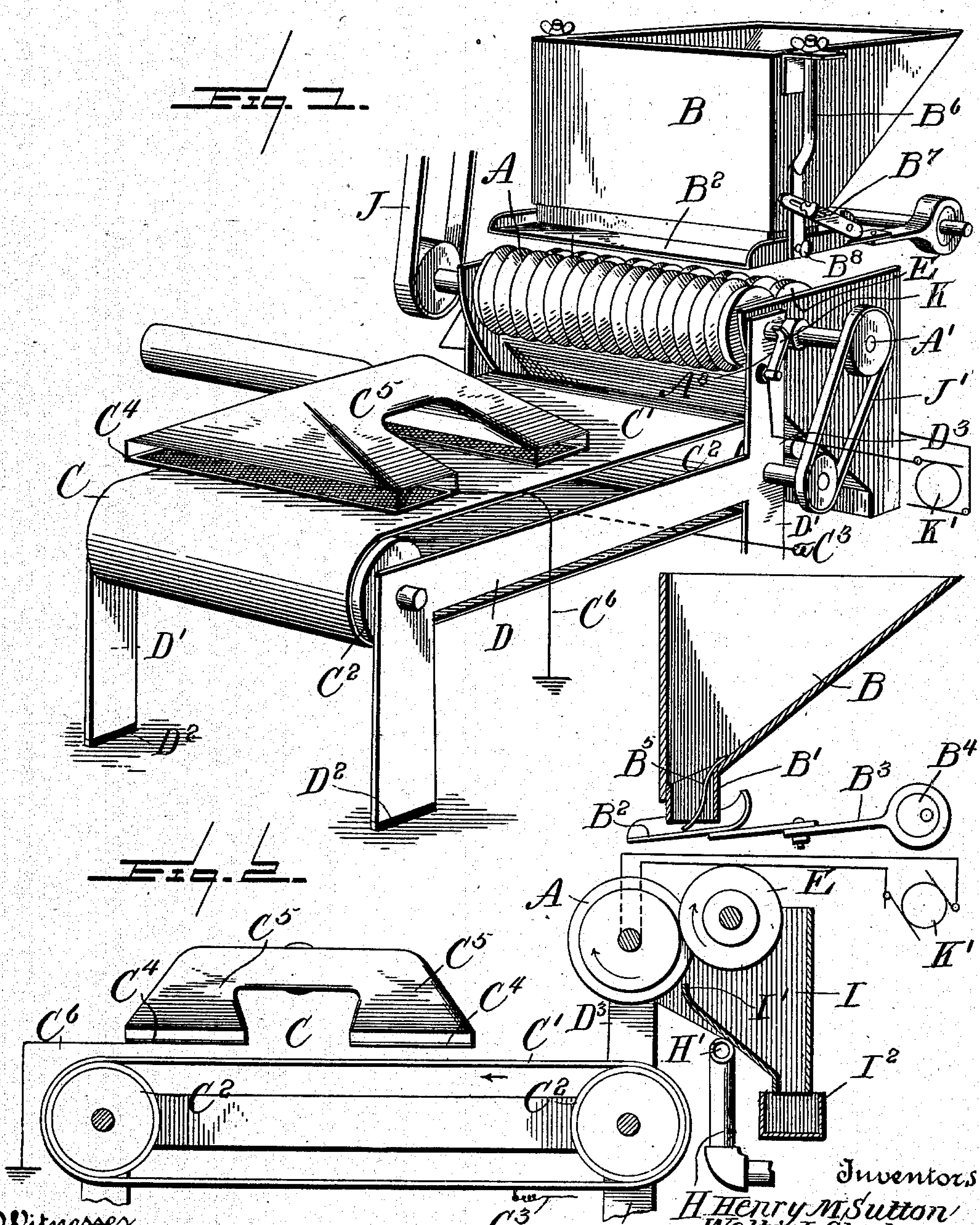
No. 714,256. Patented Nov. 25, 1902.

H. M. SUTTON & W. L. & E. G. STEELE.

PROCESS OF MAGNETICALLY AND STATICALLY TREATING ORES.

(Application filed Oct. 5, 1901.)

(No Model.) 3 Sheets—Sheet 1.



Witnesses

Wm. J. Doyle.

Alfred T. Gage

Inventors

Henry M. Sutton

Walter L. Steele and

Edwin G. Steele.

By E. B. Stocking

Attorney

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

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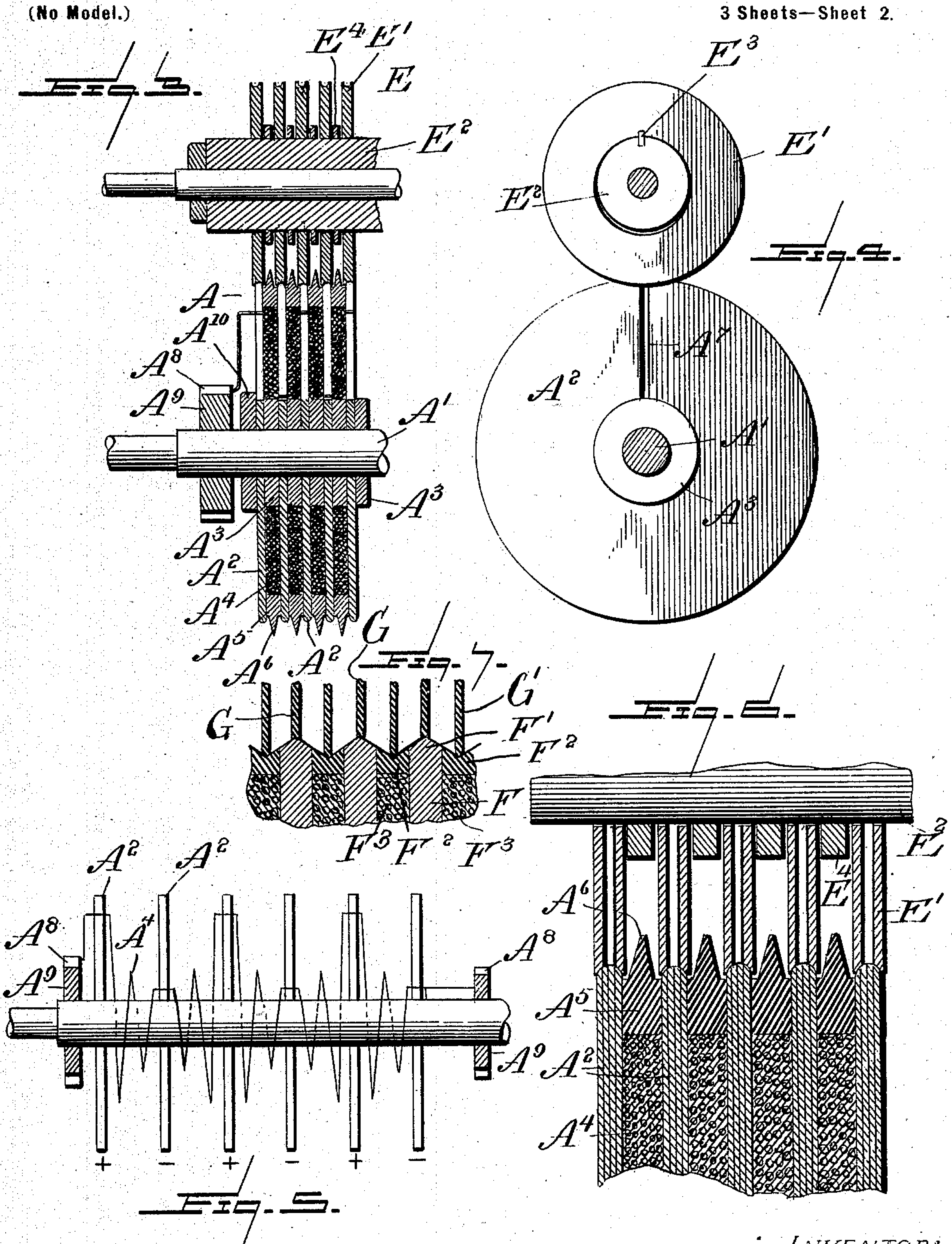

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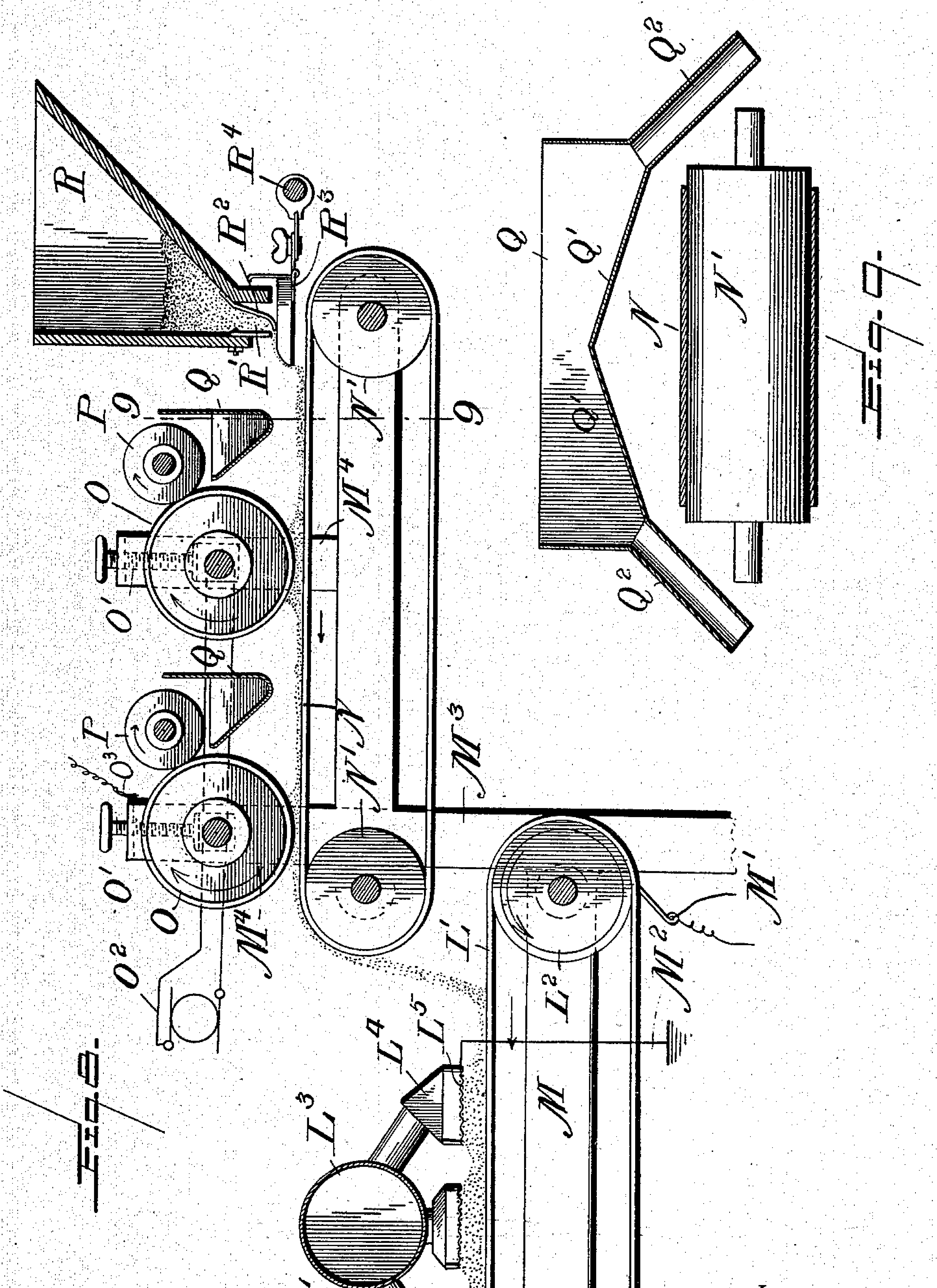

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By
E. B. Stocking
Attorney

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

HENRY M. SUTTON, WALTER L. STEELE, AND EDWIN G. STEELE, OF DALLAS, TEXAS.

PROCESS OF MAGNETICALLY AND STATICALLY TREATING ORES.

SPECIFICATION forming part of Letters Patent No. 714,256, dated November 25, 1902.

Application filed October 5, 1901. Serial No. 77,683. (No specimens.)

To all whom it may concern:

Be it known that we, HENRY M. SUTTON, WALTER L. STEELE, and EDWIN G. STEELE, citizens of the United States, residing at Dallas, in the county of Dallas, State of Texas, have invented certain new and useful Improvements in Processes of Magnetically and Statically Treating Ores, of which the following is a specification, reference being had therein to the accompanying drawings.

This invention relates to a process for magnetically and statically treating ore to separate the valuable metal therefrom during its passage through a single machine.

The process has for an object to primarily treat the ore so as to remove therefrom metallic or other particles of a magnetic character which usually are of a crystallized form, having sharp corners or points which greatly interfere with a subsequent static separation by lowering the potential of the statically-charged conveyer, and thereby diminishing the amount of material that can be treated at one time.

An important coöperation between the magnetic and static separators in their joint action is that when a static charge of any potential is given the conveyer used in the separator this charge creates an induced charge of equal potential in some adjacent part, in this instance in the frame of the machine, which is of any suitable material and insulated from the metallic belt or conveyer to which the charge is applied, and the frame is further insulated from the floor or support upon which the parts rest. From this it will be seen that the more static charge placed upon the conveyer the greater the charge received by the frame, and subsequently the more current used the better work can be accomplished. A portion of this charge upon the frame is collected and retained on the surface of the magnets used for the magnetic separation, which magnets are energized from a dynamo or other suitable source and receive an additional static charge from the framework of the machine. These magnets also act as a condenser attached to the frame of the machine, and the heavy charge carried thereby is returned to the belt the moment that the potential of the belt drops below that of the frame, and thus an even and continuous charge is maintained upon the belt to effect the most desirable, even, and successful separation. This restoring of the charge to the belt is essential, as fluctuation in the static current is liable to occur, and every particle of material which passes through the screen reduces the charge on the belt to that extent, which loss must be restored from the static generator assisted by the charge on the frame and surface of the magnetic roller.

Other objects and advantages of the invention will hereinafter appear in the following description, and the novel features thereof will be particularly pointed out in the appended claims.

In the drawings, Figure 1 is a perspective of the combined magnetic and static separator. Fig. 2 is a side elevation thereof. Fig. 3 is a horizontal section through a portion of the magnetic roller and the cleaner-roller therefor. Fig. 4 is an end elevation of the parts shown in Fig. 3. Fig. 5 is a diagrammatic illustration showing the current-winding for the electromagnet. Fig. 6 is an enlarged detail of the contact-points between the magnetic roller and cleaner, showing a modification of the cleaner-roll plates. Fig. 7 is a modified form of magnetic roller and cleaner-roller. Fig. 8 is an elevation of a modified arrangement of the separator, and Fig. 9 is a vertical section on line 9 9 of Fig. 8.

Like letters of reference indicate like parts throughout the several figures of the drawings.

As illustrating one form of apparatus adapted to accomplish the process of statically treating the ore after the same has been subjected to a combined static and magnetic action a form of the invention is shown in Figs. 1 and 2, wherein the letter A designates a magnetic separator of any desired character adapted to receive a feed of ore from a hopper B and to discharge the same upon an electrostatically-charged separator, as indicated at C. This static separator may be of any preferred construction adapted to receive the ore after having passed under the influence of the magnetic action—for instance, as disclosed in Patent No. 670,440, dated March 26, 1901, wherein the essential elements comprise the statically-charged endless belt C′, mounted upon suitable rollers C^2 and insulated therefrom in any desired manner, while bearing upon or adjacent to one surface of the belt a brush or conductor C^3 communicates with a source of electrostatic electricity. In the patent mentioned the separation is effected by means of a screening member C^4 and suction or draft through the hoods C^5. This screen member is connected to a return-circuit—for instance, by means of a grounded line C^6—so as to repel the metallic particles from the screen C^4 and permit the non-metallic particles to pass therethrough and be removed by the draft through the hoods C^5.

In the application of the present process it is desirable that the rolls C^2, which are insulated from the belt C′, should be mounted in a frame D of any suitable material—for instance, wood—having supporting-standards D′, which are insulated from the support therefor by any form of insulation, such as a block D^2, while the magnetically-charged separating device is connected to this frame by means of standards D^3, rising therefrom and forming the journal-support for the magnetic separator. Under these conditions it will be seen that the frame is insulated from the belt and a counter-induced charge is generated in the frame equal to the charge in the belt, which induced charge is opposite in polarity to that of the belt, and by means of the communication between the frame and the magnet the surface of the latter, acting as a condenser to receive a portion of the surplus static electricity, is energized, so that when the potential of the belt falls below that of the frame the charge from the magnets returns to the belt and establishes an equilibrium. This is particularly necessary, as the particles of waste in rising to and passing through the screen reduce the charge in the belt in different degrees, depending upon the character of material operated upon and at different times with the same character of material, owing to the presence of more or less metal therein, so that it is essential to statically charge the magnets adjacent to the static separator for the purpose of receiving and retaining an equalizing charge for use when necessary. In addition to the magnet acting as a condenser the effect of the combined static and magnet action upon the diamagnetic and non-magnetic particles is to cause a difference of potential between the particles, so as to assist the magnetic action in collecting the same in a separated form, which permits a much more thorough and easy separation than would be effected under the influence of the static separation alone.

In Figs. 4 to 7, inclusive, an improved form of magnetic separator has been shown, and also a cleaning-roller adapted to magnetically discharge the material collected by the magnetic roller. The magnetic roller or separator A consists of a supporting-shaft A′, adapted to receive a series of plates or disks A^2, which are suitably magnetized by passing an electric current through a winding adjacent to the plate or lamination. Between the plates A^2 a core-ring A^3 is disposed, and an electrical winding A^4 from a suitable source of current is placed thereon, while at the outer edge of this winding an insulating-ring A^5 is disposed between the plates A^2 to prevent bridging of the magnetic particles from one plate to the other. As further assisting this action the plates A^5 are provided with a beveled or inclined face A^6, which directs the particles of ore toward the plates on opposite sides of the ring and forms an insulated barrier to prevent the particles bridging between the magnetized plates A^2. For the purpose of carrying the winding of wire through the plates A^2 each of these plates is provided with a radial slot A^7, as shown in Fig. 4, which also prevents eddying currents around the plates, and the winding at opposite ends of the roller is connected to a suitable contact-ring A^8, carried upon an insulated base A^9, mounted upon the shaft A′, while brushes K, which are connected to a suitable dynamo or generator K′, bear upon said rings for the purpose of energizing the magnets. The plates A^2, collars A^3, and insulating-rings A^6 are firmly clamped together by any desired means—for instance, by a nut A^{10}, as shown in Fig. 3.

The magnetic ring is wound, as shown in the diagram in Fig. 5, so that the winding A^4 thereof magnetizes the plates A^2 alternately negative and positive, making a thoroughly saturated magnetic field through which all the magnetic particles adhere at the edges of the plates A^2, while the non-magnetic and diamagnetic materials pass over the roll without being drawn and held thereto. As each of the magnetic plates A^2 is of opposite sign, it is essential that the insulating-rings A^5 be used between the same in order to prevent bridging of magnetic particles, which would otherwise occur, and render a clean separation difficult. For the purpose of effecting a magnetic cleaning of the plates A^2, comprising the magnetic roller A, a cleaner-roller E is mounted adjacent thereto and adapted to revolve in the same direction as the magnetic roller A, which causes the edges nearest to each other to pass in opposite directions from their point of nearest approach, and these edges are adapted to come into contact with or very near each other or slightly lapped. This is effected by means of the rings E′, which are provided with a central aperture slightly larger than the insulating-core E^2, upon which they are mounted and on which they are held against rotation by means of a loose key E^3, and spaced in position upon the core by collars E^4, so as to bring the cleaner-plates E′ into alinement with the magnetized plates A^2 of the magnetizing-roller. The cleaner-plates are loose upon the core, but rotated therewith, and are made of soft iron or other suitable material, so that when the circuit is closed through the magnetic roller

A these cleaner-rings are drawn and held in contact with the same, which contact creates a magnetic pole on the cleaner-ring at the point of contact and of approximately the same strength as that of the magnetic roller or plate. The cleaner-rings rotate in the same direction as the magnetic rings, and the magnetized particles of metal are thus enabled to pass the point of contact and are attracted to and received by the cleaner-rings, by which they are carried over a hopper and discharged therein as the magnetic field weakens on the cleaner-roller in its rotation away from the point of contact until a point is reached where the reduced magnetism is too weak to sustain the adhering particles.

Fig. 6 shows a further modification of the cleaner-roll, in which the cleaner-roll plates are made of thin laminations, adapted to bear or slightly lap on either side of magnetic rings A^2. This view also shows magnetic rings A^2 constructed of thin laminations, and in energizing the magnet-roller A with alternating current this would be necessary.

In Fig. 7 a slightly-modified form of magnet-roller and cleaner-roller is shown in detail, wherein the magnetized plates F are formed with a beveled or inclined face F', to which the magnetic particles of metal will rise, and are separated by insulating-rings F^2, extending peripherally of the winding F^3 for the magnet, while the plates G of the cleaner-roller travel over and contact with the inclined face F' to receive the magnetized metal therefrom. The soft-iron plates G' of the cleaner-roller interposed between the magnetically-energized plates of the roller-magnet act as a further precaution in breaking up the bridging of the magnetic particles across the magnetized disk, which would occur in this form of the roller-magnet. In that class of separators involving the use of a magnetically-charged roller a draft or current of air is produced by the movement of the roller, which causes the fine dust or other particles to be carried back toward the magnetic roller, so that a perfectly clean separation of the ore cannot be effected, but a further cleaning of the magnetic metal is necessary. For the purpose of preventing this draft or current an air-pipe H is located below the magnetic roller A, so as to direct a current of air from the aperture H' in the pipe across and transversely to the falling particles of ore, which counteracts the air-current created by the movement of the magnetic roller. In the construction as shown in Fig. 8 this is unnecessary. The air for the purpose is supplied from any desired source, and it is only necessary to maintain a gentle pressure of air sufficient to counteract the draft and direct the dust and waste material toward the traveling static separator, by which it will be carried to a point of discharge.

For the purpose of receiving the magnetic material dropped from the cleaner-roller E a trough I is provided beneath said roller and having a wall I' extended toward the magnetic roller so as to catch all of the magnetic particles as they fall from the cleaner-roll. This trough may communicate at its lower end with any form of box or conveyer I^2 as desired. The hopper B may be of any desired construction to properly feed the pulverized ore to the magnetic roller; but a desirable construction is shown in Figs. 1 and 2, wherein a discharge-spout B' is secured at the lower portion of the hopper, under which a shaker-pan B^2 is supported and adapted to be operated by an eccentric-strap B^3, extending from a suitable driving-eccentric B^4, while within the spout B' a flexible strap B^5 is secured to force the feed of ore forward and prevent waste at the back of the shaker-pan. This pan is supported by any desired means—for instance, a hanger B^6, secured at its upper end to the hopper B—and the inclination of the pan may be adjusted by means of a link B^7 at the rear of the pan, which pan is pivotally mounted at B^8 upon the lower end of the hanger B^6 to permit this adjustment. In Fig. 1 a driving-belt J is provided at one end of the shaft of the magnetic roller A, and at the opposite end thereof a belt J' extends from said shaft to the driving-shaft for one of the rollers C^2, carrying the statically-charged belt, so that the parts are thus adapted to operate in unison, and the cleaner-roller may be likewise driven in the same direction as the magnetic roller A by means of a proper gearing. (Not specifically shown.) The electric current for the purpose of electrically magnetizing the roller A may be conveyed from a dynamo K' or any suitable source.

In Fig. 8 a modified form of apparatus for carrying out the combined magnetic and static separation is diagrammatically illustrated. In this figure the electrostatic separator L is composed of a traveling belt L', mounted upon suitable rollers L^2 and insulated therefrom. Above the belt a suction device L^3 is located and provided with hoods L^4, having screen-surfaces L^5, all as more particularly set forth in connection with Figs. 1 and 2. The rolls L^2 are mounted in a framework M of suitable material to be electrically charged from an induced static current of opposite potential to the belt L'. This belt is charged by means of a brush M', in circuit with a suitable source of static electricity, while the repelling-screen L^5 is provided with a return-circuit through the ground-line M^2. The frame M is provided with an upward extension or standard M^3, adapted to support and convey current to a secondary statically-charged belt N, which is suitably mounted upon rolls N' at opposite ends in circuit with the belt and frame, so as to repel the particles of ore upward from the belt. Above this belt one or more magnetic rollers O, similar to those hereinbefore described, may be mounted in any suitable manner. As herein shown, these rollers are secured to an adjusting device O', by which they may be raised and lowered relative to the surface of the belt N, while the magnetic plates of the roller are charged by a static current directly by induction and are energized by a current from a dynamo or other suitable source, so that the magnets act as condensers in addition to their attractive influence. The magnetic particles are removed from the roller O by means of the rotatable cleaner-rolls P, similar to those hereinbefore described, which deposit the collected material within a hopper Q, extending above the surface of the belt N, as shown in Fig. 9. This hopper is provided with an inclined bottom Q′ and oppositely-disposed discharge-chutes Q^2. The material is fed upon the belt N in any suitable manner from a hopper R, having a discharge-spout R′ and flexible flap R^2, adapted to coöperate with a shaker-pan R^3, driven by an eccentric R^4. The several rotative parts are suitably connected by any desired means to produce the movement of the several elements, as indicated by arrows thereon, such driving means not being herein specifically shown, as the application thereof is within the skill of an ordinary mechanic.

In the arrangement of parts shown in Fig. 8 the magnetic roll is charged with static electricity secured direct from the frame of the machine or by contact with a source of static electricity—for instance, as at O^3—and magnetically energized from a dynamo or other suitable source and exerts its attractive influence above the statically-charged belt, upon which the ore is fed. This secondary belt is charged by induction from the main static separator, or it may be charged direct from a static generator, so that the particles of ore are repelled from the belt toward the magnet, which collects the magnetic particles and deposits them within a hopper through the action of the cleaner-roller. The material advantage of this arrangement is that particles which are very feebly magnetic are thus brought within the influence of the magnetic roller, which is thereby saved from exerting the lifting energy necessary to attract and move the magnetic particles within or under the mass of ore upon the belt. The charge of static electricity upon the belt causes the particles of ore to have a tendency to mutually repel each other while they are being attracted by the statically-charged magnetic roller. In this manner the magnetic particles are rendered perfectly free to move in the lines of magnetic force and are not obstructed by the gangue of the ore.

With the use of the statically-charged magnetic roller it has been found that much of the very fine gold follows the magnetic particles, thus making a magnetic concentrate of the iron and gold. This is due to the well-known law that two particles statically charged at different potentials attract each other, and this attraction can be maintained as long as there is a difference of potential between the two bodies. When the ore comes in contact with the magnetically and statically charged roller, the non-metallic particles are repelled therefrom, while the magnetic particles adhere thereto, together with some of the fine gold, the reason being that the iron particles having sharp corners do not retain their static charge the same as the gold, and consequently there is a constant difference of potential between the gold and iron particles which cause them to adhere, the iron being carried by its magnetic attraction to the roller. While it is desirable in some instances to make a clean concentrate of the iron from the gold values, it frequently happens that when the gold is extremely fine it is advantageous to carry it with the iron, particularly when an electrically-repulsive screen is used to repel the metallic masses in the electrostatic separation. It has been found that a much greater difference of potential between the screens and statically-charged belt is required to separate very small metallic particles from the ore than for the separation of larger particles, and this difference of potential can only be maintained by increasing the distance between the belt and the screen, as thus a larger charge accumulates on each in an effort to bridge the intervening space. This action charges the metal within the field more strongly than otherwise; but at the same time it diminishes the amount of gangue that passes from the ore through the screen, as the discharge across this space is not as frequent as when the screens are close to the belt. The fine gold particles are but little more than points, and on account of the extremely small surface that they present a very strong static charge is required to control them, so that it will consequently be seen that if the fine particles of gold and the sharp angular iron are removed from the ore more of the static electricity can be used to move the gangue of the ore and less will be needed to control the larger metallic particles. The gold can be removed from the magnetic concentrate by a magnetic separator which is not statically charged.

The magnet-roller A carries a very strong charge of static electricity (being part of the framework) of opposite sign to that of the belt C on which the electrostatic separation is made. If the ore in passing over the surface of the magnet-roller were to make any great reduction in the charge on the electrostatic belt, the machine would be inoperative, while the fact is that the capacity of the electrostatic separator has been greatly increased by the addition of the magnet-roller.

Figs. 1 and 2 show the connection C^3 from the static generator in the rear. This generator charges belt C, we will say, with the + sign. Now according to the illustration we have given this would charge the framework and also the surface of the magnetic roller A and the shaker-pan, hopper, and its contents with the − sign. If we were now to connect the framework to the earth, this would remove the inductive charge and increase the charge of C, and if it were simply a question of electrostatic separation of an ore that had no sharp-cornered substances therein this would be the proper thing to do; but in the case of the combined magnetic and static separation this grounding of the magnetic roller would reduce it to zero potential, and consequently all material passing over it likewise. This would lose the effect of the sharp-cornered magnetic particles sustaining other particles by reason of their difference of potential, as has already been explained. To effect this, we carefully insulate the machine from the floor, as is shown by insulators D^2. Dynamo K′ is also mounted on an insulated base to prevent the grounding of the inductive charge.

In addition to the advantages and coöperation heretofore pointed out in the relation between the magnetic and static separators it will be noted that by charging the surface of the magnet with a static current while it is being energized by dynamic or voltaic electricity a joint concentration of the iron and fine gold is secured, and the static separation consequently rendered much more thorough and economical. If a statically-charged belt be used beneath the magnetic roller, another very important advantage is secured in the separation.

It must be understood that we do not confine ourselves to statically charging the belt, for the same results are obtained by grounding the belt and charging the magnet-roller, and therefore either method may be used, depending on the nature of the material and the convenience of working the same. It will also be apparent that the magnetic separator may be used without the static charge when so desired, and is adapted for use in other forms of separators than herein shown.

Many mineral substances have non-magnetic metallic bases, which become susceptible to magnetic attraction if they are simultaneously charged electrostatically, thus effecting a separation which cannot otherwise be secured. Assuming that the belt C′ is electrostatically charged with the positive sign, the magnetic roller A will be charged inductively with the negative sign, and there is a zero-line intermediate between these two surfaces where the opposing electrification of one surface will neutralize that of the other. Now if the ore be fed upon the belt in a thin layer the particles will be attracted toward the roller by the static force and on coming in contact therewith will be again repelled by the same force. In actual practice there are many of these substances which are partially conductive and do not actually come in contact with the magnet, but lose their initial electrification soon after crossing the zero-line into an opposing field. Consequently if the electrostatic charge is properly regulated these substances can be kept oscillating backward and forward across this zero-line, and thus practically suspended in space. Another feature of the electrostatic attraction is that the movement of the particles of matter under this influence is very sluggish, and this is increased as the distance between the opposing surfaces is increased. Particles of matter under magnetic attraction move with celerity toward the inducing-magnet, and their speed is increased as the square of the distance is decreased, while with electrostatic attraction the velocity of the particles can be made practically uniform. This is due to the fact that the particles after passing the zero-line begin to lose their initial electrification, which loss varies with the dielectric medium used, which may be air, liquid, or any well-known medium. It will therefore be noted that the mass containing paramagnetic particles is electrically suspended in a dielectric medium, and the removal of these paramagnetic particles is effected by a magnetic force.

It will be obvious that changes may be made in the details of construction and configuration of the several parts and that other forms of apparatus may be devised for accomplishing the process hereinbefore set forth without departing from the spirit of the invention as defined by the appended claims.

Having described the invention, what is claimed is—

1. The process of separating ore consisting in first subjecting the same to a statically-affected magnetic action and subsequently subjecting the non-magnetic and diamagnetic material to the direct action of static electricity; substantially as specified.

2. The process of separating ore consisting in first subjecting the same to a statically-affected magnetic action and subsequently subjecting the non-magnetic and diamagnetic material to the action of a static electricity and removing from the statically-charged ore the non-metallic particles contained therein; substantially as specified.

3. The process of separating ore consisting in first subjecting the same to the influence of a statically-affected magnetic current to remove magnetic particles therefrom, immediately subjecting the diamagnetic and non-magnetic particles to the action of a static current, and finally removing from the ore the non-metallic particles contained therein; substantially as specified.

4. The process of separating or concentrating ores which consists in magnetically energizing a surface and statically charging the same, whereby the magnetized particles that are attracted will sustain other particles by reason of their difference of potential; substantially as specified.

5. The process of separating or concentrating ores which consists in magnetically energizing a surface and statically charging the same whereby the magnetized particles that are attracted will sustain other particles by reason of their difference of potential, and the

removal of these particles by an extraneous force; substantially as specified.

6. The process of separating or concentrating ores which consists in first subjecting the same to a combined static and magnetic influence to separate the magnetic material, and subsequently subjecting the same to the direct action of the static electricity; substantially as specified.

7. The process of separating ores which consists in electrically suspending a mass thereof containing paramagnetic particles in a dielectric medium, and the removal of these paramagnetic particles by a magnetic force; substantially as specified.

8. The process of separating ores which consists in electrically suspending a mass thereof containing paramagnetic particles in a dielectric medium, and the removal of these paramagnetic particles by an auxiliary field of force; substantially as specified.

In testimony whereof we affix our signatures in presence of two witnesses.

HENRY M. SUTTON.
WALTER L. STEELE.
EDWIN G. STEELE.

Witnesses:
J. C. JOHNSON,
EDWIN J. REEVES.