Fig. 3
This invention relates to pulverizer mills, such as are used, for example, to pulverize coal for boiler furnaces and more particularly to a control system for pulverizer mills that shall be capable of changing the rate of feed of material to the mills to be pulverized, either automatically or by hand, in accordance with the demand for pulverized material, and of so modifying the rate of feed of unpulverized material that a balance is maintained between the rate of feed to and the amount of pulverized material delivered by the mill for any given rate of demand therefor.

Another object of this invention is to provide a control system that shall be automatic in operation, for example in connection with a steam boiler plant, and adaptable to pulverizer mills that are driven either by steam engines or turbines or electric motors.

The above stated objects and other objects of the invention will be apparent to those skilled in this art, from the following description taken in conjunction with the accompanying drawings, in which:

Figure 1 is a more or less diagrammatic view of a pulverizer mill provided with a control system arranged and constructed in accordance with an embodiment of the invention;

Fig. 2 is a view similar to Fig. 1 showing a modified form of control system;

Fig. 3 is a view of a control system of the type shown in Figs. 1 and 2 but modified for application to pulverized mills driven by electric motors, the mills of Figs. 1 and 2 being driven by steam turbines;

Fig. 4 is a sectional view of a regulator embodied in the control system of Fig. 3 and adapted for use where the pulverized mill is driven by an electric motor.

Throughout the drawings and the specification, like reference characters indicate like parts.

The invention herein disclosed is adapted for use with pulverizer mills, that is mills that grind coarse material to such a degree of fineness that the pulverized material may be carried away to the point of use in a carrier such as air, for example. Specifically, the system is shown and described in connection with a mill employed to pulverize coal to be conveyed by air to the burners of a furnace, for example a boiler furnace.

In the operation of a pulverizer mill, for furnace operation, it is desirable that the mill grind the coal at a rate corresponding to the rate at which it is burned, and that the coal be fed to the pulverizer mill at a rate corresponding to the rate at which it is ground in the mill and carried therefrom by an air blast to the burners.

In Fig. 1 of the drawings, a control system embodying one form of the invention is illustrated as applied to a pulverizer mill 1 driven by a prime mover 2 indicated diagrammatically as a steam turbine. Coal is fed to the pulverizer from a hopper 3 by means of a feeder 4 driven by an adjustable-speed electric motor 5. The speed of the electric motor is controlled by a rheostat 6 connected in circuit with the field winding of the motor, and by adjusting this rheostat, the rate of feed to the pulverizer may be varied to meet varying demands for pulverized fuel. This adjustment of the rheostat may be accomplished by hand or automatically by means of a regulator 6', disposed to operate in response to an operative that reflects the demands for combustion. In the case of a steam-boiler, variations in pressure of the steam indicate either that more or less coal must be burned to maintain the steam pressure at the desired value. For example, decreasing steam pressure indicates that the load is increasing and that the combustion rate is insufficient to supply the demand for steam, or if the pressure is increasing, that indicates that the load and therefore the demand for steam is falling off and that the rate of combustion should be reduced. In the one case the rate of delivery of pulverized fuel to the burners must be increased which means that the pulverizer must grind more coal per unit of time and in order to do that the rate of feed must be increased. In the other case, the rate of delivery of fuel to the burners must be decreased, requiring therefore, a decreased rate of feed of coal to the pulverizer.

The coal as it is pulverized is carried away by a stream of air passing through the pulverizer.
to the burners of the furnace. The air supply is also regulated in accordance with the rate at which the coal is pulverized, all as is well known in this art.

5 The air supply to the pulverizer may be controlled by a regulator 1 and this regulator may be adjusted by hand or it may be operated automatically in response to changes in the demands for combustion.

10 If the condition of the coal to be pulverized always remained fixed and constant, the feed of coal to the pulverizer as controlled by rheostat 6 would be sufficient to meet the demand. But in practical operation the condition of the coal varies so that, in some cases, for a given demand for powdered coal, the coal would be delivered to the pulverizer at a rate higher than required. At other times, not sufficient coal would be delivered to meet the demand.

15 The load imposed on the turbine which drives the pulverizer indicates the amount of coal that is being pulverized. Thus for example, if the turbine operates at variable loads, it will be apparent that the pressure of the steam as delivered to the nozzles will vary with the degree of opening of the governor controlled throttle valve 8. In order to obtain a proper balance between the demand for pulverized fuel and the rate of feed of fuel to the pulverizer, a regulator 9 is provided which responds to a control impulse delivered thereto by a master regulator M. R. in response to variations in the demand for steam on the boiler and to the pressure of the steam at the nozzles of the turbine.

20 Regulator 9 comprises a regulating element, for example, an escapement valve 10 that is actuated jointly by a pressure responsive element 11 and a pressure responsive element 12 both acting on a lever or beam 13. Beam 13 carries a stem 14 positioned to move the escapement valve 10 either toward an inlet port 15 and away from an exhaust port 16 or vice versa, depending upon the relative magnitudes of the impulses or forces acting on elements 11 and 12.

25 Beam 13 is fulcrumed at one end on a knife edge 17 and connected at the other end by means of a tension spring 18 to element 11 illustrated as comprising a bellows. If bellows 11 moves upwardly in response to a decreasing impulse delivered to a housing 19 within which it is disposed to elongate and move beam 13 upwardly, shifting the valve 10 towards its inlet port and away from its exhaust port. When moving in this direction the pressure within valve body 20 and which is transmitted to a sending line 21, to regulators 6' and 7, is also reduced. The minimum pressure occurs in line 21 when inlet port 15 is closed and the exhaust port 16 is open. If the beam is moved downwardly either as the result of increasing pressure in housing 19 or of an increasing pressure acting on element 12 disposed within a housing 22, the valve moves towards exhaust port 16 and away from inlet port 15 whereby the pressure within the valve body 25 and in the sending line 21 is increased. When the exhaust port is closed the pressure in line 21 is at a maximum.

The pressure impulses delivered to housing 19 are controlled by regulator M. R. that responds to the pressure of the steam in the steam boiler header 23. The steam pressure acts on a pressure responsive element, such as a bellows 24 disposed within a pressure tight chamber 25 and this bellows is connected by a stem or push rod 26 to lever 27 fulcrumed between knife edges 28 at one end and connected to a tension spring 29 at a point near the right hand end, that is at a point to the right of the push rod. The right hand end of this lever actuates an escapement valve 30 like the valve 10 just described in connection with regulator 9.

30 When the steam pressure rises, bellows 24 is compressed and moves the push rod upwardly against the tension of spring 29 thereby causing the escapement valve to move away from its inlet port and to allow an increased pressure to be transmitted to the housing in which the bellows 11 is disposed. If the steam pressure is falling, the bellows expands which thus moves the valve 10 towards its inlet port and away from the exhaust port thereby decreasing the pressure imposed on bellows 11. In other words, with increasing load on the boiler, the pressure acting on bellows 11 increases, and with decreasing load on the boiler the pressure on this bellows decreases.

35 In order to stabilize regulator 9, a dash-pot 34 is provided that acts on beam 13 in such manner as to avoid excessive and sudden movements thereof allowing the regulators under control of regulator 9 time to formulate the adjustments and bring matters under their control to somewhere near the proper point before requiring further adjustment if any is necessary. Lever 13 is connected by a yoke 31 to bellows 12 and the yoke is connected by means of a spring 32 to the movable element or piston 33 of the dash-pot 34. The dash-pot comprises a cylindrical member 35 having a reservoir 36 at its upper end and a variable volume chamber 37 communicating with the lower end of the cylinder. Chamber 37 is defined by a bellows 38 which is urged towards its maximum volume position by means of a spring 39. This bellows is disposed within a chamber or housing 39 to which pressure impulses are delivered by the escapement valve 10. If the pressures delivered to housing 39 are increasing, bellows 38 is compressed whereby fluid is displaced causing piston 33 to move upwardly thereby compressing spring 32 and yieldingly opposing downward movement of lever 13. A needle valve 41 associated with a bypass 42 which is connected at its lower end to chamber 37 at a point below piston 33 and at its upper end to the reservoir at a point above the piston, allows fluid to escape from the space below the piston 33 to the space above the piston. The adjustment of this needle valve ensures that over a very long period the length of time the dash-pot is effective in checking movement of lever 13. As soon as the liquid has been transferred to the reservoir above the piston, the effect of the dash-pot is nullified. If the pressure delivered to housing 39 is decreasing, the bellows expands to increase and the volume of chamber 37 so that the tendency is to pull the dash-pot piston downwardly. The expansion of the bellows allows fluid to flow from the reservoir above the piston through the needle valve into the space below the piston and the effect of the dash-pot on the regulator is therefore gradually and finally nullified.

40 In any case, whether the pressures delivered to housing 39 are increasing or decreasing, the effectiveness of the dash-pot is made proportional to the pressure delivered to it.

45 Assuming that the boiler is operating at a 70 point where sufficient fuel is supplied to maintain the steam pressure in the steam header at the desired value, and that an increased demand for steam takes place, then the steam pressure will be reduced whereby regulator M. R. reduces the
pressure imposed on bellows 11. This causes the bellows to expand and increase the tension in spring 18 whereby the left hand end of beam 19 moves in a direction to increase its inlet port and reduce the pressure delivered to the dash-pot chamber 39 and to the sending line 21. This reduced pressure in the sending line is communicated to regulators 6' and 7. In response to this reduced pressure impulse, regulator 6' sends to rheostat 6 a direct order to increase the speed of motor 5 and the rate of feed of coal to the pulverizer mill, and regulator 7 moves in a direction to open a damper 43 to increase the amount of air delivered to the pulverizer mill.

The increased rate of feed of coal to the pulverizer mill imposes greater load on turbine 2. This tends to decrease the speed of the turbine causing the governor operated valve 8 in the steam line to the turbine to open wider. As this governor operated valve opens the steam pressure at the steam nozzles (not shown) of the turbine increases and this increased pressure is communicated to housing 22 within which bellows 12 is disposed causing this bellows to be compressed and to pull downwardly on lever 13 thereby tending to move the demand indicator 24 away from its inlet port. This increases the pressure impulses delivered to the rheostat operating regulator 6' and the air control regulator 7.

When the forces imposed by bellows 11 and 12 on lever 13 are in equilibrium, the lever comes to rest in such a position that a re-adjustment of the positions of the movable elements of regulators 6' and 7 that the rate of feed of fuel to the pulverizer is caused to correspond to the rate at which it is delivered from the pulverizer to the furnace. If for some reason the rate of feed to the pulverizer should increase without any change in demand for steam or without any change in loading pressure on bellows 11, the load imposed on turbine 2 would increase whereby an increased steam pressure would be transmitted to bellows 12. This would disturb the equilibrium between bellows 12 and 11 and cause valve 10 to transmit increased impulses to regulators 6' and 7, thereby reducing the rate of feed of coal to the pulverizer and the rate of air delivery thereto to a value corresponding to the new demand for coal on the pulverizer. When this condition is attained the bellows 11 and 12 are in equilibrium. On the other hand, should the rate of feed decrease the load on the turbine would decrease thereby causing the steam pressure acting on bellows 12 to decrease, and unbalance the forces exerted by bellows 11 and 12 on beam 13. Such an unbalance results in regulator 8 sending out impulses to regulators 6' and 7 that would cause the one to increase the rate of fuel feed and the other to open damper 43 and increase the rate of air supplied to the pulverizer. As soon as balance has been restored between bellows 11 and 12 the rate of feed of coal to the pulverizer mill will remain fixed until the master regulator makes the loading pressure on bellows 11, in response to a change in steam demand.

From the above it is seen that the rate of fuel feed to the pulverizer is caused to bear such a relation to the demand for pulverized fuel that the feed of fuel to the pulverizer is caused to bear a fixed or substantially fixed relation to the amount of pulverized fuel delivered by the pulverizer to the furnace. Any change in the duty imposed on the pulverizer is primarily controlled by the master regulator acting through regulator 6" and secondarily by the unbalance between the loading pressure on the master regulator M. R. to regulator 9 and the steam pressure at the nozzles of the steam turbine acting on bellows 12.

In Fig. 3 of the drawings, regulator 9, indicated only schematically, and regulators 6' and 7 which control the feed of fuel to the pulverizer and the air pulled through the pulverizer are directly responsive to impulses sent out from the master regulator M. R. Feed control regulator 6' is also controlled by regulator 9. In the system shown in Fig. 2 steam turbine 2 drives the pulverizer and a suction fan 48 pulls air through the pulverizer, the air carrying with it pulverized coal through duct 47 into the fan from which it is discharged through a pipe 48 to the furnace (not shown). Regulator 6" operating rheostat 6 is controlled by a dual pressure responsive mechanism 49. This mechanism includes a bellows 50 or other pressure responsive element disposed in a housing 51 to which a pressure is transmitted by the master regulator. It also includes another bellows 52 disposed within a housing 53 to which pressure impulses are transmitted from valve 10 of regulator 9. Whenever a change in the pressure impulse sent out from the master regulator occurs, the air control regulator 7 responds immediately to effect an adjustment in the rate of flow of air through the pulverizer. This impulse from the master regulator also acts immediately on bellows 50 associated with regulator 6' causing that regulator to immediately respond and shift the rheostat to a point corresponding to the speed required of the coal feed motor 5. The loading pressure set out by the master regulator also acts on bellows 12 of regulator 9 to effect an unbalance between the turbine steam pressure responsive bellows 12 and bellows 11, whereby a change is produced in the magnitude of the impulses sent out from this regulator to bellows 52 of the feed controlling regulator. This change in pressure acts to operate regulator 6" and cause it to further increase or decrease, as the case may be, the speed setting of the rheostat 6. These adjustments continue until bellows 11 and 12 of regulator 9 are in balance at which time the rate of feed of fuel and of air flow to the pulverizer will be such that the proper amount of pulverized fuel is delivered to the furnace and that the amount of raw coal fed to the pulverizer will correspond to the amount of pulverized fuel delivered by the pulverizer to the furnace.

In Fig. 3 of the drawings, I have illustrated regulator 9 in a form modified to be operable in the case where the pulverizer mill is driven by an electric motor as indicated at 53. For this purpose a plurality of coil windings 54 and 55 have been substituted for bellows 12 of regulator 9. One of these coils is stationary mounted and the other movably mounted. One coil is arranged to be energized in accordance with the voltage of the power supply for the mill motor 53. The other coil is traversed by the current delivered to the motor or by a current whose value is proportional to the current delivered to the motor. These coils are so disposed with respect to each other that they move towards each other with increasing load on the motor and away from each other when the load on the motor decreases. One coil, for example coil 55, is carried by a yoke 57 connected to lever 13 of the regulator 9'. This yoke is also connected by spring 58.
shown in Figs. 1 and 2, and is in equilibrium when the pull of coils 55 and 56 is balanced by the pull exerted by bel lows 11 and spring 18 on the valve actuating lever 13. Where an electric motor is used to drive the pulverizer mill, the reg ulator 9 is unbalanced causing regulators 6' and 7 to make a change in the rate of feed of coal to the pulverizer and in the rate of air supply thereto. The pressure imposed by the pressure of the steam at the nozzles of the tur bi ne results in a change in pressure on bellows 12 which unbalances the regulator to effect a change in feed of coal and the air supply whereby the steam pressure on bellows 12 is changed until it is in balance with the loading pressure on bellows 11.

In Fig. 2, the operation is somewhat the same, except that the loading pressure sent out by master regulator acts directly on regulators 6' and 7 as well as on bellows 11 of regulator 9. Regulator 9 acts only on regulator 6' but the regulating pressure of regulator 7 is finally determined by a state of balance being maintained between the loading pressure and the steam pressure as prescribed, respectively on bellows 11 and 12. And since this loading pressure also acts on regulator 7, the required amount of air is supplied to the pulverizer and a balance is maintained between the amount of coal delivered to the pulverizer and the amount of pulverized coal delivered to the furnaces for a given demand therefor.

The regulator of Fig. 3 operates on the same principle as the regulator 9 of Figs. 1 and 2 operates, but differs therefrom in that the power delivered to the motor is measured by coils 55 and 56 and utilized to balance spring 18 for the various loading pressures on bellows 11, any unbalance between them resulting in a change in feed of coal to the pulverizer and in the rate of air supply thereto until a balance is restored between the operation and control system.

Having thus described the invention, what I desire to claim and secure by Letters Patent is:

1. A control system for regulating the output of a pulverizer mill disposed to deliver pulverized fuel to a furnace, and comprising a prime mover for driving the mill and a feeder for delivering unpulverized fuel to the mill at a rate approximating the demand for pulverized fuel, and means responsive to the load imposed on the prime mover for modifying the action of said regulator that the feeder is caused to deliver unpulverized fuel to the mill at substantially the same rate that pulverized fuel is delivered by said mill to the furnace.

2. A regulator for controlling the operation of a mill for pulverizing coal, said mill being driven by a prime mover and provided with a feeder for delivering coal to the mill and a regulator for controlling said feeder, said regulator having a control element for governing the operation of the feeder regulator, an actuating element for operating said control element to effect adjustments in the rates of feed, and an element responsive to the load on the prime mover disposed to be normally in balance with said actuating element, said load responsive and actuating elements mutually cooperating with said control ele...
ment to so adjust the rate of feed that a balance is maintained between them.

3. A system for controlling the operation of a pulverizer mill driven by a prime mover and provided with a feeder and regulator for adjusting the rate of delivery of material by the feeder to the mill, said system including a regulator having a control mechanism for controlling the feeder regulator, a spring yielding urging said mechanism in one direction, means for variably loading said spring in accordance with the demand for pulverized material to cause said control mechanism to function and change the rate of feed of material to the mill, and means responsive to the load on said prime mover and acting in opposition to the pull of said spring on said control mechanism to effect such a modification of the rate of feed that a balance is established between the load responsive means and the loading imposed on the spring by said loading means.

4. A control system for pulverizer mills driven by a prime mover and provided with a motor driven feeder and a source of supply of air for carrying pulverized material out of the mill to a boiler furnace, said system comprising a master regulator responsive to the demand for steam and means under the control of said master regulator for regulating the air supply, and a second regulator having means responsive to the operation of the mill, said regulator for adjusting the speed of the feeder motor to establish a rate of feed required by the demand for pulverized material, and means responsive to the load on the prime mover and cooperating with said regulator responsive means to so modify the speed of the feeder motor that a balance is maintained between the output of the mill and the rate of feed of unpulverized material to the mill.

5. A system according to claim 7 characterized by the fact that the master regulator embodies means for establishing control impulses whose magnitudes are dependent upon the demand for pulverized material and that said second regulator includes a control element for adjusting the speed of the feeder motor, an actuating element including a spring for actuating said control element, means responsive to the load on the prime mover and acting in opposition to said spring arranged to so modify the action of said control element that a balance is maintained between the output of the mill and the rate of feed thereto for any rate of demand as indicated by said master regulator.

6. A system according to claim 7 characterized by the fact that said second regulator comprises a regulating element for controlling said feeder motor, a spring operatively connected to said regulating element and tending to move the same in one direction, means under the control of the master regulator for applying a variable loading force to said spring, and means actuated in accordance with the load on the prime mover for balancing the loading force on said spring, whereby when an unbalance occurs the regulating element is actuated to modify the speed of the feeder motor until the spring loading is again balanced.

7. A control system for pulverizer mills adapted to supply powdered fuel to boiler furnaces, and provided with an adjustable speed motor for driving the mill, means for feeding unpulverized fuel to the mill at controllable rates, and an adjustable supply of air for carrying powdered fuel out of the mill to the furnace, said system comprising a master regulator responsive to steam demand for developing a first control force that is a measure of steam demand, a second regulator responsive to said first control force and to a condition that varies with the load on the motor for establishing a second control force whose magnitude varies with the value of said first mentioned control force and the extent of response of said second regulator to the load on the motor, and means responsive to said second control force for controlling the unpulverized fuel feeding means that said regulator is maintained substantially in a state of balance between said first control force and the effect of the motor load thereon.

8. The combination with a pulverizer mill, a steam actuated prime mover for driving the mill, and means for feeding material to be pulverized to the mill at regulatable rates, of means for developing a control force that varies with a condition reflecting the demand for pulverized material, means responsive to the load on the steam actuated prime mover for so modifying the operation of the feed controlling means that a substantially balanced relationship is maintained between the rate of feed to the mill and the load on the prime mover for each rate of feed to the mill.

9. The combination with a pulverizer mill, an electric motor for driving the mill, and means for feeding material to be pulverized to the mill at regulatable rates, of means for developing a control force that varies with a condition reflecting the demand for pulverized material, means responsive to the load on the electric motor for so modifying the operation of the feed controlling means that a substantially balanced relationship is maintained between the rate of feed to the mill and the load on the prime mover for each rate of feed to the mill.

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