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2,177,809

APPARATUS FOR MAGNETICALLY SEPARATING MATERIALS

Filed May 5, 1937

3 Sheets-Sheet 1

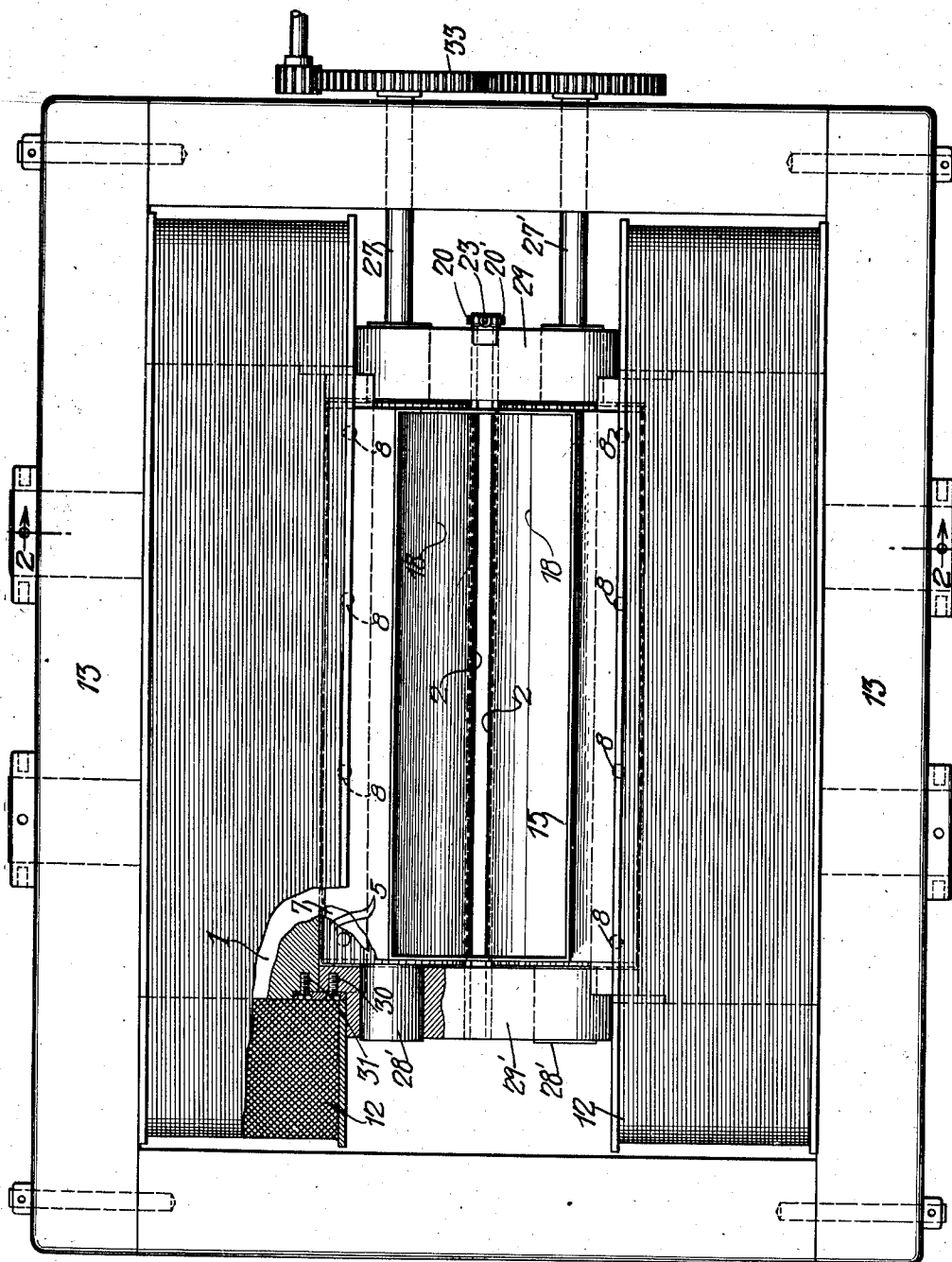


Fig. 1.

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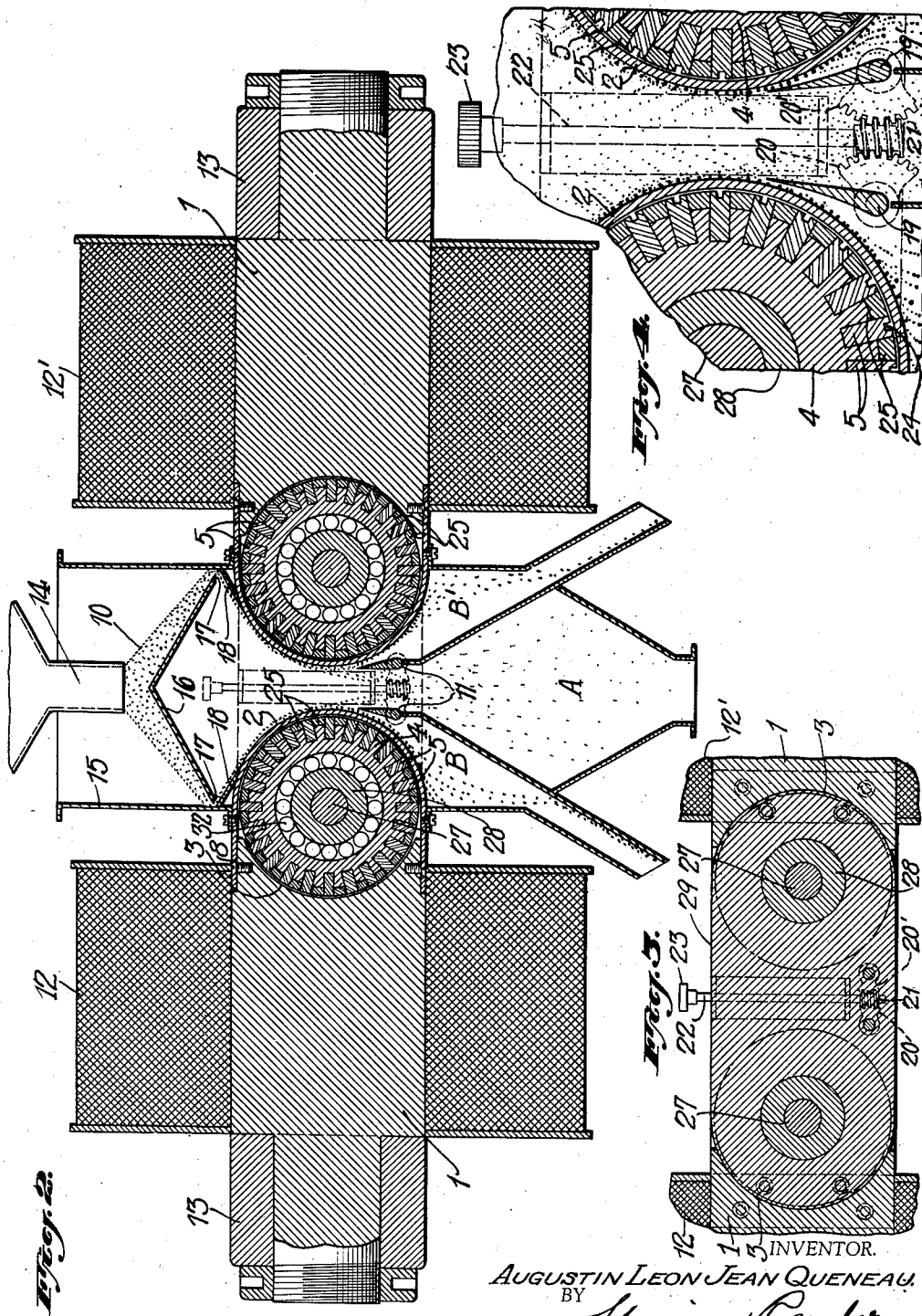
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3 Sheets-Sheet 2



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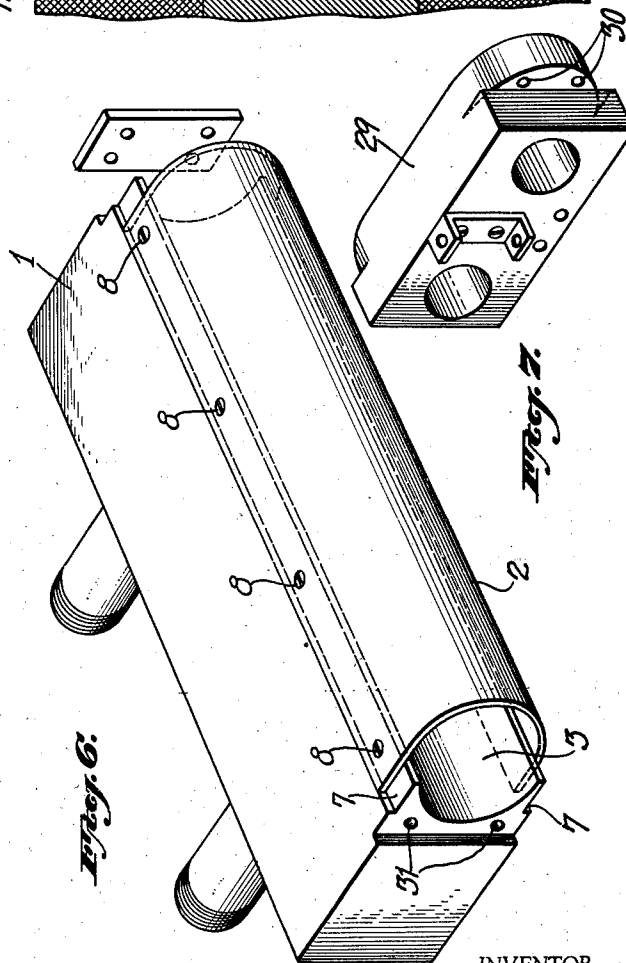
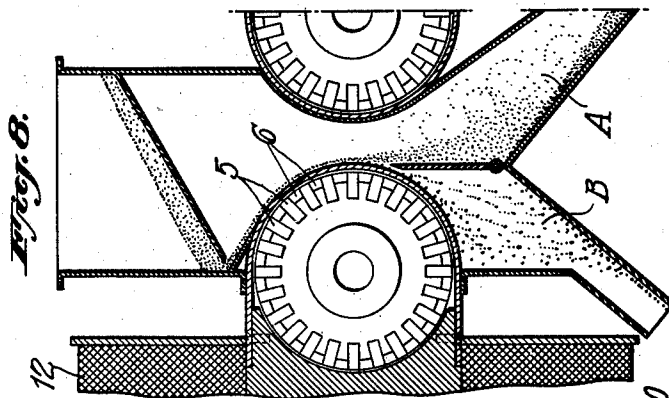
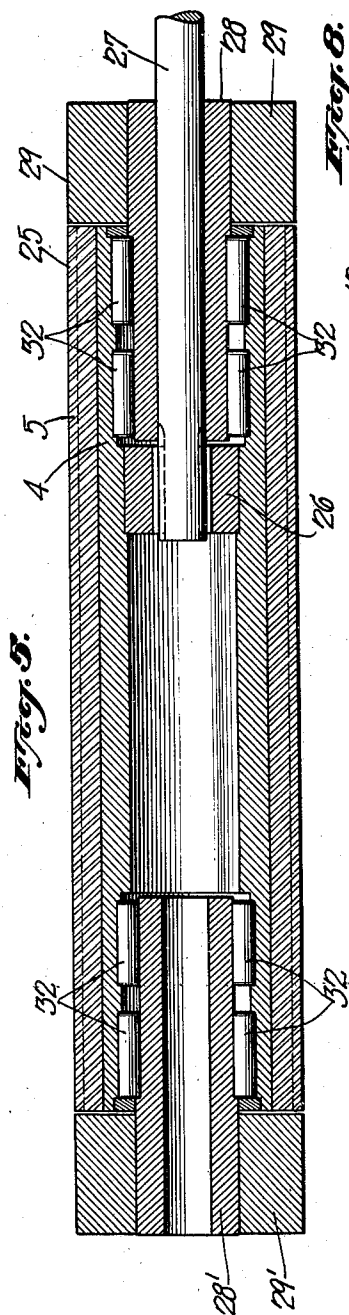
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3 Sheets-Sheet 3



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APPARATUS FOR MAGNETICALLY
SEPARATING MATERIALS

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Application May 5, 1937, Serial No. 140,930

2 Claims. (Cl. 209—219)

This invention relates to magnetic separator devices and more particularly to devices adapted to economically segregate by magnetic means the various magnetic values in ores, residues and the like.

One of the objects of the present invention is to provide an improved magnetic separator device. Another object is to provide a device operative to magnetically separate even the weakly magnetic constituents of an ore, residue and the like. Another object is to provide a magnetic separator device which is economically practical for the separation and treatment of relatively low cost ores, residues and the like. Other objects and advantages will be apparent as the invention is more fully disclosed.

In accordance with the above objects I have devised an electromagnetic separator device of which the following description together with the accompanying drawings is a full and complete disclosure. In the drawings, Fig. 1 is a top plan view of the device of the present invention; Fig. 2 is a side view in section of the same; Fig. 3 is an enlarged view illustrating one feature of the same; Fig. 4 is an enlarged view illustrating another feature of the same; Fig. 5 is an enlarged section illustrating still another feature of the same; Fig. 6 is a perspective view of one important feature of the present invention; Fig. 7 is a perspective view of the feature illustrated in Fig. 3; and Fig. 8 is a sectional view of a modification of the present invention.

Referring to these drawings, the device of the present invention consists in a novel type of electromagnet together with means to feed the material to be treated to the magnet and means to segregate the magnetically attracted particles from the non-magnetic particles.

The electromagnet of the present invention consists essentially of a pole piece 1 (Fig. 6) rectangular in section, one end 2 of the pole piece being arcuately recessed between opposite rectangular sides or edges, and being provided with an arcuately shaped non-magnetic shield 2 forming with said recess a cylindrical bore passage-way 3 the cylindrical axis of which lies substantially coincidentally with the axis of the rounded surface of shield 2. Shield 2 is comprised of non-magnetic material such as a stainless austenitic Fe.Cr.Ni alloy. A cylindrical end piece 4 (Fig. 5) comprised of magnetic material is rotatably supported within said recess 3, the peripheral cylindrical surface of which end piece is provided with a plurality of spaced and isolated points or areas 5 comprised of material of rela-

tively high magnetic flux permeability as compared to the intermediate areas 6 thereof, the said spaced and isolated points or areas 5 forming a substantially discontinuous path circumferentially about the peripheral surface of the said end piece.

The rectangular size of pole 1 may be varied markedly without departure from the present invention as will be apparent from further description.

I have found that by disposing two of these poles horizontally with the rounded non-magnetic ends in space gap relation as indicated in Figs. 2 and 8, and by passing a magnetizing current across this space gap, I may feed material 10 gravitationally onto the curved non-magnetic surface of either or both pole ends, and by rotating the cylindrical end pieces 4, I can effectively cause the magnetically attracted particles of the material 10 to be progressively moved downwardly along the curved surface through the zone of maximum flux density and thence through a decreasing magnetic field along the under side of the curved surface to the point where the flux density can no longer retain the particle adjacent the non-magnetic surface against the vertically downward gravitational pull. The non-magnetic particles of the material fall vertically off the lip of the curved surface and by the provision of adjustable gate means 11 I may accordingly obtain a relatively clean separation between the magnetic and non-magnetic particles.

The essential problem involved is to economically provide a magnetic field of adequate strength to magnetically attract and hold the desired particle to the non-magnetic surface against the gravitational pull and other interfering forces incident to the gravitational passage of the material through the magnetic field.

This problem is essentially one of magnet design and the most effective and efficient design that I have found is that indicated in the drawings. The electromagnetic coil 12 is wound about the pole 1 as close to the rounded end as is practical in view of the necessity of providing clearance for the rotatable cylindrical pole end 4. The ampere turns in coil 12 are adapted to provide any desired range of magnetic flux densities depending upon the magnetic susceptibilities of the material being treated. About the outer ends of the spaced poles I dispose rectangular yoke member 13 forming a substantially closed magnetic path horizontally on either side of the space gap between the non-magnetic pole ends. Coils 12—12'

are wound such that upon energization of the coils with a direct current one pole end at the space gap will be magnetically north and the opposite pole will be magnetically south. The two poles being shaped identically, the magnetic field induced therebetween will be substantially symmetrical and either one or both may be employed in accordance with the present invention, as indicated in Figs. 2 and 8.

10 The feeding of material to be treated through the space gap and gravitationally along the curved non-magnetic surface of the pole end may be accomplished in a plurality of ways without departure from the present invention. In Figs. 2 and 8 I have shown one convenient way of doing this. The essential feature of the feeding means is to deposit the material upon the upper curved surface in a relatively thin layer, not over 2 or 3 particles deep, so that entrapment of non-magnetic particles by the magnetic particles is substantially avoided. In the arrangement shown, the material 10 is fed through spout 14 into chamber 15 provided with a deflection plate 16 which carries the material gravitationally to the opposite side walls of container 15 and to a silt opening 17 adapted to permit the material 10 to trickle therethrough upon inclined plate 18 forming a tangential continuation of the curved outer surface of shield 2 at such an angle as will with respect to the particle size and specific gravity of material 10 promote a gravitational flow of the material 10 at a desired rate downwardly along the said non-magnetic curved surface of shield 2.

35 The magnetic field strength should be sufficient to retain the magnetic value desired to be separated adjacent the outer curved surface of shield 2. This field strength will vary with respect to the particular magnetic susceptibility of the material 10.

40 Rotation of cylindrical end piece 4 in the direction of material flow may be at various rates depending upon the rate of flow of material 10, the relative amount of magnetic and non-magnetic particles therein, the magnetic susceptibility and field strength, for example. I have found that the rate of travel of the peripheral surface of the pole end should closely approximate the rate of flow of the material 10 for best results on the majority of materials and over a relatively wide range of concentrations of magnetic and non-magnetic constituents.

In the ordinary practice of the present invention, the non-magnetic particles of material 10 will be collected in center compartment A and the magnetic particles collected in outer compartments B—B' (Fig. 2) or in compartments A and B respectively (Fig. 8), the division being made possible and positive through operation of adjustable gate means 11. In Fig. 4 I have illustrated a very convenient arrangement for adjusting gate means 11. The gates 11 are mounted on rotatable shafts 19—19' the ends of which protrude through the end walls of container 15 and to which ends are keyed sectional gears 20—20'. Gears 20—20' are disposed in a position to engage threads 21 on shaft 22 and knob means 23 is provided to rotate the shaft to obtain a desired positioning of the knife edge of gate means 11 relative to the curved surface of pole end 2. Preferably the arrangement is such as to position the upper knife edge surface of gate means 11 below the apex or lip of the curved surface of pole end 2 at which point the zone of maximum field strength will be located.

In the use and application of the present invention, it is apparent that the economic treatment of some materials, such as low grade or low cost material, will require a single device to handle relatively large tonnages of materials during a unit time interval. This may be accomplished through lengthening the rectangular section of the pole piece, thereby producing a relatively long rectangular gap through which the material 10 may be passed, substantially as indicated in Fig. 1. As the length of cylindrical end section 4 is increased, however, the difficulties of rotatively supporting the same within the bore passageway increases, and to avoid the use of relatively heavy axles and to reduce the energy required to rotate the end piece, I have designed the structure indicated in Fig. 5.

In Fig. 5 the cylindrical end section 4 is comprised substantially of a tubular length 4 of low metalloid steel having a total length substantially less than the overall length of pole 1 but approximately that of curved end piece 2 (Fig. 6). The outer peripheral surface of tube 4 is provided with a plurality of spaced grooves extending longitudinally the entire length of the tube. In each groove I dispose and seat strips 5 comprised of material of relatively high flux permeability, such as cobalt steel, which strips 5 extend above the peripheral surface of tube 4 with the intervening spaces between the extending sides of strips 5 filled with material 25 of low magnetic flux permeability, such as lead solder having a permeability substantially that of air. The combination of tube 4 with areas 5 and 25 I will hereinafter identify as a rotor 4.

I prefer to provide strips 5 with a longitudinal groove or recess 24 (as indicated in cross-section in Fig. 4) and as a specific embodiment of this structure strips 5 are comprised of cobalt steel having a cross-sectional dimension of $\frac{3}{8}$ inch by one inch and a length approximating the length of the tube 4. These strips are recessed edgewise into the surface of tube 4 about $\frac{1}{2}$ inch and the space 25 between the strips is filled with lead solder to a level approximating that of the upper surface of the strips 5. The upper surface of strip 5 is provided with a centrally located recess 24 approximately $\frac{1}{8}$ inch wide by $\frac{1}{8}$ inch deep. This arrangement provides a flux density ratio between the cobalt strip and the intervening solder of about 8:1; for example, with an exciting current of two amperes a flux density of about 13,000 gaussess will be obtained on the cobalt strips while only about 1680 gaussess will be obtained on the lead solder. This provides an ample flux differential between the strip 5 and intervening material 25 to obtain the desired movement of the magnetically attracted particles through the magnetic field. The longitudinal groove or recess 24 in strip 5 accentuates the effect desired from this flux differential in some manner not at this moment apparent. It may be that by multiplying the number of sharp corners present on strip 5 by the provision of recess 24 this accentuated effect is obtained.

To the inside of this rotor I affix a driving block 26 to which is keyed drive shaft 27. The rotor is supported within the bore passageway 3 by means of hollow stub shafts 28—28' carried by side cheek plates 29—29' which rest against the sides of pole 1 and are adapted to be bolted or otherwise positioned there as indicated by aligned openings 30 and 31. Roller bearings 32 are provided to permit free rotation of rotor 4

about stub shafts 28. Shaft 28, stub shafts 28—28', driving block 26, roller bearings 32 and cheek plates 29—29' are each comprised of non-magnetic material such as austenitic stainless steel. Drive shaft 27 is actuated by any suitable means such as a variable speed back drive electric motor through suitable gearing 33.

By the use of this rotor structure I may economically extend the length of cylindrical end section 4 to thirty inches or more without proportionately increasing the diameter thereof, and thereby markedly increasing the capacity per time unit of the device of the present invention without seriously increasing the cost of the device. It is necessary, however, to increase the coil turns of coils 12—12' to provide for the increased magnetic currents thereby required. One skilled in the art may readily calculate the number of coil turns required to obtain a desired magnetic current when given any particular pole area from which to figure.

As an example of the practical utility of the present invention, I may treat a ferruginous sandstone ore consisting principally of hematite and silica found principally in the Alabama iron ore district as follows:

The ore is crushed and ground carefully to free the hematite from the silica. In this type ore the individual grains of silica are coated or cemented together by the hematite. It is exceedingly difficult to crush the ore in such a way as to avoid breaking the silica grains and to entirely free the surfaces of the silica grains from adhering crusts of hematite. The magnetic susceptibilities of these two materials are not far apart: hematite=1.32 and silica=.37 (iron as a standard being taken at 100). Therefore it is apparent the successful application of any method of magnetic separation will depend primarily upon the efficiency of the grinding process and the extent the individual silica grains are freed from the surface coating of hematite. The most effective mode of grinding that I have found to accomplish this, is to first crush the ore to about 1/2 inch size in an ordinary rock crusher, then to place the material in a rod mill and to grind slowly therein for a prolonged time interval. The thus ground material should then be screened through 20 mesh, the oversize particles returned to the rod mill and the material passing the screen subjected to magnetic separation in the device of the present invention.

In treating the thus ground ore in the device of the present invention, I have found it preferable to recover the iron content of the ore in steps. The ore after grinding averages about 25.0% Fe (as Fe_2O_3) and the bulk of the remainder is silica.

During the first passage of the ore through the device I apply a relatively low flux density in order to remove substantially all of the iron present as magnetite (Fe_3O_4) the more magnetic iron oxide. I then increase the flux density to about 13,000 gauss and then to about 19,000 gauss, the maximum flux density permissible with-

out also attracting the silica particularly those grains containing some iron or having some hematite still adhering to the surface of the grain.

By this mode of procedure I find I may recover substantially 85% of the total iron of the ore and obtain thereby a concentrate averaging 52% Fe and the balance mainly silica which concentrate is readily adapted for use after sintering in the usual types of iron ore reduction furnaces and processes. As the iron ore itself is relatively of little value unless and until concentrated and must after concentration be able to compete from a cost standpoint with relatively low priced high grade ores, it is apparent that the device of the present invention is adapted to accomplish this very result. A relatively large tonnage per day may be treated with low labor costs as one man can supervise the operation of a large battery of such devices.

Having broadly and specifically described the present invention and several modifications of the same, it is apparent that the invention may be widely modified without departure therefrom and all such modifications are contemplated as may fall within the scope of the following claims.

What I claim is:

1. Apparatus for the magnetic separation of dry materials, comprising in combination an inclined chute member tangent to a rearwardly extending arcuate portion, the degree of inclination of the chute being sufficient to gravitationally feed the material to be treated in a relatively thin layer not over 3 particles deep along said chute towards said arcuate portion, means to magnetically attract the magnetic particles of said material to the surface of said chute as the material approaches the said arcuate portion, means to magnetically move the attracted particles along the surface of said chute and over the lip of said arcuate portion to a point on the underside of said arcuate portion adapted to provide a path of substantially free vertical fall for the said magnetic particles remote from the path of fall of the non-magnetic particles off the lip of said arcuate portion.

2. The apparatus of claim 1 wherein two said chutes are provided and are disposed opposite each other in a position to feed the said materials towards each other with the said arcuate portions located adjacent but in spaced relation and with a space gap therebetween, means to project an electromagnetic field of required intensity between said arcuate portions, said means including electromagnetic poles provided with rotatable cylindrical shaped pole ends, having a diameter and length adapting the same to be located adjacent the under surface of the said arcuate portion, the peripheral surfaces of said pole ends being provided with spaced and isolated points or areas comprised of material of relatively high flux concentration as compared to the intervening areas, said spaced areas being discontinuous in the direction of rotation of said pole end surfaces.

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