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Eder

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[54] **PROCESS AND APPARATUS FOR CLASSIFYING GRANULAR MATERIAL SUSPENDED IN A LIQUID**

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[52] **U.S. Cl.** .... **210/73**; 210/84; 210/128; 210/512 R

[51] **Int. Cl.** **B01d 37/04**

[58] **Field of Search** .... 55/52, 203, 204; 209/3, 209/13, 18, 155, 172.5, 211, 269, 496; 210/73, 84, 304, 311, 512 R, 512 M, 128, 129; 241/20, 24

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Primary Examiner—Charles N. Hart
Assistant Examiner—Robert H. Spitzer
Attorney, Agent, or Firm—Steinberg & Blake

[57] **ABSTRACT**

A method and apparatus according to which slurries are treated so as to achieve therefrom a final fraction in which particles smaller than a given size are suspended in a given concentration. The slurry is treated in a first liquid cyclone having an upper overflow discharge and a lower discharge for substantially dewatered matter. The upper overflow discharge is delivered from the first liquid cyclone to a second liquid cyclone which has an upper overflow discharge providing the desired final fraction. At least part of the dewatered matter discharged from the first liquid cyclone is delivered to a gravity separator to which liquid is supplied at a rate which controls the concentration of the particles in the final fraction. This gravity separator has an overflow which is returned to the first liquid cyclone, and the gravity separator serves to separate from the slurry therein particles which are larger than a given size.

17 Claims, 3 Drawing Figures

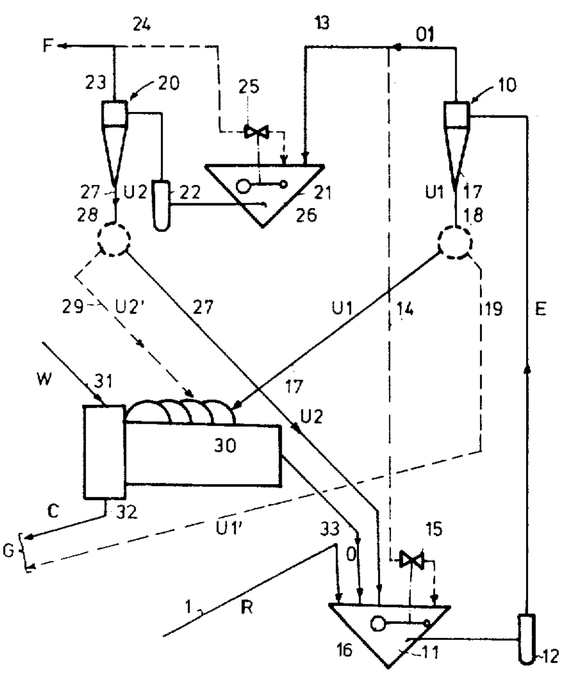

Fig.1

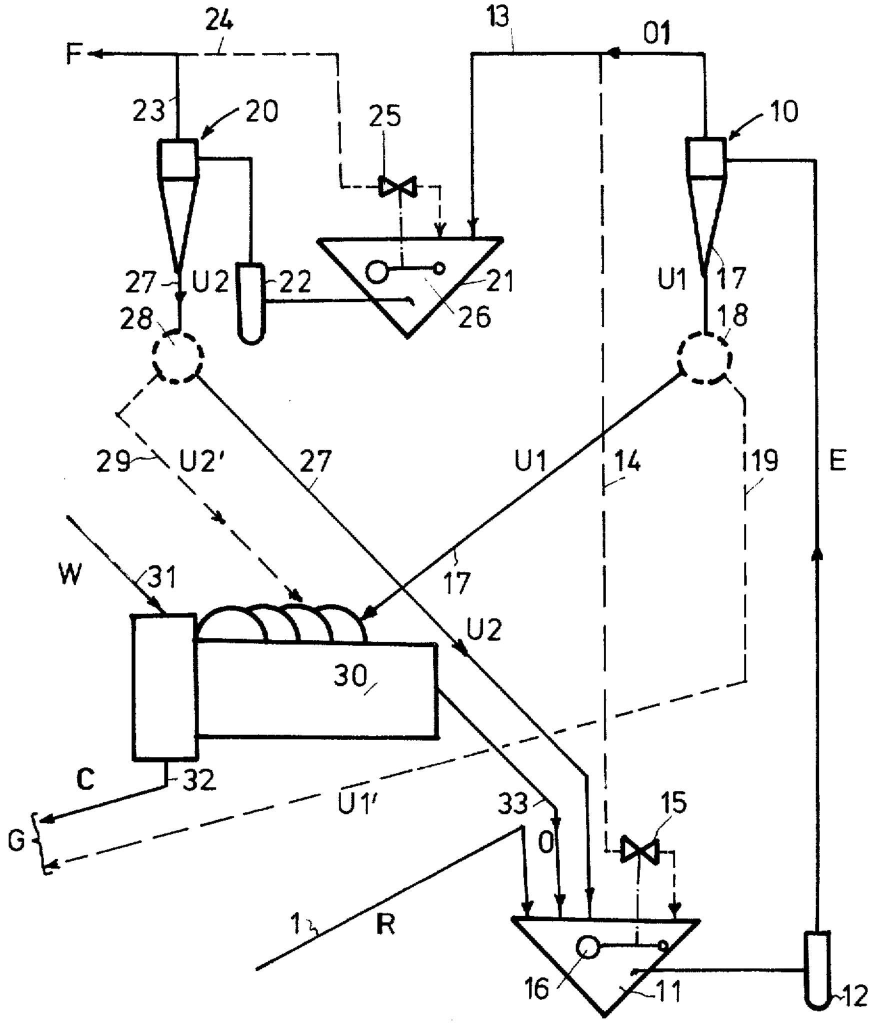
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Fig. 2

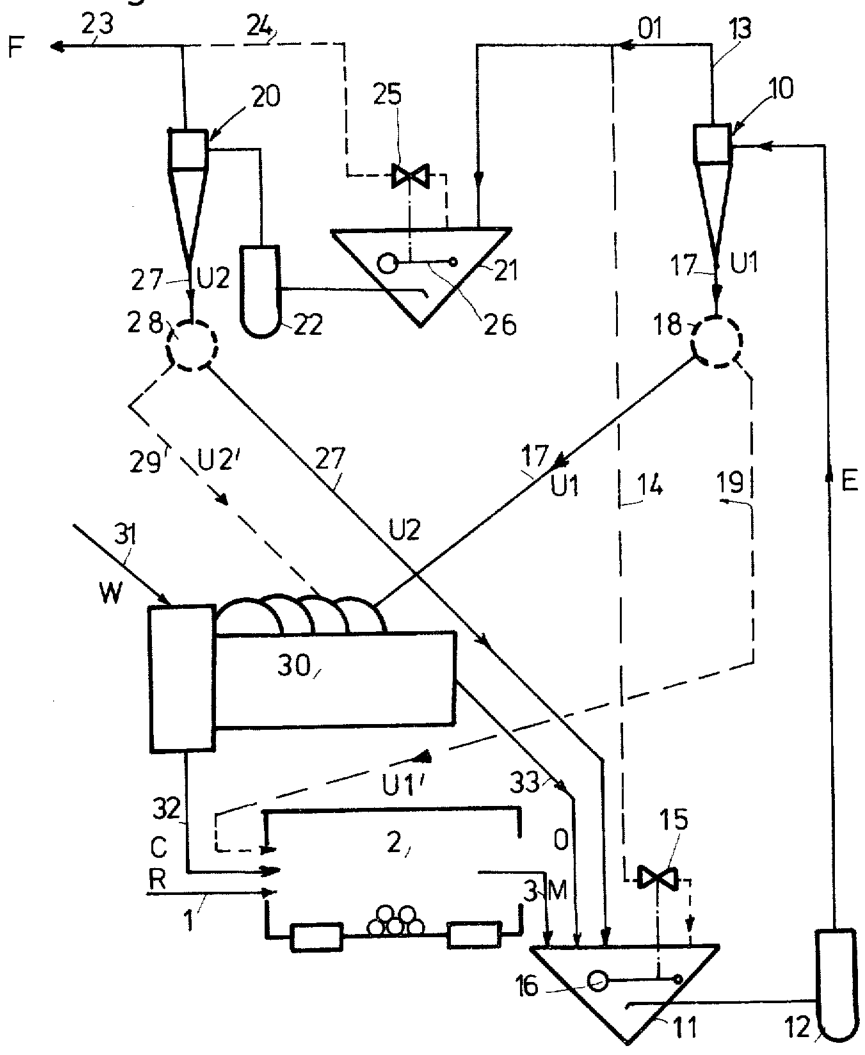
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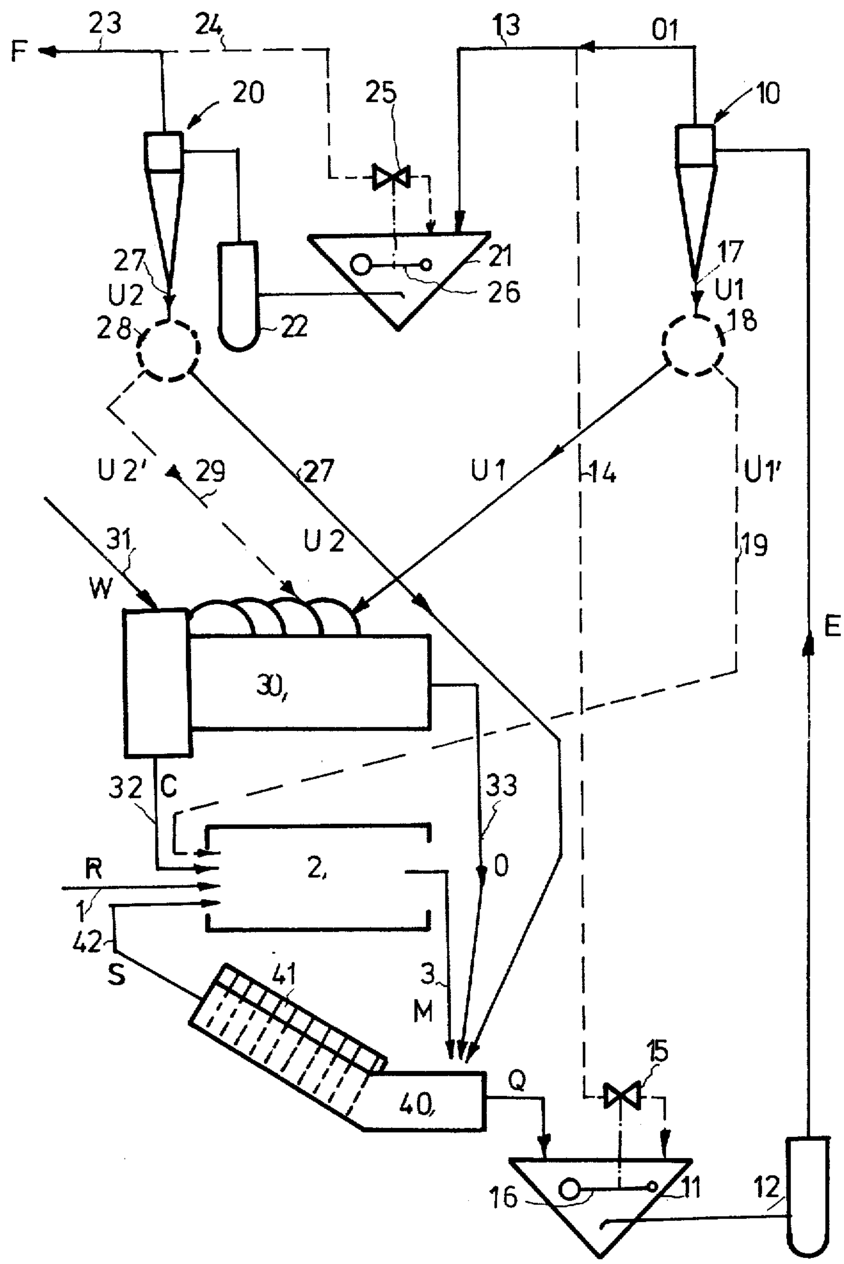
Fig. 3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PROCESS AND APPARATUS FOR CLASSIFYING GRANULAR MATERIAL SUSPENDED IN A LIQUID

BACKGROUND OF THE INVENTION

The present invention relates to slurry treating methods and apparatus.

In particular, the present invention relates to methods and apparatus capable of achieving from a given slurry a final fraction in which particles smaller than a given size are suspended in a given concentration.

It is already known to provide a pair of centrifugal stages in which a slurry is sequentially treated with the slurry initially being derived from a grinding apparatus, in such a way that the overflow of the second centrifugal stage provides the desired fraction.

There are many technical areas where it is important to be able to achieve final fractions having suspended therein particles which are smaller than a given size and containing practically no or very little particles which are larger than this given size. For example in the treatment of many different ores there are floatation stages where the slurry must be provided with a predetermined concentration of particles which must not exceed a given value of, for example, 30 percent by weight. Thus, in this case as well as in many other cases, it is desired to achieve a final fraction in the form of a highly concentrated slurry which requires no additional thickening. Liquid cyclones are capable of treating relatively thick slurries having, for example, particles in a concentration of 60 percent by weight with a specific gravity of 3 grams per cubic centimeter. Adjustment of such cyclones in order to achieve an overflow having only a small part of particles larger than a given size requires that an excessive amount of particles of the desired small size be discharged from the cyclone with the dewatered matter at the lower end of the cyclone so that an unsatisfactory output of the relatively fine particles results. On the other hand, it is possible with gravity separation of slurries, utilizing a gravity separator of the horizontal multistage type as shown, for example, in Austrian Pat. No. 253,436, to separate from the slurry particles larger than the desired size and containing practically no particles which have the desired small size. However, it is essential with such a gravity separator not to exceed a given concentration in the overflow discharge thereof, this concentration being for example 27 percent by weight of the particles with a specific gravity of, for example, 3 g/cm^3. Thus, with liquid cyclones it is possible to achieve an overflow discharge having the desired concentration but the exclusion of relatively large particles larger than a desired size from the overflow thereof is inadequate, whereas in the case of a gravity separator it is possible to provide the desired sharp classification of the particles but the desired concentration of the fine particles cannot be achieved.

It has therefore already been proposed to combine both types of methods and apparatus, so that the advantageous properties of both can be utilized while avoiding the undesired properties thereof. Thus, it is possible in fact to achieve the desired results up to a certain extent with a process or apparatus as disclosed in Austrian Pat. No. 269,018. According to the teachings of this patent the relatively thick slurry is separated either directly or after grinding in a first liquid cyclone stage into a dewatered lower discharge and an upper overflow discharge which still has particles larger than

the desired size. The lower discharge is carried away while the upper overflow is then separated a second time in a second liquid cyclone stage to provide at the second stage an overflow discharge having suspended therein relatively small particles which are substantially free of particles larger than the desired size with the small particles being in a concentrated condition in the final fraction, while the second stage has a lower discharge which contains considerably more liquid than the lower discharge of the first stage. This lower discharge from the second stage is separated in a single or multistage gravity separator into a larger-particle fraction and a small-particle fraction, the large-particle fraction being carried away and the small-particle fraction being returned to the first liquid cyclone stage. This type of combined processing is considerably superior to a classifying in a pair of sequential liquid cyclone stages with respect to achievement only of particles smaller than a given size and with respect to gravity separation in achievement of a final fraction having the desired concentration of the particles of relatively small size.

SUMMARY OF THE INVENTION

It is accordingly a primary object of the present invention to improve the above methods and apparatus in which there is a combination of centrifugal and gravity separation.

In particular, it is an object of the present invention to provide a process and apparatus which make is possible to control very precisely the concentration of particles in the final fraction while at the same time preventing any particles larger than a given size from being suspended in the final fraction.

Moreover, it is one of the important objects of the present invention to provide a process and apparatus where continuous recirculation of particles smaller than a given desired size is reliably avoided.

Moreover, it is in object of the present invention to provide a method and apparatus according to which it is possible to subject the raw slurry as well as additional components derived from the method and apparatus of the invention to a wet grinding process prior to further treatment according to the method and apparatus of the invention.

In addition, it is an object of the present invention to provide a method and apparatus according to which during gravity separation of the particles they are washed at least once by fresh liquid which is supplied to the gravity separation apparatus.

In addition, it is an object of the present invention to incorporate into the method and apparatus of the invention not only a wet grinding stage for preventing relatively large particles from being treated but also a sedimentation stage for further preventing undesirably large particles from being treated.

In addition, it is an object of the present invention to provide an apparatus which is provided with adjustable components capable of regulating the manner in which the apparatus operates and the manner in which the processing is carried out in such a way that different fractional parts of the various products achieved during the processing can be delivered between components of the apparatus with such features as automatically maintaining the level of slurries in sumps also being achieved.

According to the method and apparatus of the present invention the slurry which is to be treated is fed to a first centrifugal separation stage which has at least one liquid cyclone means provided with an upper overflow discharge and a lower discharge for substantially dewatered matter. This upper overflow discharge is delivered to a second centrifugal separation stage having at least one liquid cyclone means which has an upper overflow discharge providing the final fraction which has suspended therein a desired concentration of particles smaller than a given size. The lower discharge of substantially dewatered matter from the liquid cyclone means of the first centrifugal separation stage is delivered to a gravity separation means which has an overflow which is returned to the liquid cyclone means of the first centrifugal stage. According to one of the important features of the invention liquid is supplied to the gravity separation means at a rate which controls the concentration of the particles in the final fraction.

BRIEF DESCRIPTION OF DRAWINGS

The invention is illustrated by way of example in the accompanying drawings which form part of this application and in which:

FIG. 1 is a schematic illustration of one possible method and apparatus according to the present invention;

FIG. 2 is a schematic illustration of another possible method and apparatus of the present invention; and

FIG. 3 is a schematic illustration of a further possible method and apparatus according to the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

A relatively simple embodiment of the method and apparatus of the invention is illustrated in FIG. 1. As may be seen from FIG. 1, there are a pair of sequentially connected liquid cyclone means **10** and **20** each of which forms at least one liquid cyclone means of a centrifugal separation stage. Thus, a single liquid cyclone means **10** and a single liquid cyclone means **20** is schematically illustrated. The first stage is provided with a pump means **12** capable of handling a relatively thick slurry and a second stage is provided with a pump means **22** capable of handling a relatively thick slurry. Thus, the pump means **12** delivers the slurry which is to be treated along the conduit E to the first liquid cyclone means **10** while the pump means **22** delivers to the liquid cyclone means **20** the slurry to be treated therein. The pump means **12** receives the slurry to be treated from a sump means **11** while the pump means **22** receives its slurry from the sump means **21**. The inlet to the sump means **21** is connected to the outlet from the liquid cyclone means **10**. Thus, the liquid cyclone means **10** has an upper overflow discharge conduit **13** which delivers the upper overflow fine fraction discharge from the liquid cyclone means **10** to the sump means **21**. The second stage liquid cyclone means **20** has an upper overflow fine fraction discharge conduit **23** which provides the desired fine fraction F in which particles smaller than a given size are suspended in a desired concentration. As is shown in dotted lines, the overflow conduit **23** may have a branch conduit **24** extending therefrom and the overflow conduit **13** may have a branch conduit **14** extending therefrom. These branch conduits **24** and **14** communicate not only with the conduits **23** and **13**, respectively, but also with the sump means from which the slurry is fed to the particular stage. Thus, the branch conduit **24** leads to the sump means **21** while the branch conduit **14** leads to the sump means **11**. The branch conduits **14** and **24** respectively carry adjustable valves **15** and **25**. Moreover, the pair of sump means **11** and **21** are respectively provided with floats **16** and **26** operatively connected with the valve means **15** and **25** so as to regulate the latter, and in this way the level of the slurries in the pair of sump means **11** and **21** is automatically maintained at a desired elevation.

The lower dewatered coarse fraction discharge of the liquid cyclone means **10** of the first stage is delivered to a discharge conduit means **17** which feeds the dewatered matter discharged from the lower end of the liquid cyclone means **10** to a gravity separation means **30**. However, the lower discharge for substantially dewatered coarse fraction from the liquid cyclone means **20** of the second stage is delivered to a discharge conduit means **27** which delivers the dewatered coarse fraction from the liquid cyclone means **20** back to the sump means **11** so that the lower discharge of the liquid cyclone means **20** is recirculated through the liquid cyclone means **10** of the first stage. It is possible to operatively connect with the discharge conduit means **17** an adjustable distributor means **18** which communicates with an additional conduit means **19** so that a desired fraction of the dewatered coarse fraction discharged from the lower end of the liquid cyclone means **10** can be delivered to the additional conduit means **19** while the major portion of the dewatered coarse fraction discharged from the lower end of the liquid cyclone means **10** will be delivered to the gravity separation means **30**. In the same way, the discharge conduit means **27** may be provided with an adjustable distributor means **28** which will deliver a desired fraction of the lower discharge of the liquid cyclone means **20** to an additional conduit means **29** enabling a part of the lower discharge of the cyclone means **20** to be delivered as shown at U2′ to the gravity separation means **30**, while the major part U2 of the lower discharge of cyclone means **20** is delivered by conduit means **27** back to the sump means **11**. Thus the greater part U1 of the lower discharge of the cyclone means **10** is delivered to the gravity separator **30** while a fractional part U1′ is carried away with the conduit means **19**.

Thus, those conduits, distributors, valves and floats which are not absolutely essential to the method and apparatus of the invention are illustrated in dotted lines while the connections between the floats and valves is shown with a dot-dash line.

An adjustable liquid supply means **31** communicates with a gravity separation means **30** for delivering fresh liquid thereto at a select rate. Thus, the arrow **31** designates a supply pipe for fresh water, for example, this pipe having a valve enabling the rate of supply to be regulated. This fresh liquid is delivered to the gravity separation means **30** at the same side thereof where there is a discharge C for particles larger than a given size which are separated from the slurry in the gravity separation means **30**, these particles larger than the desired size being discharged through the discharge conduit **32**. Thus, while particles larger than a given size are discharged by way of the conduit means **32** of the gravity separation means, this gravity separation means has an overflow discharge conduit **33** returning to the sump means **11** as shown at O a slurry from which particles larger than a given size have been separated and discharged through the conduit **32.** Raw slurry R is delivered to the first stage sump means **11** by way of a feedpipe **1.**

The above-described apparatus of FIG. **1.** operates in the following manner:

By way of the slurry pump **12** the slurry E is delivered from the sump means **11** to the liquid cyclone means **10** of the first stage. This stage is regulated so as to provide a lower discharge U1 of substantially dewatered matter. The upper overflow discharge O1 which still has particles of relatively large size therein is delivered to the sump means **21** and is drawn from the latter by the pump means **22** so as to be delivered to the liquid cyclone means **20** of the second stage whose upper discharge outlet conduit means **23** provides the desired fine fraction F which contains a predetermined concentration of particles practically none of which are greater than a given size. For this purpose the second stage is adjusted in such a way that the overflow discharge **23** provides a final fraction F which is substantially free of any particles larger than a given size. The result is that the lower discharge outlet **27** has somewhat dewatered coarse fraction **U2** which is richer in liquid than the dewatered discharge outlet of the first stage and which still has some of the particles of smaller size therein.

In order to extract the particles of relatively small size from the lower discharge outlets of the first and second stages, the lower discharge outlet U2 of the second stage is returned to the sump means **11** while the lower discharge outlet U1 of the first stage is delivered to the gravity separation means **30** so that the particles of relatively small size in the discharged matter U1 will flow out of the gravity separation means **30** with the overflow discharge O thereof which is delivered by the conduit **33** back to the sump means **11.**

The liquid content of the entire process and apparatus is determined on the one hand by the liquid content of the raw slurry R and the amount of fresh liquid W supplied by the liquid supply means **31,** and on the other hand by the liquid content of the lower discharge matter U1 as well as the liquid content of the fraction C which is discharged from the gravity separation means **30** and which contains the particles larger than the desired size which are discharged through the outlet **32.** As may be seen from FIG. **1,** these particles larger than a given size discharged at the outlet **32** as well as, if desired, part of the matter U1 delivered by the distributor **18** to the conduit **19** are simply carried away from the apparatus forming the matter G which is no longer used in the method and apparatus.

The concentration of particles smaller than the desired size contained in the final fraction F is regulated by way of the liquid supply means **31** delivered to the gravity separation means **30** so that the concentration of particles can be maintained correspondingly low at the gravity separation means.

The slurry E delivered from the sump means **11** to the liquid cyclone means **10** by way of the pump means **12** contains the entire particle content of the raw slurry R, the relatively fine particles from the gravity separation means **30** and from the lower discharge outlet of the liquid cyclone means **20** as well as the relatively large particles contained in the lower discharge U2 of the second stage liquid cyclone means **20,** the extent of such large particles in the lower discharge U2 of the liquid cyclone means **20** being so small as to be negligible. The addition or blending of the overflow discharge O from the gravity separation means **30** which is rich in liquid, with the raw slurry R assures a desirable liquid content in the supply slurry E.

The conditions under which the gravity separation means **30** operates may indicate that it is advisable to provide the latter with the capability of regulating the flow of liquid. The best type of operation of the method and apparatus of the invention, from the standpoint of economy, is provided when the entire lower discharge U1 of the first stage is delivered to the gravity separation means **30.** However, it is possible to encounter situations where the concentration of particles smaller than the desired size is too great in the gravity separator. Thinning of the slurry with additional fresh liquid may result in the addition of more liquid than should be supplied for achieving a desired minimum concentration of particles smaller than a given size in the final fraction F. It is advisable, therefore, in such case to branch off from the lower discharge outlet of the first stage liquid cyclone means **10** part of the substantially dewatered matter by way of the adjustable distributor means **18** and the additional conduit means **19.** In the event that the concentration of particles smaller than the desired size is too small in the gravity separation means **30,** it is possible to deliver by way of the additional conduit means **29** and the adjustable distributor means **28** part of the matter discharged from the lower outlet of the liquid cyclone means **20** of the second stage to the gravity separation means **30.**

In the case of a non-uniform delivery of slurry to the sump means **11** or the sump means **21** which might result in a sharp drop of the liquid level in either one or both of the sump means, it is possible by way of the floats **16** and **26** to raise the liquid level in the sumps so as to prevent the liquid level therein from dropping undesirably.

The method and apparatus of the invention which is schematically illustrated in FIG. **2** is similar to that of FIG. **1.** The difference is that this method and apparatus of FIG. **2** includes a wet-grinding apparatus **2** which provides a wet-ground product M to be delivered by way of the discharge means **3** of the wet-grinding means **2** to the sump means **11** of the first stage. Thus, with the method and apparatus of FIG. **2** a wet-grinding apparatus and process is incorporated into the method and apparatus of the invention. This wet-grinding means **2,** which may take the form of a ball mill, is thus situated in advance of the liquid cyclone means **10** of the first stage. The raw slurry R is delivered in this case by way of a conduit means **1** to the inlet of the wet-grinding means **2.** In addition, the relatively large particles separated at the gravity separation means **30** and discharged therefrom by way of the outlet **32** is delivered to the inlet of the wet-grinding means **2.** In the case where an additional conduit means **19** is provided as set forth above, this conduit means **19** also delivers part of the lower discharge of the liquid cyclone means **10** to the inlet of the wet-grinding means **2.**

According to this embodiment of the method and apparatus of the invention the particles larger than the desired size which are separated from the raw slurry R are ground in the wet-grinding means **2** and returned to the sump means **11** so that there is a closed circuit along which the separated relatively large particles travel with only liquid and particles smaller than a given size in the final fraction F being separated from the closed circuit.

In the embodiment of the invention which is illustrated in FIG. 3, an installation of the above type is even further improved. With the embodiment of FIG. 3 the wet-ground product which is the output of the wet-grinding means 2 is delivered to a vibrational sedimentation settling means 40 having a series of screens or cones 41 which serve to transport the settled sedimentation product, these screens 41 vibrating along an elliptical path, for example. The settled sedimentation product S is returned by way of the conduit 42 into the wet-grinding means 2. The vibrational movements of the screens at the sedimentation settling means serve not only to transport the settled product but also serve to set the liquid in the sedimentation means 40 into motion, this vibratory movement of the liquid particles in the sedimentation means 40 also serving to separate the relatively large particles from the smaller desired particles. The inlet of the sedimentation means 40 receives not only the overflow discharge M from the wet-grinding means 2, by way of the conduit 3, but also the discharge conduit means 27 serves in this case to deliver the lower discharge matter from the liquid cyclone means 20 of the second stage to the inlet of the sedimentation settling means 40, and in addition the overflow discharge 33 from the gravity separation means 30 is delivered to the inlet of the sedimentation settling means 40, so that the thickness of the slurry which is treated in the sedimentation settling means 40 is of a sufficiently low order. The product which overflows out of the sedimentation settling means 40 forms a supply fraction Q which is delivered to the sump means 11 as illustrated in FIG. 3. The incorporation of such a sedimentation settling means into the method and apparatus of the invention brings about a preliminary classification of the wet-ground product and thus avoids undesirable circulation of particles of an undesirably large size.

Of course it is to be understood that the position of the parts is schematically illustrated. Thus it will be noted that the various components are arranged so that for the most part flow will take place gravitationally except for the use of the pumps 12 and 22. It will be noted that with respect to the sedimentation settling means 40, the depending series of fingers or cones 41, which may also take the form of suitable screens, carry out a vibratory elliptical motion which causes the heavier larger particles to be conveyed upwardly toward the left, as viewed in FIG. 3, these heavier larger particles which settle being transferred in this way from one set of fingers to the next, and this upward feeding will also cause the settled heavier particles to be moved along the feed line 42 into the wet-grinding means 2, while the lighter smaller particles remain suspended in the liquid and overflow, as shown at Q, back into the sump 11. However in an actual construction the upper end of the sedimentation-settling means could easily be arranged with respect to the inlet of the wet-grinding means so that the heavier particles settled out of the slurry in the sedimentation-settling means flow downwardly into the inlet of the wet-grinding means 2, or any other arrangment may be provided for assuring a flow as illustrated.

In order to illustrate the superior performance achieved with the present invention, data resulting from three tests are illustrated in the following table. In these tests the raw slurry R had a granular distribution according to which 29 percent by weight of the particles had a diameter greater than 0.6 mm, 24 percent by weight had a diameter of between 0.3 and 0.6 mm, 27 percent by weight had a diameter of between 0.053 and 0.3 mm, and 20 percent by weight had a diameter of less than 0.053 mm. In the table the upper portion designates as "Finished Material" the yield of fine particles less than a given size in the final fraction, while the lower portion of the table illustrates the extent to which coarse particles greater than the desired size were eliminated. Also, the table illustrates the distribution of the granular materials of various size ranges in percent by weight. In column I the data is illustrated for a method and apparatus utilizing a single liquid cyclone. Column II illustrates the performance with an installation according to Austrian Pat. No. 269,018, where only the matter discharged from the lower end of the second-stage liquid cyclone is fed to the gravity separation means which is in the form of a seven-stage horizontal gravity separator according to Austrian Pat. No. 253,436. In column III are the data achieved with the method and apparatus of the present invention as illustrated in FIG. 1, where two thirds of the dewatered matter issuing from the lower end of the first-stage liquid cyclone 10 was delivered to the gravity separation means 30.

Table

	I	II	III
Finished Material			
Yield	30	22	30
Grain dispersion: diameter d in mm			
d > 0,6	8	2	1
0,6 ≧ d ≧ 0,3	19	12	11
0,3 > d ≧ 0,053	37	38	38
0,053 > d	36	48	50
Coarse Material			
Yield	70	78	70
Grain dispersion: diameter d in mm			
d > 0,6	38	37	41
0,6 ≧ d ≧ 0,3	26	27	30
0,3 > d ≧ 0,053	23	24	22
0,053 > d	13	12	7

In all three cases the final fraction had a concentration of particles of 33–35 percent by weight.

From the table it is apparent that in test I, the yield of particles less than the desired size nevertheless contained 27 (19 + 8) percent by weight of granular material larger than the desired size, while the yield of fine particles with the remaining two tests is substantially better and practically equal. On the other hand, it will be noted from the bottom of columns II and III that the yield of coarse particles larger than the desired size nevertheless contained 12 percent by weight of particles of the smallest size in the case of test II and only 7 percent by weight of these particles of the smaller size with the present invention. Such inclusion of the extremely fine particles represents an undesired and unavoidable useless product of the grinding, which occurs during reduction in the size of a material such as ore, for example, and the transfer and inclusion of such fine particles with the coarse particles which are eliminated should be avoided to the greatest possible extent because these extremely fine particles are not extracted from the entire process and in particular load a mill such as the mill **2** which is included in the installation. Thus, the reduction of the extent of inclusion of extremely fine particles in the yield of coarse particles from 12 percent by weight down to 7 percent by weight with the present invention represents a highly important and very significant advance since it becomes possible in this way to reduce the amount of material which is required to be processed in the mill by 10 percent so that the grinding mill itself can be of a smaller size. Above all, however, reference should be made to the improvement in the yield of fine particles which with the method and apparatus of the present invention (column III) is 30 percent by weight whereas with the known installation (column II) this yield is only 22 percent by weight.

It is to be noted that the Austrian Pat. No. 253,436 shows a horizontally arranged multi-stage gravity separation unit which has a bucket wheel for removing the large particles which settle and at least one distributing bucket wheel for providing a repeated distribution of the settled material into the supplied fresh liquid which flows in countercurrent to the distributed material. Thus, for the purposes of the method and apparatus of the present invention it is important not only to achieve a sufficiently sharp separation with respect to the size ranges of the granular material, but also it is important that the method and apparatus be capable of handling a considerable load of solid particles and not require more water than is necessary for adjusting the concentration of the particles in the final fraction. These requirements can be fulfilled with a horizontal gravity separation means of the latter type.

What is claimed is:

1. In a slurry-treating method for obtaining a final fraction in which particles smaller than a given size are suspended in a given concentration, the steps of feeding the slurry which is to be treated initially to a first liquid cyclone having an upper overflow fine fraction discharge and a lower discharge for a substantially dewatered coarse fraction, then feeding the overflow fine fraction discharge from said first liquid cyclone to a second liquid cyclone having an upper overflow discharge for the final fraction and a lower discharge for a substantially dewatered coarse fraction, feeding the substantially dewatered coarse fraction from said first liquid cyclone to a gravity separator while maintaining at said gravity separator a load which is formed primarily by said coarse fraction from said first liquid cyclone and while supplying fresh liquid to the gravity separator at a rate which controls the concentration of the particles in the final fraction, discharging particles larger than said given size from said gravity separator, and returning from said gravity separtor to said first liquid cyclone a slurry from which particles larger than said given size has been separated.

2. In a method as recited in claim **1** and including the step of returning at least a major part of the substantially dewatered coarse fraction discharged from said second liquid cyclone to said first liquid cyclone while bypassing said gravity separator with said major part of said coarse fraction discharged from said second liquid cyclone.

3. In a method as recited in claim **1** and including the steps of wet grinding a raw slurry while simultaneously wet grinding with the raw slurry the particles larger than said given size discharged from said gravity separator, to achieve a wet-ground product made up in part of the raw slurry and in part of the particles of said larger size discharged from the gravity separator, and feeding the thus-achieved wet-ground product to said first liquid cyclone together with the discharge from the gravity separator from which the particles larger than said given size have been separated and to which liquid has been added for controlling the concentration of the final fraction.

4. In a method as recited in claim **1** and wherein gravity separation of the dewatered coarse fraction from said first liquid cyclone is carried out in the gravity separator in a plurality of successive stages in which the fresh liquid flows in countercurrent to the matter derived from the first liquid cyclone so that particles included in the substantially dewatered coarse fraction discharged from the first liquid cyclone are washed at least once by the liquid fed to the gravity separator.

5. In a method as recited in claim **3** and wherein prior to return of the wet-ground product and discharge from the separator to the first liquid cyclone, the wet-ground product and the discharge of the gravity separator from which particles larger than a given size have been separated are subjected to vibrational sedimentation which produces a sedimentation overflow product and a sedimentation settling product, returning the sedimentation overflow product to said first liquid cyclone and returning the sedimentation settling product to the wet grinding operation together with the raw slurry and particles larger than said given size separated at the gravity separator.

6. In a method as recited in claim **1** and wherein the particles larger than given size separated at the gravity separator and at least part of the dewatered coarse fraction discharged from said first liquid cyclone are extracted as matter having undesired coarse particles which are larger than desired.

7. In a method as recited in claim **2** and wherein at least part of the substantially dewatered coarse fraction discharged from the second liquid cyclone is fed to the gravity separator only as a small part of the load thereof.

8. In a method as recited in claim **3** and wherein at least part of the substantially dewatered coarse fraction discharged from the first liquid cyclone is wet-ground together with the raw slurry and particles of said larger size discharged from the gravity separator, so that part of the dewatered matter discharged from the first liquid cyclone contributes to the wet-ground product.

9. In a method as recited in claim **5** and wherein at least part of the substantially dewatered coarse fraction discharged from the second liquid cyclone is also subjected to the vibrational sedimentation.

10. In a slurry-treating apparatus for obtaining a final fraction in which particles less than a given size are suspended in a given concentration, first and second centrifugal separation stages each having at least one liquid cyclone means for providing an upper overflow fine fraction discharge and a lower discharge of a substantially dewatered coarse fraction, the upper overflow discharge of the liquid cyclone means of the second centrifugal stage providing the final fraction, first sump means for containing slurry to be treated, first pump means communicating with said first sump means and with the liquid cyclone means of said first centrifugal separation stage for feeding slurry from said first sump means to said liquid cyclone means of said first stage to be treated therein, second sump means for receiving the upper overflow fine fraction discharge from the liquid cyclone means of said first stage, second pump means communicating with said second sump means and with the liquid cyclone means of said second stage for feeding slurry from said second sump means to said liquid cyclone means of said second stage, gravity separation means and first discharge conduit means communicating therewith and with the lower discharge of said liquid cylone means of said first stage for directing the substantially dewatered coarse fraction discharged from the latter liquid cyclone means to said gravity separation means and for loading said gravity separation means primarily with the coarse fraction from said first stage, liquid supply means communicating with said gravity separation means for supplying liquid thereto at a rate which controls the concentration of the particles in the final fraction, said gravity separation means separating particles larger than a given size from the suspension treated by said gravity separation means, overflow discharge means communicating with said gravity separation means for discharging from the latter and feeding to said first sump means a suspension from which the particles larger than said given size have been separated by said gravity separation means, so that any particles smaller than said given size contained in the coarse fraction of said first stage are returned to the latter by said gravity separation means, and second discharge conduit means communicating with the liquid cyclone means of said second stage for receiving the lower discharge of substantially dewatered coarse fraction therefrom and for delivering at least the greatest part of the latter dewatered coarse fraction also to said first sump means, so that said gravity separation means is not loaded by the greatest part of the coarse fraction of said second stage.

11. The combination of claim **10** and wherein an adjustable distributor means is operatively connected with said first discharge conduit means for delivering a major part of the lower discharge of the liquid cyclone means of the first stage to said first conduit means to be delivered thereby to the gravity separation means, and an additional conduit communicating with said adjustable distributor means for receiving a minor part of the lower discharge of said liquid cyclone means of said first stage therefrom and for delivering the latter part to said first sump means.

12. The combination of claim **10** and wherein an adjustable distributor means is operatively connected with said second discharge conduit means for delivering a major part of the dewatered matter discharged from the liquid cyclone means of said second stage to said second discharge conduit means, and additional conduit means operatively connected with said adjustable distributor means for optionally directing a minor part of the lower discharge of the liquid cyclone means of said second stage to the gravity separation means as only a small part of the load thereof.

13. The combination of claim **10** and wherein a branch conduit means communicates on the one hand with the upper overflow discharge of the liquid cyclone means of the first stage and on the other hand with said first sump means for delivering part of the upper overflow discharge of the liquid cyclone means of the first stage to said first sump means, adjustable valve means carried by said branch conduit means, and float means situated in said first sump means and operatively connected with said adjustable valve means for controlling the latter to maintain a given level of slurry in said first sump means.

14. The combination of claim **10** and wherein a branch conduit means extends from the upper overflow discharge of the liquid cyclone means of the second stage to said second sump means for returning part of the final fraction to said second sump means, adjustable valve means carried by said branch conduit means, and float means situated in said second sump means and operatively connected with said adjustable valve means for controlling the latter to maintain a given level of slurry in said second sump means.

15. The combination of claim **10** and wherein a wet grinding means has an outlet communicating with said first sump means for delivering a wet-ground product thereto, feed means communicating with said gravity separation means and an inlet of said wet grinding means for delivering to the latter the particles larger than said given size separated by said gravity separation means, adjustable distributor means operatively connected with said first discharge conduit means for delivering a major part of the dewatered coarse fraction discharged from the liquid cyclone means of said first stage to said first discharge conduit means, and additional conduit means communicating with said adjustable distributor means and with the inlet of said wet grinding means for delivering a minor part of the dewatered coarse fraction discharged from the liquid cyclone means of the first stage also to said wet grinding means.

16. The combination of claim **15** and wherein a vibratory-screen sedimentation means is situated in the path of flow from the outlet of said wet grinding means to said first sump means for subjecting the wet ground product first to sedimentation prior to delivery to said first sump means, said sedimentation means having an overflow outlet for delivering the product subjected to sedimentation to said first sump means, the overflow separation discharge from said gravity separation means also communicating with said sedimentation means and said second discharge means communicating with an inlet of said sedimentation means for directing dewatered matter discharged from the liquid cyclone means of the second stage to said sedimentation means to be treated therein prior to delivery to said first sump means, said sedimentation means having an outlet for separated particles communicating with an inlet of said wet grinding means for delivering settled particles from said sedimentation means to said wet grinding means.

17. The combination of claim **10** and wherein said gravity separation means includes a plurality of horizontally arranged stages in which the particles flow in countercurrent to the liquid supply by the liquid supply means so as to be washed thereby, said gravity separation means including rotary bucket wheel for discharging the particles of larger size separated by the gravity separation means and at least one distributing bucket wheel for distributing the particles of larger size which settle in the gravity separation means in countercurrent to the liquid supplied by the liquid supply means.

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