Dec. 30, 1952 P. S. DICKEY 2,623,698

COMBUSTION CONTROL SYSTEM

Filed Dec. 3, 1947 3 Sheets-Sheet 1

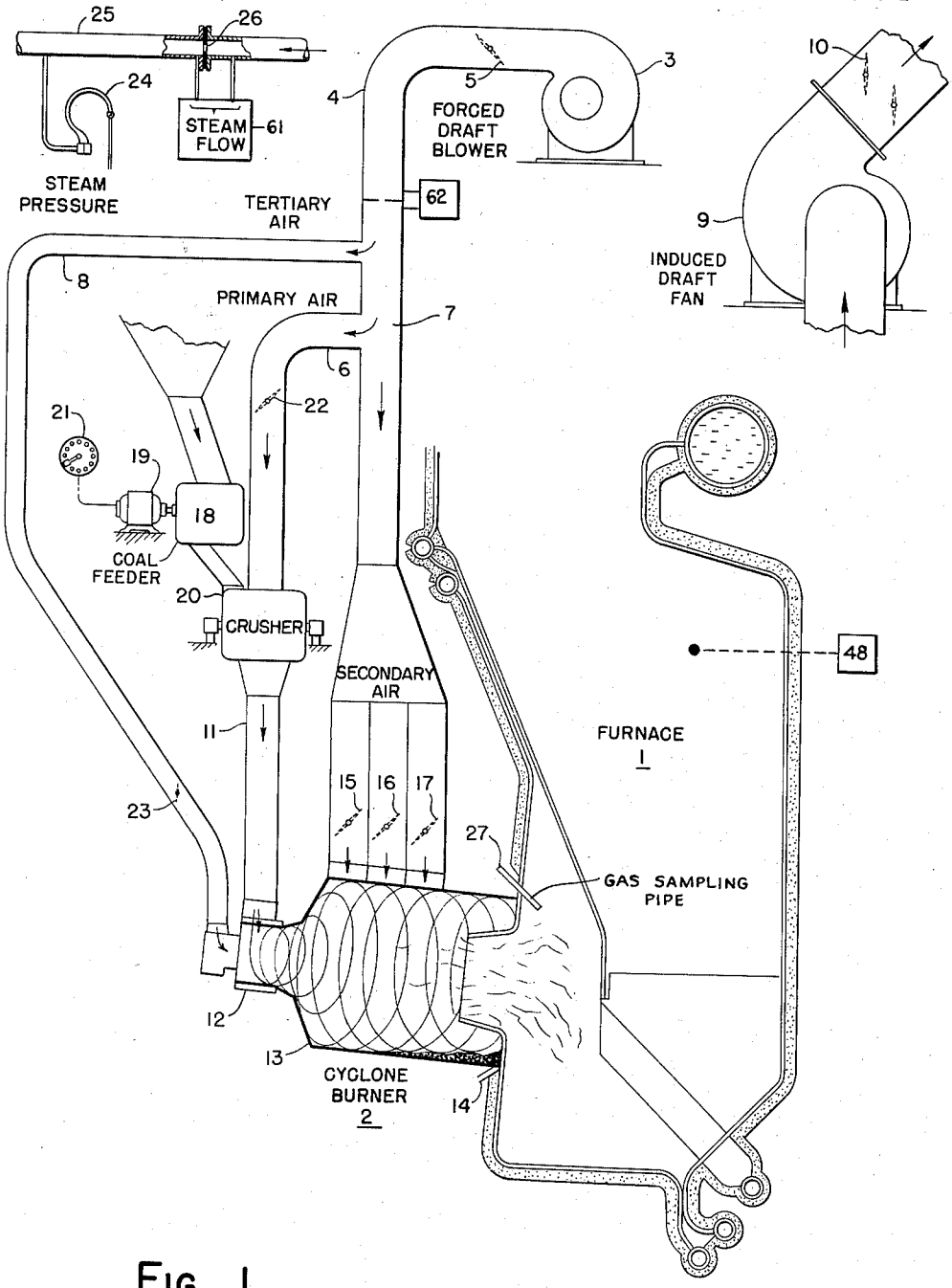

FIG. 1

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COMBUSTION CONTROL SYSTEM

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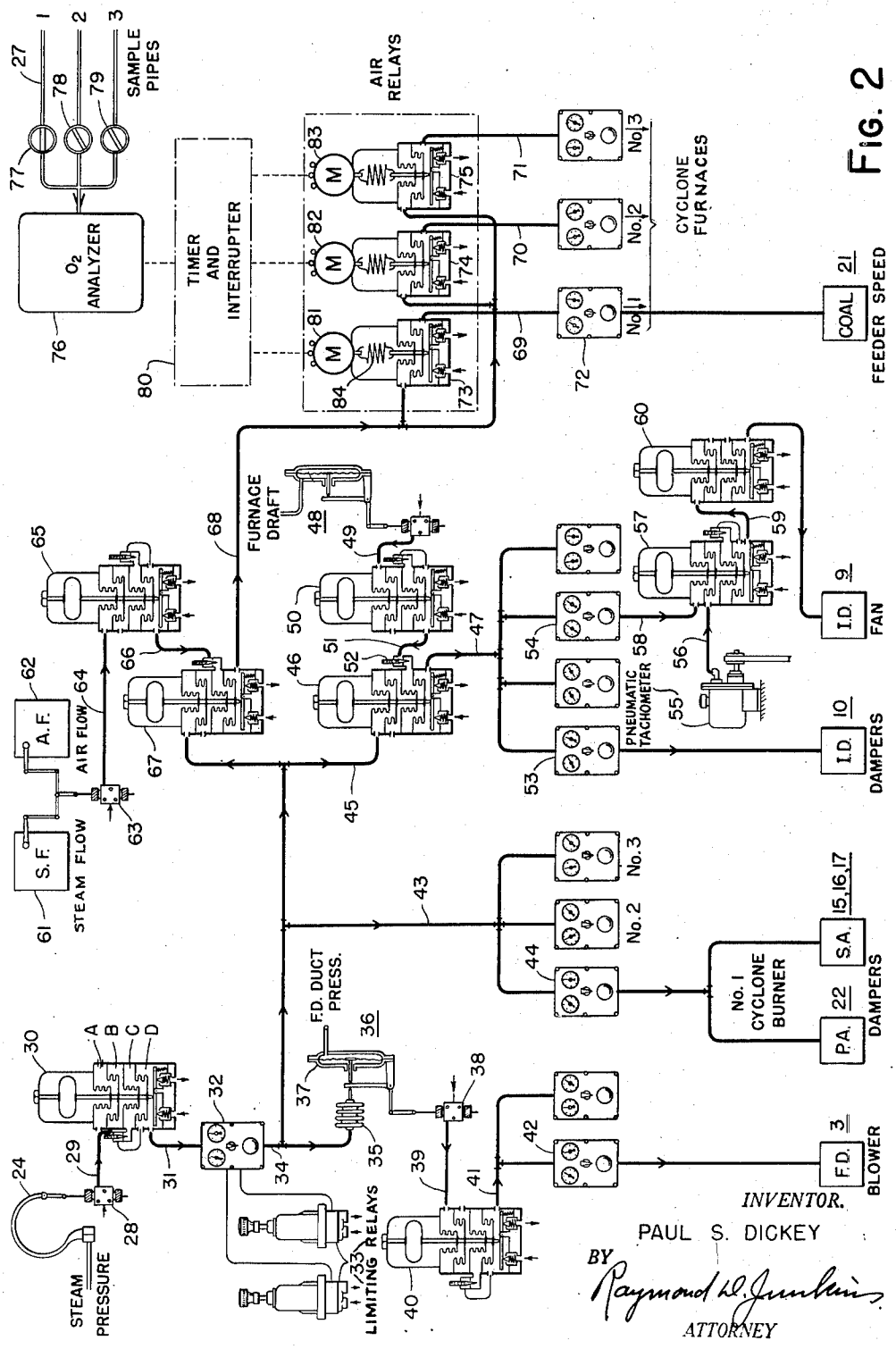

FIG. 2

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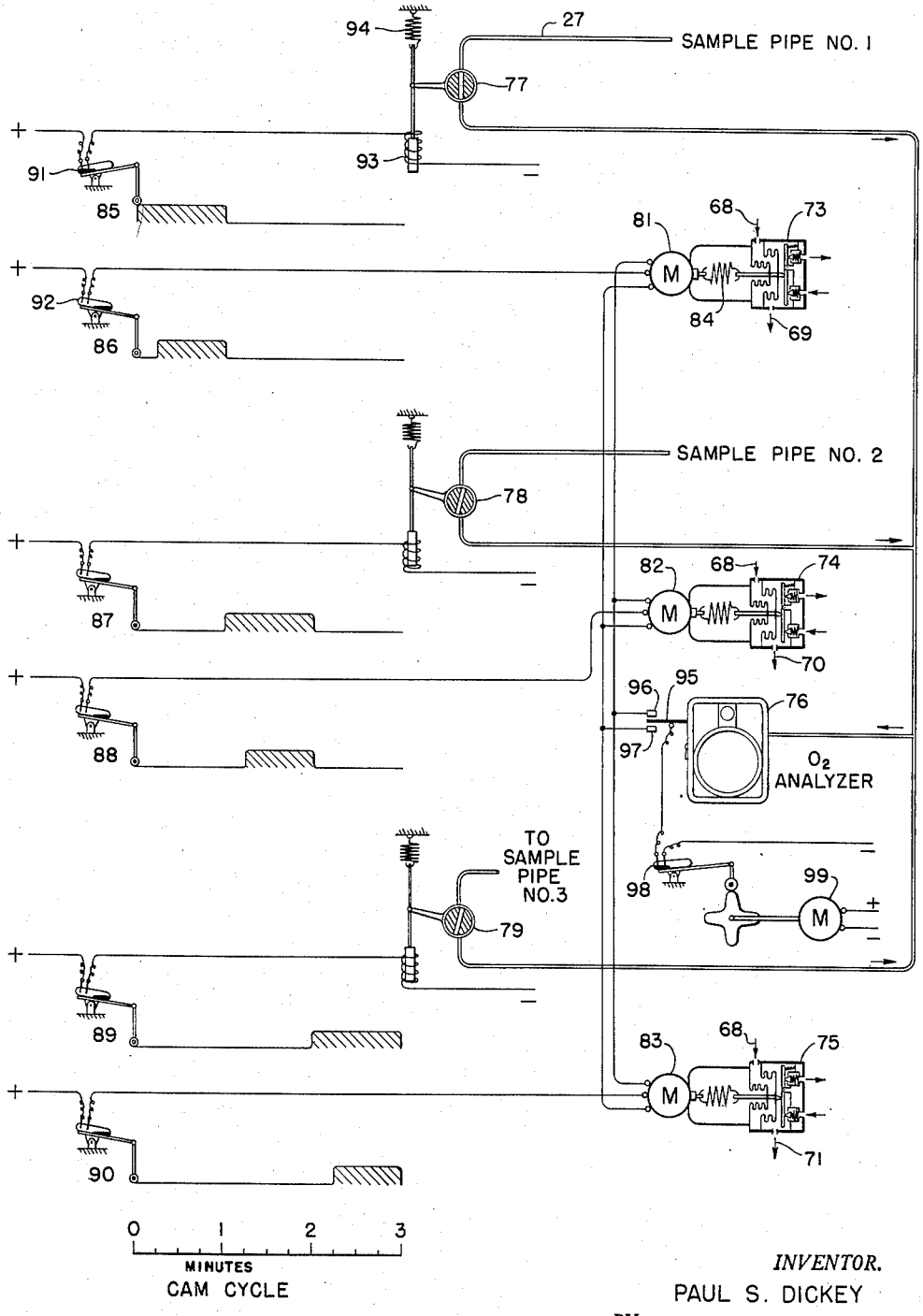

FIG. 3

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UNITED STATES PATENT OFFICE

2,623,698

COMBUSTION CONTROL SYSTEM

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Application December 3, 1947, Serial No. 789,416

2 Claims. (Cl. 236—14)

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My invention relates to the art of combustion control and particularly in connection with a furnace heated by the combustion of crushed solid fuel fired by one or more cyclone burners.

The construction, operation, features and advantages of such an installation have been described in the paper by Grunert, Skog, and Wilcoxson, entitled "The horizontal cyclone burner," published in the Transactions of the ASME, August 1947, volume 69, No. 6, and disclosed and claimed in the copending application of Kerr et al., S. N. 552,120, filed August 31, 1944, now Patent No. 2,594,312. Improvements in the control and operation of such a unit are accomplished through my invention.

In the drawings:

Fig. 1 is a sectional elevation of the furnace portion of a commercial radiant type vapor generator and including in somewhat diagrammatic fashion a cyclone burner as well as fuel feeding and air feeding means.

Fig. 2 is a diagrammatic showing of metering and controlling instrumentalities for the unit of Fig. 1.

Fig. 3 diagrammatically illustrates an elaboration of certain of the elements of Fig. 2.

Referring now to Fig. 1 it will be seen that I have illustrated therein in sectional elevation the furnace portion 1 of a radiant type vapor generator fired by one or more cyclone burners generally indicated at 2. Inasmuch as the present description is based upon a commercial unit it may be said that the vapor generator is contemplated as having a normal steam capacity of 600,000 lbs. per hr. and a maximum of 660,000 lbs. per hr. at 1525 p. s. i. g. and 1010° F. It is equipped with forced draft blowers, induced draft fans, raw coal feeders, and various dampers; all providing controllable elements for maintaining operational variables within desired limits. In Fig. 1 I show the said elements in functional relationship to the unit rather than in actual physical interrelation because the latter would add nothing to the understanding of my invention. Likewise I have not felt it necessary to show in detail the method of measuring the operational variables which in such a unit are well recognized and the means for measuring them per se form no part of my present invention.

The unit is provided with forced draft blowers 3 discharging to a duct 4 in which are located one or more dampers 5. The supply of air for combustion is divided into primary, secondary and tertiary air through the conduits 6, 7 and 8

2

respectively. The present unit has three cyclone burners so that air supply ducts similar to 6, 7 and 8 branch from the duct 4 to supply the other two cyclone burners (not shown) in a similar fashion.

One or more induced draft fans 9 provide for discharging the products of combustion from the unit. Control of the fans as well as of the dampers 10 is contemplated.

It will be appreciated that in a unit of this size and type it is usual to provide an economizer, air heater and superheater, but inasmuch as they form no part of the present invention, it is not felt necessary to complicate the drawing by including them.

The cyclone burner 2 is actually a primary furnace in which the elements of combustion combine and discharge the hot products of combustion to the secondary furnace 1 common to all of the cyclones. Crushed coal is admitted through a pipe 11 tangentially to the burner portion 12 in a stream of primary air at a sufficiently high velocity so that the particles of coal will be thrown toward the interior surface of the cylinder 13 and will be carried in the air stream along the wall of the cylinder in the form of an increasing-pitch helix until the energy of the entering stream of air has been dissipated. In addition to the primary air, sufficient secondary air for complete combustion of the coal is admitted through the duct 7 in a path parallel to the primary air and coal and at a correspondingly high velocity. At the same time the temperature within the cylinder 13 is sufficiently high to promote and maintain combustion so that the volatile matter in the coal will first be distilled off and burned, then the remaining carbon will be burned, and finally the ash will be left. As the fusing temperature of the ash is usually lower than the temperature obtained from combustion, it will be in a molten state as slag, and, due to the energy in the stream of products of combustion, will be in contact with the surface of the burner so that it becomes entirely coated with molten or sticky slag.

By inclining the axis of the burner 2 at about 5° to the horizontal the molten slag will slowly drain toward its lowest point, indicated at 14, from which it can be continuously tapped. As the molten slag inner surface of the burner is established it will act like fly-paper to entrap further crushed coal admitted with the primary air and thrown to the surface of the burner by the energy of the conveying air. The movement of the slag on the surface of the burner,

due to its viscosity, is very much less than the velocity of the entering air and this provides an intense scrubbing action of the high velocity air on the coal particles which are entrapped by and moving with the slower moving film of molten slag, with resulting extremely high combustion rate. The cylinder 13 may be surrounded by tube coils supplied with water from the unit but constructional details are believed to be unnecessary herein.

The construction and operation of the cyclone burner 2 is such that nearly theoretically correct combustion occurs therein, normal commercial operation occurring at from 5 to 8% excess air.

In operation the molten slag resulting from the high rate of combustion of the coal forms a molten layer on the surface of the cyclone burner to which the newly admitted coal adheres with a certain amount of the finer coal and resulting particles of coke churning around continuously within the burner. The secondary air also admitted tangentially at high velocity provides an intense scrubbing action with resulting high combustion rate. Gases of combustion leave the cyclone burner through the central outlet at its end and enter the secondary furnace 1 passing through or in contact with the necessary screens or tube banks for heat transfer thereto. The molten slag in the cyclone burner drains to its lowest point 14 which is below the gas outlet and may flow continuously into the secondary chamber 1 from which it can be tapped continuously or intermittently as required.

In general, substantially complete combustion occurs within the cyclone burner 2 which discharges flame and products of combustion into the secondary furnace 1. Substantially all of the ash in the fuel remains within the burner 2 in the form of molten slag and thus the heating gases passing into and through the furnace 1 are substantially clean and free of fly ash, unburned carbon, and the like.

The secondary air duct 7 connected tangentially to the cyclone burner has three adjustable velocity dampers 15, 16 and 17. In addition to controlling the high air velocity in the secondary air entrance port these dampers enable the operator to control air distribution to various zones in the cyclone burner. Coal enters at the front of the cyclone with the primary air at 12. Normal air distribution may be in the order of 10 to 15% as primary air, 5 to 8% as tertiary and the remainder as secondary. The secondary air is distributed through the three compartments according to requirements for combustion to maintain ash fluidity at the primary furnace tap. Readjustment of air distribution may be necessary with substantial firing rate changes or deviation in coal size or volatile content. The practical requirement is to have sufficient velocity in the rear zone of the cyclone burner to sustain the protective slag coat on the walls but with the quantity of air limited locally to maintain ash fluidity at the tap.

Raw coal is fed through an adjustable feeder 18 driven by an adjustable speed motor 19, through a crusher 20 to which primary air is admitted from the duct 6, discharging to the duct 11 a mixture of primary air and crushed coal which may have particles up to ⅜ to ½". Speed control for the motor 19 is attained through the positioning of the rheostat 21.

Located in the primary air duct 6 is a damper 22 while the tertiary air duct 8 is provided with a damper 23.

I have now indicated the various controllable factors or elements in the operation of the unit as a whole. In either manual or automatic control of the unit it is important to ascertain the instantaneous value of certain variables in the operation thereof. To those familiar with this art it is known that the pressure of the steam leaving the unit is desirably to be maintained at a predetermined value. In this connection I indicate a Bourdon tube 24 connected to the steam outlet main 25. Positioned in the main 25 is an orifice 26 providing a means for producing a pressure differential bearing a known relationship to the rate of steam outflow which is of course a demand factor upon the unit.

I desirably ascertain the rate of air flow through the unit by the differential pressure between two selected locations across tube banks, air heaters or locations dictated by the particular design and construction of the unit.

By "air flow" I intend to include the rate of flow of gaseous products of combustion and excess air passing through the generating unit, i. e. the assembly of vapor generator, superheater, etc. As is well known by those familiar with the art, air flow has long been utiilzed as an indication of firing rate or heat liberation and thereby an indication of heat available for vaporizing the liquid and superheating the vapor. On the other hand, the rate of flow of steam produced under constant conditions of temperature and pressure is a measure of heat absorption. Thus an interrelation of steam flow and air flow becomes a comparison of heat liberation and heat absorption.

Inasmuch as steam outflow and air flow are indexes related to the operation of the unit as a whole and I am preferably describing a unit having a plurality of cyclone burners 2 it is under certain conditions desirable to have a further individual indication of combustion conditions within each cyclone burner with the possibility of correcting the fuel-air ratio thereto as distinct from the other burners and from the operation of the unit as a whole. To obtain such an indication of the quality of the products of combustion discharging to the furnace 1 from a cyclone burner 2, I have indicated in Fig. 1 a gas sampling tube 27 so located as to sample the products of combustion discharged from the burner to the secondary furnace 1. In the present embodiment the gas sample through the pipe 27 passes through a washer system (not shown) and under pressure is supplied to an analyzer for ascertaining the percentage of free oxygen in the gases. The measuring instrumentality may be graduated in terms of free oxygen or in percent of excess air as desired. In the analyzer catalytic combustion of a vaporizable liquid fuel in the flue gas atmosphere is effected wherein the resultant temperature is a measure of free oxygen content of the gas sample.

The cyclone firing method is characterized by successful operation with very low excess air, i. e. nearly theoretical combustion proportioning of fuel and air. Precise control of the fuel-air relation has been accomplished by the use of the excess air recorder-controller sampling as at 27 and regulating the fuel feed ratio discharged through the conduit 11 to the entrance of the burner 2. Adjusting the coal feed rate to total air supply with excess air as the criterion in effect tends to provide total heat input regardless of variations in coal analysis, size or moisture content. This characteristic is demonstrated

by recorded feeder speed variations of as much as 20% during the maintenance of practically constant boiler steaming rate. Such variations in magnitude are probably due to irregularities in the operation of the feeder and air pressure and in the characteristics of the coal itself, and indicate that a measure of feeder speed is not necessarily a correct measure of fuel input rate. In addition to controlling to maintain a minimum excess of air and thus a high combustion efficiency it is of course desirable to maintain proper draft or pressure conditions throughout the unit.

Having now described the steam generating unit as a whole, along with the various controllable factors and elements, and having mentioned the variable conditions in the operation which are desirably to be measured and/or controlled, I refer now to Fig. 2 wherein I have diagrammatically indicated these various elements and variable conditions and the preferred arrangement of control. I have felt that for clarity of illustration and description and therefore of understanding that it is desirable to separate Figs. 1 and 2 rather than combine the two for such a combining would lead to a complexity of illustration more difficult I believe for understanding. Reference will now be had to Fig. 2 in detail.

I indicate in Fig. 2 that the Bourdon tube 24, sensitive to pressure of the steam leaving the unit, is arranged to vertically position the movable element of an air pilot valve 28 thereby establishing in the pipe 29 an air loading pressure representative of steam outflow pressure. The pilot valve 28 is preferably of the type disclosed and claimed in the patent to Johnson 2,054,464. The air loading pressure in the pipe 29 is admitted to the A chamber of a standardizing relay 30 which is of the type disclosed and claimed in the patent to Gorrie Re. 21,804 and which provides a proportional control with reset characteristics. It provides for the final control index (steam pressure) a delayed action floating control of high sensitivity superimposed upon a positioning control of relatively low sensitivity. The function of the adjustable bleed connection between the D and C chambers of the relay 30 is to supplement the primary control of the steam pressure effective in pipe 29 with a secondary control of the same or of different magnitude as a follow-up or supplementary action to prevent overtravel and hunting. The output of the relay 30, available through the pipe 31, is admitted to a manual-automatic selector valve 32 providing the possibility of controlling the various controllable elements of the unit either automatically or manually from a relatively remote centralized panel location. Preferably the selector valve 32 is of the type disclosed in the patent to Fitch 2,202,485 and is provided with load limiting relays 33. The limiting relays 33 are respectively connected to the air supply and exhaust connections of the selector relay 32 and are adjusted to limit the maximum and minimum values of the control pressure output of the selector valve 32 available in the pipe 34. Through this arrangement the loading pressure available in the pipe 34 cannot decrease below a predetermined minimum nor increase above a predetermined maximum. Both minimum and maximum limits are adjustable.

Considering the control arrangement of Fig. 2 as a whole it will be observed that steam pressure (being the final controllable factor in the operation of the unit) primarily dictates the controlling position of forced draft, induced draft and fuel feed in parallel. The various controllable elements may, however, be subject to readjustment from one or more of the other variables in the unit operation as will be described.

Considering first the speed of the forced draft blower 3 it will be observed that the stream pressure representative loading pressure in the pipe 34 is applied to an expansible-contractible metallic bellows 35 of a ratio device 36 having an opposing diaphragm 37 which is sensitive to forced draft duct pressure; the arrangement being such that forced draft duct pressure is maintained at a predetermined minimum value regardless of variations in steam outflow pressure. Thus the ratio device 36 operates to control the speed of the forced draft fan or fans 3 to satisfy load variations upon the unit as indicated by steam pressure and to maintain forced draft duct pressure at a constant predetermined value.

The device 36 is arranged to position the movable element of an air pilot valve 38 for establishing in the pipe 39 a loading pressure representative of a desired forced draft fan operation. The loading pressure within the pipe 39 is available within the A chamber of a standardizing relay 40 which is similar to the relay 30 previously described. The output of relay 40 leaving the D chamber is effective through a pipe 41 and manual-automatic selector valve 42 for positioning the inlet vanes or other output controlling instrumentality of the forced draft blower 3. Where a plurality of forced draft fans are utilized on the unit, the control is branched from the pipe 41 as shown and a plurality of manual-automatic selector valves 42 are provided so that each forced draft blower may be selectively operated by hand or automatically.

Connected to the air loading pipe 34 is a branch pipe 43 leading to a manual-automatic selector valve 44 for positioning the primary air damper 22 and the secondary air dampers 15, 16, 17 simultaneously responsive to steam pressure variations. Preferably the dampers 15, 16, 17 are so arranged that they may be individually positioned the one relative to the others as previously mentioned to properly distribute the secondary air along the axial length of the burner chamber. Preferably the total supply of primary air and secondary air, through the selector valve 44, for an individual cyclone burner, is raised or lowered in accordance with the dictates of steam pressure or manually through the agency of the selector valve 44. It will be appreciated that control for the second and third cyclone burners will be taken care of in similar manner by branching from the loading pressure pipe 43 as clearly indicated in Fig. 2 of the drawing.

Control of induced draft is also primarily under the control of the steam pressure Bourdon tube 24. A pipe 45, branching from the pipe 34, joins the A chamber of an averaging relay 46 whose output is effective in the pipe 47. A device 48 is sensitive to furnace draft for establishing in the pipe 49 an air loading pressure representative of furnace draft. Such pressure is imposed upon the A chamber of a standardizing relay 50 whose output is available through a pipe 51 joining the C chamber of the averaging relay 46. The pipe 51 is provided with an adjustable throttling means 52 for restricting the effect of furnace draft upon the relay 46 in a manually adjustable manner. It will be seen that the arrangement

is such that the loading pressures of the pipes 45 and 51 are averaged within the relay 46 so that the resultant is available within the output pipe 47 upon manual-automatic selector valves 53 in the control of induced draft dampers 10 and simultaneously through the manual-automatic selector valves 54 to assist in control of speed of the induced draft fan 9.

As a check back upon the actual speed and operation of the induced draft fan 9 I provide a tachometer 55 which continuously establishes a loading pressure within the output pipe 56 representative of speed of the induced draft fan 9. The pipe 56 joins the B chamber of an averaging-standardizing relay 57 whose D chamber output is available within a pipe 59 joining the A chamber of an accelerating relay 60 whose output in turn is adapted to position the speed regulating device of the induced draft fan 9.

It will thus be seen that the basic operation of the induced draft fan is conjointly under the control of steam pressure, furnace draft and fan speed while the positioning of the induced draft dampers is under the control of steam pressure and furnace draft.

Control of the rate of fuel supply to the cyclone burners is primarily in accordance with steam pressure variation and secondarily from the relation between steam flow from the unit and air flow through the unit. The speed of the individual fuel feeder to the individual cyclone burner is then further adjusted in accordance with an analysis of the products of combustion entering the secondary furnace 1 from the outlet of the burner per se. Thus the control of fuel supply to the unit as a whole is arranged to satisfy demand upon the unit as indicated by steam pressure and to approximate best combustion efficiency as dictated by the relation between the rate of steam outflow from the unit and the rate of air flow through the unit. The three cyclone burners are then separately readjusted insofar as fuel-air ratio is concerned in accordance with the completeness of combustion in the individual burner chambers as indicated by an analysis of the gaseous products of combustion leaving the individual cyclone and entering the secondary furnace 1.

At 61 I indicate a steam flow meter preferably connected across the orifice 26 for continuously measuring the rate of steam outflow from the unit. In similar fashion I indicate diagrammatically an air flow meter at 62 for continuously determining the rate of flow of the products of combustion and excess of air through the unit. The instrumentalities 61, 62 are adapted to position the movable element of an air pilot valve 63 upon departure of steam flow and air flow from desired relationship. Pilot valve 63 establishes an air loading pressure within the pipe 64 representative of such relation between steam flow and air flow and by departure in one direction or the other from desired value indicates whether the air flow is greater than or less than that which should exist for the actual rate of steam outflow. The air loading pressure within the pipe 64 is available within the A chamber of a standardizing relay 65 whose output is effective through a pipe 66 within the C chamber of an averaging relay 67, to the A chamber of which is lead the loading pressure within the pipe 34 representative of steam pressure. Thus the averaging relay 67 receives a primary impulse from steam pressure as a measure of demand upon the unit and a secondary or modifying impulse representative of relation between steam flow and air flow or combustion efficiency within the unit as a whole.

The output of the relay 67 is available within a pipe 68 branching to the pipes 69, 70, 71. By way of example, the pipe 69 joins a manual-automatic selector valve 72 and thence is arranged to position the rheostat 21 for regulating the rate of coal feed to the crusher 20 for cyclone burner 1. In similar manner the pipes 70 and 71 are arranged to regulate the speed of the coal feeder to the other two cyclone burners respectively.

Interposed between the pipe 68 and the pipes 69, 70, 71 are three air relays respectively designated as 73, 74, 75 which may be individually loaded or adjusted in accordance with the determination of the excess air condition of the flue gases leaving the individual cyclone burners. By way of example the control impulse regulating the speed of the coal feeder for cyclone burner No. 1, primarily representative of steam pressure and relation between steam flow and air flow may be further adjusted, relative to the other two burners, through a loading of the air relay 73. I will now explain the manner in which such loading is to be accomplished.

I have chosen to illustrate and describe the use of a single gas analyzer 76 periodically switched from one sample tube 27 to another and cyclically effective upon the related relays 73 or 74 or 75. I might, of course, provide individual gas analyzers in connection with the individual gas sampling pipe and its related cyclone burner.

In Fig. 2 it will be seen that sample pipe 27, from in front of cyclone burner 1, is effective upon the gas analyzer 76 because the switching valve 77 is open while the switching valves 78 and 79 are in closed position. As will be explained I provide a mechanism whereby cyclically the valve 77 is opened, then the valve 78, and then the valve 79, in each case the other two valves being closed off, so that cyclically the analyzer 76 is connected to draw a sample from in front of each of the three cyclone burners. The analyzer 76 is electrically connected to a timer and interrupter mechanism 80 which is electrically connected to control the motors 81, 82 and 83. The arrangement is such that the motor 81, through the necessary gear reduction, is adapted to load or unload the spring 84 which controls the relation between the input pressure from the pipe 68 and the output pressure of the relay in the pipe 69. In other words the relay 73 is arranged in such a manner that the air loading pressures within the pipe 68, 69 may be in a 1–1 ratio or in any given ratio depending upon adjustment of the loading spring 84 and such loading spring adjustment is varied through the agency of the motor 81 under the control of the analyzer 76. Referring now to Fig. 3 I will describe more in detail the function and operation of the devices 73 to 84.

In the timer 80 I provide a continuously running motor which through the proper gear reduction rotates a series of six generally circular cams on a three minute cycle. While it is possible to utilize other time of cycle I have preferably indicated that three minutes is the time for a complete revolution of the six cams and the arrangement is such that the first pair of cams utilize their effective surface over the first minute of operation, the second pair of cams over the second minute, and the third pair of cams over the third minute. The first pair of

cams is related to operation of the first cyclone burner while the second pair is in connection with the second cyclone burner and the third pair in connection with the third cyclone burner.

In Fig. 3 I have laid out in straight line the surface contour of the six cams and the arrangement is such that the cam surfaces are presumed to move toward the left as the drawing is observed. Thus cam surfaces **85, 86** are effective for the first minute in connection with cyclone burner **1**, cam surfaces **87, 88** for the second minute in connection with cyclone burner **2**, and cam surfaces **89, 90** for the third minute in connection with cyclone burner **3**. This cyclic operation then repeats. As viewed in Fig. 3 the electric switch **91** is close circuited while the switch **92** is still open circuited. The switch **91** is arranged to complete circuit to solenoid **93** overcoming a spring **94** and positioning the valve **77** to an open position thereby connecting the sample pipe **27** for cyclone furnace **1** to the analyzer **76**. As shown the switch **92** is open so that the motor **81** is not energized for operation in either direction. At this time in the cycle of operation the sample switches **78** and **79** are closed and the motors **82** and **83** are deenergized.

As the cyclic operation proceeds there is a time interval of 15 seconds during which the just mentioned conditions prevail. At the end of 15 seconds the switch **92** becomes energized thereby allowing the motor **81** to have its common return connected to one side of the electrical power source. If the actual value of free oxygen within the gaseous products of combustion leaving the cyclone furnace **1**, as sampled through the pipe **27**, is above or below the desired value by a predetermined amount then the contact **95** will engage either the contact **96** or the contact **97** and complete a circuit to the motor **81** to operate the same in one direction or the other for loading or unloading the spring **84** and thus varying the relation between the pressures in the pipe **68** and **69** effective for varying the speed of the coal feeder **21** to cyclone burner **1**. The contact **95** is connected to the power source through a switch **98** positioned by an interrupter motor **99** so that the electrical impulses which may pass to the motor **81** are not continuous but are adjustably of relatively short duration to prevent over correction until the effect of such correction is felt in the combustion within the burner. Preferably the contacts **96, 97** may be adjustably spaced apart so that a permissible variation in oxygen content of the flue gases will exist without varying the loading of the relays **73, 74** or **75**.

As the cams **85** to **90** inclusive move toward the left it will be apparent that at the end of the first minute the switches **91, 92** become ineffective and the switches for the second burner may be effective for the second minute of the cycle.

In general the operation of the arrangement of Fig. 3 is that successively burners **1, 2** and **3** may be readjusted insofar as the fuel-air ratio is concerned if the products of combustion leaving the respective burner indicate that readjustment is necessary to take care of variations in the particular coal feeding rate. When the analyzer **76** is connected in relation to a particular burner, the first 15 seconds that the related sample pipe is connected to the analyzer **76** is utilized for clearing the sampling and analyzing system of the gases from the previously connected burner and, while the recording chart of the analyzer may show, during said 15 seconds' interval, a reading which is incorrect for any burner, it is only the final 45 seconds of the 1 minute interval wherein it is possible for a readjustment to take place on the related burner coal feed. The recording chart of the analyzer **76** may preferably be provided with a second recording pen which would show which of the three burners is connected to the analyzer.

As I have mentioned, it may in certain installations be desirable to have an individual gas analyzer in connection with each of the burners, in which event the cyclically switching of sample tubes and of control for the air relay motors may be dispensed with. The most important feature of the present invention, insofar as this portion of the control is concerned, is that control of the coal feeder speed, while primarily from steam pressure and relationship between steam flow and air flow is readjusted if necessary from an analysis of the products of combustion leaving the individual burner.

Steam pressure as an indication of load or demand upon the unit is the primary controllable variable which operates to adjust the forced draft, induced draft and coal feed in parallel. Load limiting relays may be provided for limiting the maximum or minimum air and fuel supply rates to the unit as a whole and thus limiting the maximum and minimum loads which may be carried.

The forced draft supply blowers are controlled primarily in accordance with steam pressure deviations from standard and with readjustment if necessary to maintain the pressures in the forced draft supply duct at a predetermined value.

The primary and secondary air supply dampers to the individual cyclone burners are controlled in parallel from steam pressure and with the possibility of individual readjustment relative the one to the other manually.

The induced draft fans and dampers are controlled in parallel responsive to steam pressure and to furnace draft within the unit. The induced draft fans are further readjusted in accordance with actual speed of the fans.

The rate of supply of raw coal to the three cyclone burners is controlled in parallel in accordance with steam pressure and relationship between steam flow and air flow on the unit as a whole. The rate of supply to the individual cyclone burner is readjusted if necessary in accordance with a determination of the excess air of the products of combustion leaving the related burner if departing over an allowable amount in either direction from desired value.

Provision is made for selectively imposing manual or automatic control upon the controllable elements of the unit as a whole or upon the individual dampers, fans and feeders selectively as desired. Adjustability is, in common manner, provided at the various measuring and controlling instrumentalities and need not be further elaborated upon.

While I have chosen to illustrate and describe a commercial unit having two forced draft blowers, two induced draft fans, numerous dampers, as well as three cyclone burners each with its related coal crusher and feeder, it will be appreciated that these are not limiting factors and that my invention may equally as well be applied to a unit of different size or design and having a different number and type of fuel and air feeding devices.

Certain features of my invention, disclosed but not claimed herein, are disclosed in my copending continuation-in-part application, S. N. 253,087, filed October 25, 1951.

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

1. In a vapor generator having a plurality of fuel fired cyclone type furnaces all discharging into a common main furnace, a vapor outlet main, fuel supply devices for the cyclone type furnaces, and air supply apparatuses for the cyclone type furnaces: a control system, including in combination, a first instrument sensitive to the vapor pressure in the vapor outlet main; control means regulating the said fuel supply devices and air supply apparatuses in response to said first instrument to decrease the supplying of fuel and air to all said cyclone type furnaces as the vapor pressure in the vapor outlet main increases, and conversely; a second instrument measuring the vapor flow in the vapor outlet main; a third instrument measuring the air flow through the main furnace; regulating means responsive jointly to said second instrument and said third instrument and also operating on said fuel supply devices in a direction to maintain a constant vapor flow to air flow ratio; a gas analyzer; a sampling tube adjacent the discharge end of each cyclone type furnace, said analyzer being adapted to determine the composition of the gases discharged from each of said cyclone type furnaces; continuously operating means for sequentially connecting the sampling tubes to the gas analyzer; and other regulating means responsive to the operation of said gas analyzer and arranged to further operate upon the fuel supply device of any individual cyclone type furnace in a direction to increase the supplying of fuel of the respective furnace as the analysis of that furnace shows a deficiency of fuel, and conversely.

2. In a vapor generator having a plurality of fuel fired cyclone type furnaces all discharging into a common main furnace, a vapor outlet main, fuel supply devices for the cyclone type furnaces, and air supply apparatuses for the cyclone type furnaces, said devices and apparatuses being arranged continuously to supply fuel and air at a predetermined rate to all the cyclone type furnaces in parallel: a control system, including in combination, a first instrument sensitive to the vapor pressure in the vapor outlet main; control means regulating the said fuel supply devices and air supply apparatuses in response to said first instrument to decrease the supplying of fuel and air to all said cyclone type furnaces in parallel as the vapor pressure in the vapor outlet main increases, and conversely; a second instrument measuring the vapor flow in the vapor outlet main; a third instrument measuring the air flow through the main furnace; regulating means responsive jointly to said second instrument and said third instrument and also operating on said fuel supply devices in parallel in a direction to maintain a constant vapor flow to air flow ratio; a gas analyzer; a sampling tube in the main furnace adjacent the discharge end of each cyclone type furnace, said analyzer being adapted to determine the composition of the gases discharged from each of said cyclone type furnaces; continuously operating means for sequentially connecting the sampling tubes to the gas analyzer; and other regulating means responsive to the operation of said gas analyzer and arranged to further operate upon the fuel supply device of any individual cyclone type furnace in a direction to increase the supplying of fuel to the respective furnace as the analysis of that furnace shows a deficiency of fuel, and conversely.

PAUL S. DICKEY.

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