April 13, 1948. P. S. DICKEY 2,439,721

CONTROL SYSTEM FOR FEEDING FUEL TO FURNACES

Filed April 22, 1941 2 Sheets-Sheet 1

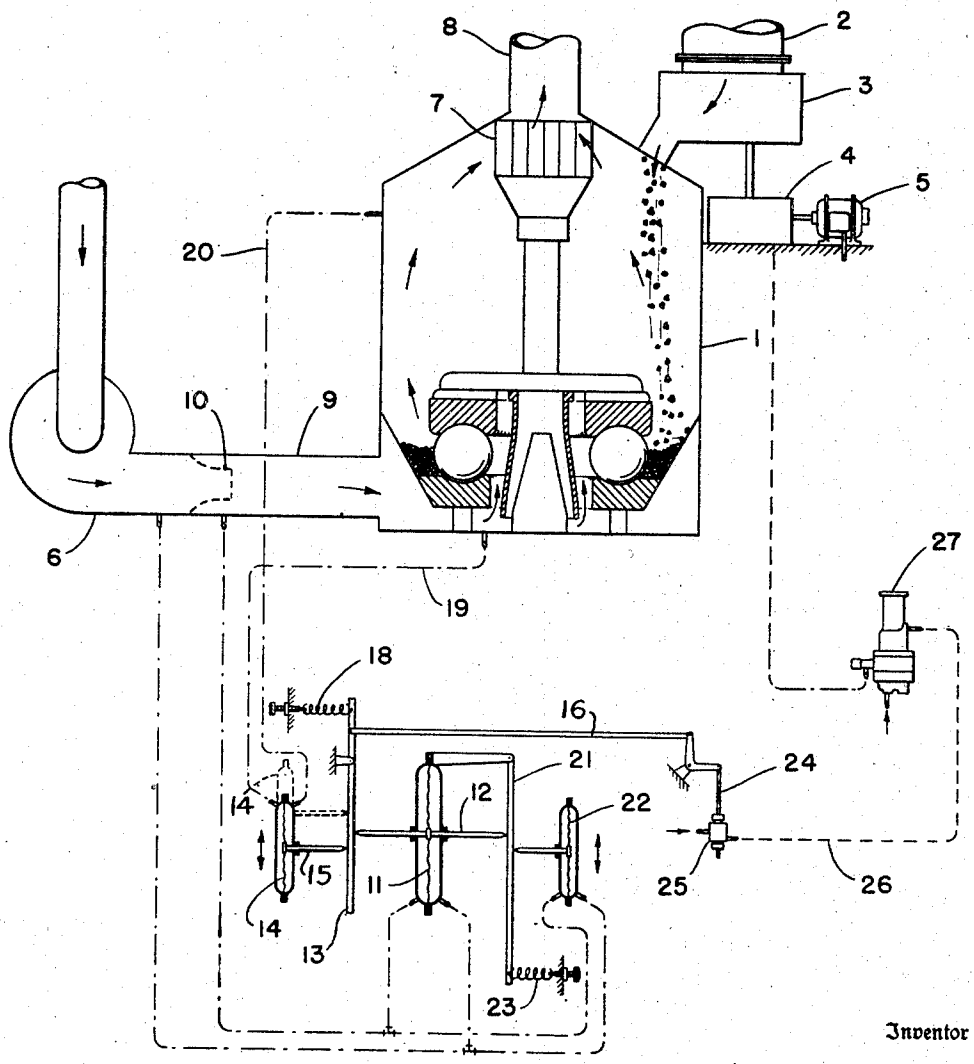


FIG. 1

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CONTROL SYSTEM FOR FEEDING FUEL TO FURNACES

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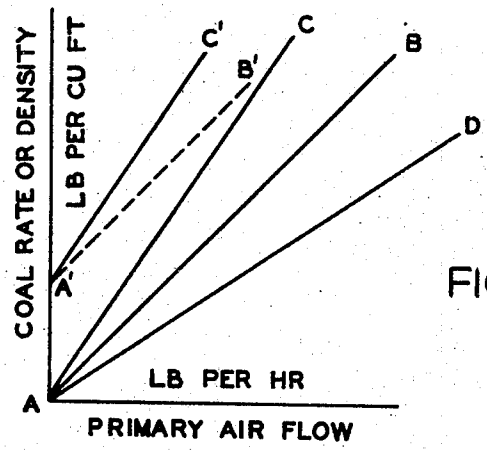


FIG.3

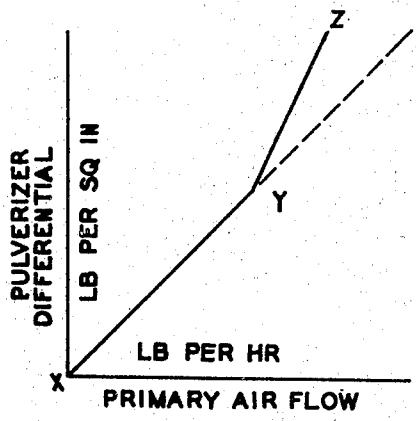


FIG.4

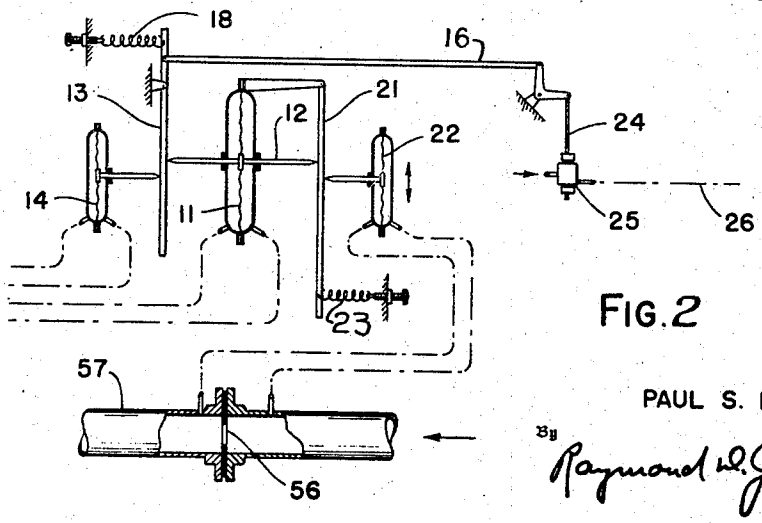


FIG.2

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Patented Apr. 13, 1948

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UNITED STATES PATENT OFFICE

2,439,721

CONTROL SYSTEM FOR FEEDING FUEL TO FURNACES

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Application April 22, 1941, Serial No. 389,777

3 Claims. (Cl. 110—106)

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This invention relates to the art of combustion, and particularly to the operation of fuel fired furnaces and to the measurement and control of variable factors in the operation of such furnaces.

One of the most commonly used fuels is coal blown into the furnace in pulverized form by means of a stream of carrier air. The carrier air is termed primary air, while the remainder of the air necessary in the combustion of the pulverized fuel is termed secondary air.

The pulverized coal may be direct fired, that is fed directly from the pulverizer to the burners; or may be transported to a bin system from which the burners are supplied. In either case the pulverized fuel is transmitted to the burner in suspension in a stream of carrier air, and a particular object of my invention is to properly proportion the carrier air to the pulverized fuel to be carried thereby, that is to supply the burner with a mixture of desired density; at the same time varying the rate of fuel supplied to satisfy the load demands on the furnace.

There are many variables in the operation of a fuel fired furnace upon which satisfactory operation depends, such for example as proper flame travel, slagging of furnace walls, efficiency of combustion, unburned fuel loss, maintenance of load, quality (such as steam temperature and pressure) of products, etc., and one of the most regulatory measures is the proper proportioning and feeding of the elements of combustion to the furnace.

The quantity of air required to carry the pulverized fuel in suspension has been found to vary with the type of fuel, as well as with its fineness and moisture content, and must be sufficient to transport the pulverized material in suspension without allowing it to drift or settle out in the pipe leading from the pulverizer. It is undesirable, however, to pass through the mill an excess of air over that required. Such an excess of air requires additional fan or blower capacity at its source, as well as additional equipment and expense in separating the pulverized material from the carrier air at a point of storage. If coal to be used as fuel is the material being pulverized, then an excess of air may introduce into the furnace a greater amount or percentage of air than is desired for efficient combustion. Furthermore, if the carrier air is not properly proportioned to the rate of grinding, either insufficient pulverized fuel will be carried out with the air, or perhaps the carrier air will cause the withdrawal from the mill of coal particles which have not been reduced to the desired

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fineness. In other words, an excess of air passing through the pulverizer mill will tend to carry from the mill not only fuel of the desired fineness, but also particles of too large a size to be burned efficiently in suspension.

It is well understood that in a direct fired furnace system, that is where a pulverizer feeds directly to a burner or burners, the quickest response for increase or decrease in the liberation of B. t. u. from the fuel is accomplished by first varying the rate of carrier air to the mill followed by adjustment in the rate at which raw fuel is supplied to the mill to be pulverized. This makes use of the fuel storage capacity of the mill and the follow-up control of rate of feed of coal to be pulverized tends to restore the level of coal within the mill to optimum level, which may be relatively uniform or may vary with rate of operation as desired.

In such a system load changes may be taken care of in a partially satisfactory manner by variations in the rate of supply of primary air, and a control of material to be pulverized is of course necessary as a follow-up condition. However, such a system does in no respect insure the proper density of the air-fuel mixture arriving at the burner for various rates or conditions of operation. This is particularly important if optimum combustion conditions are to be maintained irrespective of rate of operation. Such optimum conditions can only be attained through a direct measurement and control of the density of the fluid reaching the burner, that is the proper proportioning of primary air to the pulverized fuel carried in suspension thereby. It is a principal object of my invention to measure the density of a flowing stream of carrier air with pulverized material in suspension therein, and to control variables in the operation of a fuel fired furnace from such measurement.

I have chosen to illustrate and describe my invention primarily with reference to fuel pulverizers for providing an element of combustion for a vapor generating furnace and where the pulverized fuel is fed directly from a pulverizer to the furnace. However, it will be apparent from a study of the invention and to those skilled in the art that the invention is also applicable to all types of fuel fired furnaces, such for example as cement kilns, and furthermore is adapted to the bin system as well as to the direct firing system. Furthermore, the invention is equally applicable to pulverizers of other materials which for various reasons must be ground or pulverized to a finely divided state and desirably transported

by means of air to the point of usage or of storage, which in such instances is not a fuel fired furnace.

In general, the invention is directed to the proper porportioning of a stream of carrier air and of a pulverized material to be carried in suspension therein so that an optimum density of the suspension may arrive at a desired point; and where the optimum density may be uniform with variations in rate of supply, or may vary in desired proportion thereto.

In the drawings:

Fig. 1 is a diagrammatic representation of my invention in connection with a ball mill pulverizer.

Fig. 2 is a modification of Fig. 1.

Figs. 3 and 4 are graphs of relationships between variables in the operation of the system including my invention.

Referring first to Fig. 1, I illustrate therein in diagrammatic fashion one embodiment of my invention in connection with a ball mill or pulverizer of well known type, as for example the mill disclosed and claimed in the patent to Bailey et al. 2,076,288, although by no means limited to this particular type of pulverizer.

In the pulverizer 1 one or more rows of balls are rotated in a horizontal plane between grinding rings, one or more of which may be stationary or rotatable to drive the balls.

Coal to be pulverized is fed from a hopper opening 2 to a feeder 3 positioned or operated through a variable speed device 4 by a motor 5. The arrangement is such that a standard type of feeder 3 may be rotated or moved at a speed determined by the positioning of a variable speed driving device 4 intermediate the constant speed motor 5 and the feeder mechanism 3. The feeder 3 may comprise a rotating paddle wheel type of feeder or a movable knife or blade relative to a constant speed toothed feeder. The particular type of mechanism 3, 4, 5 forms no part of the present invention and any standard and well known pieces of feeder equipment may be utilized. It is only essential to my invention that the arrangement be such that the rate of feed of coal to be pulverized may be varied through the agency of the measuring and controlling instrumentalities which I will now describe.

The coal passes from the feeder 3 by gravity to a lower portion of the mill adjacent the rotating balls and one object of the control system is to maintain the level of material in the mill at an optimum level, which may be a constant level irrespective of rate of operation or a level varying in predetermined manner with the rate of operation. By rate of operation I mean the desired rate of supply of pulverized fuel passing with the carrier air from the pulverizer to a burner.

Carrier air is supplied to the mill 1 by a fan or blower 6 and may be of controlled temperature, although such temperature control forms no part of the present invention. In the present embodiment, carrier air from the fan 6 enters the mill below the stationary grinding ring, passing up through a central aperture therein and then between and around the moving grinding balls, passing through the material adjacent the balls, upwardly into a separating section 7 and to the discharge conduit 8 leading to a burner or burners. The pulverizer in general is known as a wind-swept ball mill and it will be apparent that the carrier air in its passage through the mill will pick up and carry in suspension particles of pulverized fuel below a certain size.

It is known that if the rate of supply of carrier air is relatively great, while at the same time the resistance to the passage of air of the bed through stored material is relatively low, that the relatively high velocity of the carrier air may pick up particles of a size larger than is desired. Such larger particles will tend to drop out or drift in the pipe lines between the discharge 8 and the burner, or if they reach the burner and are projected into the furnace they may fail to burn completely in suspension, with consequent large unburned carbon loss.

The efficiency with which the pulverized material is carried in suspension is therefore a function of the pressure differential or resistance to passage of the carrier air through the grinding mechanism and stored material in partially ground condition adjacent the rotating balls. It is usually desirable, therefore, that the level of material within the mill be not held constant with variable rating, but that the level be increased in some functional relation with rating, so that at an elevated rating and correspondingly large passage of air through the mill there will be a relatively greater storage of material in the mill, and vice versa.

Inasmuch as all of the air passing through the pulverizer and forming a carrier fluid for the pulverized coal comes from the blower 6 through the conduit 9 it is evident that if I measure the rate of flow of the clean air passing through the conduit 9, separately measure the rate of flow of carrier air with pulverized fuel in suspension therein, and then compare the two rates of flow, I may arrive at a continuous determination of the weight rate of supply of pulverized fuel being produced by the pulverizer, and also a continuous measurement of the density of the fuel-air mixture leaving through the conduit 8 to the burner or burners.

At 10 I show a flow nozzle located in the conduit 9 for producing a pressure differential bearing a functional relation to the rate of flow of carrier air from the blower 6 to the pulverizer 1. This pressure differential is applied to the opposite sides of a diaphragm 11 adapted to exert a force representative of such differential through a member 12 upon a pivoted lever 13. Opposing the force of the diaphragm 11 is a diaphragm 14 acting upon the lever 13 through a member 15. The diaphragm assembly 14 is adjustable relative to the fulcrum of the lever 13 to vary its effectiveness thereon and comprises a ratio adjustment between the forces of the diaphragms 11, 14 and correspondingly the ratio between the differential pressures acting upon said diaphragms.

In Fig. 1 I have shown the diaphragm 14 connected at one side to a pressure pipe 19 leading to the air intake of the pulverizer and connected at its other side to a pressure pipe 20 leading to the pulverizer adjacent the inlet to the separator 7.

The control thus far described will tend to produce a curve, such as the curve A—B of Fig. 3, as a straight line. Adjustment of the ratio or the relative moment arms of the diaphragms 11, 14 along the lever 13 will move the curve A—B parallel therewith on Fig. 3. For instance, a movement of the diaphragm 14 to the position shown in dotted lines in Fig. 1 will result in a movement of the curves AB and AC to the positions A'B' and A'C' in Fig. 3.

It has been found to be desirable not to carry

a constant level of coal within the mill, but to carry a level which varies in the same direction as rating, i. e. an increasing level with rating, and to accomplish this I include in Fig. 1 an adjustable biasing spring 18 so arranged as to vary the slope of the relationship between primary air flow and coal rate, as for example along the lines A—C or A—D of Fig. 3. It is to be noted, however, that the various curve relationships shown on Fig. 3 as accomplished through the agency of the ratio adjustment of moment arms of the diaphragms along lever 13, or the biasing spring adjustment, are all straight lines, even though the biasing spring accomplishes the result of a level varying in desired relation to rate of output.

Effective upon the lever 13 are the diaphragms 11 and 14, as well as the adjustable biasing spring 18. Additionally I load the lever 13 through the member 12 and lever 21 by a diaphragm 22, adjustable as to moment arm relative to the fulcrum of lever 21, and for applying to the lever 13 a force representative of rate of operation, which in this case is a differential representative of rate of flow of primary air through the conduit 9. The diaphragm 22 and lever 21 are provided with an adjustable loading spring 23, which in addition to the possible positioning of the diaphragm 22 along the lever 21 controls the location of the break-off point Y of Fig. 4. When the unbalanced force on the diaphragm 22 becomes sufficient to overcome the spring 23, the lever 21 is actuated to change the response of the control system so that the operating curve then follows a different slope, as at YZ of Fig. 4.

It will be seen therefore that by the arrangement described in connection with Fig. 1 I have the possibility of adjusting the ratio between the forces of diaphragms 11 and 14 or basic density of the coal-air mixture leaving the conduit 8; secondly by the biasing spring 18 I may carry a level of material in the mill 1 varying in predetermined relation to the rate of operation of the unit; and thirdly through the loading of the lever 13 by the diaphragm 22 I impose upon the lever 13 a force representative of rate of operation whereby at a desired rate of operation I can change the slope of the operating curve from its previous line of activity. In general, I am able to attain substantially any desired operating curve between primary air flow (rate of operation) and coal rate or coal density in the exit air stream.

Through the arrangement described I control the rate of feed of raw material to the pulverizer to maintain the level of material within the pulverizer at a level in desired relation to the optimum rate of fuel leaving through the conduit 8. While the pressure differential across the pipes 19, 20 is varied somewhat by the amount of material in storage in the mill 1, it also bears a functional relation to the amount of coal in suspension passing from the mill, that is the density of the coal-air mixture leaving the conduit 8. Thus with a constant speed pulverizer 1 I vary the rate of feed of raw material from the feeder 3 to basically satisfy the relation between rate of primary air flow and differential across the pipes 19, 20. This results in a level of material within the mill 1 varying in predetermined relation with rate of primary air flow. Assuming that the motor 5 is a constant speed motor, I control the variable speed drive 4 between the motor and the feeder 3 to control the rate of supply of raw material to the mill. I have indicated this control diagrammatically as an air actuated or pneumatic type of control.

The lever 13 carries a link 16 which is adapted to position a movable element 24 of a pilot valve 25, which is of the general type disclosed and claimed in the patent to Johnson 2,054,464. In general, the positioning of the element 24 in the pilot valve 25 establishes an air loading pressure in the pipe 26 representative of the position of the lever 13, and thus of the relationship of forces acting upon the lever 13. This air loading pressure is applied to a capacity relay 27 of the general type disclosed and claimed in my prior Patent 2,098,913, to which reference may be had. From the relay 27 I apply the resultant air loading pressure to any standard type of pneumatic actuator in the mechanism 4 for varying the feed of the feeder 3. The connections between the lever 13 and the feeder 3 is such that a swinging of the lever in a clockwise direction effects an operation of the feeder to reduce the supply of material to the pulverizer.

In Fig. 2 I show an arrangement in which the rate of vapor outflow from a vapor generator is effective in controlling the feeding of fuel to the pulverizer. This arrangement is like that of Fig. 1 except that the diaphragm 22 is sensitive to pressure differential across an orifice 56 positioned in a vapor outflow pipe 57 leading from the vapor generator having a furnace to which the burner is feeding pulverized fuel and air. In this arrangement all of the vapor leaving the vapor generator passes through the conduit 57 and therefore through the orifice 56, producing thereby a pressure differential effective upon the diaphragm 22 for loading the lever 13 representative of load upon the system. An increase in the load on the system is represented by a drop in the flow of vapor through the conduit 57. This reduced flow results in a decreased pressure unbalance on diaphragm 22, so that less opposition is offered to the swinging of lever 13 in a counterclockwise direction by diaphragm 14 to effect an increase in the feeding of coal to the pulverizer.

While I have illustrated and described certain preferred embodiments of my invention, it will be understood that the invention is susceptible of taking many forms without departing from its spirit or the scope of the appended claims.

What I claim as new, and desire to secure by Letters Patent of the United States, is:

1. A system for controlling a variable feeding means for a pulverizer through which air is discharged for carrying away the pulverized material comprising, in combination, a pivoted lever, means for producing a force by the air flow to the pulverizer and representative of rate of flow, means for subjecting said lever to said force, means for producing a second force by the flow of air and pulverized material leaving the pulverizer and representative of the rate of said flow, means for imparting said second force to said lever in opposition to said first force, a second pivoted lever, means for producing a third force representative of demand upon the pulverizer, means for subjecting said second lever to said third force, means for imparting forces from said second lever to said first lever in opposition to said second force, and means responsive to movement of said first lever for controlling said feeding means.

2. A system for controlling means feeding fuel to a pulverizer through which air is discharged for carrying the fuel to a furnace comprising, in combination, a pivoted lever, means for produc-

ing a force in response to the rate of air flow to the pulverizer, means for subjecting said lever to said force, means for producing a second force in response to the rate of flow of air and pulverized fuel leaving the pulverizer, means for imparting said second force to said lever in opposition to said first force, a second pivoted lever, means for producing a third force in response to the rate of steam flow from the furnace, means for subjecting said second lever to said third force, means for imparting forces from said second lever to said first lever in opposition to said second force, and means responsive to movement of said first lever for controlling said fuel feeding means.

3. A system for controlling means variably feeding fuel to a pulverizer through which air is discharged for carrying the fuel to a furnace comprising, in combination, a pivoted lever, a diaphragm, means for subjecting the opposite sides of said diaphragm to pressures at opposite sides of an orifice in the air suppply line to the pulverizer, means for subjecting said lever to forces equal to the pressure differences acting on said diaphragm, a second diaphragm, means for subjecting the opposite sides of said second diaphragm to pressures at the intake and discharge of the pulverizer, means for subjecting said lever to forces opposing the force of said first diaphragm and equal to the pressure differences acting on said second diaphragm, a second pivoted lever, a third diaphragm, means for subjecting the opposite sides of said third diaphragm to

pressures at opposite sides of an orifice in the steam line from the furnace, means for subjecting said second lever to forces equal to the pressure differences acting on said third diaphragm, means for imparting forces from said second lever to said first lever in opposition to forces of said second diaphragm, and means responsive to movement of said first lever for controlling said feeding means.

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