June 7, 1960 J. H. CARPENTER 2,939,580

MAGNETIC ORE SEPARATOR

Filed May 27, 1957 3 Sheets-Sheet 1

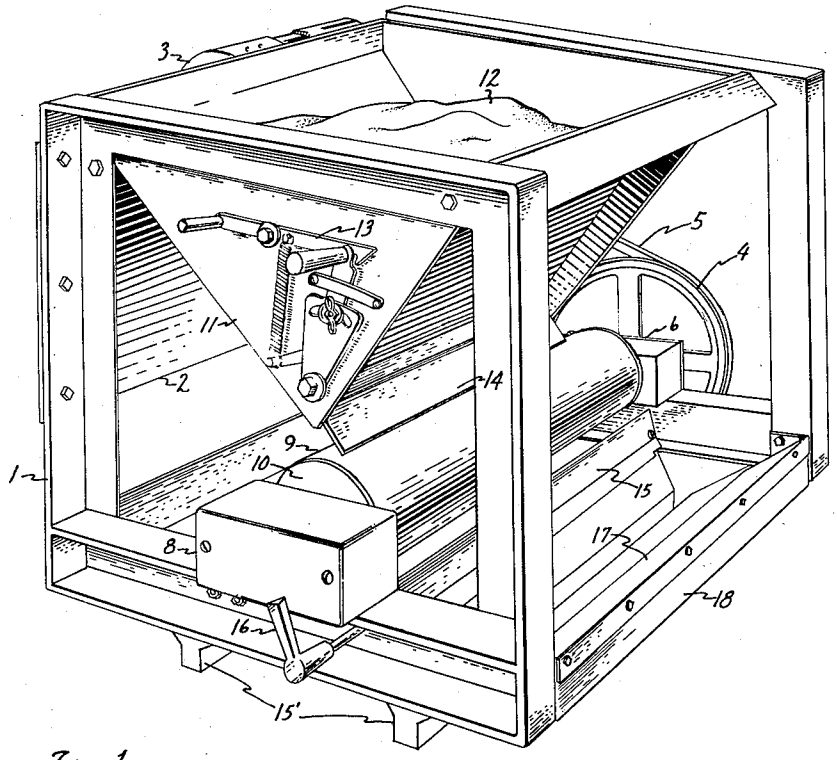


Fig. 1.

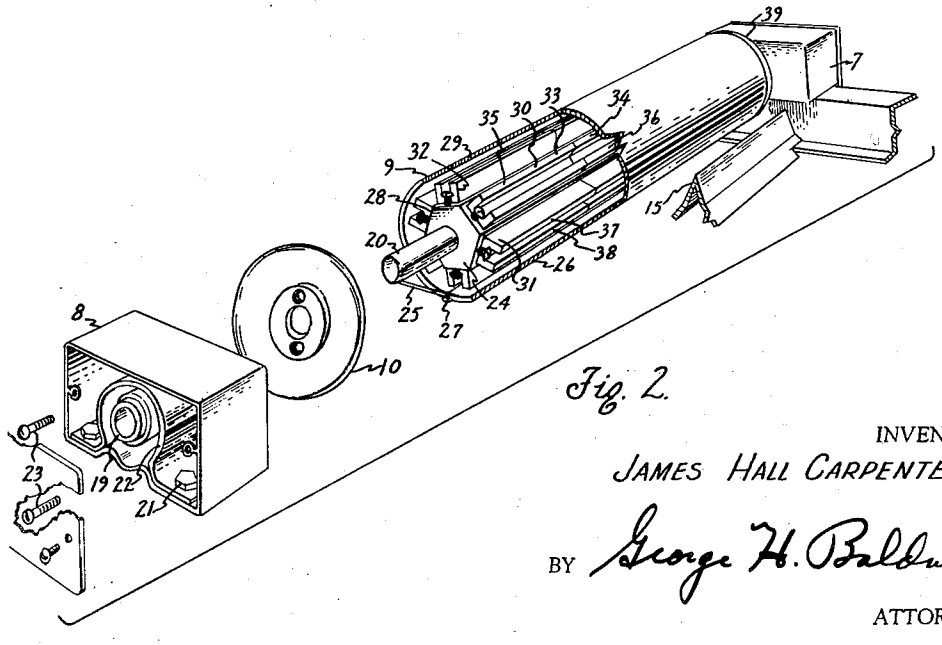


Fig. 2.

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MAGNETIC ORE SEPARATOR

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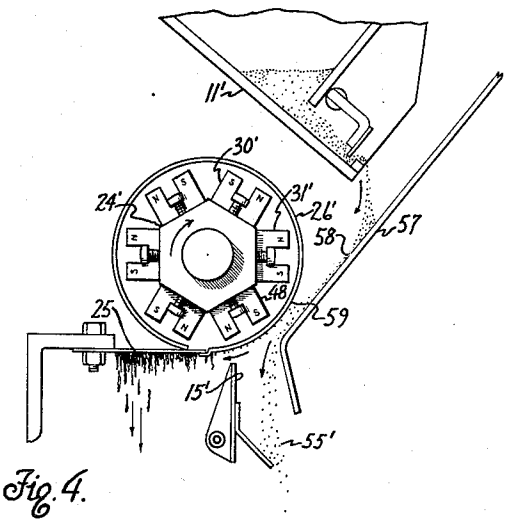


Fig. 4.

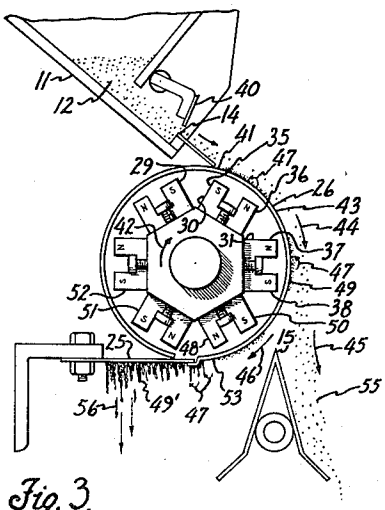


Fig. 3.

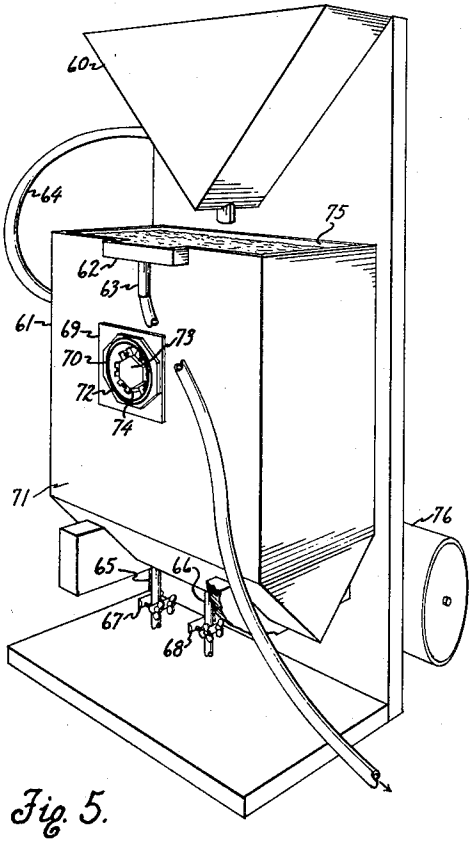


Fig. 5.

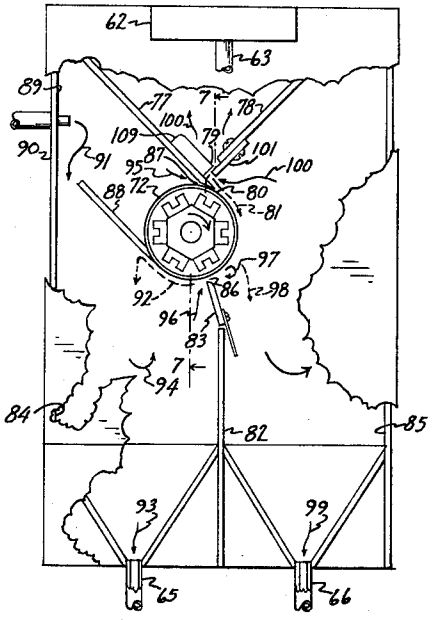


Fig. 6.

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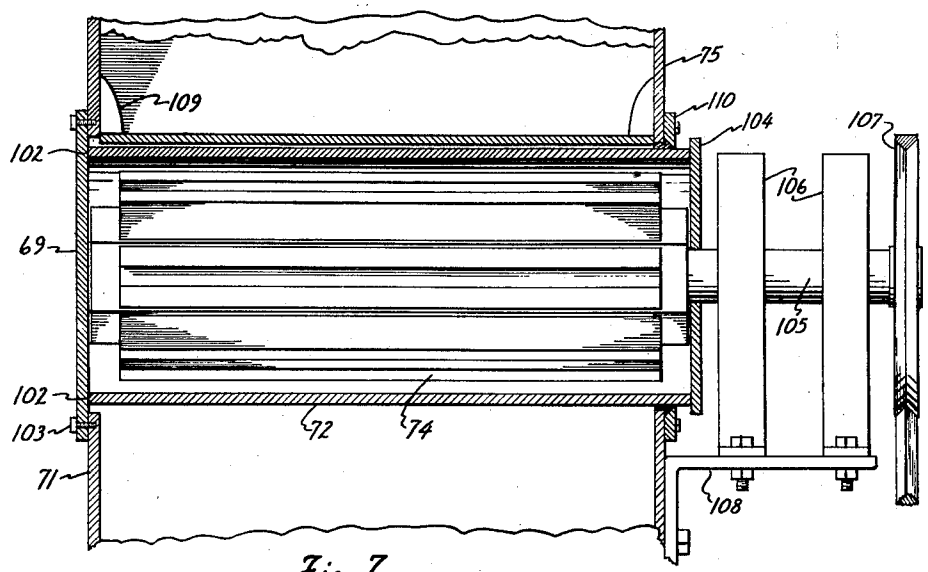


Fig. 7.

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2,939,580

MAGNETIC ORE SEPARATOR

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Filed May 27, 1957, Ser. No. 661,800

2 Claims. (Cl. 209—219)

This invention pertains to magnetic ore separators, and particularly relates to wet ore separators wherein water or other liquid is caused to flow in a direction generally opposite to the direction of passage of the more magnetic ore particles through the separation zone. The invention further relates to a novel permanent magnet rotor and housing particularly adapted for use in wet separation processes in which such opposed water flow is accomplished, and also suitable for dry separation. The invention relates, additionally, to methods of magnetic separation of ores.

A general object of the invention is to provide improved apparatus and methods for separating particles in accord with the respective magnetic characteristics thereof.

It will be understood that, while the major field of use of magnetic separators of the type herein disclosed is, at present, in the beneficiation of comminuted mineral ores, such separators have utility in other fields wherein differences in magnetic characteristics of particles will permit the separation of magnetic from non-magnetic particles, or more magnetic from less magnetic particles.

In one aspect, this invention pertains to a simple, inexpensive, enclosed rotor magnetic separator, having high tonnage, requiring small amounts of power, and being highly resistant to wear. In the preferred embodiment herein illustrated, in accord with this aspect of the invention, the separator comprises a non-magnetic hollow cylinder, with a horizontal axis, a coaxial rotor within the cylinder comprising a plurality of permanent magnet elements with poles directed outwardly toward the cylinder walls, and arranged with the north poles of adjoining magnets adjacent each other, and, correspondingly, with the south poles of adjoining magnets adjacent each other, together with means for rotating the rotor and means for feeding the ore mass or stream, or the mass or stream of other particles to be separated, adjacent to or directly onto the external cylinder surface.

In another aspect, this invention relates to apparatus providing a flow of water, or other fluid, in and about certain critical areas existing in connection with the feeding of ore particles to, and the separation of the particles by, a magnetic rotor. In an embodiment of the system illustrated herein in accord with this aspect of the invention, a hollow non-magnetic cylinder is disposed in a water-filled tank, a permanent magnet rotor is disposed in the cylinder as above described, a splitter blade is disposed below the cylinder and arranged with a tank wall to divide the tank into two collection tanks below the cylinder, a feed bin or trough is arranged generally above the cylinder, and a supply of water is so connected to the tank as to cause water to flow between the cylinder and the upper edge of the splitter blade counter current to the direction in which magnetic materials are carried over the splitter blade, and also, preferably, up through the ore supply outlet of the supply bin, the water finally spilling from the top of the supply bin. Water is also conducted

out of the tank with the magnetic fraction and with the non-magnetic, or less magnetic, fraction.

With wet type magnetic separators, it is often found that the water currents, or the currents of other fluids, have more effect on the particles than do the magnetic fields. A constant and troublesome problem has also existed in obtaining slow, non-channelling, constant-density wet feeds for wet type separators. Objects of this invention are to minimize in wet separators undesired separation of particles in accord with characteristics other than magnetic characteristics, such as size, weight, shape, and the like, to improve the feed, and to provide thorough washing of the non-magnetic or less magnetic from the more magnetic particles, the improved washing being the result of novel water current techniques employed herein and the result of a tumbling action of the magnetic particles resulting from the arrangement of the magnet rotor herein shown.

The apparatus and methods herein shown and claimed have proved particularly effective and desirable in connection with the scalping of relatively highly magnetic particles, such as ferric materials, i.e. magnetite, from relatively weakly magnetic or non-ferric minerals such as those containing tin, tungsten, titanium, columbium, zirconium, rare earths and the like. The apparatus and methods are also useful in recovering iron-containing magnetic particles from granular or broken slag or the like wherein the non-magnetic particles are of little or no value. Such applications of the present invention, however, are not to be understood as limiting, in that many fields of application will be suggested to those skilled in the art, and not only in connection with ore or mineral beneficiation or recovery but also, for example, in the removal of bits of iron or steel from foods or other organic materials.

The novel features which are believed to be characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings, in which:

Fig. 1 is a perspective view of a dry separator in accord with this invention;

Fig. 2 is an exploded perspective view of portions of the separator of Fig. 1, partially broken away;

Fig. 3 is an end view, on an enlarged scale, of the rotor, the rotor-enclosing cylinder with an end thereof removed, the splitter blade, portions of the feed system, and associated elements, of the separator of Fig. 1, and being illustrative of details of arrangement and operation of the separator;

Fig. 4 is an end view similar to Fig. 3 but illustrative of arrangement and operation of a modified dry separator construction in accord with the invention;

Fig. 5 is a perspective view of a wet separator in accord with the invention;

Fig. 6 is a front elevation of the wet separator of Fig. 5, portions being broken away to illustrate the construction and operation of the device, the support and certain other external portions being omitted for clarity; and

Fig. 7 is a fragmentary sectional view of portions of the wet separator taken along line 7—7 of Fig. 6.

The dry separator shown in Fig. 1 comprises a suitable frame 1 including a motor mounting plate 2 on which motor 3 is supported. Drive pulley 4 is driven by means of belt 5 from motor 3 and rotates a shaft 6, journalled in bearings housed in protective covers 7 and 8. Shaft 6 mounts a magnetic rotor which is disposed within a hollow cylindrical casing 9 closed by end plates, such as

plate 10. A bin 11 is disposed generally above rotor housing 9 to contain a supply of particles to be treated as indicated at 12. A suitable control mechanism generally indicated at 13, which may be of the type shown and claimed in my Patent No. 2,767,844, is arranged to control the supply or flow of particles 12 over a feed plate or lip 14 onto the rotor housing 9. A splitter blade 15 is arranged generally below rotor housing 9 in position to divide the magnetics from the non-magnetics, a suitable adjustment handle 16 being further provided. The arrangement as shown includes a non-magnetic guard plate 17 to prevent particles from accumulating in angle member portion 18 of frame 1, and further includes suitable troughs 15' for collecting the separated particles.

Details of a novel operative portion of the separator of Fig. 1 are found disclosed in Fig. 2, wherein it will be seen that bearing housing 8 enclosed a bearing 19 in which the rotor shaft end 20 is supported, bolts 21 being arranged to connect pillow block 22 and housing 8 to the frame. Bolts 23 are arranged to hold end plate 10 in position to complete the enclosure of rotor 24 within the closed hollow cylindrical housing 9. Housing 9 is preferably formed of thin smooth-surfaced stainless steel, or of other suitable non-magnetic, wear-resistant sheet material, and it includes a generally horizontal rearwardly extending deflecting plate 25 joined to the cylindrical body portion 26 of housing 9 at a bottom seam or joint 27. Rotor 24 comprises an elongated hexagonal block 28 on which are mounted a plurality of elongated permanent magnets 29, 30, 31. Bolts, such as bolt 32, threaded into block 28, hold the permanent magnets to the block completing a unitary assembly. The length of the rotor is preferably several times the diameter of housing 9 and it has been found convenient to construct the rotor employing magnet elements of shorter lengths, whereby the complete magnet 30, for example, comprises a plurality of separate pieces, such as pieces 33 and 34. As assembled on the block 28, however, magnet 30 comprises an elongated U-shaped magnet with, for example, a south pole 35 extending the full effective length of the rotor and with a north pole 36 similarly extending the full length of the rotor. Magnet 31, according to the invention, will then comprise a north pole 37 and a south pole 38 which similarly extend for the full length of the rotor. The magnets, such as magnet 30, have an overall length slightly less than the overall length of cylinder 26, and, for example, if the distance between end plates 10 and 39 is twenty inches, the overall length of the magnets, such as magnet 30, may be nineteen and one-half inches. The diameter of the cylindrical body portion 26 of the rotor housing 9 may be about four inches. The position of splitter blade 15 is generally indicated in Fig. 2 with respect to the rotor housing 9, and the blade may, of course, be adjusted by handle 16 as required for the specific conditions encountered with each type of feed mixture.

The relationship of the parts and the operation of the dry separator will be further understood with reference to Fig. 3, wherein it will be seen that an adjustable blade 40 controls the feed rate of the granular materials 12 from bin 11 over feed lip or plate 14 onto an upper portion 41 of the housing body 26. The rotor is rotated in the direction of arrow 42 providing a magnetic field rotating in the direction in which the particles are passing along the outer surface 43 of the housing body 26, as indicated by arrow 44. The non-magnetic or very slightly magnetic particles fall freely under the effect of gravity in the direction of arrow 45 in front of splitter blade 15 while the more magnetic particles take the path indicated generally by arrow 46. If the magnetic particles being removed are magnetite, or similarly relatively high magnetic particles, a tumbling action of the particles is clearly noticeable, the tumbling action being generally indicated by arrows 47. This tumbling action permits the non-magnetic or very slightly magnetic particles to become separated from the magnetite or other magnetic particles and greatly reduces the tendency of the non-magnetics to be trapped and held within "strings" of the magnetite particles. Since exemplary utility of the device includes the removal of magnetite from less magnetic particles or substances, the description herein of operation may specify magnetite as the attracted and removed material, although, of course, other materials of relatively high magnetic susceptibility are attracted and removed in the same manner, and whether or not magnetite is present at all.

The arrangement of the magnets 29, 30, 31, 48, 51 and 52 is such that the north pole of each magnet is disposed toward the north pole of a next adjacent magnet and, subsequently, the south pole of each magnet is disposed toward the south pole of a next adjacent magnet. Thus, north pole 37 of magnet 31, which is elongated and extends the full effective length of the rotor, is parallel to similarly elongated north pole 36 of next adjacent magnet 30, and magnets 30 and 31 are oriented to dispose their respective north poles 36 and 37 toward each other, that is, with no south pole interposed. South poles 38 and 50 of next adjacent magnets 31 and 48 extend in parallel longitudinally of the rotor and are disposed toward each other, with no north pole interposed. This arrangement is repeated for each succeeding magnet around the rotor.

The arrangement of the magnets, with north poles of adjacent magnets toward each other and south poles of adjacent magnets toward each other, provides a rotating field which reverses direction sharply and rapidly as each magnet passes. The lines of force, which pass substantially unaffected through the non-magnetic cylinder, are concentrated by the adjoining magnets, while the magnetic force on the magnetic particles at any given point on the cylinder becomes low in the area between the magnets. Thus, there is an intense field at the area between poles 37 and 38 and the field reverses within this area, while the field in the area between poles 38 and 50 becomes weak and, of course, there is no reversal in this area. Magnetite 49 tends to collect on the outer surface 43 and to slide along the surface concentrated opposite the respective magnet poles and between the poles of each magnet. As the groups of magnetite approach the lower portions 53 of the cylinder, and while they are originally collecting near the point of feed, at upper portion 41 of the cylinder, they tend to tumble and to become freed from the non-magnetics 55.

The magnetic particles are pulled around the smooth outer surface 43 of casing 26 and out onto the under surface of a deflecting plate 25 connected to and extending, in the exemplary embodiment, generally tangentially from the surface of the lower portion 53 of the casing. Plate 25 constitutes an outwardly extending discontinuity or non-cylindrical deflecting portion of the casing 9 serving to direct the magnetic particles pulled thereon by the rotating magnets of the rotor outwardly further and further from the cylindrical path of the magnet poles, until the particles, which tend to collect in strings 49' resembling nothing so much as an unkempt, thin, straggly black bear, fall away in clumps 56 as shown. As the particles pass to the left along plate or discontinuity 25, the effect of the magnets thereon decreases, while the continued supply of additional magnetic particles 49 added to those on the discontinuity by each passing magnet increases the size and, consequently, the weight of the depending strings, the strings finally breaking away as at 56 under the force of gravity, either as whole strings or as clumps of the lower ends of strings.

The modified dry separator of Fig. 4 may comprise a rotor and housing arrangement identical to the rotor and housing of Figs. 1–3, but in the machine of Fig. 4 the particles to be separated are fed from bin 11' down an inclined non-magnetic plate 57 to pass close to cylinder 26', the magnetics being lifted upwardly out of the non-

magnetics in the passing stream 58 of the unseparated feed particles. Plate 57 is, accordingly, disposed to extend in a direction inclined downwardly to pass a short distance to one side of and below a lower side portion 59 of cylinder 26', being, preferably, approximately parallel to a tangent of the cylinder in the area of portion 59. The inclination of plate 57 is selected to cause the stream of dry particles to move or slide down the plate at a sufficient speed to permit an economically high feed rate of particles to be separated, while, at the same time, sufficiently slowly to permit the magnets 30', 31', 43' and the like of the rotor 24' to attract and remove substantially all of the magnetic particles which it is desired to scalp from the feed.

The fields of magnets 30', 31' and the like move with the rotating rotor along the plate 57 with a sweeping motion at a greater speed than the speed of the stream 58 thereby sweeping along the stream. If a magnetic particle in the stream is first affected by a south pole but if, because of its being held by surrounding non-magnetic particles in the stream against the pull of the south pole, it fails to jump to the cylinder 26', the particle will be affected by the north pole of the magnet a very short time later. The south pole of the magnet will have tended to induce a north pole at one end of the particle and the north pole of the magnet will now tend to rotate the particle and to pull it at its other end in a different and constantly changing direction. The result is that even those magnetic particles that happen to be more or less trapped in or intimately mixed with the non-magnetic particles of the stream are worked out of the stream and respond to the attraction of the magnets.

In the machine of Fig. 4, the magnetics 56' are drawn out along deflecting plate 25' and fall into a suitable collecting trough on one side of splitter 15', while the less magnetics and non-magnetics 55' fall to the other side of the splitter for separate collection.

The rotor magnets 30, 31, 30', 31' and the like of Figs. 1–4 are preferably U magnets of elongated shape, having elongated parallel-extending pole faces, formed of aluminum-nickel-cobalt-iron materials or the like to have high intensity permanent fields.

If the plate 57 of Fig. 4 is flat in the area of its closest approach to cylinder 26', for treatment of materials of about 10–20 mesh to scalp or remove and concentrate magnetite, the rotor speed may be about 200 revolutions per minute and the plate 57 may be inclined at between about 40 and 50 or 55 degrees to the horizontal and the plate may pass within about one-quarter or one-eighth of an inch from the cylinder portion 59. Suitable magnet elements for use in the machine and which are commercially obtainable are six inches in length. Three such elements arranged end to end, as suggested at 33, 34 of Fig. 1, may make up a suitable magnet 30'. A single element eighteen inches long, if obtainable, would provide, of course, substantially equal results. It will further be understood that the overall length of the rotor magnets may be increased or decreased as desired but that the permissible feed rate, in tons per hour, will be substantially directly proportional to the length of the rotor magnets if other factors remain the same.

It is important in accord with this invention that the rotor is completely enclosed, such as within casing 9 of Figs. 1 and 2, whereby no magnetic or abrasive particles are permited to accumulate in or around the magnets or moving parts of the machine.

The motor 3 is required to deliver only sufficient power to overcome belt and bearing friction and the friction of the magnetic particles on the cylinder surface 43. Since surface 43 is preferably smooth, the power absorbed by friction of the particles on the cylinder surface will, in practice, usually amount to a small fraction of the belt and bearing friction losses. With the exception of the type or direction of feed, the machines of Figs. 1–3 and of Fig. 4 are substantially identical, and the rotor, casing, motor and other parts common to the machines are preferably of identical structure and arrangement.

The active portions 41, 43 and 53 of the cylinder 26 constitute a curved, non-magnetic, stationary plate behind which the magnets move and along which, from portion 41 to portion 53 and beyond, the magnetic particles are pulled by the moving magnets. While the plate 26 which shields the magnets is shown and described herein as being cylindrical in shape, the shape of the active portion of the plate is not necessarily that of a portion of a cylinder. It is to be noted that the magnets provide effective holding force for the magnetic particles some distance out on discontinuity 25. The cylindrical shape from portion 41 to a point beyond the splitter blade provides the advantage that the magnetic particles are pulled through portions 41 and 43 for a distance which is long enough to provide considerable tumbling and jostling of the particles, minimizing entrapment of non-magnetics, but, while the distance is much less in the machine of Fig. 4, it is still sufficient to provide effective separation, and it will be seen that there is very little curvature of the plate against which the magnetics are attracted between the area of attraction 59 and the point at which the magnetics would have been pulled beyond the splitter blade. Accordingly, while maximum field strength on the particles is obtained by using a housing having a cylindrical surface starting with the area in which the feed first approaches the magnet poles and extending to at least a point or area just beyond the splitter blade, slight departures from the cylindrical are tolerable and would make less effective the separation only insofar as the specific geometry of the machine caused such departures to result in increased distance between the magnet poles and the particles attracted thereby. The specific shape of the housing through its inactive portion, beyond the deflecting plate 25 to the area of feed at 41, is of little importance, since the primary purpose of this back portion is to complete the total enclosure of the rotor. It has proved to be particularly convenient and appropriate to form the whole housing as a cylinder because of, for example, the ease of fabrication thereof, the minimizing of space and materials, and the resultant accuracy of the preferred cylindrical shape of the active portions.

It will be noted that particles attracted by north pole 37, for example, of the Fig. 3 construction, tend to follow the pole along the cylinder surface 43. Since the next following pole 36 is also a north pole, the outer ends of the strings of attracted particles tend to incline forwardly, toward south pole 38, rather than to incline rearwardly toward pole 36. The speed of rotation of the rotor in this embodiment is appropriately adjusted to cause the magnet poles to move at approximately the same speed as the speed at which the non-magnetic particles are falling along the cylinder surface. While the rotor revolutions per minute vary with diameter of the cylinder and rotor, and with the rate of falling speed of the non-magnetics, as determined in part by the height of the feed hopper and inclination of the feed lip and the like, an exemplary rotor speed for the device of Fig. 3 with the specific dimensions herein given is 30 revolutions per minute, although, depending upon the nature and size of the particles, the specific results sought and other factors, the speed may be adjusted within relatively wide limits, from about 3 or 4 up to about 100 or 150 r.p.m. Speeds higher than 200 r.p.m. appear unsatisfactory with the arrangement of Fig. 3, and with the dimensions given, causing the magnetic particles to tend to remain stationary or even to tend to climb upwardly on the cylinder surface and not to progress to the discontinuity 25.

It has been further found that the machine according to Fig. 3 may be satisfactorily operated with reversed rotation, i.e. with the rotor turning in the direction opposite to arrow 42, if the rotor speed is adjusted to between about

400 and 1700 r.p.m. Reversed rotation operation is particularly desirable in removing fine magnetic particles of, for example, 40 or 50 mesh and smaller, while for feed mixtures containing magnetic particles as large as about 10 mesh, forward rotor direction, in the direction of arrow 42, is preferred. With higher speed reverse rotation, the magnetic particles progress around the cylinder in the same direction as with lower speed forward rotation, the progression of the particles with reverse rotation of the rotor apparently being the result of rapid rotation or turning end-for-end of the attracted particles. The rotation of the individual particles tends to cause the particles to "walk" in the direction opposite to the direction of the rotor poles, and there is a critical range of speeds for forward as well as for reverse rotor rotation within which the particles tend to remain stationary on the cylinder surface, above which the particles tend to progress in the direction opposite to the rotational direction of the rotor, and below which the particles progress in the same direction as the rotor. The critical speed, in a machine of the exemplary dimensions given herein, may be of the order of 300 r.p.m. for small particles of minus 50 mesh, ranging upwardly to speed ranges of between about 600 or 1000 r.p.m. for particles as large as 10 mesh. A reverse rotational rotor speed of about 800 r.p.m. provides satisfactory scalping of magnetite particles of minus 40 mesh size from weakly magnetic ore and sand particles. Reversed rotor rotation seems, particularly with smaller particles, to reduce entrapment of non-magnetics with the removed magnetic particles.

It has proved desirable to employ somewhat higher forward rotor speeds in the underfed machine of Fig. 4 than for the top feed machine of Fig. 3, and speeds of from about 50 to 200 r.p.m. are most suitable.

In connection with operation of the wet separators hereinafter described and shown in Figs. 5 through 7, it has been found that reverse rotor rotation tends to provide excessive build-up of particles at the lower portions of the cylinder and progressive build-up back around the active portions of the cylinder surface and, accordingly, unless some auxiliary means are employed to remove the accumulating particles, reverse rotation is not recommended in the wet separator. The accumulated particles could, for example, be wiped off by hand.

A wet separator embodying a permanent magnet rotor with magnets arranged similarly to those of the above described constructions is shown in Figs. 5 and 6, portions of the construction being broken away and omitted in Fig. 6 for clarity.

The wet separator comprises a supply bin 60 for feeding dry, damp or wet particles to be separated into the fluid-filled tank 61. The tank includes an overflow outlet comprising a projecting tray 62 connected to drain 63. A fluid, such as water, is supplied into one side of the tank by a supply line 64 and a slurry of magnetics is removed from the tank through a bottom outlet 65, while non-magnetics in a fluid slurry are removed through a second bottom outlet 66. Flow through outlets 65 and 66 is regulated by respective valves 67 and 68 to be sufficient to remove the accumulating separated particles, but the flow rate from outlets 65 and 66 is limited in an exemplary process to aggregate less than the flow rate from supply 64, and, preferably, to be about one-half of the supply rate, whereby the overflow of liquid through drain 63 is at about one-half the supply rate through line 64.

A transparent plastic plate 69, in the machine as shown in Fig. 5, covers an opening 70 in the wall 71 of the tank, and a closed cylinder 72 is sealed with a watertight or hermetic seal to plate 69. A rotor block 73 is disposed within cylinder 72 and carries six permanent magnets, such as magnet 74, in an assembly which is the equivalent of that shown and described in connection with Figs. 1–4. The rotor, however, may be shorter, and it may be supported in a bearing at only one end, as later described. Cylinder 72 is sealed to the respective front and back walls 71 and 75 of the tank to be internally completely dry. A driving motor 76 for the rotor is provided in any convenient location.

Operation of the wet separator is best understood with reference to Fig. 6 disclosing the interior arrangement within tank 61. The materials fed, as from bin 60, fall into a flooded hopper or bin formed by inclined plates 77 and 78 to pass through a feed slot 79 onto an upper portion 80 of cylindrical casing 72, in the direction of arrow 81. Broken arrows in Fig. 6 represent flow of particles, while solid line arrows represent flow of fluid. In the further description herein it will be assumed that the fluid involved is water, since water is highly satisfactory in the operation and has obvious economic advantages over more expensive liquids.

A dividing wall 82, terminating upwardly in a movable splitter blade portion 83, together with cylinder 72, separates the tank 61 below the feed slot 79 into two main compartments or chambers 84 and 85 communicating with one another through a passage 86 between the splitter blade and the cylinder and, preferably, also, through a passage 87 between the feed-directing wall 77 and the cylinder. A deflecting plate 88 extends from cylinder 72 within chamber 84 to provide the function of plate 25 of the dry separator construction as explained above in removing magnetics from the effects of the rotating magnets thereby to release the materials scalped from the feed for desired disposition. The plate 88 further provides a current controlling function in connection with water entering the tank from supply 64. Plate 88 defines, as seen, a subchamber 89 within chamber 84 into which the incoming water is directed and from which the incoming water passes in a smooth flow between plate 88 and tank side wall 90, as generally indicated by water flow arrow 91. Plate 88, accordingly, minimizes turbulence in the flow of water entering chamber 84.

Magnetic particles are extracted from the entering stream 81 of particles to be separated and, as in the dry separator, are pulled by the rotor magnets along the cylinder surface and out onto the discontinuity or deflecting plate 88, from which clumps of magnetics drop, all as suggested by broken arrow 92, into chamber 84 and toward outlet 65 through which they are removed accompanied by a small stream of water indicated by arrow 93. The main body of water in compartment 84 circulates slowly in the direction indicated by arrow 94, helping to wash the magnetics from plate 88.

All of the supply stream of water, except the small portion thereof which flows out through outlet 65, passes from chamber 84 into chamber 85 through passages 86 and 87. In passing through passage 87, which is preferably very small, a small current 95 is thus directed between cylinder 72 and the incoming particle feed 81 tending to cause turbulence in the feed stream, reducing the entrapment of magnetics within groups of non-magnetics and, thereby, permitting the magnets to accomplish the selective attraction to the cylinder of substantially all magnetic particles. Additionally, this current tends to wash or carry non-magnetics away from the cylinder.

The water flow over the splitter blade 83 through passage 86, indicated by arrow 96, washes through the magnetics which are being pulled along by the rotating magnets and washes therefrom non-magnetics which have been trapped within clumps of the magnetics, carrying such non-magnetics over into chamber 85.

A small current of water circulates, as indicated by arrow 97, adjacent cylinder 72 and blade 83 within chamber 85, generated in part by non-magnetics falling from the cylinder. This current 97 tends to sweep the non-magnetics away from blade 83, and away from cylinder 72 into the particle path 98. The non-magnetics fall toward outlet 66 for removal with a small flow of water 99.

The water entering chamber 85 through passages 86 and 87 which does not pass off through outlet 66 flows up

through feed slot **79** causing turbulence in the particles and bubbling up through the mass of particles above slot **79**, as generally indicated by arrows **100**, thus improving the particle feed, making it uniform, and maintaining the particles in loose suspension in the liquid and preventing the formation of clumps of material.

The water passing up through the feed material finally trickles over into tray **62**, carrying with it very little of the solids and with little turbulence, and finally the water passes off through drain line **63**. To conserve water, the water flow through line **63** may, of course, be recycled, as may be the water drawn off with particles through outlets **65** and **66** when the particles have been settled out and removed from the water. A feed rate adjusting blade **101** may be screwed in adjustable position to plate **78** to regulate the size of feed slot **79**.

The specific construction of cylinder **72**, rotor block **73** and associated parts of the wet separator are further shown in Fig. 7. As there seen, the forward end **102** of cylinder **72** is sealed, such as by gluing or, simply by pressure, against plate **69**, and this plate is, in turn, sealed against front tank wall **71**, such as by gluing or by bolts such as bolt **103**. The cylinder is thus completely sealed against any ingress of water at its forward end. A rear end cover **104** is applied to cylinder **72** to complete the sealing thereof, and the cylinder is sealed through the rear tank wall **75**, by a compression ring **110** or the like, adjacent cover **104**. Shaft **105** which carries the rotor block **73** inside cylindrical housing **72** passes through bearing box **106** and carries, also, an external driving pulley **107**. Bearing box or pillow block **106** is suitably supported as by an angle member **108** attached to the tank. Suitable director plates **109**, shown also in Fig. 6, are provided to limit the width of the feed to the cylinder, thereby to insure that the feed will not extend beyond the ends of the rotor magnets, such as magnet **74**.

It will be understood that, while a particularly effective use of the machines of this invention is to remove or scalp magnetite, or other iron-containing minerals, from more valuable minerals which it is desired to recover but in which iron is a troublesome contaminant, the machines are also useful generally for recovering any relatively strongly magnetic particles from less magnetic and non-magnetic particles or fluent substances. Either or both separated fractions may, accordingly, be recovered for use.

It will be further understood that, while the separator of Figs. 1–3 and the separator of Fig. 4 are arranged for a dry feed, wet feed may be provided for these machines. A specific utility of such machines, for example, is in the removal of iron filings or shavings from cutting oil in machine shops or factories. The cutting oil from a lathe, milling machine or the like, or from several such machines, is merely fed into bin **11** or bin **11'** and permitted to flow therefrom over or adjacent the cylinder of the machine. The non-magnetic fraction, in such case, may comprise only the stream of cutting oil from which the iron particles have been removed.

It will be further apparent that the feed in the case of the machine of Figs. 5 and 6 may be dry, and, if desired, the tank **61** may have no liquid in it at all. In operation with a fluid introduced through line **64**, while water is, in many cases, an inexpensive and desirable fluid, other fluids of greater or less density or specific gravity than water may be desirable to give, for example, greater or less washing of the magnetics and greater or less settling time of the non-magnetics, even to the extent of floating and exhausting lighter weight particles from the hopper formed by plates **77**, **78** without passage of such lighter particles through feed slot **79**. Such floating off of light particles would not be the primary function of the machine but only an auxiliary result of operation which might or might not be desirable, and which could be changed as by changing the rate of flow of the fluid, by substituting other fluids, by enlarging the hopper or the like.

While only certain preferred embodiments of this invention have been shown and described by way of illustration, many modifications will occur to those skilled in the art and it is, therefore, desired that it be understood that it is intended in the appended claims to cover all such modifications as fall within the true spirit and scope of this invention.

What is claimed as new and what is desired to secure by Letters Patent of the United States is:

1. A permanent magnet scalping unit comprising a hollow, thin walled, non-magnetic material, fixed, closed cylindrical casing with a smooth outer surface and with its axis horizontal, a shaft extending coaxially in said cylinder, an even plurality of at least four permanent magnets each having parallel axially extending N and S poles mounted on said shaft with their pole faces adjacent the walls of said cylinder and extending longitudinally therealong, said magnets being arranged with the S pole of each magnet toward the S pole of the next adjacent magnet at one side and with its N pole toward the N pole of the next adjacent magnet at the other side, means to direct a stream containing magnetic particles and relatively much less magnetic or non-magnetic substances in immediate proximity to a portion of the outer surface of said casing, splitter means positioned generally below said portion, means to rotate said shaft and magnets in a direction from said portion across said splitter means toward a second portion of said cylinder surface, and a non-magnetic deflecting element extending outwardly from said cylinder at said second portion.

2. The unit according to claim 1 further comprising a tank of liquid, and wherein said first and second portions of said casing surface are at least partially submerged in said liquid and said splitter is completely submerged in said liquid in said tank.

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