The present invention relates to air-swept pulverizers, and more particularly to a method of and apparatus for controlling the operation of an air-swept pulverizer particularly when used to supply pulverized coal to a furnace.

The use of air-swept pulverizers for the direct supply of pulverized coal to a furnace is well known. In such installations, the pulverizer provides coal as it is needed in the furnace to satisfy combustion requirements. An air-swept pulverizer is supplied with air, or other fluid, at a rate determined by the requirements of the pulverizer for separation of fine and coarse coal within the pulverizer, with the air further providing a carrier medium for transporting the pulverized coal to the furnace or other points of use.

Therefore, it has been customary to control the supply of air and raw coal to the pulverizer so as to deliver a preferred ratio of air to coal at the burner to serve the furnace. The flow of air may be manually or automatically controlled, with the rate of raw coal delivered to the pulverizer also controlled manually or automatically in a predetermined air to coal ratio for best classification within the pulverizer and for desirable transportation to and combustion in the furnace.

In the present invention, the volumetric rate of raw coal delivery to the pulverizer is continuously determined, the determinations suitably amplified and the resultant amplified indications are compared with a desired standard indication so that the deviation in the actual volumetric rate of flow of raw coal to the pulverizer from the standard may be continuously used to transmit an impulsion in proper amplitude and direction to a controlling device operating a mechanism regulating the flow of air to the pulverizer. A known system of coordinating air flow to raw coal delivery to the pulverizer is utilized to coordinate the air flow and the coal flow in a predetermined ratio for delivery to the associated burner. A temperature corrective device may be utilized to compensate for changes in the moisture content of the raw coal delivered to the pulverizer. With this device, the temperature of the coal and air mixture leaving the pulverizer is maintained at a selected value, with the temperature of the air entering the pulverizer changed as required to maintain a uniform leaving temperature. The control system air temperature regulation compensates for the change in volume of air delivered to the pulverizer so as to maintain the weight of air delivered to the pulverizer in predetermined ratio to the weight of raw material delivered thereto. In addition, means are provided for bypassing some of the air around the pulverizer so as to change the coal and air ratio at the burner without adversely affecting the operations of the pulverizer. Such changes in coal and air ratio delivered to the burner may be desirable to alter the flame characteristics of the burning stream of coal and air delivered to the furnace, or to cool the burner tip.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of the invention.

The single sheet of drawings is a schematic showing of a pulverized coal system supplying a rotary kiln where the pulverizer is controlled in accordance with the present invention.

For convenience in illustrating the inter-control connections of the invention, the electrical lead connections are shown in dotted lines while the pneumatic connections are shown solid.

While the invention is illustrated as applied in supplying pulverized coal to a rotary kiln, it will be understood the control system may be effectively applied to other furnaces, such as metallurgical furnaces. In fact, the control system of this invention may be used wherever a pre-selected, substantially uniform weight of pulverized fuel is desired, with the ratio of coal to carrier air maintained at a desired optimum value.

As shown in the drawing, the rotary kiln 10 is arranged with the usual hood 11 which is provided with a bottom opening 12 for the discharge of the product treated in the kiln. The kiln is supplied with pulverized coal entrained in a carrier air stream through a burner 13 which projects through an opening in the hood so that the burner is generally in alignment with the axis of the rotary kiln. Secondary air for combustion purposes is supplied to the kiln upwardly through the material outlet 12, where such air is preheated in cooling the product discharged from the kiln. Heated air is withdrawn from an opening 14 in the upper portion of the kiln hood to provide heated air for use in the pulverizer 15 supplying the pulverized coal to the burner 13.

When the pulverizer and control system of the present invention is applied to a rotary kiln used in the production of, for example, cement clinker, it is desirable to maintain a constant heat input to the kiln so that with a substantially uniform delivery of raw materials to the kiln, equilibrium combustion and burning conditions can be established and maintained. Not only should the heat input to the kiln be maintained constant, but equilibrium combustion conditions necessitates that pulverized coal of uniform fineness will be delivered to the kiln. Although the limits of the ratios of fuel to air delivered to the kiln are to some extent contingent upon the air classification characteristics of the particular type of pulverizer in use, the percentage of primary air delivered with the coal is quite critical in rotary kiln operation to attain the proper flame velocities and flame placement in the kiln for optimum product quality and fuel utilization. Nevertheless, efficient coal classification in the pulverizer can be maintained with the control of the present invention with an optimum ratio of fuel to air for combustion purposes.

As shown in the drawing, the heated air withdrawn from the kiln hood 11 is drawn through a duct 16 into the inlet 17 of a high pressure blower 18 which discharges to the pulverizer 15. The air inlet line, or duct 16 is provided with a suitable damper 20 to control air flow.
therethrough. Upstream of the flow control valve, in an air system, a breather inlet 21 is provided for the introduction of ambient temperature air. The inlet is likewise provided with a flow control damper 22. As hereinafter described, the control of ambient air flow to the system is automatically accomplished to maintain the temperature of the coal and air mixture leaving the pulverizer at a selected value.

The pulverizer is supplied with raw coal which is delivered by a variable speed motor driving a feeder 23 which, as illustrated, is of the rotating table type. Raw coal passes from an overhead bin 24 through connecting spout 25 which opens to the rotating table of the feeder. The rate of raw strip delivered to the pulverizer is regulated by the change in speed of operation of the motor 26 driving the table feeder 23.

As described in U.S. Patent 2,775,595 to T. T. Schwartz, filed March 10, 1942, the pulverizer 15 may be of the rotating ring and ball type where grinding balls rotate in a circular race formed between a lower rotating ring and an upper stationary ring. The raw coal delivered to the grinding zone formed by the grinding elements is at least partly reduced in size and discharged outwardly of the grinding elements into a rising stream of air. The air entering the pulverizer through the duct 27 from the blower 18 passes upwardly beyond the grinding rings and lifts the finer particles of coal into a classifying zone in the upper portion of the pulverizer. The classifier rejects the coarser coal particles entrained in the carrier air stream, such particles returning to the grinding zone for further pulverization. The finished product, of finer particles of coal, conveyed in the carrier air stream passes through an outlet in the upper portion 28 of the pulverizer into a burner pipe 30 to the burner nozzle 13 and thence to the kiln 10.

In accordance with the present invention, I provide a rotatable helical strip 31 of metal which is mounted on the coal spout 25 leading to the pulverizer feeder 23. The helical strip of metal rotates at a slow speed which is proportional to the rate of movement of the raw coal through the spout 25. Actually, the movement transmitted to the helical strip is proportional to the volumetric movement or displacement of the raw coal. The movement of the helical strip is converted into a mechanical or electrical impulse, suitably amplified in instrument 32. These impulses are transmitted to a control mechanism 33 which compares them with a desired standard, and deviations in the volumetric flow of raw material through the spout 25 are corrected by a pneumatic device to a mechanical movement of an air flow control damper 20 in the air inlet pipe 16.

A suitable electrical mechanism for converting the volumetric flow of coal through the spout to a measurable value which is continuously compared with a desired standard value is shown where the movement of the helical strip in the raw coal spout may be calibrated in terms of a percentage of the capacity of the pulverizer on an instrument such as indicated at 34 where the desired rate of flow of material may be manually set by adjustment of the instrument. A recording instrument 39 may be used to keep a visual record of actual volumetric flow to the pulverizer. Thus, to maintain a uniform volumetric flow of raw coal to the pulverizer, the instrument 34 will maintain the actual volumetric rate of flow as determined by the helical strip at a desired value comparable with the selected desired rate of flow, with the said rates transmitted in the form of power impulses delivered to the power piston 35 positioning the damper 20.

The shaft of the helical strip is mechanically connected with the rotor of a synchro transmitter. The synchro transmitter is electrically connected to a synchro transmitter range from the transformer being proportional, in magnitude and phase, to the relative angular displacement between the synchro transmitter and the synchro control transformer. The output of the synchro transformer is connected to a servo amplifier which drives the servo motor 26, which is mechanically coupled to the rotor of the synchro transformer so that the synchro transformer rotor follows the rotational displacement of the synchro transmitter. The servo motor drives the synchro transformer through a speed reducing gear box so that the servo motor rotates at a higher speed of rotation than that of the transformer with the servo motor connected to a tachometer generator the electrical voltage produced by the latter will be proportional to the rotational speed of the helical strip 31.

The ratio between the rate of flow of air to the pulverizer and the rate of flow of raw coal to the pulverizer is established and maintained by a ratio controller 40, such as disclosed and claimed in U.S. Patent 2,783,948, issued on March 5, 1957. This mechanism is actuated by the differences in the static air pressures of the air flowing to the pulverizer and through the pulverizer. This is accomplished by means of an orifice, or Pitot tube 36, positioned in the duct 27 connecting the outlet of the blower 18 and the pulverizer 15 housing. As shown in the drawing, a Pitot tube is provided with two static pressure connecting lines 37 and 38 which transmit pressures having a difference resulting from and proportional to the rate of air passing through the duct 27 to the ratio controller 40. The static pressure drop of the air flow through the pulverizer is measured by static pressure impulses transmitted to the ratio controller 40 through the connecting lines 41 and 42. One of the connecting lines 41 opens to the air inlet side of the pulverizer 15 while the other line 42 opens to the upper part of the pulverizer. Thus, the differential pressure between these two connections is indicative of the resistance of air flow through the pulverizer caused by the coal within the grinding and classifying zones of the pulverizer.

The differential pressure delivered to the ratio controller 40 are combined in opposing relationship to mechanically indicate a proportional value which is transmitted to a magnetic feeder control mechanism 43 as disclosed in said U.S. Patent 2,783,948. The controller transmits impulses to the motor 26, which in turn adjusts the rotational speed of the raw coal feeder, and thus regulates the coal feed rate in proportion to the rate of air flow to the pulverizer. The pulverizer directly serving the furnace or kiln 10 may be supplied with raw material which may have variations in the amount of moisture it contains. It then becomes necessary to change the temperature of the air entering the pulverizer so as adequately dry the pulverized coal delivered to the furnace. As shown on the drawing, the temperature of the coal and air mixture passing through the burner pipe 30 is determined by temperature sensitive means 44 which transmits a proportional impulse to a temperature controller 45 which is operatively connected through a power piston 46 to regulate the position of the damper 22 in the ambient air inlet duct 21.

Normally, the temperature of the coal and air mixture leaving the pulverizer 15 will be selected to provide a temperature range from 130 to 200°F, for example 175°F. Experience has indicated that such an outlet temperature range assures adequate drying of the raw coal delivered to the pulverizer. When the percentage of moisture in the coal delivered to the pulverizer rises, it is necessary to increase the temperature of the air entering the pulverizer so as to maintain the outlet temperature in the pipe 30 at the selected value. This is accomplished by adjusting the damper 22 in the ambient air inlet duct. The controller 45 is of the recording type, for both the temperature of the coal-air mixture in the pipe 30, and the temperature of the hot air in duct 16 as indicated by a temperature sensing device 49.

Changes in the temperature of the air delivered to the pulverizer 15 also will change the weight of that air, and concomitantly will change the static pressure as measured.
by the Pitot tube 36 in the air inlet duct 27. This static pressure change will influence the rate of delivery of raw coal through the operation of the feed control mechanism 43, such effect will be sensed immediately by the helical strip 31 which rotates in proportionality with the volumetric flow of coal through the feed spout 25. This in turn will promptly act through the control mechanism 33 to adjust the position of the damper 20 in the air inlet pipe. Thus the temperature of the air delivered to the pulverizer 15, as regulated by the controllers 33 and 43, will immediately and automatically adjust the air and coal flow to the pulverizer to maintain a uniform volumetric delivery of coal and weight of air flow to the pulverizer.

As hereinbefore pointed out, it is sometimes desirable to provide additional air to the burner 13, whether this may be occasioned by a desire to change the flame characteristics in the furnace 10 or to cool the burner. This is accomplished, as shown in the drawing, by providing a bypass air connection 50 between the housing of the blower 18 and a manifold 51, or baffle, associated with the burner 13. The bypass air line 50 is provided with a suitable damper 52 for manual regulation of air flow through the bypass line. It will be noted that the primary air flow control to the pulverizer is regulated by the damper 20 on the inlet side of the fan. Thus, if the flow of air through the by pass line is increased, it will be necessary for the control system to be so actuated as to open the primary air flow damper 20. This will alter the air flow measurement obtained through the Pitot tube 36, in turn actuating the controller 43 regulating the feeder motor and actuating the volumetric controller 33, repositioning the primary air damper 20 to meet the changed requirements of the system so as to maintain a uniform volumetric flow of coal to the pulverizer 15 and thus to the burner 13.

In summation, the present invention provides a control for the pulverized material supply system wherein the actual flow rate of raw material to the pulverizer is compared with a desired flow rate, and the deviation is utilized to coordinate the rate of air flow to the pulverizer and to correct the actual rate of raw material flow to the desired standard. The control also regulates the rate of flow of air and raw material to the pulverizer under changes in the temperature of the air delivered to the pulverizer, and changes in the amount of air bypassed around the pulverizer, to maintain the weight ratios of air to material delivered to the pulverizer.

In the description and claims, the term "air" has been used generically and may include any gaseous fluid, vapor or mixtures of gaseous fluids. While in accordance with the provisions of the statutes I have illustrated and described herein the best form and mode of operation of the invention now known to me, those skilled in the art will understand that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by my claims, and that certain features of my invention may sometimes be used to advantage without a corresponding use of other features.

What is claimed is:

1. In an air swept pulverized material supply system the method of control comprising the steps of continuously measuring directly the rate of raw solid fuel delivery to a pulverizing zone, continuously comparing said rate of raw material delivery with a desired standard rate of delivery in terms of a deviation value, converting said deviation value to an impulse proportional in direction and amplitude to the deviation of said raw fuel rate from said standard, transmitting said impulse to a receiver effective to alter the rate of flow of carrier air to said pulverizing zone, and regulating the rate of raw material flow to said pulverizing zone in coordination with said rate of flow of carrier air to said pulverizing zone to maintain a predetermined ratio therebetween.

2. In a pulverized fuel supply system the method of control comprising measuring directly the rate of raw solid fuel delivery to a pulverizing zone, continuously comparing said rate of fuel delivery with a desired standard rate in terms of a deviation value, converting said deviation value to an impulse proportional in direction and amplitude to the deviation of said raw fuel rate from said standard, transmitting said impulse to a receiver effective to alter the rate of carrier air flow to said pulverizing zone, regulating the rate of raw material flow to said pulverizing zone in coordination with said flow of carrier air to said pulverizing zone and maintaining the temperature of the pulverized fuel and carrier air flow from said pulverizing zone at a substantially uniform selected value.

3. In a pulverized fuel supply system the method of control comprising measuring directly the comparative rate of raw fuel delivery to a pulverizing zone on a volumetric basis, continuously comparing said rate of fuel delivery with a desired standard in terms of an electrical value, converting said electrical value to a pneumatic impulse proportional in direction and amplitude to the deviation of said actual raw fuel feed rate from said standard, transmitting said pneumatic impulse to a receiver effective to alter the weight of carrier air flow to said pulverizing zone, regulating the rate of raw material flow to said pulverizing zone and maintaining the temperature of the pulverized fuel and carrier air flow from said pulverizing zone at a substantially uniform selected value.

4. In an air swept pulverized material supply system including an air swept pulverizer, means including a fan for passing a controlled flow of carrier air through said pulverizer, means for introducing raw material to said pulverizer, ratio control means for regulating said feeder means in response to a measurement of the rate of air flowing to and through said pulverizer, means for comparing the actual volumetric rate of raw material flow to said pulverizer with a desired standard volumetric rate of raw material flow, and means operable to regulate the rate of air flow through said pulverizer in response to the magnitude and direction of the deviation between said actual and desired standard rate of raw material flow to said pulverizer.

5. In an air swept pulverized fuel supply system including an air swept pulverizer and a furnace, means including a fan for passing a controlled flow of carrier air through said pulverizer to entrain pulverized fuel for delivery to said furnace, means for introducing raw fuel to said pulverizer, means for maintaining the temperature of the pulverized fuel and carrier air mixture leaving said pulverizer substantially constant, ratio control means for regulating said feeder means in response to a measurement of the weight of air flowing to and through said pulverizer, means for comparing the actual rate of raw fuel flow to said pulverizer with a desired standard rate of raw fuel flow, and means operable to regulate the weight of air flowing through said pulverizer in response to the magnitude and direction of the deviation between said actual and desired standard rate of raw fuel flow to said pulverizer.

6. In an air swept pulverized fuel supply and consuming system including an air swept pulverizer and a furnace, means including a fan for passing a controlled flow of carrier air through said pulverizer to entrain pulverized fuel for delivery to said furnace, means for introducing raw fuel to said pulverizer, control means for regulating said feeder means in response to a measurement of the weight of air flowing to and through said pulverizer, means for comparing the actual rate of raw fuel flow to said pulverizer with a desired standard rate of raw fuel flow, means including an air duct from said
fan by-passing said pulverizer for the delivery of a controlled quantity of air to said furnace to change the ratio of combustion air to pulverized fuel delivered to said furnace, and means operable to regulate the weight of air flowing through said pulverizer in response to the magnitude and direction of the deviation between said actual and desired standard rate of raw fuel flow to said pulverizer irrespective of the by-pass air delivered to said furnace.

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