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

Filed Nov. 13, 1962 2 Sheets-Sheet 1

FIG. 4.

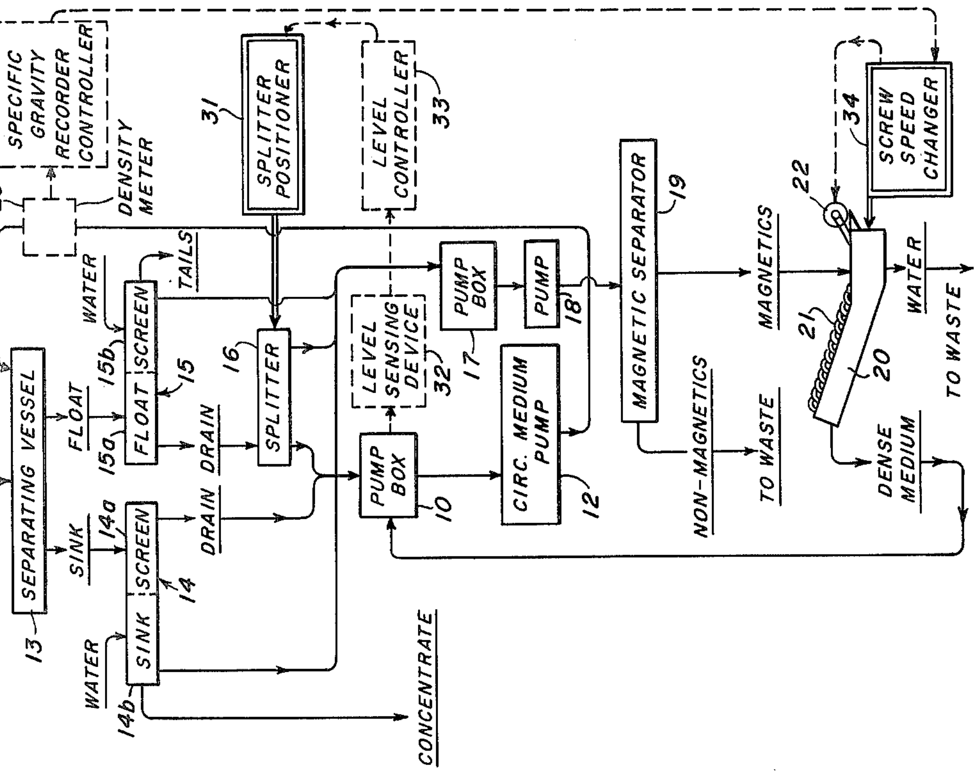

FIG. 1.

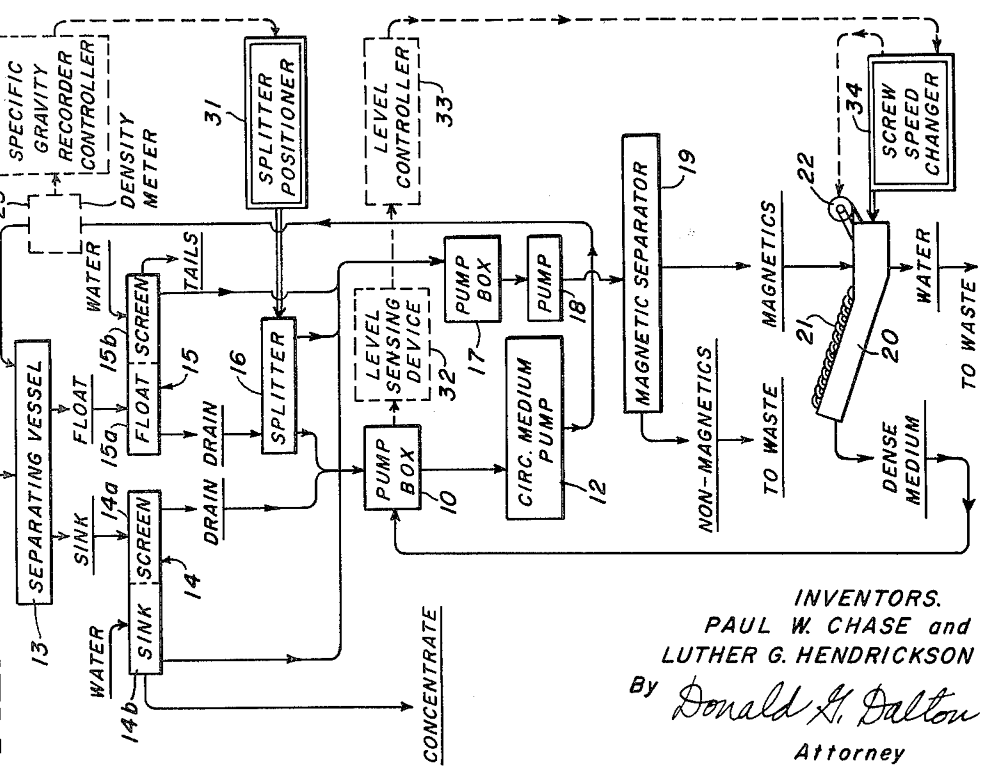

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FIG. 2.

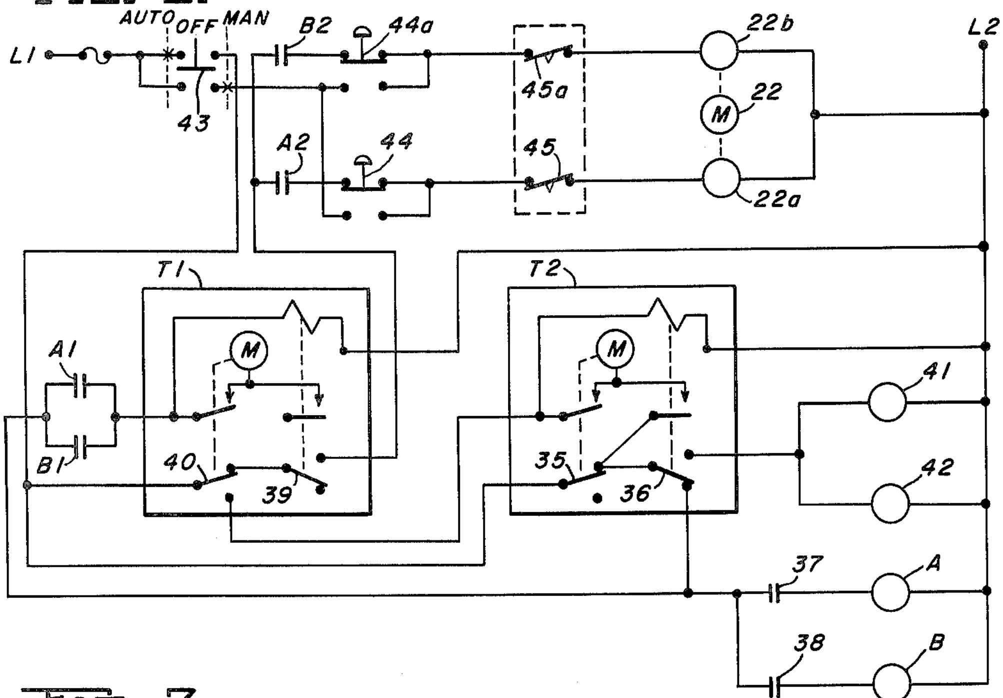
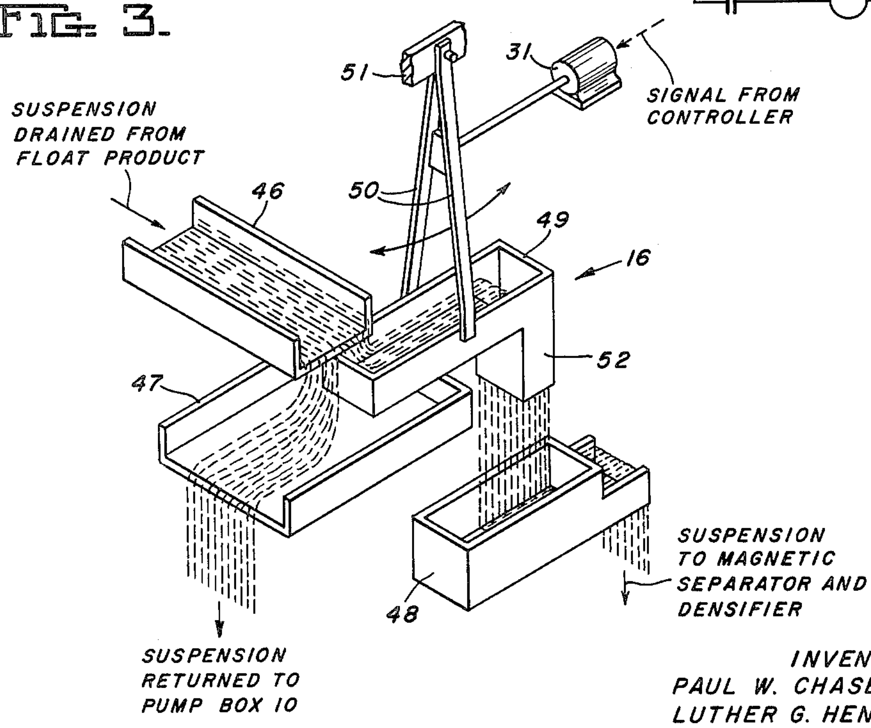


FIG. 3.



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

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12 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 used 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. Automatic controls also have been proposed heretofore, but those with which we are familiar have disadvantages. For example, it is known to measure the specific gravity of the suspension as it enters the separating vessel and introduce additional water there to control the specific gravity. When water is introduced to the separating vessel for control purposes, the suspension introduced thereto must be at a specific gravity higher than otherwise desirable to leave room for adjustment. Consequently a larger fraction of the drained suspesnion than otherwise necessary must be treated in the magnetic separator and densifier. These devices operate at unnecessarily high rates, and the losses of medium may be excessive. This form of control also necessitates a measurement of the level of material in the separating vessel. Modern separating vessels usually are of the rotating drum type in which it is difficult to measure the level of material. The float product discharges over a weir; hence there is little measurable variation in the level.

An object of our invention is to provide an improved method and apparatus for automatically controlling the specific gravity of the medium in a heavy medium minerals separation process and to overcome the disadvantages of previous automatic controls.

A further object is to provide an improved method and apparatus for automtaically controlling specific gravity in which we avoid introducing water to the separating vessel for control purposes or taking measurements in this vessel.

A more specific object is to provide an improved automatic control method and apparatus in which the controlled variables include (a) the proportion of the drained suspension going to the densifier, (b) the densifier screw speed, and (c) the relative height of the densifier screw.

In the drawings:

FIGURE 1 is a schematic flowsheet of a heavy medium minerals separation plant equipped with one form of our control apparatus;

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

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

FIGURE 4 is a flowsheet similar to FIGURE 1, but showing a modification.

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*** returns 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 portions 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 both the speed and 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.

In accordance with our invention, 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-controller **25** to this meter. The specific gravity of the medium carried in this line is a little higher than that of the medium actually in the vessel, but it may be considered representative for control purposes. The recorder-controller transmits a signal representative of the density of the medium in vessel **13** to a splitter-positioner **31**, which is mechanically connected to the splitter **16**. The positioner **31** adjusts the splitter to vary the fraction of the drained suspension treated in the magnetic separator **19** and densifier **20** inversely with changes in specific gravity. If the specific gravity of the medium entering vessel **13** goes down from its set value, the positioner adjusts the splitter to route a larger fraction of the drained suspension through the magnetic separator and densifier, whereupon larger quantities of non-magnetic contaminants and water are removed from the circulating suspension and its specific gravity thus raised. The reverse action occurs if the specific gravity of the medium goes up from its set value.

After an adjustment is made in the splitter position, there would normally be a time lag of several minutes before medium of corrected specific gravity reaches the separating vessel **13**, but there is an immediate change in the level of medium in the pump box **10**. If a larger fraction of the drained suspension goes to the magnetic separator **19** and densifier **20**, less of course returns directly to the pump box and the level falls from its set value. The reverse action occurs if a smaller fraction goes to the magnetic separator. We connect a level-sensing device **32** to the pump box and connect a controller **33** to the level-sensing device. Controller **33** transmits a signal representative of the level of medium in the pump box to a speed-changing device **34** for the motor which drives the densifier screw **21**. When the level falls or rises from its set value, the screw immediately commences to turn faster or more slowly. As a result particles actually in transit within the screw feed faster or more slowly to the pump box, and both the specific gravity and the level of the medium in the pump box are corrected promptly. The speed change itself produces only a temporary change in the feed rate. After the screw has fed all the medium particles actually in transit at the moment of the speed change, the speed change ceases to be factor, but by this time the change caused by adjustment of the splitter takes effect. Hence medium in the pump box continues to be of the corrected specific gravity.

Electric circuit

As the plant operates, medium particles gradually are depleted. Hence the trend is for splitter **16** to route a larger and larger fraction of the drained suspension to the magnetic separator **19** and densified **20** and for the densifier screw **21** to run faster and faster. We connect the screw speed-changing device **34** with the raise-lower motor **22**. When the speed of the densifier screw **21** approaches a set maximum or minimum, a signal for a further increase or decrease in speed operates motor **22** to lower or raise the screw.

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 control 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-throw contact **36** which are internally connected. 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. Switches **37** or **38** closes when the speed-changing device **34** reaches a setting at which the densifier screw **21** is operating at a speed approaching its maximum or its minimum respectively, whereupon 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 connected internally. We connect line L_1 with contact **40** and connect one end of the coils of "lower" and "raise" relays **22**a and **22**b 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 **22**a 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 **22**b 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 **22**a or **22**b 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 **22**a and **22**b includes a "manual-automatic" selector switch **43** and push buttons **44** and **44**a for lowering or raising the densifier screw under manual operation. The circuit can also include limit switches **45** and **45**a 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 is located in the space between the fixed launders 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 outlet 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 (FIGURE 1) or controller 33 (FIGURE 4). The splitter construction per se is claimed in another application filed by the co-inventor Hendrickson.

Modification

FIGURE 4 shows a modification in which we connect the specific gravity recorder-controller 25 with the speed-changing device 34, and connect the level controller 33 with the splitter-positioner 31. When the specific gravity of the medium changes from its set value, the recorder-controller 25 adjusts the screw speed-changer 34 to produce an inverse change in the speed of the densifier screw 21. The change in the screw speed changes the volume of material going to the pump box 10. As a result of the change in the screw speed, the level of medium in the pump box 10 rises when the specific gravity goes down or falls when the specific gravity goes up. Controller 33 transmits a signal representative of the change in level to the splitter-positioner 31, which adjusts the splitter 16 in a direction to restore the level to its set value. That is, if the level in the pump box 10 rises, 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. The reverse action takes place if the level in the pump box falls. As in the embodiment shown in FIGURE 1, the effect of the screw speed change is temporary, but by the time the medium in transit in the screw has all been fed, the change brought about by adjustment of the splitter becomes effective. In this manner the specific gravity of the medium is corrected to its set value. In other respects the flowsheet shown in FIGURE 4 is similar to that shown in FIGURE 1; hence we have not repeated the description.

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 instruments suitable 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-positioner 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 "ND–46–33 (106) 80–558" and "ND–46–51 (100) 60–658" and Folder "ND4 (76) 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 32 and level controller 33 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, Bulletin F–4A. A suitable screw speed changer 34 is available commercially from Louis Allis Co., Milwaukee, Wis., as the "Select-a-speed" drive, and is described in a printed publication by the supplier, Service Manual, Section 14A, July 1, 1957. Suitable timers T_1 and T_2 are available commercially from Eagle Signal Co., Moline, Illinois, as the "Cycl-Flex" reset timer and are described in a printed publication by the supplier, Bulletin 120, August 1955.

Our illustrative recorder-controller 25 generates an electric signal. When we use this signal to control a pneumatically operated positioner 31, as shown in FIGURE 1, we include an electric-to-pneumatic transducer. A suitable transducer for this purpose is available commercially from Fisher Governor Co. as "Type 543" and is described in a printed publication by the supplier, Bulletin E543. Our illustrative level controller 33 generates a pneumatic signal. When we use this signal to control the speed of the densifier motor, also as shown in FIGURE 1, we include a pneumatic-to-electric transducer. A suitable transducer for the latter purpose is available commercially from Taylor Instrument Companies, as the "Transcope Servomatic Transducer" and is described in a printed publication by the supplier, Bulletin 98375, May 1960.

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 process. We avoid introducing water to the separating vessel for control purposes, as well as taking measurements in this vessel, thereby overcoming difficulties encountered with previous automatic controls.

While we have shown and described certain preferred embodiments of the invention, it is apparent that other 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 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 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, measuring changes in the level of the suspension in the pump box from a set level, and adjusting both the magnitude of the treated fraction of the drained suspension and the rate at which said densified suspension is transferred to the pump box in response to these measurements to treat a larger fraction and transfer more of said densified suspension as the specific gravity goes down from said set value and the reverse as the specific gravity goes up, with one of the adjusting steps following the other.

2. 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 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 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, adjusting the magnitude of the treated fraction of the drained suspension to produce more of said densified suspension as the specific gravity goes down from said set value and less as the specific gravity goes up, measuring changes in the level of the suspension in the pump box from a set level, and adjusting the rate at which said densified suspension is transferred to the pump box in accordance with the level measurement to transfer more of said densified suspension as the level falls from said set level and less when the level rises, with the second-named adjusting step following the first.

3. 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 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 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, adjusting the rate at which said densified suspension is transferred to the pump box in accordance with changes in the specific gravity measurements to transfer more when the specific gravity goes down and less when the specific gravity goes up, measuring changes in the level of the suspension in the pump box from a set level, and adjusting the magnitude of the treated fraction of the drained suspension to produce more of said densified suspension as the level rises and less as the level falls, with the second-named adjusting step following the first.

4. 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 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 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 the specific gravity of the suspension feeding from the pump box to the vessel, measuring changes in the level of the suspension in the pump box from a set level, adjusting the magnitude of the treated fraction of the drained suspension in accordance with changes in one of the measurements to correct the specific gravity after an interval required for suspension of corrected specific gravity to get back to the vessel, and temporarily adjusting the rate at which said densified suspension is transferred to the pump box in accordance with changes in the other measurement to correct the specific gravity promptly until the first correction takes effect.

5. A method as defined in claim 4 in which the magnitude of the treated fraction is adjusted in accordance with changes in the specific gravity measurement, and the rate at which densified medium is transferred is adjusted in accordance with changes in the level measurement.

6. A method as defined in claim 4 in which the magnitude of the treated fraction is adjusted in accordance with changes in the level measurement, and the rate at which said densified medium is transferred is adjusted in accordance with changes in the specific gravity measurement.

7. 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 particles sink while lighter mineral particles float, means for successively draining the suspension from sink and float products from said vessel and washing the products with water, means for treating both the wash water and a variable fraction of the drained suspension to remove nonmagnetic contaminants and water and thereby producing a densified suspension, a pump box to which are transferred said densified suspension from said treating means and the remainder of the drained suspension, 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 said set level, means operatively connected with one of said measuring means for varying the magnitude of the treated fraction of the drained suspension in accordance with changes in the measurement, and means operatively connected with the other measuring means for varying the rate at which said densified suspension is transferred to the pump box in accordance with changes in the other measurement, with the means for varying the magnitude and the means for varying the rate operating so that one follows the other.

8. A combination as defined in claim 7 in which the means for varying the magnitude of the treated fraction is operatively connected with the means for measuring the specific gravity, and the means for varying the rate is operatively connnected with the means for measuring the level.

9. A combination as defined in claim 7 in which the means for varying the magnitude of the treated fraction is operatively connected with the means for measuring the level, and the means for varying the rate is operatively connected with the means for measuring the specific gravity.

10. 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 particles sink while lighter mineral particles float, means for successively draining the suspension from sink and float products from said vessel and washing the products with water, an adjustable splitter for dividing into variable fractions the suspension drained from at least one of the products, means for treating both the wash water and a fraction of the drained suspension to remove nonmagnetic contaminants and water and thereby produce a densified suspension, a pump box to which are transferred said densified suspension from said treating means and the remainder of the drained suspension, 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, means operatively connected with one of said measuring means and with said splitter to adjust the magnitude of the treated fraction in accordance with changes in the measurement to correct the specific gravity after an interval required for suspension of corrected specific gravity to get back to said vessel, and means operatively connected with the other of said measuring means and with said treating means for temporarily adjusting the rate at which said densified suspension is transferred to said pump box to correct the specific gravity promptly until the first correction takes effect.

11. A combination as defined in claim **10** in which the treating means for removing water from the drained suspension includes a densifier having a rotatable screw, drive means for said screw, and means for raising and lowering said screw, and in which the means for temporarily adjusting the rate at which said densified suspension is transferred includes means for adjusting the speed of said drive means to transfer particles actually in transit within said screw at a changed rate.

12. A combination as defined in claim **11** including means for adjusting said raising and lowering means

when large adjustments are needed in the rate at which said densified suspension is transferred.

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