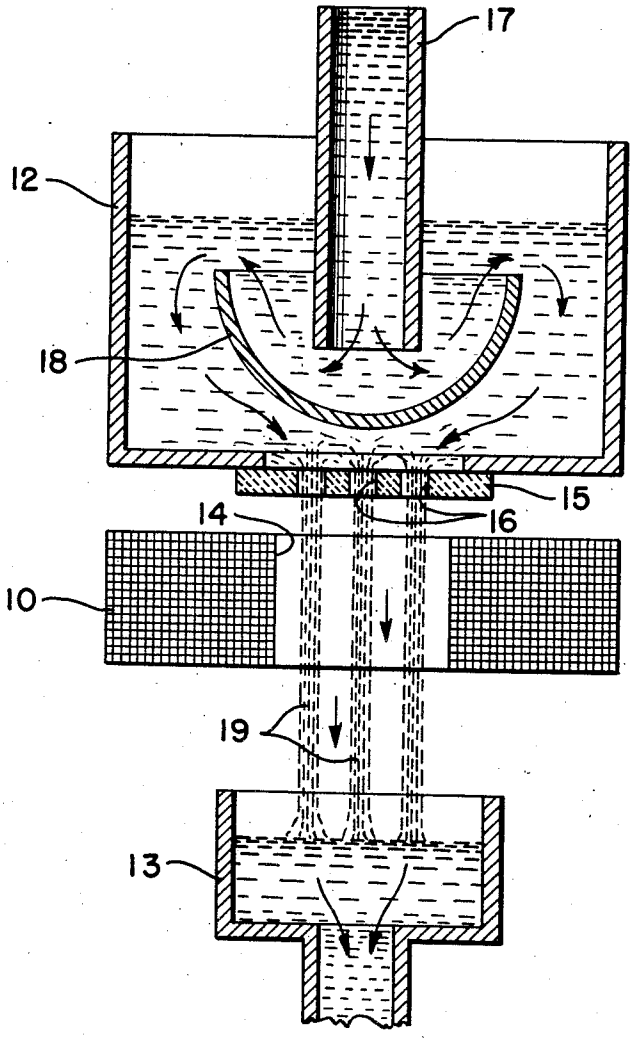
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METHOD AND APPARATUS FOR DEPOLARIZING PARTICLES OF MAGNETIC MATERIAL

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FIG. 1



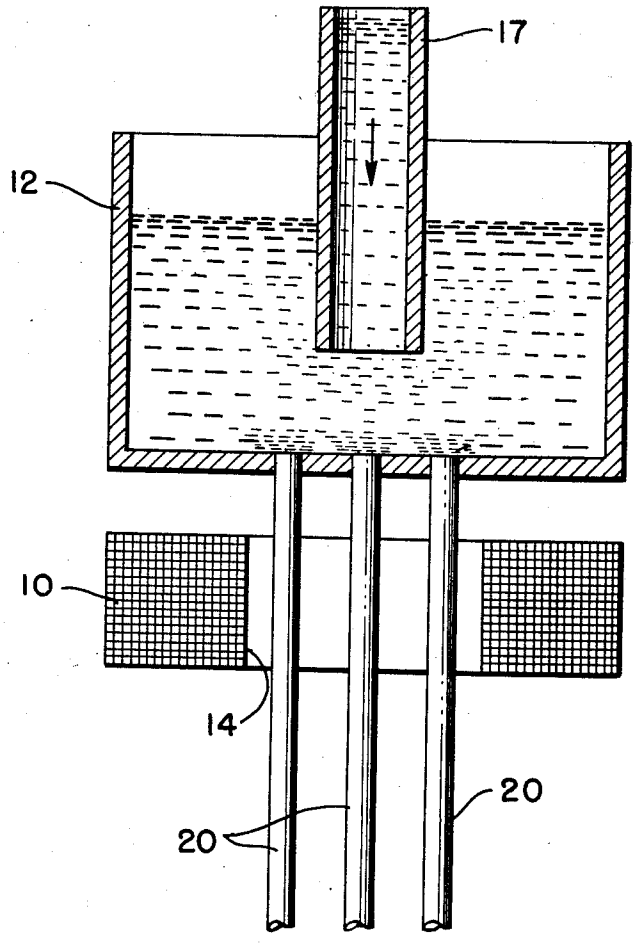

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FIG. 2




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2,807,363

# METHOD AND APPARATUS FOR DEPOLARIZING PARTICLES OF MAGNETIC MATERIAL

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12 Claims. (Cl. 209—8)

This invention relates to improved methods and apparatus for depolarizing magnetic particles.

Many processes which involve treating magnetic particles include a step of removing their residual magnetism or "depolarizing" them. One example is magnetic concentration of some types of iron ore, such as magnetic taconites. A typical procedure in concentrating such ore is to crush it to about ¾" to 1", grind the crushed product in a rod mill to about 8 to 10 mesh, separate a coarse tailing and rougher concentrate magnetically ("cobbing"), and grind and classify the rougher concentrate in a "closed circuit," which includes a ball mill and a hydraulic classifier. In the classifier the fine product is levitated over an overflow lip for subsequent treatment with a magnetic separator to recover a final concentrate and tailing; the coarse product returns to the ball mill for further grinding. When magnetic particles reach the classifier, they should be free of residual magnetism or depolarized. Otherwise fine magnetic particles, already reduced sufficiently to overflow the classifier, tend instead to flocculate and settle, thus clogging the circuit and causing unnecessary grinding. Consequently the usual practice is to include a depolarizer in the circuit between the ball mill and the classifier.

The usual depolarizer comprises a coil that carries alternating current and has an air core. A pulp or water suspension of particles flows through this core, and the current reversals randomize magnetic poles on the particles. Large depolarizers are not as effective as those of smaller size, such as those used in laboratory practice. The field strength of a depolarizer coil is highest near its inside windings and lowest at the axis. A common assumption has been that loss of effectiveness in larger equipment is due to this nonuniformity in field strength. To counteract low field strength near the center, the obvious remedy is to increase the total field strength of the coil, but this remedy has not been successful, thus tending to disprove the assumption.

Another way of depolarizing, confined mainly to laboratory operations, is to heat particles above an elevated temperature, known as the "Curie point," and allow them to cool, all in an inert atmosphere. This method has been thought to produce the most complete depolarization theoretically attainable and has been accepted as a standard of excellence for comparing other depolarizing methods. The results are reproducible, which renders the method very useful for such comparisons.

An object of the present invention is to provide improved depolarizing methods and apparatus which are capable of use in large scale operations and yet are more effective than those previously known, in fact more effective than heating to the "Curie point."

A further object is to provide improved alternating current depolarizing methods and apparatus which take into account a factor heretofore neglected, namely turbulence of the pulp stream as it flows through the coil.

A further object is to provide improved alternating current depolarizers which have means for reducing turbulence of flow therethrough and thus, in accordance with the present invention, produce more effective depolarization.



In accomplishing these and other objects of the invention, we have provided improved details of structure, preferred forms of which are shown in the accompanying drawings, in which:

Figure 1 is a schematic vertical sectional view of a depolarizer which embodies one form of the present invention; and

Figure 2 is a schematic vertical sectional view of a depolarizer which embodies an alternate form of the invention.

In the hydraulics art the term "Reynolds number" refers to a dimensionless quantity indicative of the type of flow that can be expected through any hydraulic apparatus. The Reynolds number depends on such factors as linear dimensions of an apparatus, linear velocity of flow therethrough, and density and viscosity of the liquid. When the Reynolds number is less than 2,000, flow is almost always streamline. Reynolds numbers between 2,000 and 12,000 represent a transition range in which flow can be either turbulent or streamline. When the Reynolds number is greater than 12,000, flow is usually turbulent, although under favorable conditions streamline flow can persist with Reynolds numbers as high as 50,000. In practicing our invention, we provide conditions that produce streamline flow through our depolarizer coil, and preferably a Reynolds number in the range where streamline flow is assured.

Figure 1 shows one form of depolarizer which is constructed in accordance with our invention and comprises an alternating current coil **10**, a feed tank **12** and a receiving tank **13**. The coil has an air core **14** and the feed tank is located directly above this core. The bottom of the feed tank carries a multiple orifice plate **15** preferably formed of a wear-resistant material, such as silicon carbide or aluminum oxide. The plate **15** contains a plurality of orifices **16**, each of which preferably is circular in plan and of a diameter of about ¾ to 1½ inches, although the maximum orifice diameter we can tolerate is about 3 inches. A pulp or water suspension of particles is introduced to the tank **12** via a feed pipe **17**. The pulp within this tank forms a static head which is as quiescent as possible. The tank can contain a hemispherical baffle **18** to assist in maintaining quiescence.

A multiplicity of pulp streams **19** discharge from the tank **12** through the orifices **16** and are in a state of free fall as they pass through the core **14** of the coil **10**. We find with this arrangement we can tolerate a Reynolds number at the orifices as high as about 30,000. We believe the flow tends to become streamline when the streams are in free fall, even though it may be somewhat turbulent at the orifices. The particles should remain within the field of the coil for at least two or three complete alternating current cycles in the decreasing lower portion of the field. The field strength required in the coil depends somewhat on the coercive force of the magnetic particles. For particles of low coercive force, such as natural magnetite, any field strength over 200 oersteds is satisfactory.

Figure 2 shows a modification in which a series of parallel discharge tubes **20** extend from the feed tank **12** through the core **14** of the coil **10**. With this modification it is unnecessary that the feed tank **12** be placed directly above the coil. Instead these parts can be oriented in any convenient manner. However, this modification requires a lower Reynolds number to assure streamline flow of the pulp as it passes through the field of the coil. We prefer a maximum Reynolds number of about 2,000 although under favorable conditions we can tolerate a somewhat higher Reynolds number, up to

about 8,000. Streamline flow and low Reynolds number are favored by low flow velocities and small tubing diameters. The maximum inside diameter of the tubes **20** is about 3 inches.

The beneficial results which our invention affords are demonstrated by the following examples. The "depolarizing index" used in these examples is a comparison of the degree of depolarization obtained under the conditions indicated with that obtained by heating similar material to the "Curie point." This comparison is made by observing the rate at which particles of an otherwise similar pulp settle in water after depolarization by the different methods. A convenient way of observing these settling rates is to weigh the magnetic material which remains in suspension after the material has settled in water for a designated time period. Depolarizing by heating above the "Curie point" gives a standard index of 1.00, and we have found an index of about 1.25 is necessary for efficient operation of a hydraulic classifier.

*Example I*

A pulp of natural magnetite was passed through an alternating current coil of 400 oersteds maximum field intensity at increasing flow rates through tubes of 1½ inches and 1 inch nominal inside diameter in accordance with the second embodiment of our invention. The results were as follows:

| Nominal tube diameter, inches | Actual tube diameter, feet | Volume rate, cu. ft./sec. | Linear velocity, ft./sec. | Reynolds number | Depolarizing index |
|---|---|---|---|---|---|
| 1½ | 0.125 | 0.060 | 4.9 | 11,700 | 0.93 |
| | 0.125 | 0.044 | 3.5 | 8,400 | 1.08 |
| | 0.125 | 0.019 | 1.5 | 3,650 | 1.26 |
| 1 | 0.0727 | 0.052 | 12.8 | 18,200 | 1.02 |
| | 0.0727 | 0.019 | 4.6 | 6,330 | 1.10 |
| | 0.0727 | 0.011 | 2.6 | 3,700 | 1.36 |

Coil: tapered coil, approx. 5" I. D., 400 oersteds maximum field intensity (effective value).
Pulp density, 1.87; percent solids, 62.
Entrance conditions: No precautions taken to minimize turbulence.

This table indicates that the effectiveness of depolarization increases with decreasing velocity in any particular size tube, and that best results are obtained only when the Reynolds number is low enough to insure streamline flow. The comparison also indicates that the permissible linear velocity increases with decrease in pipe diameter—thus good results are obtained at a linear velocity of 2.6 ft. per sec. with the one inch tube, whereas the maximum permissible linear velocity for the 1½ inch tube is only about 1.5 ft./sec.

*Example II*

A pulp of natural magnetite was passed through an alternating current coil of 400 oersteds maximum field intensity through tubes of varying inside diameters and at varying rates again in accordance with the second embodiment of the invention. The results were as follows:

| Nominal tube diameter, inches | Actual tube diameter, ft. | Volume rate, cu. ft./sec. | Linear velocity, ft./sec. | Reynolds number | Depolarizing index |
|---|---|---|---|---|---|
| 3 | .245 | 0.072 | 1.54 | 7,080 | 1.05 |
| 2 | .1615 | 0.030 | 1.47 | 4,400 | 1.09 |
| 1½ | .125 | 0.019 | 1.54 | 3,650 | 1.26 |
| 1 | .0727 | 0.011 | 2.62 | 3,700 | 1.36 |

Coil: tapered coil, approx. 5" I. D., 400 oersteds maximum field intensity (effective value).
Pulp density, 1.87; percent solids, 62.
Entrance conditions: No precautions taken to minimize turbulence.

In this example approximately the same linear velocity was maintained, except for the smallest tube in which the velocity was higher. This example demonstrates that



the permissible linear velocity decreases as the tubing diameter increases.

The data presented in Examples I and II show clearly the advantage of using a multiplicity of small-diameter tubes rather than a single large-diameter tube to carry any given volume of pulp through a depolarizer coil. If large-diameter tubes are used, the maximum permissible linear velocity becomes very low, requiring either an extremely large coil, or a multiplicity of moderate diameter coils. If a large-diameter tube is used with a high linear velocity, it is not possible to obtain effective depolarization.

*Example III*

We dropped a magnetite pulp through a coil in free fall after it had discharged from orifices of various sizes. We next passed a similar pulp through the coil in tubes of comparable sizes. The comparative results shown in the next table demonstrate that the free fall method is superior. In two instances the volume rate of flow, as well as the depolarization index, is considerably greater with the orifice than with the tube.

| Type flow | Diameter, inches | Volume rate, cu. ft./sec. | Linear velocity, ft./sec. | | Reynolds number | Depolarizing index |
|---|---|---|---|---|---|---|
| | | | At orifice discharge | At point of max. field intensity | | |
| Orifice | ¾ | 0.0135 | 6.9 | 11.8 | 6,210 | 1.59 |
| Tube | ¾ | 0.0152 | 7.3 | 7.3 | 7,010 | 1.18 |
| Orifice | 2 | 0.121 | 9.3 | 10.6 | 23,050 | 1.36 |
| Tube | 1½ | 0.091 | 7.4 | 7.4 | 17,800 | 1.15 |
| Orifice | ¾ | 0.018 | 9.1 | 14.0 | 8,250 | 1.56 |
| Tube | ¾ | 0.025 | 11.8 | 11.8 | 11,420 | 1.09 |
| Orifice | 2¾ | 0.198 | 8.0 | 9.0 | 28,400 | 1.22 |
| Tube | 2 | 0.091 | 4.6 | 4.6 | 14,500 | 0.98 |

Coil: tapered coil, approx. 5" I. D., 400 oersteds maximum field intensity (effective value).
Pulp density, 1.87; percent solids, 62.
Entrance conditions: No precautions taken to minimize turbulence.

*Example IV*

Another set of data demonstrating the same effect are given in the next table. The tests listed there were made in the same manner as those listed in Example III, except that a different coil and a different method of introducing the pulp into the tubes and orifice were used. The coil was a cylindrical coil with maximum field strength of 446 oersteds. To provide a minimum of agitation upon entrance, a surge tank with a quiescent pool of pulp was used and the tube entrances were shaped to conform with natural flow lines. Thus it is possible to estimate the effect of minimizing turbulence by comparison of the present example with Example III.

This table shows that with small diameter tubes there is little difference in effectiveness of depolarizing between the two methods of flow, but at increasing size of conduit there is a progressively greater difference in favor of discharge through an orifice. It also demonstrates the decrease in depolarizing index with increasing Reynolds number—substantial in the case of flow through tubes, but slight in the case of discharge through an orifice.

Comparison of the results obtained with tubes with and without precautions to minimize entrance turbulence (Examples IV and III respectively) shows that in general, depolarizing results are considerably better for the same Reynolds number when such precautions are taken. For instance, a Reynolds number of 7000 without these precautions gave a depolarizing index of only 1.18. With such precautions, a similar depolarizing index (1.17) was obtained at a substantially higher Reynolds number (12,000). Similarly, for the same Reynolds number, depolarizing indexes for orifice discharge are generally improved by minimizing entrance agitation.

| Type flow | Diameter, feet | | Volume rate, cu. ft./sec. | Linear velocity, ft./sec. | Reynolds number | Depolarizing index |
|---|---|---|---|---|---|---|
| | Actual | Effective | | | | |
| Orifice | 0.0677 | 0.0526 | 0.0173 | 7.97 | 7,651 | 1.46 |
| Tube | 0.0516 | | 0.0121 | 5.79 | 6,275 | 1.34 |
| Orifice | 0.0833 | 0.0646 | 0.0269 | 8.20 | 10,640 | 1.31 |
| Tube | 0.0625 | | 0.0195 | 6.33 | 8,149 | 1.30 |
| Orifice | 0.1250 | 0.0972 | 0.0552 | 7.46 | 15,008 | 1.33 |
| Tube | 0.0940 | | 0.0469 | 6.70 | 12,393 | 1.17 |
| Orifice | 0.1614 | 0.1256 | 0.097 | 7.82 | 20,430 | 1.20 |
| Tube | 0.1250 | | 0.077 | 6.26 | 15,957 | 1.00 |
| Orifice | 0.2294 | 0.1612 | 0.112 | 5.49 | 18,317 | 1.24 |
| Tube | 0.1615 | | 0.123 | 6.00 | 20,156 | 0.86 |

Coil: Cylindrical, 6" I. D., 446 oersteds maximum field intensity (effective value).
Pulp density, 1.93-2.04; percent solids, 65-68.
Entrance conditions: Surge tank to provide quiescent pool and rounded edges on tubes to conform with natural flow patterns.

The two columns in the foregoing table headed "Actual Diameter" and "Effective Diameter" for the orifices show, respectively, the actual orifice diameter and the effective size of stream due to contraction of a fluid when flowing past an orifice.

*Example V*

The next table illustrates the advantage of providing a quiescent surge tank to effect gravity flow through a tube within the alternating current coil. In the first two tests listed, such a surge tank with gravity flow was used. In the last three, the pulp was pumped through the tube, causing much more turbulence upon entrance to the tube. In the tests with gravity flow from a quiescent pool, good depolarizing was obtained with Reynolds numbers as high as 3700. In the third and fourth tests, with pumping, depolarizing was poor, even though the Reynolds numbers were somewhat lower, 3010 and 2680, respectively. In the last test, also with pumping, good depolarizing was obtained as the Reynolds number was only 2220, approaching the range where streamline flow invariably occurs. Similar results were obtained in discharge through an orifice when comparing quiescent and turbulent entrance of pulp to the orifices.

| Type of entrance | Actual I. D., feet | Volume rate, cu. ft./sec. | Linear velocity, ft./sec. | Reynolds number | Depolarizing index |
|---|---|---|---|---|---|
| Gravity flow | 0.125 | 0.019 | 1.54 | 3,650 | 1.26 |
| Do | 0.0727 | 0.011 | 2.62 | 3,700 | 1.36 |
| Pumping | 0.146 | 0.018 | 1.09 | 3,010 | 0.83 |
| Do.[1] | 0.146 | 0.018 | 1.08 | 2,680 | 1.07 |
| Do | 0.243 | 0.51 | 0.51 | 2,220 | 1.35 |

[1] Pulp density: 1.67, 53% solids.

Coil, pulp density and percent solids: As listed in Example I (except as noted above).

From the foregoing description and examples it is seen that the present invention affords a simple method and apparatus for greatly increasing the effectiveness of alternating current depolarizers. The invention produces a degree of depolarization as much as 50 percent greater than was heretofore considered even theoretically possible.

While two embodiments of our invention have been shown and described, it will be apparent that other adaptations and modifications may be made without departing from the scope of the following claims.

We claim:

1. A depolarizer comprising a coil having an air core, means for supplying alternating current to said coil, and a feed vessel located directly over said core and adapted to contain a relatively quiescent static head of a liquid suspension of particles, the bottom of said vessel having a plurality of outlets, each of which has a maximum diameter of about three inches, said outlets being adapted to direct a plurality of parallel streams from said vessel vertically downward through said core exclusively under the influence of the static head, the flow of each of the streams being streamline.



2. A depolarizer as defined in claim 1 in which the bottom of said vessel includes a multiple orifice plate, and said outlets are in the form of orifices in said plate adapted to discharge streams in free fall through said core.

3. A depolarizer as defined in claim 1 in which said outlets include a plurality of parallel tubes extending from the bottom of said vessel through said core.

4. A depolarizer comprising a coil having an air core, means for supplying alternating current to said coil, a feed vessel above said core adapted to contain a relatively quiescent static head of a liquid suspension of particles, and a multiple orifice plate at the bottom of said vessel adapted to discharge parallel streams in free fall through said core with the flow of each being streamline, the maximum orifice diameter being about 3 inches.

5. A depolarizer as defined in claim 4 in which said feed vessel contains a hemispherical baffle concave upwardly and means for introducing liquid above the central part of said baffle.

6. A method of depolarizing magnetic particles to a degree exceeding that attainable by heating similar particles to the "Curie point" comprising flowing a water suspension of the particles through an air core of a coil that carries alternating current, controlling the diameter of the stream as it enters said core to a maximum of about 3 inches, and streamlining the flow of said stream by relating the factors that determine the Reynolds number to give a maximum of about 30,000.

7. A method of depolarizing magnetic particles to a degree exceeding that attainable by heating similar particles to the "Curie point" comprising flowing a water suspension of the particles through an air core of a coil that carries alternating current, dividing the flow through said core into a plurality of parallel streams each of whose diameter as it enters said core is a maximum of about 3 inches, and streamlining the flow of said streams by relating the factors that determine the Reynolds number to give a maximum of about 30,000.

8. A method of depolarizing magnetic particles to a degree exceeding that attainable by heating similar particles to the "Curie point" comprising flowing a water suspension of the particles vertically downwardly through an air core of a coil that carries alternating current, dividing the flow through said core into a plurality of parallel streams each of whose diameter as it enters said core is a maximum of about 3 inches, and streamlining the flow of said streams by relating the factors that determine the Reynolds number to give a maximum of about 30,000.

9. A method of depolarizing magnetic particles to a degree exceeding that attainable by heating similar particles to the "Curie point" comprising introducing a water suspension of the particles to a vessel wherein the suspension forms a relatively quiescent static head, flowing the suspension vertically downwardly from the vessel through an air core of a coil that carries alternating current, controlling the diameter of the stream as it enters said core to a maximum of about 3 inches, and streamlining the flow of said stream by relating the factors that determine the Reynolds number to give a maximum of about 30,000.

10. A method of depolarizing magnetic particles to a degree exceeding that attainable by heating similar particles to the "Curie point" comprising introducing a water suspension of the particles to a vessel wherein the suspension forms a relatively quiescent static head, flowing the suspension vertically downwardly from said vessel under the influence of said head through an air core of a coil that carries alternating current, dividing the flow through said core into a plurality of parallel streams each of whose diameter as it enters said core is a maximum of about 3 inches, and streamlining the flow of said

streams by relating the factors that determine the Reynolds number to give a maximum of about 30,000.

11. A method as defined in claim 10 in which the streams are in free fall as they flow through said core.

12. A method of depolarizing magnetic particles to a degree exceeding that attainable by heating similar particles to the "Curie point" comprising introducing a water suspension of the particles to a vessel wherein the suspensions forms a relatively quiescent static head, flowing the suspension vertically downwardly from said vessel under the influence of said head through an air core of a coil that carries alternating current, dividing the flow through said core into a plurality of parallel streams confined within tubes, the diameter of each of said streams being a maximum of about 3 inches as it enters said core, and streamlining the flow of said streams by relating the factors that determine the Reynolds number to give a maximum of about 2000.



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