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

FIG. 2.

FIG. 3.

INVENTORS.
P. W. CHASE and LUTHER G. HENDRICKSON
By Donald L. Dalton

Attorney
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 nonmagnetic materials, such as coal. After the sink and float products leave the separating vessel, the suspension is drained therefrom and recovered for re-use. Now 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 the 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 or additional medium 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 manual means. 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 suspension 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 therein to determine when the 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 automatically 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.
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 in 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 here 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, whereas when the 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 will normally be a time 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 levelsensing 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 a 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 densifier 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 L1 and L2 connected to a suitable power source, and two timers T1 and T2. Timer T1 controls the length of time motor 22 runs each time it is energized, and timer T2 the interval which must elapse before motor 22 can run again after it once runs. Timer T2 operates with a "maintained contact" control switch and we set it to "time out" after a relatively brief period (for example 8 seconds). Timer T2 operates with a "momentary contact" control switch and we set it to time out after a longer period (for example 10 minutes). Timer T2 has a normally closed contact 35 and a double-throw contact 36 which are normally connected. We connect line L1 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 L2. As long as timer T2 is in its "off" or "reset" position, relay A is energized for control purposes to connect the relay coils with line L2. 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 T2 to have reset. Relay A has normally open contacts A1 and A2 and relay B normally open contacts B1 and B2. Whenever either relay is energized, its contacts remain closed even though switch 37 or 38 may open. Whereupon timer T2 resets.

We connect the timing circuit of timer T1 across contact 36 of timer T2 and line L2 in series with contact A1 or B1, whereby timer T1 is energized and commences to time when either contact A1 or B1 closes. Timer T1 has a normally open contact 39 and a double-throw contact 40 lag of several seconds, respectively.

We connect line L1 with contact 40 and connect one end of the coils of "lower" and "raise" relays 22a and 22b with contact 39 via contacts A2 and B2 respectively. We connect the other ends of the relay coils with line L2. As soon as timer T1 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 L1. Thus whenever relay A is in "latch" position, relay 22a is energized via contacts 40, 39 and A2 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 B2 to operate motor 22 in the other direction to raise the screw.

We connect the timing circuit of timer T2 across contact 40 of timer T1 and line L2. When timer T1 "times out," contact 40 moves to a position to disconnect and deenergize relay 22a or 22b and to connect timer T2 with line L2, whereupon timer T2 is energized and commences to time. As soon as timer T2 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 L2, whereby these coils are energized when contact 36 changes position. The normally open contacts of relay A or B open, whereupon timer T2 is deenergized and resets to the position shown in FIGURE 2. Timer T2 continues to run, since it operates with a "momentary contact" from timer T1. When timer T2 "times out," contact 35 momentarily opens and deenergizes the reset coils 41 and 42. Finally timer T2 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 operating the latch-type 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 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 53 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 level of the 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 10 falls. As is 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 flowchart 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 16-37) 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) 80-555” 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 “Ohmag” as shown in Ohmart’s 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 “Selecta-speed” drive, and is described in a printed publication by the supplier, Service Manual, Section 14A, July 1, 1957. Suitable timers T1 and T2 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 the speed of the densifier motor, also 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 98775, May 1955.

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 rate at which densified medium is transferred 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 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 said vessel 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 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 connected 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 said vessel 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 said 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.

References Cited by the Examiner

UNITED STATES PATENTS

2,584,076 1/1952 Wurzback 209—489
2,690,261 9/1954 Mast 209—172.5
2,690,262 9/1954 Bean 209—172.5
2,933,187 4/1960 Old 209—464
3,093,577 6/1963 Wilmot 209—172.5

FOREIGN PATENTS

136,541 3/1950 Australia.
938,831 4/1948 France.
753,541 7/1956 Great Britain.

HARRY B. THORNTON, Primary Examiner.
HERBERT L. MARTIN, Examiner.