(No Model.) 4 Sheets—Sheet 1.

D. E. LAIN.

MAGNETIC SEPARATOR.

No. 456,622. Patented July 28, 1891.

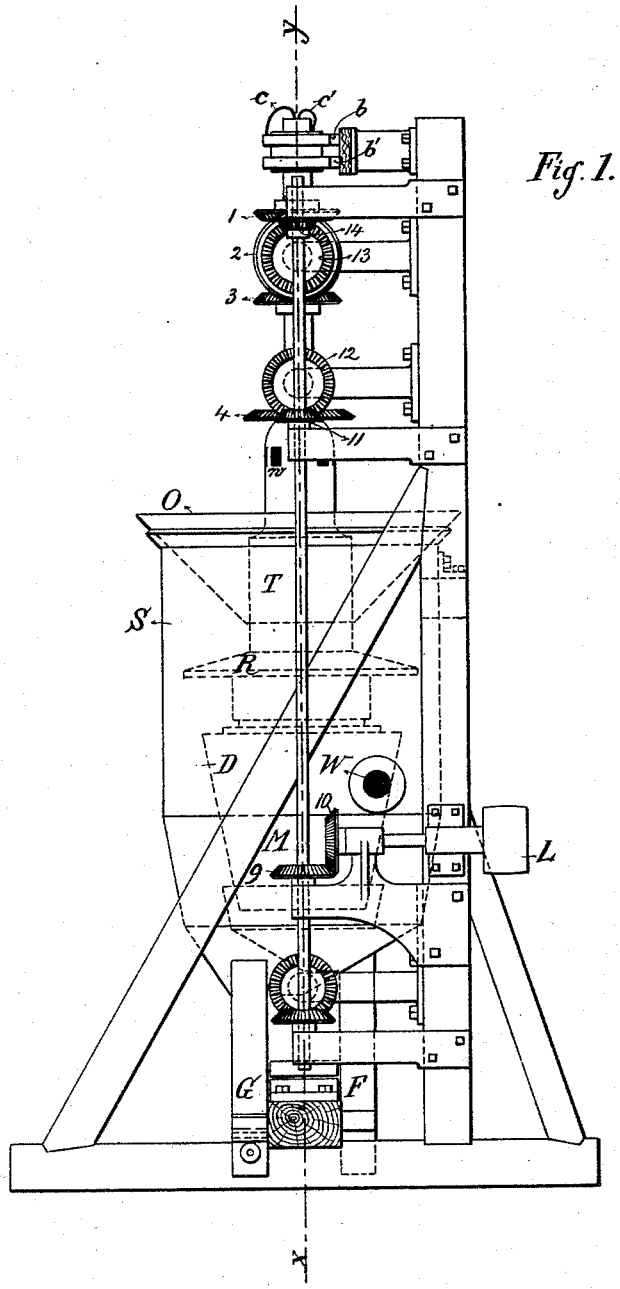

Fig. 1.

Witnesses:
Thos. P. Rooney Jr.
H. A. St. John

Inventor:
David E. Lain

(No Model.) 4 Sheets—Sheet 2.

D. E. LAIN.

MAGNETIC SEPARATOR.

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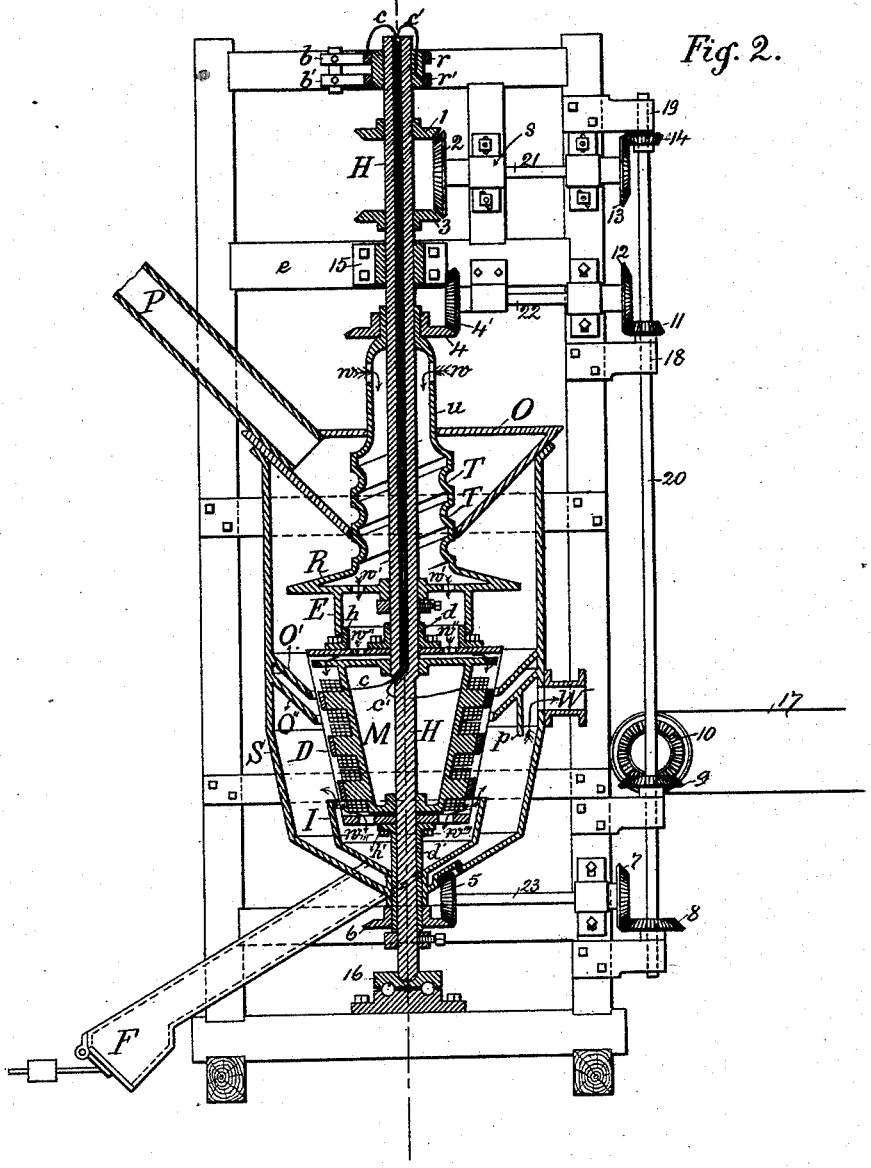
Fig. 2.



Witnesses:
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Inventor:
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(No Model.) 4 Sheets—Sheet 3.

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No. 456,622. Patented July 28, 1891.

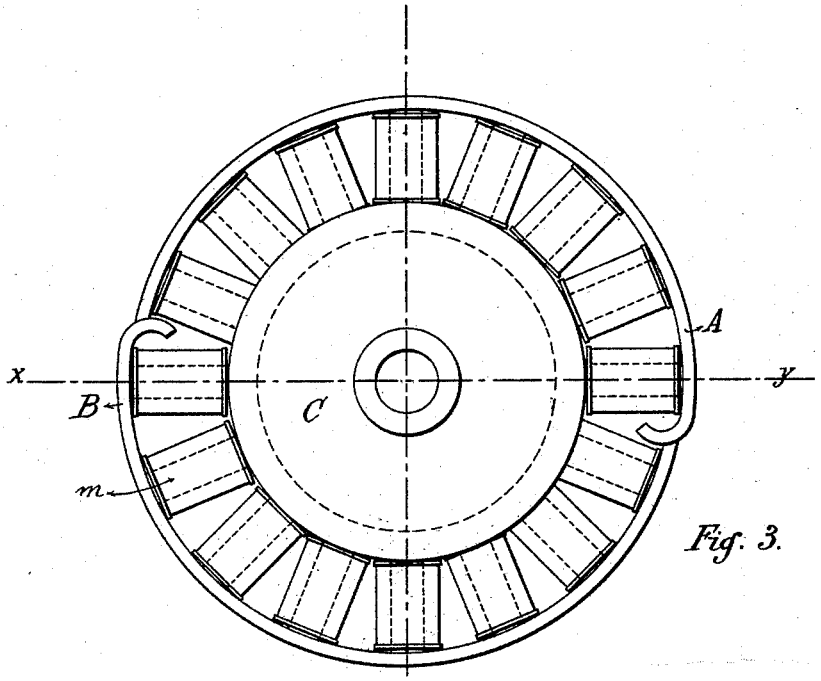

Fig. 3.

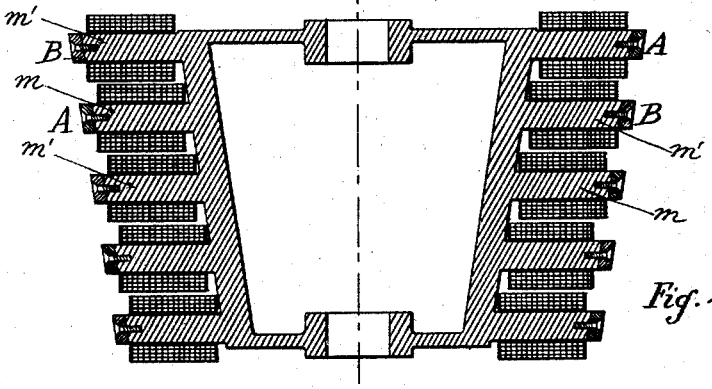

Fig. 4.

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(No Model.) 4 Sheets—Sheet 4.

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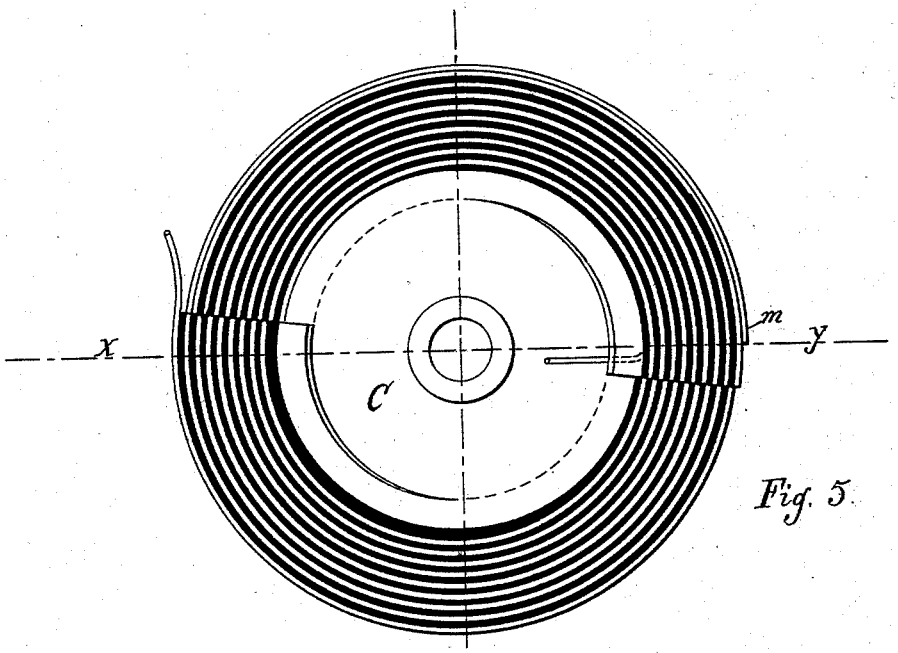

Fig. 5.

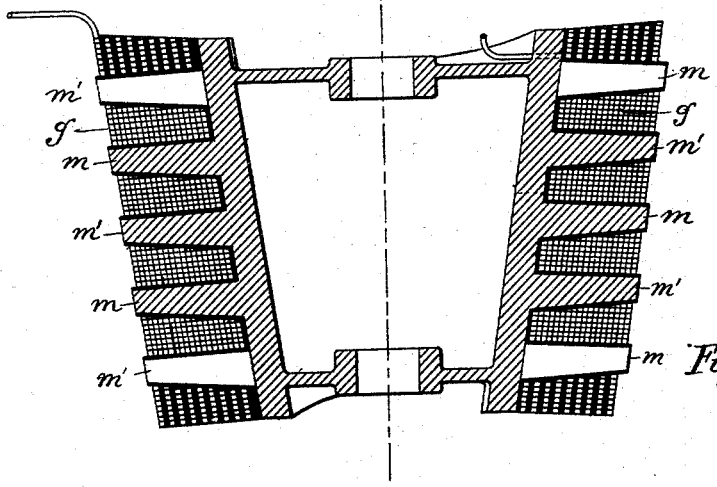

Fig. 6.

Witnesses:
Thos. P. Ropes Jr
A. A. St. John

Inventor:
David E. Lain

UNITED STATES PATENT OFFICE.

DAVID E. LAIN, OF YONKERS, NEW YORK.

MAGNETIC SEPARATOR.

SPECIFICATION forming part of Letters Patent No. 456,622, dated July 28, 1891.

Application filed August 2, 1890. Serial No. 360,839. (No model.)

To all whom it may concern:

Be it known that I, DAVID E. LAIN, a citizen of the United States, and a resident of Yonkers, in the county of Westchester and State of New York, have invented certain new and useful Improvements in Magnetic Separators, of which the following is a specification.

My invention relates to an improved form of magnetic separator, and contains such an arrangement of parts that the material to be separated is subjected to the action of gravity and of a centrifugal force of variable amount, which tend to remove the material from an apron or barrel on which it is carried, while the magnetic line of force from a battery of magnets inside the barrel tends to hold the magnetic part of the material against the barrel; also, the magnetic poles of this battery of magnets are so disposed relatively to the barrel that the magnetic particles are caused to move in a direction along the barrel at right angles to the direction of the action of the centrifugal force referred to. By this motion of the magnetic particles along the barrel they are easily removed out of the way of the non-magnetic particles, and thus the divided parts can be separately carried to such places that they need not again intermingle. I attain these objects by a machine illustrated in the four sheets of accompanying drawings, in which—

Figure 1, Sheet 1, is a side elevation of the machine. Fig. 2, Sheet 2, is a front elevation in section on the line $x\ y$, Fig. 1. Fig. 3, Sheet 3, is a plan view of one form of the magnetic battery for the machine. Fig. 4 is an elevation view in section of Fig. 3. Fig. 5, Sheet 4, is a plan view of another form for the magnetic battery; and Fig. 6 is an elevation view in section of Fig. 5.

Like figures and letters refer to like things in all of the views.

In Fig. 2, Sheet 2, H is a shaft hollow throughout part of its length. The battery of magnets M is rigidly fastened to the shaft H and may revolve with this shaft. One end of the shaft H finds a support and bearing in the ball foot-step 16. This shaft also finds another bearing and support in the bracket and box 15, which is securely fastened to the cross-piece *e* of the supporting frame-work. The external surfaces of the poles of the battery of magnets M lie in the surface of a cone, and the center line of the shaft H is the axis of this cone.

Fastened to the shaft H are the two beveled gear-wheels 1 and 3. A beveled gear-wheel 2 on the counter-shaft 21 may be made to mesh with either gear 1 or 3, or neither, as desired, by raising or lowering the bracket and box *s* on the cross-beam *e*. Thus rotary motion in either direction may be given to the magnets M from the main shaft 20 through beveled gear-wheels 14 and 13, respectively, fastened to the main shaft 20 and counter-shaft 21. Therefore by setting gear 2 to mesh with gear 1 rotary motion in one direction is given the magnets from the main shaft 20, and by setting gear 2 to mesh with gear 3 the same motion of the main shaft produces an opposite rotary motion in the magnets, while by setting gear 2 to mesh with neither gear 1 nor gear 3 the motion of the main shaft is not transmitted to the battery of magnets.

Inclosing the battery of magnets M is the apron or barrel D, of non-magnetic material. *h* and *h'* are the heads of this barrel, respectively above and below the magnets. The heads *h* and *h'* are respectively attached to the sleeve-bearings *d* and *d'* on the shaft H. The barrel D is in the form of a truncated cone and fits as nearly as it may to the poles of the magnets, and yet be free to revolve independently of these magnets. Fastened to the lower end of the sleeve *d'* is a beveled gear-wheel 6, which meshes with the gear 5 on the counter-shaft 23. Counter-shaft 23 is driven from main shaft 20 through the beveled gears 7 and 8, respectively, fixed to the counter-shaft and main shaft. Hence the barrel D is constantly revolved in one direction from the main shaft. Next above the barrel D, free to revolve on the shaft H, is the hollow cylinder *u* terminating below in the broad conical flange R. The hollow cylinder *u* has deep helical grooves T in its outer surface. The upper part of the cylinder *u* is provided with a beveled gear-wheel 4, which meshes with the beveled gear 4' on counter-shaft 22. Counter-shaft 22 is driven from main shaft 20 through gears 12 and 11, respectively fastened to the counter-shaft and the main shaft. Thus the hollow cylinder and flange *u* R are continuously revolved from the main shaft.

The ends of the insulated electrical conductors, the current in which energizes the battery of magnets, terminate in the conductors c and c', which pass through the hollow shaft H, and are respectively connected to the insulated metallic rings r and r' on one end of the shaft H. The brushes b and b' rub, respectively, on the rings r and r' and are the positive and negative terminals of the source of electricity for energizing the magnets M.

O is a covered receptacle for the ore or other material to be separated as it comes into the machine from the chute P. The bottom of O slants downward toward its center and closely embraces the threaded cylinder u. The receptacle O also forms a cover for the casing S, which tightly incloses the flange R and the barrel D. The bottom of the casing S slants downward to the entrance of the downwardly-inclined exit-chute G, Fig. 1, which terminates in an automatic exit-trap.

Projecting from the inner surface of the casing S at points somewhat below the top of the magnets M are two conical annular aprons O' and O'', slanting downward and embracing the barrel D, yet leaving a small free space between the barrel and themselves. These aprons are parallel and the one a short distance above the other. The lower part of the barrel D is surrounded by the inner casing I, which rises to a height a little above the bottom of the magnets M. The bottom of casing I slants downward to the entrance to the exit-chute F, which terminates below in an automatic exit-trap. On one side of the casing S is placed a flanged pipe W, and on the inside of the casing, in front of the opening into this pipe, is placed a screw or shield p. The main driving-shaft 20 is connected to a counter-shaft through gears 9 and 10, respectively fastened to the main shaft and the counter-shaft. This counter-shaft carries a fast pulley L, on which is placed the belt 17 from the source of power for the machine. A suitable timber frame-work (shown in Figs. 1 and 2) furnishes the necessary support for the whole machine.

Referring to Sheet 3, Fig. 3 is a plan view of the battery of magnets M, Figs. 1 and 2, Sheets 1 and 2, and Fig. 4 is an elevation view, in section, of Fig. 3. $m\ m\ m$ and $m'\ m'\ m'$ are the individual magnets of the battery. The cores of these magnets are projections from the conical surface C of magnetic metal. The cores of magnets $m\ m\ m$ are arranged on the cone at equal distances apart, and also in a spiral row around the cone. The cores of magnets $m'\ m'\ m'$ are arranged in a spiral row parallel to the spiral row of cores of $m\ m\ m$. A bar of magnetic metal A is bent to form a continuous spiral pole for the row of magnets $m\ m\ m$ and is securely attached to the ends of the cores of these magnets. Magnets $m'\ m'\ m'$ are provided with a spiral pole B, similar and parallel to A. The outer surface of these spirals A and B lies in the surface of a cone parallel to the conical surface of C. The gang of magnets $m\ m\ m$ are so magnetized that their pole A becomes positive through its whole length, while the gang of magnets $m'\ m'\ m'$ are so magnetized that their pole B becomes polarized negative throughout its whole length. The ends of the spiral poles A and B are bent inward toward the center of the cone. This is done in order that the field of force produced by the magnets M on the outer surface of the barrel D may gradually disappear at the ends of the barrel.

Figs. 5 and 6, Sheet 4, show another form for the battery of magnets M. Fig. 5 is a plan view of the magnetic battery, and Fig. 6 is an elevation view, in section, of Fig. 5. Here the cone of magnetic metal C has two high spiral ridges m and m' on its outer surface. These spirals are parallel, one of them being wound with several turns of an insulated electrical conductor g, the electric current in which may polarize spiral m' negative and spiral m positive, and, as in Figs. 3 and 4, we here may have a pair of parallel spiral poles on the surface of a cone oppositely polarized throughout their entire length. The ends of these cores m and m', Figs. 5 and 6, are chamfered off for the same purpose that the ends of the poles A and B, Fig. 3, were bent inward.

Referring to Fig. 2, Plate 2, a pipe (not shown) is to be attached to the flanged pipe W. This pipe leads to a suction-fan. (Also not shown in this figure.) This suction-fan when driven tends to produce a vacuum inside the casing S. When the receptacle O is full of ore, the only free ingress of air into S is through the hole w in the top of the hollow cylinder u. From this hollow cylinder the air finds a passage through the holes w' in the bottom of the hollow flange R. Here a sleeve E prevents the free passage of the air into S; but it finds a free passage through holes w'' in the upper head h' of the barrel. After entering the barrel it passes downward between the barrel and the poles of the magnets, thus cooling the electrical conductors, and out of the barrel through holes w''' in the lower head h'. The air now enters the inner casing I and passes upward between the sides of the barrel and this casing and into the casing S, from which it may pass through the pipe W into the suction-fan. The office of this air-current will be more fully explained later.

Now let us briefly consider the method by which this machine separates magnetic from non-magnetic particles. Main shaft 20 being set in motion from the counter-shaft and belt 17, the battery of magnets M, the barrel D, and the feeding device u R are each set in motion on or about the shaft h. Electric current is supplied to the magnets through the brushes b and b'. Finely-pulverized ore or other material to be separated is admitted to the receptacle O from the chute P. Owing to the heli-

cal grooves T in the revolving cylinder *u* the ore is carried downward from O onto the revolving conical flange R at a rate proportional to the speed at which *v* is driven. The revolving cone R evenly distributes the ore against the sides of the casing S. By gravity it then falls downward onto the conical apron O′, which directs it against the side of the barrel D. The magnetic field produced by the magnets M will cause the magnetic particles that may strike the barrel to adhere to it; but the non-magnetic particles will be thrown off by the centrifugal force of the revolving barrel or fall downward onto the lower apron O″, which gives whatever magnetic particles may have failed to adhere to the barrel when impelled against it from apron O′ another chance to become fastened to it. The non-magnetic particles then pass downward between the lower apron O″ and the barrel D, and finally find an egress through the tailings-trap G, Fig. 1. The barrel D is revolved in such a direction that if it were threaded to fit the spiral poles of M it would be passed downward on these spirals. Then, consequently, by virtue of the spiral lines along which the strongest part of the magnetic field on the surface of the revolving barrel is arranged, the magnetic particles adhering to the barrel are passed downward toward the inner casing I. During this downward passage of the magnetic particles on the barrel everything on the surface of the barrel is acted on by a considerable centrifugal force. Therefore, whatever non-magnetic particles may have been built in with the magnetic particles when they were first impelled against the barrel from the aprons O′ and O″ are very likely to be thrown from the barrel. The rate at which the magnetic particles may be carried down the barrel will depend on the pitch of the spiral poles and on the relative rates of revolution of the barrel and the battery of magnets. So, if it be desired to subject the material to the action of a strong centrifugal force while slowly moving down the barrel, the magnets may be revolved in the same direction as the barrel is moving, though slower; or if it should be desired to rapidly pass the material down the barrel while under the action of a smaller centrifugal force the magnets may be allowed to remain at rest or be revolved in a direction opposite to that in which the barrel is revolving. When the magnetic particles have passed inside the casing I, they have reached such a weak magnetic field that they can no longer be held against the barrel, and consequently are thrown off by the centrifugal force or fall off by the action of gravity. Owing to the conical form of the barrel, the non-magnetic particles that fall from the apron O″ or from among the material on the barrel until it has reached a point very near the casing I will fall clear of this casing. Now it will be remembered that there is an upward current of air between the casing I and the barrel. This serves to remove whatever non-magnetic dust may still have clung to the magnetic particles. Thus it is believed that a more perfect and rapid separation can be obtained than by any other machine for a similar purpose of which I have knowledge; but I do not want to be understood as limiting myself to the exact methods of construction here described. For instance, it might be found best in some cases to make the poles of the magnets helices on a cylinder rather than spirals on a cone, or it might be best in some cases to invert the conical form battery of magnets and use it with truncated end uppermost. Again it might sometimes be advisable to so revolve the barrel that the magnetic particles would be carried upward by the helical or spiral poles rather than downward, as here described.

I am aware that prior to my invention an air-blast has been used in substantially a similar manner and for a similar purpose to that which I have described. Therefore I do not claim that as part of my invention.

I am also aware that prior to my invention Letters Patent have been granted for a magnectic separator in which downwardly-inclined rows of magnet-poles were placed behind a moving endless apron, and thus a transverse motion of the magnetic particles was obtained; but I am not aware of any invention prior to my own in which the magnetic poles of opposite polarity in a magnetic separator are arranged in the form of parallel spirals in the surface of a cone.

I am also unaware of any other magnetic separator in which the combination of a centrifugal force, the force of gravity, and a magnetic force opposing the action of the centrifugal force and the force of gravity, and so disposed that magnetic particles upon which the centrifugal force is acting will tend to move in a direction at right angles to the line of action of the centrifugal force, is used to separate the magnetic from the non-magnetic particles. Therefore,

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

1. In a battery of magnets for a magnetic separator, the combination of a hollow cone of magnetic metal, two spiral rows of projections of magnetic metal from the external surface of the cone to form the cores for the electro-magnets, windings of insulated electrical conductors for each of the cores, and a continuous spiral pole for each of the two rows of cores, substantially as and for the purpose described.

2. In a battery of magnets for a magnetic separator, the combination of a hollow truncated cone of magnetic metal, two parallel spiral threads of considerable height of magnetic metal projecting from and magnetically connected to the hollow cone, and windings of insulated electrical conductor around one of these spiral threads, the electric current in which will produce an opposite magnetic

polarity in the two threads, substantially as and for the purpose described.

3. In a battery of magnets for a magnetic separator, the combination of a hollow truncated cone of magnetic metal, two parallel spiral threads of considerable height projecting from the cone of magnetic metal and magnetically connected to the cone, windings of insulated electrical conductor around one of the threads, the current in which conductor will magnetically polarize the two threads in an opposite manner, the ends of each of these threads being obliquely chamfered down to the surface of the cone, and a shaft, hollow throughout part of its length, projecting from each end of the cone and rigidly attached to the cone in the axis of the same, said shaft being provided with beveled gear-wheels rigidly attached, and also insulated metallic rings, substantially as and for the purpose specified.

4. In a magnetic separator, the combination of a battery of magnets the opposite poles of which are two parallel spirals in the surface of a cone with a continuous apron or barrel of non-magnetic material fitting closely around the spiral poles of the magnet and fitted to revolve around and independently of the same, substantially as and for the purpose specified.

5. In a magnetic separator, the combination of a battery of magnets the opposite poles of which are two parallel spirals in the surface of a cone, a shaft rigidly attached to the cone in its axis and fitted with suitable gears and bearings, also prepared with insulated metallic rings, the terminals of the electric conductors of the magnets, and a conical apron or barrel fitting close to and over the spiral poles and prepared to revolve independently of the battery of magnets and on their shaft, substantially as and for the purpose described.

6. In a magnetic separator, the combination of a battery of magnets the opposite poles of which are parallel spirals in the surface of a cone, a shaft rigidly attached to the cone in its axis and fitted with gears and bearings, as described, also prepared with insulated metallic rings, the terminals of the electric conductors of the magnets, a conical apron or barrel fitting close to and over the spiral poles of the magnets and prepared to revolve on their shaft, a casing embracing one end of this barrel and having a downwardly-inclined bottom leading into a downwardly-inclined exit-chute, a larger casing inclosing the whole barrel and smaller casing, also having a downwardly-inclined bottom leading into a downwardly-inclined exit-chute, and one or more downwardly-inclined conical annular aprons embracing one end of the barrel, but not touching the same, substantially as and for the purpose described.

7. In a magnetic separator, the combination of a battery of magnets the opposite poles of which are parallel spirals in the surface of a cone, a shaft rigidly attached to the cone and in the axis of the same and fitted with gears and bearings, as described, also prepared with insulated metallic rings, the terminals of electric conductors from the magnets, a conical apron or barrel fitted close to and over the spiral poles of the magnets and fitted with suitable bearings and gears for being revolved on the shaft to the magnets, a small casing embracing one end of this barrel and having a downwardly-inclined bottom leading into a downwardly-inclined exit-chute, a feeding device consisting of a cylinder with deep helical grooves and terminating below in a broad conical flange and fitted with gears and having boxes which find journals in the shaft to the battery of magnets, a receptacle with downwardly-inclined bottom, the vertex of which embraces the cylinder of the feeding device, a casing inclosing the smaller casing, barrel, and flange of the feeding device and finding a cover in the bottom of the receptacle and having a downwardly-inclined bottom leading into a downwardly-inclined exit-chute, one or more conical annular aprons embracing one end of the barrel and projecting from the interior of the larger casing, a main shaft provided with gears and connected with counter-shafts, which also is provided with suitable gears, a counter-shaft provided with a pulley and suitable gear connections to the main shaft, a dynamo-electric machine or other source of electric energy electrically connected to the brushes of the magnetic separator for energizing the battery of magnets, and a suitable framework for providing the necessary supports for the different parts of the machine and for holding the shaft to the battery of magnets in a vertical position, all substantially as and for the purpose specified.

In testimony that I claim the foregoing as my invention I have signed my name, in presence of two witnesses, this 23d day of July, 1890.

DAVID E. LAIN.

Witnesses:
JOHN P. ROOSA, Jr.,
H. A. ST. JOHN.