(No Model.) 3 Sheets—Sheet 1.

C. Q. PAYNE.

METHOD OF AND APPARATUS FOR SEPARATING ORES.

No. 500,604. Patented July 4, 1893.

Fig. 5.

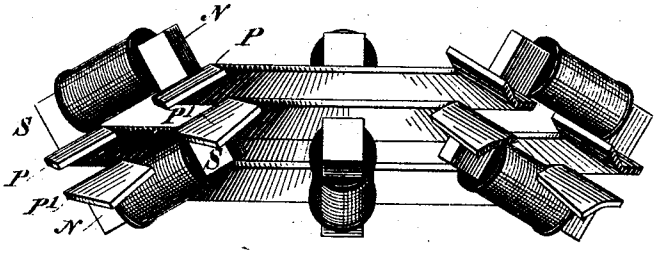
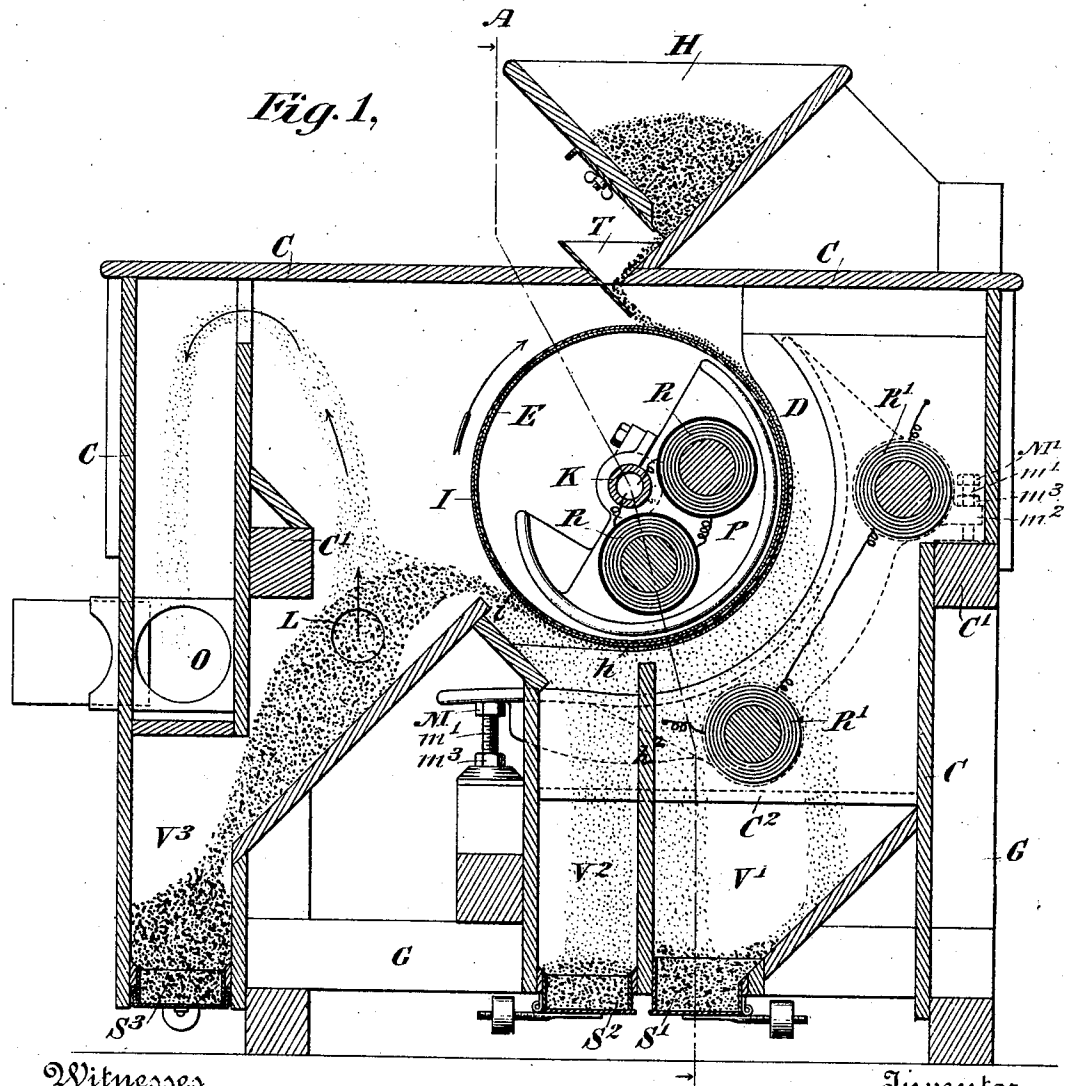


Fig. 1.



Witnesses

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(No Model.) 3 Sheets—Sheet 2.

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METHOD OF AND APPARATUS FOR SEPARATING ORES.

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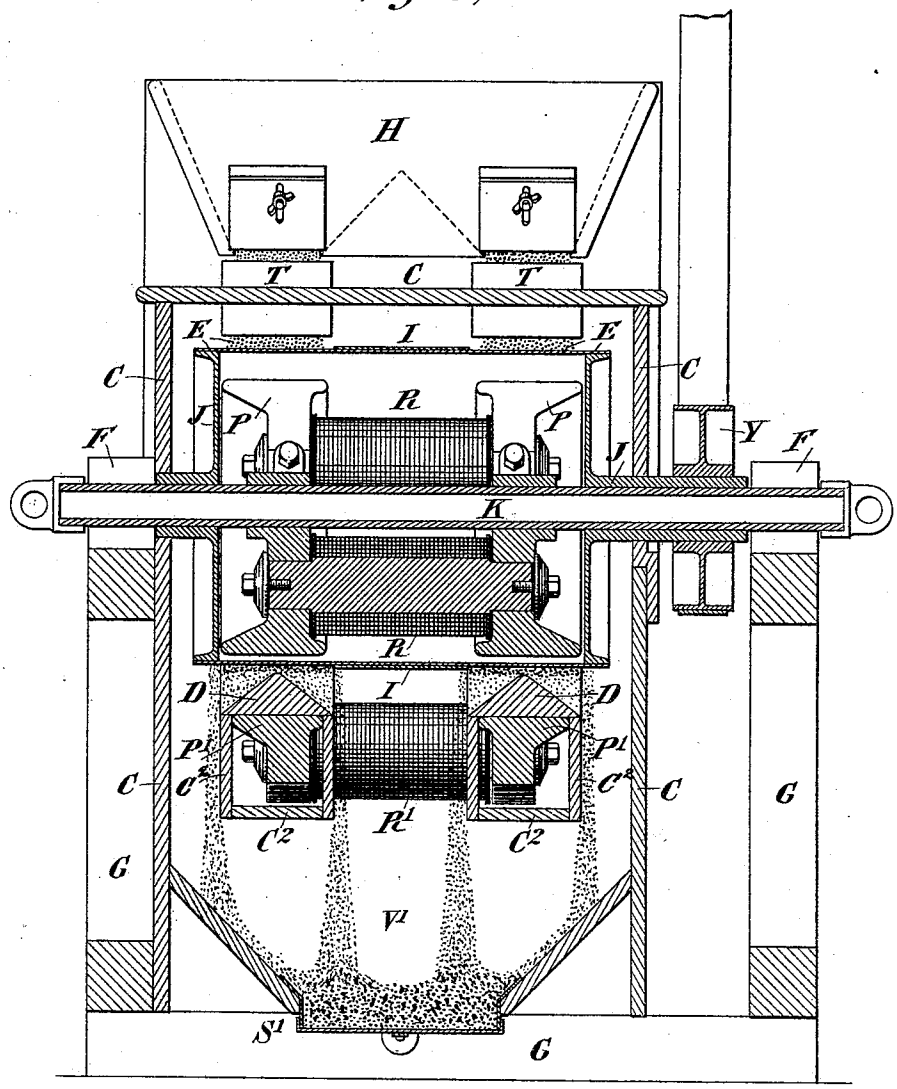
Fig. 2,



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METHOD OF AND APPARATUS FOR SEPARATING ORES.

No. 500,604. Patented July 4, 1893.

Fig. 3,

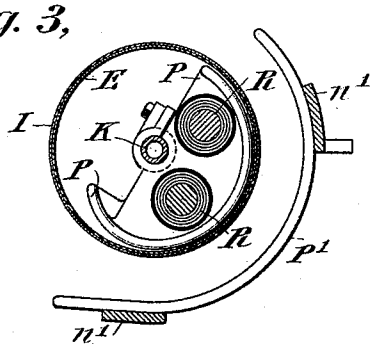


Fig. 4,

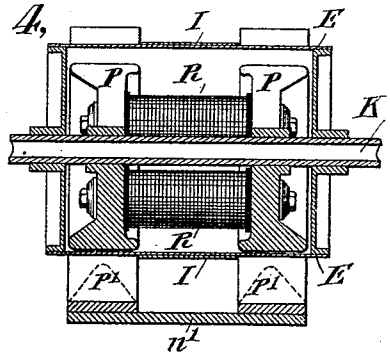
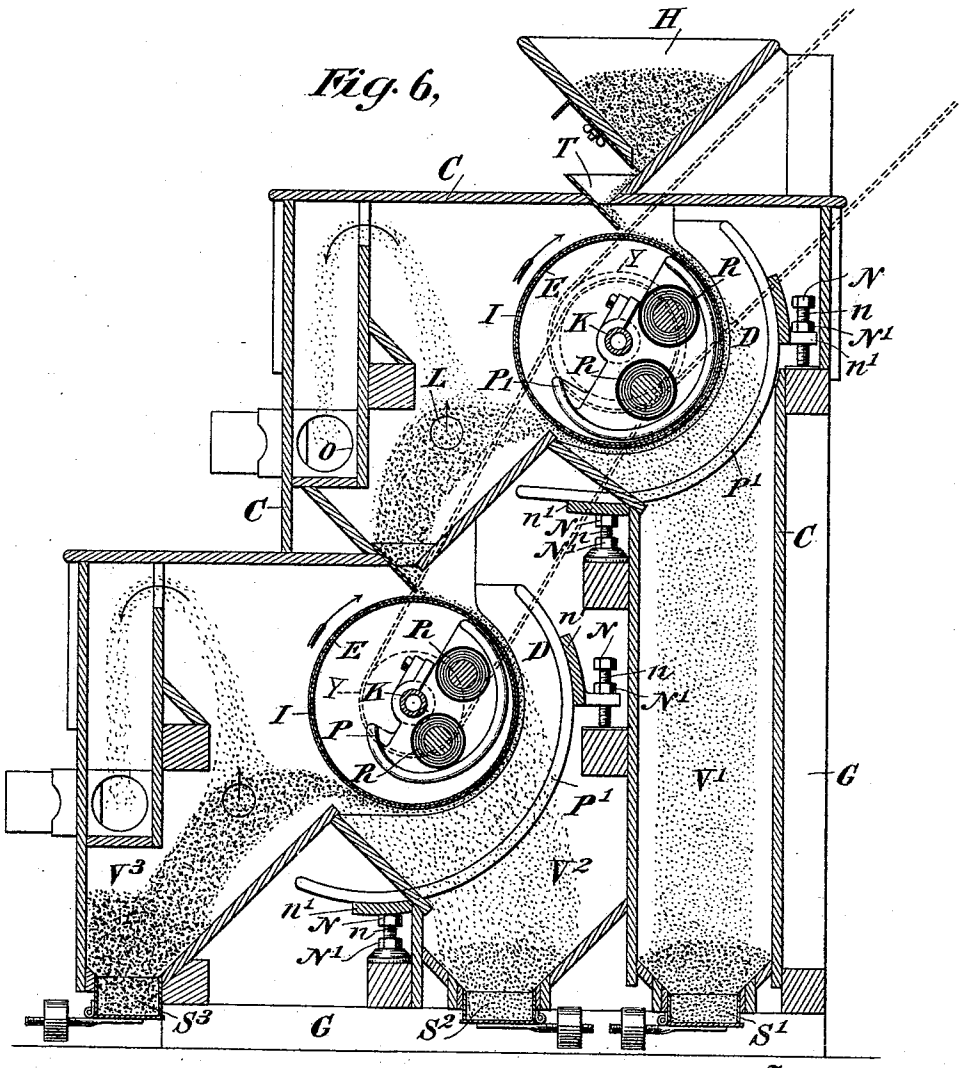


Fig. 6,



Witnesses

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UNITED STATES PATENT OFFICE.

CLARENCE QUINTARD PAYNE, OF STAMFORD, CONNECTICUT.

METHOD OF AND APPARATUS FOR SEPARATING ORES.

SPECIFICATION forming part of Letters Patent No. 500,604, dated July 4, 1893.

Application filed April 19, 1892. Serial No. 429,753. (No model.)

To all whom it may concern:

Be it known that I, CLARENCE QUINTARD PAYNE, a citizen of the United States, and a resident of Stamford, Fairfield county, State of Connecticut, have invented a new and useful Improvement in Methods of and Apparatus for Separating Ores, of which the following is a specification.

My invention relates to improvements in magnetic separators for the separation of iron in a magnetic form, from any non-magnetic material with which it may be mixed; and the invention is particularly adapted to the treatment of crushed magnetic iron ore, so as to secure a high efficiency and economy of operation in the process of separating it into different grades or classes.

The present invention consists of a novel design and arrangement of the electromagnets and pole pieces of the separator, whereby the position of the lines of force in the fields, and the strength of the field-magnetism, are more perfectly controlled and better adapted to the work of separation. In the arrangement of the electromagnets described hereinafter, one circuit for the lines of force generated by the electromagnets is maintained, whereby two magnetic fields of the so-called unipolar type are secured in this circuit, that is, fields in which the lines of force in each, all pass in the same direction, and do not reverse at any point.

It also comprises devices for controlling the attracting force in two directions, namely across and along the surface of the apron or screen on which the separation takes place, so that throughout the field it is possible to obtain along the surface of the screen, between any desired limits, one of two conditions, viz: first, a uniform attracting force; and second, a gradually diminishing attracting force. This control of the attracting force whereby the latter may be varied in the same magnetic field, or in fields which are separate and independent of each other, permits a higher efficiency of separation than would otherwise be possible.

The invention also consists in the arrangement of unipolar fields in combination with an iron screen, whereby a lamellar distribution of magnetism is obtained in portions of the screen, so as to secure what is technically known as a "magnetic" shell in those portions.

It consists finally, of a method of separating a crushed iron ore into heads, middlings and tailings, by subjecting the ore first to magnetic attraction of uniform intensity, and then to magnetic attraction of gradually diminishing intensity, either in one or in successive magnetic fields, and at the same time subjecting it to the action of one or more distractive forces, such as gravity or centrifugal force, acting in a direction opposed to that of the magnetic attraction.

In United States Letters Patent No 444,223, issued January 6, 1891, I have described and claimed an apparatus and method for separating crushed iron ore from its gangue or impurities, in which the mixture of the magnetic and non-magnetic particles is passed through a unipolar magnetic field, in such a manner that the magnetic portion of the ore is held to the surface of a rotating apron, while the non-magnetic portion is thrown off by centrifugal force. The present invention, while broadly retaining the principle of operation of said Letters Patent, secures at the same time, by the addition of certain new devices, a greater capacity of treatment, and a more perfect control of the attracting force along the surface of the screen upon which the separation takes place; thus obtaining a greater degree of efficiency than has heretofore been possible.

The invention will be best understood by reference to the accompanying three sheets of drawings, in which—

Figure 1, is a vertical transverse section of the entire separator. Fig. 2, is a vertical longitudinal section on the line A—B of Fig. 1. Figs. 3 and 4, show in transverse and longitudinal sections, a separating drum in which the electromagnet-cores attached to the outer pole-pieces are eliminated and the outer pole-pieces connected to form an armature. Fig. 5, is a view of two pairs of conical pole-pieces and their electromagnets, showing two magnetic fields on the same magnetic circuit, with a view to illustrating the principle of the machine. Fig. 6 is a vertical transverse section of a modified form of separator, in which the material to be treated is passed over two drums.

Similar letters refer to similar parts throughout the several views.

In Fig. 5, in order to illustrate the present invention more clearly and the method of arranging two magnetic fields on one circuit, two pairs of pole-pieces are shown, similar to those shown in the aforesaid Letters Patent No. 444,223. These pole-pieces, as will be seen, are made in the form of segments of cones.

In the form of apparatus shown in the above mentioned patent, several horseshoe electromagnets are used to charge with uniform polarity, two segmental cone-shaped pole-pieces, which pole pieces connect and form the respective terminals of the north and south poles of the separate horseshoe electromagnets. The lines of magnetic induction or lines of force, generated by the electromagnets, are thus permitted to close their circuits through a single extended air-gap between the surfaces of the two pole-pieces. If now the yokes or back pieces which form parts of the horseshoe electromagnets are removed, and the free ends of the resulting bar-electromagnets connected by two additional pole-pieces placed concentrically, so that each one shall only join like poles of the electromagnet-cores, the construction shown in Fig. 5 will then be obtained. In this case, there will be four pole-pieces, as shown, and each one will be charged with a uniform polarity which is of opposite sign to that of its opposing pole-piece. It will thus be seen that the magnetic lines of force which are generated in the electromagnet-cores and then distributed along the pole-pieces, must finally complete their magnetic circuit through the two extended air-gaps between the opposing faces of the two pairs of pole-pieces. It will be evident, that each of the two magnetic fields formed in these air-gaps, may be used for magnetic separation, in the same way as the single field described in the above mentioned patent was used, and in this manner the capacity of the machine may be doubled.

So far as the principle of the present invention is concerned, the shape of the pole-pieces is quite immaterial, but in cases where it is desired to use centrifugal force for the purpose of aiding the separation between the magnetic and non-magnetic particles and of removing the magnetic particles after passing through the field, or where for the purpose of classifying or grading the material treated in the field, it is sought to diminish the attracting force through a part of the field, as hereinafter described, it will be found advisable to employ pole-pieces the faces of which form segments of cylinders in connection with a cylindrical screen or screens.

In the complete working machine shown in Figs. 1, 2, 3, 4 and 6, the cylindrical form of pole-pieces has been shown applied to the invention.

Referring now to Figs. 1 and 2 of the drawings, G G is the frame which supports the operating mechanism, and which is completely surrounded on all sides by the casing C C C. At the lower part of the frame are placed the separate hoppers V', V^2, V^3, of convenient shape and size, for the collection of the different products of the separation. The hoppers are provided with discharge valves S' S^2 S^3 which are suitably counterweighted so that they remain closed until opened by the weight of the material which collects above them, and can thus discharge without permitting ingress of air.

K represents a hollow shaft or tube, made preferably of some non-magnetic material such as brass, bronze, &c., which is supported by suitable bearings F F on the frame of the machine. This shaft supports the drum E, with its drumheads J J, which rotate freely thereon, and also the pole-pieces P P and their connecting electromagnet cores R R, inside the drum. The pole-pieces P P are clamped to the shaft K in any convenient manner, and the latter is supported at each end in the bearings or standards F F, which are made in two sections so as to clamp the shaft rigidly in position, after the proper rotary adjustment of the pole-pieces has been obtained, to permit those portions of the ore adhering to the drum surface to be discharged from it at the desired point. The outer pole-pieces P' P', are placed concentric with the pole-pieces P P within the drum, and are provided with adjusting screws M M', supported by the frame of the machine, for maintaining them in the proper position. The two outer pole-pieces are shown connected by two electromagnet-cores, and likewise the two inner pole-pieces. The number of the electromagnet-cores is not essential, and may be varied in any case to suit the particular dimensions of the pole-pieces to be charged, so as to secure a substantially uniform distribution of the magnetism along their faces. A pulley Y which is belted or otherwise connected to an outside source of power, not shown in the drawings, is keyed to the extended hub of one of the drumheads J J. These drumheads are preferably made of bronze, and are connected by, and serve to support, a thin cylindrical shell E, so that it revolves freely with the minimum clearance in front of the inner pole-pieces P P. The copper wire of the two inner electromagnet-cores is so wound and connected that the electric current which energizes them passes around both cores in the same direction. The lines of force thus generated, therefore, emerge from like ends of the cores, and hence one of the two pole-pieces in which the two electromagnet cores terminate, is charged with magnetism of a positive polarity and the other with magnetism of negative polarity. In the case of the outer pole-pieces, the electric current is made to pass around the cores of the outer electromagnet, in a reverse direction from that in which it passes around the cores of the inner electromagnet. Hence if the lines of force generated in the cores of

described above, as the two portions of the screen pass out of the fields, the lines of force no longer occupy positions perpendicular to the screen surface, but positions which coincide with the rectilinear elements of the screen in short-circuiting the lines of force between the fields through the drum-shell. The effect is thus to permit the magnetic portions of the ore to be discharged from the screen surface by centrifugal force, and the use of brushes or scrapers is in this way avoided which is an obvious advantage.

In Fig. 1, I have shown at O a blast-gate which communicates with a partitioned space above it, inside the inclosed frame of the separator. This blast-gate is connected on the outside with an exhaust-fan of convenient construction, not shown in the drawings. By opening the blast-gate, a strong current of air is caused to enter the inclosed space within the separator on each side of the casing C C, by the openings L L, passing upward in the direction of the arrows, and then down and out through the exhaust-fan. The object of the current of air set in motion in this way, is to remove from the magnetic portion of the ore, as it is discharged from the drum-surface, the fine dust which is carried by the motion of the drum beyond the point *l*.

At H in Figs. 1 and 2, is shown a hopper from which the ore to be separated is fed upon the drum E. This hopper is provided with two openings which correspond in length and position with the two portions of the drum-surface that are magnetized by the pole-pieces of the two fields. Each has an adjustable slide so that a regulated amount of ore can be fed into the chutes T T, from which it is guided upon the drum E.

As will be seen from Fig. 1, the two lower ends of the inner and outer pole-pieces P P and P′ P′ are curved respectively inward and outward so as to gradually increase the width of the air-gap between their adjacent surfaces. The object of this construction is to gradually diminish the strength of the magnetic field beginning about at the point *h*, Fig. 1. From the upper ends of the pole-pieces to the point *h*, the inner and outer pole-pieces are concentric, and the distance between them is therefore uniform; hence the attracting force due to the magnetic potential along the drum surface is also uniform through this portion of each field. Beyond the point *h*, however, the distance between the opposing pole-pieces increases, and hence the attracting force along the drum-surface gradually diminishes until it becomes practically zero outside of the two fields.

The objects attained by gradually reducing the attracting force at the end of the fields, as affected by the construction, are two in number. The first is to permit the magnetic portion of the ore, adhering to the surface of the drum, to emerge from the magnetic field and then be readily discharged from its surface. In any case, but more especially where strong magnetic fields are employed, the magnetic portion of an ore tends to remain in the strongest portion of the field, and if the strength of this field is too suddenly reduced, the ore can only be removed with great difficulty. By making the reduction of the attracting force at the ends of the fields quite gradual, magnetic fields of great strength can be employed while at the same time the ore can be readily discharged from them.

The second object depends on a consideration of ore-dressing. In the majority of cases the material to be treated by magnetic separation consists of a mixture which can be divided into three classes: The first contains those particles which consist of magnetic material only; the second, those particles which consist of non-magnetic material only; and the third, those particles each of which consists of magnetic and non-magnetic material in varying proportions; this third class is commonly known as middlings.

By arranging the magnetic fields as already described, so as to secure a uniform attracting force along the drum-surface through a certain portion of each field, and a very gradual reduction of the attracting force at the discharge end of the same, the non-magnetic portion of the ore can be separated from the middlings and heads in that part of the field in which the attracting force at the drum-surface is uniform, while the separation of the middlings from the heads is made in that part of the field where the attracting force gradually diminishes.

It will be evident that during the second part of the separation, those mixed particles in each of which the largest proportion consists of non-magnetic material, will be the first to be thrown off from the drum-surface when the point *h* is passed, for in them centrifugal force and gravity most quickly balance the centripetal attracting force with which they are held to the drum-surface when the attracting force begins to diminish. Those mixed particles of which a less and less proportion in each consists of non-magnetic material, will in the course of the revolution of the drum be gradually removed from its surface at points farther and farther away from the point *h*, until the particles which are thrown off at the point *l* contain the least proportion of non-magnetic material. The result will be that only heads will be carried beyond this point *l*, and the position of this point will be determined by the rotary adjustment of the inside pole-pieces P P. It will thus be seen that between the point *h* on the drum, where the attracting force is sufficient to prevent any mixed particles from being thrown off the drum-surface, and the point *l*, where the mixed particles can no longer be held to the drum, the gradually diminishing attracting force between these points, and the constant centrifugal force and gravity, exert a sorting action on the mixed

the inner electromagnet, pass from right to left, those generated in the cores of the outer electromagnet will pass from left to right; and the inner pole-piece which is charged with positive polarity, is then opposite to the outer pole-piece charged with negative polarity, and vice versa. In this way, two strong magnetic fields are formed in the extended annular air-spaces between the two pairs of inner and outer pole-pieces, as each pole reinforces its opposing pole. It will be evident from the above considerations, that all the lines of force together or the total magnetic flux thus generated, form one and the same circuit, and that for the lines of force in this circuit there are two iron paths, composed of the cores and pole-pieces of the inner and outer electromagnets, respectively, and two air-paths formed by the annular air-gaps between the opposing faces of their respective pole-pieces. In both of these magnetic fields, the lines of force occupy positions normal to the opposing faces of their pole-pieces, and in each field all the lines of force pass in the same direction, and do not reverse at any point, although the direction of the lines of force in one field is opposite to the direction of those in the other field. Hence a body passing between the two pairs of pole-pieces P and P′, as does the drum-shell E when rotated, passes through two separate and distinct unipolar fields, in both of which the lines of force pass through the shell in directions which are normal to its surface. In transverse section Fig. 1, the lines of force in each field would be represented diverging radially, while in longitudinal section, Fig. 2, their positions would be parallel.

By the construction and arrangement described above, operating surfaces of relatively large area, are obtained in the magnetic fields and in these fields the lines of force are constrained to occupy practically normal positions with reference to the drum-shell. Hereby I avoid the formation of clots, loops or bunches of magnetic particles which occurs where a number of opposite poles are placed near together, so as to form either directly, inductively, or by the interposition of an apron or screen, an attracting surface on which the separation takes place. In such cases the magnetic particles tend to bridge the spaces between two opposite poles, by inductive action in the direction of the lines of force, and thus bunches of magnetic particles are formed, that hold or entangle a certain percentage of non-magnetic particles which are difficult to separate.

D D represent conical guide-ways or deflectors, which conform in shape to the inner faces of the outer pole-pieces, and are made of non-magnetic material such as wood, brass, &c. The object of these guides is to deflect the material thrown off from the surface of the drum so as to remove it from the fields. Each deflector is made of sufficient size to cover that portion of the field between the neutral line and the face of the outer pole-piece. In this way no magnetic particles removed from the drum E, can attach themselves to the outer pole-pieces P′ P′. The sides and bottoms of the latter are also inclosed by the casings c^2 c^2 c^2. The form of magnetic fields which is thus developed permits the drum shell E to be made of iron, quite as well as of any non-magnetic material; and for this purpose a cylinder, preferably made of a continuous sheet of soft iron will be used, mounted on the drumheads J J and made to rotate through the magnetic fields. The lines of force pass through those portions of the cylindrical iron screen which are in the magnetic fields and in those portions induce a lamellar distribution of magnetism. In other words the magnetism is distributed in thin sheets through the cylindrical screen, so that each portion of the screen which is between two opposing polar faces, has at its inner surface magnetism of one kind, while at its outer surface it has magnetism of the other kind; the two adjacent surface distributions of magnetism being respectively of opposite polarity. These two portions of the cylindrical screen form by their positions in the fields what is known as "magnetic shells." That portion of the cylinder which lies between the two fields is saturated with lines of force, as the resistance between the fields by way of the cylinder is less than by way of the two outer pole-pieces and air-gaps. The amount of short-circuiting of the lines of force between the fields, due to the presence of the iron cylinder, is however, insignificant, so far as the absorption of magnetism is concerned; but an iron cylinder has the advantage over one in which the operating surfaces only are of iron, and the intermediate portion is composed of non-magnetic material, that, in the former, the continuous iron path between the operating surfaces prevents a condensation of the lines of force that in the latter takes place along the inner edges of said surfaces. In this way a more uniform separating action is obtained across the whole width of both operating surfaces. The lines of force which traverse the intermediate portion of the iron cylinder, between the two operating surfaces do not emerge from said portion, and therefore will not hold magnetic particles accidentally thrown upon it. As a further means of insuring this result in the case of imperfections of material and construction a thin brass band or cylinder I, may be placed on the outer periphery of the iron cylinder between the two fields as shown by I in Fig. 2.

While it would be quite possible to use a cylinder made of non-magnetic material such as brass, wood-fiber, &c., the iron cylinder is preferable for the reason that with it the same strength of magnetic field produces a greater attracting force, and hence a better separation is possible.

Through the use of a continuous iron screen or drum-shell, which is made to pass through two separate unipolar fields in the manner

particles. In this way, a crude ore may be differentiated or separated sharply into its three classes; a result which has hitherto been difficult to accomplish, on account of the varying magnetic susceptibility of the mixed particles.

If an ore does not contain any mixed particles or middlings, the partition *h*, between the hoppers V′ V², may be removed, and only two products, viz: heads and tailings will then be made. By making the drum E of sufficient size, ample space can be obtained along its circumference to separate a crude crushed ore into the three classes described above.

In certain cases where the proportion of middlings to heads and tailings is quite large, it is preferable to use two independent drums in order to separate the ore into its three classes. Fig. 6 shows a separator of this character. Here, the inner and outer pole-pieces of the first drum, are concentric and the ore is carried by the drum-shell through a magnetic field of uniform attracting force, the tailings being separated in this part, and the attracting force at the end of the field being diminished only sufficiently to allow the enriched product to discharge freely. The pole-pieces of the second drum are not concentric as in the first, but are of such curvature that they gradually diverge, so as to produce fields of diminishing attracting force throughout.

In practice, middlings have been separated approximately from the ore by passing it at increased speeds through successive magnetic fields the strengths of which may be varied by the introduction of electric resistances.

In the present invention, a more perfect separation between the middlings and those particles consisting of purely magnetic material, is accomplished by passing them through a single field of diminishing attracting force, this field being combined either with a field of uniform attracting force for the elimination of the non-magnetic portion of the ore, or arranged independently of it, as explained above.

Figs. 3 and 4 show a modified arrangement of the electromagnets and pole-pieces, so as to produce two unipolar fields on the same magnetic circuit. In this arrangement, the electromagnet-cores are omitted from the outer pole-pieces, and the latter connected by means of iron plates of sufficient cross-section to permit the passage of the lines of force in the circuit. The electromagnet-cores are thus placed on one side of the air-gaps only, and the same strength of intensity of the magnetic fields is obtained with this arrangement as in that shown in Figs. 1 and 2, provided the total magneto-motive force be the same in each case. By the removal of the electromagnet-cores from the outer pole-pieces, the latter then form, with their connecting plates, what may be more strictly called a large armature. In each case, however, whether two outer pole-pieces with their electromagnet-cores or a large armature of a corresponding shape be employed, the objects gained are the same, namely, the lines of force in the magnetic fields are maintained normal to the opposing iron faces which bound the air-gaps on two sides, so that the magnetic portion of the ore is held to the drum surface in positions which do not interfere with the free discharge of the non-magnetic material; and the magnetic fields, whether of uniform or diminishing attracting force, are maintained at a substantially uniform strength or intensity along rectilinear elements of the drum surface.

The operation of the apparatus shown in Figs. 1 and 2 and the method of separation effected by it, is as follows: The electromagnet-cores which connect the two inner and two outer pole-pieces, are energized by means of an electric current, preferably from a dynamo-electric machine and the drum is set in rotation in the direction shown by the arrows. A regulated amount of the ore to be separated, is then allowed to pass from the hopper H, through the chutes T T, and to fall in a thin sheet upon those portions of the drum surface which by the rotation of the drum are made to pass through the two magnetic fields formed between the two pairs of pole-pieces P P and P′ P′. As by the rotation of the drum the ore is carried within these two fields, the purely magnetic particles, as well as the mixed particles of the ore, at once attach themselves firmly to the magnetized surface of the drum-shell, in positions which are determined by the direction of the lines of force in the two fields. As the lines of force are normal to the faces of the inside and outside pole-pieces, it follows that in all parts of the fields these adhering particles are held perpendicularly to the drum surface. This open method of attachment of the magnetic portions of the ore, permits the non-magnetic particles, which are intermixed with the former, to be freely discharged from the drum surface by centrifugal force and gravity with least interference from the magnetic portions of the ore. In this way the non-magnetic particles of the ore are removed from the other portions which remain adhering to the drum-surface, while being carried through those parts of the two fields which are of uniform attracting force, and which extend from the entrance of the fields to the point *h*. On being thrown off of the drum surface, the non-magnetic particles of the ore strike the inclined sides of the deflectors D D, and are guided below into the hopper V′ where they are collected and eventually discharged through the valve S′. As the drum continues its rotation, the heads as well as the middlings are carried beyond the point *h*, into that portion of the field which is of diminishing attracting force. Here the mixed particles of the ore are thrown off by centrifugal force and gravity into the hopper V², and discharged through the valve S². At the point *l*, on the drum-surface, the attract-

ing force is to such an extent diminished, that no mixed particles can any longer adhere to the drum. Beyond this point, by reason of the continued diminution of the magnetic potential at the drum surface, the attracting force is so far reduced that the centrifugal force and gravity then operate to remove the purely magnetic particles of the ore from the drum surface. These are then collected in the hopper V^3, and descend through the discharge valve S^3, while at the same time the fine dust is removed from the heads by air-currents entering at the openings L L, and passing out through the blast-gate O.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. In a magnetic separator, the combination substantially as hereinbefore set forth, with pole-pieces placed on each side of an operating screen, and electromagnet-cores for charging the same, two magnetic fields being formed on the same circuit of the lines of magnetic induction generated by the electromagnet cores, each independently available for the purpose of separation.

2. In a magnetic separator, the combination substantially as hereinbefore set forth, of an operating screen, pole-pieces on one side of the screen charged with respect to each other with magnetism of opposite polarity by means of electromagnet-cores, pole-pieces on the opposite side of the screen, separated therefrom by air-spaces and charged with respect to each other with opposite polarity by means of electromagnet-cores, each of the latter pole-pieces being respectively the reverse in polarity to each of the former and opposing pole-pieces.

3. In a magnetic separator the combination substantially as hereinbefore set forth, of a screen of suitable construction, pole-pieces on one side of the screen, suitable electromagnet-cores, whereby they are charged with respect to each other with magnetism of opposite polarity, and devices on the other side of the screen for controlling the direction and intensity of the lines of force.

4. In a magnetic separator, the combination of an operating screen and an electromagnet provided with pole-pieces, the attracting force being equalized across the widths of the two portions of the screen opposite the faces of said pole-pieces, by means of devices exterior to the electromagnet and forming part of the same magnetic circuit, substantially as described.

5. In a magnetic separator, the combination substantially as hereinbefore set forth, of an operating screen, pole-pieces on one side of the screen, charged with respect to each other with magnetism of opposite polarity by means of electromagnet-cores, and pole-pieces on the other side of the screen charged with respect to each other with magnetism of opposite polarity by suitable electromagnet-cores and separated therefrom by an air-space; the latter pole-pieces being so arranged with reference to the former pole-pieces, that the lines of force are constrained to occupy positions normal to the surface of the screen, and to exert a substantially uniform attraction along rectilinear elements of the screen or across the widths of the two fields at the surface of the screen.

6. In a magnetic separator, the combination substantially as hereinbefore set forth, of a rotary screen, two inner pole-pieces within said screen charged with respect to each other with magnetism of opposite polarity by suitable electromagnet-cores, and devices substantially as described without the screen, for controlling the direction and intensity of the lines of force and maintaining the positions normal along the rectilinear elements of the screen.

7. In a magnetic separator, the combination of an iron screen and an electromagnet provided with pole-pieces, a lamellar distribution of magnetism being produced in those portions of the screen opposite the faces of said pole-pieces, substantially as described.

8. In a magnetic separator, the combination substantially as hereinbefore set forth, with the pole-pieces and the electromagnet-cores for energizing the same, two unipolar fields being formed upon the same magnetic circuit, of an iron screen passing through both of said fields between the faces of the pole-pieces, a lamellar distribution of magnetism being produced in those portions of the screen opposite the faces of said pole-pieces.

9. In a magnetic separator, the combination substantially as hereinbefore set forth, in a single magnetic circuit, of a rotary iron screen on which the separation takes place, two inner and two outer pole-pieces, between which said screen rotates, magnetized by suitable electromagnet-cores; said pole-pieces being so arranged that the two magnetic fields formed in the said circuit of the lines of magnetic induction, produce a lamellar distribution of magnetism in those portions of the screen within the said fields.

10. In a magnetic separator, the combination of an electromagnet provided with pole pieces and an operating screen passing through the magnetic field opposite the faces of the pole-pieces and devices exterior to the electromagnet on the opposite side of the screen for controlling the direction and intensity of the lines of force; so constructed and arranged that a uniform attracting force is exerted along the two portions of the screen opposite the faces of said pole-pieces, for a part of each of their lengths, and a gradually diminishing attracting force is exerted throughout the remainder thereof.

11. In a magnetic separator, the combination substantially as hereinbefore set forth, of a rotary screen revolving through two unipolar magnetic fields, upon the same magnetic circuit; pole-pieces placed respectively within and without said screen, energized by suitable electromagnet-cores, said pole-pieces be-

ing so constructed and arranged with reference to the screen and to one another, that a uniform attracting force is exerted along curvilinear elements of the surface of the screen, in a portion of each field, and a gradually diminishing attracting force along curvilinear elements throughout the remainder thereof.

12. In a magnetic separator, the combination substantially as described, of an operating screen passing through two unipolar magnetic fields on the same magnetic circuit; pole-pieces energized by electromagnet-cores placed on each side of said screen and at equal distances between their opposing faces during a portion of their length and at a gradually increasing distance during the remainder.

13. In a magnetic separator, the combination substantially as hereinbefore set forth, of a rotary screen rotating through two unipolar magnetic fields, on the same magnetic circuit, two inner pole-pieces with the screen magnetized by electromagnet-cores, two outer pole-pieces magnetized by similar electromagnet-cores, the opposing faces of said inner and outer pole-pieces being placed at equal distances apart during a portion of their lengths and at a gradually increasing distance apart during the remainder thereof, so that a uniform attracting force is exerted along curvilinear elements of the surface of the screen in a portion of each field, and a gradually diminishing force during the remainder.

14. In a magnetic separator, the combination of a screen passing through unipolar fields on the same magnetic circuit formed by inner and outer pole-pieces with respect to the screen surface, and inclined deflectors or guides placed lengthwise in each field so as to occupy that portion between the neutral surface and the face of the outer pole-pieces in said fields for the purposes hereinbefore set forth.

15. In a magnetic separator, the combination in a single magnetic circuit of pole-pieces energized by suitable electromagnet-cores, a screen arranged with reference to said pole-pieces to pass through two separate unipolar fields in the said magnetic circuit, and devices substantially as described on the opposite side of the screen, for equalizing and controlling the attracting force along rectilinear elements of the surface of said screen.

16. In a magnetic separator, the combination, substantially as hereinbefore set forth, of an electromagnet provided with pole-pieces and an operating screen passing in front of the polar faces and devices exterior thereto forming a part of the same magnetic circuit, the distance between the surface of the screen and the polar faces varying in the direction of the length of the magnetic field.

17. The method of separating a crushed iron ore into heads, middlings and tailings, substantially as described, consisting first, in passing the same through a magnetic field in which a constant attracting force is maintained, and in which the tailings are removed from the ore by the combined action of centrifugal force and gravity, while the remaining particles are carried through the field and thrown off the screen by centrifugal force; and second, in passing said remaining particles through a magnetic field in which a diminishing attracting force is maintained and in which the middlings are removed by the combined action of centrifugal force and gravity, while the heads are carried through the field and are then discharged by centrifugal force.

18. The method of separating a crushed iron ore into heads, middlings and tailings, substantially as described, by passing the same through a magnetic field in a portion of which a constant attracting force is maintained whereby the tailings are eliminated, and in the remainder of which a diminishing attracting force is maintained, whereby the middlings are separated from the heads and the latter are discharged at the end of the field.

In testimony that I claim the foregoing as my invention I have signed my name, in presence of two witnesses, this 18th day of April, 1892.

CLARENCE QUINTARD PAYNE.

Witnesses:
EDWIN T. RICE, Jr.,
WILLARD PARKER BUTLER.