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D. WESTON ET AL

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AUTOMATIC CONTROL FOR WET GRINDING MILLS

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2 Sheets-Sheet 1

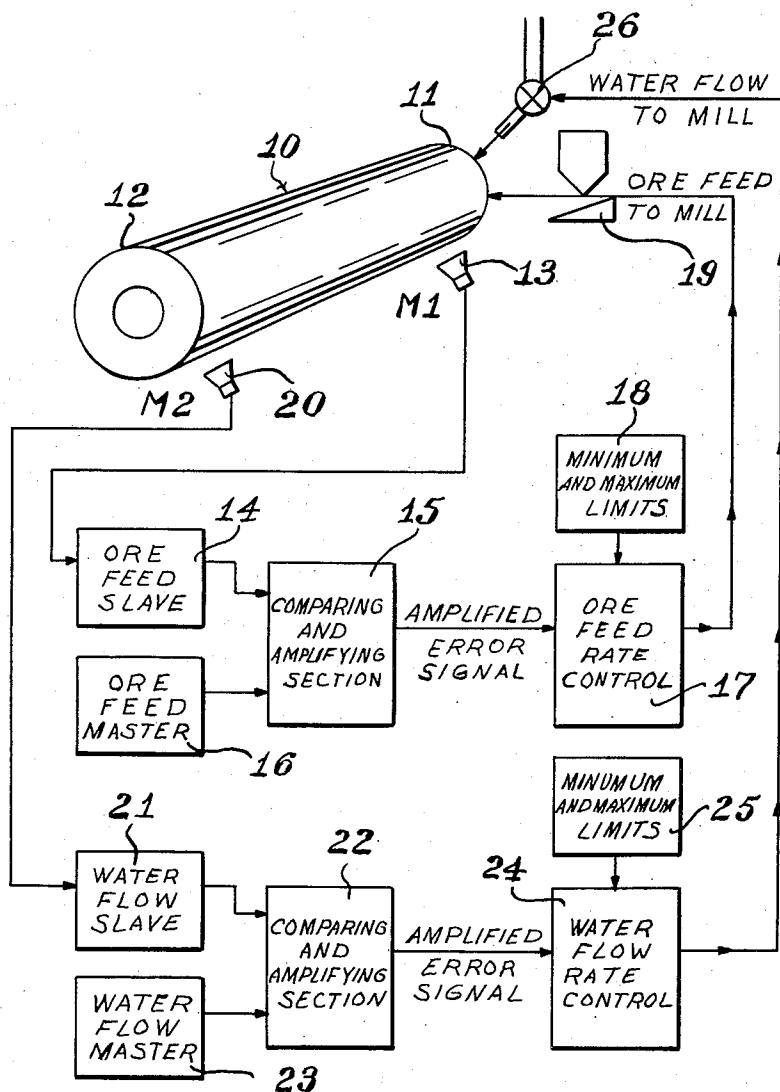


FIG. 1.

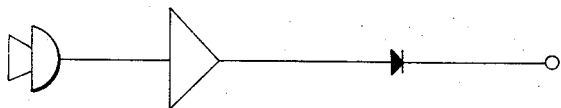


FIG. 1A

INVENTORS
DAVID WESTON &
STEWART W. DANIEL
BY *Smart & Biggar*
ATTORNEYS.

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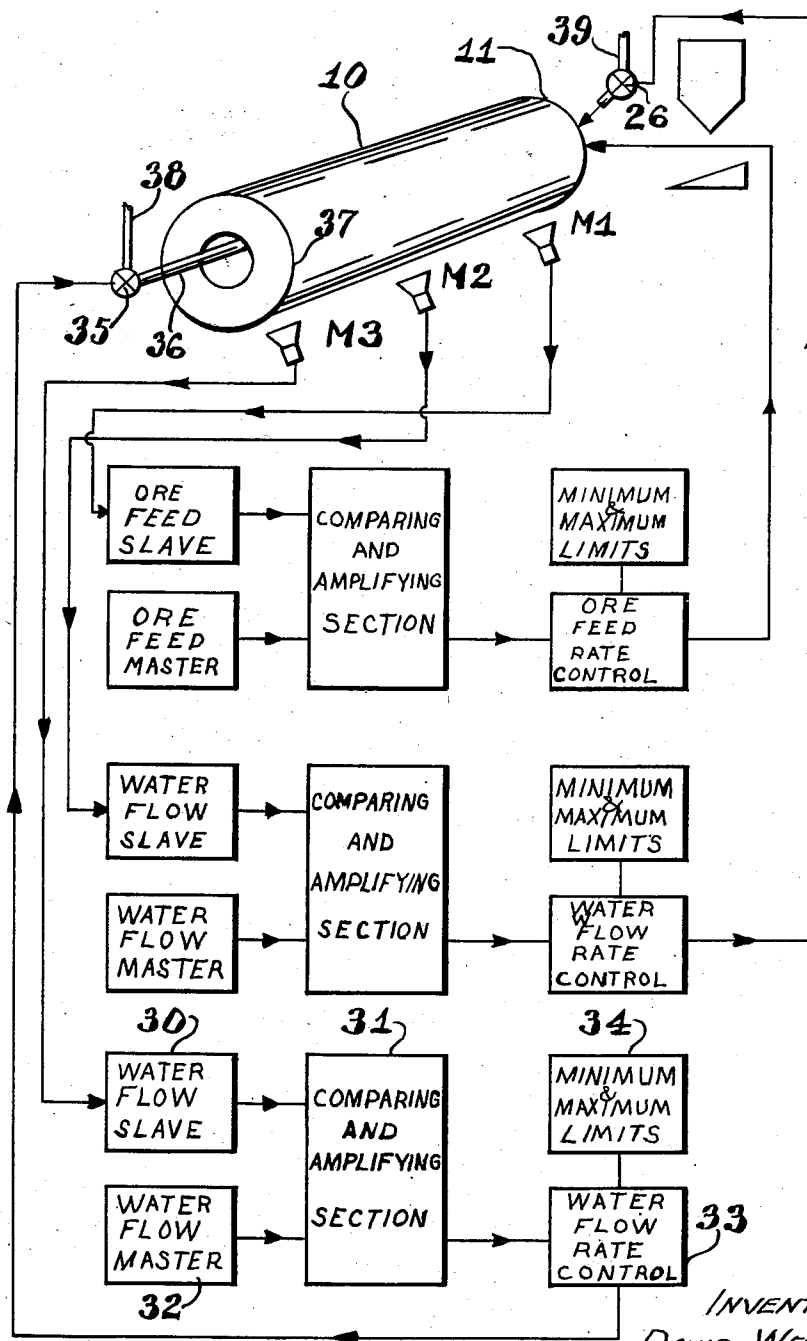


FIG. 2.

INVENTORS
DAVID WESTON &
STEWART W. DANIEL
By *Smart & Biggar*
ATTORNEYS

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AUTOMATIC CONTROL FOR WET GRINDING MILLS

David Weston and Stewart W. Daniel, Toronto, Ontario, Canada; said Daniel assignor to David Weston, Toronto, Ontario, Canada

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9 Claims. (Cl. 241—30)

This invention relates to the control of wet grinding mills, i. e. mills which are fed both liquid and solid feed components such, for instance as ball mills, rod mills, tube mills, pebble mills, and the like.

It has previously been proposed to regulate the feed supplied to such mills automatically in response to sound emanating from the mill. Various control systems in which this is done are described in Patent No. 2,766,940 of October 16, 1956, which employ a microphone which feeds a signal which varies with the magnitude of at least a selected frequency band of the noise produced by the mill to one or more comparators to produce error signals which are used to vary the rate of supply of solid and liquid feed to maintain the operating conditions of the mill substantially constant at a desired operating point. Such systems, while representing a substantial improvement over previously proposed control systems, were relatively insensitive to changes of viscosity in the charge brought about by changing ore conditions with the result that under certain conditions the mill would be permitted to operate at less than its maximum efficiency when a change in viscosity resulting from changed ore conditions took place.

It is the purpose of the present invention to improve on the said previously proposed systems by the use of at least two separately generated control signals, one of which is generally responsive to mill loading and is used to regulate the solids feed rate, and the other or others being generally responsive to pulp viscosity and used to regulate the liquids feed rate.

Other objects and advantages of the invention will become apparent as the specification proceeds.

During normal operation of a wet grinding mill, the conditions existing at the feed end of the mill are such that the solids feed substantially fills the voids in the ball charge. As the particles of solid feed are relatively coarse, variations in the relative amount of liquid feed have only a minor effect upon the viscosity of the charge. The principal effect of changes in relative amounts of solid and liquid feed present is a change in the pulp density of the charge. The sound emitted in this region will essentially reflect mill loading conditions.

Conditions at the outlet end of the mill are very different indeed. Here the solids are principally of relatively fine particle size and changes of pulp density are accompanied by relatively large changes in viscosity. If the viscosity is too high very little grinding work is done and energy is wasted in the work done simply moving the viscous charge. If the viscosity is too low the solids particles are too freely suspended in the liquid to be effectively engaged between the balls. The sound produced in this region of the mill is essentially a function of pulp viscosity for as the viscosity of the pulp increases the action of the balls becomes muffled due to their movement in the charge being resisted or dampened by the resistance to flow of the pulp. The optimum viscosity can readily be determined as a function of sound intensity, and in-

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creases and decreases in sound intensity from the predetermined optimum will respectively reflect too low and too high viscosities in the pulp which require correction by decreased and increased liquid-feed ratios respectively.

According to the invention the rates of solid feed to a wet grinding mill are controlled by the method which comprises continuously producing a first electrical signal which varies with mill loading in the region of the inlet side of the mill continuously producing a first reference signal of predetermined magnitude corresponding to a desired mill loading, comparing the said first electrical signal with the said first reference signal, varying the rate of feed of solids to the mill responsively to the difference between said signals whereby to increase the rate of solids feed when the mill loading is too low and vice versa, while the rate of feed of liquid feed is controlled by continuously producing a second electrical signal which varies with the viscosity at a selected region within the mill, continuously producing a second reference signal which corresponds to a desired viscosity and varying the rate of feed of liquid to the mill responsively to the difference between the said second signals whereby to increase the rate of liquid feed when the viscosity is too high and vice versa.

Preferably in mills of substantial length, viscosity responsive control signals are generated at two or more points along the length of the mill, each control signal being associated with a liquid supply which delivers liquid in controlled amounts to selected points within the mill.

Preferably also, according to the invention the rate of liquid and solid feed components will be controlled between maximum and minimum limits which are selected having regard to the general operating conditions which exist. It is desirable that neither feed component should be entirely cut off at any time and that the maximum feed rates in each case should not be unduly higher than those which will exist during normal operation in order to prevent localized variations in the conditions existing within the mill along its length.

The use of a monitoring control signal in conjunction with the method above outlined may prove advantageous in some circumstances. It is obvious that the system described lends itself to monitoring, and should this be employed it will generally be preferable to employ the type of monitoring system described in the aforesaid United States Patent No. 2,766,940.

The invention also comprises apparatus for carrying out the aforesaid method, which apparatus comprises: means for producing a first control or slave signal which varies with mill loading in the region of the inlet of a mill; means for producing a first reference or master signal of predetermined magnitude; means for comparing the said first slave and master signals to produce a first difference signal; a solids feeder adapted to feed solids to the mill at a controllable rate; means for applying said first difference signal to control the rate of feed produced by said solids feeder so that increases in mill loading above the point corresponding to the magnitude of the first master signal will cause decreases in the feed rate and vice versa; means for producing a second slave signal corresponding to viscosity at a selected region within the mill; means for producing a second master signal of predetermined magnitude; means for comparing said second slave and master signals to produce a second difference signal; means for controllably feeding liquid feed component to said mill; and means for applying said second difference signal to control the rate of feed of liquid feed component so that increases in viscosity above the point corresponding to the magnitude of the second master signal will cause increases in the rate of feed of liquid feed component and vice versa.

The apparatus is preferably supplied with means for

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pre-establishing maximum and minimum feed rates for either the liquid and solid feed components or both.

The invention and its operation will be more particularly described in conjunction with the attached drawings which illustrate diagrammatically two control systems according thereto:

Figure 1 is a schematic illustration of a control system according to the invention embodying the use of two separate control signals.

Fig. 1A is a detail schematic of a typical "sound" signal source.

Figure 2 is a schematic illustration of a control system according to the invention embodying three separate control signals.

Referring more particularly to Figure 1, the numeral 10 indicates a wet grinding mill having an inlet end 11 and an outlet end 12, stationed so as to receive the sound generated by the grinding action of the mill at the inlet end 11 is the microphone 13 which is connected to an amplifier 14 arranged to produce a solids feed "slave" signal which is transmitted to the comparator 15. A solids feed "master" signal of predetermined magnitude is produced in component 16 and is also fed to the comparator 15, which comparator produces an amplified error signal which is transmitted to the solids feed rate control 17. The rate control 17 is arranged to controllably vary the feed rate of the solids feeder between minimum and maximum limits pre-established by component 18 and controls the operation of the feeding device 19. The microphone 20 is positioned so as to pick up the grinding noises produced in the operation of the mill in the region of the outlet end 12 thereof and is connected to the amplifier 21 which produces a water flow "slave" signal which is transmitted to the comparator 22. The component 23 produces a water flow "master" which is also fed to the comparator 22, which comparator transmits an amplified error signal to the water flow rate control 24. The latter controls the rate of flow of water between minimum and maximum limits pre-established by component 25 by opening and closing a water supply valve 26. The circuitry employed for carrying out the functions of the various components of the control circuit are conventional and may suitably be of similar type to those used for analogous purposes in the control circuit which is described in the aforesaid United States Patent No. 2,766,940.

The grinding vibrations reaching microphone 13 are amplified, differentiated, rectified and integrated to produce a unidirectional control or "slave" voltage which varies substantially with the amplitude of sound frequencies higher than 2000 cycles per second received by the microphone 13. The solids feed reference or "master" 16 produces a unidirectional reference voltage and the function of the solids feed control system is to automatically increase or decrease the solids feed rate to keep the "slave" signal equal in magnitude to the "master" signal.

The "slave" and "master" signals are compared in the comparator 15 and the difference in magnitude is expressed as an error signal which is amplified and used as a measure of the required feed rate necessary to hold the "slave" signal constant at the established level. An increasing error signal will increase the solids feed rate. Conversely, a decreasing or low error signal will call for a low feed rate. For convenience, the solids feed "slave" signal may be made positive with respect to common or ground and the solids feed "master" signal may be made negative.

As will be observed from the drawing, the circuit components in the liquid feed control system are analogous to those used in the above described solids feed control system. However, if the vibrations reaching microphone 20 tend to become louder indicating too low a viscosity, the water flow rate must be decreased. This requires a reversal of signal since compared to

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that in the solids feed control system, and this is conveniently accomplished by making the water flow "slave" signal negative with respect to common or ground and the water flow "master" signal positive with respect to common or ground.

The control system illustrated in Figure 2 differs from that illustrated in Figure 1 in that there are two control systems for the liquid feed. In this system, the microphone M1 and M2, as before, control respectively the solids and liquid feed to the inlet side 11 of the mill 10. Like reference numerals are used to indicate the circuit components associated with these two microphones as are used in Figure 1 inasmuch as the circuits are the same.

The microphone M3 is connected to amplifier 30 which feeds a water flow slave signal to the comparator 31 where it is compared with a water flow master produced in component 32. The amplified error signal from the comparator 31 is fed to the water flow rate control 33 which again is equipped with means 34 which establish the minimum and maximum limits within which the water flow rate control 33 will operate. The water flow rate control 33 controls the water flow valve 35 which controls the flow of water through the delivery pipe 36 which extends in through the outlet 37 of the mill to a point slightly towards the inlet side 11 of the microphone M3. The water supply line 38 with which the valve 35 is associated and the water supply line 39 with which the valve 26 is associated may be connected to the same or different sources of water supply. Preferably, they will both be connected to the main water header or to a surge tank or other supply system which is adapted to maintain a substantially uniform head regardless of fluctuations in water demand for delivery to the mill.

The control systems associated with both the microphones M2 and M3 are arranged so as to increase the supply of water through their associated valves 26 and 35 respectively whenever the sound picked up indicates a higher than desirable viscosity and vice versa. In theory the amount of water needed to produce ideal grinding conditions varies in proportion to the total surface area of the charge material. As the total surface area of the charge increases progressively as the material passes toward the outlet end of the mill, the ideal wet mill according to this theory would be one in which controlled increments of liquid feed were added all along the mill in such a way as to maintain the ratio of the surface area of the material to the liquid present constant. Obviously, meeting such an ideal would involve an uneconomically large number of liquid feed control systems. In practice in short mills a single liquid feed control system such as is illustrated in Figure 1, represents a practical solution because excesses of water present at the feed end of the mill will flow to the outlet side relatively rapidly. In longer mills, however, it is preferable to add further liquid feed controls as the occasion may demand and to introduce liquid feed at selected points along the length of the mill in response to the conditions prevailing at the regions within the mill corresponding to the various liquids feed control microphone stations.

The wet grinding mill control described herein by maintaining substantially constant viscosity in the region of the outlet side of the mill with substantially constant mill loading in the inlet side thereof, avoids difficulties previously encountered with single control signal systems where changes in ore condition during the operation of the mill tended to bring about changes in viscosity in the region of the outlet side of the mill. It will be appreciated that the liquid feed component may in accordance with the present invention be introduced at the inlet side of the mill in conventional manner or it may partly be introduced at some intermediate point along the length of the mill towards the outlet end. One

system which is effective to produce preferred results is that which involves feeding a minimum constant amount of liquid at the feed end of the mill and then introducing a variable amount of water determined by the control of the present invention at the same point and/or one or more points along the length of the mill towards the outlet end from the inlet end thereof. Other arrangements will readily present themselves to those skilled in the art.

As stated hereinbefore, the circuitry employed for carrying out the functions of the various components of the control circuit are conventional and similar to those used for analogous purposes in the control circuit described substantially in columns 7 and 8 of the previously mentioned U. S. Patent No. 2,766,940 as follows:

Control or slave signals

As previously mentioned, the control signal for the solid feed may be derived from the sound emanating from the mill, from vibrations emanating from the mill other than sonic frequencies. If the control signal is to be proportional to the sound emanating from the mill, the circuit components represented by the box 14, in Figure 1 will consist essentially of a dynamic microphone 13, an amplifier and a rectifier (as indicated in Figure 1A). If it is desired that the signal thus produced be proportional to the sound emitted within only a limited frequency band, the circuit can include a band pass filter, or the elements of the sound pickup can be selected so that they are very sensitive to the sound frequencies which it is desired to utilize and relatively insensitive to sound frequencies outside the selected range. For instance, it has been found that audible frequencies emitted from a primary ball mill which are above 2,000 cycles per second vary in intensity in close relationship to the actual conditions within the mill whereas frequencies substantially below 2,000 cycles per second are not very satisfactory as a source of a control signal for purposes of the present invention because an appreciable proportion of the intensity of sound within these low frequencies can be attributed to extraneous causes such as the mechanical noise of the mill and power transfer system.

If the control signal is to be derived from vibrations other than sonic emitted by the mill during operation, apart from the type of pickup used, the circuit components required will be essentially the same as they will be when sound is used. In this case, however, the selection of a predetermined frequency band will more conveniently take place essentially within the circuit rather than as a result of selection of pickup components of selected characteristics.

Where electromagnetic pulse type feeders are employed and the control of the feed rate is effected by a phase shift in a saturable core reactor controlling thyatron power output tubes associated with the feeder, it will be convenient to invert the voltage of the control signal when it is derived from sound or vibration since the amount of phase shift effected, and hence the amount of power which is passed to the feeders, is proportional to the voltage applied to the saturable core reactor. (This is apparent from the fact that the sound or vibration produced by the mill will in general be less for high rates of feed than for low rates of feed when operating under ideal conditions.)

The "slave" signal for the liquid feed (microphone 20 and box 21), may likewise be derived from the sound emanating from the mill as explained earlier, the amount of sound being functionally related to the viscosity of the mill charge at a selected point of the mill.

Reference or master signals

The circuit components represented by boxes 16 and 23 in Figure 1 consist essentially of a means for providing a regulated voltage which can be adjusted to a

predetermined desired value and a rectifier. For instance, it may be convenient to use a voltage regulator which receives as input the standard 115 volts line voltage and produces as output a regulated voltage of say 210 volts, a rectifier, and a potentiometer which may be set at a desired value to give as final output a desired rectified voltage which may be used as a reference signal.

Comparators

The circuit components represented by the comparators of boxes 15 and 22 may be of any conventional type. For instance the comparator may consist of a simple bridge circuit, or alternatively an electronic grid which may or may not, depending upon the circumstances, be connected so as to form an integral grid system with components of the amplifier. The only important feature of the comparator circuit is that it must produce as output a signal which is proportional to the difference between the master signal and the slave signal and which has a sense which is opposite for opposite values of the algebraic sum of the slave signal and the master signal.

Amplifiers

Any suitable amplifier may be used with each of the comparators which will fulfill the functions required in the particular application, the function of the amplifier simply being to amplify the signal produced by the comparator to a sufficient extent so that it may effect control of the particular type of feeder being used. The amplifier may, and in the preferred instance is, integrally associated with the comparator grid system.

Solids feeder

There are various types of solids feeders which are available on the market, perhaps the commonest type being the electromagnetic pulse type feeder of which a typical example is the type manufactured by the Syntro Company of Homer City, Pennsylvania, United States of America. This type of feeder feeds solids from the bottom of a bin along a plate which is vibrated by a magnetic pulse with an amplitude which varies as the amount of power fed to the feeder is varied. The amount of material fed is proportional to the amplitude of the vibration of the feeder plate. Another suitable type of feeder consists of a variable speed conveyor belt arranged beneath the feed bin in such a way that, as the belt moves, a relatively constant load of ore per foot of belt is fed from the bin. In this type of feeder, the rate of feed to the mill is proportional to the speed of the belt.

Liquid feeder

Where it is the liquid feed component which is being controlled, the feeder may take the form of a motor operated valve 26 in the liquid supply line. Such valves are generally controlled by the position of a potentiometer arm and open to a position corresponding to the voltage applied for any given position of said arm. Such valves may be used in accordance with the present invention by automatically actuating the potentiometer to correspond to the output voltage of the amplifier. This may be accomplished by a simple circuit arrangement which compares the potentiometer voltage with the slave signal from the amplifier and operates the valve motor in an appropriate direction until the potentiometer voltage and the slave signal voltage are equal. Other methods of accomplishing a similar function will be obvious to those skilled in the art.

What we claim as our invention is:

1. The method of controlling the feed to a wet grinding mill of liquid and solid feed components, which method comprises; continuously producing a first electrical signal which varies with mill loading in the region of the inlet side of the mill; continuously producing a

first reference signal of predetermined magnitude corresponding to a desired mill loading; comparing the first electrical signal with the first reference signal; varying the rate of feed of solid feed component to the mill responsively to the difference between said signals whereby the rate of solids feed is increased when the mill loading is too low and vice versa; continuously producing a second electrical signal which varies with viscosity of charge in a selected region of the mill; continuously producing a second reference signal of predetermined magnitude which corresponds to a desired viscosity; comparing the second electrical signal with the second reference signal; and varying the rate of feed of liquid feed component to the mill responsively to the difference between said second signal and said second reference signal whereby to increase the rate of feed of liquid feed component when the viscosity is too high and vice versa.

2. The method defined in claim 1 which comprises continuously producing a plurality of electrical signals each of which varies with a viscosity of charge in a different selected region of the mill; continuously producing a plurality of reference signals of predetermined magnitude, each of which corresponds to a desired viscosity in one of said selected regions; comparing the electrical signals with the reference signals which relate to the same selected regions; and supplying liquid feed to each of said selected regions at a rate which is varied respectively to the difference between the electrical signal and the reference signal relating to that particular selected region whereby to increase the rate of feed of liquid feed component when the viscosity is too high and vice versa to maintain a relatively constant viscosity throughout all of said selected regions.

3. The method defined in claim 2 wherein all of the plurality of reference signals are of the same magnitude.

4. The method of controlling the feed to a wet grinding mill of liquid and solid feed components, which method comprises; continuously producing a first electrical signal which varies with grinding noise produced in the region of the inlet side of the mill; continuously producing a first reference signal of predetermined magnitude corresponding to a desired magnitude of grinding noise; comparing the first electrical signal with the first reference signal; varying the rate of feed of solid feed component to the mill responsively to the difference between said signals whereby the rate of solids feed is increased when the grinding noise is too loud and vice versa; continuously producing a second electrical signal which varies with grinding noise produced in a selected region of the mill; continuously producing a second reference signal of predetermined magnitude which corresponds to a desired magnitude of grinding noise in said region comparing the second electrical signal with the second reference signal; and varying the rate of feed of liquid feed

component to the mill responsively to the difference between said second signal and said second reference signal whereby to decrease the rate of feed of liquid feed component when the grinding noise in the region of the outlet side of the mill is too loud and vice versa.

5. The method defined in claim 4 wherein the first and second electrical signals vary only with the grinding noise of over 2000 cycles per second frequency.

6. The method defined in claim 4 wherein the rate of feed of solid and liquid feed components is varied only between predetermined maximum and minimum feed rate limits.

7. Apparatus for controlling the feed to a wet grinding mill of liquid and solid feed components, which apparatus comprises; means, including a first microphone and amplifier for continuously producing a first electrical signal which varies with mill loading in the region of the inlet side of the mill; means for continuously producing a first reference signal of predetermined magnitude corresponding to a desired mill loading; means for comparing the first electrical signal with the first reference signal; means for feeding solid feed to the mill at a controlled rate; means for varying the rate of feed of solid feed component to the mill responsively to the difference between said signals whereby the rate of solids feed is increased when the mill loading is too low and vice versa; means including a second microphone and amplifier for continuously producing a second electrical signal which varies with viscosity of charge in a selected region of the mill; means for continuously producing a second reference signal of predetermined magnitude which corresponds to a desired viscosity; means for comparing the second electrical signal with the second reference signal; means for feeding liquid feed to the mill at a controlled rate; and means for varying the rate of feed of liquid feed component to the mill responsively to the difference between said second signal and said second reference signal whereby to increase the rate of feed of liquid feed component when the viscosity is too high and vice versa.

8. Apparatus as defined in claim 7 wherein the first and second microphones and amplifiers are arranged to produce a signal which varies substantially with amplitude of sound having a frequency above 2000 cycles per second.

9. Apparatus as defined in claim 7 wherein the solid and liquid feeding means are provided with means for establishing predetermined maximum and minimum feed rates.

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