This invention relates to electromagnetic separator devices and more particularly to such devices which are adapted to treat ores, residues and the like materials while in suspension in a fluid medium. Still more particularly this invention is an improvement of the invention described and claimed in a prior Patent No. 2,088,364, issued July 27, 1937, to E. E. Ellis and Augustin Leon Jean Queneau. The present applicant is one of the joint inventors of the invention of the said patent.

One of the objects of the present invention is to provide a magnetic separator device incorporating an improvement of the principles of the said prior patent. Another object of this invention is to increase the capacity of the device of the said patent. Still another object is to provide a duplex magnetic type of magnetic separator device based on the principles of the said prior invention which is adapted to more economically treat ores, residues and the like of relatively low commercial value. Other objects and advantages will be apparent as the invention is more fully disclosed.

In accordance with the above objects I have devised the duplex separator device of the present invention of which the following description together with the accompanying drawings is a full and complete disclosure. Before further disclosure reference should be made to the accompanying drawings wherein—

Fig. 1 is a side elevational view in section of the device of the present invention; Fig. 2 is a top view partly in section of the same; Fig. 3 is a view taken along plane 3—3 of Fig. 1; Fig. 4 is an enlarged end view illustrating one feature of the present invention; Fig. 5 is a perspective view of the same; Fig. 6 is an opposite perspective view of the same; and Figs. 7 and 8 illustrate optional modifications of another feature of the invention.

The present invention incorporates the essential features of flowing a suspension of materials under hydrostatic pressure in a container through an electromagnetic field projected through the suspension transversely to the direction of flow of the suspension between rotatable magnetic pole ends disposed adjacent opposite side walls of the container and in progressively moving the magnetically attracted particles along the inner face of the container side walls, by a rotation of the said rotatable pole ends, through the magnetic field and into channels of flow separate from the channel of flow of the main body of the suspension, which features were described and claimed in the above identified patent.

The invention of this said Patent No. 2,088,364 has been subject to improvement in other ways as indicated by my applications for Letters Patent Serial No. 130,987, filed January 16, 1937; Serial No. 133,242, filed March 26, 1937; Serial No. 140,-930 filed May 5, 1937. The inventions of these said applications have in part or in whole also been utilized in the present invention, together with new features as will be hereinafter described.

I have found that in the treatment of ores, residues and the like in the general type of device described and claimed by the prior patent identified particularly in the treatment of those ores of relatively low magnetic susceptibilities and of relatively small magnetic susceptibility differences between the desired and undesired constituents and also those in which the desired magnetic constituent is present in relatively low proportions, it is necessary to separate the desired magnetic constituent in a succession of cuts or steps, making the first separation with the lowest operable magnetic field strength and succeeding separations at progressively higher field strengths until the maximum field strength permissible for any given constituent is applied, or until an economically practical total removal of the constituent has been obtained. This necessitates the repeated passage of the suspension through the device of the said patent even though at each pass through the device the magnetically attracted particles are separated in two portions, one at each pole.

In the treatment of ores in which the desired constituent is of relatively low market value, such as low grade iron ores, it is desirable to reduce the costs incident to the recovery or segregation of the iron constituent from the gangue to the lowest practical figure to enable the recovered iron constituent to compete economically with natural ores of higher iron content.

I have accordingly devised the duplex device indicated in the drawings whereby in one passage through the electromagnetic separator device I may obtain twice the amount of concentrate without substantial increase in the cost of operation, construction costs, etc. heretofore experienced with the single device of the said patent. In order to accomplish this result certain modifications are necessary in the device of the said prior patent which briefly stated are (1) means to horizontally sustain two pairs of electromagnetic poles in horizontal spaced relation with the
spaced ends of each pole adjacent opposite side walls of the container; (2) means to uniformly energize the two pairs of electromagnetic poles; (3) the provision of means to progressively remove the concentrate separated by the two upper magnetic poles; (4) the provision of hydraulic barrier means at the entrance to each concentrate collecting chamber for the magnetically suspended particles; and (5) means to progressively remove the separated magnetic particles from the lower concentrate collecting chamber without disturbing the hydraulic balance of the system.

The device illustrated in the accompanying drawings includes these several modifications above noted.

The first modification above identified was obtained by changing the pole structure from a rectangular cross-section to a substantially T-shaped cross-section as indicated in Figs. 4, 5 and 6, wherein the pole piece generally is identified by letter P, P'. Adjacent the top and bottom of the T portion of each pole (P-P') I provide parallel spaced arcuate recessed extensions I-I' adapted to receive rotatable pole ends 2-2'. As indicated in Fig. 1, I provide container 3 with appropriately located arcuate recesses in opposite side walls to receive the rotatable pole ends 2-2' leaving interiorly the container 3 between the inner curved surfaces a desired space between opposite spaced pole ends. A central partition 4 is provided in container 3 to effectively divide the container into two symmetrical halves, the structure to the left of partition 4 and the pole pieces and other means associated therewith being substantially identical to the structure to the left of the partition 4 and being essentially complementary thereto. Accordingly, in the following description the structure to the left of partition 4 will be referred to specifically, it being understood that the same description applies to the opposite or right half of the device.

Pole piece P is provided with a main magnetizing coil C encircling the rectangular shank thereof and two auxiliary magnetizing coils c-c', c'' located respectively on stubs 5-5' disposed on the back of the T portion of the pole P in a position adapted to bring the centers of coils c-c', c'' in horizontal alignment with the horizontal axis of rotors 2-2'. The outer ends of poles P-P' are linked together by rectangular shaped yoke Y to form a closed magnetic path horizontally about the spaced inner end of the poles P-P'. Means, not shown, are provided to energize the coils C, c' and c'', either in series or in parallel, to obtain the desired uniform magnetizing field between the two sets of oppositely located pole ends 2-2', as one skilled in the art will recognize.

Container 3 is provided with aligned arcuate recesses in opposite side walls adapted to receive rotating pole ends 2-2 and 2'-2' as above noted and preferably in the manner and by the structure substantially as indicated in the drawings, with the opposite side walls above and below the said rotating pole ends extending vertically above and below the said ends at approximately the vertical axis center of the said pole ends. This particular feature may be widely varied without departing from the nature and scope of the present invention. The space gap between the pole ends 2-2 or 2'-2' also may be varied widely without departure from the present invention but by way of example, I prefer to maintain a gap between opposite inner curved surfaces of the opposite side walls to not over two inches at the closest point. Partition 4 is relatively thin, being not over \( \frac{1}{8} \) inch thick, thereby leaving a distance of three inches each side of the partition of about \( \frac{1}{8} \) inch wide.

The depth of the container between opposite end walls should approximate the length of rotor 2-2' and may be varied widely depending upon the capacity desired. I prefer to employ a rotor (2-2') of about thirty inches long, and to employ a corresponding depth of container 3, thereby giving a space gap of about two by thirty inches through which to flow the suspension of materials for treatment.

The rate of flow of the suspension or the hydrostatic pressure of the flowing suspension may be widely varied without departure from the present invention. Preferably I employ a rate of flow approximating twenty-five linear feet per minute through each space gap regulating this by means of outlet opening 20.

The surfaces of rotors 2-2' are each provided with spaced and isolated points or areas \( S \) of relatively high magnetic flux permeabilities as compared to the intervening areas \( A \), which functions to magnetically urge the magnetically attracted particles along the inner curved face of the container wall in the direction of suspension flow through the magnetic field and into channels of flow (indicated as separating chambers 8-8) separate from the channel of flow 10-11 (on opposite sides of partition 4) of the main body of the suspension, substantially as indicated by solid and dotted arrows respectively (Fig. 1). The rate of rotation of the rotors 2-2' may be widely varied without departure from the present invention but preferably should approximate the rate of flow of the suspension.

To prevent the entrance of non-magnetic particles in upper separating chamber 8, I provide a hydraulic barrier means consisting of a current of water into and out of chamber 8 in a direction countercurrent to the flow of suspension into the chamber through the space gap between the top of partition 15 and the inner surface of the curved side wall of container 3 as indicated by arrows, which flow of water is at a pressure sufficiently high to prevent the suspension entering chamber 8 but insufficient to keep out the magnetic particles as they are magnetically urged through the gap. The pressure of water is obtained from reservoir 13 provided with a constant level overflow 14, a supply feed 15, and a delivery pipe 16 provided with a control valve 17 regulating the flow of water under the head of pressure in reservoir 13 to twin conduits 18-19 opening into opposite ends of chamber 8 as indicated at 19.

To provide means to remove the magnetic concentrates collecting in upper separating chambers 2'-2' I provide a plurality of conduits 20 opening at spaced intervals into the bottom of chamber 8 and adapted to convey the concentrates collecting in the bottom of chamber 8 through the lower magnetic field between poles 2'-2' into the bottom chamber 8 substantially as indicated by arrows extending across a relatively small cross-sectional area and in order to avoid restricting the surface area for separating magnetic particles in the lower magnetic field are preferably spaced inwardly from the inner curved surface of the bottom recess of container 3 a distance permitting free access of the suspension flowing through the lower space gap to this inner
The magnetic particles concentrating in upper chamber 8 feed first by gravity into conduits 20 assisting in the delivery of concentrates through into lower concentrate chamber 9. The concentrates in passing through the lower magnetic field are progressively moved through and by the combined action of hydrostatic pressure in conduits 20 and the magnetic pull of rotating rotors 2'—2". In Figs. 7 and 8 I have indicated two optional modifications of conduits 20 as 20' and 20" respectively.

The lower rotors 2'—2" deliver additional concentrates into lower chamber 9 in the same manner as hereinafore described with respect to the separator obtained in the upper magnetic field and the two concentrates thus obtained pass by gravity into collecting chamber 21 (21'). In the arrangement shown, collecting chamber 21 is in a closed hydraulic circuit with lower separating chamber 3 and the concentrates collected in chamber 21 create, by displacement, an additional hydrostatic pressure in separating chamber 9 to that introduced by the magnetic action of the suspension into separating chamber 9.

It is desirable, however, to provide means to continuously remove the accumulating concentrates from collecting chamber bin 21 so that continuous operation of the separator device may be obtained. I accomplish this by means of motor driven rotary valving cylinder 23 provided with a plurality of chambers 24 which are arranged to be sequentially positioned upon rotation beneath an opening in the bottom of chamber 21 and to be aligned with said slot openings from the chamber. By means of motor driven pump means 25 I may regulate the flow of water from reservoir 26 through conduit 27 into chamber 9 exactly to the amount necessary to replace the volume of material removed by chambers 24, thereby maintaining the hydraulic balance in the closed circuit of collecting chamber 21 and separating chamber 9. If necessary, I may provide such an excess of volume of water to supplement that already present as may be necessary to complete the hydraulic barrier at the entrance to lower separating chamber 8.

As indicated in the drawings, the main flow of suspension in container 3 passes on both sides of center partition 4, baffles 28 serving in part to divert the flow of suspension from feed pipe 29 to each side of partition 4. Partition 4, however, does not extend all the way to the bottom of container 3 and the suspension from each side of partition 4 joins in passing to a common valve outlet opening 30. Baffle means 31 is provided so as to prevent dripping of vertically falling suspension towards the inclined bottom walls of container 3 to prevent chocking of the valve outlet 30. The desired hydrostatic head of pressure in container 3 is maintained with any given sized openings in valve 30 by adjusting the rate of feed of suspension into container 3 through feed pipe 29 to that which will maintain a slight overflow through overflow conduit 32.

The particular structural features of the rotors 2—2", the manner and means for rotatably mounting the rotors 2—2" and the manner and means for driving the same are substantially the same as I have heretofore described and claimed in my prior applications above identified, and as these features specifically form no part of the present invention will not be described in detail although indicated in the drawings.

Whereas, I have indicated in the above description and drawings a pair of horizontally disposed electromagnetic fields, it is within the scope of the present invention to employ three or more and the term "duplex" as herein employed is to be construed to mean "two or more pairs of poles or two or more parallel spaced electromagnetic fields."

From the above description of the present invention and from the drawings illustrating the same, it is apparent that many modifications and departures may be made without essentially departing from the nature and scope thereof as may be included within the following claims.

What I claim is:

1. An electromagnetic separator device comprising a vertically sustained container, means to flow a suspension of materials under hydrostatic pressure downwardly through said container, means to project at least two vertically spaced electromagnetic fields through said container between opposite side walls of the container, vertically spaced slot openings in each side wall of said container, said openings being disposed in a position relative to the electromagnetic fields to lie in the lower portion of each said field, upper and lower separating chambers exteriorly of said container and communicating with said slot openings, each said chamber being in substantially closed hydraulic circuit with the container, means to magnetically move the magnetically attracted particles in each said field downwardly along the inner surface of the container and through said slot openings into said separating chambers, means to progressively discharge the magnetic material collected in the upper separating chambers into the lower separating chambers without disturbing the closed hydraulic relationship of the chambers and container and means to remove the magnetic material from the lower separating chambers without disturbing the hydraulic relationship of the lower chambers and container.

2. The combination of claim 1, including means to supply to each said separating chamber fluid under sufficient pressure to induce a flow of fluid from the said chambers into said container through said slot openings counter-current to the magnetic particles entering the said chambers thereby to effectively prevent the passage of suspension through the slot openings into said chambers.

3. The combination of claim 1, said last mentioned means including means to replace an equivalent volume of fluid in the said separating chambers simultaneously with the removal of said magnetic material from the chamber, thereby to preserve the hydraulic equilibrium between the chambers and the container.

4. An electromagnetic separator device comprising in combination a vertically sustained container substantially rectangular in cross-sec-
tion, each opposite side wall of the container being provided with two vertically spaced and horizontally opposite arcuate recesses extending inwardly a distance leaving a restricted rectangular shaped passageway therebetween, horizontally disposed electromagnetic pole pieces located adjacent each said recess, each said pole piece being provided with a rotatable cylindrical end piece having a diameter adapted to be received in said recesses, the peripheral surface of each said end pieces being provided with a plurality of spaced and isolated areas comprised of material of relatively high magnetic flux concentration as compared to the material of the intervening areas thereof, means to rotate each of said end pieces towards its horizontally opposite end piece and in a direction adapted to move the peripheral surface in the direction of suspension flow, means to energize said poles with a magnetizing current of desired intensity, a partition member located within the container below each said arcuate recess, the upper edge of the partition being spaced from the under curved surface of the recess forming a space gap therebetween, and the bottom and side edges of the partition joining the side and end walls of the said container to form therewith a separating chamber substantially closed to the flow of suspension therethrough, means to feed water under pressure into each said separating chamber to provide a flow through said space gap into said container countercurrent to the flow of suspension therethrough, a fluid filled collecting chamber, means to gravity feed the magnetic particles from said separating chambers into said collecting chamber, and means to discharge the collecting particles from said collecting chamber without substantial disturbance to the hydraulic balance in said collecting and separating chambers.

5. An electromagnetic separator device having a plurality of horizontally spaced magnetic separating zones each operative to remove a portion of the magnetic constituents of a material passing through said zones, said device comprising a vertically spaced elongated container substantially rectangular in cross-section each opposite side wall of the container being provided with a plurality of vertically spaced inwardly arcuate and substantially identical recesses, the recesses in one side wall being disposed opposite the recesses in the other side wall leaving a restricted rectangular shaped passageway therebetween, means to flow a suspension of materials downwardly through the container, means to maintain a substantially constant fluid level of said suspension in the container, means to magnetically attract the magnetic particles in said suspension to the inner curved surface of each said recess, means to progressively advance the magnetically attracted particles along the inner surface of each said recess in the direction of suspension flow to the under curved surface of the recess, a partition member located within said container immediately under each said recess the upper edge of the partition being spaced from the inner curved surface of the recess to form a space gap therebetween through which the said magnetic particles may be passed and the bottom and side edges forming with the container walls a separating chamber substantially closed to the flow of suspension therethrough, means to feed a pressure of water into each said separating chamber to provide a flow of water from the said settling chamber through the said space gap into said container countercurrent to the direction of flow of the suspension into the chamber, means to feed the magnetic particles by gravity from said separating chamber into a fluid filled collecting chamber, and means to remove the magnetic particles from said collecting chamber without substantial disturbance to the said hydraulic equilibrium within the said settling and collecting chambers.

6. In the combination of claim 5, said means to magnetically attract and said means to advance the magnetically attracted particles comprising two electromagnetic pole pieces in cross-section and having a height at the T section at least equal to the overall spacing between said arcuate recesses and a depth approximating that of the horizontal depth of the said side walls of the container, the top surface of the T section being provided with a plurality of arcuate recesses substantially identical to those in the side walls of the container, the rear surface of the T section being provided with a cylindrical end piece adapted to receive an electromagnetic coil, said extensions lying in about the same plane as said recesses, a cylindrical end piece for each said pole piece having a diameter adapting it to be rotatably seated within said pole recess, means to horizontally sustain said pole pieces and each said end piece in a position adapting the end pieces to rotatably seat within the side wall recesses and the pole recesses, an electromagnetic energizing coil about the shank portion of each said pole piece, an electromagnetic coil about each said extension, a horizontally sustained yoke member rectangular in shape around said pole pieces and electrically connected to the outer ends to form a closed path for magnetic flux around the pole pieces, means to energize each said magnetic coil to induce between each opposite rotatable pole end a substantially uniform and symmetrical magnetic field of desired intensity, and means to rotate each said cylindrical pole end the direction of rotation of each opposite pole end being towards the container and vertically downward, the speed of rotation being substantially uniform with each pair of opposite rotating ends.

7. In the combination of claim 5, said means to remove the collected particles from the collecting chamber without disturbance to the hydraulic balance in the collecting chamber comprising a gravity feed discharge opening in the bottom of said chamber, a motor driven rotary valving cylinder provided with a plurality of chambers each adapted to sequentially close said opening upon rotation of the said valving cylinder, a source of water, a motor driven pump to draw water from said source, means to deliver the water drawn from the source by the said pump to said chamber, and means to synchronize the operation of said pump with the operation of said valving cylinder to deliver to said chamber a substantially equivalent volume of water to that withdrawn by said valving cylinder.

8. In the combination of claim 5, said means to feed the collected magnetic particles from each said collecting chamber comprising a plurality of conduits each of relatively small cross-sectional area, and each opening at one end at spaced points along the bottom of the chamber into the bottom of each of the upper chambers and at the lower end opening similarly to the lower chambers, said conduits being comprised of
non-magnetic material and extending through the space gap between said arcuate recesses in said container side walls but in spaced relation to the inner curved surface of said recesses, the bottom of the lower said separating chambers opening into said collecting chamber to permit the gravity feed of magnetic particles thereinto, and to permit the water displaced by the accumulating magnetic particles in said collecting chamber to pass into said lower separating chamber and thence out into said container through the space gap between the upper edge of the partition and the inner curved surface of the recess adjacent thereto.

AUGUSTIN LEON JEAN QUENEAU.