This float-sink apparatus utilizes media of two different densities in which the liquid level in the higher density media sump is automatically sensed and controlled through the addition of media makeup to the sump when the level is low. The change in density is sensed by a density sensor which controls the addition of water in the flow line between the high density sump and the high density separator. The low density system is similarly controlled, except that the level sensor controls the diversion of high density media from a drain screen into the low density sump, rather than controlling the addition of media makeup to the low density sump. The wash circuit of the system directs washed media makeup from both the high density separated product and the low density separated product to a magnetic separator and then to a densifier which acts at a constant rate to feed all of the washed and separated media makeup directly into the high density media sump.

18 Claims, 3 Drawing Figures
MINERAL SEPARATION CONTROL SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates to the separation of materials of differing densities by the float-sink technique. The separating media which is employed commercially, consists of a suspension of finely divided, insoluble particles in a liquid. Usually, finely divided ferrosilicon or magnetite is suspended in water.

The apparatus for float-sink systems employs basically a separator in which the materials of differing densities are separated and a media sump in which media is stored, mixed and pumped to the separator. Media is returned from the separator to the media sump by being carried with separated materials to screens which are positioned over the media sump.

Additionally, such systems incorporate wash circuits where media makeup is washed off of the separated materials and is carried to a magnetic separator where it is separated from non-magnetic particles which are impurities in the system and from a good deal of the wash water used to wash media makeup off the separated materials. From whence the regenerated media make-up is carried to a densifier, comprising basically a screw in a settling tank, where the remainder of the water is largely separated from the media makeup. Finally, such systems include a means for adding new media makeup to the system as necessary to compensate for losses.

The fundamental problem encountered in such systems is that of control of the density of the media. In most prior art systems currently in use, density is sensed periodically by an operator who dips a cup into the sump, measures the density of the media so acquired, and then adds water or media makeup to the sump as necessary. Some systems incorporate automatic sensing devices and add or subtract water and media makeup to the sump as necessary in response to an automatic density measurement.

However problems are encountered no matter which of these density sensing techniques are utilized. First of all, the addition of water to the sump frequently acts to poison the system and upsets the balance of the sensitive suspension of media makeup in water. Secondly, the addition of water or media makeup directly to the sump fails to effectuate a sufficiently rapid response to the density excess or deficiency which has been detected. Accordingly, the effectiveness of the separation process can be impaired during periods of adjustment.

Another and somewhat related problem is that of controlling the water level or liquid level in the media sump. Such control is necessary in order to maintain the balance of the system and to insure a sufficient supply of media for pumping to the materials separator. Most prior art systems detect the level in the sump visually or automatically and then add water to the sump if the level drops. As noted above, this poisons the sump and tends to upset the suspension balance. More importantly, the addition of water to control liquid level in the sump renders the problem of density control more difficult to solve. The indiscriminate addition of water to control liquid level in the sump amounts to an intentional dilution of the system which compounds the natural tendency of the system to be diluted as a result of water which adheres to the washed materials as they are fed into the separator.

The above problems are merely compounded in dual media separation systems. Such systems incorporate media of two different densities to effectuate a more thorough separation of materials. They require the control of density in two systems and the control of liquid level in two separate sumps. Prior art systems now known achieve control for the two separate systems either by treating them as two separate systems or by utilizing a complicated means for transferring media directly from the heavy media sump to the less dense media sump.

SUMMARY OF THE INVENTION

In the present invention, control of the liquid level in the sump is achieved by addition media makeup, rather than water, to the sump in response to a low level indication while density control is effectuated by sensing density in the system and by introducing water into the system in response to such density sensing. Thus, water need never be introduced directly into the media sump. Further, water is added to control liquid level in the sump only in response to the addition of media makeup. Thus the problems of density dilution through liquid level control are eliminated. Any slight water which is introduced into the system by wet materials can be compensated for by adjusting the basic media makeup feeder rate. In a preferred embodiment of the invention, adjustments in density are effectuated immediately by adding water in the flow line from the media sump to the separator rather than by merely dumping water into the sump. Density adjustment response is immediate.

In another aspect of the invention, the liquid level of a second, lower density media sump is controlled by regulating the amount of high density media allowed to drain from a heavy density media drain screen into the lower density media sump. As above, the increased density of the system is then sensed by a density sensor which adds water directly in the line from the low density media sump to the low density separator. Thus, this system enjoys the same advantages set forth above and simplifies the control of the lower density media system.

Another aspect of this invention which is important if dual media separation is utilized is the feeding of regenerated media makeup from both the high density media and low density media separation products directly into the high density media sump. By thus feeding all of the regenerated media makeup from both systems into the high density media system only, one tends to achieve a bias in the system which tends to increase the density of the high density media system slightly. With this accomplished, one need not be concerned about having to make any significant adjustments as a result of a decreasing density in the system. The natural loss of media makeup can be calculated in advance as a result of laboratory experiments and can be compensated for by providing a basic rate of speed for operation of the new media makeup feeder.

Finally, one aspect of the invention which is significant to the control of either the high density media system or the low density media system is that of sensing the density of the system directly in the flow line between the sump and separator and correspondingly introducing liquid directly into this flow line at a point
upstream from the sensor. This eliminates the need for complicated plumbing and effectuates the goal of rapid adjustment of media density as required. The foregoing advantages along with additional objects and advantages of this invention will be further understood by reference to the written specification and appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective schematic view of the media sumps and of the flow control system between the media sumps and the materials separator; FIG. 2 is a perspective schematic view of the materials separator; and FIG. 3 is a perspective schematic view of the wash circuit.

PREFERRED EMBODIMENT

While various aspects of the invention can be used to advantage in systems utilizing only a single separating media of given density, the preferred embodiment of the invention encompasses a system using both a high density media and a low density media. By using two separate media separated by approximately 0.4 density, a more thorough separation of materials of different density can be effectuated.

In accordance with the use of two separate media, drum separator 10 includes a high density compartment 11 for high density media and a low density compartment 12 for low density media (FIG. 2). High density compartment 11 is in flow communication with high density sump 20 (FIG. 1) through a flow circuit which includes high density flow line 40. Liquid level in high density sump 20 is controlled through the automatic addition of media makeup to high density sump 20 by media makeup feeder 80 (FIG. 3). Level sensor 60 (FIG. 2) positioned in high density sump 20 senses the level therein and when the level is low, signals media makeup feed controller 70 which in turn controls feeder 80 and steps up the rate of addition of media makeup to high density sump 20.

The increase in density due to this increase in the media makeup feed rate is sensed by density sensor 90 (FIG. 1) positioned in high density flow line 40. Density sensor 90 signals liquid feed controller 100 controlling liquid feed valve 110 whereby the rate at which water is introduced into high density flow line 40 through liquid line 111 is increased. Liquid line 111 joins high density flow line 40 at a point upstream from density sensor 90 such that adjustments in density are effectuated continuously and immediately on a very closely controlled basis.

The control of liquid level and density in the low density media system is analogous to the control set forth above. The key distinction is the manner in which liquid level is controlled in low density media sump 30. A level sensor 60a in low density media sump 30 senses the level therein and when the level is low, activates diverter gate controller 120 (FIG. 1) controlling diverter gate 130. Diverter gate 130 is positioned between high density sump 20 and low density sump 30 and is positioned below high density float drain screen 140 and high density sink drain screen 141. When the level in low density media sump 30 is too low, diverter gate controller 120 is signaled to rotate diverter gate 130 and thereby increase the surface area of high density float drain screen 140 and high density sink drain screen 141 which is positioned above diverter gate 130. In this manner, more high density media drains off of the separated materials leaving high density compartment 11 of drum separator 10 and drains down into low density media sump 30. The increased density of low density media is sensed by a density sensor 90a on flow line 50 which activates liquid feed controller 100a for controlling liquid feed valve 110a on liquid line 111a. This operation is the same as that of the density control means for the high density media system.

Theoretically the present system is one in which the density of media in both high density media sump 20 and low density media sump 30 tends to increase slightly during operation of the system. This is due primarily to the fact that water is never introduced directly in response to a need for increasing liquid level in either sump. Rather, liquid level is increased by first adding media makeup and by then adding required water. The addition of water into the system by being carried with feed stock into drum separator 10 is compensated for by the fact that there is a natural tendency for the system to lose media as a result of laundering and drainage. This lost media results in the addition of media makeup as a result of the need for increasing the liquid level in the media sump.

In any event, slightly increasing density can be insured by adding media makeup to the high density media system at a slightly greater rate than would be required to replace media makeup which is lost due to being carried away on separated materials. This is accomplished in the preferred embodiment by returning all media makeup which is regenerated in the wash circuit directly to high density media sump 20 or by pre-setting media makeup feeder 80 at a certain base level, referring to the former technique, the wash circuit includes a dilute media sump 160 and a water sump 170 over which wash water and pure water respectively are sprayed downwardly onto separated materials to wash off as much media makeup from the separated material as possible (FIG. 1). The resulting dilute media is directed to magnetic separator 180 and then to densifier 190 in customary fashion (FIG. 3). From densifier 190, regenerated media makeup is added at a constant rate directly to high density media sump 20. This results in slightly more media makeup being introduced into high density sump 20 than would be necessary to replace any losses. This effect is carried over into the low density system by controlling low density sump level by diverting higher density media, as set forth above.

Drum Separator, Sumps and Media

As discussed above, drum separator 10 (FIG. 2) includes a high density media compartment 11 and a low density media compartment 12. A conventional rotating dual compartment drum separator can be used. Feed stock is fed through feed chute 17 into low density compartment 12. Heavy material sinks to the bottom in low density compartment 12 and is picked up by low density lifters 14. Low density lifters 14 carry this sink material upwardly to a position above low density slide 16 from whence the sink materials fall downwardly on low density slide 16 and slide into high density compartment 11. The float particles from low density compartment 12 are carried away through launder 51.
In high density compartment 11, sink materials are picked up by high density lifters 13 as drum separator 10 rotates and are carried to a position above high density slide 15 into which they fall and slide out of drum separator 10 to be carried away on sink launder 42. The float materials of high density compartment 11 are carried away through float launder 41.

High density sump 20 and low density sump 30 are holding tanks for holding the respective media (FIG. 1). These can be conventional sumps and are generally shaped like inverted pyramids. Each sump holds approximately 300 gallons of media.

The media used is preferably ferrosilicon and water or magnetite and water. The densities of the high density media and low density media are varied in accordance with the densities of the particular materials which must be separated. In one system for separating copper ore from slag, it has been found that a high density media of 3.4 density and a low density media of 3.0 density result in satisfactory separation of the particular copper ore from the particular slag.

Flow Circuits

High density compartment 11 and low density compartment 12 are connected to high density sump 20 and low density sump 30 respectively through flow circuits which carry media from the particular sump, to the separating compartment and back again to the sump. The high density flow circuit includes high density flow line 40 to which is operably connected pump 43 for pumping media through high density flow line 40 to high density compartment 11 (FIG. 2). Specifically, high density flow line 40 is a pipe which empties out onto low density slide 16 and from thence drains into high density compartment 11.

The return circuit from high density compartment 11 to high density sump 20 includes high density float launder 41 and high density sink launder 42 (FIGS. 1 & 2). Float launder 41 carries materials that float in high density media to high density float drain screen 140 (FIG. 1). Similarly, high density sink launder 42 carries materials that sink in high density media to high density sink drain screen 141. Both of these drain screens are positioned adjacent one another above high density sump 20. They are vibrated by a conventional vibrating means such that separated materials tend to vibrate along the length of the screen and high density media tends to drain through the screen and into high density sump 20.

The low density flow circuit is similar to the high density flow circuit. The low density flow circuit also includes a flow line, i.e., low density flow line 50, which is a pipe extending from low density sump 30 (FIG. 1) to feed chute 17 (FIG. 2) of drum separator 10. Pump 53 pumps media through flow line 50 (FIG. 1). Low density media is returned to low density media sump 30 by being laundered through low density launder 51 (FIG. 2) to low density drain screen 150 positioned above low density sump 30 (FIG. 1). Low density drain screen 150 is operably connected to drain screens 140 and 141 and is thereby vibrated in conjunction with the vibration of drain screens 140 and 141. This causes materials that float in low density media to vibrate down the length of low density drain screen 150 and it causes low density media to drain downwardly into low density media sump 30.

Both flow circuits include recycle lines which short-circuit the flow of media to drum separator 10. Thus, high density flow line 40 includes a recycle line 45 which short-circuits high density compartment 11 and low density flow line 50 includes recycle line 55 which short-circuits low density compartment 12 (FIG. 1). Both recycle lines 45 and 55 include valves 46 and 56, respectively, which control the volume of media which is directly recycled to the sumps. By controlling the setting of valves 46 and 56, one can control the volume of media which is allowed to flow through the flow circuits. When the system is started up initially, valves 46 and 56 are maintained wide-open in order to completely short-circuit drum separator 10 until a proper suspension of media makeup in water is obtained.

In this manner, media from each of the two sumps is carried first to drum separator 10 and then back to either high density sump 20 or low density sump 30.

Sump Level And Media Density Control

Each of the level sensors 60 and 60a positioned respectively in high density sump 20 and low density sump 30 (FIG. 1) serves the function of sensing the level in its respective media sump. Such devices can be purchased commercially and generally operate by sensing the pressure within the sump. The specific level sensor utilized in the preferred embodiment is of the differential pressure transducer type and a suitable model can be purchased from any number of suppliers.

When level sensor 60 in high density media sump 20 senses that the level therein is low, it signals media makeup feed controller 70. Media makeup feed controller 70 utilizes a comparator circuit to compare the signal received from level sensor 60 with the signal generated in a control circuit which has previously been set in accordance with the level of media desired in sump 20. Such controllers are generally available in the trade and one model which has been found acceptable is the Leeds and Northrup Model 420.

The compared signal is sent to media makeup feeder 80 (FIG. 3) to increase the rate at which media makeup is added to high density media sump 20. Media makeup feeder 80 serves the function of adding new media makeup to high density sump 20. Any of many available media makeup feeders are acceptable for serving this function. In operation, a base setting is established for media makeup feeder 80 in accordance with the anticipated loss of media makeup in the system due to media makeup being carried away on separated materials. Variations from this base setting either in an increasing or decreasing direction are then achieved in response to readings by level sensor 60. As the media level in high density sump 20 increases, level sensor 60 signals media makeup feed controller 70 to decrease the rate of addition of new media makeup by decreasing the rate of operation of media makeup feeder 80. If the media level in sump 20 becomes too high, high density media simply spills over into low density sump 30.

A density sensor 90 is connected to high density flow line 40 for sensing the density of high density media passing therethrough (FIG. 1). Density sensor 90 is a nuclear sensing device which directs a beam of gamma rays through the stream of passing media. The gamma rays are absorbed by suspended particles in proportion to the density of the media. A receiver senses the degree of absorption of the rays and an amplifier ampli-
fies the resulting signal to a level acceptable for sending to a liquid feed controller 100. Such nuclear sensing devices are generally available and one acceptable unit is Model 5130 of Chicago Nuclear Company.

The signal emitted from density sensor 90 is received by liquid feed controller 100 which operates in a manner identical to the mode of operation of media makeup feed controller 70. Liquid feed controller 100 operates a motorized liquid feed valve 110 which is positioned on liquid feed line 111. Liquid feed line 111 joins high density flow line 40 at a point upstream from density sensor 90 such that changes in media density effected through the addition of water through liquid feed line 111 are sensed immediately.

Thus, when the density of the media is increased due to the addition of media makeup, this increase is sensed by density sensor 90 which in turn signals liquid feed controller 100 to increase the rate at which water is introduced through liquid line 111 into high density flow line 40. Because the system is biased towards gradually increasing density, a small amount of water flows through motorized liquid feed valve 110 and liquid feed line 111 when media makeup feeder 80 is operating at its maximum. If the magnitude of this decrease in density is small, the decrease in density will be also sensed by density sensor 90 and will be accommodated for by decreasing the opening in motorized liquid feed valve 110 from its initial preset position.

The high density media system employs generally the same control equipment as does the high density media system. Thus, a level sensor 60a is positioned in low density media sump 30, a density sensor 90a is positioned on low density media flow line 50, a liquid feed controller 100a is actuated by density sensor 90a and a motorized liquid feed valve 110a on liquid feed line 111a is operated by liquid feed controller 100a. As with liquid feed line 111, liquid feed line 111a joins low density flow line 50 at a point upstream from density sensor 90a. All of these components serve the same function and operate in the same manner as their counterparts bearing the same numerals, without the letter a, described in connection with the high density control system.

The basic distinction between the control of the two media systems is the manner in which liquid level in low density media sump 30 is controlled. Even then, the manner of control is analogous. The difference is that level sensor 60a in low density sump 30 actuates a diverter gate controller 120 (FIG. 1) which in turn controls diverter gate 130 positioned between high density media sump 20 and low density media sump 30. Diverter gate controller 120 operates on the same principle as media makeup feed controller 70 and liquid feed controllers 100 and 100a.

Diverter gate 130 comprises a panel which is pivotally mounted between high density sump 20 and low density sump 30 on axle 133. It is oriented generally below drain screens 140 and 141 which carry materials separated in high density compartment 11 of drum separator 10. By pivoting diverter gate 130 towards high density media sump 20, the relative surface area of drain screen 140 and sink drain screen 141 positioned directly above diverter gate 130 is increased. In this manner, a greater proportion of high density media draining off drain screen 140 and sink screen 141 is diverted into low density media sump 30. By pivoting gate 130 back towards low density media sump 30, the quantity of high density media so diverted is decreased. The rotation of diverter gate 130 is controlled by a small motor 131 which in turn is controlled by diverter gate controller 120. A counterweight 132 is provided on the axle 133 of diverter gate 130 such that the weight of diverter gate 130 tends to be offset.

As with media makeup feeder 80, a basic position is determined for diverter gate 130 and diverter gate controller 120 is set accordingly. Deviations in the system from this basic position are then detected by diverter gate controller 120, these correcting signals are sent to motor 131 to vary the position of diverter gate 130 accordingly. If the media level in low density sump 30 becomes too great, excess media spills over into dilute media sump 160.

The high point for the media level in low density sump 30 is controlled by a manually operated gate 31 (FIG. 1). Gate 31 allows low density media to spill over into dilute media sump 160. By properly setting the position of gate 31, one can control the level of dirt, clay and other impurities which collect in the media. That portion of low density media which spills over into dilute media sump 160 will be pumped to magnetic separator 180 where the media makeup will be regenerated and impurities will be removed.

In this manner, the level in low density media sump 30 is increased through the addition of a higher density media from drain screens 140 and 141. (In fact, diverter gate 130 may at sometimes be positioned only below drain screen 140). The increase in density is sensed by density sensor 90a which then operates to adjust the low density media system in the same manner as does high density media sensor 90. In all other respects, the control systems are also identical.

Wash Circuit

The wash circuit comprises a means for regenerating media makeup which would otherwise be carried away on separated materials as they pass off the ends of drain screens 140, 141 and 150 respectively. In order to effectuate such regeneration, high density float drain screen 140, high density sink drain screen 141 and low density float drain screen 150 all extend beyond high density sump 20 and low density sump 30 to a position above dilute media sump 160 and water sump 170 (FIG. 1). Here, the separated materials are exposed to washing liquids to wash media makeup off of the separated materials. As separated materials are vibrated over water sump 170, fresh water is fed through spray nozzle assembly 171 and is sprayed onto the materials as they pass over water sump 170. The water draining into water sump 170 is then carried by water pump 172 to a wash water spray nozzle assembly 161 which directs a spray of wash water down onto materials being carried over dilute media sump 160. This wash water contains fresh water plus any media which has been washed off the materials passing over water sump 170. The wash water and media makeup draining down into dilute media sump 160 is then carried by dilute media pump 162 to a magnetic separator 180 (FIG. 3). Magnetic separator 180 separates media makeup, which is magnetic, from various other fines and suspended particles washed off of the separated materials, and thereby tends to purify the media makeup. Some water is also separated from the media makeup in this separator. Many such magnetic separators are available on the market and are well-known in the art. From magnetic separator 180, regenerated media makeup
and any remaining water are carried to densifier 190 from whence the regenerated media makeup is finally separated from the remaining water. Densifier 190 comprises generally a screw or auger 191 positioned in a settling tank for carrying settled media makeup up and out of water held in the densifier. Water flowing out of densifier 190 is carried back to dilute media sump 160 and regenerated media makeup is carried through a demagnetizing coil 200 and is then diverted directly into high density media sump 20 (FIG. 1). Demagnetizing coil 200 removes any residual magnetism in the media makeup before it is reintroduced into the system.

In most prior art systems, means are provided for automatically changing the rate at which densifier 190 separates regenerated media makeup by changing the rate of operation of screw 191 or by changing the level of screw 191 in densifier 190. In the preferred embodiment of the present invention, the rate of operation of densifier 190 is maintained constant, with necessary changes in the rate of media makeup introduction into the system being controlled through the rate of operation of media makeup feeder 80. This results in a far more instantaneous response to the changing media makeup requirements of the system.

The overflow from densifier 190 passes through overflow line 192 from whence it is carried to dilute media sump 160 (FIG. 3). In this manner, overflow re-enters the wash circuit and is pumped by pump 162 back through magnetic separator 180. Densifier 190 also includes a flush line 193 which empties into dilute media sump 160. However, flush line 193 is normally closed and is used only when densifier 190 is flushed out and cleaned.

System Bias

In prior art float-sink systems, there seems to be a tendency for the density of the system to decrease slightly during continued operation. This decreasing density appears to be caused by a combination of two factors. First, the materials fed into drum separator 10 are generally washed and accordingly, carry with them into drum separator 10 a certain amount of diluting water. Secondly, prior art systems control the liquid level in the sump through the addition of diluting water to the sump. Both of these water additions must then be compensated for by the addition of media makeup.

In the present invention, the system is much more closely balanced at all times due first of all to the fact that liquid level in high density sump 20 is controlled by the addition of media makeup to the sump, followed by the addition of compensating water, rather than by the addition of water to the sump followed by the addition of compensating media makeup. In an analogous manner, the liquid level in low density sump 30 is controlled through the addition of higher density media to the low density media sump 30, rather than through the addition of water to the sump 30. Of course, these additions of media makeup are offset by subsequent additions of water. However, since some water is being introduced into the system anyway as a result of the washed feed stock materials, a relatively lesser amount of water will be added to the system than would be the case if water were added to the sump as the primary means for controlling liquid level in the sumps and were then followed by the addition of compensating media makeup.

In addition, a certain amount of bias is achieved by the fact that all of the regenerated media from both the high density system and the low density system is diverted back into the high density media sump 20. This tends further to bias at least the high density media system towards slightly increasing density.

This slight bias is important because it allows one to adjust valves 110 and 110a to a base setting at which water is continually introduced into the system during its normal operation. (If necessary, the base setting of media makeup feeder 80 can be set higher than anticipated requirements for new media makeup.) If for any reason the density of the system does then tend to decrease, the rate of introduction of water can then be decreased from this base setting.

OPERATION

In operation, the materials to be separated are fed into feed chute 17 of drum separator 10 (FIG. 2). These materials slide into low density compartment 12 and that portion of the materials which float in the low density media are laundered through low density launder 51 to low density float drain screen 150 (FIG. 1).

That portion of the materials which sink are picked up by low density lifters 14 and are carried to a position above low density slide 16 into which they drop and slide downwardly into high density compartment 11 (FIG. 2). The materials floating in high density compartment 11 are laundered through high density float launder 41 to high density float drain screen 140 (FIG. 1). Those materials which sink are picked up by high density lifters 13, carried to position above high density slide 15 onto which they are dropped and slide downwardly into high density sink launder 42 (FIG. 2) which carries them to high density sink drain screen 141 (FIG. 1). The continual flow of low density media from low density sump 30 into low density compartment 12 provides a sufficient flow of media to act as a launder agent for laundring low density float materials through low density launder 51. Similarly, the flow of high density media from sump 20 to high density compartment 11 is sufficiently great to provide a laundring agent for laundring separated materials through high density float launder 41 and high density sink launder 42.

The separated products are carried to a drain screen assembly which includes low density float drain screen 150, high density float drain screen 140 and high density sink drain screen 141 (FIG. 1). Low density float drain screen 150 is positioned above low density sump 30, dilute media sump 160 and water sump 170. High density drain screens 140 and 141 are positioned above high density sump 20 and above dilute media sump 160 and water sump 170. All of the screens are vibrated by a vibrating means such that the separated materials are gradually carried across the screen over their respective sumps and discharged out of the systems at the opposite ends. High density media drains downwardly into high density sump 20 and low density media drains downwardly into low density sump 30.

In operation, a relatively small quantity of media makeup is lost from the system, i.e., it is carried away with separated materials as they leave the system. This relative quantity is determined in advance through laboratory tests and is then compensated for by providing a base adjustment for media makeup feeder 80 (FIG. 3). Media makeup feeder 80 then operates at this par-
ticular rate to add media makeup into high density sump 20.

If the liquid level in high density sump 20 becomes too high, excess media drains over into low density media sump 30 (Fig. 1). The increasing liquid level is also sensed by liquid level sensor 60 in high density media sump 20 which sends a corresponding signal to media makeup feed controller 70. Media makeup feed controller 70 then acts to decrease, from its base setting, the rate at which media makeup feeder 80 introduces media into high density sump 20.

As the level in high density media sump 20 decreases, the decrease is sensed by level sensor 60 which sends a corresponding signal to media makeup controller 70 which in turn increases the rate at which media makeup feeder 80 adds media makeup to high density sump 20.

As more media makeup is introduced into high density sump 20, the increasing density is sensed by density sensor 90 which signals liquid feed controller 100 to increase the opening of motorized liquid feed valve 110 and thereby effectuate the increased rate of addition of water into high density flow line 40. While the system density will generally tend to increase rather than decrease, for the reasons explained above, any slight decreases in density will be sensed by density sensor 90 which will ultimately cause motorized liquid feed valve 110 to close somewhat from its base setting.

The control of the low density media system is identical except that when the liquid level in low density media sump 30 increases, it spills over into dilute media sump 160. Also, level sensor 60a signals diverter gate controller 120 which activates motor 133 to thereby pivot diverter gate 130 towards low density sump 30. This decreases the relative surface area of drain screens 140 and 141 above diverter gate 130 and thereby decreases the volume of high density media diverted into sump 30. When the level in sump 30 decreases, the decreasing level is sensed by level sensor 60a which signals diverter gate controller 120 to pivot diverter gate 130 towards high density sump 20 and thereby increase the relative surface area of drain screens 140 and 141 which are positioned directly above diverter gate 130. This causes more heavy density media to be diverted into dilute media sump 30. The resulting increasing density is sensed by density sensor 90a and is compensated for through liquid feed controller 100a and motorized liquid feed valve 110a on liquid feed line 111a.

Thus it can be seen that the present invention contemplates a revolutionary control system in which the liquid level in the media sump is controlled through the increased addition of media makeup to the sump, rather than through the addition of water to the sump. The relative density of the system is then compensated for through the addition of water directly into the flow line from the media sump to the drum separator. As a result, adjustments in the system density are achieved quickly and without the need for poisoning the sumps through the addition of fresh water thereinto.

Of course, it is understood that the above is merely a preferred embodiment of the invention and that many changes and alterations can be made thereof without departing from its spirit and broader aspects.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows.

1. In an apparatus for separating materials of different densities by a float-sink process using a suspension type separating media and including a media sump, a separator, a flow circuit for conveying media from said sump to said separator and back again, and a level sensing means for sensing the level of liquid in said sump, the improvement comprising: media makeup feed controller means for adding media makeup to said sump; makeup feeder control means operably connected to said level sensing means and to said media makeup feeder means for controlling the rate of addition of media makeup to said sump in response to said level sensing, increasing said rate in response to a low level and decreasing said rate in response to a high level; density sensing means positioned in said flow circuit for sensing the density of media passing therethrough; liquid introducing means operably connected to said flow circuit for introducing liquid into said flow circuit; control means operably connected with said liquid introducing means and with said density sensing means for controlling the rate of introduction of liquid into said flow circuit only in response to the density of media in said flow circuit as sensed by said density sensing means.

2. In an apparatus for separating materials of different densities by a float-sink process using a suspension type separating media and including a media sump, a separator, a flow circuit for conveying media from said sump to said separator and back again, and a level sensing means for sensing the level of liquid in said sump, the improvement comprising: media makeup feeder means for adding media makeup to said sump; makeup feeder control means operably connected to said level sensing means and to said media makeup feeder means for controlling the rate of addition of media makeup to said sump in response to said level sensing, increasing said rate in response to a low level and decreasing said rate in response to a high level; density sensing means positioned in said flow circuit for sensing the density of media passing therethrough; liquid introducing means operably connected to said flow circuit for introducing liquid into said flow circuit; control means operably connected with said liquid introducing means and with said density sensing means for controlling the rate of introduction of liquid into said flow circuit in response to the density of media in said flow circuit as sensed by said density sensing means; means for washing media makeup off separated materials with a washing liquid after they have left said separator; densifier means for separating washed media makeup from said washing liquid; means operating said densifier at a constant feed rate; said densifier being operably connected to said sump for returning washed media makeup to said sump at said constant feed rate; said media makeup feeder means comprising a source of media makeup other than said densifier.

3. In an apparatus for separating materials of different densities by a float-sink process using a suspension type separating media and including a media sump, a separator, a flow circuit for conveying media from said sump to said separator and back again, and a level sensing means for sensing the level of liquid in said sump, the improvement comprising: media makeup feeder means for adding media makeup to said sump; makeup feeder control means operably connected to said level sensing means and to said media makeup feeder means for controlling the rate of addition of media makeup to said sump in response to said level sensing, increasing
said rate in response to a low level and decreasing said rate in response to a high level; density sensing means positioned in said flow circuit for sensing the density of media passing therethrough; liquid introducing means operably connected to said flow circuit for introducing liquid into said flow circuit; control means operably connected with said liquid introducing means and with said density sensing means for controlling the rate of introduction of liquid into said flow circuit in response to the density of media in said flow circuit as sensed by said density sensing means; said density sensing means is located in said flow circuit at a first point where media is being conveyed to said separator; and said liquid introducing means joins said flow circuit at a second point where media is being conveyed to said separator, said second point being approximately at or upstream of said first point.

4. The apparatus of claim 2 which comprises: means for washing media makeup off separated materials with a washing liquid after they have left said separator; densifier means for separating washed media makeup from said washing liquid; means operating said densifier at a constant feed rate; said densifier being operably connected to said sump for returning washed media makeup to said sump at said constant feed rate; said media makeup feeder means comprising a source of media makeup other than said densifier.

5. In an apparatus for separating materials of different densities using a float-sink process using a suspension separating media and including a high density media sump, a low density media sump, a high density separator, a low density separator, a first drain screen positioned above said high density media sump for allowing high density media to drain off separated materials located on said first screen and into said high density media sump after they leave said high density separator, the improvement comprising: diverter means positioned between said high density media sump and said low density media sump and below said first drain screen, said diverter means having a media capturing surface positioned below said first drain screen for diverting a portion of said high density media from said first drain screen to said low density media sump; first level detecting means operably connected with said low density media sump for detecting the level of media therein; diverter gate control means operably connected to said first level detecting means and to said diverter means for varying the relative area of said first drain screen which is above said capturing surface of said diverter means in response to a variation in media level in said low density sump; a first flow circuit for conveying low density media from said low density media sump to said low density media separator; first density sensing means positioned in said first flow circuit for sensing the density of media passing therethrough; first liquid introducing means operably connected to said flow circuit for introducing liquid into said first flow circuit; first control means operably connected with said liquid introducing means and with said density sensing means for controlling the rate of introduction of liquid into said first flow circuit in response to the density of said low density media in said first flow circuit as sensed by said first density sensing means.

6. The apparatus of claim 5 which further comprises: means for introducing liquid into said high density sump, second level sensing means positioned in said high density media sump for sensing the level of liquid in said high density media sump; makeup feeder control means operably connected to said second level sensing means and to said media makeup feeder means for controlling the rate of addition of media makeup to said high density sump in response to said level sensing, increasing said rate in response to a low level and decreasing said rate in response to a high level; a second flow circuit for conveying media from said high density sump to said high density separator; second density sensing means positioned in said second flow circuit for sensing the density of media passing therethrough; second liquid introducing means operably connected to said second flow circuit for introducing liquid into said second flow circuit; second control means operably connected with said second liquid introducing means and with said second density sensing means for controlling the rate of introduction of liquid into said second flow circuit in response to the density of media in said second flow circuit as sensed by said second density sensing means.

7. The apparatus of claim 6 which comprises: means for washing media makeup off separated materials with a washing liquid after they have left said high density separator and said low density separator; densifier means for separating washed off media makeup from said washing liquid and being operably connected to said high density sump for introducing all of said washed-off media makeup directly into said high density sump.

8. The apparatus of claim 7 which comprises: means operating said densifier means at a constant feed rate.

9. In a system for separating materials of different densities by a float-sink process using a suspension type separating media and including a media sump, a separator, a flow circuit for conveying media from said sump to said separator and back again, and a level sensing means for sensing the level of liquid in said sump, the improvement comprising: media makeup feeder means for adding media makeup to said sump; means operably connected to said level sensing means and to said media makeup feeder means for controlling the rate of addition of media makeup to said sump in response to said level sensing, increasing said rate in response to a low level and decreasing said rate in response to a high level; density sensing means for sensing the density of media; liquid introducing means for introducing liquid into the system; control means operably connected with said liquid introducing means and with said density sensing means for controlling the rate of introduction of liquid into said system only in response to the density of media as sensed by said density sensing means.

10. In an apparatus for separating materials of different densities by a float-sink process using a suspension type separating media and including a media sump, a separator, a flow line for conveying media from said sump to said separator and back again, the improvement comprising: density sensing means intersecting said flow line for sensing the density of media passing therethrough; liquid introducing means intersecting said flow line at a point upstream from said density sensing means for introducing liquid into said flow line; control means operably connected with said liquid introducing means for introducing means and with said density sensing means for controlling the rate of introduction of liquid into
15. A method for controlling the density of media used in a float-sink materials separation system and for controlling the level of media in a media sump used in such a separation system, said method comprising the steps of: sensing the level of media in said media sump; introducing media makeup into said media sump; controlling the rate of introduction of media makeup in response to said level sensing, increasing the rate when the level is low and decreasing the rate when the level is high; sensing the density of media in the system; introducing liquid into the media; controlling the rate of introduction of liquid in response to said sensing of density only.

16. A method for controlling the density of media used in a float-sink materials separation system and for controlling the level of media in a media sump used in such a separation system, said method comprising the steps of: sensing the level of media in said media sump; introducing media makeup into said media sump; controlling the rate of introduction of media makeup in response to said level sensing, increasing the rate when the level is low and decreasing the rate when the level is high; sensing the density of media in the system; introducing liquid into the media; controlling the rate of introduction of liquid in response to said sensing of density; balancing an optimum rate for the introduction of media makeup against an optimum rate for the introduction of liquid such that the rate of change of media density is biased towards slightly increasing density.

17. A method for controlling the density of a low density media and the media level of said low density media in a low density sump used in a dual media float-sink materials separation system, said method comprising the steps of: allowing high density media to drain off materials laundered over a high density media sump; diverting a portion of said high density media into the low density media sump; detecting the level of media in said low density media sump; controlling the volume of high density media diverted in said diverting step in response to said level sensing, increasing the volume diverted when the level is low and decreasing the volume diverted when the level is high; sensing the density of low density media as it passes from said low density sump to a materials separator; introducing liquid in said low density media as it passes from said media sump to a materials separator; controlling the rate of introduction of liquid in response to said density sensing step.

18. A method for controlling the density of media used in a float-sink materials separation system, said method comprising the steps of: conveying media through a flow line from a media sump to a separator and sensing the density of media along said flow line; introducing liquid into said flow line at a point upstream from the point at which said density of said media is determined in response to the density of media as determined by said density sensing step.

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