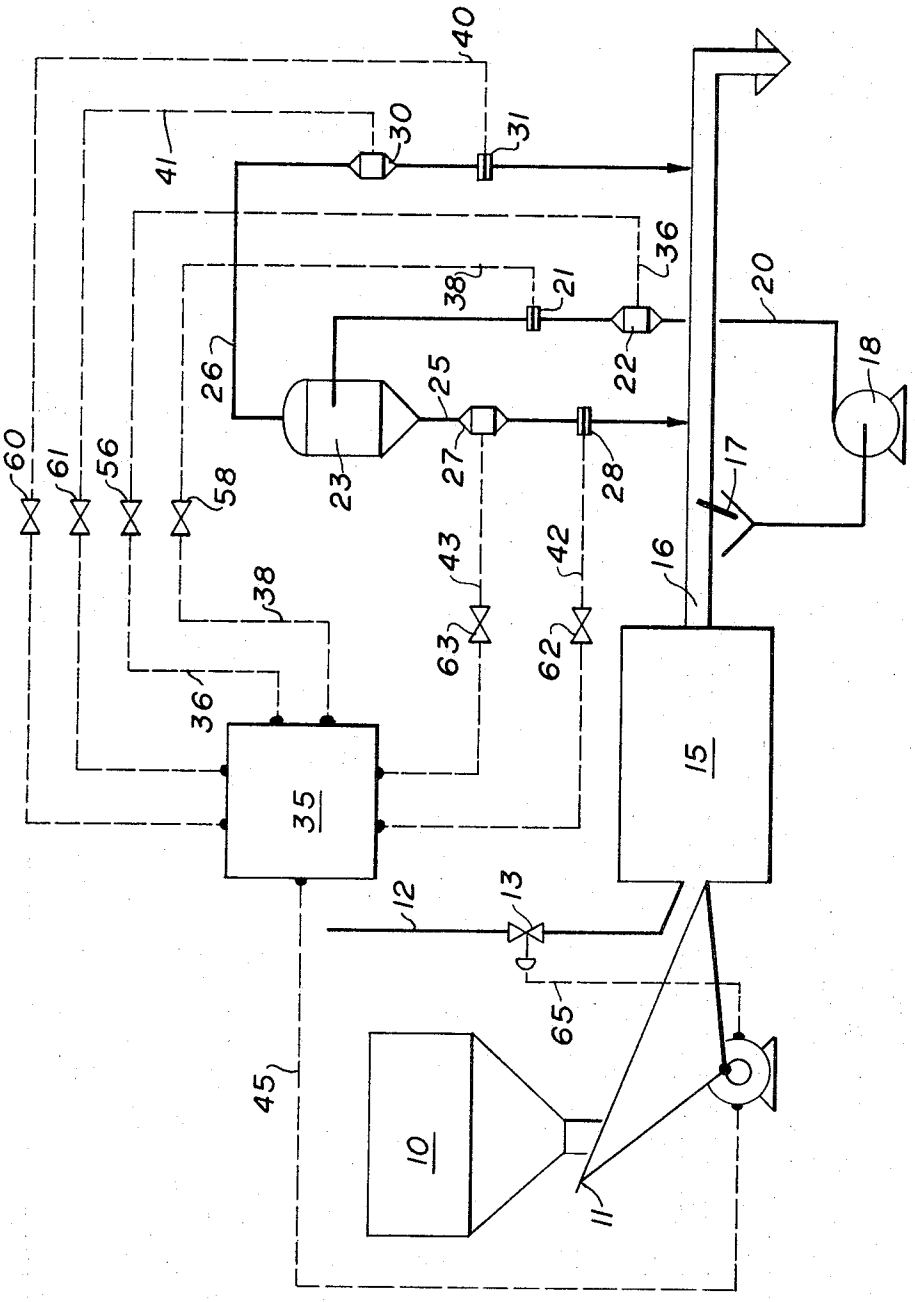
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GRINDING MILL AND METHOD OF OPERATION

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GRINDING MILL AND METHOD OF OPERATION

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This invention relates to open circuit grinding of solids.

Grinding mills for reducing the size of solid particles may be open circuit mills or closed circuit mills. A closed circuit mill is one in which the material being ground passes through the mill and is subsequently classified so that oversize product is isolated and returned to the grinding mill feed. An open circuit mill is one in which the product passes through the mill just once, and the mill operation must be controlled to obtain the desired size distribution in the mill product in the single pass. The advantage of an open circuit mill is that it is not necessary to subject the full product stream to classification and recirculation of the oversize.

Open circuit mills can presently be controlled by varying the feed rate, the amount of grinding medium charge, or the speed at which the mill rotates. When too much oversize appears in the product reducing the feed rate, increasing the grinding medium charge, or reducing the speed of the mill within its operating range, will reduce the average size of the product.

This invention provides an open circuit mill with a control system for producing particles in a desired range of sizes. The device of this invention includes a grinding mill of any suitable type which is capable of reducing large particles to smaller particles, and a variable rate solids feeder which may feed solids per se or solids entrained in a fluid, for example as an aqueous slurry. The solids are fed to the mill at a rate regulated by the variable rate feeder and are ground while passing through the mill.

The mill product passes from the mill to recovery equipment, typically flotation machines. In the operation of the present invention a pilot stream is removed from the main product stream and analyzed for particle size distribution. The pilot stream is very small in volume compared with the mill product stream. Good sampling techniques should be used to select a pilot stream that is representative of the product being produced.

The pilot stream is passed to a size classification device and classified into streams of larger particles and smaller particles at any useful division point. Three streams are then available for control; the pilot stream, the stream of large particles and the stream of small particles. Any two of the streams may be used as control streams. The control streams are metered to determine their total volume and density, and these values are integrated to determine the total solid content. Control of the mill feed is based on the ratio of the integrated values of small to large particles or the ratio of either small or large particles to the pilot stream which includes all particles. The values for the control streams are fed into a controller which is capable of holding a "set point" relationship between the control streams by adjustment of the solids feed rate.

The output from the controller regulates the feed rate to the mill by suitable adjustment of the feeding means and it is varied so that the particle feed rate is inversely proportional to the quantity of particles in the stream of larger particles from the size classifier or directly proportional to the quantity of small particles from the classifier. With either manner of controlling, as the amount of large particles in the product increases the feed rate to the mill decreases and the average particle size of the product becomes smaller.

This invention can be best described with reference to the accompanying drawing which illustrates a schematic representation of one device embodying the invention.

Referring to the drawing, solid feed from bin **10** is withdrawn by feeder **11** and mixed with water added from line **12** and controlled by valve **13**. The water is controlled as described hereinafter to provide a slurry of the proper density for grinding. The slurry is either formed before grinding, or it is formed directly in the mill **15**. Feeder **11**, the regulation of which will be described hereinafter, regulates the rate at which the solids are passed into mill **15**.

Mill **15**, which may be a ball mill or rod mill or other conventional grinding device, is operated at constant speed, and in passing through the mill from the inlet to the mill product stream, the solids are ground. The mill product passes through line **16** to equipment for beneficiating, filtering, drying or otherwise preparing it for its ultimate use.

Closely adjacent the outlet of the mill, sample cutter **17** withdraws a small portion of the mill product called the pilot stream and pump **18** passes the pilot stream through line **20** containing flow meter **21** and densimeter **22**, into a classification device **23**. In classifier **23** the pilot stream is divided into a stream containing large particles discharged through line **25** and a stream containing small particles discharged through line **26**. The stream of large particles in passing through line **25**, is metered through a means **27** for measuring the solids content of the stream, and through a means **28**, which measures the total flow of the stream after which the line **25** passes back into the main product stream in line **16**. The stream of smaller particles in line **26** similarly passes through a means for measuring the solids content shown at **30**, and a flow meter **31** after which it, too, passes back into line **16** rejoining the total mill product.

The broken lines in the figure indicate input into controller **35**, the input from each of the measuring devices being consistent with the device that is employed with it. The input may be varying electrical, pneumatic, hydraulic, or other energy forms which are proportional to the condition being sensed. It may also be emphasized here that all of the controls illustrated need not be used and in alternative modes of operating the invention it is sufficient to use only two of the illustrated streams for control. In one mode of operation which is perhaps the simplest, the steady operation of pump **18** provides an unvarying volumetric flow through the line **20**. In this method there is no need to measure the volume flow as with flow meter **21**. However, the density in line **20** must be measured as with instrument **22** in order to compare the total solids content of the pilot stream with whichever stream from the cyclone is to be used as the second control stream. As illustrated, the controller **35** is capable of accepting input from densimeter **22** through line **36**, in conjunction with measuring the flow rate at flow meter **21** and fed to the controller through line **38**. Lines **40** and **41** transmit an input from flow meter **31** and densimeter **30**, respectively, which are employed to meter the stream containing large particles. Similarly, the measurements from flow meter **28** and densimeter **27** provide input to controller **35** through lines **42** and **43**. respectively. Input from all of the sensing means is not necessary in this invention. For example, if controller **35** is to operate on the ratio of large particles to small particles, the input through lines **40**, **41**, **42** and **43** will operate the controller. Then the rate at which solids are fed through feeder **11**, operated by a control impulse passed from controller **35** through line **45**, is controlled by the relationship between the amount of larger particles in line **25** to the amount of

smaller particles in line **26**, comparing that relationship with a predetermined standard, i.e., the setpoint, and regulating the operation of feeder **11** to change the solids feed rate consistent with variations from the setpoint.

The controller **35** may also function by comparing the total solids input in line **20** with the either amount of larger particles in line **25** or the amount of smaller particles in line **26**. Since control of the mill of this invention is effected with two of the three streams available, means for producing discontinuity in the control lines are provided. These means are selected to be appropriate to the mode of transmitting signals, valves for pneumatic or hydraulic lines or switches for electrical, and are shown schematically as means **56, 58, 60, 61, 62** and **63** in lines **36, 38, 40, 41, 42** and **43** respectively. It is contemplated that at any time only four of the six lines will be operative.

Regardless of how the controller **35** functions it is evident that the device of the present invention provides an open circuit grinding mill which does not require classification of the full mill product stream and recirculation of oversize particles. The device of the present invention also does not require variable speed mill drive but effects control by the solid feed rate. The schematic drawing illustrates only one mode of controlling the solid feed rate although others may be used. The drawing also illustrates schematically that the liquid feed rate should be related ot the solid feed rate, and to this end a serial control system is shown wherein valve **13** is controlled through line **65** responsive to variations in the rate at which the solids feeder **11** is functioning. The liquid feed rate may also be controlled directly by controller **35**, or independently by sensing the particle loading in the feed or product streams.

Conventional and commercially available sensing devices and controllers are contemplated for use in this invention. Flow rate measuring devices such as flow meters, Venturi meters, Pitot tubes, positive displacement meters, etc. may be employed where indicated as **21, 28** and **31** in the schematic drawing, and densimeters **22, 28** and **30** may be any known means for measuring the solids content of a flowing stream.

Having thus described the invention,

What is claimed is:

1. An open circuit device for grinding solids which comprises:

(A) a mill for grinding solids,

(B) means for feeding solids to the mill at a variable rate,

(C) a classifier for separating a stream of solids entrained in a fluid into a stream of larger particles and stream of smaller particles,

(D) means for passing a pilot stream of ground solids entrained in a fluid stream from the mill to the classifier,

(E) means for measuring the solids content and flow rate of at least two of the pilot stream, the stream of larger particles and the stream of smaller particles,

(F) means for transmitting signals proportionate to said measurements to control means for:

(i) determining the total quantity of particles in each of the measured streams,

(ii) comparing the relationship of particle quantity in the control streams with a predetermined standard, and

(iii) regulating the solid feeding means to maintain the relationship at the predetermined standard.

2. A method for grinding solids which comprises:

(A) passing a mixture of fluid and solids into a constant-speed grinding mill,

(B) passing a mill product stream containing ground solids from the mill,

(C) passing a pilot stream from the mill product stream to a classifier which separates the pilot stream into a stream of larger particles and a stream of smaller particles,

(D) measuring the total particle content of two of the pilot stream, the larger particle stream, and the smaller particle stream and passing the resultant measurements as input to a controller which determines the relationship between the measurements,

(E) comparing the relationship between the measurements with a predetermined standard, and,

(F) regulating the solids feed rate to be directly responsive to the quantity of smaller particles when said relationship does not conform to the standard.

3. The method of claim **2** wherein the fluid content of said mixture of fluid and solids is regulated by the rate of solid feed.

4. The method of claim **2** wherein control of the solid feed rate is responsive to the relationship between the particle content of the larger particle stream and smaller particle stream.

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