

April 2, 1963

A. T. BRODERICK
MAGNETIC CONCENTRATION OF LOW GRADE ORES
CONTAINING MAGNETIC ORE MINERALS

3,083,830

Filed Oct. 28, 1960

4 Sheets-Sheet 1

Fig. 1

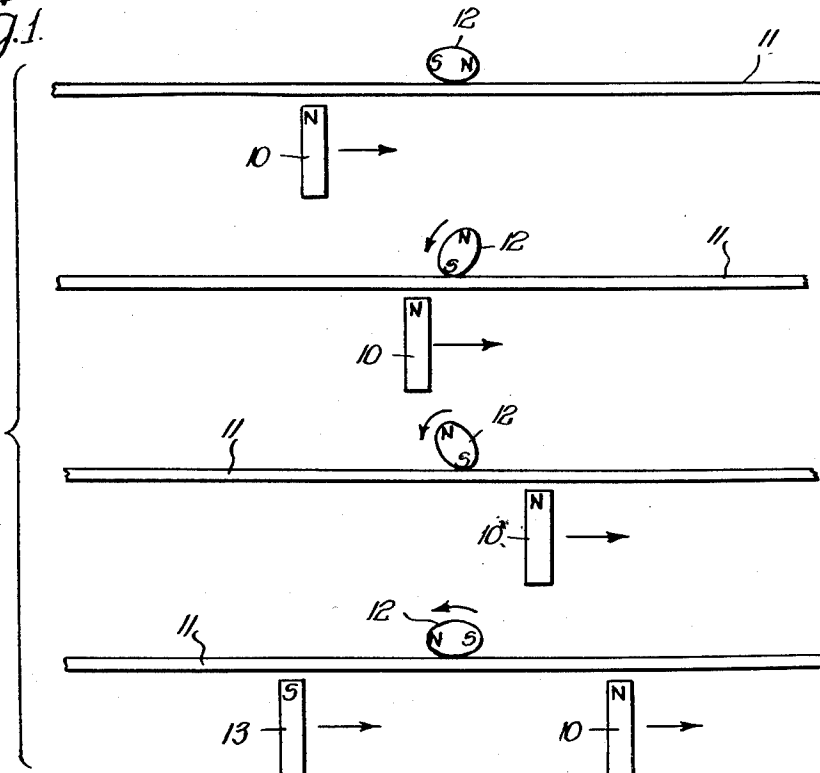
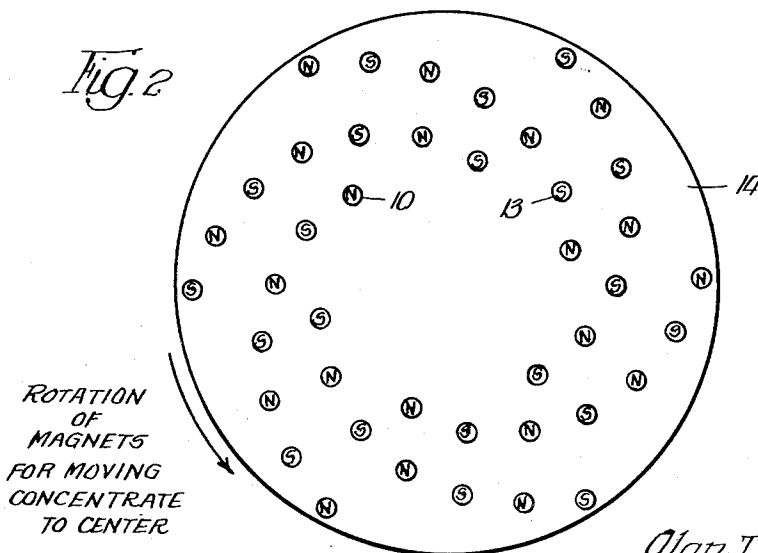


Fig. 2



ROTATION
OF
MAGNETS
FOR MOVING
CONCENTRATE
TO CENTER

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Fig. 3

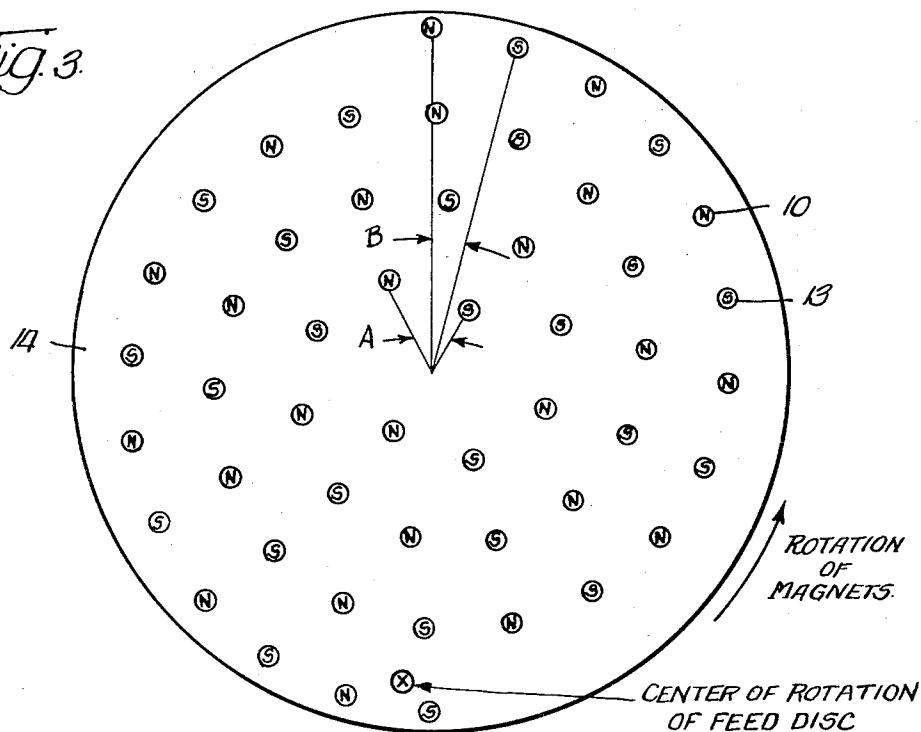
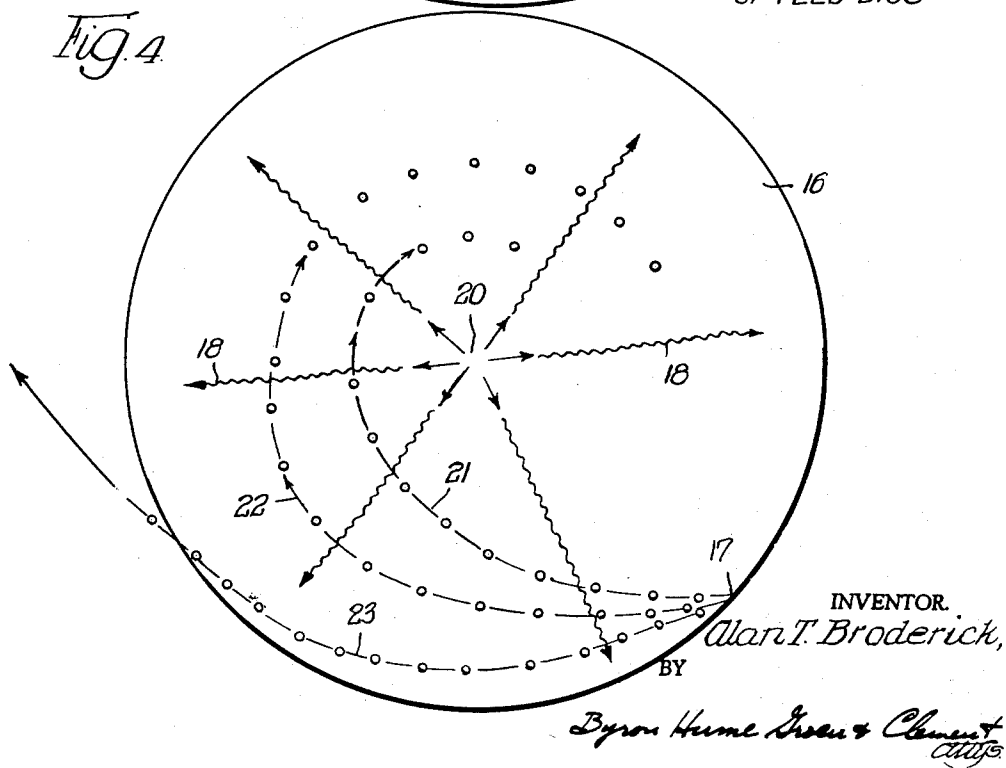


Fig. 4



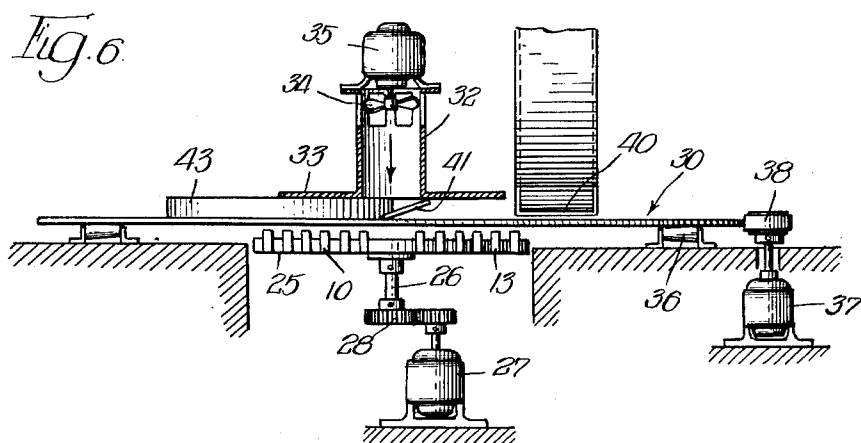
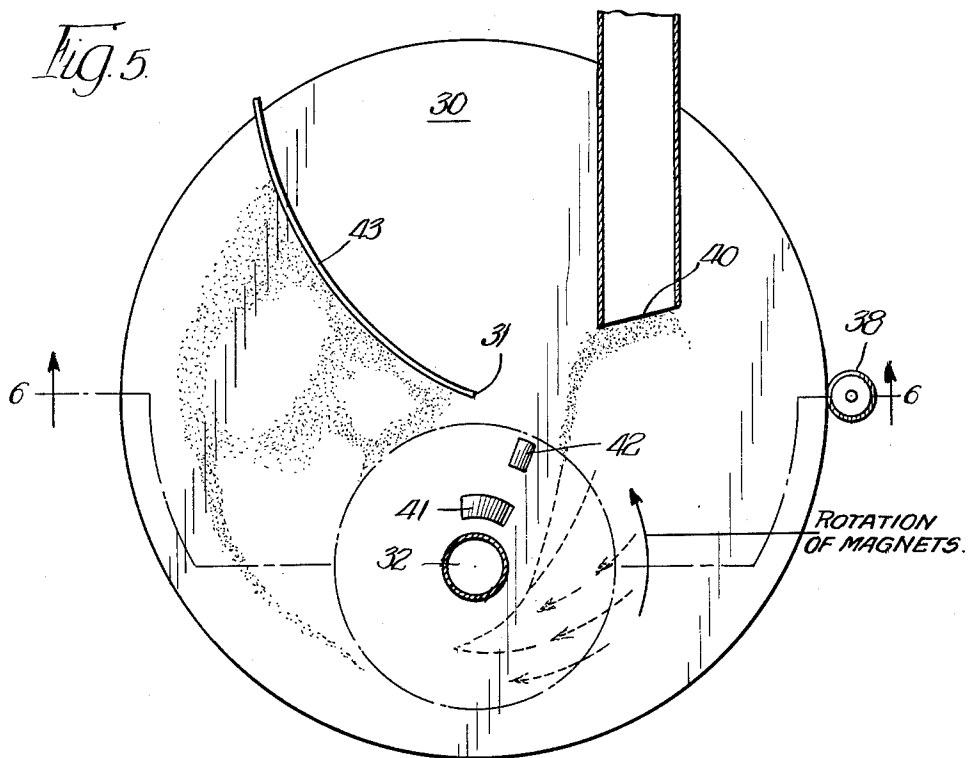
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Fig. 7

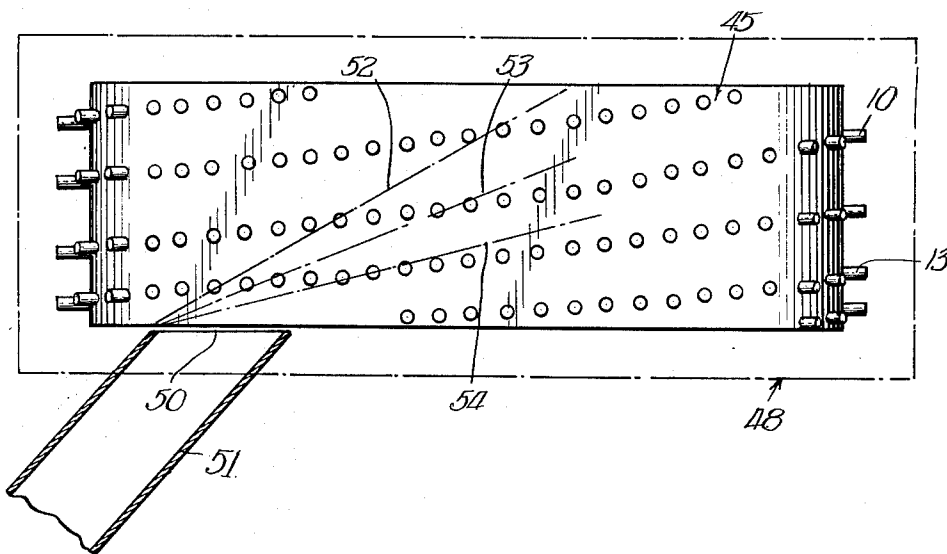


Fig. 8

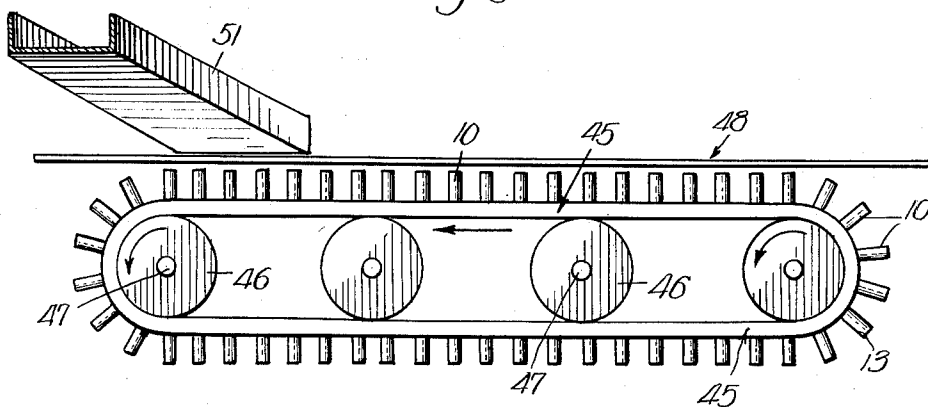
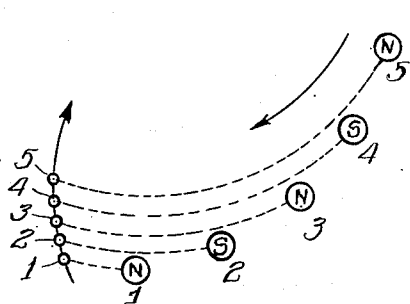


Fig. 9



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MAGNETIC CONCENTRATION OF LOW GRADE ORES CONTAINING MAGNETIC ORE MINERALS

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3 Claims. (Cl. 209-222)

The invention relates to a method of magnetically concentrating low grade ores which contain magnetic ore minerals and has reference in particular to apparatus for carrying out said method and which can be employed in separating mineral particles from one another on the basis of their relative content of magnetic components.

Although the present method was devised for use in the beneficiation of magnetic iron ores, it will also have utility in the separation of other finely-divided mixtures of magnetic, weakly magnetic, and non-magnetic materials, both natural and artificial. In the case of magnetic iron ore beneficiation, one of the outstanding metallurgical difficulties has long been that of separating particles which consist of practically pure magnetite from middling particles containing mixtures of magnetite and non-magnetic gangue minerals. The method of the invention affords an economical means of making such a separation in the dry state although not limited thereto since the method can also be applied with equally efficient results to the separation of mineral particles in a liquid medium such as water. However, by separating mineral particles in the dry state the present method is particularly applicable for use in conjunction with other dry processes of ore dressing such as that of dry grinding.

In the apparatus which has been devised for attaining the objects of the invention the finely divided mineral particles are deposited on a flat supporting surface of non-magnetic material and while thus supported the particles are subjected to alternate north and south pole magnetic forces. When a predetermined speed of relative movement is attained, depending on the strength of the magnetic forces, the individual magnetic iron ore particles are caused to undergo a rolling or tumbling action on the supporting surface and which will take place in a direction opposite to the effective movement of the magnetic forces. Accordingly, the rolling and tumbling action of the particles containing magnetic mineral is employed in separating them from the non-magnetic gangue material.

A more specific object resides in the provision of a magnetic separator having operation in accordance with the principles as herein described and which may additionally employ a current of air directed against the finely divided mineral particles to deflect the same in the direction taken by the lower grade particles, whereby the tendency of the particles to separate on the basis of their magnetic mineral content will be intensified.

Another object of the invention is to provide apparatus for the purposes described wherein a supporting surface for the mineral particles and a series of north and south pole magnets are caused to move relative to each other, and with the magnets in close proximity to the supporting surface, for concentrating the particles on the basis of their magnetic mineral content by effecting a rolling or tumbling action of the magnetic particles in a direction opposite to the travel of the magnets. It has been demonstrated that a highly magnetic particle may even jump toward each succeeding magnet to thus increase its speed relative to a less magnetic particle which merely rolls. It is also significant that the magnetic particles tend to rotate or tumble individually rather than in clumps. Thus, the tendency of weakly magnetic or non-magnetic particles to be pulled along by highly magnetic particles is eliminated.

With these and various other objects in view, the invention may consist of certain novel features of construction

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and operation as will be more fully described and particularly pointed out in the specification, drawings and claims appended thereto.

In the drawings, which illustrate an embodiment of the invention, and wherein like reference characters are used to designate like parts—

FIGURE 1 comprises a series of views in elevation illustrating the fundamental principle involved in the present invention;

FIGURE 2 is a plan view illustrating an arrangement of north and south pole magnets which, if rotated in the direction shown, will cause magnetic particles lying on an overlying plate to move toward the center;

FIGURE 3 is a plan view of another arrangement of north and south pole magnets which will produce the same effect upon magnetic particles above it;

FIGURE 4 is a view diagrammatically illustrating the path of the concentrate, middling and tailing particles on the overlying feed plate with the magnet arrangement of FIGURE 2;

FIGURE 5 is a plan view illustrating the essential parts of apparatus embodying the principles of the present invention;

FIGURE 6 is a vertical sectional view of the apparatus of FIGURE 5 taken substantially along line 6—6 of FIGURE 5;

FIGURE 7 is a plan view of still another arrangement of magnets for an endless belt type of apparatus;

FIGURE 8 is an elevational view of the complete device which employs the endless belt arrangement of FIGURE 7; and

FIGURE 9 is a view diagrammatically illustrating the mode of operation of a row of magnets in effecting movement of a magnetic particle.

This application is a continuation-in-part of the copending application of Alan T. Broderick, Serial No. 711,984, filed January 29, 1958, for Magnetic Concentration of Low Grade Ores Containing Magnetic Ore Minerals, which is now abandoned.

In order to understand the fundamental principles involved in the present invention, reference is made to the several views of FIGURE 1, wherein a magnet 10 of north polarity is located beneath a thin sheet 11 of non-magnetic material such as brass, copper, aluminum, plastic, etc., and which sheet supports a magnetic ore particle 12. It is preferred that the non-magnetic sheet be also a non-conductor for better power efficiency. In copper plate, for example, the eddy currents which are developed increase the power demand on the motor turning the magnets. Magnetic polarity, as shown, will be induced in the ore particle and it will tend to move either by sliding or tumbling in a direction toward the left, or, in other words, toward the magnet 10, which is moving toward the right. In the second view of FIGURE 1 the ore particle has rotated for approximately half of its circumference in a direction opposite to the movement of the magnet. Even those particles which tend to slide will at times be caused to rotate and thus to move in a direction opposite to movement of the magnet, provided the speed of the magnet is increased to the proper extent relative to the magnet's strength. If the first magnet 10 of north polarity is now followed by a second magnet 13 of such polarity, as shown in the bottom view of FIGURE 1, the magnetic ore particle will proceed to rotate an additional half revolution, thus completing a full turn for the particle from its original position. As long as a series of magnets of sufficient strength, and which alternate in polarity, continue to move under the non-magnetic supporting surface 11 and in close proximity thereto, the magnetic ore particle will continue its bodily rotation and movement in a direction opposite to the travel of the magnets. A highly

magnetic ore particle may even jump toward each succeeding magnet, thus increasing its speed relative to a less magnetic particle, which may merely roll or slide. Accordingly, if a mixture of mineral particles, some being highly magnetic, others less magnetic, and the remaining constituting the gangue and being practically non-magnetic, is placed on the flat supporting surface 11, then those containing the greater proportion of magnetic mineral will roll more easily or jump farther than those containing less. The principle accordingly affords a means for the efficient separation of such particles on the basis of their magnetic mineral content.

There are obviously many possible arrangements of components which may employ the above principles in the concentration of magnetic ores. For illustrative purposes reference is made to FIGURES 2 and 3, wherein upright bar magnets such as 10 and 13 are disposed in spiralling paths, being suitably fixed or carried by a support which may be rotatable. In FIGURE 2 the numeral 14 indicates a support or the like to which the magnets 10 and 13 are fixedly secured and to complete the apparatus it will be understood that a non-magnetic supporting surface, as described in connection with FIGURE 1, is disposed over the bar magnets in relatively close proximity to their top ends, and which bar magnets have the polarity as indicated in said figure. For effecting movement of the concentrate, namely, the highly magnetic ore particles toward the center, the magnet arrangement is rotated in a counterclockwise direction.

In FIGURE 3 the arrangement of the magnets 10 and 13 is substantially similar to FIGURE 2. However, whereas FIGURE 2 employs six arcuate paths for the magnets, the same being directed inwardly toward the center, the magnet arrangement of FIGURE 3 employs only two paths and which are continuous from the outer periphery and spiral inwardly to terminate relatively close to the center of the arrangement. In each figure the bar magnets in their respective paths alternate as regards their magnetic polarity and the rotation of the magnet arrangement is counterclockwise in order to produce movement of the concentrate toward the center. Although the spacing between magnets in the various paths is disclosed as approximately the same, it is obviously possible to increase the spacing as the center is approached, which will make it difficult for the particles to jump the gaps between magnets. Also in FIGURE 3, it will be observed that the centermost magnets subtend an angle A which is about four times as great as the angle B subtended by the outermost magnets. Therefore there is considerably more opportunity for a particle between the last two magnets at the center to be deflected by movement of the feed plate, or by a radially flowing air stream, as there is between the first two magnets at the periphery. In addition the intensity of the effect of the magnets in different positions can be varied simply by mounting them nearer or farther from the non-magnetic supporting surface. Supporting the magnets so that they are progressively farther from the plate as the center is approached will also tend to allow only the highly magnetic particles to reach the center.

For illustrative purposes the feed of the mineral particles to the plate 16, FIGURE 4, is illustrated as taking place adjacent the lower right hand corner 17, and said figure further illustrates by wavy lines 18 the radial flow of air currents from the center 20 to the peripheral edges of the plate 16. Since the highly magnetic particles are affected the most by the magnetic forces and the least by the radially flowing air streams, the same will be caused to move inwardly toward the center of the feed disc approximately along the path as indicated by numeral 21 and which may be referred to as the concentrate path. The gangue material, which is the least magnetic of the particles, is practically unaffected by the magnets although the same are affected by the air streams to the greatest extent and, accordingly, this material generally referred to

as the tailings, takes the path indicated by numeral 23. The middlings comprise those particles intermediate between the concentrate and the tailings in their reaction to these forces and therefore the middlings will be found along the path 22.

The separation of the mineral particles by the apparatus of FIGURE 4 into concentrates, middlings and tailings can best be understood from the diagrammatic illustration of FIGURE 9. The magnets are arranged in a row which may be described as forming a spiralling path. At least magnet 1 is most distant from the center of rotation of the magnet arrangement with magnets 2, 3, 4 progressively decreasing in distance from the center. The magnets may be considered as moving clockwise or the supporting plate for the mineral particles may be moving toward the magnets. In either case relative movement is effected as described between the magnets and the magnetic particles so that magnet 1 is first caused to influence the magnetic particle at position 1. Thereafter magnet 2 will be so located as to influence the particle which thus moves into position 2. This is followed by magnet 3 which effects movement of the particle into position 3 and so on. As a result the magnetic particle will have a path of movement as shown and which spirals inwardly toward the center of the magnet arrangement. In general it can be stated that the magnets in each individual row are longitudinally spaced and said magnets alternate as regards north and south polarity. Also the magnets are so disposed that certain particles for each row will be subjected to the influence of the magnets of its row in sequence.

The spacing of the magnets in the rows and the spacing between adjacent rows is variable largely depending on the size and strength of the magnets. Also the optimum relative speed for each installation will have to be determined. In a test run for experimental purposes the magnets were rotated at about 300 to 400 r.p.m. and the feed supporting disc was rotating at about 6 to 10 r.p.m.

In FIGURES 5 and 6 which show the essential parts of the apparatus, the bar magnets 10 and 13 are suitably supported by the member 25 to form a magnet arrangement as illustrated in FIGURES 2 and 3, for example, and the said arrangement is mounted for rotation by shaft 26 which is rotated by the motor 27 through the connecting gearing 28. A feed disc 30 of larger diameter is employed and the same is adapted to rotate about axis 31 in a clockwise direction opposite to the direction of rotation of the magnet arrangement. Air is supplied at 32 which is the center of rotation for the magnet system and the said air flows radially outward under a stationary cone member, such as 33, which is suspended a short distance above the feed disc 30. Air pressure is developed by the fan 34 driven by the motor 35.

The feed disc is supported for rotation on the rollers 36 and said disc is driven at the desired speed by the motor 37 by means of the friction wheel 38. The mineral particles for magnetic separation are applied to the feed disc at 40, the said location being in advance of the magnet system, considering the direction of rotation of the feed disc. As the particles enter the area of influence of the magnets, the highly magnetic particles are quickly separated from the middlings and from the tailings, since these particles will move into the concentrate path and they may be removed from the disc by simply employing a suction tube or the like.

Another method consists in providing a ramp 41 up which the highly magnetic particles may be rolled by the moving magnets. At the top of the ramp the particles will enter an area of influence of a suction tube as described. This method will yield a cleaner concentrate. It may be desirable to space the ramp 41 from the disc in order to leave on the disc the fine middlings which will eventually work their way to the outside. The separation from the suction air stream is merely a matter of allowing the velocity to drop in a large chamber or a

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cyclone separator may be used. The middlings may be removed from the feed disc in a similar manner at a location 42 in the rotating orbit of the magnetic particles. The tailings are removed from disc 30 at locations beyond the magnet system. This can be done by suction, by blowing or by means of a scraper 43, as shown.

FIGURES 7 and 8 illustrate a horizontally moving magnet system wherein spaced magnets 10 and 13 are fixed to an endless belt 45. The magnets are disposed diagonally of the endless belt and in fact are in spiral paths with the magnets in each row being spaced longitudinally and the rows being spaced as shown. A plurality of rollers 46, journaled for rotation by shafts 47, are provided for supporting and for driving the endless belt 45. The plate 48 is in close spaced relation with respect to the magnets and said plate is a non-conductor and which may also take the form of an endless belt or simply a thin plate which may be vibrated in any suitable manner as by a rapid forward movement followed by a slower return movement. Also an air stream may be directed over the feed plate and which would be caused to flow in a direction to deflect the particles from the path of the concentrate toward the path of the tailings. The direction of feed, the movement of the magnets and the movement of the air streams can, of course, be varied relative to each other for optimum separation efficiency.

As shown in FIGURES 7 and 8 the top run of the magnets as regards the endless belt 45, is adapted to move in a direction toward the left, and assuming that mineral particles to be separated are fed at point 50 by the chute 51, then the highly magnetic particles comprising the concentrate will be separated along path 52, the middlings along path 53 and the tailings, which contain very little magnetic material, along path 54.

The invention is not to be limited to or by details of construction of the particular embodiment thereof illustrated by the drawings, as various other forms of the device will of course be apparent to those skilled in the art without departing from the spirit of the invention or the scope of the claims.

What is claimed is:

1. In a magnetic separator of the character described for separating mineral particles on the basis of their relative content of magnetic components, in combination, a feed disc of non-magnetic material providing a flat, approximately horizontal supporting surface for the mineral particles, an arrangement of magnets disposed below said disc in spaced relation but in relatively close proximity

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thereto so as to magnetically influence the mineral particles supported on the disc, said arrangement of magnets including a plurality of spaced spiralling rows of magnets with the magnets of each row being longitudinally spaced approximately equal distances and arranged with adjacent poles of opposite polarity, and means for effecting relative movement between the feed disc and the arrangement of magnets in a direction approximately longitudinally of said rows of magnets, whereby certain mineral particles for each row will be subjected to the influence of the magnets of its row in sequence.

2. In a magnetic separator of the character described for separating mineral particles on the basis of their relative content of magnetic components, in combination, a feed disc of non-magnetic material providing a flat, approximately horizontal supporting surface for the mineral particles, an arrangement of magnets disposed below said disc in spaced relation but in relatively close proximity thereto so as to magnetically influence the mineral particles supported on the feed disc, said arrangement of magnets including at least one row of magnets longitudinally spaced in the direction of the row being so disposed as to form a spiralling path, the magnets of said row being arranged with adjacent poles of opposite polarity, and means for effecting relative movement between the feed disc and said arrangement of magnets.

3. In a magnetic separator for separating mineral particles into highly magnetic concentrate particles, into tailing particles having practically no magnetic content and into middling particles having a magnetic content between the concentrate and the tailings, in combination, a rotating feed disc providing a flat, horizontal supporting surface for the mineral particles, an arrangement of magnets located below said disc in spaced relation but in relatively close proximity thereto, said arrangement of magnets comprising a series of spiralling rows of magnets disposed so as to spiral inwardly toward a common center, the magnets of each row being arranged with adjacent poles of opposite polarity, and means for rotating the magnet arrangement about said common center as an axis.

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