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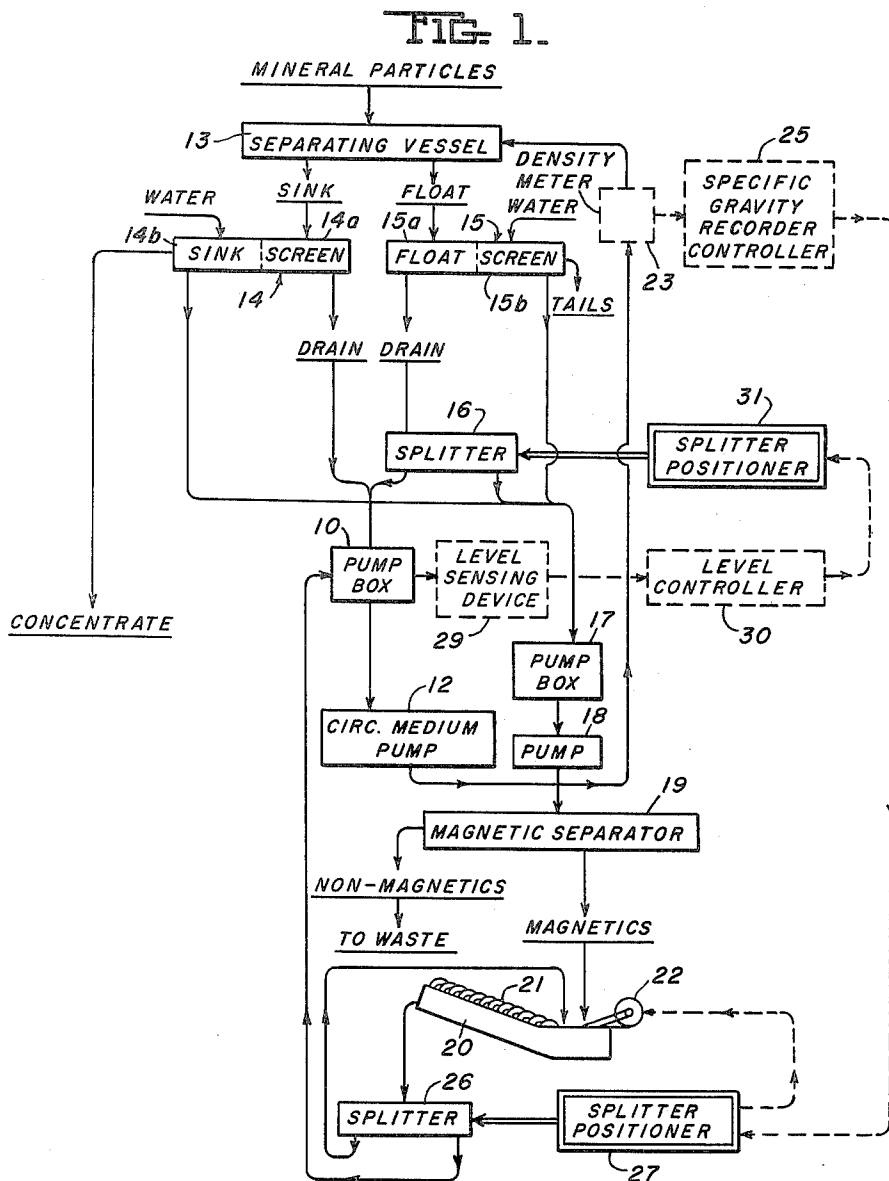
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METHOD AND APPARATUS FOR CONTROLLING SPECIFIC GRAVITY IN A HEAVY MEDIUM PROCESS

Filed Nov. 13, 1962

2 Sheets-Sheet 1



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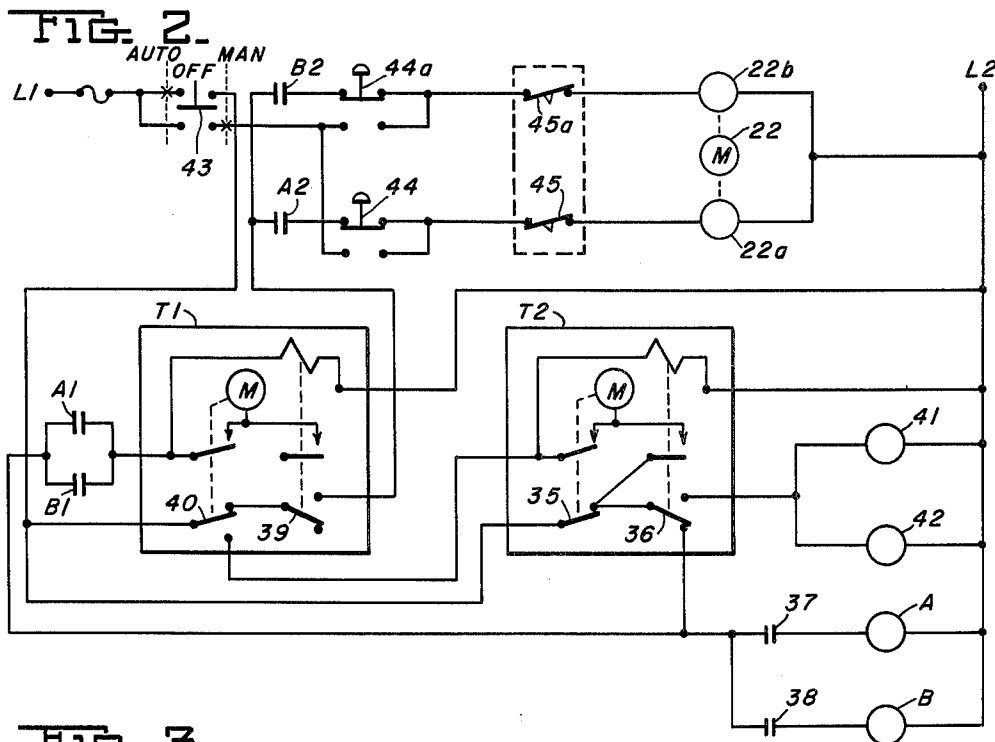
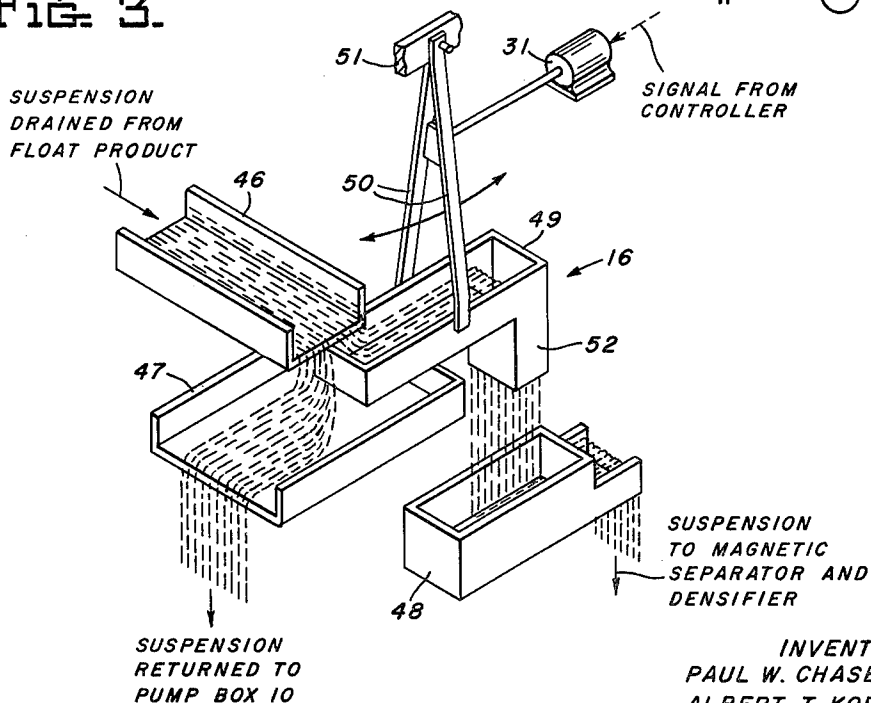


**FIG. 3.**



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## METHOD AND APPARATUS FOR CONTROLLING SPECIFIC GRAVITY IN A HEAVY MEDIUM PROCESS

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3 Claims. (Cl. 209—12)

This invention relates to an improved method and apparatus for controlling specific gravity in a heavy medium minerals separation process.

In a conventional heavy medium process, mineral particles are introduced to a vessel which contains a medium of specific gravity intermediate that of the values and gangue in the mineral. Commonly, the medium is a water suspension of a finely divided magnetic substance, such as ferrosilicon or magnetite. If the mineral is an ore, such as iron ore, the values sink while the gangue floats. The reverse occurs with some materials, such as coal. After the sink and float products leave the separating vessel, the suspension is drained therefrom and recovered for re-use. Next, the sink and float products are washed. The wash water, along with a fraction of the suspension drained from the products, goes to a magnetic separator and thence to a densifier. The magnetic separator removes nonmagnetic contaminants and the densifier removes water to produce a densified medium of higher specific gravity than that use in the separating vessel. This densified medium joins the remainder of the drained suspension and returns to the separating vessel. Water accompanying the mineral particles dilutes the medium in the vessel to the proper specific gravity. Reference can be made to Wade Reissue Patent No. 22,191, dated September 29, 1942, for a detailed showing of a process of this type, although the specific pieces of equipment Wade shows are not of the most modern construction.

To achieve a maximum recovery of the values at the desired grade, the specific gravity of the medium in the separating vessel must be maintained uniformly at a substantially constant value. The usual practice has been for the operator to check the specific gravity of samples of the medium at intervals by manual means, and make any necessary adjustments after each check. Variations in the feed rate, water content of the feed, and densifying characteristics make it difficult to exercise effective control by this procedure. Chase and Hendrickson application Serial No. 236,944, filed the same date as the present application discloses and claims an improved automatic method and apparatus for controlling specific gravity of the medium. One feature of the Chase and Hendrickson invention is that they vary the speed of their densifier screw to effect a quick but temporary change in the rate at which densifier medium feeds back into the system. The present invention concerns an improvement over this feature.

An object of the present invention is to provide an improved method and apparatus for controlling the rate at which densified medium feeds from a densifier into other parts of a heavy medium system.

A more specific object is to provide an improved method and apparatus for controlling the feed rate from a densifier in which the densifier operates at constant speed and the feed rate is controlled by a splitter adjusted to return a variable fraction of the densifier output back to the densifier.

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In the drawings:

FIGURE 1 is a schematic flowsheet of a heavy medium minerals separation plant equipped with our improved apparatus for controlling the rate at which medium feeds from the densifier;

FIGURE 2 is a schematic wiring diagram of the circuit which controls the height of the densifier screw; and

FIGURE 3 is a perspective view of a preferred form of splitter embodied in our apparatus.

### Flowsheet

FIGURE 1 shows a flowsheet of a heavy medium plant which includes a pump box 10, a medium-circulating pump 12, a separating vessel 13, and sink and float screens 14 and 15. Pump 12 continuously feeds the medium, a water suspension of magnetic particles, from the pump box 10 to the separating vessel 13. Mineral particles (for example 1¼ x ¼ inch iron ore) also are introduced to this vessel. Heavier mineral particles sink in the medium and discharge from the separating vessel to the sink screen 14, while lighter mineral particles float and discharge to the float screen 15. Screens 14 and 15 have "drain" sections 14a and 15a and "wash" sections 14b and 15b over which the sink and float products pass in succession. Suspension drained from the sink product as it passes over the drain section 14a return directly to the pump box 10. Suspension drained from the float product as it passes over the drain section 15a goes to an adjustable splitter 16, which routes variable fractions to the pump box 10 and to another pump box 17. Water is applied to both the sink and float products as they pass over the wash sections 14b and 15b to wash away additional medium. Wash water from both products goes to the pump box 17, from which a pump 18 delivers the contents to a magnetic separator 19 to remove nonmagnetic contaminants. The remaining magnetic particles and water go to a densifier 20, which removes water. Densified suspension from the densifier returns to the pump box 10. In the example of an ore, sink particles leaving screen 14 usually are a finished concentrate product, while float particles leaving screen 15 and nonmagnetic contaminants from the magnetic separator 19 usually are a finished tailing product.

The individual pieces of apparatus other than our preferred splitter, as well as the portion of the flowsheet thus far described, are conventional and hence not described in greater detail. However, we point out that the densifier is of a type in which the depth of the rake can be changed to increase or decrease the quantity of densified suspension feeding therefrom. We have illustrated a densifier which has a rotating rake or screw 21 and a motor 22 for lowering or raising the screw. A densifier of this type, and also a suitable separating vessel and pumps, are available commercially from Western Machinery Co., San Francisco, California, and are described in a printed publication by the supplier entitled, "Wemco Equipment for Heavy Media Separation," Bulletin No. H1-B12. Another example of a suitable densifier is a reciprocating rake type of classifier available commercially from Dorr-Oliver Incorporated, Stamford, Connecticut, and is described in a printed publication by the supplier, Bulletin 2281. We also point out that the plant may include other conventional pieces of apparatus, such as demagnetizing coils for the recovered suspension, which we have not shown, since they are not involved in the present invention.

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As in the invention disclosed in the aforementioned Chase and Hendrickson application, we mount a density meter 23 at a convenient place in the flowsheet, illustrated in the line which carries medium from pump 12 to the separating vessel 13, and we connect a specific gravity recorder 25 to this meter. The specific gravity of the medium carried in this line is a little higher than that of the medium in the vessel, but it may be considered representative for control purposes. In accordance with our invention, we interpose a second adjustable splitter 26 between the densifier 20 and pump box 10. Densified suspension from the densifier goes to this second splitter, which transfers only a variable fraction of this suspension to the pump box 10 and returns the remainder to the densifier. In the arrangement illustrated, the recorder-controller 25 transmits a signal representative of the density of the medium in vessel 13 to a splitter-positioner 27, which is mechanically connected to splitter 26. The positioner 27 adjusts the splitter to vary the fraction of the densified suspension transferred to the pump box inversely with changes in specific gravity. If the specific gravity of the medium entering vessel 13 goes down from its set value, splitter 26 transfers a larger fraction of the densified suspension to the pump box 10. The reverse action occurs if the specific gravity goes up from its set value.

After an adjustment is made in the position of splitter 26, there is an immediate change in the level of medium in the pump box 10. If a larger or smaller fraction of the densified suspension goes to the pump box, the level rises or falls. We connect a level-sensing device 29 to the pump box and connect a controller 30 to the level-sensing device. Controller 30 transmits a signal representative of the level of medium in the pump box to a splitter-positioner 31, which is mechanically connected to splitter 16. When the level rises or falls, the positioner 31 adjusts splitter 16 to restore the level to its set value. That is, if the level in the pump box rises from its set value, the splitter routes a larger fraction of the drained suspension to the magnetic separator 19 and densifier 20 and a smaller fraction directly to the pump box 10. Thus the net effect of a decrease in specific gravity from the set value is that a larger quantity of densified suspension goes to the pump box 10 and a larger quantity of drained suspension goes to the magnetic separator 19 and densifier 20. The net effect of an increase in specific gravity from the set value is the reverse. In either event the system stabilizes when the medium reaches a specific gravity substantially equal to a set value.

As the plant operates, the medium particles gradually are depleted. Hence the trend is for splitter 26 to transfer a larger and larger fraction of the densified suspension to the pump box 10 and return less to the densifier. We connect the splitter-positioner 27 with the raise-lower motor 22. When splitter 26 approaches its extreme positions, in which it is transferring almost all or almost none of the densified suspension to the pump box, a signal for a further increase or decrease operates motor 22 to lower or raise the densifier screw 21.

#### Electric circuit

FIGURE 2 is a schematic wiring diagram of one form of circuit we can use for operating the raise-lower motor 22. The circuit includes lines  $L_1$  and  $L_2$  connected to a suitable power source, and two timers  $T_1$  and  $T_2$ . Timer  $T_1$  controls the length of time motor 22 runs each time it is energized, and timer  $T_2$  the interval which must elapse before motor 22 can run again after it once runs. Timer  $T_1$  operates with a "maintained contact" control switch and we set it to "time out" after a relatively brief period (for example 8 seconds). Timer  $T_2$  operates with a "momentary contact" control switch and we set it to time out after a longer period (for example 10 minutes). Timer  $T_2$  has a normally closed contact 35 and a double-

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throw contact 36 which are connected internally. We connect line  $L_1$  with contact 35. We connect one end of the coils of two parallel latch-type relays A and B to contact 36 through normally open switches 37 and 38 respectively and connect the other end of each coil to line  $L_2$ . As long as timer  $T_2$  is in its "off" or "reset" position, contact 35 is closed and contact 36 positioned to connect the relay coils with line  $L_1$ . Switch 37 closes when splitter 26 reaches a position in which it is transferring almost all the densified suspension from the densifier 20 to the pump box 10. Switch 38 closes when the splitter is returning almost all the densified suspension to the densifier. When switch 37 or 38 closes, relay A or B is energized, provided sufficient time has elapsed since the previous operation for timer  $T_2$  to have reset. Relay A has normally open contacts  $A_1$  and  $A_2$  and relay B normally open contacts  $B_1$  and  $B_2$ . Whenever either relay is energized, its contacts remain closed even though switch 37 or 38 may open, since the relays are of the latch-type.

We connect the timing circuit of Timer  $T_1$  across contact 36 of Timer  $T_2$  and line  $L_2$  in series with contact  $A_1$  or  $B_1$ , whereby timer  $T_1$  is energized and commences to time when either contact  $A_1$  or  $B_1$  closes. Timer  $T_1$  has a normally open contact 39 and a double-throw contact 40 which are internally connected. We connect line  $L_1$  with contact 40 and connect one end of the coils of "lower" and "raise" relays 22a and 22b with contact 39 via contacts  $A_2$  and  $B_2$ , respectively. We connect the other ends of the relay coils with line  $L_2$ . As soon as timer  $T_1$  is energized, contact 39 closes. As long as the timer is in its "reset" position or while it is timing, contact 40 is positioned to connect contact 39 with line  $L_1$ . Thus whenever relay A is in "latch" position, relay 22a is energized via contacts 40, 39 and  $A_2$  to operate motor 22 in a direction to lower the densifier screw 21. Similarly whenever relay B is in "latch" position, relay 22b is energized via contacts 40, 39 and  $B_2$  to operate motor 22 in the other direction to raise the screw.

We connect the timing circuit of timer  $T_2$  across contact 40 of timer  $T_1$  and line  $L_2$ . When timer  $T_1$  "times out," contact 40 moves to a position to disconnect and deenergize relay 22a or 22b and to connect timer  $T_2$  with line  $L_1$ , whereupon timer  $T_2$  is energized and commences to time. As soon as timer  $T_2$  is energized, contact 36 moves to its other position. We connect parallel "reset" coils 41 and 42 for relays A and B across contact 36 and line  $L_2$ , whereby these coils are energized when contact 36 changes position. The normally open contacts of relay A or B open, whereupon timer  $T_1$  is deenergized and resets to the position shown in FIGURE 2. Timer  $T_2$  continues to run, since it operates with a "momentary contact" from timer  $T_1$ . When timer  $T_2$  "times out," contact 35 momentarily opens and deenergizes the reset coils 41 and 42. Finally timer  $T_2$  resets automatically to the position shown in FIGURE 2, whereupon the cycle can repeat whenever switch 37 or 38 closes.

Preferably the circuit to relays 22a and 22b includes a "manual-automatic" selector switch 43 and push buttons 44 and 44a for lowering or raising the densifier screw under manual operation. The circuit can also include limit switches 45 and 45a which open when the screw reaches its extreme positions to prevent further operation of motor 22.

#### Splitter

FIGURE 3 shows structural details of our preferred form of splitter 16. A first fixed launder 46 receives suspension drained from the float product on screen 15. A second fixed launder 47 is located beneath launder 46 to receive the fraction of the suspension which returns directly to the pump box 10. A third fixed launder 48 is located beneath launder 46 and offset therefrom to receive the fraction which goes to the magnetic separator 19 and densifier 20. The splitter includes a swinging launder 49 and a pair of links 50 attached to this launder

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and pivoted to an overhead support 51. The swinging launder is located in the space between the fixed launders 46 and 47 and it has an output spout 52 in its end above the fixed launder 48. The positioner 31 is connected to the links 50 to move the swinging launder back and forth in response to signals from the recorder-controller 25. Splitter 26 is of similar construction; hence we have not repeated the description. The splitter construction per se is claimed in another application filed by Luther G. Hendrickson, Serial No. 361,498, filed April 21, 1964, which is a division of application Serial No. 208,757, filed July 10, 1962.

#### Instruments

The individual instruments used in our control apparatus are of conventional construction and available commercially. Hence we have not shown nor described them in detail, but instead reference can be made to printed publications for showings.

Considine, "Process Instruments and Controls Handbook," published by McGraw-Hill Book Company, copyright 1957, Library of Congress Catalog Card No. 56-8169, shows and describes suitable instruments for several of our purposes. Considine shows a recorder-controller (page 11-22 or 11-26) suitable for our recorder-controller 25, and a cylinder-type operator with positioner (page 10-37) suitable for our splitter positioners 27 and 31. A suitable recorder-controller 25 also is available commercially from Leeds and Northrup Company, Philadelphia, Pa., as "Type H" with "CAT" controller, and is described in printed publications by the supplier, Data Sheets "ND46-33(106)80-558" and "ND46-51(100)60-658" and Folder "ND4(7b)80-1158," pages 9 and 10. A suitable positioner is available commercially from Foxboro Company, Foxboro, Mass., as the "Stabiload," and is described in a printed publication by the supplier, Bulletin No. 446. Our density meter 23 can be an "Ohmart Cell," as shown in Ohmart Patent No. 2,763,790, or a gamma gage. A suitable level sensing device 29 and level controller 30 are available commercially from Fisher Governor Company, Marshalltown, Iowa, as "Type 249P" and "Type 2500 Fisher Level-Trol" and are described in a printed publication by the supplier, Data Sheets "ND46-33(106)80-558" and available commercial from Eagle Signal Co., Moline, Ill. as the "Cycl-Flex" reset timer and are described in a printed publication by the supplier, Bulletin 120, August 1955. Our illustrative recorder-controller generates an electric signal, which we use to control a pneumatically operated positioner 27. A suitable transducer for converting electric signals from the recorder to pneumatic pressure signals is available commercially from Fisher Governor Co. as "Type 543" and is described in a printed publication by the supplier, Bulletin E543.

From the foregoing description it is seen our invention affords a relatively simple yet effective method and apparatus for controlling the specific gravity of the medium used in a heavy medium minerals separation process. We avoid any need to vary the speed of the densifier screw, as shown in other applications herein discussed. It is apparent also that the connections between the controllers 25 and 30 and the splitter-positioners 27 and 31 could be interchanged after the fashion of the modification shown in FIGURE 1 of the aforementioned Chase and Hendrickson application. In this event the specific gravity recorder-controller 25 would operate the splitter-positioner 31 through a suitable electric-to-pneumatic transducer, and the level controller 30 would operate the splitter positioner 27 directly. We can also use our invention in conjunction with a cleanness control as shown in another Chase and Hendrickson application Serial No. 236,945, filed the same date as the present application. As long as the cleanness control is not used, we avoid introducing water to the separating vessel for control purposes.

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While we have shown and described only a single embodiment of the invention, it is apparent that modifications may arise. Therefore, we do not wish to be limited to the disclosure set forth but only by the scope of the appended claims.

We claim:

1. In a heavy medium minerals separation process in which mineral particles are introduced to a water suspension of magnetic particles, heavier mineral particles sink in the suspension while lighter mineral particles float, the resulting sink and float products are successively drained of suspension and washed with water, both the wash water and a variable fraction of the drained suspension are treated in a magnetic separator and a densifier to remove nonmagnetic contaminants and water and thereby produce a densified suspension, said densified suspension together with the remainder of the drained suspension is transferred from the densifier to a pump box, and the suspension feeds from the pump box to a vessel where the mineral particles are introduced, the combination therewith of a method of controlling the specific gravity of the suspension in the vessel to a set value comprising measuring a specific gravity representative of the suspension in the vessel, splitting the flow of said densified suspension from the densifier to transfer only a variable fraction thereof to the pump box and return the remainder to the densifier, adjusting the magnitude of the fraction transferred to the pump box in response to the specific gravity measurement to transfer more and raise the level in the pump box when the specific gravity goes down from said set value and transfer less and lower the level in the pump box when the specific gravity goes up, measuring changes in the level of suspension in the pump box from a set level, and adjusting the magnitude of said fraction of drained suspension treated in the magnetic separator and densifier to increase the fraction as the level rises and decrease the fraction as the level falls and thereby restore the level in the pump box to said set level.

2. In a heavy medium minerals separation plant, which includes a separating vessel adapted to contain a water suspension of magnetic particles in which heavier mineral sinks while lighter mineral particles float, means for successively draining the suspension from the sink and float products from said vessel and washing the products with water, a magnetic separator and a densifier, a first adjustable splitter for routing a variable fraction of the drained suspension to said magnetic separator and densifier along with the wash water to remove nonmagnetic contaminants and water and thereby produce a densified suspension, a pump box to which are transferred said densified suspension from said densifier and the remainder of the drained suspension from said first splitter, and a pump for feeding the combined densified and drained suspension from said pump box to said vessel, the combination therewith of an apparatus for controlling the specific gravity of the suspension in said vessel to a set value comprising means for measuring a specific gravity representative of the suspension in said vessel, means for measuring changes in the level of suspension in said pump box from a set level, a second adjustable splitter for splitting the flow of said densified suspension from said densifier to transfer only a variable fraction thereof to said pump box and return the remainder to said densifier, means operatively connecting said specific gravity-measuring means with one of said splitters, and means operatively connecting the level-measuring means with the other of said splitters, said connecting means adjusting said splitters to vary the magnitudes both of the treated fraction of the densified suspension and of the fraction of the drained suspension treated in the magnetic separator and densifier to transfer and treat larger fractions as the specific gravity goes down from said set value and smaller fractions as the specific gravity goes up, with the adjustments taking place one following the other.

3. An apparatus as defined in claim 2 in which said

specific gravity-measuring means adjusts the fraction of the densified suspension transferred to said pump box, and said level-measuring means adjusts the fraction of the drained suspension treated in said magnetic separator and densifier.

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