

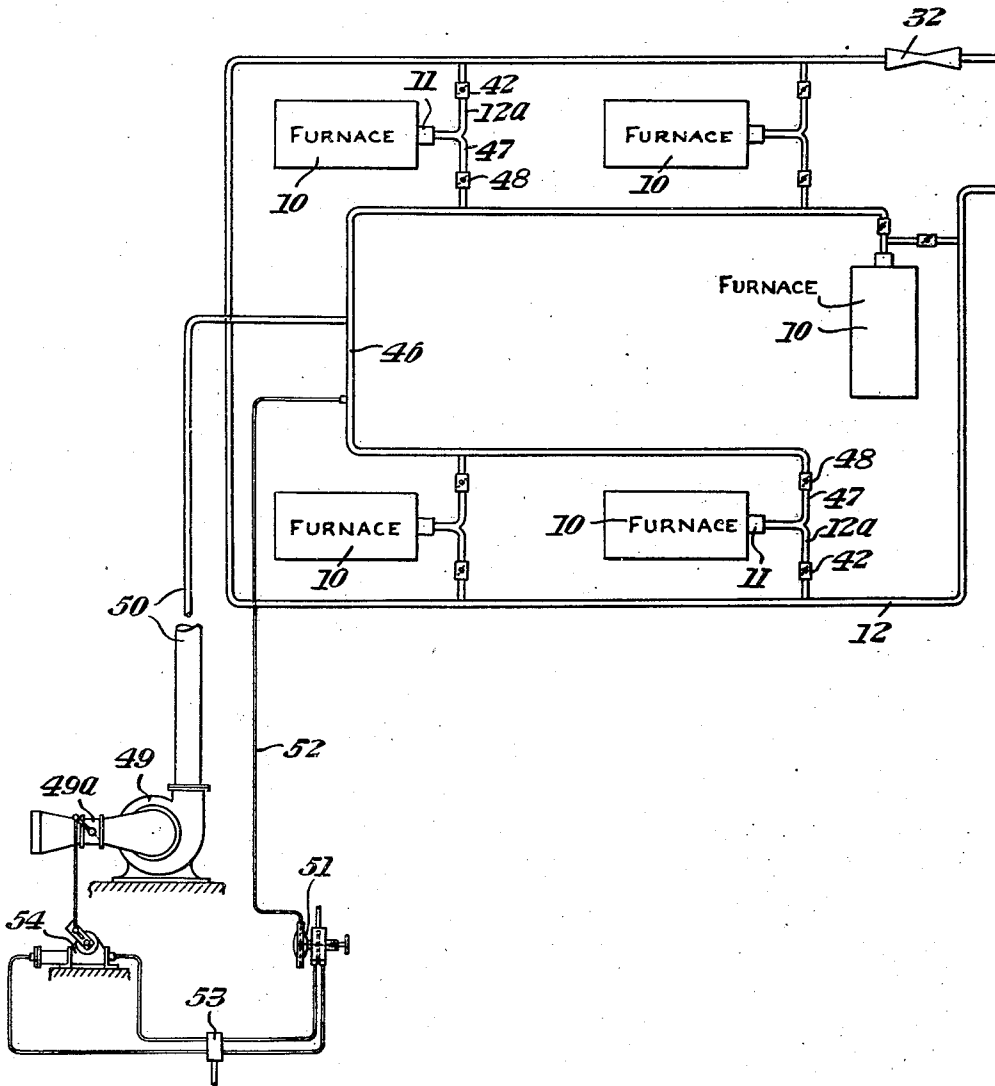
Oct. 8, 1946.

E. G. SMITH
METHOD AND APPARATUS FOR SUPPLYING
PULVERIZED COAL AND AIR TO FURNACES
Filed June 12, 1943

2,409,002

4 Sheets-Sheet 1

Fig. 1A.



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The diagram illustrates a vacuum system for a storage bin. Key components include:

- Storage Bin (21):** A central vertical container with a conical bottom.
- Motor Starter (27):** Connected to a **PULVERIZER (28)** and a **MOTOR STARTER (27a)**.
- Vacuum Pump (13):** A bellows-style pump connected to the system via pipe 20.
- Valves and Pipes:** Numerous numbered components (12, 14, 15, 16, 17, 18, 19, 22, 23, 24, 25, 26, 29, 30, 31, 33, 34, 35, 36, 37, 38, 39, 40, 41, 51, 53, 54, 55, 56, 57, 58, 58a, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100) represent various pipes, valves, and mechanical parts.
- Control System:** Includes a **MOTOR STARTER (27a)** and a **PULVERIZER (28)** connected to the main system.

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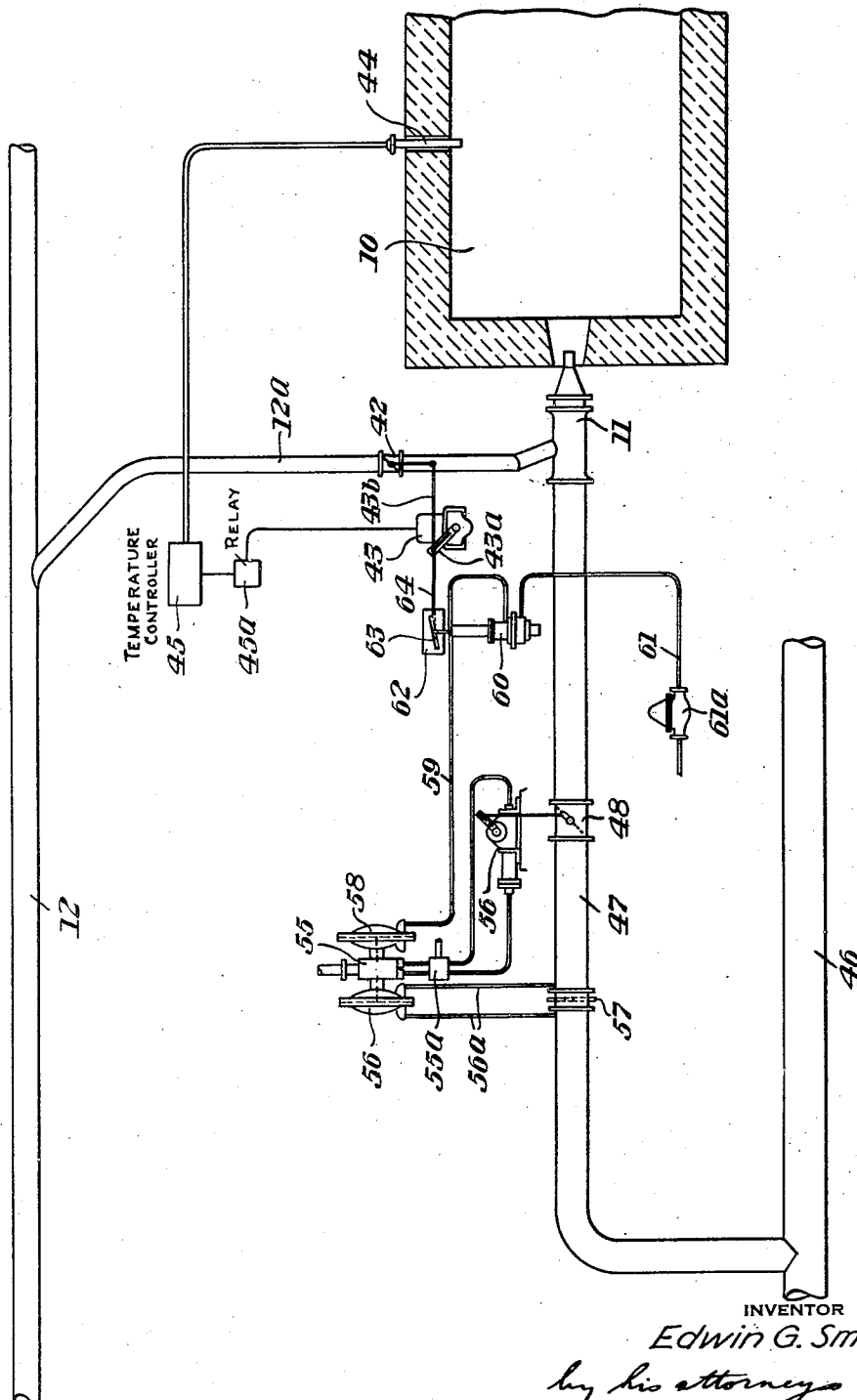
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Fig. 2.



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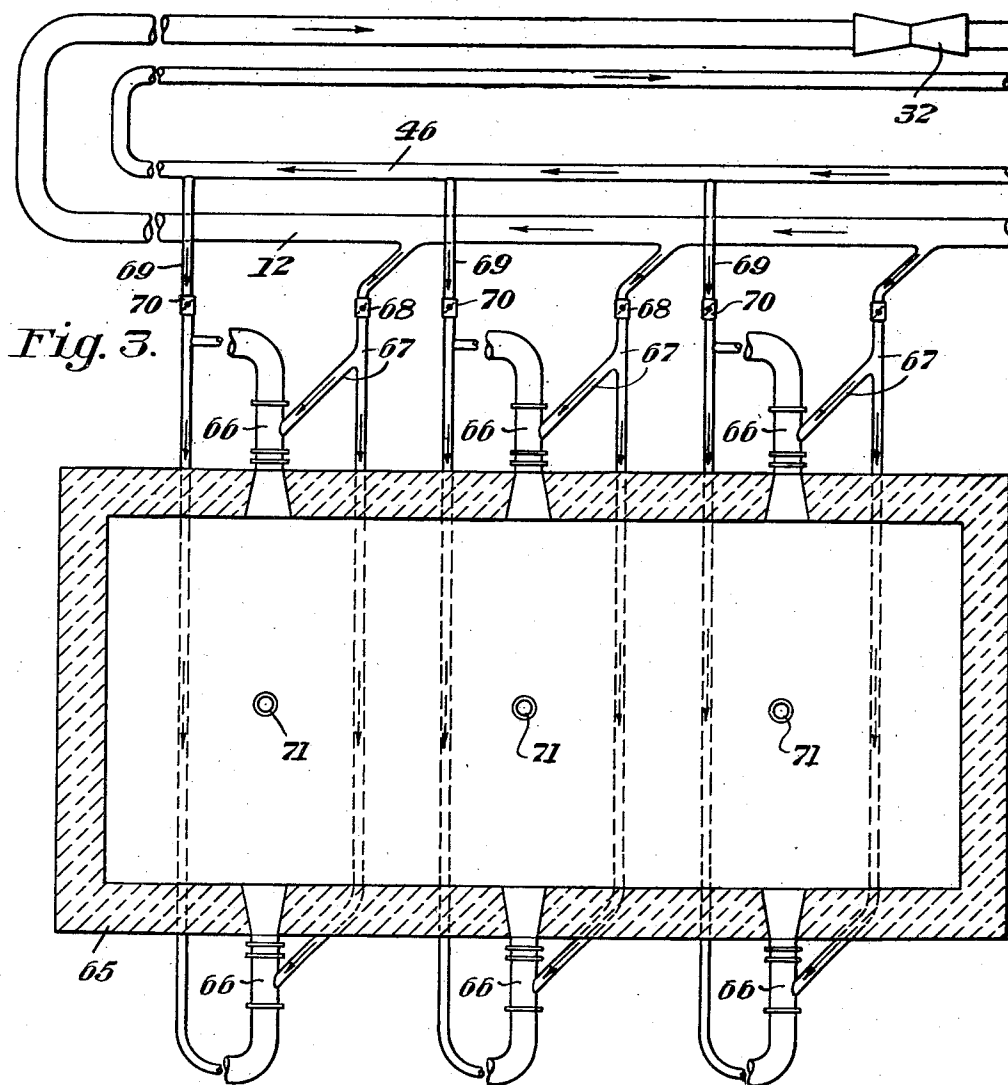
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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,409,002

METHOD AND APPARATUS FOR SUPPLYING
PULVERIZED COAL AND AIR TO FURNACES

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5 Claims. (Cl. 110—104)

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This invention relates to a control system for supplying pulverized solid fuel and air for combustion to the burners of one or more furnaces or other similar fuel-consuming apparatus.

Systems for supplying pulverized solid fuel such as coal have been applied heretofore chiefly to boiler furnaces particularly in central-station power plants where load conditions are fairly constant and the fuel may, therefore, be fed at a substantially uniform rate. It is one object of this invention to provide a control system capable of supplying fuel such as pulverized coal, and air to a plurality of furnaces or to a plurality of burners in a single furnace. Since conditions may vary materially between the several furnaces or even between the different portions of a single large furnace, fuel-supply systems known heretofore are not adapted to this type of installation.

I have invented a novel system for controlling the supply of pulverized coal and air to a plurality of burners by which the fuel and air supplied to each burner are individually controlled in accordance with the conditions existing in the region heated by the particular burner. To accomplish this, I deliver pulverized coal to a main circulating pipe with a volume of air so proportioned as to produce a non-explosive mixture, and maintain the air under sufficient pressure to convey the coal through the pipe. I provide means for automatically controlling the fuel taken from the main pipe by each burner in accordance with the temperature existing in the region heated thereby. I also provide means for maintaining substantially constant the pressure of the air in the main circulating pipe and means for changing the rate of supplying fuel to the pipe according to the demands for fuel made by the several burners connected thereto.

I also supply secondary air to the several burners through a main circulating pipe and control the amount of secondary air supplied to each burner in accordance with the amount of fuel delivered thereto.

I introduce in the main pipe for circulating pulverized coal a variable restriction in order to produce a minimum back pressure when the burners are being fired at a low rate. This insures that pressure impulses will be generated in the pipe on a change in the fuel demand of any burner. I utilize these pressure impulses to operate the various control devices embodied in a completely automatic system according to my invention.

A complete understanding of the invention

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and the various novel features and advantages thereof may be obtained from the following detailed description and explanation which refer to the accompanying drawings illustrating the preferred embodiment briefly outlined above. In the drawings,

Figures 1A and 1B together constitute a diagrammatic layout of my system for supplying pulverized solid fuel and air to a plurality of burners;

Figure 2 is a similar view showing the auxiliary apparatus located adjacent each burner; and

Figure 3 is a similar view showing the control system adapted to an installation including a plurality of burners in a single furnace.

Referring now in detail to the drawings and, for the present, to Figures 1A and 1B, a plurality of furnaces 10 are provided with burners adapted for the combustion of pulverized coal, each furnace having at least one burner such as indicated at 11. The apparatus for supplying fuel and air to the burners of the several furnaces includes a main header pipe 12 adapted to convey a mixture of fuel and primary air to the burners of the several furnaces. Branch connections 12a extend from the pipe 12 to each burner 11. Air is supplied to the pipe 12 by a blower 13 driven by any convenient means such as a suitable electric motor. A damper 14 controls the volume of air delivered by the blower to the pipe 12 and, therefore, the pressure of air in the latter.

A regulator 15 has a diaphragm chamber connected to the pipe 12 on the downstream side of the damper 14 for maintaining substantially constant the pressure of the air in the pipe 12. The regulator includes a swinging nozzle 16 which operates a valve 17 and a hydraulic motor 18. The regulator and its associated control mechanism are all of known construction so a detailed description thereof is unnecessary. It is sufficient to state that when the pressure in the pipe 12 changes, for any reason, the regulator 15 operates the swinging nozzle to supply air from a source to which it is connected by a pipe 16a, under suitable pressure, to one of the two pipes leading to the valve 17. The valve is thus operated to control the supply of fluid from a source to which it is connected by pipe 17a, to the motor 18 in such manner as to actuate the damper 14 through a crank 19 and link 20 to cause the pressure in the pipe 12 to be restored to normal. The motor 18 may, as illustrated, comprise a cylinder and piston operating the crank 19 through a rack and pinion. In a system such as that shown diagrammatically, the regu-

lator 15 is preferably set to maintain a pressure of about 7" of water in the pipe 12.

Pulverized coal is delivered to the pipe 12 on the downstream side of the damper 14 from a storage bin 21 through a connection 22 by a feeder 23 having a variable-speed drive 24. An adequate supply of coal is maintained in the bin 21 by pressure-switches 25 and 26 which may be of the diaphragm or other suitable type, controlling a starter 27 for the motor 27a of a pulverizing mill 28. The mill delivers fuel under air blast through a pipe 29 to a collector 30 above the bin 21. The switch 25 starts the mill when the level of fuel in the bin has fallen to a predetermined point and the switch 26 stops the mill when the level of fuel in the bin has been raised to the desired height. The pipe 12 extends from the blower 13 and the fuel bin 21 to each of the furnaces 10 in turn making a complete circuit thereof and finally returning to the bin 21. A collector 31 is disposed in the return portion of the pipe as is also a variable restriction 32 of any suitable construction.

The amount of fuel delivered to the pipe 12 through the connection 22 by feeder 23 is automatically controlled in accordance with the amount of air supplied to the pipe by blower 13. For this purpose, a ratio regulator 33 controls the variable-speed transmission 24 through a hydraulic motor 34 in the form of a cylinder and piston. The regulator 33 has a diaphragm in a chamber 35 subject, through suitable pipe connections 35a, to the pressure on opposite sides of an orifice plate 36 in the inlet of the blower 13. The regulator also has a diaphragm in a chamber 37 subject by means of a pipe 37a to the pressure in a compressed air line 38 including a constant pressure regulator 38a, as controlled by an adjustable regulator 39 connected therein.

The diaphragms in the chambers 35 and 37 are disposed in opposition and the differential effect thereof operates the nozzle of the regulator to control a valve 40 governing the motor 34 in the same manner that the valve 17 controls the motor 18. A connection 41 from the variable speed drive 24 to the regulator 39 adjusts the latter after an operation of the former to restore the regulator 33 to neutral or balanced position. In this manner, the regulator 33 controls the amount of coal supplied to the pipe 12 in accordance with the amount of air passing there-through. The regulator 33 is preferably adjusted to maintain the fuel-air ratio at a value which furnishes only about 35% of the amount of air theoretically required for complete combustion. With this amount of primary air, the fuel-air mixture is not explosive.

The supply of coal and primary air from the pipe 12 to the individual burners is regulated by control valves 42 in the branch pipes 12a. Each furnace 10 has automatic means for controlling its valve 42, the equipment making up the automatic control for one furnace being shown in detail in Figure 2. As there shown, the valve 42 is operated by an actuating mechanism 43 preferably including an electric motor and drive mechanism suitable for swinging a crank arm 43a pivoted to a linkage 43b connecting it to the valve. A thermo-couple 44 at a suitable point in the furnace 10 is connected to an automatic temperature control 45 of known construction, including a relay 45a which directly controls the motor of the mechanism 43.

Secondary air is supplied to the burners 11 in

quantity sufficient to effect complete combustion of the fuel from a header 46. Branch pipes 47 each including a control valve 48 extend from the header 46 to each burner 11. Air is supplied to the header 46 by a blower 49 through a pipe 50. The amount of air supplied by the blower is so controlled as to maintain a substantially constant pressure of air in the header. To this end, the inlet of the blower 49 is provided with a damper 49a. A pressure regulator 51 similar to that shown at 15 is subject to the pressure in the header by virtue of a connecting pipe 52 and operates a valve 53 similar to that shown at 17 to control hydraulic motor 54 for the damper 49a in the same manner that the motor 18 controls the damper 14. The regulator 51 is set to maintain sufficient pressure in the header 46 to supply to the burners the amount of air required for complete combustion of the fuel. While the pressure in the header 46 will vary with the individual conditions of a particular installation, a relatively low pressure such as between 7" and 16" of water will generally be found sufficient.

The amount of secondary air supplied to individual burners is controlled according to the amount of fuel supplied thereto, in order to insure efficient combustion at each burner, regardless of the firing rate. To this end, each valve 48 is provided with automatic control means including a ratio regulator 55, control valve 55a and a hydraulic damper-operating motor 55b similar to those shown at 18 and 54. The regulator 55 is similar to the regulator 33. It includes a chamber 56 having a diaphragm subject by means of pipes 56a to the pressures on opposite sides of an orifice plate 57 in the branch pipe 47, and a chamber 58 containing a diaphragm subject to the pressure in a pipe 59 connected through a regulator 60 to a compressed air line 61 having a constant-pressure regulator 61a therein. The line 61 may be connected to the same source as the line 38. The regulator 60 is adjusted in accordance with the position of the actuating mechanism 43 for the fuel valve 42. While any convenient mechanism may be employed for adjusting the regulator 60, I have illustrated diagrammatically a drum 62 mounted for rotation about a vertical axis, having a helical slot 63 therein in which the adjusting member of the regulator 60 rides. The drum 62 has a cable 64 wound around it and connected to the crank arm 43a of the mechanism 43. The drum 62 has a spring or counterweight tending to return it to starting position when the crank arm swings back toward the position it occupies when the valve 42 is closed. It will be evident that by means of the mechanism described, the regulator 55 is subjected to opposing pressures, one proportional to the flow of air through the branch pipe 47 and the other proportional to the flow of fuel through pipe 12a. The regulator 55 is operated by the differential between the pressures on the diaphragms and shifts its swinging nozzle to operate valve 55a which controls the motor 56.

The method of my invention will doubtless be apparent from the foregoing description of the apparatus which I prefer to employ in order to obtain automatic operation, but will nevertheless be explained briefly. For the purpose of explaining my method, it will be assumed that the system is in operation under normal conditions, the blower 13 and feeder 23 supplying a non-explosive mixture of fuel and air to the pipe 12, the individual burner valves 42 being controlled to divert from the pipe 12 the amount of fuel neces-

sary to maintain the temperature required in the furnaces, and the blower 49 operating to furnish secondary air to the burners under the control of valves 48 to effect complete combustion of the fuel. The restriction 32, having been adjusted to an appropriate position, causes a predetermined back pressure to be built up in the pipe 12 between it and the damper 14. Any excess fuel and air supplied to the pipe 12 above the requirements of the several furnace burners are returned to the bin 21 through the collector 31 and the proper reserve of pulverized coal is maintained in the bin 21 by the switches 25 and 26 which control the starter for the mill driving the pulverizer. As already indicated, the regulator 15 maintains a predetermined constant air pressure in the pipe 12. The regulator 51 performs the same function in respect to the header 46 and the regulator 33 automatically proportions the amount of fuel fed into the pipe 12 according to the volume of air flowing therethrough.

If the temperature in any one of the furnaces 10 should vary from the desired value, for any reason, the controller 45 for that furnace immediately operates to shift the fuel control valve 42. The shifting of the valve 42 causes a pressure impulse to travel back through the pipe 12. If the valve 42 is shifted toward the closed position, the pressure in the pipe 12 will be slightly increased. Conversely, if the opening of the valve 42 is increased, a slight drop will occur in the pressure in pipe 12. In either case, the regulator 15 will operate to shift the damper 14 in the proper direction to restore the pressure in the pipe 12 to its previous value. This will involve a change in the amount of air supplied to the pipe 12 which will be effective through regulator 33 to adjust accordingly the speed of the feeder 23 and thus appropriately control the rate at which fuel is fed to the pipe 12.

Any change in the position of the fuel valve 42 of any burner thus causes the entire system to be readjusted in accordance with the firing rate demanded by the conditions then existing in the furnace in which the burner is installed. Any change in the adjustment of the fuel valve 42 of any burner as indicated above, immediately effects operation of the valve 48 controlling the supply of secondary air to that burner. This results from the connection between the valve-operating mechanism 43 and the adjustable regulator 60 which governs the counter-pressure applied to the regulator 55. The volume of secondary air supplied to the particular burner is thus altered according to the requirement of the adjusted fuel supply. The regulator 51 then controls the damper 49a to bring the pressure in the header 46 back to its normal value.

Figure 3 illustrates the application of my invention to a furnace 65 having a plurality of burners 66 firing therein, the burners being spaced along opposite sides of the furnace. These burners are connected to the main circulating pipe 12, shown in a complete system in Figures 1A and 1B, by connections 67 including control valves 68. Similarly, connections 69 including control valves 70 extend from the secondary air header 46 to the burners. Thermo-couples 71 spaced along the length of the furnace control the valves 68 through operating mechanisms such as shown at 43 in Figure 2 and the valves 70 are automatically controlled in accordance with the rate at which fuel is supplied, by the automatic means already described, i. e., the regulator 55. In the embodiment illustrated in Figure 3, there

are three pairs of burners firing into the furnace, one burner of each pair being on each side of the furnace. The three thermo-couples each control one pair of burners. It will thus be apparent that the system shown diagrammatically in Figure 3 is similar to that shown in the other figures except that the burners all fire into one furnace and are controlled in pairs instead of individually. It will be noted that the branch pipes 67 and 69 are connected to both burners 66 of each pair which are in alignment on opposite sides of the furnace 65. It will be understood that in the system of Figure 3, the zone or area heated by each pair of burners is controlled by its own thermo-couple 71 independently of the other zones or areas. This makes it possible to maintain a uniform temperature throughout the furnace or a predetermined temperature radiant longitudinally thereof, if desired.

It will be apparent from the foregoing that my invention is characterized by numerous important advantages over methods and apparatus known previously for supplying pulverized solid fuel to burners and controlling the combustion thereof. The system of my invention maintains a constantly circulating supply of fuel of uniform concentration in a conveying air stream, the ratio of fuel to air being controlled, preferably in about the ratio of 1 pound of coal to not over 5 pounds of air, thereby producing a non-explosive mixture. The concentration of fuel in the circulating pipe is controlled automatically at various rates of fuel consumption and air flow, as determined by the pressure in the circulating pipe at a point upstream from that at which fuel is introduced. The invention maintains the fuel-air mixture in the circulating pipe at substantially constant pressure, despite variations in the rate of fuel consumption.

The invention also provides automatically a supply of secondary air proportioned to the rate of feeding fuel, for effecting the combustion thereof with the utmost efficiency.

It is to be noted that the fuel is delivered to the burners in suspension in low-pressure air and that the fuel does not pass through the blower supplying primary air. The use of a variable restriction in the circulating pipe assures satisfactory operation of the automatic control even at relatively low firing rates. The invention also provides for maintaining an ample supply of pulverized fuel for immediate introduction into the circulating pipe as required by the demand of the several burners. The delivery of pulverized coal to the storage bin from the pulverizing mill is controlled automatically.

Although I have illustrated and described but a preferred embodiment of the invention, it will be recognized that changes in the details of the system or its exact mode of application may be made without departing from the spirit of the invention or the scope of the appended claims.

I claim:

1. In a method of supplying pulverized solid fuel to a combustion chamber, the steps including circulating primary air through a delivery conduit, injecting the fuel into the air stream through the conduit, diverting a portion of the air and fuel from the conduit to the combustion chamber, varying the amount of fuel and air diverted in accordance with the temperature in said chamber, varying the amount of fuel and air supplied to the conduit in accordance with the air pressure therein, supplying secondary air to the chamber and controlling the amount of sec-

ondary air in proportion to the amount of primary air and fuel supplied.

2. In a method of supplying pulverized solid fuel to a plurality of burners spaced along a combustion chamber the steps including circulating primary air through a delivery conduit, injecting fuel into the air stream through the conduit, diverting a portion of the fuel and air from the conduit to each burner in accordance with the temperature in the chamber adjacent such burner, supplying secondary air to the several burners, and controlling the supply of secondary air in accordance with the amount of fuel and primary air supplied to said burners.

3. A system for supplying pulverized solid fuel to a plurality of burners comprising a container for storing fuel, a circulation pipe extending from said container to said burners in series and returning to said container, means for feeding fuel to said pipe from said container, means for automatically controlling the flow of fuel from the pipe to the burners individually, means for supplying air to the pipe, means controlling the air supply to maintain the pressure in said pipe substantially constant, and means for so proportioning the amount of fuel supplied to the pipe to the amount of air supplied thereto, as to maintain substantially constant the ratio therebetween.

4. A system for supplying pulverized solid fuel

to a plurality of burners comprising a container for storing fuel, a circulation pipe extending from said container to said burners in series and returning to said container, means for feeding fuel to said pipe from said container, means for automatically controlling the flow of fuel from the pipe to the burners individually, means for supplying secondary air to the burners, and means controlling the input to the secondary air-supplying means to maintain the pressure of the secondary air substantially constant adjacent the burners.

5. A system for supplying pulverized solid fuel to a series of furnaces, each having one or more burners, comprising a container for storing fuel, a circulation pipe extending from the container to said furnaces and burners in series and returning to said container, means for feeding fuel to said pipe from said container, means for automatically controlling the flow of fuel from the pipe to the burners individually, means for supplying air to said pipe to convey fuel to the burners, means for automatically proportioning the air supplied to the fuel conveyed, means for supplying secondary air to the burners, and means controlling the input to the secondary air-supplying means to maintain a predetermined pressure therein, and thereby proportion the amount of secondary air supplied.

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