ABSTRACT: Method and apparatus for determining the particle size distribution in a slurry in a grinding circuit with the method and apparatus operative in an online manner and at frequent intervals for effecting this determination. A high-speed computer is used to better control the operation of the circuit. Such particle size distribution, obtained through a determination of the cumulative percentage of solids in the grinder output slurry, is regulated in relation to the infeed of slurry material into the grinder as a predetermined function of the weight of new material introduced into the grinder unit circuit, the known particle size distribution of that new material from classifiers returned as infeed to the grinder and the calculated particle size distribution of that overflow material.
83 PERCENTAGE OF SOLIDS DETERMINING APPARATUS

FIG. 4
SLURRY PARTICLE SIZE DETERMINATION

The present patent application is a continuation of an earlier-filed patent application Ser. No. 601,608, filed Dec. 14, 1966 now abandoned.

In the milling and grinding of mineral ores, it is desirable to know the particle size distribution at frequent and regular intervals in order to determine how the grinding operation is proceeding, to check the operation of the classifiers and to ascertain whether liberation of the desirable mineral elements has proceeded as intended.

It has been known in the prior art to take a sample of the output slurry from the grinding circuit and apply it to a device in diluted form, the size and number of the particles being counted by photoelectric or other methods. Another prior art particle measurement technique is to wash the sample through a series of screens having different mesh sizes, and to then dry and weigh the amount of solid material retained on each screen.

In the desired operation of the grinding mill, the particle size in the output slurry has to be fine enough such that the right and desired grade is reached. If the particles are ground too fine, slimes are formed which inhibit flotation and cause valuable mineral to pass to tailings. On the other hand, if the particles are ground too coarse there is an inadequate separation of the desired mineral from the host rock. It should be further noted that the subsequent flotation process, employing a coating agent such as lead xanthate which has a special affinity for metal sulfide particles and causes them to adhere to air bubbles, themselves produced by the presence of a frothing agent, requires a consistent particle size distribution in the feed slurry for optimum performance of the flotation process.

It is an object of this invention to provide an improved measurement method and apparatus operative to better determine the particle size distribution in the output of a mineral-grinding circuit where the output is contained in a form which is adapted for sensing of the density and flow conditions thereof.

It is another object of the present invention to provide an improved technique for the determination of particle size in the output of a mineral ore-grinding circuit, which technique is better adapted for online operation with a high-speed computer for better controlling the operation of the grinding circuit.

It is further object to provide an improved control method and apparatus for the operation of a mineral-grinding circuit wherein a better control of particle size distribution is obtained through a determination of the cumulative percentage of solids in the output slurry from the grinding device.

Experimentation shows that the separation of solids fed to a fixed cyclone classifier is a function of the inlet velocity and particle size. Thus, for a given output slurry from the grinder at a given density and inlet velocity, the fraction of solids in the overflow from the classifier cyclone to the total solids fed to the inlet of the classifier cyclone is a measure of the percentage of solids which were below the corresponding particle size or mesh number for that particular mineral ore. By varying the inlet velocity, the percentage at the particle size corresponding to that new velocity may also be determined, and repeatedly so over the range of particle sizes which is of interest in the particular application where this technique is applied.

In accordance with the teachings of the present invention, at any given instant of time, the cumulative percentage of solids Φ in the overflow from the cyclone classifier may be expressed in accordance with the following formula:

\[ \Phi = \frac{D_2 - D_1}{F_2 - F_1} \]

where \( F_1 \) and \( F_2 \) are in volumetric units and \( D_1 \) and \( D_2 \) are in specific gravity units. Experimentally the mesh number or limiting particle size \( d \) corresponding to a given \( F_1 \) and \( D_1 \) will have been determined. The computer will set \( F_1 \) at various values, measure the quantities \( D_1, F_2 \), and \( D_2 \), and calculate the corresponding values of \( \Phi \). These may be printed out and/or the data used to regulate the classifiers and mesh so that the desired particle size distribution information is obtained for the grinder device.

Additionally, in accordance with the teachings of the present invention, the particle size distribution is regulated in relation to the infed of slurry material into the grinder unit as a predetermined function of the weight of new material introduced into the grinder unit circuit, the known particle size distribution of that new material, the weight of the overflow material from the classifiers returned as infed to the grinder unit and the calculated particle size distribution of that overflow material.

For a more detailed understanding of the present invention both as to its organization and its method of operation together with additional objects and advantages thereof, reference should be made to the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a diagrammatic showing of the present control apparatus, including the condition-sensing devices, operative to determine the particle size distribution in accordance with the teachings of the present invention;

FIG. 2 shows the general arrangement of a typical ore-grinding installation and including the measurement cyclone classifier in accordance with the teaching of the present invention;

FIG. 3 shows a curve to illustrate the technique for determining the reduction modulus \( N \) and the size modulus \( K \) in accordance with the present invention;

FIG. 4 illustrates a modification of the particle size distribution sensing apparatus which enables the regulation of the particle size distribution;

FIG. 5 illustrates the additional feature of regulating the particle size distribution of the infed material supplied to the grinding mill; and

FIG. 6 illustrates the already well-known relationship between particle size distribution, particle size and percentage of solids in the slurry.

In FIG. 1. there is shown a grinder 10 for grinding a water slurry of mineral ore to a desired particle size for some subsequent separation operation which is per se well known at the present time. The output of the grinder 10 is fed through a conduit 11, while a sample of the output is fed to a measurement cyclone classifier 16 which is per se well known in the art and operative to overflow the smaller sizes of particles of mineral ore through an overflow outlet 18. In the output slurry from the measurement cyclone classifier 16 as supplied through conduit 18 there is included a flow-sensing device 22 and a density sensing device 24 from which the overflow slurry is fed back to the grinder through a conduit 26.

In FIG. 1. there is shown a slurry-holding tank 30 for receiving at least a sample amount of the output slurry from the grinder 10 supplied through conduit 32. A pump 34 is operative to pump material slurry from the tank 30 and supply it through the flow-sensing device 12 and density-sensing device 14 leading to the measurement cyclone classifier device 16. The slurry pump 34 is preferably operated in a continuous manner and should not be throttled, but rather maintains a constant flow, with the bypass valve 36 being regulated by a flow controller 38 as determined by the computer 46 to be operative to bypass the undesired portion of the mineral slurry back into the holding tank 30 as will be subsequently explained. Water is supplied from a water supply 39 through a control valve 40 in accordance with the operation of a density controller 42 having a manual set point signal applied to input to provide a predetermined percentage operation of solids by weight in the flow of slurry fed into the measurement cyclone classifier device 16.

The flow-sensing device 12 is operative with the material slurry supplied by the pump 34 to provide a control signal to the flow controller 38 in accordance with the instantaneous flow into the measurement cyclone classifier 16. The flow
controller 38 is operative with a reference flow set point signal supplied by the computer 46 to determine the operation of the bypass valve 36 to provide this predetermined and desired flow \( F \) through the conduit 48 leading to the measurement cyclone classifier device 16. The density-sensing device 14 is operative as a transducer to provide an output signal \( D \) in accordance with the instantaneous density of the slurry passing through the conduit 48, which control signal is supplied to a density controller 42 to be compared with the reference density set point supplied through the input 44 for determining the operation of the control valve 40 to regulate the instantaneous density in terms of solids by weight in the slurry passing through the conduit 48.

The computer 46 similarly receives a control signal \( F_2 \) in accordance with the flow of the slurry in the overflow conduit 26 from the measurement cyclone classifier device 16 and the density-sensing device 24 provides a control signal \( D_2 \) to the computer 46 in accordance with the density of the overflow slurry passing through the conduit 26 from the measurement cyclone classifier device 16.

The output underflow slurry flow from the fixed bottom apex valve 20 of the classifier device is returned to the grinder through the conduit 27. The overflow material from the classifying device 16 is returned to the grinder through the conduit 26. New material is supplied to the grid circuit from the classifier device 50. A mixing device 52 collects the various input feeds of slurry to the grinder 10 and feeds these to the grinder device 10.

In FIG. 2 the grinder 10 is shown operative with the measurement cyclone classifier 16 and additionally with a plurality of separators 60, 62, 64 and 66. The measurement cyclone classifier 16 is a smaller device handling 40 or 50 gallons per minute whereas the output from the grinder 10 may be in the order of 1,000 gallons per minute or so and the production cyclone classifiers are substantially large devices handling a much greater flow of material slurry for production classification, with the desired overflow output slurry therefrom being passed through the conduit 68 to a subsequent process such as a well-known flotation process to separate the mineral ore from the remaining rock and similar undesired materials.

It was known in the prior art to operate a measurement cyclone classifier manually on a sampling basis by initially calibrating the classifier by feeding it with slurry of a given density and a given velocity and then manually measuring the limiting particle size \( d \) of the overflow slurry passing through the screen or photocell-type device or the like. This operation was repeated several times to establish the relationship between input slurry flow and overflow particle size. The operation contemplated by the measurement technique of the present invention leads itself to an online operation particle size classification installation.

In the operation of the control apparatus shown in FIGS. 1 and 2, and with particular reference to FIG. 1, the flow controller 38 is operative to control the valve 36 for varying the bypass of mineral slurry from the constant speed pump 34 in a predetermined manner as determined by the computer 46 to set a reference inlet velocity and its corresponding flow \( F_1 \).

The computer 46 then senses the respective output control signal \( F \), from the inlet flow-sensing device 12 and the control signal \( D \) from the inlet density-sensing device 14 and the control signal \( F_2 \) from the outlet flow-sensing device 22 and the control signal \( D_2 \) from the outlet density-sensing device 24 and calculates \( \Phi \) in accordance with the formula relationship:

\[
\Phi = \frac{F_2 (D_2 - 1)}{F_1 (D - 1)}
\]

To provide a determination of \( \Phi \) the cumulative percentage of solids in the overflow slurry from the measurement cyclone classifier device 16. Then this is repeated for several predetermined inlet velocities and corresponding values of \( F_1 \) is determined by the operation of the computer 46 to vary the set point of the flow control 38, with the density-sensing device 14 and density controller 42 being operative to regulate and maintain a reference density set point such as 40 percent solids by weight for the mineral slurry supplied to the measurement cyclone classifier device 16 through the conduit 48. In this manner a table for control operation of the grinder 10 may be plotted with the cumulative percentage of solids \( \Phi \) plotted as the ordinate versus the associated particle size \( d \) as the abscissa. With such a table any desired limiting particle size \( d \) can be obtained by a selection of the proper value of \( \Phi \) from that plotted table and then effecting the necessary control of the flow controller 38 to achieve the required operation of the bypass valve 36.

In FIG. 3 there is shown a curve to illustrate the plotted relationship of log \( \Phi \) versus log \( d \), where \( \Phi \) is the cumulative percentage of solids and \( d \) is limiting particle size. The limiting particle sizes \( d \) of each of a given two samples are known from previous calibration and the cumulative percentage of solids \( \Phi \) for those samples are calculated as previously explained. This will yield the quantities \( \Phi_1 \) and \( \Phi_2 \) for those samples.

On the resulting straight line portion of the curve 69 including points 1 and 2 for the respective two samples as shown in FIG. 3, any point can be defined according to the following equation:

\[
\log \Phi = n \log d + \log C
\]

when \( \Phi = 100, \log d = \log K \)

therefore, \( \log 100 = \log K + \log C \)

from which, \( \log C = \log 100 - \log K \)

therefore, \( \Phi = \log 100 + n (\log d - \log K) \)

or \( \log K = n \log d/d \)

Using the values \( \Phi_1 \) and \( d_1 \) for sample 1 in one application of the last equation and \( \Phi_2 \) and \( d_2 \) for sample 2 in a second application of the last equation, this will provide simultaneous equations which the computer can solve for the value of \( n \), the reduction modulus, and for the value \( K \), the size modulus.

The value \( n \) does not change appreciably throughout the normal particle size distribution range from a grinder for a given ore material, but the value \( K \) does change. The computer can use the value \( K \) determined in this manner to provide a control signal to regulate the size of the bottom apex value of the respective production classifiers in an effort to regulate the value \( K \) to a desired and known value for correcting undesired changes in the particle size distribution from the grinder output. The slope of the curve 69 shown in FIG. 3 is determined by the values of \( n \) and \( K \), with the intersection of the curve 69 being the value \( K \). With the \( n \) not changing appreciably throughout the desired operational particle size distribution from the grinder 10, the value \( K \) can be controlled between predetermined limits by the computer and in this manner control the overflow particle size distribution from the cyclone classifiers. It is preferable that the curve 100 shown in FIG. 6 not become too low since the smallest particle in the overflow should not be too small and it is also preferable that the curve 100 not become too high. For taconite ore, for example, 95 percent of the material should be less than 325 mesh or 40 microns in size. By controlling \( K \) in a manner to be later explained, the position of the curve 100 can be maintained within predetermined limits of \( K \) to yield the preferred particle size distribution from the grinding circuit. The following mathematical derivation for the calculation of the amount of solids in a mineral slurry can be utilized to derive the cumulative percentage of solids formula as above set forth.

**Computer Calculation of Amount of Solids in a Slurry**

Let \( D' \) = density of slurry (lb./ft.\(^3\)) as measured by a gamma gauge

\[ F' \] = flow rate of slurry (ft.\(^3\)/min.) as measured by a magnetic flow meter.

\( X = \) weight of solids (lbs.) per ft.\(^3\) slurry

\( Y = \) weight of water (lbs.) per ft.\(^3\) slurry

\( \delta X = \) density of solids lb./ft.\(^3\)

\( \delta Y = \) density of water lb./ft.\(^3\)

\( \epsilon = \) fraction of solids by weight in slurry (100 percent = 1.0)

Then \( K_2 = 1/\delta X \) and \( \delta Y = 1/\delta Y \)
5

Then one cu. ft. slurry, equating volumes,

\[ K_x X + K_y Y = 1 \]

dividing by

\[ x K_y - K_y Y = \frac{1}{K_y} \]

and

\[ \frac{y}{x} = \frac{1}{K_y} \left( \frac{1}{x} - K_x \right) = \frac{1}{K_y} \left( \frac{1 - z K_z}{x} \right) \]

Also

\[ C = \frac{x}{y - y} \]

\[ C = \frac{K_y}{C} \]

\[ C = \frac{K_y}{C} \]

and

\[ \frac{y}{x} = \frac{1 - C}{z} \]

From (1) and (2)

\[ \frac{1}{1 - z K_z} = \frac{1 - C}{K_y} \]

\[ C = \frac{K_y}{C} \]

\[ X = \frac{K_y - K_y C + K_y C}{C} \]

\[ X = \frac{K_y - K_y C}{C} \]

\[ D = \frac{z + y}{x} \]

For taconite: If

\[ K_y = \frac{1}{62.3} \text{ lb./ft.}^3 \]

\[ K_z = \frac{1}{5 \times 62.3 \text{ lb./ft.}^3} \]

\[ D' = \frac{1}{62.3} \left( \frac{62.3}{62.3} \right) = \frac{62.3}{62.3} = 1 - 0.8 C \]

Total mass flow = \( D' F \) lb./min.

Solids flow = \( C D' F \) lb./min.

Kearranging (5):

\[ 1 - 0.8 C = \frac{62.3}{62.3} \]

\[ C = \left( \frac{62.3}{62.3} \right)^{1/0.8} \]

Solids flow in any slurry = \( \left( 1 - \frac{D'}{62.3} \right) \cdot \frac{L'}{0.8} \)

\[ T \cdot D = \frac{D'}{62.3} = \text{Sp. gr. then } D' \]

\[ = 62.3 D \text{ and solids flow } = \frac{62.3}{0.8} \left( D' - 1 \right) \]

Assuming at cyclone inlet there is a flow \( F_1 \) and sp. gr. \( D_1 \) and at cyclone outflow there is a flow \( F_2 \) and sp. gr. \( D_2 \),

Then cumulative \( \frac{C}{C} = \frac{F_2 (D_2 - 1)}{F_1 (D_1 - 1)} \)

The measurement cyclone classifier is initially calibrated by manual experiment to determine the limiting particle size \( d \) in its overflow in relation to the inlet velocity or the directly related flow \( F \).

It should be noted that the present invention is applicable to particle size distribution control of a dry grinding process, such as is practiced in the grinding of hematite and in the manufacture of cement. A sample is removed and fed into a container of water, and then passed through a measurement cyclone classifier as already described, and then returned to the initial container. When the density of the resulting slurry has reached a desired value, for example 60 percent solids by weight, the determination of particle size distribution can take place as above described. The slurry is then passed back into the grinding mill. Since the flow of this slurry material will be small in relation to the new material infeed, and considerable heat is generated in the grinding process, no adverse effect on the moisture content of the raw material leaving the grinding mill will be realized. The associated computer can be programmed to control the sampling of the material to be taken into the container of water and to continue the same until the resulting density of the slurry is as desired, to stop the sampling and conduct the particle size testing by varying the flow rates as above described according to the particle size being measured. The computer can be made to periodically repeat this testing procedure on a regular basis, such as every 5 minutes, to give a continuous and current measurement of particle size distribution at the mill discharge.

An alternative presentation of the data may be made in the form of the instantaneous values of both size and reduction moduli current at the time of sampling.

In FIG. 4 there is shown a modification of the slurry grinder arrangement, with a two-way rotary valve 80 being operative in the conduit 82 to permit the slurry sample to be selectively removed from either one of the conduits of the material to be taken from the cyclone classifier. There can result under certain conditions of grinder operation, and when only the slurry sample is removed from the conduit 84 as shown in FIG. 2, a surging of the grinding operation due to corrections made through operation of the measurement cyclone classifier 16. However, by rotation of the valve 80 to permit a sampling of the slurry from the conduit 86 to provide a control anticipation effect, suitable control of the apparatus can be provided and the computer 46 can be programmed to vary the bottom apex values of the respective production classifiers 60, 62, 64 and 66 to vary the slurry underflow therefrom and thereby control the overflow particle size distribution.

As shown in FIG. 4 a slurry-sampling device, such as a four-section rotating funnel unit 88 having one section operative to divert a sample of the slurry, could be made operative with each of the production classifiers and periodically stepped in rotary position to sample sequentially the output overflow slurry from the different one of the production classifiers, on a one-at-a-time basis, such that the conduit 86 would then receive the overflow slurry sample from only the production classifier supplying a slurry sample through the funnel unit 88 during the particular period of time under consideration. During the operation of the funnel unit 88, the rotary position of the funnel unit 88 is determined by the associated computer 46 or other suitable controller. There are many well-known position-stepping devices that would be suitable in operation to control the rotary position of the funnel unit 88 as well as the position of the valve 80 in response to a control signal from the associated computer 46. In conjunction with positioning the rotating funnel unit 88 to sample the overflow output slurry from a selected one of the production classifiers, the computer 46 could control the size of the inflatable bottom apex valve of that same one production classifier to vary the underflow therefrom as desired to maintain the desired range of output particle size distribution from the grinder apparatus shown in FIG. 4. The size modulus \( K \) is calculated by the computer sequentially utilized to regulate the actual size of the bottom apex from of the involved production cyclone classifier.

More specifically, the rotary valve 80 is shown in FIG. 4 permits a determination of the particle size distribution both before and after the slurry material from the grinder passes through the production cyclone classifiers. With the valve 80 positioned as shown in FIG. 4, the measurement cyclone classifier within the percentage of solids-determining apparatus 83, corresponding to the apparatus shown in FIG. 1, operates in a manner already described in relation to the showing of FIG. 1, with the conduit 82 of FIG. 4 corresponding with the conduit 32 of FIG. 1. On the other hand, with the valve 80 positioned to connect the conduit 86 to the conduit 82, the computer 46 is instructed in its program to sequence to position the funnel unit 88 to sample the overflow output from each respective production cyclone classifier on a one-at-a-


In FIG. 5, there is an arrangement for regulating the particle size distribution of the infeed material supplied to the grinding mill 10. Through a mass balance technique, since the sum of the weights of the materials leaving a given cyclone classifier in the overflow and in the underflow is equal to the infeed of material, the computer 46 can determine the underflow particle size distribution from the calculated size modulus and corresponding particle size distribution in the conduit 84 leading to a classifier, such as the production cyclone classifier 60 for example, and the calculated overflow particle size modulus and corresponding particle size distribution in the conduit 86 leading away from the classifier. The computer 46 determines the weight \( W_S \) of the underflow slurry in the conduit 85 and the weight \( W_W + W_S \) of the infeed slurry in conduit 84 and the weight \( W_S \) of the overflow slurry in the conduit 86; it is per se already well known in this particular art how to determine these weights through the use of presently available devices employed for this purpose. The computer 46 determines the particle size distribution in the conduit 85 by solving for \( \text{psd}_d \) in the following relationship:

\[
W_f(\text{psd}_d) = W_f(\text{psd}_d) = W_f(\text{psd}_d)
\]

Now the computer 46 can control the speed of the motor 87 and thereby the feed of new material supplied to the grinder 10 to regulate the particle size distribution of the slurry within the container 89. FIG. 6 is provided to show the presently well-known relationship of particle size modulus \( K \) and corresponding particle size distribution of the overflow material 45 from a cyclone classifier illustrated by curve 100, the particle size distribution of the underflow material per curve 102 and the particle size distribution of the infeed material to the cyclone classifier illustrated by the curve 104. A family of these curves can be empirically determined and plotted in relation to variations of the limiting particle size of sand and the cumulative percentage of solids \( \Phi \) for a given cyclone classifier by persons skilled in this particular art. The curve 100 has been extended in a straight dotted line manner to indicate the size modulus \( K \) for the particular curve 100. Assuming the slope of the curve 100 does not appreciably change for the intended particle size range of the controlled grinding operation, the control of this size modulus \( K \) effectively determines the particle size distribution as desired. This information can be included in the programmed instructions given to the computer 46 to enable the computer to provide the desired particle size distribution information in relation to measured limiting particle size \( d \) and calculated cumulative percentage of solids \( \Phi \) in accordance with the above description.

The computer 46 can regulate the operation of the motor 87 shown in FIG. 5 to maintain a predetermined particle size distribution within the container 89 leading into the grinder 10, through operation of the following relationship between the readily determinable quantities, the known weight \( W_f \) of new material supplied by the feed conveyor 91 driven by the motor 87, the known weight \( W_l \) of underflow slurry from the cyclone classifier 60, the known particle size distribution \( \text{psd}_d \) of the new material, such as one-fourth inch to one thirty second inch or the like, and the particle size distribution \( \text{psd}_d \) of the underflow slurry from the conduit 85, and the combined weight \( W_r = W_l \) of the slurry within the container 89. The particle size distribution \( \text{psd}_d \) within the container 89 can now be calculated by the computer 46 from the following relationship:

\[
W_r(\text{psd}_d) + W_f(\text{psd}_d) = W_f + W_r(\text{psd}_d)
\]

and solving for \( \text{psd}_d \). Any difference from a predetermined or reference particle size distribution \( \text{psd}_d \) desired within the container 89 can be corrected through operation of the computer 46 to vary the speed of the motor 87 and thereby to vary the feeding of new material into the container 89 to hold more uniform the desired particle size distribution within the container 89. This greatly improves the operation of the grinder 10 in its operation to provide the desired particle size distribution to enhance the efficiency of subsequent mineral removal processes.

While a preferred embodiment of the present invention has been illustrated and disclosed herein, the present invention is not to be limited thereto in that many modifications are within the scope of the present teachings.

I claim:

1. In a control system for grinding apparatus supplying an output slurry to a measurement device, the combination of first means for initiating the feeding of a first inlet flow operation of said slurry to said measurement device and subsequently providing a second inlet flow operation of said slurry to said measurement device, second means for establishing a first cumulative percentage of solids in the overflow slurry leaving said measurement device during said first inlet flow operation and for subsequently establishing a second cumulative percentage of solids in the overflow slurry leaving said measurement device during said second inlet flow operation, third means for establishing the particle size modulus of said output slurry in accordance with a predetermined relationship between at least said first cumulative percentage of solids and said second cumulative percentage of solids, and fourth means for controlling the apparatus in accordance with said particle size modulus.

2. In a system for controlling the particle size distribution from a grinder supplying an output slurry to a measurement device, the combination of means for sensing predetermined flow and density conditions relative to a first operation of said grinder and for sensing said predetermined flow and density conditions relative to a second operation of said grinder, means for establishing a first cumulative percentage of solids in the slurry leaving said measurement device in accordance with said flow and density conditions for said first operation of said grinder and for establishing a second cumulative percentage of solids in the latter said slurry leaving said measurement device in accordance with said flow and density conditions for said second operation of said grinder, means for establishing the particle size modulus of said output slurry in accordance with a predetermined relationship between said first cumulative percentage of solids and said second cumulative percentage of solids, and means for controlling the particle size distribution of said output slurry from said grinder in accordance with said particular size modulus.

3. In a control system for a grinding device supplying an output slurry to a classifier device, the combination of first means operative with said output slurry from the grinding device for determining at least one of a first flow characteristic and a first density characteristic of the slurry supplied to said classifier device, second means operative with the slurry leaving said classifier device for determining at least one of a second flow characteristic and a second density characteristic of the slurry leaving said classifier device, third means operative with said first and second means for establishing the percentage of solids relationships in said
output slurry in accordance with a predetermined relationship between at least said one of said first flow characteristic and said density characteristic, and control means operative to control the operation of said grinding device in accordance with said percentage of solids relationship.

4. The control system of claim 1 with said measurement device being a measurement cyclone classifier and with said grinding apparatus including said production cyclone classifier, with said measurement cyclone classifier being operative with the output slurry from the grinding apparatus which appears in the overflow slurry from said production cyclone classifier, and with said third means for establishing the particle size modulus being operative in relation to the percentage of solids in the overflow from said production cyclone classifier.

5. The control system of claim 3, with said grinding device having a portion of said output slurry returned to said grinding device and including a new material supply, with said third means being operative to determine the particle size distribution in at least the slurry returned to said grinding device and with said control means being operative to control said new material supply to maintain a predetermined particle size distribution in the slurry supplied to said grinding device.

6. The control system of claim 1, with said grinding apparatus including a plurality of production cyclone classifiers, said combination including overflow slurry sampling means operative to supply said output slurry to said measurement device for sequentially sampling the overflow slurry from each one of the respective production cyclone classifiers, and with said fourth means being operative in response to said particle size modulus to control the particular production cyclone classifier being sampled.

7. The method of controlling a grinding system including a grinding device connected to supply an output slurry to a classifier device, the steps of determining a first flow and a first density of the slurry leading to said classifier device, determining a second flow and a second density of the slurry leaving said classifier device, establishing the particle size modulus of said output slurry in accordance with a predetermined relationship between said first and second flow and said first and second density, and controlling the particle size distribution of said output slurry in response to said particle size modulus.

8. The method of claim 7 with said classifier device being a measurement classifier device and with said grinding system including a plurality of production particle size classifiers, said method including the steps of determining in sequence the particle size modulus of a sample of the output slurry from each selected one of the respective production classifiers, and controlling the particle size distribution of the output slurry from the selected production classifier corresponding with the particular sample for which the particle size modulus has been determined.

9. In a control system for a grinding device connected to supply an unknown slurry to a classifier device having an output slurry, the combination of first flow-sensing means and first density-sensing means operative with the unknown slurry from the grading mill for determining respectively the inlet flow $F_1$ and the inlet density $D_1$ of the slurry supplied to said classifier device, second flow-sensing means and second density-sensing means operative with the output slurry of said classifier device for determining respectively the output flow $F_2$ and the output density $D_2$ of the output slurry of said classifier device, third means operative with said flow and density sensing means for establishing a percentage of solids relationship $\phi$ in said output slurry in accordance with the predetermined formula

$$\phi = \frac{F_2(D_2 - 1)}{F_1(D_1 - 1)}$$

and control means responsive to said percentage of solids $\phi$ in accordance with formula for controlling of operation of said grinding device to provide a desired operation of said grinding device.

10. The control system of claim 1, with said measurement device being a measurement cyclone classifier, with said grinding apparatus being operative with a production cyclone classifier, and with said measurement cyclone classifier being operative with said output slurry from the grading apparatus which appears in the overflow slurry from said production cyclone classifier, the combination including said third means being further operative to calculate the particle size modulus in relation to the particle size distribution in said overflow slurry, and with said fourth means being responsive to said particle size modulus to control the particle size distribution from said grinding apparatus.

11. The control system of claim 1, with said grinding apparatus having a portion of said output slurry returned to said grinding apparatus and including a new material supply, with said third means being further operative to determine the particle size distribution in at least said output slurry returned to said grinding apparatus and being operative to control said new material supply to maintain a predetermined particle size distribution in said output slurry from said grinding apparatus.

12. The control system of claim 3, with said grinding device including a plurality of production cyclone classifiers, said combination including overflow slurry sampling means operative with said first means for sequentially sampling the overflow slurry from each one of the respective production cyclone classifiers, and with said control means being operative to control the particle size distribution of the particular production cyclone classifier being sampled.

13. The method of controlling a grinding system connected to supply an output slurry to a classifier device, the steps of determining at least one of the flow and density of the slurry leading to said classifier device, determining at least one of the flow and density of the slurry leaving said classifier device, establishing the particle size modulus of said output slurry, and controlling the particle size distribution of said output slurry in response to said particle size modulus.

14. The method of claim 13 with said classifier device being a measurement classifier device and with said grinding system including a plurality of production particle size classifiers, said method including the steps of determining in sequence the particle size modulus of a sample of the output slurry from each one of the respective production classifiers and controlling the particle size distribution of the output slurry from each one of the respective production classifiers.