MATERIAL PULVERIZING SYSTEM

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ABSTRACT

A material pulverizing system includes an air-swept pulverizing mill that produces and delivers pulverized material to utilization apparatus at a variable mill output rate determined by a variably and independently controlled air flow. The pulverizing system includes a pulverizable material feeder that delivers raw material to the pulverizing mill at a variable and controlled rate to establish and maintain the stable and efficient operation of the pulverizing mill at any mill output rate. The pulverizing system further includes automatic control apparatus that controls the material feeder at a rate determined by the power consumed by a motor driving the pulverizing mill, the sound intensity of the pulverizing mill and the mill output or fuel demand signal.

33 Claims, 7 Drawing Figures
MATERIAL PULVERIZING SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The system of the present invention generally relates to apparatus for pulverizing material and, more particularly, to a new and improved material pulverizing system that includes a pulverizing mill and control apparatus for automatically controlling and maintaining the stable and efficient operation of the pulverizing mill at any mill output rate.

2. Description of the Prior Art

A typical prior art material pulverizing system includes a double-ended pulverizing mill, raw material feeders, crusher-dryers to pre-condition the material fed to the mill, an air fan to provide an air flow for drying the raw material and for transporting the pulverized material to utilization apparatus, classifiers for controlling the size of the pulverized material output and control apparatus for controlling the operation of the material pulverizing system. The control apparatus of prior art material pulverizing systems utilize various means, for example, pneumatic devices actuated by sensing probes physically positioned in the interior of the pulverizing mill or sonic intensity detecting means for detecting the total pulverizing system sonic intensity, for controlling the feeding rate of the raw material feeder to thereby control the output rate of the pulverizing mill.

The control apparatus of typical prior art material pulverizing systems are typically incapable of simultaneously effectively controlling the feeding rates of the raw material feeders for material pulverizing systems having continuously varying pulverizing mill output rates that vary over substantially wide ranges and maintaining pulverizable material charges in the pulverizing mills of sufficient amounts to provide for the stable and efficient operation of the pulverizing mills. Examples of typical prior art material pulverizing systems are disclosed in U.S. Pat. Nos. 2,136,907; 2,235,928; 2,240,822; 2,381,351; 2,466,939; 2,466,940; 2,766,941; 2,833,482; 2,922,587; 2,929,878; 3,050,264; and 3,471,094.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a new and improved material pulverizing system.

Another object of the present invention is to provide a new and improved material pulverizing system including a new and improved control apparatus for providing and maintaining the stable and efficient operation of the pulverizing system over a substantially wide range of operation.

Another object of the present invention is to provide a new and improved control apparatus for controlling the operation of a material pulverizing system that utilizes electrical signals representing the power consumed by a motor driving a pulverizing mill, the sonic intensity of the pulverizing mill and the mill output or fuel demand signal for controlling the operation of the material pulverizing system.

Briefly, the device of the present invention comprises a material pulverizing system that includes a pulverizing mill that produces and delivers pulverized material to utilization apparatus, for example, a steam generator for a steam-driven electric generator, at a variable output rate determined by a variable and independently controlled air flow. The pulverizing mill receives raw material to be pulverized from a material feeder at a variable and controlled feeding rate to establish and maintain the stable and efficient operation of the pulverizing mill at any mill output rate. The rate of the air flow is controlled in response to a mill output or fuel demand signal. The feeding rate of the raw material feeder is controlled by control apparatus in response to signals representing the power utilized by a motor driving the pulverizing mill, the sonic intensity of the pulverizing mill and the mill output or fuel demand signal. When the mill is operating at or near its rated capacity, the feeding rate of the raw material feeder is primarily controlled by a signal representing the power consumed by the motor driving the pulverizing mill. When the mill is operating substantially above its rated capacity, the feeding rate of the raw material feeder is primarily controlled by signals representing the power consumed by the motor driving the pulverizing mill and the sonic intensity of the pulverizing mill. When the mill is operating below its rated capacity, the feeding rate of the raw material is primarily controlled by signals representing the power consumed by the motor driving the pulverizing mill and by the mill output demand signal.

BRIEF DESCRIPTION OF THE DRAWING

The above and other objects and advantages and novel features of the present invention will become apparent from the following detailed description of a preferred embodiment of the invention illustrated in the accompanying drawings wherein:

FIG. 1 schematically illustrates a typical controlled process system that utilizes the material pulverizing system of the present invention to provide a controlled variable input to the controlled process system;

FIG. 2 schematically illustrates a material pulverizing system constructed in accordance with the principles of the present invention for providing a controlled variable input to the controlled process system of FIG. 1;

FIG. 3 schematically illustrates a control circuit constructed in accordance with the principles of the present invention for controlling the operation of the material pulverizing system of FIG. 2;

FIG. 4 graphically illustrates the relationship between the charge or the amount of material in a pulverizing mill and the power utilized by a motor to drive the pulverizing mill;

FIG. 5 graphically illustrates the relationship between the amount of material in a pulverizing mill and the corresponding sonic intensity of the pulverizing mill at a preseleced frequency or frequency range;

FIG. 6 graphically illustrates the relationship between the output of a pulverizing mill and the corresponding sonic intensity of the pulverizing mill at a preselected frequency or frequency range; and

FIG. 7 graphically illustrates the relationship between the amount of the material in a pulverizing mill as controlled in accordance with the principles of the present invention and the pulverizing mill output.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawing and initially to FIG. 1, a typical controlled process system 10 is depicted. The controlled process system 10 may be used for converting...
a raw material such as coal to electrical energy. The system 10 includes a steam-driven electric generator 12 that provides a variable electrical power output in response to a variable load or electrical demand signal. A variable steam input to the generator 12 is provided by a steam generating system 14 in response to a variable load or steam demand signal. The steam generating system 14 is controlled by a steam master control 16. The master control 16 receives the steam demand signal and transmits a fuel demand signal to a material pulverizing system 18 constructed in accordance with the principles of the present invention.

In accordance with an important feature of the present invention, the material pulverizing system 18 (FIG. 2) generates and transmits a highly efficient and stable variable supply of fuel in the form of pulverized material to the steam generating system 14 (FIG. 1). The material pulverizing system 18 (FIG. 2) includes an elongated, double-ended pulverizing mill 20 which receives a mixture of raw or pulverizable material and air at its inputs and which provides a mixture of pulverized material and air at its outputs. The mill 20 may comprise any one of the well known grinding or pulverizing mills. In a preferred embodiment, the mill 20 comprises a pulverizing mill that utilizes a ball charge as the grinding or pulverizing media.

A pulverizing mill drive motor 22 is provided to drive the mill 20 through a speed reducer 24 and a pair of gears 26 and 28. A power sensor or power transducer 30 is provided to monitor the power utilized by the motor 22 and to provide an electrical output signal proportional to the power utilized by the motor 22.

The raw material to be pulverized by the mill 20 is fed to the mill 20 by a pair of raw material feeders 32. The feeders 32 are driven by a pair of variable speed drivers 34 under the control of a feeder drive speed control 36. The control 36 controls the speed of the drivers 34 in response to a control signal from a mill system control 40.

The feeders 32 supply raw pulverizing material to the mill 20 through a pair of crusher-dryers 42 that precondition the raw material before it is fed into the mill 20. The feeding rate of the feeders 32 is controlled by the control 40 to provide a sufficient amount of raw material in the mill 20 to both replace the pulverized material output and maintain an adequate reserve of charge or material in the mill 20 to rapidly increase the pulverized material output as necessitated by a rapidly increased mill output or fuel demand signal.

An air fan 44 provides a transport air flow at a variable air flow rate as controlled by an air flow control 46 in response to the mill output or fuel demand signal. The air flow is directed through the crusher-dryers 42 to the inputs of the mill 20 and provides a carrier or transmission medium for transferring pulverized material from the output of the mill 20 through a pair of classifiers 47 to the input of the steam generating system 14 (FIG. 1). The classifiers 47 (FIG. 2) separate coarse material from the pulverized material and return the coarse material to the inputs of the mill 20.

In accordance with an important feature of the present invention, the mill system control 40 (FIG. 3) controls the variable speed drivers 34 through the speed control 36 in response to the mill output or fuel demand signal, to a signal from the power transducer 30 corresponding to the power utilized by the mill drive motor 22 and to a signal corresponding to the sonic intensity of the pulverizing mill 20. The sonic intensity of the pulverizing mill 20 is detected by a microphone 48 (FIGS. 2 and 3) positioned within a mill silencer housing 50. The silencer housing 50 prevents the microphone 48 from detecting spurious signals or ambient noise from the remaining portions of the material pulverizing system 18. The detected sonic intensity of the pulverizing mill 20 is transmitted by the microphone 48 to a pre-amplifier 52 positioned in the vicinity of the pulverizing mill 20 which amplifies the signal from the microphone 48 and transmits the amplified signal to the mill system control 40 positioned in a remote location.

Generally, the output rate of the mill 20 is determined by the charge or amount of pulverizable material in the mill 20 and by the air flow rate of the fan 44 as controlled by the mill output or fuel demand signal. The amount of raw material fed into the mill 20 to replace the pulverized material output and to maintain a sufficient reserve to supply high mill output demands is basically controlled by an electrical signal from the power transducer 30 proportional to the electrical power consumed by the mill drive motor 22 in operating the mill 20.

As illustrated in FIG. 4, as raw material is initially fed into the mill 20 when the mill 20 contains merely grinding media or ball charge, the power consumed by the motor 22 in driving the pulverizing mill 20 in the illustrated stripping range of operation increases as the material in the mill 20 increases. The power consumed by the motor 22 reaches a peak at the transition between the stripping range and a stable range of operation of the mill 20 and, thereafter, decreases with increases in the amount of material in the mill 20.

The optimum automatic control range for controlling the operation of the mill 20 is found to be along the stable range of the curve of FIG. 4 where an increase in the amount of material in the mill 20 results in the decrease of the power consumed by the motor 22. Within the optimum automatic control range, a value of material charge weight is empirically determined that enables the mill 20 to efficiently supply current mill output demands while simultaneously providing an adequate reserve to satisfy rapid increases in the mill output or fuel demand signal. A power set point 53 corresponding to the power consumed by the motor 22 in operating the mill 20 containing the predetermined optimum charge weight as discussed above is determined and manually entered into the mill system control 40 by means of a potentiometer 54.

The mill system control 40 includes a signal summer 56 for comparing the electrical signal from the potentiometer 54 with the electrical signal transmitted by the power transducer 30 through a signal conditioner or amplifier 58. In a preferred embodiment, the signal summer 56 comprises a conventional operational amplifier circuit that provides an output error signal to an output amplifier 60 proportional to the difference between the signals from the potentiometer 54 and from the amplifier 58. If both of these signals have the same values, no output signal is supplied by the signal summer 56 and the amplifier 60 to the speed control 36. Thus, the feeding rate of the feeders 32 is maintained constant.

However, if the mill output or fuel demand signal is increased or decreased by the master control 16 (FIG. 1) to increase or decrease the mill output rate by an
crease or decrease in the air flow rate from the air fan 44 (FIG. 2), the weight of material or charge in the mill 20 decreases or increases causing a corresponding increase or decrease, respectively, in the power utilized by the drive motor 22 in operating the mill 20. Thus, an inequality exists between the signals from the amplifier 58 and the potentiometer 54 to cause a correction signal from the signal summer 56 and the amplifier 60 to be directed to the speed control 36. The correction signal is applied to the speed control 36 to alter the feeding rate of the feeders 32 until the signal from the amplifier 58 once again equals the signal from the potentiometer 54.

The electrical signal from the amplifier 58 may also be used to operate a remotely positioned power indicator 62 that provides a visual indication of the power being utilized by the drive motor 22 to enable supervisory personnel to monitor the operation of the material pulverizing system 18. Further, the electrical signal from the amplifier 58 may be used to energize a low power alarm to provide an audible warning to the supervisory personnel that the mill 20 contains an excess amount of raw material. The low power alarm is activated when the signal from the amplifier 58, as compared by a high speed integrator 64, exceeds a manually preset low power alarm set point 66 (FIG. 4). When the set point 66 is exceeded by the signal from the amplifier 58, the integrator 64 sounds a low power alarm device through a high gain amplifier or Schmitt trigger 68.

In accordance with an important feature of the present invention, when the mill 20 is providing pulverized material at a high output rate, that is, substantially above its rated capacity (FIGS. 6 and 7), the mill system control 40 utilizes both a signal corresponding to the power consumed by the drive motor 22 and a signal corresponding to the sonic intensity of the mill 20 to adjust the feeding rates of the feeders 32 to supply raw material at an increased feeding rate in order to prevent a depletion in the amount of material in the mill 20. In a preferred embodiment, the microphone 48 is positioned within the housing 50 to eliminate the detection of sonic impulses by the microphone 48 from operating equipment other than the mill 20, for example, the drive motor 22, the speed reducer 24 and the gears 26 and 28. The placement of the microphone 48 within the housing 50 results in a marked improvement over the typical prior art sonic control systems that measured the sonic intensity not only of the pulverizing mill, but also of all other associated equipment in a material pulverizing system. The sonic intensity of interest, that is the sonic intensity produced by a charge or a particular amount of material in a pulverizing mill was typically a very small component of the total sonic intensity detected and measured by such prior art sonic control systems. Thus, the change in the total sonic intensity due to relatively minor changes in the sonic intensity emanating from the interior of the pulverizing mill was usually too small to be utilized as a satisfactory control signal.

In accordance with an important feature of the present invention, only the sonic intensity generated within the pulverizing mill 20, that is, the sound resulting from the vibration of the metallic structures within the pulverizing mill 20 resulting from the impact of the grinding media or ball charge, is detected by the microphone 48 and is used by the mill system control 40 for controlling the feeding rate of the feeders 32.

The specific sonic control signal utilized by the mill system control 40 to alter the feeding rate of the feeders 32 is obtained by sensing and converting to an electrical signal the total sound generated by the pulverizing mill 20, filtering the electrical signal to remove all frequency components except those within a narrow frequency band found by experimentation to best represent the damping of material masses within the pulverizing mill 20, and utilizing the amplitude of those frequency components in the narrow frequency band as a control signal to adjust the feeding rates of the feeders 32.

Examinations of sonic intensity emanating from a typical pulverizing mill 20 indicate that sonic components of several frequency bandwidths in the frequency range from 140 Hz. to approximately 10,000 Hz. exhibit amplitudes that are inversely proportional to the charge or amount of material within a pulverizing mill 20. Three of the more significant frequency bandwidths are 140 to 320 Hz., 500 to 1000 Hz. and 1400 to 2100 Hz.

Frequency components within the range of 140 to 320 Hz. result from the vibrations of portions of the metal forming the housing of the mill 20 caused by grinding media or ball charge impact transmitted to the exterior housing of the mill 20 through the interior lining of the mill 20. Frequency components within the range of 500 to 1000 Hz. result from interaction of or the impact of the grinding media or ball charge within the mill 20. Frequency components within the range of 1,400 to 2,100 Hz. result from the natural frequencies of vibration of the larger balls in the grinding media or ball charge caused by the impact of the larger balls with the interior lining of the mill 20.

The amplitudes of frequency components emanating from the mill 20 are greatest for frequency components in the range of 140 to 320 Hz. However, this frequency bandwidth is not considered to be the optimum bandwidth for controlling the feeding rates of the feeders 32 due to the relatively high probability of the presence of spurious signals or frequency components from sources other than the mill 20. For example, signals resulting from the harmonics of the constant high intensity noise emanating from the mill drive motor 22 may be present in that frequency bandwidth. Of the remaining preferred frequency bandwidths discussed above, the frequency bandwidth of 1,400 Hz. to 2100 Hz. is the preferred bandwidth based upon experimental evidence showing a more consistent change in amplitude of the frequency components in this frequency bandwidth with changes in the charge or the amount of material in the mill 20.

An electrical signal corresponding to the sonic intensity of the pulverizing mill 20 is generated by the microphone 48, amplified by the preamplifier 52 and directed to an amplifier 70. The amplified signal from the amplifier 70 is filtered by a manually variable frequency selector, filter or tuner 72 to pass a frequency bandwidth of interest, as indicated above. The resulting filtered signal from the filter 72 is converted to a direct current signal by an AC to DC converter 74 and is subsequently directed to a signal conditioner or amplifier 76.

The output signal from the amplifier 76 is used to control a remotely positioned sonic indicator 78 to provide a visual indication of the sonic intensity of the mill
The output signal from the amplifier 76 is also directed to a high speed integrator or operational amplifier 80 for comparison with a high sonic alarm set point 82 (FIG. 5). The integrator 80 provides an output signal to activate an audible or visual high sonic alarm through a high gain amplifier or Schmitt trigger 84 when the signal from the amplifier 76 exceeds the high sonic alarm set point 82. The high sonic alarm alerts the supervisory personnel that an undesirably small amount of material is present in the mill 20 and that any further decrease would put the mill 20 in an emptying or stripping mode of operation. When the mill 20 is in an emptying or stripping mode of operation, the response of the mill control system 40 to further decreases in the charge or amount of material in the mill 20 is opposite to the response of the mill control system 40 when the mill 20 is operating in a stable mode of operation (FIG. 4). Thus, the signal from the power transducer 30 would not be able to correct the low charge condition of the mill 20.

The output signal of the amplifier 76 is further directed to a summing or operational amplifier 86 and compared to an electrical signal corresponding to a sonic swamp set point 88 (FIG. 5), corresponding to a sonic intensity indicative of the emptying or stripping mode of operation of the mill 20. When the electrical signal from the amplifier 76 exceeds the sonic swamp set point 88, the amplifier 86 provides an output signal through a high speed integrator or operational amplifier 90 and through a low limit or threshold circuit 92 to the signal summer 56 of a sufficient magnitude and correct polarity to provide a corrective signal through the amplifier 60 to the speed control 36 to operate the feeders 32 at their maximum feeding rates to thereby return the mill 20 to its stable mode of operation. The low limit or threshold circuit 92 may be formed by any conventional threshold circuit and is used to block all signals from the amplifier 86 and the integrator 90 resulting from sonic intensities less than the sonic swamp set point 88.

Several conditions may cause the sonic intensity of the pulverizing mill 20 to increase to the high sonic alarm set point 82 and, possibly, to the sonic swamp set point 88. For example, if a raw material feed operation is interrupted, such as by a complete obstruction of the inlet to one of the feeders 32, and if the pulverizing mill 20 is operating at or above the set point 53 (FIG. 4) or its rated capacity (FIGS. 6 and 7), the feeding rate of the remaining feeder 32 would be increased by the mill system control 40 in response to the electrical signal from the power transducer 30 but not by an amount sufficient to prevent depletion of the charge in the mill 20, thereby placing the mill 20 in its emptying or stripping mode of operation. The sounding of the high sonic alarm therefore alerts the supervisory personnel to correct this condition.

Also, a decrease in the grinding media or ball charge weight in the mill 20 due to normal wear could eventually cause a decrease in the total weight of the material in the mill 20 and thus a shifting of the power curve (FIG. 4) from the solid line curve representing a high ball charge to the dotted line curve representing a low ball charge. Such a shift results in the shifting of the power sonic control range such that a smaller charge or amount of material is maintained in the mill 20 for the same power set point 53. Such a shift results in a decrease in the output capacity of the mill 20 and in the less stable operation of the mill 20.

The mill system control 40 detects this condition by detecting the increase in the sonic intensity within the mill 20 (FIG. 5) resulting from the decrease in the charge or amount of material within the mill 20. When the sonic intensity exceeds the set point 82, the high sonic alarm is activated to alert the supervisory personnel to check the grinding media or ball charge within the mill 20 for excessive wear. If such a condition exists, the supervisory personnel may either replace the grinding media or ball charge to restore the power sonic control range to its original value (FIG. 4) or adjust the power set point 53 to a lower value resulting in a decreased mill output capacity until replacement grinding media or ball charge is available.

A third condition which could result in the signal from the amplifier 76 exceeding the set point 82 or the set point 88 may occur when the quality, that is, the "grindability" or "pulverizability" of the raw material fed by the feeders 32 into the mill 20 deteriorates significantly below the design value of the mill 20. If this condition should occur and if the mill output of fuel demand signal should require a pulverized material output greater than the reduced capacity of the mill 20, the mill output or fuel demand signal would condition the air flow control 46 to increase the speed of the air fan 44 to thereby provide a greatly increased air flow through the mill 20 to meet the mill output demand. Eventually, the abnormally high air flow entering the mill 20 at both of its ends reduces the charge or amount of material adjacent the ends of the mill 20 and increases the charge or amount of material disposed near the center of the mill 20. The depletion of the charge or material from the ends of the mill 20 causes an increase in the sonic intensity of the mill 20.

Eventually, the high sonic alarm is sounded and an override or corrective signal from the threshold circuit 92 causes the feeders 32 to increase the feeding rate of raw material to the mill 20. If this overfeeding is permitted to continue in spite of the high sonic alarm, the central portion of the mill 20 eventually overfills resulting in the reduction of the power consumed by the drive motor 22.

Eventually, the power consumed by the drive motor 22 decreases below the low power alarm set point 66 to cause the activation of the low power alarm. The activation of the low power alarm provides an additional indication to the supervisory personnel that the mill output capacity must be reduced to a value capable of being satisfied in order to avoid the existence of an unstable mode of operation of the pulverizing mill 20. This unstable mode of operation would eventually substantially reduce the output capacity of the mill 20 due to the loss of charge or material from the ends of the pulverizing mill 20 and the overfilling of the charge or material at the central portion of the mill 20. Thus, the activation of both the low power alarm and the high sonic alarm alerts the supervisory personnel to this unstable mode of operation.

The output signal from the amplifier 76 is also directed to a summing or operational amplifier 94 and compared to an electrical signal corresponding to a sonic trim set point 96 (FIG. 5). The output signal from the amplifier 94 is proportional to the difference between these two signals and is used to correct or comp-
compensate for raw material quality and feeding irregularities or inconsistencies.

The raw material pulverized by the mill 20 is normally obtained from several different sources and can vary widely in moisture content, grindability and other material properties. In transferring raw material from a storage location to the feeders 32, normally, transferring procedures are utilized that attempt to obtain a uniform blend of the different raw materials. Typically, however, a uniform blend of raw materials is rarely achieved by the two feeders 32 such that identical blends of raw material are fed to the inputs of the mill 20. Additionally, foreign objects may be inadvertently added to the raw material during the transferring procedures.

When the mill 20 is operating below its rated capacity (FIGS. 6 and 7), such irregularities or inconsistencies have little or no effect on the operation of the mill 20. However, when the mill 20 is operating substantially above its rated capacity, and significant irregularity or abnormality could result in an imbalance in the air flow through the mill 20 sufficient to result in an asymmetrical or uneven axial distribution of the charge or material in the mill 20. Eventually, an operational instability may result if this asymmetrical charge distribution remains uncorrected. An indication of this unstable condition is an increase in the sonic intensity at one of the two opposite ends of the mill 20. Since the power consumed by the drive motor 22 is substantially unchanged by the asymmetrical charge distribution, the electrical signal from the amplifier 58 is incapable of providing corrective action.

Thus, the signal from the amplifier 76 is compared to the sonic trim set point 96 by the amplifier 94 to provide a modifying signal to the signal summer 56 through a low load inhibitor 98 and a low limit or threshold circuit 100 to modify the output signal from the signal summer 56 to increase the feeding rates of the feeders 32. The increased feeding rates provide a sufficient additional charge in the mill 20 to stabilize or reverse the trend of the mill 20 to an unstable mode of operation.

The sonic trim set point 96 and the amplification of the amplifier 94 are preset during the initial calibration of the mill system control 40 to provide a sufficiently large corrective signal to the speed control 36 to increase the feeding rates of the feeders 32 thereby eliminating the unstable mode of operation of the mill 20. The low load inhibitor 98 is utilized to block the signal from the amplifier 94 during operational conditions of the mill 20 in which high sonic intensities are normally present, as more fully described hereinlater. The low limit or threshold circuit 100 blocks the transmission of modifying signals to the signal summer 56 for electrical signals from the amplifier 76 representing sonic intensities less than the sonic trim set point 96.

In accordance with a further important feature of the present invention, the mill output or fuel demand signal is also utilized by the mill system control 40 to automatically control the feeding rates of the feeders 32 when the mill 20 is operating below its rated capacity (FIGS. 6 and 7). When the mill output of the mill 20 is reduced by the mill output or fuel demand signal to low than an approximately fifteen percent of its rated capacity, the axial distribution of the material charge in the mill 20 changes significantly from its distribution or condition when the mill 20 is operating at its rated capacity. The low mill output or fuel demand signal results in a low rate of air flow from the fan 44. The reduced air flow from the fan 44 results in a uneven axial distribution of the material charge in the mill 20.

Further, since the grinding capacity of the mill 20 is increased due to a reduced pulverized material output rate, the material entering the mill 20 is rapidly ground to a fine size. The fine size of the ground material permits the material to be removed from the mill 20 by the air flow from the fan 44 at a higher pulverized material concentration rate than is possible when the mill 20 is operating at or near its rated capacity. Thus, the air flow rate is reduced even further.

This combination of a very low air flow rate and an increased grinding capacity of the mill 20 results in a depletion of the material charge in the central portion of the mill 20 and a corresponding increase in the sonic intensity of the mill 20 at its central portion. The increased sonic intensity as detected by the microphone 48 and as received by the mill system control 40 could result in increasing the feeding rate of the feeders 32 to eventually cause the plugging or obstruction of the inlets to the mill 20.

This unstable operating condition of the mill 20 is prevented by monitoring the mill output or fuel demand signal and by using that signal to modify the output from the signal summer 56 and the amplifier 60 for low pulverized material output rates. The mill output or fuel demand signal is received by a signal conditioner or amplifier 102 and, in a preferred embodiment, inverted by an inverting amplifier 104. The output signal from the amplifier 104 is compared to a feed forward trim set point 106 by a summing or operational amplifier 108. The set point 106 electrically corresponds to the value of a mill output or fuel demand signal below which it is experimentally found desirable to decrease the material charge in the mill 20.

The set point 106, in a preferred embodiment (FIG. 7), is preset to correspond to a mill output or fuel demand signal that causes the mill 20 to operate at its rated capacity. Thus, when the mill output or fuel demand signal is low, that is, below the set point 106, the mill 20 is not operating at its rated capacity, a signal proportional to the difference between the signal from the amplifier 104 and the set point 106 is transmitted to the signal summer 56 through a high limit or blocking circuit 110 to modify the output signal from the signal summer 56 and the amplifier 60, to decrease the feeding rates of the feeders 32 and to thereby decrease the material charge in the mill 20 (FIG. 7).

The modifying signal from the amplifier 108 is typically experimentally determined and preset during the initial calibration of the mill system control 40. The modifying signal is preset to have a proper polarity and sufficient magnitude to adjust the feeding rates of the feeders 32 sufficiently to simultaneously (1) supply the required pulverized material output from the mill 20 at the lowest mill output or fuel demand signal, (2) maintain a sufficient material charge in the mill 20 to prevent the mill 20 from entering its emptying or stripping mode of operation and (3) prevent raw material fed by the feeders 32 from blocking or plugging the inlets to the mill 20. The high limit or blocking circuit 110 prevents any modifying signals from the amplifier 108 from reaching the signal summer 56 for mill output or fuel demand signals higher than the feed forward trim set point 106.
Thus, the underfeeding of raw material by the feeders 32 to the mill 20 for high mill output rates is prevented.

The signal from the amplifier 104 is also compared to a low load set point 112 (FIG. 6) by a high speed integrator or operational amplifier 114. An output signal from the integrator 114 is used to activate the low load inhibitor 98 through a high gain amplifier or Schmitt trigger 16 to block or inhibit any modifying signal from the amplifier 94 for mill output or fuel demand signals that reduce the mill output rate below the low load set point 112. Thus, for such mill output or fuel demand signals, the modifying signal from the amplifier 94 is prevented from increasing the feeding rates of the feeders 32 in response to an increase in the sonic intensity of the mill 20.

Obviously, many modifications and variations of the present invention are possible in light of the above disclosure. For example, by appropriately modifying the circuit disclosed in FIG. 3, the mill output or fuel demand signal could be utilized to automatically modify or readjust the power set point 53 rather than merely providing a modifying signal to the signal summer 56. However, by utilizing the mill output or fuel demand signal to directly modify the signal from the signalsummer 56, the feeding rates of the feeders 32 are automatically rapidly adjusted to more rapidly achieve the stable and efficient operation of the pulverizing mill 20. Otherwise, the feeding rates of the feeders 32 would be adjusted downwardly only after a change in the signal from the power transducer 30 which typically occurs relatively slowly in response to changes in the material charge in the mill 20. Thus, it is to be understood that, within the scope of the appended claims, the invention may be practiced otherwise and as specifically described.

What is claimed and desired to be secured by Letters Patent of the United States is:

1. A material pulverizing system comprising
a power operated pulverizing mill for providing a pulverized material output in response to a variable mill output demand signal,
means for feeding pulverizable material to said mill at a variably controlled feeding rate and means for automatically controlling the feeding rate of said feeding means, said automatically controlling means comprising
first means for generating a first electrical signal indicative of the power consumed by said mill, second means for generating a second electrical signal indicative of the sonic intensity of said mill,
third means for generating a third electrical signal indicative of said mill output demand signal and
fourth means for generating an output control signal for controlling the feeding rate of said feeding means in response to said first, second and third electrical signals.

2. A material pulverizing system as defined in claim 1 wherein said automatically controlling means further includes first means for establishing a first reference signal corresponding to the magnitude of the power consumed by said mill in operating at a predetermined operation level.

3. A material pulverizing system as defined in claim 2 wherein said automatically controlling means further includes second means for establishing a second reference signal corresponding to the magnitude of power consumed by said mill in operating at an undesired operational level in which an excess amount of material is present within the mill, means for producing a sensorially perceptible alarm and second means for comparing said first electrical signal with said second reference signal and for activating said alarm producing means when said second reference signal exceeds said first electrical signal.

4. A material pulverizing system as defined in claim 3 wherein said automatically controlling means further includes third means for establishing a reference signal corresponding to a predetermined sonic intensity of said mill.

5. A material pulverizing system as defined in claim 3 wherein said automatically controlling means further includes third means for comparing at least a portion of said second electrical signal with said third reference signal and, when said portion of said second electrical signal exceeds said third reference signal, for modifying said output control signal from said fourth generating means by an amount corresponding to the difference between said second electrical system and said third reference signal to thereby increase the feeding rate of said feeding means in order to reduce said second electrical signal below said third reference signal.

6. A material pulverizing system as defined in claim 5 wherein said automatically controlling means further includes third means for comparing at least a portion of said second electrical signal with said third reference signal and, when said portion of said second electrical signal exceeds said third reference signal, for modifying said output control signal from said fourth generating means by an amount corresponding to the difference between said second electrical system and said third reference signal to thereby increase the feeding rate of said feeding means in order to reduce said second electrical signal below said third reference signal.

7. A material pulverizing system as defined in claim 6 wherein said automatically controlling means further includes fourth means for establishing a fourth reference signal corresponding to an unusually small amount of pulverizing media or pulverizable material in said mill, means for producing a sensorially perceptible alarm and fourth means for comparing at least a portion of said second electrical signal with said fourth reference signal and for activating said alarm producing means when said portion of said second electrical signal exceeds said fourth reference signal.

8. A material pulverizing system as defined in claim 6 wherein said automatically controlling means further includes fifth means for establishing a fifth reference signal corresponding to an unstable mode of operation of said mill and fifth means for comparing at least a portion of said second electrical signal with said fifth reference signal and, when said portion of said second electrical signal exceeds said fifth reference signal, for modifying said output control signal from said fourth generating means sufficiently to greatly increase the feeding rate of said feeding means to rapidly return said mill to a stable mode of operation.

9. A material pulverizing system as defined in claim 6 wherein said automatically controlling means further includes means for inhibiting said third comparing and modifying means from modifying said output control signal from said fourth generating means when said mill output demand signal is less than a predetermined low level.

10. A material pulverizing system as defined in claim 6 wherein said automatically controlling means further
3,856,214

13 includes means for filtering said second electrical signal to remove all components of said second electrical signal except those having frequencies within a preselected frequency passband.

11. A material pulverizing system as defined in claim 10 wherein said frequency passband includes all frequencies from approximately 1,400 Hz. to approximately 2,100 Hz.

12. A material pulverizing system as defined in claim 6 wherein said automatically controlling means further includes sixth means for establishing a sixth reference signal corresponding to a predetermined pulverized material output rate of said mill.

13. A material pulverizing system as defined in claim 12 wherein said automatically controlling means further includes sixth means for comparing said third electrical signal with said sixth reference signal and, when said third electrical signal is less than said sixth reference signal, for modifying said output control signal from said fourth generating means by an amount corresponding to the difference between said third electrical signal and said sixth reference signal to reduce the feeding rate of said feeding means thereby reducing the average amount of pulverizable material present in said mill.

14. A material pulverizing system as defined in claim 3 wherein said automatically controlling means further includes sixth means for establishing a sixth reference signal corresponding to a predetermined pulverized material output rate of said mill.

15. A material pulverizing system as defined in claim 14 wherein said automatically controlling means further includes sixth means for comparing said third electrical signal with said sixth reference signal and, when said third electrical signal is less than said sixth reference signal, for modifying said output control signal from said fourth generating means by an amount corresponding to the difference between said third electrical signal and said sixth reference signal to thereby reduce the average amount of pulverizable material present in said mill.

16. A material pulverizing system as defined in claim 1 wherein said second generating means comprises a microphone, wherein said mill includes a silencing housing enclosing at least a portion of said mill and wherein said microphone is positioned within said silencing housing to prevent the detection by said microphone of substantially all sounds except those generated within or by said mill.

17. A material pulverizing system as defined in claim 1 wherein said mill comprises an elongated ball charge mill having a plurality of inputs and wherein said feeding means comprises means for providing pulverizable material at each of said plurality of inputs.

18. A material pulverizing system as defined in claim 1 further comprising means for supplying a flow of transport air at a variable, controlled air flow rate and means for controlling the flow rate from said supplying means in response to said mill output demand signal.

19. A material pulverizing system comprising a power operated pulverizing mill for providing a pulverized material output in response to a variable mill output demand signal.

20. A material pulverizing system as defined in claim 19 means for feeding pulverizable material to said mill at a variably controlled feeding rate and means for automatically controlling the feeding rate of said feeding means, said automatically controlling means comprising first means for generating a first electrical signal indicative of the power consumed by said mill, second means for generating a second electrical signal indicative of said mill output demand signal, and third means for generating an output control signal for controlling the feeding rate of said feeding means in response to said first and second electrical signals.

21. A material pulverizing system as defined in claim 19 wherein said automatically controlling means further includes first means for establishing a first reference signal corresponding to the magnitude of power consumed by said mill in operating at a predetermined desired operational level.

22. A material pulverizing system as defined in claim 20 wherein said automatically controlling means further includes first means for comparing said first electrical signal with said first reference signal to cause said third generating means to generate an output control signal corresponding to the difference between said first electrical signal and said first reference signal.

23. A material pulverizing system as defined in claim 21 wherein said automatically controlling means further includes second means for establishing a second reference signal corresponding to the magnitude of power consumed by said mill in operating at an undesired operational level at which an excess amount of material is present within the mill, means for producing a sensually perceivable alarm and second means for comparing said first electrical signal with said second reference signal and for activating said alarm producing means when said reference signal exceeds said first electrical signal.

24. A material pulverizing system as defined in claim 23 wherein said automatically controlling means further includes third means for comparing said second electrical signal with said third reference signal and, when said second electrical signal is less than said third reference signal, for modifying said output control signal from said generating means by an amount corresponding to the difference between said second electrical signal and said third reference signal to thereby reduce the average amount of pulverizable material present in said mill.

25. A method of controlling a material pulverizing system comprising the steps of feeding pulverizable material to a pulverizing mill at a variably controlled feeding rate, operating a power operated pulverizing mill to provide a pulverized material output in response to a variable mill output demand signal, generating a first electrical signal indicative of the power consumed by said mill, generating a second electrical signal indicative of the difference between said second electrical signal and said third reference signal to thereby reduce the average amount of pulverizable material present in said mill.
generating an output control signal for controlling said pulverizable material feeding rate in response to said first, second and third electrical signals.

26. A method for controlling a material pulverizing system as defined in claim 25 further comprising the steps of

establishing a first reference signal corresponding to the magnitude of the power consumed by said mill in operating at a predetermined operational level,

comparing said first electrical signal with said first reference signal and

generating said output control signal corresponding to the difference between said first electrical signal and said first reference signal.

27. A method for controlling a pulverizing system as defined in claim 26 further comprising the steps of

establishing a second reference signal corresponding to the magnitude of power consumed by said mill in operating at an undesired operational level in which an excess amount of material is present within said mill,

comparing said first electrical signal with said second reference signal and

activating a sensually perceptible alarm when said second reference signal exceeds said first electrical signal.

28. A method for controlling a material pulverizing system as defined in claim 26 further comprising the steps of

establishing a third reference signal corresponding to a predetermined sonic intensity of said mill,

comparing at least a portion of said second electrical signal with said third reference signal and

modifying said output control signal by an amount corresponding to the difference between said second electrical signal and said third reference signal when said portion of said second electrical signal exceeds said third reference signal to thereby increase the material feeding rate to said mill in order to reduce said second electrical signal below said third reference signal.

29. A method for controlling a material pulverizing system as defined in claim 28 further comprising the steps of

establishing a fourth reference signal corresponding to an undesirable small amount of pulverizing media or pulverizable material present in said mill,

comparing at least a portion of said second electrical signal with said fourth reference signal and producing or generating a sensually perceptible alarm when said portion of said second electrical signal exceeds said fourth reference signal.

30. A method for controlling a material pulverizing system as defined in claim 28 further comprising the steps of

establishing a fifth reference signal corresponding to an unstable mode of operation of said mill,

comparing at least a portion of said electrical signal with said fifth reference signal and, when said portion of said second electrical signal exceeds said fifth reference signal,

modifying said output control signal sufficiently to greatly increase the material feeding rate to said mill to rapidly return said mill to its stable mode of operation.

31. A method for controlling the material pulverizing system as defined in claim 28 further comprising the step of filtering said second electrical signal to remove all components of said second electrical signal except those having frequencies within a preselected frequency passband.

32. A method for controlling a material pulverizing system as defined in claim 31 wherein said step of filtering said second electrical signal comprises the step of filtering said second electrical signal to remove all components of said second electrical signal except those having frequencies within a frequency passband of approximately 1,400 Hz. to approximately 2100 Hz.

33. A method for controlling a material pulverizing system as defined in claim 28 further comprising the steps of

establishing a sixth reference signal corresponding to a predetermined pulverized material output rate of said mill,

comparing said third electrical signal with said sixth reference signal and

modifying said output control signal by an amount corresponding to the difference between said third electrical signal and said sixth reference signal when said third electrical signal is less than said sixth reference signal to thereby reduce the material feeding rate to said mill and to reduce the average amount of pulverizable material present in said mill.