

UNITED STATES PATENT OFFICE

2,597,652

METHOD OF MAGNETIC SEPARATION

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Application February 20, 1947, Serial No. 729,704

1 Claim. (Cl. 209—39)

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The present invention relates in general to improvements in the art of refining granulated magnetic material, and relates more specifically to an improved method of and apparatus for magnetically treating pulverized ore so as to eliminate finely divided gangue and other useless material from the main ore body.

One of the primary objects of our invention is to provide an improved method of separating undesirable non-magnetic gangue material and useless ore, from valuable magnetic ferrous ore, by utilizing certain natural characteristics of the valuable or desirable materials to effect elimination of the useless ingredients at a pre-selected stage of the ore processing or treating system.

Within a limited size range the saturation point of a particle of magnetically susceptible material varies directly with the size of the particle, while the residual induction in such a particle varies directly with the grain size. Particles or pieces of magnetic ore, upon entering a magnetic field, are first attracted to each other to form clusters, and are subsequently attracted en masse to the source of the field. From this phenomenon it will be apparent that when pulp containing coarse and fine particles of magnetic material is admitted to a field of magnetic influence, masses will be formed varying in size according to the strength of the field, size of the particles, and the susceptibility of the magnetic particles. The larger pieces become the strongest magnets and attract and hold a bristly coating of smaller particles while advancing through the magnetic field, and after leaving the field the largest pieces retain sufficient residual induction to hold the bristly coatings.

When pulverized magnetic ore, containing both large and fine magnetic particles intermingled with useless non-magnetic gangue material plus iron silicates of low magnetic susceptibility, is subjected to a field of magnetic influence, most of the useless materials may be readily washed or otherwise removed from the mass, but many finer particles of useless materials become imprisoned in the masses or clusters of valuable substance. As the firmly compacted magnetized clusters of valuable magnetic material leave the field of the primary magnetic separator, the individual pieces or particles of the clusters are held together only by their own residual induction and tend to loosen somewhat into porous bristly masses adapted to be readily penetrated by washing liquid. While in such condition, the clusters or masses are still relatively heavy and sink

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readily in liquid, but we have discovered that by subjecting such sinking magnetized clusters to rising currents of wash water, the finely divided and entrapped useless particles of gangue and iron silicates may be quickly and effectively released and floated away from the sinking valuables.

It is common present practice in the art of magnetic ore separation, to initially pulverize and to thereafter wet-grind the ore to a fineness sufficient to free the valuable ore particles from the waste rock and gangue. Physical separation of magnetic from non-magnetic particles of the pulverized mass has heretofore been effected at various points in the treating circuits with the aid of diverse types of machinery, and especially by utilizing an initial magnetic separator followed by other equipment intended to eliminate the residual gangue and other valueless particles from the final ore concentrates, and adapted to return the oversize ore particles to the grinders and magnetic separator for retreatment. Considerable finely divided gangue is however produced during each pass through the pulverizers, and it is therefore of primary importance to remove this useless product from the circuit as quickly and as effectively as possible in order to enhance the grinding capacity and the efficiency of the classifiers to a maximum, but none of the prior systems has been satisfactory in effecting proper elimination of such waste materials without excessive retreatment.

It is therefore a more specific object of the present invention to provide an improved process of effecting thorough purification of the concentrates in such magnetic separating circuits while reducing to a minimum the quantity of material which must be returned to the initial or primary separator for retreatment, thus materially enhancing the capacity of the refining systems.

Another specific object of the invention is to provide improved apparatus for effectively carrying on the improved method of refining or purifying pulverized magnetic ore.

A further object of our invention is to provide an improved method of and apparatus for utilizing the above described principles and characteristics of magnetic ore particles and the like, for the purpose of effecting concentration thereof in a most expeditious manner.

These and other specific objects and advantages of the invention will be apparent from the following detailed description.

A clear conception of the new steps involved in the improved method, and of the construction and

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operation of the apparatus for effecting commercial exploitation of the method, may be had by referring to the drawing accompanying and forming a part of this specification, wherein like reference characters designate the same or similar parts in the several views.

Fig. 1 is a flow sheet or diagram depicting the steps of our improved process of magnetic treatment of magnetite ores;

Fig. 2 is an enlarged diagrammatic central vertical section through the improved magnetic separating unit; and

Fig. 3 is a top view of the concentrate purifying launder or wash box of the separating unit.

While our improved process of magnetic separation and beneficiation has been shown and described herein as being advantageously usable for the treatment of iron ore with the aid of a drum type of separator cooperating with an improved concentrates purification launder, it is not our desire or intention to unnecessarily restrict the scope or utility of the method by virtue of this limited disclosure.

In accordance with our improved method of eliminating useless gangue and iron silicates from valuable magnetic ore concentrates, the ore is first crushed and wet-ground as usual, after which the fluent mass is subjected to the influence of a relatively strong magnetic field. The magnetic material which passes through and is ultimately delivered from the magnetizing zone, is in the form of bristly masses or clusters each comprising one or more larger magnetized particles coated or covered with a layer of finer particles, within and surrounding which considerable gangue and fine iron silicate is intimately confined; and when these clusters leave the zone of magnetic influence they tend to spread or loosen to form porous masses. In order to remove the relatively fine useless particles from these porous clusters, we promptly subject the flocculated magnetized masses to thorough washing sufficiently intense to remove the useless fine particles by floatation, but not sufficient to release the fine magnetic particles adhering to the magnetized larger particles which are heavy enough to sink or drop away from the washing zone. We thereafter demagnetize the washed concentrates and subject the same to classification as to size, returning the oversize to the pulverizing zone and delivering the satisfactory concentrates to a thickener and to selected localities, either for further more intense concentration or for final storage or conversion, thus insuring the production of concentrates of maximum purity and eliminating the necessity of re-handling the excess quantities of gangue and other impurities which have been removed from the circuit during washing of the magnetized clusters or masses discharged from the magnetic separator.

Referring to the drawing, and especially to the flow sheet of Fig. 1, the improved method is adapted to be effectively carried on with the aid of a crusher such as a coarse-grinding open-circuit rod mill 6, a fine wet grinding ball mill 7 in closed circuit with a magnetizing device such as drum-type magnetic separator 8, a mid-circuit cleaner 9, a classifier 11, and a suitable thickener for receiving and for dewatering the final concentrates.

As shown, the fresh supply of the preliminarily crushed mine-run magnetic ore, is supplied to the rod mill 6 by a feeder 14, and in the mill 6 the solids are reduced to -4 mesh with a slight percentage of +4 mesh, in the presence of water.

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The pulp or fluent mixture of liquid and thus reduced material discharged from the mill 6 may be passed through a suitable screen 15, the rejects of which are +4 mesh and may be returned to the feeder 14 while the finer product containing all -4 mesh and approximately 20% -150 mesh is delivered to a hopper 16. From the hopper 16, the ore pulp is constantly delivered by a pump 13 to the supply trough 17 of some type of magnetizing device such as the drum type magnetic separator 8, and the mixture is fed through a feed chute 18 along and against the lower outer surface of the revolving separator drum 19, the upper inner face of which is subjected to the action of a stationary bank of electro-magnets 20 confined within the drum 19, see Figs. 1 and 2.

The drum 19 is revolved by a motor 21 and the magnets 20 are of successively reversed polarity and create a separating zone or field of strong magnetic influence beneath the constantly revolving drum 19, within which the magnetic ore particles are confined and advanced, while most of the worthless non-magnetic particles or tailings drop by gravity into a liquid basin 22 having a lower outlet 23 communicating with a tailings discharge pipe or line 24, and some of the remaining free gangue particles are washed off and carried away through overflow weirs at both sides of the separator. As the magnetic material proceeds along the separating zone at the bottom of the revolving drum 19, it is preferably subjected to liquid sprays delivered reversely along and against the conveying surface of the drum by a series of nozzles 25, but the valuable magnetic particles are maintained within the zone of intense magnetic influence by a plate 25 extending along and beneath the drum periphery and spaced therefrom in a manner whereby any coarse or fine particles of high magnetic susceptibility which drop from the drum surface will be recaptured, while released non-magnetic material is washed into the basin 22 and is discharged into the tailings delivery line 24 and over the side weirs. The magnetic grains however become magnetized and intimately coated with finer magnetic particles, and these clusters or masses are eventually carried beyond the zone of magnetic influence and are ultimately delivered toward the wash box 9 over the discharge chute 10.

The flocculated magnetic material which is thus constantly deposited into the mid-circuit cleaner or washer 9 together with water from a spray pipe 27, is magnetized to an extent which causes the fine coatings to cling firmly to the larger particles, but when the clusters leave the zone of magnetic influence, they spread so as to form porous masses having fine gangue and iron silicate particles embedded therein, and it is the function of the wash box 9 to remove this undesirable finished ground waste material immediately thereafter in order that the classifier 11 may most effectively separate the oversize unfinished ground material from the finished ground concentrates. The launder or wash box 9, as shown in Figs. 2 and 3, preferably comprises a tank forming a liquid basin 30 having an inclined screen or perforated deck 31 at its bottom, and being provided at its inlet end with a barrier wall 32 for directing the entering material downwardly toward the upper end of the deck 31, while its opposite discharge end is provided with a lower concentrate discharge pit 33 and with an upper overflow trough 34. The inclined deck 31 is completely immersed within

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the basin 30 and is supplied from beneath with liquid under pressure through an inlet 35; and it is preferable to pulsate the entering liquid or to vibrate the deck so as to spread the flocculated masses or porous clusters of magnetic material and to cause the coated masses to gravitate rapidly toward the pit 33. The deck perforations should also be formed so as to deliver a multiplicity of relatively powerful liquid jets upwardly into the basin 30, uniformly throughout the entire area of the tank 9, and the liquid discharged from the top of the basin 30 into the trough 34 carries with it the released finely ground gangue and other fine floatable substances which have been removed from the porous clusters by the rising jets.

Since the larger ore particles which are delivered in a constant stream from the magnetic zone of high intensity within the main separator 8, are magnetized to such an extent that they will attract and firmly hold the finer magnetic particles in flocculated condition, it is possible to subject these flocculated clusters to thorough washing immediately following delivery thereof from the high intensity magnetic zone, without danger of having the finer finished ground valuable particles float away with the finished ground gangue and other useless finished ground material. Many of these finer magnetic particles are normally adapted to float and would thus be lost with the floatable gangue and slimes, if the larger highly magnetized particles were not present in the clusters or masses; but with these larger particles available, and by subjecting the magnetized masses to thorough jet washing while passing through the liquid basin 30, it has been found possible to thoroughly cleanse and to remove large quantities of non-magnetic floatable material such as gangue without losing appreciable quantities of the valuable magnetic fines. This removal of useless gangue and other material prior to demagnetization of the valuables, and subsequent treatment of the latter in the classifier, ball mill and other equipment, is an important feature of our present invention, and insures an enriched feed to the classifier while also enlarging the available capacity of the regrinder.

The bottom of the trough 34 communicates directly with the tailings discharge line 24 through a duct 36, while the lower portion of the pit 33 delivers the purified finished ground concentrates together with unfinished ground material through a conduit 37 past a demagnetizing coil 38 to the classifier 11 as shown in the flow sheet of Fig. 1. In the classifier 11 the demagnetized concentrates are no longer flocculated, and may therefore be readily classified as to size, the oversize being delivered through a chute 39 to the fine wet-grinding ball mill 7, while the sufficiently reduced and relatively pure concentrates are conveyed to a final thickener 12 through a conduit 40, and from which the final concentrates may be delivered by a pump 42 for further grading, purification, or other disposition. The oversize concentrates delivered from the classifier 11 to the ball mill 7 are further pulverized and discharged into the hopper 16 for return to the magnetic separator 8 together with the mine-run ore which has been reduced in the rod mill 6. The raw material fed to the rod mill 6 and the oversize from the classifier 11 which are delivered to the ball mill 7, are thus simultaneously transported to the magnetic separator 8 by the pump 13 and after being separated into tailings and

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valuable magnetic material, the latter are initially purified in the wash box 9 and are subsequently demagnetized and deposited within the classifier 11 in relatively clean condition. The classifier 11 thus receives relatively pure magnetic material which is free from objectionable finished ground gangue and can therefore deliver exceptionally high grade finished ground concentrates.

At the classifier overflow 40 the finished concentrates are buoyant and the individual particles settle slowly in water. Rapid settling may be attained by lightly magnetizing the pulp as it enters the thickener. A weak magnetic field will cause the metallic particles to form flakes, and these will readily sink and be deposited on the bottom of the thickener tank where they are gathered toward the center discharge opening. The excess water in the pulp entering the thickener 12 overflows and carries with it some remaining gangue, and further beneficiation of the finished concentrates beyond this point in the circuit are expensive and difficult. Tests have shown that with the use of the mid-circuit cleaner 9, a commercial product of the desired grade may be attained at the thickener discharge with no further beneficiation required.

While the important step of subjecting the flocculated magnetic material to thorough washing and consequent removal of gangue has proven advantageous in a closed circuit system such as above described, it has also been found possible to further augment the purification of the concentrates by installing another magnetic separator 8 and wash box 9 directly following treatment of the magnetic ore in the thickener 12. The use of a single separator 8 and mid-circuit wash box 9 has however been found to produce approximately ten percent purer concentrates than it has been possible to produce with prior similar systems wherein the magnetic material was not thoroughly washed and cleansed prior to classification and retreatment of the oversize, but the utilization of an additional separator and washer following thickening would obviously further increase the percentage of purification of the magnetic concentrates.

From the foregoing detailed description, it will be apparent that our present invention provides an improved process of separating magnetic ore particles from non-magnetic materials, in a most efficient manner and with the aid of simple, compact and automatically functioning apparatus having enormous capacity. The improved beneficiation unit comprising the magnetic separator 8 and the mid-circuit wash box 9 associated directly with the separator discharge 10, is of relatively small size considering its capacity, and may be operated with minimum power consumption; and by quickly and effectively removing most of the gangue and iron silicate from the flocculated clusters or masses before the latter are demagnetized and delivered to the classifier 11, the latter as well as the ball mill 7 are relieved of the work of handling excessive quantities of non-magnetic material which is of no value. This removal of the gangue and slimes also permits the classifier 11 and the ball mill 7 to function most effectively, since the improved washing tank 9 actually removes great quantities of non-magnetic and worthless material especially when the system is operating at full capacity. The improved method and apparatus have proven highly satisfactory and successful in actual use, and while being especially useful in

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the treatment of low grade ferrous ores, may also be utilized in treating other materials having magnetic characteristics.

It should be understood that it is not our desire to limit this invention to the exact steps of the method or to the precise details of construction, herein described and shown, for various modifications within the scope of the appended claim may occur to persons skilled in the art; and it is also contemplated that specific terms employed herein shall be given the broadest interpretation consistent with the general disclosure.

We claim:

The method of magnetic separation which comprises, subjecting masses of granulated iron ore to a zone of intense magnetic influence within an initial bath of liquid to produce highly magnetized flocculated clusters of relatively large iron granules having finer magnetic particles adhering thereto while hydraulically eliminating the tailings within the initial bath, thereafter completely and rapidly removing the flocculated clusters from said zone of magnetic influence and initial bath to permit the clusters to spread and to thus increase the porosity thereof and while said granules are still highly magnetized promptly immersing the expanded clusters in a second bath and subjecting a thin slowly advancing layer thereof to a multiplicity of powerful jets projected upwardly through the second bath to release and remove fine tailings which may have

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been entrapped within the clusters during the initial separation, removing the released fine tailings from the second bath by floatation while allowing all of the iron particles to sink and be withdrawn from the bottom of said second bath, and subsequently demagnetizing the removed iron clusters to produce disintegration thereof and classifying the ingredients.

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