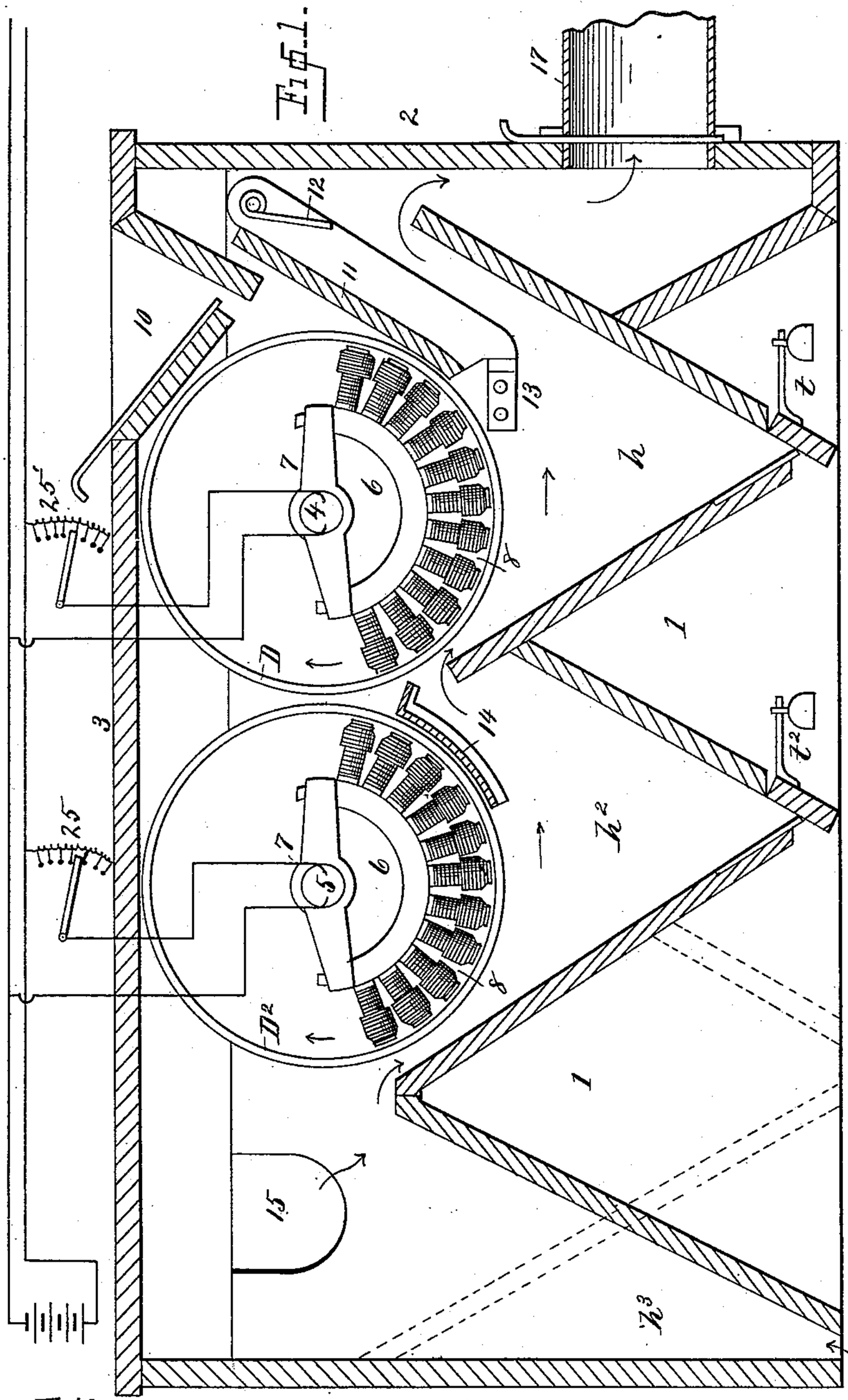
(No Model.)

C. M. BALL.

MAGNETIC ORE SEPARATOR.

No. 465,349. Patented Dec. 15, 1891.



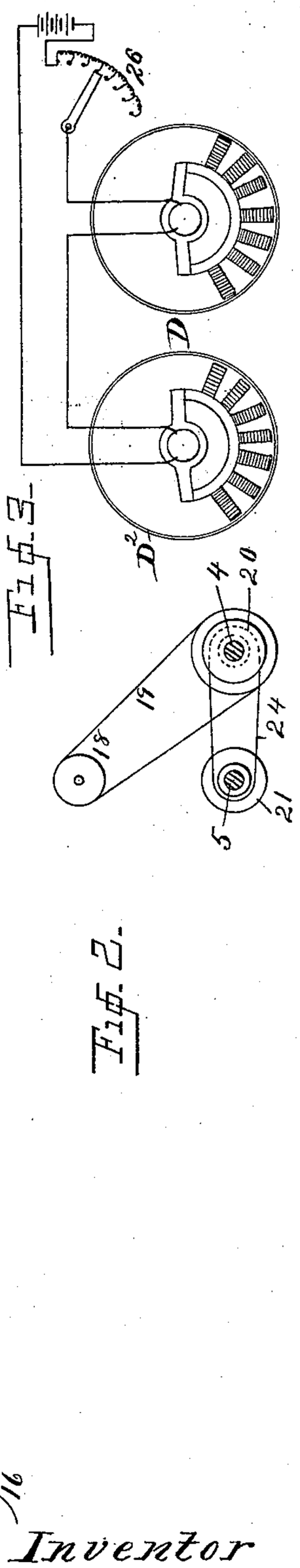


Fig. 2.

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UNITED STATES PATENT OFFICE.

CLINTON M. BALL, OF TROY, NEW YORK.

MAGNETIC ORE-SEPARATOR.

SPECIFICATION forming part of Letters Patent No. 465,349, dated December 15, 1891.

Application filed December 11, 1890. Serial No. 374,384. (No model.)

To all whom it may concern:

Be it known that I, CLINTON M. BALL, a citizen of the United States, residing at Troy, in the county of Rensselaer and State of New York, have invented certain new and useful Improvements in Methods of and Apparatus for Separating Ores; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention relates to a novel method of and apparatus for separating iron or its crushed ore from the impurities with which such are generally found associated and for grading the separated products.

In a prior patent granted to me and Sheldon Norton was described a mode of separation involving as its characteristic feature the passage of the mixed iron ore and gangue through a magnetic field, during which tangential inertia is imparted to the ore by means of a rotary screen interposed between the magnets creating the field and the passage for the ore. In another case was described a similar mode involving as an additional feature the idea of using two or more magnetic fields and corresponding rotating screens, which were driven at different rates of speed, resulting in the separation of the material operated upon into three grades: concentrate, middlings, and tailings.

The present invention constitutes an improvement more especially upon the apparatus described in the last-mentioned case, although it is also applicable to the case in which a single rotary screen is used. It also involves a new mode of treatment of the magnetic ore. The screens are belted or otherwise geared to a suitable source of motion, so that they may impart the necessary tangential inertia to the material being operated upon to separate said material into proper grades, varying according to the percentage of iron contained therein, and the magnetic fields are varied in strength, so as to adapt the operation of the machine to the character of the ore as to its magnetic susceptibility and preserve the uniformity of the separated products. Where the two rotating screens are driven at different speeds, the ability to vary the strength of the field is a matter of considerable importance, as it enables the difference in speed, which may be somewhat too great or somewhat too slight, to be compensated or graduated to exactly the proper point to secure the best results.

My present invention therefore comprises an apparatus for separating the ore from its impurities by passing it through one or more magnetic fields while under the influence of tangential inertia and adjusting the strength of the field to the proper point to yield the best results.

It also comprises a series of magnetic fields and means for varying the strength of field magnetism and means for conducting the ore through said fields while under the influence of tangential inertia.

It also consists of a method of separation consisting in first separating the ore into several grades, according to the percentage of iron contained, and then recrushing the impure material to mechanically dissociate the iron, and then withdrawing the said iron from the crushed material.

In the accompanying drawings, which illustrate the invention, Figure 1 is a longitudinal vertical section of a separating device for carrying out my invention. Fig. 2 is a diagrammatic view illustrating a method of producing variable velocities in the several rotating screens; and Fig. 3 shows a modification of the electrical system and means for controlling the strength of the field magnetism.

The apparatus is constructed in the form of a chest having the sides 1, ends 2, top 3, and the bottom constructed in the form of several hoppers h h^2 h^3. In the upper portion of this structure I place two revolving drums D D^2, respectively, which are fitted on the respective shafts 4 and 5, which latter may conveniently be made hollow, so as to give access to the interior of the drum, the shaft being laterally perforated inside the drums for conveniently introducing the electrical conductors. The drums D are preferably made of non-magnetic material—such, for instance, as brass or copper—or more preferably still of an electrically non-conductive material, such as indurated fiber, hard rubber, &c. Inside of each of the drums and upon its shaft is suspended a cylindrical segment of iron 6, having the sleeve 7, which forms the point of

suspension for the segment on the shaft. Radiating from the lower surface of the segments 6 are a number of magnets 8, which extend almost into contact with the inner surface of the drums. These radiating magnets are wound with insulated wire, and by preference are connected into the exciting-circuit in such way as to make the successive poles alternately N and S. The structure 6 7 8 is secured so that the drum may be rapidly rotated around the same and out of contact therewith without disturbing the normal position of the magnetic structure.

While I have given preference to the alternating character of the poles of the magnetic system, I wish to state that this is not essential to the carrying out of the invention.

In the top of the structure I arrange a hopper 10 between the drum D and the adjacent end of the chest for the introduction of the ore and gangue. Below this I place an apron 11, inclined toward the surface of the drum D, and I prefer to suspend this apron on a suitable pivotal point and provide it with the spring 12, whose tendency is to press the apron toward the drum, actual contact being prevented by the stop 13. The purpose of such spring-suspension is that when a lump of ore or other matter happens to be too large to pass through the opening which I desire to maintain between the apron and the surface of the drum the apron yields sufficiently to permit the lump to pass through without injury to the drum and at once resumes its normal position. The direction of rotation of the drum D is, as indicated by the arrow, in a direction away from the apron 11 on the under side of the drum. The hopper *h* rises up to a point near the drum D on the side opposite that occupied by the apron 11 to a point not quite reaching the farthest of the series of magnets inside the drum.

The drum D^2 is arranged in the same position with reference to hopper h^2 that the drum D occupies with reference to hopper *h*. A combined deflector and apron 14 is arranged in a position under drum D^2 similar to that occupied by apron 11 with reference to drum D, for the purpose of insuring the retention of the material delivered from drum D within the influence of the magnet in drum D^2. Hopper h^2 has its breast rising to a point slightly beyond the last magnet in the drum D^2. I prefer to place the apron 14 slightly closer to drum D^2 than apron 11 is to drum D, and the space between the upper end of the breast of hopper h^2 and the drum D^2 is wider than the similar space between hopper *h* and drum D. These drums are both driven in the same direction, and both the hoppers *h* and h^2 are provided with the automatic weighted valves *t* and t^2, which are constructed and operated on the same principles as set forth in said Letters Patent No. 430,058.

The chest structure is provided with a suitable air-inlet 15, and the outlet 16 for the concentrated ore also serves as an inlet for air, the proportions of the opening 15 being preferably made so as also to compel an inward movement of air through the opening 16. At the opposite end of the chest I place the pipe 17, which is connected to an exhaust-fan or similar device for the purpose of enforcing a movement of air from the distant end of the structure through the spaces existing between the two hoppers and their respective drums, all intermediate points of the structure being practically closed to further this object.

The gearing may consist of a variety of devices, a simple form of which is illustrated in the diagram Fig. 2, in which 18 is the driving-pulley; 19, a belt; 20 and 21, reverse cone-pulleys on the respective shafts 4 and 5, which are connected together by a belt 24. By means of the cone-pulleys the relative speeds of the drum may be varied by steps, after which the field magnetism may be finely graduated to attain the best result.

The apparatus as thus far described is the same as that illustrated and described in Patent No. 449,726, issued to me and Sheldon Norton on the 7th day of April, 1891.

The operation of this apparatus will be as follows: Assuming, for example, that the drum D is given a speed of two hundred revolutions per minute, the drum D^2 might to advantage be given a speed of three hundred per minute. Under these circumstances it is obvious that if the magnetic field be of substantially the same strength in the two drums the tangential inertia which will be impressed upon the mass of material clinging to the drums by the magnetic attraction will be considerably greater on drum D^2 compared with that of drum D. The ore and gangue to be separated is passed into the hopper 10 and dropped from that onto apron 11. The ore and gangue, passing down the apron 11, are brought into close proximity to the surface of the drum, and when the first magnetic pole is reached a powerful magnetic attraction is set up for the particles of ore, causing the same to cling to the surface of the drum. As the mass moves forward with the drum, as soon as the lower edge of apron 11 has been passed the tangential inertia, together with the force of gravity, come into play and the unattracted particles of gangue are violently thrown off the drum down into the hopper *h*, while the remaining particles are held against the drum as it moves to the left. This operation continues upon the mass of ore and gangue as rapidly as it falls from the hopper 10, and when the hopper *h* has a sufficient quantity in it to cause the weighted valve to operate the latter will yield, permitting the gangue to pass away through valve *t* in proportion as it is received in the hopper *h*. As the drum D moves onwardly, the adhering magnetic ore, finally passing the last magnet of the series inside the drum D, reaches a position where the tangential inertia which has been impressed upon it overcomes the attractive force of the magnet, and the entire mass is

thereupon thrown off. This obviously will occur at a point where the tangential movement thus imparted will throw the entire body of ore which has reached this point over against the surface of the other drum D^2 and within the inductive influence of the series of magnets inside such drum, the two magnetic systems being so shaped and located relatively as to accomplish this purpose. Some of the ore thus projected against the drum D^2 is immediately held there by the magnetic attraction, and such ore as is not directly held by the internal magnetic field falls upon the apron 14 and is by it guided into closer proximity to the drum, so that the material will be well spread out and every particle brought within the active range of the magnetic system inside drum D^2. As the drum D^2 revolves, the layer of ore passes away from the lower edge of apron 14. The portions which are not rich enough in iron to cling to the external surface of the drum in spite of the increased tangential inertia which has now been impressed upon them fall into the hopper h^2, and this hopper may be considered as delivering at the valve t^2 a good grade of separated ore, but not the best. The latter on account of its high relative percentage of iron still clings to the surface of drum D^2 so long as it is within the inductive influence of the magnets inside, and upon passing out of their influence to a degree sufficient to overcome the attraction the tangential inertia becomes active and the entire mass, which is then held against the surface of the drum, is projected over the wall of hopper h^2 into hopper h^3, where it falls and emerges at the opening 16 at the bottom. During this operation the exhaust-fan produces a powerful current of air at the opening between hopper h^2 and the drum D^2, also a powerful current of air between the upper front edge of hopper h and the drum D, as indicated by the curved arrows, and at the same time a substantially horizontal current is established across the hoppers, as indicated by the straight arrows. The effect of these currents of air is to thoroughly cleanse the material operated upon of all the fine non-magnetic dust, which can be carried away along with the air discharged by the fan to any desired point. The result is that the immediate vicinity of the apparatus is clean and free from dust. It will thus be seen that the material operated upon is separated into three distinct grades in its passage through the machine: tailings, middlings, and concentrate. The first of these products is free from magnetic material and is disposed of as refuse or as a by-product. The last is pure iron ore. In the middle grade, however, there still remains a percentage of iron in the form of small grains or crystals attached to fragments of gangue. My invention contemplates the separation and recovery of the iron from these impurities, and I attain these results by recrushing or grinding the middlings and passing the recrushed material again through the machine, thus separating the free iron or ore from the gangue to which it before adhered.

I am well aware that separators have heretofore been proposed in which it was contemplated to separate the ore into several distinct grades, varying in percentage of iron contained; but, so far as I know, an intermediate grade after such separation has never been acted upon so as to mechanically dissociate the iron and gangue and then acted upon to separate it into its magnetic and non-magnetic components by a second passage through the machine. Now, inasmuch as all ores are not of the same character as to the amount and character of distribution of the magnetic material and gangue and their magnetic susceptibility, and as even the same material varies more or less, the speed of the rotating screen or screens which would yield the best results at one time would not at another. If the speed be too high, the matter thrown off from the first one, instead of being simply gangue, will contain more or less material which should be classed as middlings and in which occur small particles of ore adhering to the granules of worthless material which are worth recovery. By setting the speed of the screens at precisely the proper limit this difficulty could be obviated; but I prefer to preserve the selective power of the successive parts of the apparatus by varying the strength of the magnetic fields in proper relation to the differing speeds of the rotating screens, and this may be done by including in the exciting-circuits of the magnets a variable resistance or variable resistances, by the adjustment of which the strength of the field may be increased or decreased until the centripetal and centrifugal forces developed by the magnets and the screens, respectively, reach the exact stage best suited to the ore being worked, which can readily be ascertained by examination of the products of separation. This resistance is located at any point where it may be conveniently adjusted while the machine is in operation and is shown diagrammatically at 25 25′ in Fig. 1 of the drawings, and at 26 in Fig. 3. Generally the arrangement illustrated in Fig. 3, in which the field magnetism is varied by a single switch, will be sufficient, inasmuch as by such a variation the character of the products of separation of any given ore being operated upon may be preserved uniform by simply manipulating the switch. In the arrangement illustrated in Fig. 1, with independent switches for the magnets corresponding to the several drums, the selective power of either drum may be varied at will irrespective of the other, thus giving the apparatus the same capability in effect as if the relative speed of the two drums were changed. Ordinarily, however, a fixed ratio of speed will exist for a particular quality of ore and the selective power of the apparatus will be

made uniform in spite of a slightly-varying percentage of iron in the ore by the adjustment of a single switch. I do not of course limit myself to the use of a variable resistance for varying the strength of the field magnetism, as many other ways which will occur to the electrician might successfully be adopted.

Having thus described my invention, what I claim, and desire to secure by Letters Patent, is—

1. An ore-separator comprising a rotary screen in a magnetic field, means for passing the ore to the screen, and means for varying the strength of the field.

2. An ore-separator comprising a series of rotary screens in successive magnetic fields, means for imparting different speeds to the successive screens, means for feeding the ore to the screens in succession, and means for varying the strength of the magnetic fields, as and for the purpose described.

3. The method of separating magnetic ore from its impurities, which consists, first, in crushing the ore, then magnetically separating the mass into three grades—tailings, middlings, and concentrate—varying in the quantity of iron contained, then recrushing the middlings which contain a percentage of iron to mechanically dissociate the iron from the adherent gangue, and then magnetically withdrawing the iron from the recrushed material.

In testimony whereof I affix my signature in presence of two witnesses.

CLINTON M. BALL.

Witnesses:
E. D. MYERS,
E. C. GRIGG.