and by no means in a limiting sense, said embodiments being illustrated in the accompanying diagrammatic drawings wherein:

10 Fig. 1 is a diagrammatic perspective view of a first embodiment of the pole-pieces.

Fig. 2 is a horizontal cross-section of the same embodiment showing the lines of force.

15 Fig. 3 is a similar cross-section showing the action of the magnetic channel.

Fig. 4 is a horizontal cross-section of a further embodiment of the pole-pieces with the magnetic channel between same.

20 Fig. 5 is a horizontal cross-section of a still further similar embodiment wherein the pole-pieces are dissymmetrical and have elliptic outlines.

Fig. 6 illustrates diagrammatically and in perspective view another embodiment of the pole-pieces of the type illustrated in Fig. 1, the pole pieces being given furthermore a curvature which constrains the particles to be subjected to centrifugal force.

25 Fig. 7 is a perspective view of a similar embodiment of the pole-pieces for the case where the latter are dissymmetrical.

30 Fig. 8 illustrates diagrammatically in vertical cross-section the dissymmetrical pole-pieces of Fig. 4 through which a transverse flow of water is provided.

35 Fig. 9 is a vertical diagrammatic cross-section of the main elements of a separator according to my invention associated with means for introducing a second stream of water.

Fig. 10 is a perspective view of the same separator.

40 Fig. 11 is a vertical cross-section of the injectors and of the pole-pieces of said separator.

Fig. 12 is a graph with a curve illustrating the behaviour of my improved separator.

45 Fig. 13 illustrates diagrammatically a separator which allows the aqueous mixture to pass twice through the same magnetic channel.

50 Different advantageous characteristics of the magnetic channel forming one of the chief elements of the invention result from the special shape given to the pole-pieces of an electromagnet as illustrated in Figs. 1 to 8. It should be understood that the magnetic channel is obtained as a consequence of the shape of the pole-pieces. In Fig. 1, for instance, the pole-pieces 1 and 2 the horizontal cross-section of which has a curvilinear S-shaped cross-section are separated by a relatively small distance d . Between said pole-pieces is thus formed a material channel 3; the height of the channel as shown in the drawing determines the time during which the granular ore forming a suspension in a comparatively large amount of water remains in said channel, taking into account the speed of the stream of water and the length, i.e. the third dimension of the channel defining the throughput. As shown in the drawing, the meandering shape of the gap is uniform throughout its height.

55 Fig. 2 is a cross-section of the gap of Fig. 1 and shows the lines of force across it. The characteristic action of this gap consists in attracting and collecting the magnetic particles towards the projecting sections 4 and between opposite projecting sections on either side of the gap so that they are concentrated in the areas illustrated by a hatching in Fig. 3. Said areas forming thus the actual magnetic channel 5 are defined by the pole-pieces 1 and 2 and by virtual magnetic barriers drawn diagrammatically at 6. This shape of the gap is of particu-

lar advantage since the magnetic particles which may have gone astray into the concavities 7 are urged back into the magnetic channel 5.

The horizontal outline of the pole-pieces may differ from that which has just been described. For instance Fig. 4 shows pole-pieces with deeper recesses 8 and 9, the magnetic channel being again shown at 5 by a hatching. The characteristic magnetic features of said channel differ but slightly from those of the above described channel. However, the shape illustrated in Fig. 4 has the advantage of allowing an auxiliary stream of water to flow in parallelism with the magnetic channel or else transversely with reference to same, for instance, from the areas 8 towards the areas 9 through the magnetic channel 5. In contradistinction, it shows a drawback since the magnetic particles gone astray into the areas 8 or 9 are urged back with a lesser energy towards the magnetic channel 5. In the case of a transverse stream of water being provided, the preceding shape may be advantageously modified and become dissymmetrical and include even substantially elliptic outlines for the elementary pole-pieces as illustrated in Fig. 5 and in fact such a dissymmetrical elliptic shape leads to the formation of a magnetic channel the magnetic barriers of which are more efficient and show advantages from a hydrodynamic standpoint.

The non-magnetic particles forming the deads of the magnetic ores are thus urged into the lateral areas on the side of the magnetic channel such as 7, 8, 9 in the case of Figs. 3 and 4 and, according to a further chief object of my invention, there is provided a structure for removing these non-magnetic substances. In the modification illustrated in Figs. 1 to 3, the throughput of water should be sufficiently large so as to prevent the magnetic particles from adhering to the pole-pieces. In practice and by reason of the small cross-section of the material channel 3 (Fig. 1), the speed of the aqueous stream is of the order of 1 to 2 meters/second and consequently there arise permanently eddies which disperse energetically the particles of deads and much less energetically the magnetic particles. It is then possible to collect a fraction of the particles of deads inside the areas 7 (Fig. 3), but the removal of such particles through said means is obtained on a comparatively reduced scale.

A more favorable arrangement is illustrated in Fig. 6 which is a perspective view of the pole-pieces 1 and 2 the vertical outlines of the operative surfaces of which have a predetermined curvature. In this case, the aqueous mixture of the particles of magnetic ore and of deads injected at the upper end of the arrangement is partly subdivided, the particles of deads being projected centrifugally into the grooves or recesses 10 shown on the left hand side of the figure while the magnetic particles follow mainly the magnetic channel defined precedingly.

Obviously, this principle of a curvature of the vertical outline of the pole-pieces is of interest whatever may be the horizontal outline of such pole-pieces and Fig. 7 illustrates diagrammatically and in perspective view pole-pieces the vertical outline of which has a predetermined curvature while the outline of a horizontal cross-section is given a dissymmetrical shape of the type illustrated in Fig. 5.

Lastly, and as disclosed hereinabove, the shape of the pole-pieces according to Fig. 4 allows a transverse auxiliary stream of water to pass through the channel. Fig. 8 is a vertical cross-sectional view of the arrangement of Fig. 4, said cross-section passing through the grooves or recesses 9 and 8 and crossing an auxiliary stream of water, which flows out of the groove 8, as shown at 11, into the magnetic channel 5 and is exhausted at 12 through the groove 9. This stream of water removes the non-magnetic particles of deads while the magnetic particles are retained inside the magnetic channel 5. A deflector 12a at the output end of the arrangement pro-

vides for the separation between the two kinds of particles.

Obviously, it is possible to associate any possible type of magnetic channel with either of the means used for the circulation of the aqueous medium between the pole-pieces so as to remove the non-magnetic particles. It is possible for instance to associate the magnetic channel having a horizontal meandering or substantially S-shaped outline with a removal of the deads through a dispersion by eddies or else with their removal through centrifugal force. It is also possible to associate the magnetic channel with deep grooves or recesses either with the removal of the deads through a dispersion by eddies together for instance with an auxiliary injection of water on either side or else with the elimination of the deads through a transverse stream of water or again with the removal of the deads through centrifugal force cooperating with a transverse stream of water.

The above referred to embodiments will be better understood when considering Figs. 9, 10 and 11 which show diagrammatically, in perspective view and in partial cross-sectional view respectively the main elements forming a preferred embodiment of a complete separator according to my invention.

In said figures is shown a funnel 13 containing at 14 (Fig. 9) the crushed ore constituted for instance by granules of 0.5 millimeter; said ore includes magnetic particles and particles of deads. The ore is covered by a layer of water 15 which serves for fluidizing the particles at the output end of the funnel. Ports of different sizes are provided selectively at 16, said ports serving for the adjustment of the throughput of ore. The latter drops into the mixer 17 and is intimately mixed with the water introduced at 18, the output of which water is measured by the manometer 19 and adjusted by the throttled opening 20.

An auxiliary water injector 21 is fed with water entering it at 22 while its output is measured by the manometer 23 and is adjusted by the throttled opening 24. The ore which is fluidized inside the water contained in the mixer passes through the injector 25 into the gap between the pole-pieces 27 and 28 of the electro-magnet 26 (Fig. 9), said pole-pieces being laterally protected by the casing 29 (Fig. 10), at the lower end of the apparatus the water laden with ore enriched with deads flows out at 30 while the water enriched with magnetic particles is exhausted at 31.

The main stream of water containing the particles of magnetic ore which comes from injector 25 (Fig. 9) and the auxiliary stream of water which enters from injector 21 will form, as soon as they enter the gap between pole-pieces 27, 28, a single mass of water which must necessarily pass through the inclined magnetic channel to escape to a larger extent through line 30 and to a smaller extent through line 31. The particles of non-magnetic ore will follow chiefly the stream of water passing through line 30. The magnetic particles which are maintained in the specially created magnetic channel will follow the latter in a direction slightly inclined to the stream of water flowing in direction of line 30 and will be evacuated through the line 31.

The above described apparatus is of a reduced size while it allows the passage of a large hourly tonnage of ore to be magnetically sifted, say one to two tons per hour and per meter of length of the magnetic channel or slot, this large tonnage being ensured by the speed of the stream of water. The height of the pole-pieces in the example illustrated is equal to about 5 centimeters while the sinuosities of the magnetic channel are of the order of six millimeters. The pole-pieces are rounded at their upper and lower ends so as to prevent any ancillary attraction which might risk clogging the sinuosities and said pole-pieces are carefully chromium-coated so as to cut out any corrosion through the water. As disclosed hereinabove, one or more separating blades or deflectors 12a

(Fig. 8) are fitted inside the lower part of the pole-pieces along the boundary of the magnetic channel.

When gauging the various types of apparatus described hitherto, hematite has been used as a magnetic substance while diamagnetic sand has formed the deads. For each magnetic energization, the losses P of magnetic substance passing out with the deads have been plotted against the throughput of water D (see graph of Fig. 12) and on the series of curves thus obtained it is possible to select the magnetic energization and the throughput of water which lead to a minimum for such losses P. In the case of an apparatus through which a transverse stream of water flows for instance, I have obtained for an average field inside the gap of say 5,000 to 7,000 oersteds and for the most favorable throughput of water a loss P equal to about 1% while the percentage of deads removed was equal to about 30%. When resorting to similar apparatus, wherein the shape of the magnetic channel and the means for removing the deads were different, the results obtained were substantially the same. These experiments have been made with pole-pieces the height of which was about 5 centimeters. It is possible to substantially improve the rate of elimination of the deads by resorting to higher pole-pieces.

Furthermore, it should be remarked that it is an easy matter to modify the above results through slight modifications in the arrangement, for instance by modifying the distance between the pole-pieces, by changing the location of the deflector, by adjusting the amount of auxiliary water entering the arrangements, etc.

Similarly, it is possible to recycle the enriched fraction of the ore several times through the apparatus so as to increase the amount of deads removed and the final deads obtained may be subjected to a further treatment for recovering the para-magnetic particles which have found their way into the deads, while the intermediate products ranging between the concentrated ore and the deads collected at the output of the separators between suitably positioned partitions may be subjected to further treatment and in fact these three treating procedures may be applied in succession by resorting to arrangements suiting each type of treatment.

An advantageous system of pole-pieces, illustrated in Fig. 13, provides two passages 32 and 33 for the ore carrying liquid in the same magnetic circuit.

Lastly, it is possible to provide two arrangements similar to that of Fig. 13, associated with a single field coil so as to cut out any overhanging and to allow the same loading and discharging means to serve for both arrangements.

Obviously, my invention is by no means limited to the embodiments described and it is possible without widening the scope of the invention as defined by the accom-

panying claims to resort to many detail modifications and improvements and also to substitute for the means described other equivalent means.

What I claim is:

1. An apparatus for separating particles of different magnetic characteristics forming a suspension in an aqueous fluid, said apparatus comprising, in combination, two pole pieces the cross-sections of which throughout their height and in a direction perpendicular to that intended for the flow of the suspension have meandering outlines, said pole pieces defining therebetween a gap comprising a median part and comparatively small recess bounded by said outlines whereby a non-uniform magnetic field of a high intensity is produced in said median part, the portions of the magnetic field in said recesses being weaker and more uniform than the portion of the magnetic field in the median part of said gap, said last mentioned portion of the magnetic field constituting a magnetic channel and two magnetic barriers being formed between said channel and the portions of the magnetic field in said recesses whereby the magnetic particles already located in said channel remain in the channel and the magnetic particles located in said recesses are attracted into said channel; and means for causing the suspension to flow through said gap whereby the paramagnetic and weakly ferromagnetic particles accumulate in and are discharged from the median part of said gap and only the weakly magnetic particles are discharged from said recesses.

2. The apparatus of claim 1, wherein said pole pieces consist of an alloy of high magnetic saturation and high mechanical hardness.

3. The apparatus of claim 1, wherein said gap is incurved in such manner that the weakly magnetic particles are urged from the median part of said gap into said recesses under the action of centrifugal force while the magnetic particles are maintained in said channel by the magnetic force.

4. The apparatus of claim 1, further comprising means for feeding a second aqueous fluid into the gap and at an angle with respect to the flow of said suspension in the channel, said second fluid entraining the weakly magnetic particles from said channel into said recesses.

References Cited in the file of this patent

UNITED STATES PATENTS

2,056,426 Frantz ----- Oct. 6, 1936

FOREIGN PATENTS

337,759 Great Britain ----- Apr. 30, 1929

633,373 Great Britain ----- Dec. 12, 1949

684,279 Great Britain ----- Dec. 17, 1952

729,487 Germany ----- Dec. 17, 1942