July 7, 1970 R. E. PUTMAN 3,519,254

METHOD AND APPARATUS FOR THE CONTROL OF BURNER HEAT DISTRIBUTION

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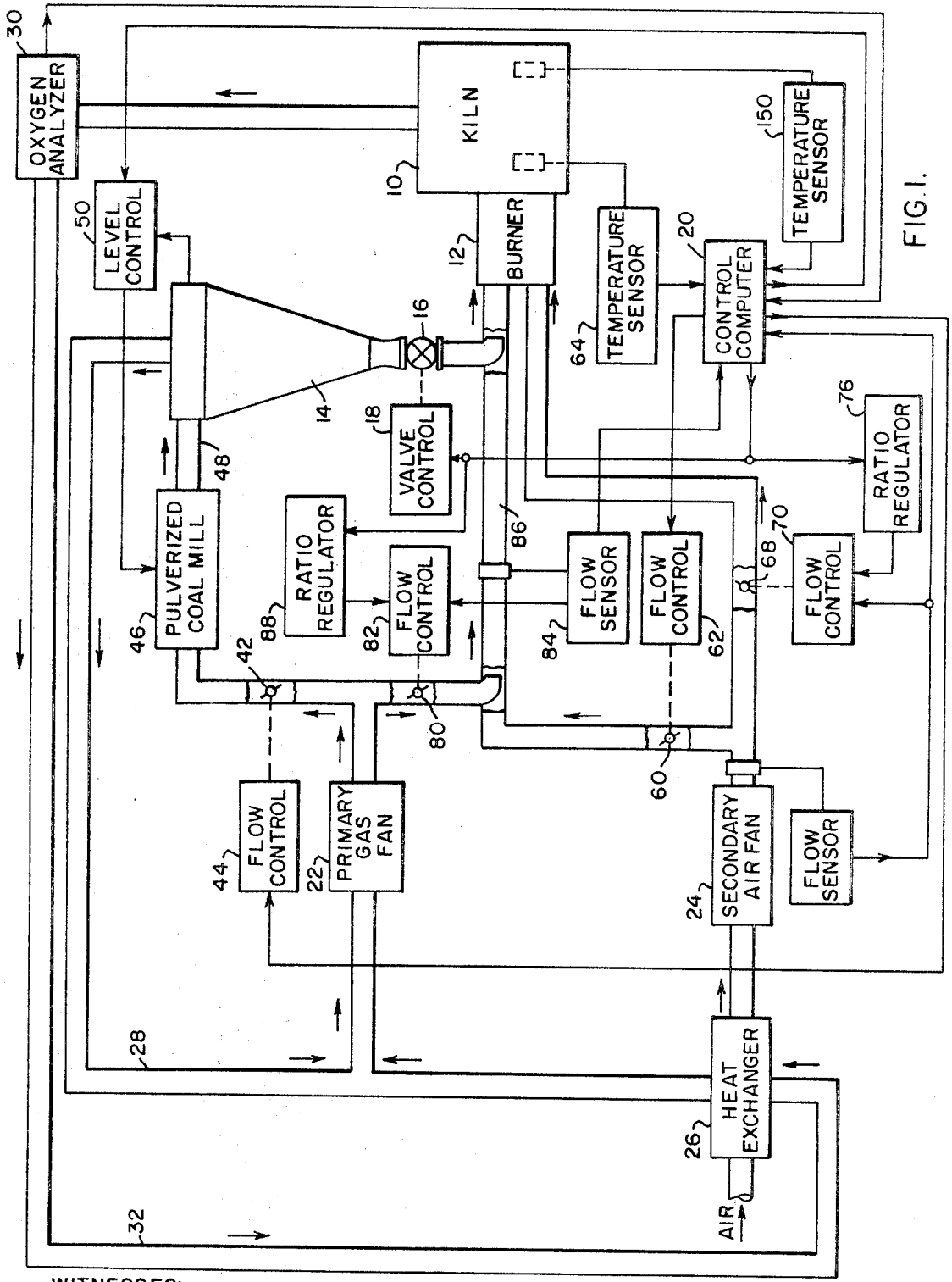

FIG. 1.

WITNESSES:

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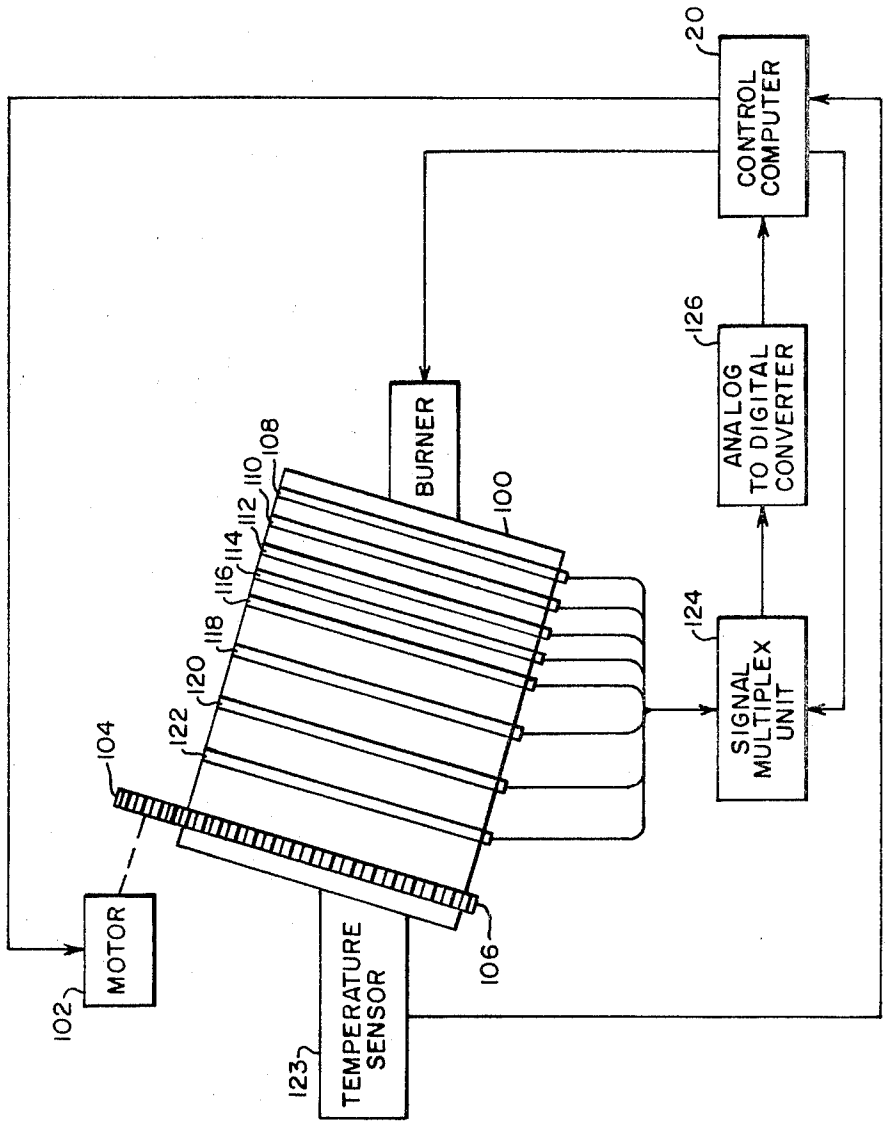
FIG. 2.



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METHOD AND APPARATUS FOR THE CONTROL OF BURNER HEAT DISTRIBUTION

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Int. Cl. F27b 1/26
U.S. Cl. 263—10 9 Claims

ABSTRACT OF THE DISCLOSURE

There is disclosed a method and apparatus for the control of the length of the flame from a fuel burner device, for better distribution of the heat from the flame within a furnace or kiln, by including inert gas such as furnace flue gas along with the air supplied to the burner and controlling the proportion of the inert gas, to vary the total oxygen in the resulting gas flow to the burner relative to the desired supply of fuel to the burner and the desired operation of the furnace or kiln.

BACKGROUND OF THE INVENTION

In the control of reverberatory furnaces and cement kilns, the point of application of the heat input is of significance. In the case of reverberatory furnaces it assures that the concentrate in the different zones is properly smelted, while in the case of cement kilns it assures that the correct position of the burning zone along the length of the kiln is maintained while at the same time giving the calcining and heating zones the necessary amounts of heat.

In boilers and cement kilns there is a problem as to how the heat from the flame is being distributed within the furnace and the kiln. For the operation of a straight burner with fuel and primary and secondary air, which, in accordance with the teachings of the prior art, has come direct from the atmosphere via a heat exchanger, there is little opportunity for control except by regulating the primary and secondary air distribution but this provides a limited amount of control.

SUMMARY OF THE INVENTION

The present invention relates to the regulation of burner flame length by the dilution of air supplied to the burner with inert gas. In particular reference to a pulverized coal burner, the coal entering the pulverizing mill is separated from the gas purging the mill in a cyclone which is also used as a storage hopper for the pulverized coal. The gas used to purge the mill is substantially inert gas drawn from the exhaust of the furnace or kiln, and the gas separated from the cyclone is taken back and added to the primary gas fan inlet. In this way the amount of substantially inert gas circulating through the primary gas fan, mill and cyclone system is a function of the requirements of the mill, with the mill output being regulated from the level of the fuel stored in the cyclone. The pulverized coal is fed to the burner by means of a speed controlled rotary valve which deposits the pulverized coal in the primary air duct gas stream leading to the burner.

Warm secondary air is conveyed by a fan to the burner registers with a branch leading to the primary air duct of the burner. Inert gas passes from the discharge of the primary gas fan to the burner primary air duct.

It is an object of the present invention to provide a better control of the flame length and heating pattern for better heat distribution in relation to a fuel burner operating with a kiln or boiler or the like and particularly more beneficial when applied to a pulverized coal burner device.

It is another object to provide an improved flame length control for a burner device, which recognizes that the amount of oxygen in the primary air supply is a significant parameter and determines flame length for a given primary air/fuel flow ratio.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates the burner flame length control of the present invention; and

FIG. 2 illustrates one way to sense and provide the desired temperature profile in a cement kiln or the like.

DESCRIPTION OF A PREFERRED EMBODIMENT

In the present method and apparatus for the control of the flame length and heat distribution from a burner device, the resulting temperature in the kiln, or pressure in the boiler, associated with that burner is sensed and used as an operating condition for the regulating of the supply of fuel to the burner. This same control signal is used to determine the gas mixture flow of both air and inert gas to the burner in the primary air duct leading to the burner. There is a desired fixed ratio between the primary air duct gas velocity and the supply of fuel, since the velocity must be high enough to insure that the fuel remains in suspension and is properly transported to the burner. There is also an optimum ratio of total air flow to total fuel supplied for the most efficient combustion of the fuel. A damper in the branch from the discharge of the secondary air fan to the primary air duct is regulated in accordance with desired flame length. Since the total air flow is controlled by a damper in the secondary air duct to the burner registers, this damper in the branch pipe determines the distribution of air between the primary and secondary ducts while the total air is the proper amount required for efficient combustion of the fuel. By regulating the gas flow into the primary duct so as to maintain the total primary duct flow at the desired value for transport purposes, the total amount of gas required to convey the fuel to the burner can be considered as consisting of the air coming through the branch pipe plus the amount of primary gas required to make up the difference.

The principle of the present invention is applicable for the regulation of flame length with fuel burners. In addition to being able to regulate flame length, a further advantage of the present invention is the better utilization and distribution of heat within the furnace. The use of the bin and feeder system also allows closer control of the air fuel ratio to be carried out.

The amount of air provided in the primary duct leading to the burner is an important parameter for the desired control of flame length. The oxygen content of the primary duct air and gas mixture can be determined by the controlled dilution of this mixture by readily available low oxygen and substantially inert waste gas. This provides the additional safety benefit that the pulverized coal mill is operated with this same waste gas.

The amount of fuel supplied to the burner requires a predeterminable velocity of primary duct transport gas mixture, and the use of a mixture including relatively inert waste gas with air permits a desired control of the oxygen content while still providing the desired velocity of this primary duct gas.

In FIG. 1 there is shown a kiln **10** including a burner **12** which is supplied pulverized coal from a storage cyclone **14** through a rotary valve **16**, the position of which is controlled by a valve control **18** to determine the amount of fuel supplied through the valve **16** to the burner **12** in accordance wtih the fuel demand con-

trol signal from a control computer **20** to maintain a desired burning zone temperature as sensed by a temperature sensor **64** operative with the computer **20**. The burner **12** is suppled a controlled gas mixture through the primary duct **86** from a primary gas fan **22** and a secondary air fan **24**. The secondary air fan **24** receives heated input air through a heat exchanger **26**. The primary gas fan **22** receives substantially inert gas back from the cyclone separator **14** through a conduit **28** and exhaust flue gas from the kiln **10** through a conduit **32** after passing through the heat exchanger **26**. The output gas from the primary gas fan **22** passes through a damper **42** operative with a mill transport gas flow control **22** as determined by a signal from the control computer **20** in relation to the controlled operation of the pulverized coal mill **46**, which gas passes to the pulverized coal mill **46** where the input coal is pulverized and carried through a conduit **48** to the cyclone separator **14**. The cyclone separator **14** functions as a separator device to separate the mill transport gas from the pulverized coal, which mill transport gas is supplied back through the conduit **28** to the input of the primary gas fan **22**. The cyclone separator **14** further functions as a storage device for the pulverized coal fuel, the level of which is sensed by a level control **50** and compared with a reference signal from the computer **20** for determining the operation of the pulverized coal mill **46**. The level control **50** receives the set point or reference signal from the control computer **20** to set and control the desired reference level of the pulverized coal within the cyclone separator **14**.

The secondary air fan **24** receives inlet air through the heat exchanger **26** and passes it through a first flow control damper **60** leading to the primary air duct, with the damper **60** operation determined by a flow control **62** in accordance with a temperature profile or heat distribution control signal from the computer **20**. The temperature profile or heat distribution is sensed by a temperature sensor **150** operative to sense the temperature profile or heat distribution within the kiln **10**. The secondary air also passes through a second damper **68** operative with a flow control **70** in accordance with the sensed flow of total secondary air as determined by the flow sensor **74**. In addition a ratio relay **76** is operative with the flow control **70** in accordance with the total fuel supply to the burner **12**.

The primary gas flow to the burner is controlled by a damper **80** operative with a flow control **82** in accordance with a signal from a flow sensor **84** operative with the primary duct **86**. A ratio relay **88** also provides a control signal to the flow control **82** for determining the flow of primary gas flowing through the conduit **86** in relation to the actual amount of fuel and as desired for transport purposes to carry the fuel to the burner **12**.

In FIG. 2 there is shown an illustrative rotary kiln **100**. A kiln of this type is typically used for the manufacture of cement. In the kiln there are four discrete zones consisting of drying, calcining, burning and cooling. The actual values of the temperatures and distribution of the temperatures throughout the process have an important effect on the nature and degree of the reactions taking place in the corresponding zones. In the operation of the kiln the processed material flows through the kiln toward the burner or front end, while the air and gases pass through the kiln from the burner towards the feed or back end of the kiln. Even if the material feed flow and gas flow rates are held substantially constant, the temperature distribution and heat exchange between the gases and raw materials can vary to distrube the effectiveness of the cement making process. The two primary kiln operation control parameters are the temperature of the clinker in the burning zone and the speed of the kiln which controls material retention time and the material profile within the kiln. Burning zone temperature is controlled by varying the fuel combustion rate as related

to the amount of fuel supplied to the burner **12**. Since the maximum combustion efficiency coincides with a predeterminable maximum oxygen in the flow gases, the ratio of total air to the fuel fired by the burner is to this extent fixed. Thus air mixture volumes and temperature vary with firing rate and can change the heat transfer characteristics along the whole length of the kiln. In FIG. 2, the rotary kiln **100** includes a motor **102** operative to provide a computer controlled rotation of the kiln **100** through a drive gear **104** and a ring gear **106** fastened to the kiln. A plurality of electrical temperature signal collector rings **108, 110, 112, 114, 116, 118, 120** and **122** are provided with suitable transducers for indicating heat flow or temperature condition measurements from the interior of the kiln through the kiln wall to the outside atmosphere at the respective locations of the provided collector rings for the purpose of indicating the temperature at the respective zones of the interior of the kiln. These temperature signals received from the latter collector rings are applied sequentially through a signal multiplex unit **124** and an analog-to-digital converter **126** to the control computer **20**. The signal multiplex unit **124** is sequence controlled in its operation by suitable control signals from the control computer **20**, as is the operation of the motor **102** controlled in relation to desired material flow and treatment by the control computer **20**. A temperature sensor **123** is operative to sense the temperature of the exhaust gases leaving the kiln **100**. The respective collector rings can be opeartive with thermocouples or suitable temperature sensing devices extending through the walls of the kiln to sense the respective zone interior temperatures at the location of the collector rings if desired. In this way a profile of the selected temperatures relative to the desired operation of the kiln is obtained.

In reference to the illustration of FIG. 1, and in the particular illustrated example of a pulverized coal fired burner **12** operative with a kiln **10**, the pulverized coal requires a certain air and gas mixture volume because the gas mixture operates as a transport medium as well as a combustion control medium for the operation of the burner **12**. Therefore, a certain amount of gas mixture flow is required in relation to a certain amount of fuel, but the gas mixture supplied to the burner **12** does not have to be all air. It is feasible that by combining in the primary gas fan **22** a regulated amount of inert gas from the flue exhaust of the kiln **10** and the overflow of the cyclone separator **14**, the output of the primary gas fan **22** would be a substantially inert gas having a high nitrogen and carbon dioxide content, and the gas volume can be maintained as required to act as a transport medium for the pulverized coal, with the oxygen content of the gas mixture as supplied to the burner **12** being subjected to regulation by controlling this mixture for the purpose of controlling the length of the flame from the burner **12**. Thusly, two functions are provided by the gas mixture flow through the primary duct **86**, one being the transport of the pulverized coal fuel and the other controlling the oxygen content for operation of the burner **12**, with the latter being subjected to regulation by the addition of substantially inert gas or flue gas through the damper **80** and having a low oxygen content. Thusly, the primary duct gas mixture and the secondary duct air drawn from heat exchanger are passed through to the burner **12**, with the primary duct gas mixture being the pulverized fuel transport gas as correlated with the operation of the rotary valve **16** and passing through the primary duct or conduit **86** leading to the burner **12**. The primary duct gas mixture is made up of inert gas from the flue of the boiler **10**, which is supplied by the primary gas fan **22**.

This inert gas also passes through the damper **42** and to the pulverized coal mill **46** for the purpose of moving the pulverized coal into the cyclone hopper **14**. It should be noted that inert gas has an advantage here since there

is less danger in the operation of the pulverized coal mill **46** with inert gas passing through it of the coal spontaneously igniting. The mill **46** is essentially a ball mill, and coal is fed into the mill and ground up and carried out by the inert gas flow. The coal from the mill **46** is deposited in the cyclone separator **14** and is metered through operation of the rotary valve **16** into the primary gas duct or conduit **86**, as required for the proper operation of the burner **12** and the kiln **10**. The inert gas passing through the damper **80** and into the primary duct **86** permits a desired control of the flame envelope shape to determine for a certain amount of fuel how the resulting heat is to be distributed within the kiln **10**. More specifically, if less oxygen is supplied in the gas mixture passing through the primary duct **86** to the burner **12**, a longer flame results such that if the amount of inert gas increases, as determined by operation of the damper **80** in the output of the primary gas fan **22**, this results in a lengthening of the flame of the burner **12**. On the other hand if the amount of inert gas supplied by the primary duct **86** through operation of the damper **80** is decreased, the flame of the burner **12** shortens such that the whole intensity of the combustion provided by the burner **12** and the distribution of heat therefrom is determined by the primary duct oxygen to fuel ratio which can be determined in this manner. In a normal burner configuration, increasing the secondary air flow does not reduce the primary air oxygen and therefore has less influence on the flame characteristic other than varying excess air and turbulence.

By the teachings of the present invention which uses the exhaust flue gas from the kiln as an inert gas to mix in a controlled manner with the primary duct air, the oxygen in the primary duct gas mixture is diluted and thereby controls the length of the flame from the burner **12** since the dilution of the primary duct air is more important for this purpose than is the secondary duct air regarding the length of the flame from the burner **12**.

In relation to a cement kiln, the flame length is critical because there are a plurality of heat zones such as the calcining, heating, drying and burning zones, and these each have certain heat requirements in order to achieve their intended functions which they are designed to perform. If the exhaust flue gases leaving the exit or back end of the kiln are not hot enough as sensed by temperature sensing device **123** shown in FIG. 2, but the burning zone temperature is right, this indicates that more heat must be put in and passed back into the kiln to allow the calcining and drying to proceed as desired but the burning zone temperature should not be disturbed. Thusly, a longer flame with a new amount of heat going back into the calcining and drying zones is required while leaving the same amount of heat going into the burning zone. The teachings of the present invention can be utilized for this purpose. It should be noted that if the flame is longer, the heat has more tendency to go past the burning zone and into the calcining zone. It should be understood that a typical flame of the type under consideration here may be in the order of thirty feet in length, leaving a twelve inch jet pipe which comprises the burner **12**.

In regard to a boiler, the steam temperature particularly of the superheat portion of the boiler can be controlled by the length of the flame of the burner operative with the boiler. In the case of a boiler, a temperature sensor such as temperature sensor **150** shown in FIG. 1 would provide an indicative signal to the control computer **20** for controlling the length of the flame, which temperature sensor **150** could be operative with a particular location such as the superheat region of the boiler.

In the case of the cement kiln, a combination of burning zone temperatures and other temperatures along the kiln, such as generally shown in FIG. 2, would be sensed by the control computer **20** and utilized to provide a measurement profile of the temperature along the kiln, which profile would be compared with a stored profile entered into the program memory of the control computer **20**. Adjustments of the actual profile, relative to the reference or desired profile, could then be made by adjusting the length of the flame to increase or concentrate the heat energy input into the kiln at the desired zone area. Knowing the desired end condition of the cement product to get the proper chemical combination of the oxides, it may be advantageous to know the oxygen content as well as the temperature of the flue gas leaving the kiln which is desired to prevent condensation in the precipitators or to make sure that adequate drying and calcining are taking place. The flame length can be adjusted as desired to provide the desired heat distribution and related operating conditions for the kiln. An oxygen analyzer **30** can be included as shown in FIG. 1 for sensing the oxygen content of the flue gas if desired.

The control computer such as shown in FIG. 1 would be operative in response to burning zone temperature to control the amount of pulverized coal fuel supplied to the burner **12** by suitable speed control of the rotary valve **16**. The heat distribution within the kiln is controlled in relation to the control of the damper **60** relative to the primary duct air mixture flow to the burner and the control of the damper **80** relative to the primary gas flow introduced into the primary duct **86** leading to the burner. The control of the damper **68** relative to the secondary duct air flow to the burner is determined in relation to the total fuel supplied to the burner, and considering the proper gas and air mixture flow to the burner **12** in the primary duct **86** in relation to the desired percentage of inert gas in that duct **86**. The damper **80** is operative to control the supply of inert gas from the primary gas fan to the burner, which is determinative of the length of the flame of the burner. It should be noted that the control computer **20** is operative to determine the total air flow, from the secondary air fan **24**, which would be desirable for the proper combustion of the provided amount of fuel. The damper **80** is controlled to make up any primary duct gas mixture required to provide an adequate trasport air and gas mixture flow through the primary duct **86** for proper physical transport of the pulverized coal fuel supplied by the rotary valve **16**, and to control the amount of oxygen supplied through the primary duct **86** to the burner **12** in relation to the total air supplied through both the primary duct and the secondary duct for the proper combustion of the fuel and for the determination of the proper length of flame from the burner **12**. The desired ratio of fuel to the total air for the desired operation of a fuel burner is a weld-known relationship to persons familiar with the combustion characteristics of pulverized coal fuel and the operation of fuel burners. The secondary air fan **24** provides the total air going to the burner, with the primary duct air and inert gas mixture flow being controlled in relation to the fuel determined by the operating speed of the rotary valve **16**. The transport air and gas mixture needed to physically move the provided fuel is made up of the air passing through damper **60** and the inert gas passing through damper **80**. The heat distribution of the flame from the burner **12** is measured by one of more temperature sensors **150** for controlling the primary duct air containing oxygen relationship supplied to the burner. If the computer shuts the primary duct air damper **60**, this causes the make-up of inert gas to increase to make the flame longer; if more inert gas is included, the flame goes longer, while less inert gas causes the flame to shorten.

Thusly, it will be seen that the control computer **20** is operative to control the total amount of heat going into the kiln by setting the amoun of fuel going in through control of the rotary valve **16**, and the computer determines the required fuel to air ratio to satisfy desired combustion through its operation to set the amount of air being supplied from the secondary air fan **24** to the burner.

Further, when adjustments are made in the amount of fuel supplied, the computer coordinates the desired amount of transport gas mixture flowing through the primary duct **86** by controlling the amount of transport gas in relation to the amount of fuel supplied. The computer then controls the length of the flame to satisfy the heat distribution requirements by varying the the amount of air mixed with the inert gas in the primary duct **86** while holding the supply of total air. If desired, there can be included the measurement of the oxygen in the flue gas by operation of the oxygen analyzer **30** and adjusting the damper **60** to a hold a predetermined oxygen to fuel relationship compared to the pulverized coal of about 1½ to 2% for a cement kiln and this ratio is adjusted as necessary for corrections. The oxygen analyzer **30** will permit an adjustment of the ratio of total air to total fuel for improved control of the combustion operation. If the residual oyxgen in the flue gas is not enough, this indicates the efficiency of burning the fuel can be improved. If too much oxygen is present in the flue gas, this indicates that heat is being wasted to heat up an excess of air. The damper **60** can be adjusted to optimize the operation of burner **12** in his regard.

While a preferred embodiment of the present invention has been described, it should be understood that various modifications and changes in the arrangement of parts may be made within the scope and spirit of the present invention.

I claim as my invention:

1. The method of controlling the distribution of heat from a fuel burner operative with an air supply and a substantially inert gas supply, including the steps of

sensing a first burner operation condition for controlling the amount of fuel supplied to said burner,

controlling the amount of air supplied from said air supply to said burner in accordance with a predetermined air to fuel ratio desired for the operation of said burner,

and sensing a second burner operation condition for ctntrolling the amount of inert gas supplied from said inert gas supply to said burner in according with a predetermined heat distribution desired for the operation of said burner.

2. The method of claim **1**, with said first burner operation condition being the burning zone temperature of a kiln operative with said burner and with said second burner operation condition being a predetermined temperature profile of said kiln.

3. The methof of claim **1**, with said first burner operation condition being a predetermined pressure of a boiler operative with said burner and with said second burner operation condition being a predetermined temperature of said boiler.

4. The method of claim **1** operative with a burner having a primary gas duct, including

maintaining an adequate flow of fuel transport gas in the primary gas duct leading to said burner in accordance with the amount of fuel supplied to said burner.

5. In fuel burner operation control apparatus operative with said burner having an air supply and a substantially inert gas supply, the combination of

first sensing means responsive to a first operation parameter of said burner for providing a first control signal in accordance with the desired supply of fuel to said burner,

second sensing means responsive to a second operation parameter of said burner for providing a second control signal in accordance with the desired supply of air with said fuel to said burner,

and control means operative with said supply of substantially inert gas and responsive to at least said first control signal for controlling the supply of substantially inert gas to said burner such that a desired operation of said burner is provided and operative with said supply of air and responsive to at least said second control signal for controlling the supply of air to said burner such that a desired operation of said burner is provided.

6. The control apparatus of claim **5** with said burner having a primary air duct and a secondary air duct,

said control means being responsive to at least said first control signal for controlling the fuel supplied through said primary air duct to said burner,

said control means being responsive to at least said second control signal for controlling the air supplied through said primary air duct to said burner,

and said control means being responsive to at least said first control signal for controlling the inert gas through said primary air duct to said burner such that a desired transport of said fuel to said burner is thereby effected.

7. The control apparatus of claim **5**, with said fuel burner being operable with a kiln,

said first operation parameter being the burning zone temperature of said kiln,

said second operation parameter being the temperature profile along at least the back end of the kiln away from the burner.

8. The control apparatus of claim **5**, with said fuel burner being operable with a boiler,

said first operation parameter being a predetermined pressure of the boiler,

said second operation parameter being a predetermined temperature of the boiler.

9. The method of claim **1**, with said fuel burner having a primary air duct and a secondary air duct,

with said control of the amount of fuel supplied to said burner being in relation to the fuel supplied through said primary air duct to said burner,

with said control of the amount of air supplied to said burner being such that the air supplied through the primary air duct is controlled to provide a predetermined distribution of the heat from said burner and the air supplied through the secondary air duct makes up the additional air needed for providing a predetermined air to fuel ratio for the operation of the burner,

and with said control of the amount of inert gas being in relation to the inert gas supplied through said primary air duct to said burner being adequate to provide a predetermined transport of the amount of fuel supplied through said primary air duct to said burner.

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JOHN J. CAMBY, Primary Examiner

U.S. Cl. X.R.

236—15; 263—52