July 17, 1951 H. K. MARTIN 2,560,809

METHOD AND APPARATUS FOR SEPARATING MATERIALS

Filed July 10, 1946 3 Sheets-Sheet 1

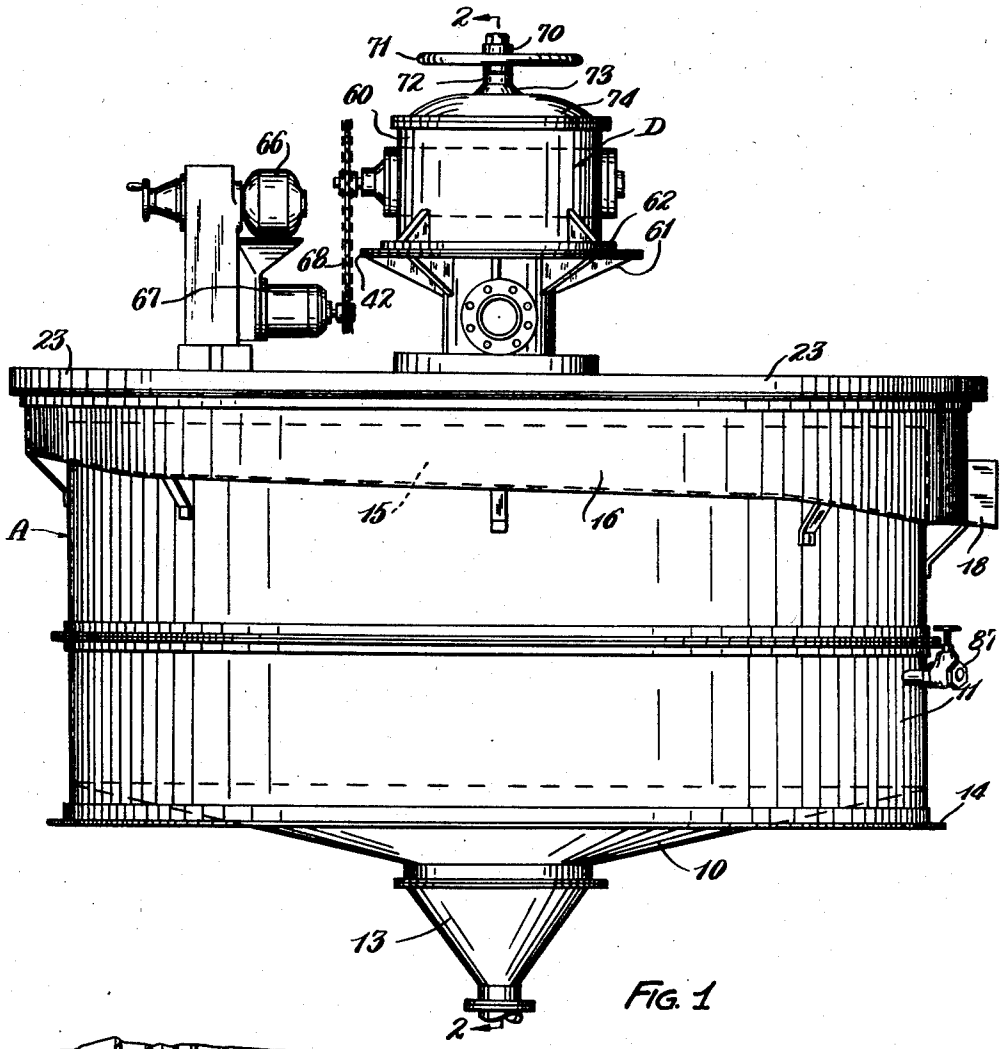


FIG. 1

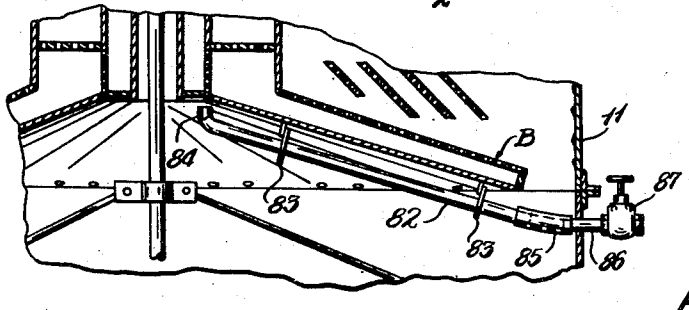


FIG. 6

INVENTOR.
HENRY K. MARTIN
BY
Kuis, Hudson, Boughton & Williams
ATTORNEYS

July 17, 1951 H. K. MARTIN 2,560,809

METHOD AND APPARATUS FOR SEPARATING MATERIALS

Filed July 10, 1946 3 Sheets-Sheet 2

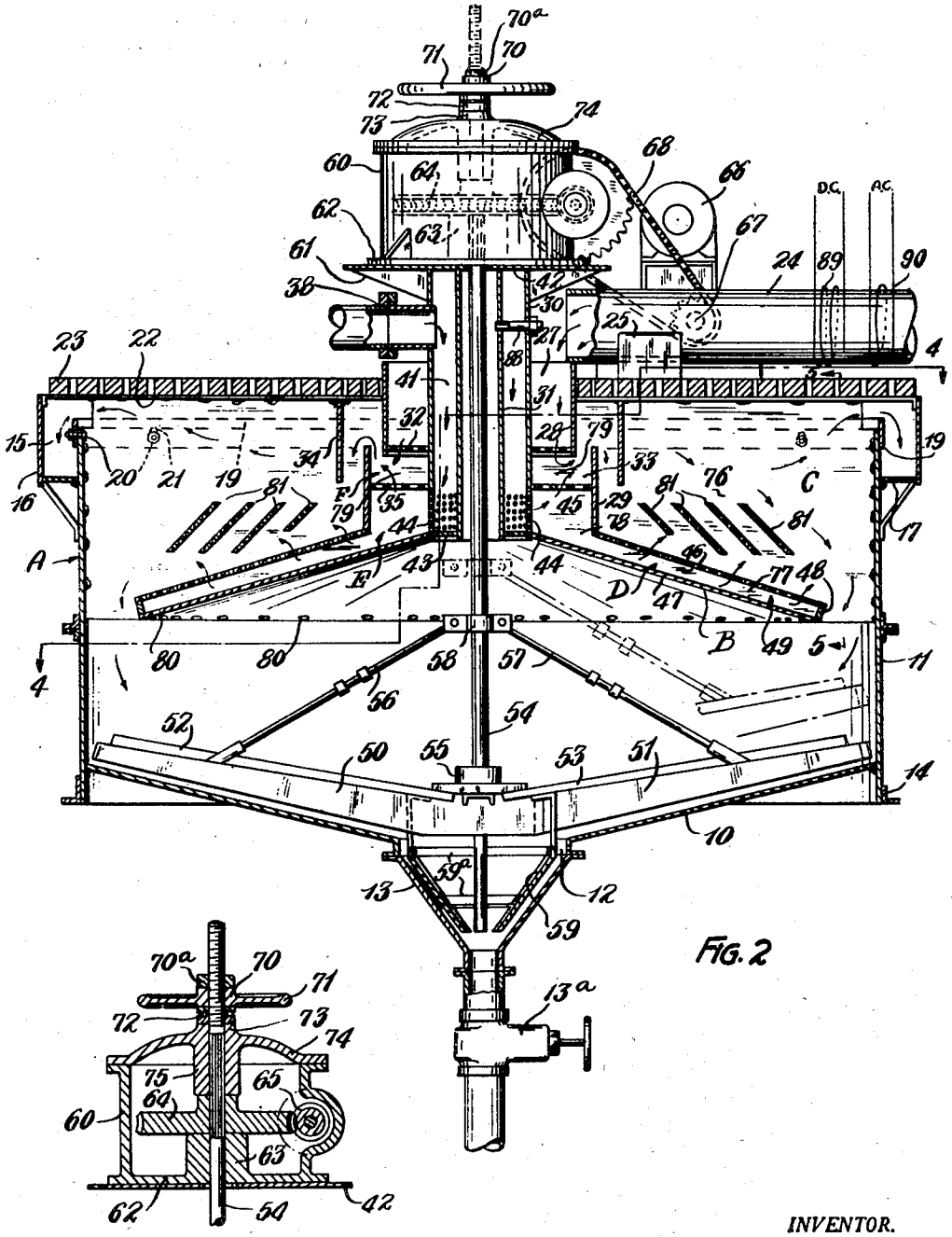


FIG. 2

FIG. 3

INVENTOR.
HENRY K. MARTIN
BY
Kuis, Hudson, Boughton & William
ATTORNEYS

July 17, 1951 H. K. MARTIN 2,560,809

METHOD AND APPARATUS FOR SEPARATING MATERIALS

Filed July 10, 1946 3 Sheets-Sheet 3

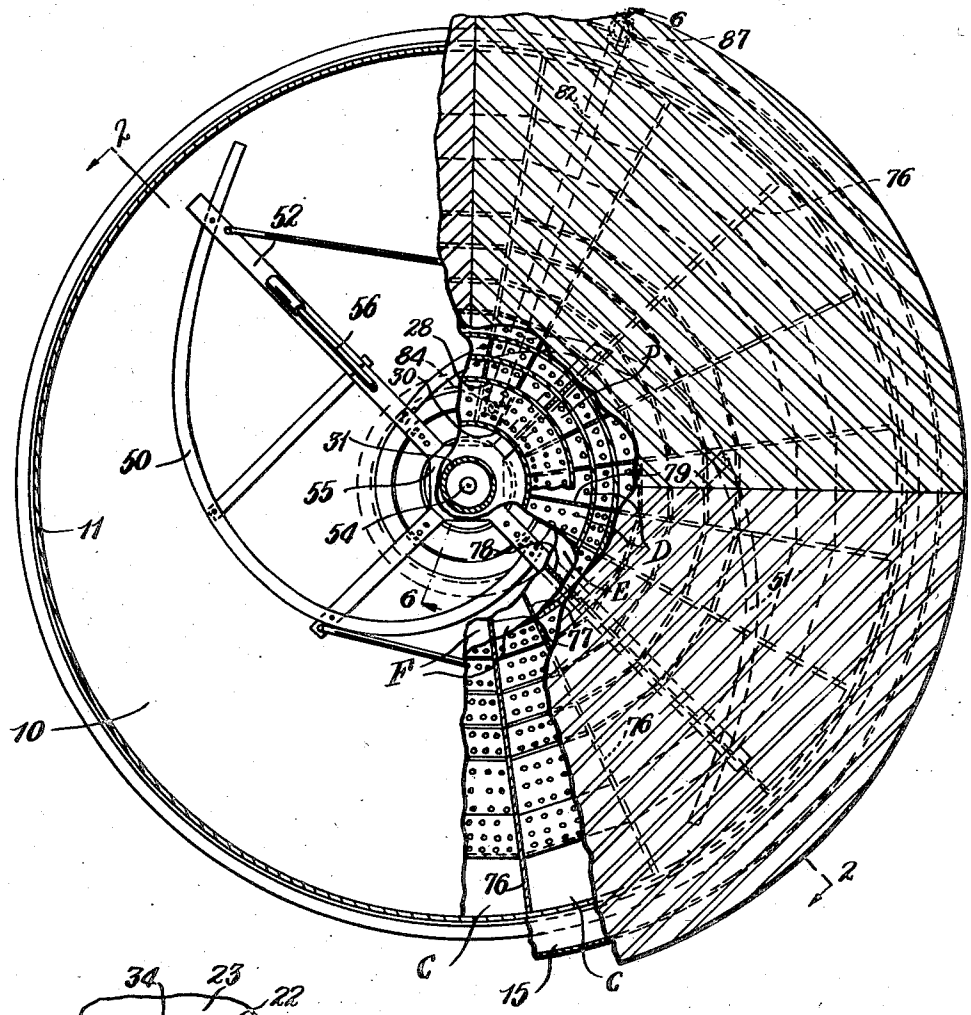


FIG. 4

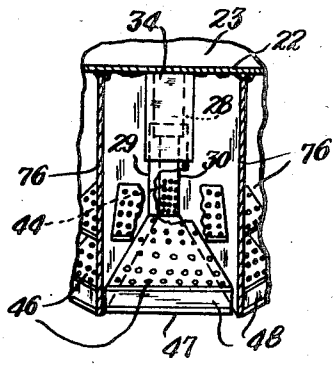


FIG. 5

INVENTOR.
HENRY K. MARTIN
BY
Kuris, Hudson, Boughton & Williams
ATTORNEYS

Patented July 17, 1951

2,560,809

UNITED STATES PATENT OFFICE

2,560,809

METHOD AND APPARATUS FOR SEPARATING MATERIALS

Henry K. Martin, Ironwood, Mich., assignor to Reserve Mining Company, Babbit, Minn., a corporation of Minnesota

Application July 10, 1946, Serial No. 682,632

11 Claims. (Cl. 209—8)

1

The present invention relates to the classification or separation of mixed material of different specific gravity and/or of different particle size. More particularly, the invention relates to method and apparatus for classifying or separating mixed material of different specific gravity and/or different particle size by mixing the material to be separated with water in such a manner that the material of lesser specific gravity and/or smaller particle size is washed away by the water while the material of greater specific gravity and/or larger particle size remains behind.

It is now well known that separation and washing of mixed insoluble materials of different specific gravities may be effected by introducing the mixed materials into a body of flowing liquid so that the lighter particles of the mixture are carried away from the liquid and the heavier particles settle. However, difficulty is encountered when the particles of greater specific gravity are relatively fine since they will not settle rapidly and hence are frequently carried away by the liquid along with the lighter particles. If the rate of flow of the liquid be reduced sufficiently to allow the said fine particles of greater specific gravity to settle, then the larger particles of lesser specific gravity will also settle so that the separation effected is very unsatisfactory.

Therefore, one of the principal objects of the present invention is the provision of a novel and improved method and apparatus for classifying or separating mixed material of different specific gravity and/or particle size by washing the material with water in a manner to cause the material of lesser specific gravity and/or smaller particle size to be carried away by the water while the material of greater specific gravity and/or larger particle size settles.

More specifically, it is an object of the invention to provide an improved method and apparatus for classifying or separating mixed material of different specific gravity and/or particle size by introducing the mixed material into a separating zone containing uprising currents of liquid whereby the particles of greater specific gravity will settle while the particles of lesser specific gravity will be carried away by the liquid, the rate of settling being controlled by the withdrawal of liquid from a point in the separating zone intermediate the top and bottom thereof.

The above mentioned difficulties of separation are particularly prevalent when the material to be separated is magnetic ore which is mixed with silica and other substances constituting what are

2

known as gangue and middling materials. In order to free the magnetic ore from the undesired substances such material is customarily ground or pulverized to relatively small particle sizes with the result that the higher grade ore particles are frequently of smaller size than the particles of the foreign substances and the lower grade ore. Hence, when separation has been attempted by prior methods and apparatus employing a flowing liquid, the results are unsatisfactory since, in order to enable the fine particles of higher grade ore to settle, the rate of flow of the liquid has had to be reduced to the point where larger particles of unwanted substances of lesser specific gravity also settle.

Therefore, another object of the invention is the provision of a novel and improved method and apparatus of the character described for separating ore concentrates from tailings and/or middling particles.

A further object of the invention is to provide an improved method and apparatus for separating magnetic ore concentrates from tailings and/or middling particles by applying a predetermined magnetizing force to the mixed material and then introducing the material into a body of flowing liquid, whereby the magnetic particles will flocculate or collect into small aggregates and settle while the non-magnetic particles will be carried away by the flowing liquid.

It is also an object of the invention to provide a novel and improved method and apparatus of the character referred to which will be capable of continuous operation, efficient, and yet simple and inexpensive to operate.

The invention further resides in certain steps of procedure and constructions, combinations and arrangement of apparatus; and further objects and advantages thereof will be apparent to those skilled in the art (to which the invention relates) from the following detailed description of the preferred embodiments thereof and from the appended claims.

Before entering upon a detailed description of the preferred embodiment of the apparatus, it is believed the invention can be better understood by first disclosing the improved procedure for effecting separation of insoluble material existing as a mixture of particles having different specific gravities and/or particle sizes.

In accordance with this procedure such a mixture is fed into the top of a separating zone containing water or other liquid in a manner to substantially uniformly distribute the mixed material throughout the upper portion of the separating zone without producing turbulence in the

liquid contained therein. At the same time liquid is introduced into the separating zone below the point of introduction of the mixture, under sufficient head and so directed as to produce substantially uniform, non-turbulent upward currents within the separating zone. These currents encounter the particles of the mixture to wash and separate them. Simultaneously, liquid is withdrawn from the zone from a region intermediate the top and bottom of the zone and below the point of introduction of the liquid therein. This withdrawal of liquid is at a rate so correlated with the rate of introduction of the liquid and of the mixture as to produce an overflow of the liquid at the top of the zone sufficient to carry off therewith the particles of the mixture having specific gravities and/or particle sizes less than a predetermined value. The particles of greater specific gravity and/or particle size therefore settle to the bottom of the separating zone from which they are removed.

When the material to be separated is magnetic ore concentrates which are mixed with tailings and/or lower grade ore, the procedure further includes the step of subjecting the mixture to a predetermined magnetizing force prior to the introduction of the material into the separating zone. This magnetizes the particles of high grade ore so that they will flocculate or gather into small masses within the separating zone and hence facilitate the settling thereof. The lower grade or and/or tailings will either not be magnetized, or only slightly magnetized, so that this material will not flocculate and hence will act as individual particles which, being relatively small and light, will be carried upwardly by the rising currents of liquid and pass out of the separating zone in the overflow therefrom.

While the steps of this procedure may be carried out by a variety of different devices, the invention also includes an apparatus which is operable to perform the method; the present preferred embodiment of the apparatus being described with reference to the accompanying drawings forming a part of this specification in which similar reference characters designate corresponding parts, and in which:

Fig. 1 is a side elevational view of an apparatus embodying the present invention with the outlet valve at the bottom omitted;

Fig. 2 is a sectional view, with portions in elevation, approximately one the line 2—2 of Figs. 1 and 4 and showing the outlet valve at the bottom of the apparatus;

Fig. 3 is a fragmentary sectional view of the upper part of the apparatus, approximately on the line 2—2 of Fig. 1 but showing the parts in a different operating position;

Fig. 4 is a sectional view, with portions in plan, approximately on the line 4—4 of Fig. 2;

Fig. 5 is a fragmentary sectional view, approximately on the line 5—5 of Fig. 2 with certain elements partially broken away; and

Fig. 6 is a fragmentary sectional view of the central portion of the apparatus taken approximately at right angles to the line 2—2 of Fig. 4.

Referring to the drawings, the reference character A designates generally a vessel or tank having a funnel-shaped bottom 10 and vertical, cylindrical, side walls 11. The bottom 10 is provided with a central opening 12 communicating with the upper end of a funnel-shaped member 13, the lower end of which constitutes the discharge outlet or opening for the material of greater specific gravity or larger particle size which settles and collects at the bottom of the tank. The lower end of the member 13 may be connected to a pipe or other suitable means for carrying off the material discharged therethrough, the rate of discharge being regulated by a valve 13a, pump or other suitable means. The tank A may be supported in any suitable manner. As shown, the bottom 10 is slightly recessed with respect to the lower edge of the side walls 11 and the lower circumference of the tank has an angle iron 14 welded or bolted thereto which forms a base or means through the medium of which the tank is adapted to be supported upon a suitable foundation or structure, not shown.

The top of the tank proper is surrounded by a discharge chamber 15 into which liquid and material of lesser specific gravity or of smaller particle size suspended therein may overflow from the tank proper. An annular member 16 surrounding the upper edge of the tank proper and extending above and below the top thereof forms the outer wall of the discharge chamber 15, the bottom being formed by a helically arranged member 17 interposed between the tank proper and the member 16. The construction is such that material in the discharge chamber 15 is caused to flow toward an outlet 18 at one side of the apparatus. The upper edge of the tank proper is formed by an annular member or ring 19 connected to the side walls 11 and adjustable vertically with respect thereto so that the top of the tank can be leveled thereby assuring a uniform flow of liquid and material from the tank to the discharge chamber 15 around the entire periphery of the tank. As shown, the member or ring 19 is bolted to the side walls 11 by bolts 20 which project through elongated slots 21 in the ring 19.

The tank, including the discharge chamber 15, is provided with a cover 22 supported by and secured to the upper edge of the annular member 16. The cover 22 may be of any desired construction. In the embodiment shown, certain apparatus, hereinafter referred to, is mounted on or supported by the cover which is provided with a wood flooring 23 to facilitate walking thereon, etc.

Material to be treated or separated, mixed with water or other suitable liquid, is supplied to the tank A by a suitable conduit or launder which is here represented by a pipe 24 supported upon the wooden flooring 23 by blocks or brackets 25. The left-hand end of the conduit or pipe 24 (as viewed in Fig. 2) terminates in overhanging relationship to a central, annular opening through the cover 22 and flooring 23 through which a vertically positioned, cylindrical member 28 extends with its upper end in contact with, or closely adjacent to, the lower side of the pipe 24. This cylindrical member 28 is welded or otherwise secured to the cover 22 and constitutes the outer wall of an annular chamber 27 into which the material supplied by the pipe 24 is discharged. Equal distribution of the material within the chamber 27 may be effected by any conventional means; for example, by the use of a plurality of spaced feeding conduits 24 or by means of a mechanical distributor, not shown. However, since the material generally contains considerable liquid, its angle of repose will be substantially zero and hence a single pipe or conduit 24 will ordinarily be satisfactory.

The inner wall of the chamber 27 is formed by the outer cylindrical member 30 forming a part of a double-walled tubular member, the inner wall of which is formed by a cylindrical member

31. The cylindrical members 30, 31 are coaxially arranged with respect to each other and to the cylindrical member 28 and are fixedly supported therein, as will be hereinafter apparent. The lower end of the cylindrical member 28 extends below the top of the tank proper and the bottom of the chamber 27 is formed by a perforated annular plate 32 interposed between and welded to the cylindrical members 28 and 30.

A cylindrical member 29, having a diameter larger than the diameter of member 28, is positioned within tank A coaxially with the members 28, 30 and 31, and so disposed that the lower end of the member 28 extends a short distance below the upper edge of the member 29. Perforated annular plates or members 35 extend between the tubular members 29 and 30 and are welded or otherwise secured thereto. As will be seen in Fig. 2, the perforated members 35 are spaced vertically below and parallel with the perforated plate 32 so that a chamber 33 is formed by the members 29, 30 and 35 and this latter chamber is below the aforementioned chamber 27.

Depending from and welded to the lower surface of the cover 22 is a cylindrical member 34 which has a diameter greater than the diameter of the cylindrical member 29. The members 29 and 34 are coaxially disposed and the length of the latter is sufficient to extend below and surround the upper portion of the former. There is thus provided a tortuous path for the material to be separated. As indicated by the arrows in Fig. 2, the material discharged from the conduit 24 enters chamber 27, flows through the holes in plate 32 into chamber 33 where water or other liquid flowing upwardly through the holes in plates 35 (as hereinafter described) carries the material to and through the spaces between the cylindrical members 28, 29 and 34 and into the main body of the vessel or tank A.

In addition to the liquid or water supplied to the tank A, along with the material to be separated through the feed pipe 24, additional liquid or water, hereinafter referred to as wash water, is supplied under pressure to the tank by a conduit or pipe 38, the right-hand end of which (as viewed in Fig. 2) projects through an aperture in the cylindrical member 30 and communicates with the upper end of a chamber or well 41 intermediate the tubular members 30, 31. The upper end of the well 41 is closed by a plate-like member 42 and the lower end thereof by a plate-like member 43. The plate-like member 43 is interposed between the inner and outer cylindrical members 30, 31 and is welded thereto. The plate 42 is welded to the upper ends of the cylindrical members 30, 31 and extends outwardly therebeyond to provide a support for a gear housing subsequently to be described. Suitable angle members 61 may be welded between the lower side of plate 42 and the outer surface of cylindrical member 30 to reinforce the overhanging portion of the plate 42.

The lower portion of the cylindrical member 30 is provided with a plurality of apertures 44 which establish communication between the interior of member 30 and a chamber 45, formed by the lower ends of cylindrical members 29, 30 and the perforated plates 35. The lower end of the cylindrical member 29 or, more specifically the chamber 45 communicates with the interior of a relatively flat, cone-like, hollow member or washpan, designated generally by the reference character B. The upper side of the washpan B

is formed by a plurality of perforated plates 46 which have their adjacent edges secured together and their inner ends welded to the lower edge of the cylindrical member 29. The lower side of the washpan B is formed by a plurality of plates 47 which have their adjacent edges secured together and their inner ends welded to the lower end of the cylindrical member 30. The outer ends of the plates 46, 47 are connected by plates or members 48 welded thereto which close the outer ends of the space 49 between the vertically spaced plates 46, 47.

Wash water entering through pipe 38 flows downwardly through the well 41 and enters chamber 45 through the apertures 44 in the lower end of cylindrical member 30. Part of this wash water, entering the chamber 45, flows through the perforations in the plates 35 into the chamber or feed well 33 where it mixes with the water and material entering through the perforations in the plate 32. The rest of the wash water entering the chamber 45, flows into the space 49 in the washpan B and enters the tank proper through the perforations in the members 46. The material of greater specific gravity or the particles of larger size entering the tank A through the tortuous path previously described, fall towards the top of the inverted, cone-like member or washpan B where they are washed by the water entering the tank A through the perforations in the plates 46 as the said particles move toward the lower outer edge of the washpan. The lighter or smaller particles are carried upwardly within the upper portion of the main body of the vessel or tank A by the uprising currents of water flowing through the perforations in the plates 46. The number and spacing of these perforations are such that these uprising currents are substantially uniformly distributed throughout the cross sectional area of tank A above the washpan B.

The material to be separated is, therefore, agitated and washed in the feed well 33 by the water entering the same through the perforations in the plates 35 and again in the tank by the water entering the tank proper through the perforations in the plates 46. This separates the material of greater specific gravity or of larger particle size from that of lesser specific gravity or smaller particle size and causes the material of lesser specific gravity or of smaller particle size to be floated or washed out of the tank proper by the portion of the water which flows over the edge of plate 19 and into the discharge chamber 15. The material of greater specific gravity or of larger particle size enters the lower part of the tank through the space or slot between the periphery of the washpan B and the side walls 11. As the material of greater specific gravity or of larger particle size collects in the bottom of the tank, it is withdrawn therefrom through the discharge opening 12 in the bottom of the tank.

In the embodiment shown, the material which collects at the bottom of the tank is scraped toward the opening 12 by a spiral rake comprising a pair of blades 50, 51 connected to radially extending arms 52, 53 operatively connected to a vertically extending shaft 54 located centrally of the tank A. The inner ends of the arms 52, 53 are connected to a collar member 55 fixed to the shaft 54. This rake structure is strengthened by braces 56, 57 connected between the arms 52, 53 and a member 58 fixed to the shaft 54 above the collar 55. The shaft 54 is adapted to

be rotated and/or raised and lowered in a manner hereinafter specifically described.

To further assist the discharge of material through the opening 12, a plurality of arms 59 are connected to the lower sides of the arms 52, 53. These arms 59 extend below the blades 50, 51 and are shaped to fit within the opening 12 and the inner surface of funnel member 13 in spaced relationship thereto. The arms 59 are strengthened and held from deflection by bands or rings 59a. The rate of discharge may be controlled by the amount of opening of valve 13a.

The shaft 54 extends upwardly through the center of the member B and through a housing 60 resting upon and fixed to the plate 42 which is secured to and closes the top of the cylinder members 30 and 31. The bottom member 62 of the housing 60 includes an upwardly projecting, cylindrical boss 63 through which the shaft 54 projects and which boss forms a guide means for the upper part of the shaft. A part of the shaft 54 adjacent to the boss 63 is splined and the shaft above the splined section is of reduced diameter and threaded. The splined section of the shaft 54 has a worm wheel 64 splined thereto, which worm wheel is continuously in mesh with a worm 65 rotatably supported in the housing 60 and connected to an electric motor 66 through a variable speed change transmission 67, and a sprocket chain drive 68, all of which are of commercial design. The construction is such that the shaft 54 can be driven at any desired speed.

The reduced threaded part of the shaft 54 above the splined section just referred to is provided with a nut 70, including a hand wheel 71, for facilitating adjustment thereof.. The shaft 54 is supported by an anti-friction thrust bearing 72 interposed between the lower surface of the nut 70 and an upwardly extending boss 73 on the dome-shaped cover 74 of the housing 60. The cover 74 has a downwardly extending boss 75 formed integral therewith, which boss together with the boss 63, previously referred to, limits the vertical movement of the worm wheel 64 and forms a guide for the upper end of the shaft 54. A jam nut 70a is provided on the threaded portion of the shaft 54 to lock nut 70 in any adjusted position. The construction is such that manipulation of hand wheel 71 raises or lowers the blades 50 and 51 thus enabling them to be adjusted relative to the bottom 10 of the tank or vessel A to regulate their action upon the material which settles to the bottom of the tank. Fig. 2 shows the blades in their lowermost position, while Fig. 3 illustrates the position of the handwheel 71 and shaft 54 corresponding to the uppermost position of the blades.

Thus far the apparatus has been described as though the upper part of the tank proper and the chambers 33, 45 and 49 were annular in shape and permitted free circulation of the liquid in a horizontal plane, but preferably the upper part of the tank proper and the chambers 33, 45 and 49 are divided into comparatively small compartments C, D, E and F by vertically positioned, radial partitions or webs 76, 77, 78 and 79, respectively. In the present embodiment, which is constructed of welded-up steel plates, the webs 76, 77, 78 and 79 in any one vertical plane are formed by a single plate which extends from the bottom of the washpan B to the cover 22 and from the outside walls 11 to the cylindrical member 30, excepting the chamber 27 within member 28, and that small part of the feed well 33 located above the lower end of the cylindrical member 28.

As shown, (see Figs. 2, 4 and 5) the lower end of the cylindrical member 29 is slotted to allow the web plates to pass therethrough; the top of the washpan B is made up of a plurality of plates 46 welded to and separated by the web plates; and the bottom of the feed chamber 33 is made up of a plurality of plates 35 with the web plates extending therebetween. Alternatively, the top of the washpan and/or the bottom of the feed well 33 could each be formed of a single plate and the various compartments in the respective chambers formed by separate web members. The web construction not only permits a better controlled flow of liquid and material through the apparatus (by preventing swirling) but also provides a strong rigid construction. The lower end of each compartment D is provided with one or more holes 80 through which material that may collect therein can escape.

To provide a more thorough washing of the material and further prevent swirling of the material and liquid, each compartment C has a plurality of inclined perforated baffle plates 81 extending thereacross and secured to the adjacent vertical baffle plates 76. Preferably the top edges of the baffles 81 are located a substantial distance below the top of the overflow plate 19 and the bottom edges of the baffles 81 are spaced from the plates 46 forming the top of the washpan B. The inclination of the baffles 81 is towards the central portion of the tank A thus tending to direct the water rising from the washpan towards the material entering from chamber 33.

As previously mentioned, the material of greater specific gravity, or the particles of larger size, settle downwardly in the tank or vessel A passing through the slot or space between the outer walls 11 of the tank and the outer edge of the washpan B. The rate of this settling must be accurately controlled for if the rate is too fast the material of lesser specific gravity and smaller particles size, which should pass out the overflow, will also settle. Conversely, if the rate of settling is too slow, some of the heavier and large particles will be carried into the overflow. The rate of settling may be controlled by regulating the rate of feeding of material through pipe 24, by regulating the rate of supply of water to the washpan B, by the amount of opening of valve 13a, and by the width of the space or slot between the outer edge of the washpan B and the walls 11 of the vessel A. However, for a given installation, the last of these factors (i. e., the width of the slot) is fixed. Moreover, the rate of supply of wash water must be kept within a certain range to provide adequate washing. Likewise, for efficient operation the rate of supply of material to the apparatus cannot be too slow. Finally, if the valve 13a be opened too wide, an undue amount of water will be discharged with the settled material which is undesirable. Conversely, if valve 13a be closed too far, the removal of separated material is impeded.

In order to overcome these limitations and to secure a better regulation of the rate of settling, the tank or vessel A is provided with an additional means to withdraw liquid therefrom at a controlled rate. In the present preferred form, this means comprises a pipe or conduit 82 (see Figs. 4 and 6) supported by brackets or hangers 83 from the lower side of the washpan B. The inner end 84 of the pipe or conduit 82 is open and terminates adjacent the lower surface of the

plate 43 which is disposed within the central portion of the washpan as previously described. The pipe 82 slopes downwardly to a point adjacent the side wall 11 of the tank A where a coupling 85 unites it to a pipe 86 extending through the wall 11. The coupling 85 may be flexible, if desired, to enable the pipe 82 to be easily installed and its angle of inclination adjusted. A valve 87 is provided on the end of pipe 86 exteriorly of the sidewall 11 to provide a means for controlling the rate of withdrawal of liquid from the tank. Obviously, a pump or other means to control the flow of liquid from the tank could be substituted for the valve 87, if desired.

The liquid within the tank A will rise up under washpan B and into the interior of cylindrical member 31 to the same level as the liquid overflowing ring 19 since the interior of the tubular member 31 is vented to the atmosphere by a means of pipe 88 passing through the cylindrical members 30 and 31. This liquid under the washpan and within the cylindrical member 31 will be substantially clear and free from solids so that it may be removed without loss of the material which has settled to the bottom of the tank. The rate of withdrawal of this clear liquid is regulated by the amount of opening of the valve 87. Since the liquid so removed can only be replaced by the liquid which is supplied to the portion of the tank above the washpan and passes downwardly through the annular space between the edge of the washpan and the side wall 11 of the tank, the amount of opening of valve 87 provides an accurate means to control the rate of settling of material without disturbing the optimum rate of supply of material, wash water, and the desired opening of the discharge valve 13*a*.

The apparatus described thus far will operate satisfactorily to separate many types of material; as for example, sand from clay and other substances. However, when the material to be separated contains magnetic iron ore in the form of relatively small particles, it has been found that separation is facilitated if the material be subjected to a predetermined magnetizing force prior to introduction into the vessel or tank A. For example, Eastern Mesabi magnetic taconite, after a preliminary treatment including grinding, contains fine particles which are ordinarily of higher grade ore, the coarser particles generally being lower grade because of comparatively large attached particles of silica or silicate. It has been found that if such material be magnetized after grinding and then demagnetized, the magnetic particles attached to particles of silica are more easily demagnetized than the fine unattached particles. Hence, under proper magnetizing and/or demagnetizing prior to introduction into the vessel A, the fine particles (high grade ore) will have sufficient magnetism to collect into comparatively large masses in the vessel and settle to the lower discharge opening while the less strongly magnetized, coarse middling particles will not so collect and hence will be carried into the overflow.

The desired magnetization of the material prior to introduction into vessel A may be effected by associating suitable demagnetizing and magnetizing means with the material supply conduit 24 to act upon the material as it passes therethrough. For example, a magnetizing coil or solenoid 89 and a demagnetizing coil or solenoid 90 are schematically represented in Fig. 2 as disposed about the conduit 24 and supplied with D. C. and A. C. current, respectively, which may be varied by conventional means not shown. These solenoids may be of any desired construction and the order in which they are arranged is immaterial since the strength of the field produced by the respective coils or solenoids can be varied to give the best results on any given ore.

Whether one, both or none of the coils 89 and 90 be used, and the strength of the field produced thereby, is dependent upon the nature of the material to be separated and its prior treatment. Thus, if the prior treatment of the material has included a preliminary separation by means of a conventional magnetic separator (such as that known as a "Dings" separator), the material may be sufficiently magnetized so that neither coil need be employed. If the material be magnetized, but the extent of magnetization be not known, it is frequently desirable to demagnetize it by means of coil 90 and remagnetize it by means of coil 89 so as to produce the desired amount of magnetization. Finally, if the material was not previously magnetized, or magnetized to a lesser extent than desired, only coil 89 need be employed. In all cases, however, the resulting magnetization of the material should be sufficient to enable the fine particles of higher grade ore to flocculate, or collect together into small masses, but not so great as to interfere with the separation (as by enabling the higher grade ore particles to cling to the gangue or middling material, or to mechanically hold such undesired substances in masses of the flocculated higher grade particles).

It is believed that the steps of the method and the operation of the device will be apparent from the foregoing description thereof. Suffice it to say that material to be separated is introduced through the feed pipe 24 and, if the material includes magnetic ore, may be subjected therein to a controlled magnetic force (by solenoids 89 and/or 90). From the discharge end of pipe 24 the material enters the feed chamber 27 and passes therefrom through the perforated plate 32 into the chamber 33, the plate 32 assisting in uniformly distributing the material within the chamber 33. The material is further distributed within chamber 33 and is washed by water admitted under pressure through the pipe 38 and perforated plates 35. The extent to which the material is washed at this point can be controlled by varying the amount and/or pressure of the wash water admitted through the pipe 38 in relation to the amount of material introduced through the feed pipe 24.

The material and washing water then flow over the upper edge of the cylindrical member 29, and through the space between the latter and cylindrical member 34, into the upper portion of main body of the tank A. Here the material is further washed and separated by the currents of water rising through the opening in the top of the washpan B. The particles of greater specific gravity and/or particle size settle to the bottom of the tank through the slot between the washpan and the side walls of tank A. When the material being separated is finely ground magnetic iron ore, the settling of the iron ore concentrates is facilitated by the flocculation thereof due to the prior magnetization of the particles. The tailings or material of lesser specific gravity, or of small particle size, rise and overflow the sides of the tank proper and are carried away by the discharge chamber 15. The settled material in the lower portion of tank A is raked to the center of the tank and discharged through the opening 12, the

amount of opening of the valve 13*a* controlling the dilution of the material leaving the tank. In addition to washing the material being concentrated, the water added through the washpan assists in controlling the velocity or flow through the tank, a further and finer control being exercised by the rate of withdrawal of water through pipe 82. The small arrows in Fig. 2 suggest the direction of flow through the apparatus.

From the foregoing, it will be apparent that the objects of the invention heretofore enumerated have been accomplished and that a novel and improved method and apparatus have been provided for separating or classifying material of different specific gravity and/or different particle size. While the preferred embodiment of the apparatus of the invention has been described in considerable detail, the invention is not limited to the particular construction shown, which may be varied. Also, while the method of this invention may be performed by the apparatus described above, it is not limited thereto since the procedural steps may be effected by other and different devices and certain of the steps may be varied or omitted. Therefore, I do not regard my invention as confined to the exact procedural steps and structural details disclosed, but it is my intention to cover hereby all adaptations, modifications and uses thereof which come within the practice of those skilled in the art to which the invention relates and within the scope of the appended claims.

Having thus described my invention, I claim:

1. A method of separating magnetic particles from a mixture containing magnetic particles non-magnetic particles, and particles of magnetic material united with non-magnetic material, comprising applying a demagnetizing force to the mixture, applying a magnetizing force to the demagnetized mixture to produce a predetermined magnetization of the magnetic particles and a lesser magnetization of the particles of magnetic material united with non-magnetic material, introducing the magnetized mixture into the upper portion of a separating zone containing flowing liquid, controlling the flow of the liquid in the separating zone so that the rate thereof is sufficient to prevent flocculation of the particles which contain magnetic material united with non-magnetic material while permitting the magnetic particles to collect together and settle to the bottom of the zone under the influence of gravity, the rate of flow of the liquid being sufficient to cause some of the liquid to flow out of the top of the zone and carry therewith the non-magnetic particles and the particles of magnetic material united with non-magnetic material, and removing the magnetic particles from the lower end of the said zone.

2. A method of separating magnetic particles from a mixture containing magnetic particles non-magnetic particles, and particles of magnetic material united with non-magnetic material, comprising applying a demagnetizing force to the magnetized mixture to partially demagnetize the mixture whereby a predetermined magnetization of the magnetic particles and a lesser magnetization of the particles of magnetic material united with non-magnetic material is produced, introducing the mixture into the upper portion of a separating zone containing flowing liquid, controlling the flow of the liquid in the separating zone so that the rate thereof is sufficient to prevent flocculation of the less strongly magnetized particles while permitting the more strongly magnetized particles to collect into masses and settle to the bottom of the zone under the influence of gravity, the rate of flow of the liquid being sufficient to cause some of the liquid to flow out of the top of the zone and carry therewith the non-magnetic particles and the less strongly magnetized particles and removing the magnetic particles from the bottom of said zone.

3. A method of separating a mixture of insoluble material into two components having specific gravities, respectively, greater than and less than a predetermined value, which comprises providing a separating zone containing liquid, introducing the mixture into the liquid in the upper portion of the zone without turbulence, introducing liquid into said zone from a region below the point of introduction of the mixture in a manner to produce a substantially uniform, non-turbulent upward current within the said zone, withdrawing liquid which is substantially free of said insoluble material from a point substantially centrally of said zone intermediate the top and bottom of the zone beneath the upward current of liquid in said zone, the rate of withdrawal of the liquid being so related to the rate of introduction of liquid as to result in an overflow of liquid at the top of the zone sufficient to carry therewith the material of the mixture having specific gravities less than said predetermined value while permitting the material having specific gravities greater than said predetermined value to settle to the lower portion of the zone, and withdrawing the settled material from the lower portion of the zone.

4. In apparatus of the character referred to, a vessel having an overflow opening adjacent to the top and an outlet adjacent to the bottom, means for controlling flow through said outlet, a hollow member within said vessel extending adjacent to but spaced from the side walls of the said vessel, the said member having an inclined upper surface provided with a plurality of openings communicating with the interior of the member, means for conducting liquid under pressure into the interior of said member, means for supplying material to be separated to said vessel above said inclined upper surface, means adjacent to the bottom of said vessel for stirring the portion of the material which descends thereto for directing the said material to the outlet, and means having an inlet positioned substantially centrally of said vessel below said hollow member and above the outlet of the vessel for withdrawing liquid from the vessel at a controlled rate to thereby regulate the rate of descent of the material in said vessel.

5. In apparatus of the character referred to, a generally cylindrical vessel having an overflow opening adjacent to the top and an outlet in the center of the bottom, means for controlling flow through said outlet, a generally cone-shaped hollow member within said vessel extending adjacent to but spaced from the vessel walls, the upper surface of said hollow member having a plurality of openings communicating with the interior of the member, means for conducting liquid into the interior of said member, means for supplying material to be separated to said vessel above said surface and adjacent to the central portion thereof, and means having an inlet positioned substantially centrally of said vessel above the outlet of the vessel and adjacent the lower side of said hollow member in a position where the inlet to the last-mentioned means

is shielded by said hollow member from material settling in said vessel so that the said last-mentioned means is effective for withdrawing liquid which is substantially free of material particles from the vessel at a controlled rate to thereby regulate the rate of descent of the material in said vessel.

6. In apparatus of the character referred to, a generally cylindrical vessel having an overflow opening adjacent to the top and an outlet in the center of the bottom, valve means for said outlet, a generally cone-shaped hollow member within said vessel extending adjacent to but spaced from the side walls of the vessel, the upper surface of said member having a plurality of openings communicating with the interior of said member, means for conducting liquid into the interior of said member, means for supplying material to be separated to said vessel above said upper surface and adjacent to the central portion thereof, a conduit for withdrawing liquid from said vessel, the said conduit having its inner end open and located substantially centrally of said vessel above the outlet of the vessel and adjacent the lower side of said hollow member in a position where the said inner end of the conduit is shielded by said hollow member from material settling in said vessel so that the said conduit is effective for withdrawing liquid which is substantially free of material particles, and means for controlling the withdrawal of liquid through the conduit to thereby regulate the rate of descent of the material in said vessel.

7. In apparatus of the character referred to, a generally cylindrical vessel having an overflow opening adjacent to the top and an outlet in the center of the bottom, valve means for said outlet, a generally cone-shaped hollow member within said vessel extending adjacent to but spaced from the side walls of the vessel, the upper surface of said member having a plurality of openings communicating with the interior of said member, vertically positioned radial baffles in said vessel above said member, means for conducting liquid into the interior of said member, means for supplying material to be separated to said vessel above said upper surface and adjacent to the central portion thereof, and means having an inlet positioned substantially centrally of said vessel above the outlet of the vessel and adjacent the lower side of said hollow member in a position where the inlet to the last-mentioned means is shielded by said hollow member from material settling in said vessel so that the said last-mentioned means is effective for withdrawing liquid which is substantially free of material particles from the vessel at a controlled rate to thereby regulate the rate of descent of the material in said vessel.

8. In apparatus of the character referred to, a generally cylindrical vessel having an overflow opening adjacent to the top and a funnel-shaped bottom having an outlet in the center, valve means for said outlet, a hollow member within said vessel having a substantially circular side wall concentric with but spaced from the side wall of the vessel, said member having an upper surface including a portion sloping substantially uniformly downwardly toward the side wall of the vessel and provided with a plurality of openings communicating with the interior of said member, means for conducting pressure liquid into the interior of said member, means for supplying material to be separated to said vessel above said surface and adjacent to the central part thereof, a plurality of vertically extending radial baffles in said vessel above said hollow member, a plurality of spaced inclined baffles extending between adjacent ones of said radial baffles, and means below said hollow member and above the outlet of the vessel for withdrawing liquid from the vessel at a controlled rate.

9. In an apparatus of the character referred to for separating material containing magnetic particles non-magnetic particles and particles of magnetic material united with non-magnetic material, a vessel having an overflow opening adjacent to the top and a restricted outlet adjacent to the bottom, a hollow member within said vessel, said hollow member having an upper surface extending generally transverse of said vessel and adjacent to but spaced from the side walls of the vessel, the said upper surface of said hollow member being provided with a plurality of openings communicating with the interior of the member, means for supplying liquid to the interior of said hollow member under sufficient head to flow through the said openings and produce uprising currents in the portion of the vessel above the said hollow member, means for supplying a material to be separated to said vessel above the upper surface of said hollow member, means for regulating the magnetization of the material as it is introduced into said vessel in a manner such that the magnetic particles in said material have sufficient magnetism to flocculate and settle through the liquid in said vessel to the bottom thereof and the particles having magnetic material united with non-magnetic material have insufficient magnetism to flocculate and are carried with the non-magnetic particles to and through the overflow opening by the rising currents of liquid, means having an inlet positioned substantially centrally of said vessel above the said outlet and adjacent the lower side of the said hollow member in a position where the inlet to the last-mentioned means is shielded by said hollow member from material settling in said vessel so that the last-mentioned means is effective for withdrawing liquid which is substantially free of material particles from the vessel, and means cooperating with the last-mentioned means to regulate the withdrawal of liquid and thereby control the rate of settling of the magnetic particles.

10. The combination as defined in claim 9 and further including a plurality of baffle plates within said vessel above the upper surface of the hollow member to prevent turbulence.

11. In the method of separating magnetic particles from mixed material containing such particles, non-magnetic particles and particles of non-magnetic material united with magnetic material, the steps of regulating the magnetization of the mixed material so that the magnetic particles are more strongly magnetized than the particles containing non-magnetic material united with magnetic material and then introducing the mixed material into the upper portion of a separating zone containing an upwardly flowing liquid while removing liquid which is substantially free of material particles from said zone in a region intermediate the top and bottom of the zone beneath the point of introduction of the material and liquid into the zone and above the outlet of material from the zone, the magnetization of the material and the rate of flow of said liquid being so regulated that the magnetic particles flocculate and descend to the bottom of the zone while the particles containing non-magnetic

material united with magnetic material do not flocculate and are carried together with the non-magnetic particles to the upper portion of the zone by the liquid.

HENRY K. MARTIN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
954,015	Bent	Apr. 5, 1910
1,106,630	Darrow	Aug. 11, 1914
1,456,563	Noriega	May 29, 1923
1,490,420	Elder	Apr. 15, 1924
1,705,351	Andrews	Mar. 12, 1929
1,953,672	Daman	Apr. 3, 1934
2,373,635	Wuensch	Apr. 10, 1945