(No Model.) 2 Sheets—Sheet 1.

C. Q. PAYNE.

MAGNETIC ORE SEPARATOR.

No. 500,605. Patented July 4, 1893.

Fig. 1,

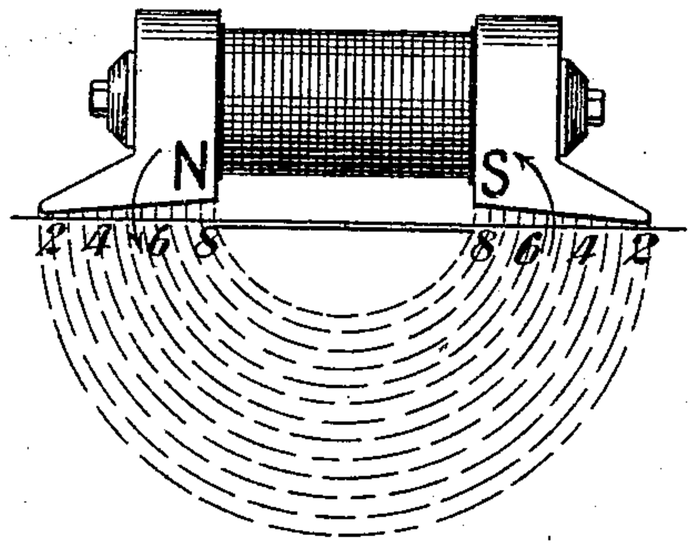


Fig. 2,

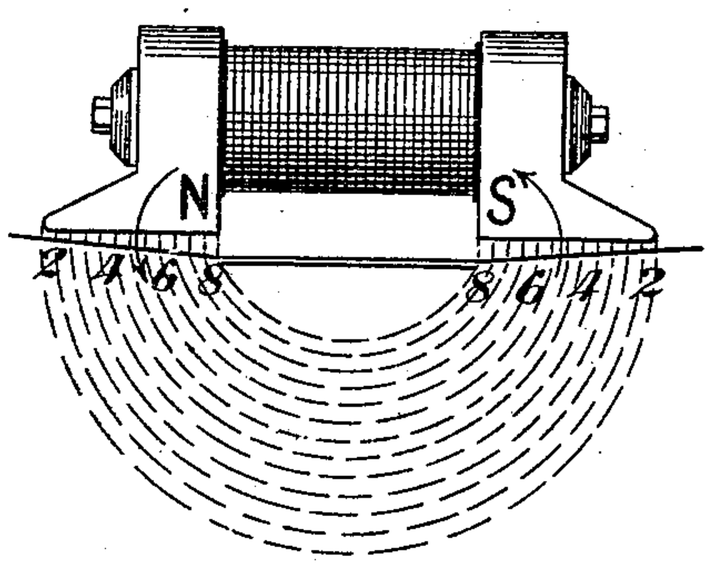
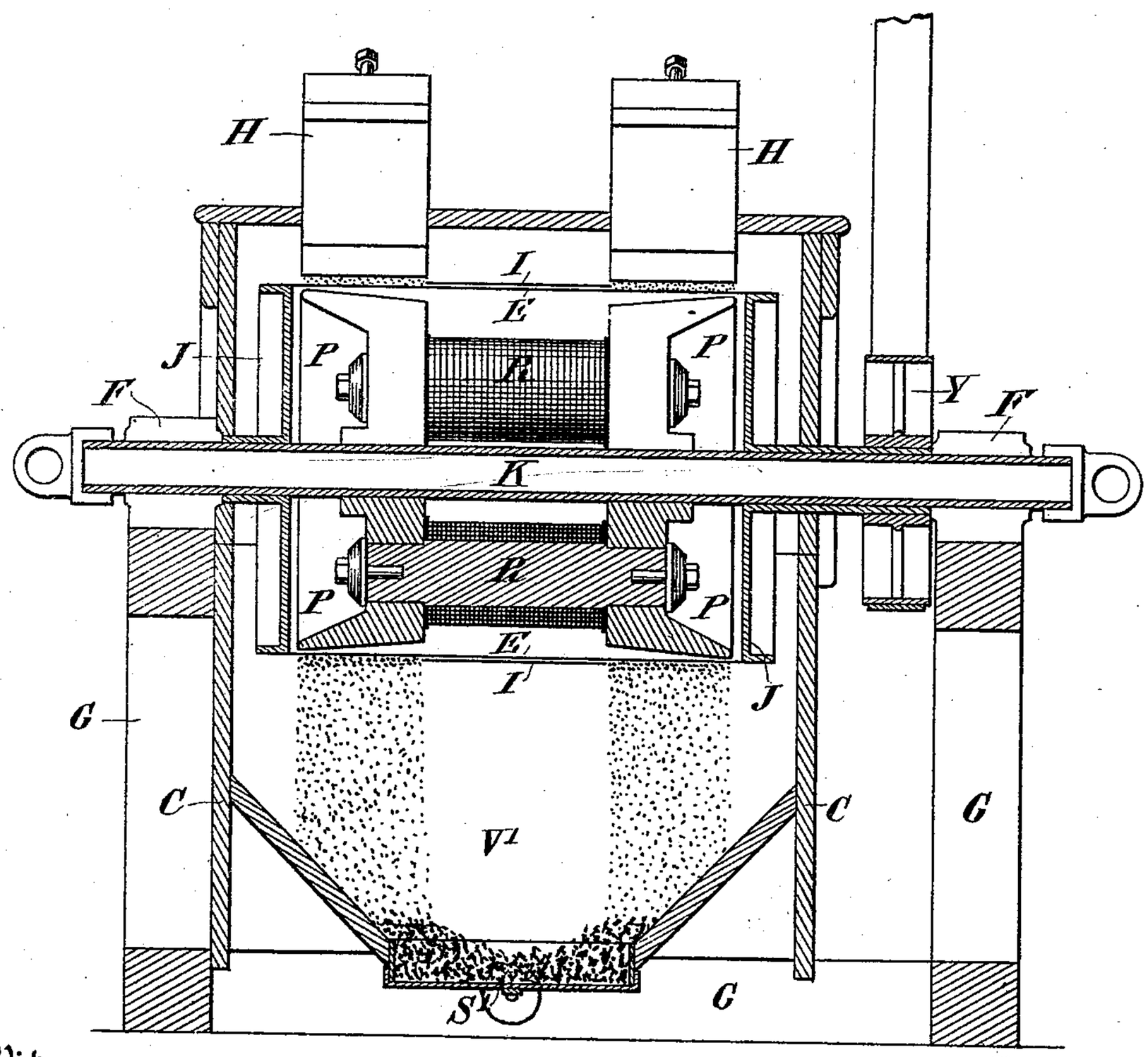


Fig. 3,



Witnesses
C. E. Ashley
H. W. Lloyd.

Inventor
Clarence Quintard Payne
By his Attorney
Willard Parker Butler

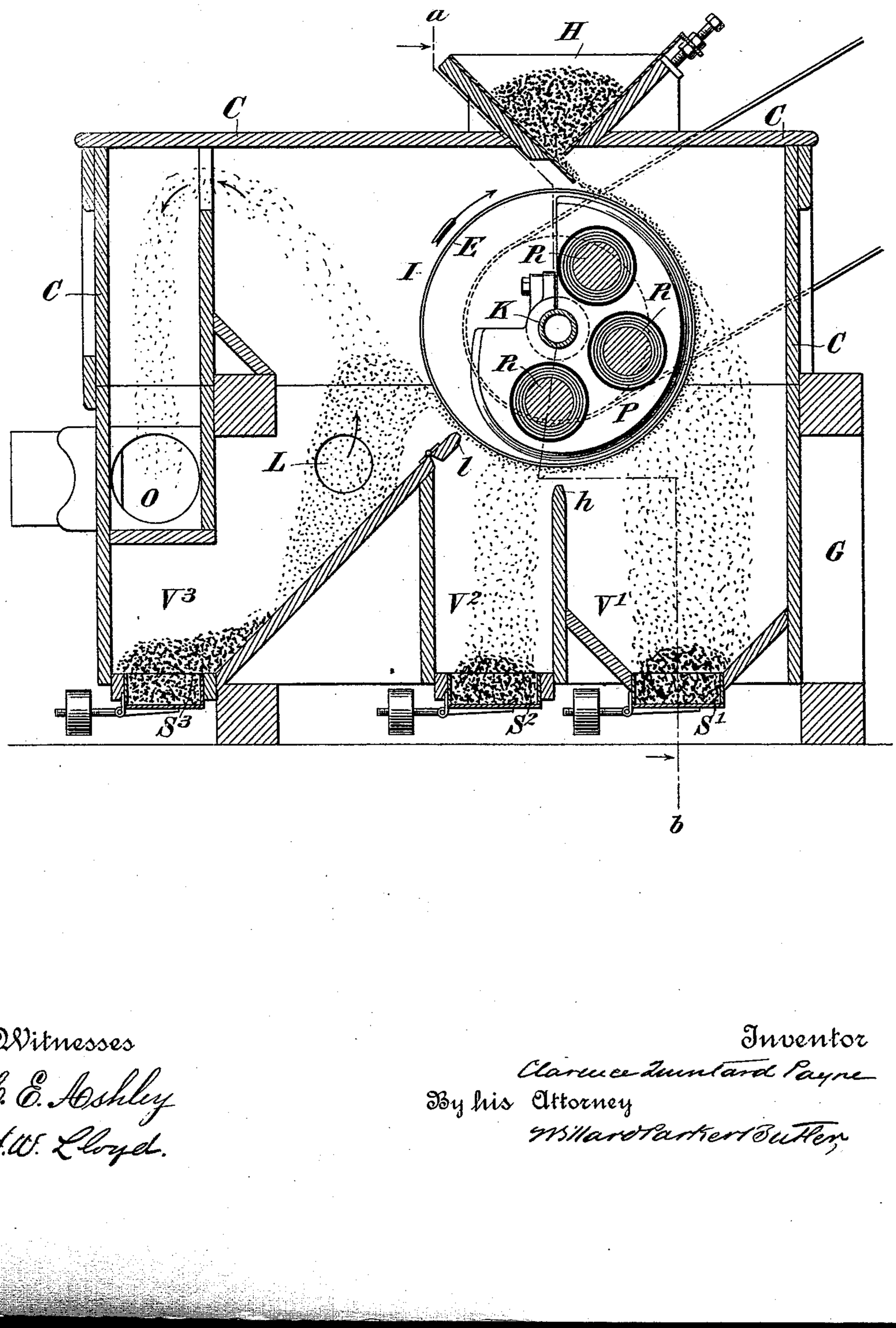
(No Model.) 2 Sheets—Sheet 2.

C. Q. PAYNE.

MAGNETIC ORE SEPARATOR.

No. 500,605. Patented July 4, 1893.

Fig. 4.



Witnesses
C. E. Ashley
H. W. Lloyd.

Inventor
Clarence Quintard Payne
By his Attorney
Willard Parker Butler

UNITED STATES PATENT OFFICE.

CLARENCE QUINTARD PAYNE, OF STAMFORD, CONNECTICUT.

MAGNETIC ORE-SEPARATOR.

SPECIFICATION forming part of Letters Patent No. 500,605, dated July 4, 1893.

Application filed May 23, 1892. Serial No. 434,079. (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, county of Fairfield, and State of Connecticut, have invented a new and useful Improvement in Magnetic Ore-Separators, of which the following is a specification.

My invention relates to improvements in apparatus for the separation of particles of iron in any magnetic form from non-magnetic materials with which they may be mixed, and is especially adapted to the separation of a crushed iron ore into the different grades or classes known as heads, middlings and tailings, whereby a more perfect classification of the products is obtained, and greater economy of operation thus secured.

In a previous application for Letters Patent filed in the United States Patent Office, Serial No. 429,753, I have described a method of separation and form of apparatus in which a novel arrangement of electromagnets and pole-pieces is employed, whereby in connection with an operating screen, two magnetic fields of the so-called "unipolar" type are secured on the same circuit of the lines of magnetic induction, or lines of force, generated by the electro-magnets. In that application means are shown by the use of inner and outer pole-pieces, or an outer armature, in connection with an operating screen passing between them; whereby the attracting force is controlled, across and along those portions of the screen surface, that are in the magnetic fields. Now I have discovered that it is possible to omit the outer polepieces with their electromagnet cores, or the outer armature and still obtain by other means the same control of the attracting force across and along the surface of the operating screen. The same method of separating a crushed iron ore into heads, middlings and tailings, described in the above mentioned application, is then made possible.

The present invention constitutes, therefore, in part, an improvement over the apparatus described in the above mentioned application for Letters Patent.

The invention consists in the use of two unipolar attracting surfaces upon a screen which passes through a single magnetic field, each surface being independently available for the purpose of separation, while, for reasons hereinafter given, that portion of the field lying between the two attracting surfaces, is not used for such purpose.

It also consists of devices or means for equalizing the attracting force across those portions of the operating screen which are opposite the polar faces of the electro-magnet.

In the drawings illustrating the present invention, Figures 1 and 2 are diagrams showing equivalent devices for controlling the attracting force across those portions of the screen surface which are opposite the polar faces. Figs. 3 and 4 show in longitudinal and cross-sections a complete separator, in which use is made of the devices which form in part the subject of the present application for Letters Patent.

It is customary to designate that portion of space filled with lines of force which surrounds and joins two opposite or north and south poles of a magnet, as the "external magnetic field," or simply "field."

It will be seen from each of the diagrams Figs. 1 and 2, that the operating screen which is shown there in section, passes through a single magnetic field. Here the lines of force generated by the electro-magnet occupy curved positions between corresponding points on the faces of the polepieces, while at these points their positions are approximately to the polar faces. From this normal position of the lines of force with respect to the polar faces, and the position of the screen surface, in close proximity to the latter, it is evident that there will be an advantage in confining the operating surfaces of the screen to those portions which pass in front of the extended polar faces, of the electro magnet, for the magnetic particles of the ore, when distributed in a thin sheet over these portions of the screen surface, are held in positions approximately normal to it; and in such positions offer the least possible interference to one another, and the least obstruction to the discharge from the screen, of those less magnetic or non-magnetic particles which it is the object of the separation to remove. As this advantage pertains only to those portions of the screen surface which pass in front of the polar faces, that part which lies between said portions is eliminated, as far as

the separation is concerned, by not feeding the ore upon it. By this selective use of those portions of a single magnetic field in which the best separating action can be secured, I am enabled to avoid the formation of objectionable clots, loops or bunches of magnetic material which otherwise are formed when a series of poles of opposite polarity produce either directly, inductively, or by the interposition of an apron or screen, an attracting surface on which the separating action takes place, for then the magnetic particles bridge the space between two opposite poles, and hold mechanically a certain percentage of non-magnetic particles which is difficult to separate.

In Fig. 1, the distribution of the lines of force or the magnetic density, is not uniform at the faces of the polepieces, provided the limit of saturation is not reached; and as a rule the lines of force will be more closely crowded together at the inner edges of the two polepieces than at the outer edges of the same. The attracting force along the surface of a screen placed opposite to and parallel with the faces of the polepieces, will therefore be unequal in the direction corresponding to the width of the polar faces. I have found, however, that by inclining the faces of the polepieces with respect to the screen, or the screen with respect to the polar faces, so as to form wedge shaped air gaps between them, as shown in Figs. 1 and 2, it becomes possible to secure at those portions of the screen surface opposite the polar faces a practically uniform attracting force in directions coinciding with the planes of the air paths of the lines of force, between the polar faces, which follows as a result of a uniform distribution of magnetic density at said portions of the screen surface. In Fig. 1, the distance between the points 2 2 on the screen surface measured along the air path of the corresponding line of force between those points, is considerably greater than that between the points 8. 8. measured in the same way; and yet with relation to the attracting force the closer proximity of the points 2 2, to their respective polar faces balances the effect of the greater air path, so that the attracting force at the points 2, 4, 6, 8, opposite the two polepieces is in this way made uniform.

As far as the principle involved in the present invention is concerned, the shape of the polepieces is immaterial, but as there is a practical advantage in employing a uniform centrifugal force for the removal of the material from the magnetic field or fields, in separating the ore into the different grades or classes, I have preferred to show in Figs. 3 and 4, the use of polepieces of such shape as may be used advantageously in connection with a cylindrical screen or screens. The application of the present invention, is however in nowise limited to any particular form of screen, and in those cases, where it may be desirable to use water, to aid the separation a belt, apron or chute may be preferred in place of the cylindrical screen.

In Figs. 3 and 4, G G is the frame which supports the operating mechanism of the separator, and within which it is completely inclosed on all sides by the casing, *c*, *c*, *c*. At the lower part of the frame are placed the hoppers V′ V², V³, for the collection of the different products of the separation. The hoppers are provided with discharge valves, S′, S², S³, which are suitably counterweighted so as to remain closed until opened by the weight of the material which collects above them and which can then discharge without permitting ingress of air. K. represents a hollow shaft or tube, made preferably of some nonmagnetic material such as brass, bronze, &c. It supports the drum E., with its drum heads J J., and also the polepieces P P, and their connecting electromagnet spools R R R. Two electrical conductors are led into the drum E. through the hollow shaft, for the purpose of charging the electro magnet R. P. The thin cylindrical drum shell E., is made to rotate freely in front of the polepieces P P. The drum-heads J J, are preferably made of some nonmagnetic material such as bronze, and the hub of one of them is extended and a pulley Y, which is belted or otherwise connected with an outside source of power, not shown in the drawings, is keyed to it. The polepieces P P are clamped to the shaft K., and the latter is supported in suitable standards or bearings F F. These are preferably made in two sections, so as to clamp the shaft K. rigidly in position after obtaining the proper rotary adjustment of thepole pieces, which permits the adhering portions of the ore to discharge from the drum surface at the desired point.

In Fig. 4, the two polepieces are shown to be connected by means of three electromagnet-cores. The number of these cores however is not essential, and it may be varied in any case to suit the particular dimensions of the polepieces to be charged, so as to secure a uniform distribution of magnetism along their faces.

The copper wire of the electromagnet-cores R R R, is so wound and connected that the electric current which energizes them, passes around all the iron cores in the same direction. The lines of force thus generated therefore pursue paths of like direction through the cores, and the polepieces which form the terminals are charged with a polarity which in each is of opposite sign to that of the other. It will thus be evident that the three electromagnet-cores with the pole-pieces P P, together form a large electromagnet in which the lines of force generated in the cores, are distributed in the polepieces, and finally complete their circuits in curved air paths between the faces of the polepieces, emerging from the latter substantially at right angles to the polar faces. The space in front of and between the polar faces thus forms the mag-

netic field through which the drum screen E. is made to pass, upon whose surface in portions opposite the pole-pieces the separating action takes place.

While it would be possible to use a drum screen of non-magnetic material, such as brass, wood, fiber, &c., I prefer to make the drum screen E. of iron. I accordingly use for this purpose a cylinder made of a continuous sheet of soft iron, which is mounted on the drum-heads J J, and made to rotate through the field. The advantage of a cylinder of iron is that a greater attracting force is obtained with it with the same strength of magnetic field, and hence a better separation is possible.

The position of the cylinder with respect to the lines of force in the field, is such that in those portions of it which are opposite the polar faces, an approximately lamellar distribution of magnetism is obtained, and they therefore here coincide with and form part of what are technically known as "magnetic shells." That portion of the cylinder which is between the two pole-pieces, is saturated with lines of force, but the amount of short circuiting is insignificant as far as the absorption of magnetism is concerned, and the use of a continuous iron cylinder in place of two separate cylinders adjacent to the polar faces only, separated by one of non-magnetic material, has the advantage that a more uniform distribution of the maguetism is obtained in the former case than in the latter, where a condensation of the lines of force is apt to occur at the edges of the cylinder which are opposite the inner edges of the pole-pieces. As the lines of force do not tend to emerge from that portion of the drum screen which is between the polepieces, the magnetic portion of the ore does not attach itself here; but as a precaution against accidental attachment due to imperfections in the material or inaccuracy in workmanship, I prefer to place a band of non-magnetic material, such as brass, &c., around that portion of the cylinder between the polepieces.

In Fig. 4 it will be seen that beginning about at the point *h*, the faces of the pole-pieces P P are made to curve inward so as to gradually increase the distance between them and the drum screen and thereby gradually diminish the attracting force along the curvilinear elements of the surface of the drum screen beginning at the point *h*. As explained in the previous application for Letters Patent, it is possible in this way to discharge the magnetic portion of the ore from a field of strong magnetic intensity, and at the same time to use that portion of the field in which the attracting force diminishes gradually, for the separation of those mixed particles or middlings which from the fact that they are composed with respect to one another, of varying proportions of magnetic and non magnetic material, possess correspondingly different degrees of magnetic susceptibility. At a point of the field *l*, which is determined by the rotary adjustment of the polepieces P. P., the attracting force is so far reduced, that only the heads remain adhering to the screen surface, while beyond this point they are discharged by centrifugal force as they are gradually carried out of the field by the motion of the drum.

It will be evident that it is possible, and in some cases desirable, to perform the complete separation of the ore into the three different grades or classes by the use of two separate drums instead of one drum only. In this case, the first drum may be most conveniently used for the separation of the tailings from the heads and middlings; and the pole-pieces will therefore be so arranged with reference to the drum screen, as to provide attracting surfaces of uniform strength, except at the end of the field where the attracting force will be so far diminished as to permit the free discharge of the heads and middlings. On the second drum, the pole-pieces will be so shaped with reference to the drum screen, as to produce along its curvilinear elements surfaces of gradually diminishing attracting force, for the separation of the middlings from the heads.

At O, Fig. 4, a blast gate is shown, which communicates with a partitioned space above it, inside the inclosed frame of the separator. This blast gate is connected with an exhaust fan, not shown in the drawings. By opening the blast gate, a current of air is caused to enter from each side the inclosed space within the separator, at 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 currents 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, any fine non-magnetic dust which may be carried by the motion of the drum beyond the point *l*.

At H., in Figs. 3 and 4, are shown hoppers from which the ore to be separated is fed upon the drum E. These hoppers are provided with openings which correspond in position with the two portions of the drum screen which are adjacent to the faces of the pole-pieces P P. Each opening has an adjustable slide, so that a regulated amount of ore can be fed upon the drum E.

The operation of the apparatus shown in Figs. 3 and 4, is as follows:—The electromagnet-cores which connect the two polepieces P P, are energized by an electric current, preferably from a dynamo-electric machine, and the drum is set in rotation in the direction shown by the arrow. A regulated amount of the ore to be separated is then allowed to pass from the hoppers H H and fall upon those portions of the drum surface which are adjacent to the faces of the polepieces P. P. As the ore is carried into the field, by the rotation of the drum the heads, as well as the middlings, at once attach themselves firmly to the attracting surfaces of the drum screen in positions which are determined by the po-

sitions of the lines of force in the two fields. As the lines of force are substantially perpendicular to the faces of the pole-pieces, and the ore is distributed in a thin sheet upon the two portions of the drum shell adjacent to said polar faces, it follows that the more or less magnetic particles are held to the drum surface in positions approximately normal to it. By this method of attachment of the magnetic portions of the ore, the least possible interference or obstruction is offered to the free discharge of the intermingled non magnetic particles, by gravity and the centrifugal force which is generated by the rotation of the drum. In this way the tailings are removed from the other portions of the ore which remain adhering to the drum surface while being carried through those portions of the field where the attracting force is uniform, and which extend from the beginning of the field to the point *h*. On being thrown off the drum surface, the tailings fall into the hopper V′, where they are collected and eventually discharged through the valve S′. As the drum surface continues its rotation, the heads and middlings are carried beyond the point *h* into that portion of the field which with respect to the passage of the ore offers the mixed particles diminishing attracting force. Here the mixed particles between the points *h* and *l*, the middlings are discharged from the drum surface by the action of gravity and centrifugal force. They are then collected in the hopper V^2 and removed through the valve S^2. At the point *l*, the attracting force is so far diminished that no middlings can any longer be held to the drum surface. The heads are carried beyond this point by the rotation of the drum, and finally discharged from its surface by centrifugal force as they pass out of the magnetic field. They are then collected in the hopper V^3 and descend through the valve S^3, while at the same time the fine non-magnetic dust is removed from them by the air currents entering at L L and passing out through the blast gate O.

I claim as my invention—

1. In a magnetic separator, the combination hereinbefore described, of an electromagnet provided with pole-pieces, the faces of which lie in surfaces which make an angle with each other, and an operating screen passing through the magnetic field, opposite the faces of the pole-pieces, for the purpose set forth.

2. In a magnetic separator the combination substantially as hereinbefore described, with an electro-magnet provided with pole pieces whose polar faces are not opposed but lie adjacent in surfaces, and which make an angle with each other; and an operating screen passing through the magnetic field in front of the polar faces; of two unipolar attracting surfaces occupying those portions of the operating screen opposite said polar faces and which are at right angles to the rectilinear elements of the screen surface substantially as described.

3. In a magnetic separator, the combination substantially as described, of an electromagnet provided with pole-pieces, an operating screen passing through the field opposite the faces of the pole-pieces, the faces of each pole-piece and the surface of the screen being so inclined with respect to each other, that a wedge shaped air gap is formed between them, substantially as described, for the purpose set forth.

4. In a magnetic separator, the combination hereinbefore set forth, of an electro-magnet provided with pole-pieces, an operating screen passing through the magnetic field opposite the faces of the pole pieces, the face of each pole piece being inclined inwardly with respect to the screen surface, so that a wedge shaped air gap is formed between them substantially as described.

5. In a magnetic separator, the combination of an electro-magnet provided with pole pieces the faces of which lie in surfaces making an angle with each other and an operating screen passing through the magnetic field opposite the faces of the pole pieces, a uniform attracting force being 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 along the remainder thereof.

6. In a magnetic separator, the combination of an operating screen and an electro-magnet 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, substantially as described.

7. In a magnetic separator, the combination of an operating screen and an electro-magnet provided with pole-pieces, a uniform attracting force being 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 being exerted throughout the remainder thereof.

8. The combination of an electro-magnet provided with pole-pieces, and an operating screen passing through the field opposite the polar faces, the different opposing points of the screen surface and of each polar face being at different distances apart.

In testimony that I claim the foregoing as my invention I have signed my name, in presence of two witnesses, this 17th day of May, 1892.

CLARENCE QUINTARD PAYNE.

Witnesses:

WILLARD PARKER BUTLER,

GUY VAN AMRINGE.