June 18, 1968 J. E. GABRIELSON 3,388,862

PNEUMATIC CONTROL OF FURNACES

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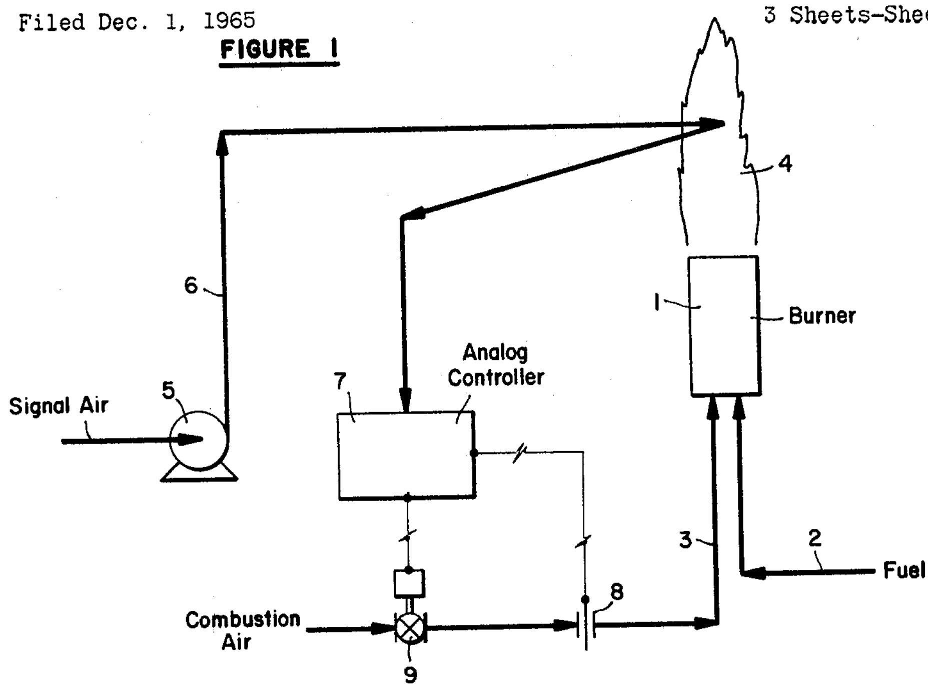
FIGURE 1



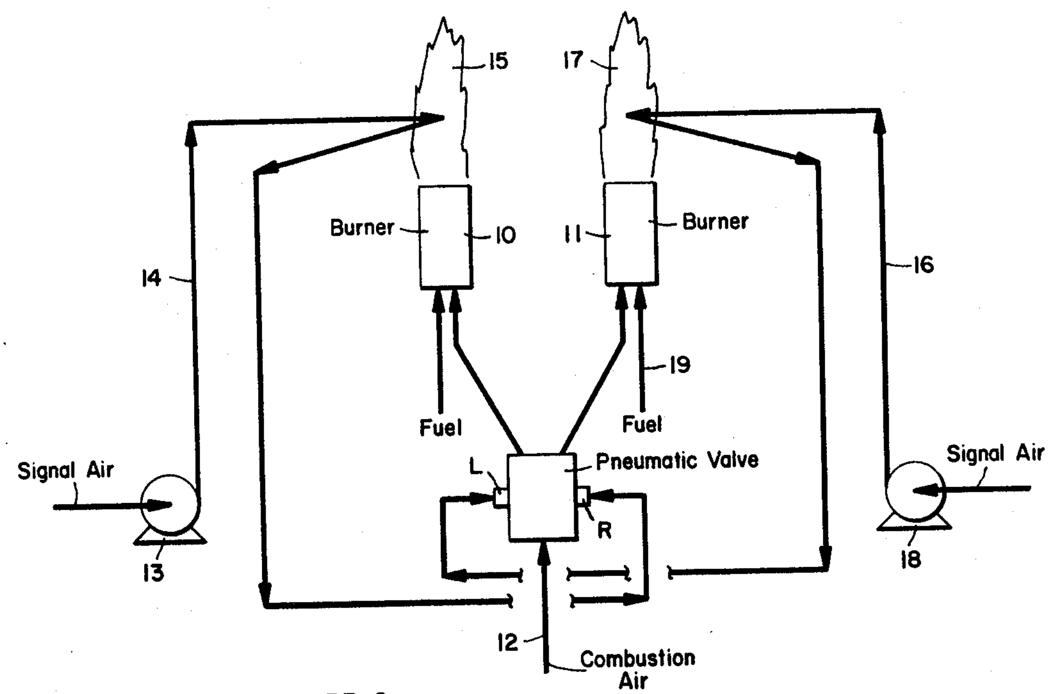


FIGURE 2a

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FIGURE 2b

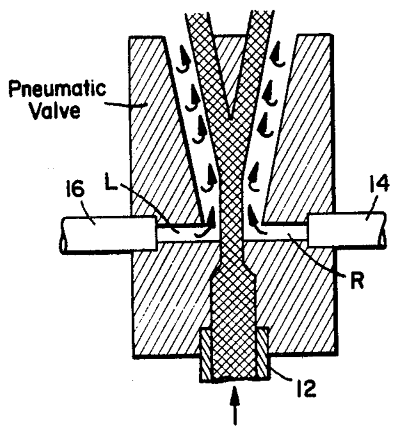
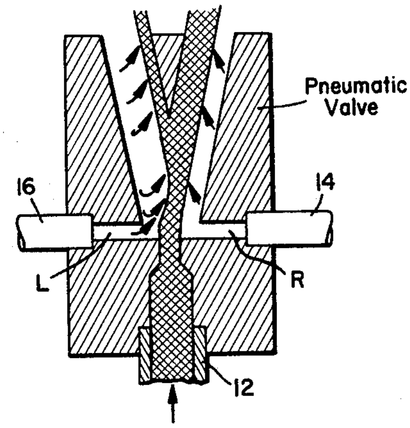


FIGURE 2c



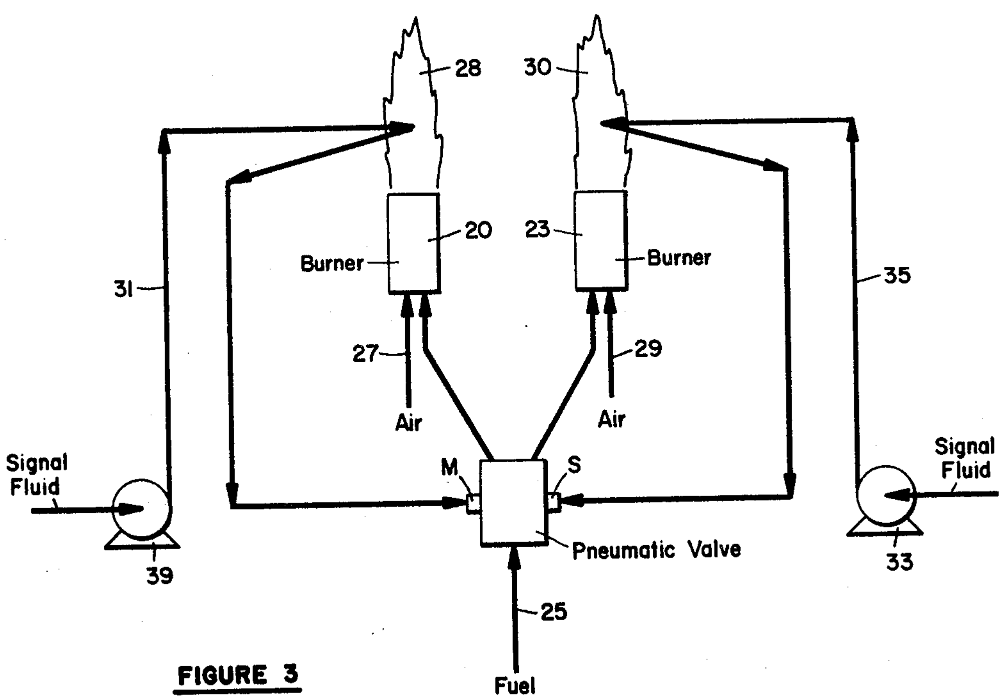


FIGURE 3

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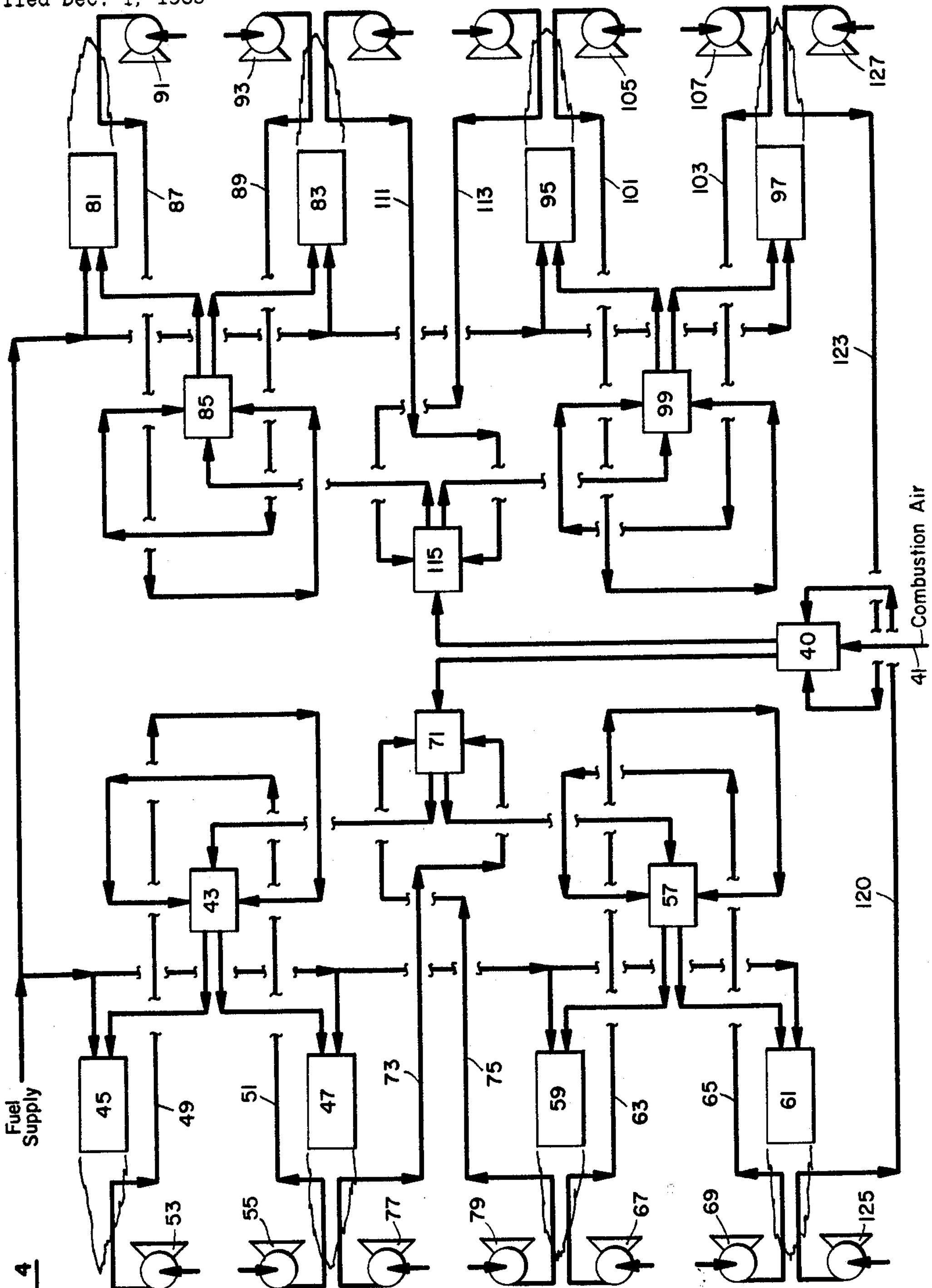

FIGURE 4

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PNEUMATIC CONTROL OF FURNACES

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ABSTRACT OF THE DISCLOSURE

A method and apparatus for controlling the fuel rate or combustion air rate to a burner. A Y-shaped flow diverter valve is controlled by a constant volume pump supplied stream of control fluid which passes in a conduit through the burner flame. More or less combustion air or fuel is directed by the diverter valve through the burner in response to changes in energy level of the heated control fluid.

This invention relates to multiple-burner fluid hydrocarbon fuel fired furnaces. In particular, it relates to the pneumatic control of the air flow to burners in order to maintain the optimum level of excess air at the burners.

Multiple-burner residual fuel fired furnaces or boilers are commonly used in firing power plants. Such furnaces or boilers may have a dozen burners, be as tall as an eight story building, and consume up to 400 barrels of fuel per hour. The residual fuel oils employed in such furnaces contain sulfur and metallic contaminants, both combustible and noncombustible, that form ash upon the combustion of the fuel. The formation of ash as a result of the combustion of the residual fuel results in deposit formations or slagging which reduces heat transfer efficiency. The sulfur in the fuel also causes problems. Some heavy fuels derived from high sulfur crudes contain as much as from 1 to 5 wt. percent sulfur. The burning of the sulfur-containing fuels results in the formation of sulfur trioxide which promotes corrosion in the superheaters and preheaters.

It is well known that the operation of residual fuel fired furnaces can be substantially improved in terms of inhibiting the amounts of sulfur trioxide formation by carrying out the combustion at levels of low excess air that are only slightly higher than stoichiometric; for example, from 0.01 to 5% excess. The use of higher amounts, for example, 10 to 15% excess air results in the formation of the highly corrosive sulfur trioxide. The use of low excess air is an effective method of inhibiting corrosion, but it must be carefully controlled because the use of air in less than stoichiometric amounts results in smoke formation and poor combustion. In short, at least a stoichiometric amount of air must be used in order to avoid excessive smoke production and not more than 5% excess air can be used or excessive amounts of sulfur trioxide are produced.

Even though it is well recognized that burners in such furnaces or boilers should be operated at slightly more than stoichiometric and less than 5% excess air, one still finds that there are problems in controlling the system to achieve the optimum operation. If only one or two burners out of twelve are not operating within the proper range, either excessive amounts of smoke or sulfur trioxide will be produced. Thus, it is preferable to have all the burners in the furnace operating at either end of the optimum range rather than having ten or eleven operating in the middle of the range and one or two operating outside of the range. It is difficult to maintain the proper amount of excess air at each burner, because conditions may change for one or more burners during operation. For example, the nozzle of one burner may wear or the

quality, inlet temperature, or rate of the fuel to an individual burner may change during operations.

It is therefore an object of this invention to provide a system for proportioning the combustion air so that each burner is operating within the optimum range of excess air.

Other objects of this invention will become apparent as one reads the following description in connection with the attached drawings in which:

FIGURE 1 schematically depicts a control system for single burner.

FIGURES 2*a*, 2*b*, and 2*c* are cross-sectional views of the control valve employed by the invention.

FIGURE 3 depicts of a proportioning system wherein fuel rate is the manipulated variable.

FIGURE 4 is a schematic diagram of a bank of burners wherein the combustion air is proportioned in accordance with the present invention.

Flame temperature is an indication of the amount of excess air provided to each burner. If flame temperature is too high, the burner is not receiving enough excess air. Thus, if the flame temperature goes above the desired range, the flow of combustion air to the burner can be increased or the fuel rate decreased to return the system to optimum conditions. Various temperature measuring devices can be employed to determine flame temperatures such as thermocouples, photopyrometers, ultraviolet analyzers, and microwave analyzers. These devices can be adapted to give an accurate determination of flame temperature. However, many of the devices, along with the associated control equipment, are complicated and expensive to install as well as expensive to maintain.

In accordance with this invention, a change in flame temperature is detected by a stream of control fluid, for example, air, and the resulting change in energy of the control fluid initiates corrective action either to the combustion air flow rate or the fuel rate. In one embodiment of this invention, there is a control loop for proportioning excess air between burners which has two small pumps as the only moving parts.

In each embodiment of the present invention a control fluid, for example, air, nitrogen, or other suitable fluid, is heated by the flame of a burner to be controlled. The heat from the flame increases the energy of the control fluid thereby increasing the temperature and increasing the momentum of the control fluid. The change in momentum of the stream is used to initiate a change in either combustion air or fuel to the burner.

In the first embodiment of this invention, the control fluid actuates an analog controller which in turn adjusts the flow of combustion air or fuel. In a preferred embodiment of this invention, combustion air is proportioned between pairs of burners by utilizing a simple pneumatic valve. In this preferred embodiment excess air is proportioned between two burners with the use of control loops having only two moving parts, two constant volume pumps.

The invention is best understood by referring to the accompanying drawings wherein FIGURE 1 depicts the first embodiment of this invention. A burner 1 having a fuel inlet line 2, combustion air inlet line 3, and frame 4 is controlled by a stream of control fluid supplied by constant volume pump 5 via conduit 6 to an analog controller 7. The fluid conduit 6 is placed in a position relative to the flame 4 so that it is heated exclusively by that flame and not by the flames of the burners. Thus, the increase in energy of the control fluid in conduit 6 is a function of the flame temperature of flame 4 and not of any other flame. In addition, the fluid conduit should be insulated downstream from the flame so that it does not lose a substantial portion of the energy received from the flame. The analog controller 7 continuously or intermittently obtains a signal representing the flow rate of combustion air from orifice 8 and changes the flow of combustion air by adjusting valve 9 in response to a change in energy of the heated control fluid. Thus, in response to an increase in pressure or volume of the control fluid resulting from an increase in flame temperature the pneumatic analog controller would adjust valve 9. If the flame temperature goes up, the analog controller will increase the flow of air to the burner.

Instead of controlling the flow of combustion air to maintain the optimum excess air to a burner, the fuel flow may be controlled. Thus, if conduit 3 were the fuel line and conduit 2 the combustion air line, the pneumatic analog controller 7 would increase the flow of fuel in response to a decrease in energy of the control stream which indicates that the flame temperature went below the desired range.

In each embodiment of the present invention, the control fluid pumps should provide a constant volume of control fluid to the system. Moreover, the temperature of the incoming control fluid should be maintained substantially constant so that a constant mole flow rate of control fluid is achieved.

FIGURE 2*a* illustrates the preferred embodiment of this invention wherein a constant volume of combustion air is proportioned between two burners. A constant supply of combustion air is fed to burners 10 and 11 via conduit 12. The combustion air from conduit 12 is divided in a pneumatic valve described in FIGURES 2*b* and 2*c* which are hereinafter described. A constant mole rate of control fluid is pumped by constant volume pump 13 into conduit 14 which passes in close proximity to flame 15 of burner 10. Likewise, control fluid is provided by pump 18 to conduit 16 which passes in close proximity to flame 17. Conduits 14 and 16 must be placed so that they are heated exclusively by flames 15 and 17, respectively. In this system the mole flow rate of control fluid entering conduit 14 must be the same as that entering 16, and the control fluid conduits must be placed so that there is no substantial disparity between the energy increases of the two streams when their respective burners have flames at the same temperature. Conduit 14 leads to port R in the pneumatic valve, whereas conduit 16 leads to port L on the pneumatic valve. Thus, in the situation where the flame temperature of flame 15 is the same as that of flame 17, the momentum of the control fluid to port L will be the same as the momentum of the control fluid to port R. In this situation the flow of combustion air coming through conduit 12 will be equally divided between the two burners. If, however, the flow of fuel via conduit 19 to burner 11 increases or if there is nozzle wear at burner 11 causing an increased fuel flow to burner 11, which increases the flame temperature, the increased temperature of flame 17 will heat the control fluid in conduit 16 to a higher temperature than that of the control fluid in conduit 14. Therefore, the stream of fluid to port L will have greater momentum than that of the stream of fluid to port R. In this situation, the flow of combustion air is diverted so that an increased amount goes to flame 17 thereby decreasing the flame temperature. The decrease in flow of combustion air to flame 15 will result in an increase in flame temperature thereof. Therefore, the control fluid in conduit 14 will be heated and the flow of momentum fluid to port R will be increased, thus tending to divert a portion of the combustion air back to flame 15. The system will soon balance out and the result will be that burners 10 and 11 will be operating at different levels of excess air and flames 15 and 17 will be at different flame temperatures but the difference will be slight and each burner will be operating within the optimum range of excess air rather than having one burner operate out of the range and one in the middle of the range.

For violent upsets the flow of combustion air in conduit 12 may not be sufficient to permit the balancing of the burners within the optimum range. Therefore, periodically a flue gas analysis should be performed to determine whether the burners are operating outside of the range. Even with more elaborate and complicated control systems, a flue gas analysis must be performed periodically. In the simple system described herein, the need for obtaining a flue gas analysis at frequent intervals is obviated. The proportioning system of this invention will keep each pair of burners operating within the optimum range as long as sufficient combustion air is provided. It must be stressed, however, that this is not a primary control technique and that the fuel air ratio must periodically be adjusted if the flue gas analysis so indicates.

A better understanding of the pneumatic valve used in this system is achieved by examining FIGURE 2*b* wherein is shown a valve for splitting the combustion air in conduit 12. The control fluid in conduit 16 enters port L and the heated control fluid in conduit 14 enters port R as is shown in the drawing. When the momentums of the control streams are equal, the supply of combustion air is evenly distributed to both burners (see FIGURE 2*b*). However, in the instance where the flame temperature of flame 17 increases, the energy of the control fluid in conduit 16 increases, thereby diverting a greater portion of the combustion air to burner 11 (see FIGURE 2*c*). It is thus seen that the proportion of the total amount of combustion air supplied via conduit 12 that is sent to burner 11 varies directly with the flame temperature of flame 17.

The amount of control fluid that is needed in conduits 14 and 16 relative to the amount of combustion air supplied in conduit 5 (see FIGURE 2*a*) is very small. If the control fluid is air, the fluid would have to be supplied within the range of from 1 to 5 mole percent of the combustion air and preferably only 2 mole percent. Larger amounts of control fluid can be used, but are not usually needed.

The Y-shaped pneumatic control valve depicted in FIGURES 2*b* and 2*c* has heretofore been used to switch the flow of liquids, gases, slurries, or pneumatically-conveyed solids from one outlet to another in large pipelines. Such valves have not been used for the purposes described herein and additionally, it should be noted that the control fluid which initiates changes in a manipulated variable, combustion air flow rate, or as hereinafter described, fuel rate, does so in direct response to a change in flame temperature which is an indirect measurement of a controlled variable, to wit, the amount of excess air.

The manipulated variable in the system described in FIGURES 2*a*, 2*b*, and 2*c* is the flow rate of the combustion air. However, since the pneumatic valves can be used to proportion liquid streams, the manipulated variable can be the fuel flow. Referring to FIGURE 3, one sees two burners, 20 and 23, fed by fuel via conduit 25 and combustion air via conduits 27 and 29. Control fluid is heated by flames 28 and 30 via pump 39, conduit 31, and pump 33, conduit 35, respectively. Where the fuel rate is the manipulated variable, however, the control fluid in conduit 31 is fed to port M, whereas the control fluid in conduit 35 is fed to port S so that the flow rate of fuel to a burner is made to vary inversely with the flame temperature of that burner.

A flow diagram for proportioning the supply of combustion air to eight burners is illustrated in FIGURE 4. The pneumatic valves shown therein are the same as the one described in FIGURE 2*b*. Pneumatic valve 40 proportions the combustion air entering the furnace via conduit 41 between the two banks of burners. In the first bank of burners pneumatic valve 43 proportions air between burners 45 and 47 in response to control fluid supplied via conduits 49 and 51 by the constant volume pumps 53 and 55. Pneumatic valve 57 proportions a supply of combustion air between burners 59 and 61 in response to control fluid furnished via lines 63 and 65 by control pumps **67** and **69**. Pneumatic valve **71** proportions combustion air between pneumatic valves **43** and **57** in response to signals via conduits **73** and **75** wherein control fluid is supplied by pumps **77** and **79**.

Likewise, in the second bank of burners, the flow of combustion air to burners **81** and **83** is proportioned by pneumatic valve **85** in response to control fluid supplied via conduits **87** and **89** by pumps **91** and **93**. The combustion air to burners **95** and **97** is proportioned by pneumatic valve **99** in response to control fluid signals received via conduits **101** and **103** and supplied by pumps **105** and **107**. In response to changes in energy of the control streams supplied by conduits **111** and **113**, pneumatic valve **115** proportions the combustion air between pneumatic valves **85** and **99**. If there is a discrepancy between the average flame temperature of the burners in the first bank and the second bank, pneumatic valve **40** adjusts the sytem to send more combustion air to the bank of burners having the higher average flame temperature in response to a difference in signals received via conduits **120** and **123** wherein control fluid is passed through the flames of burners **61** and **97** as a result of the pumping action of pumps **125** and **127**. In this fashion, a fixed amount of combustion air supplied via conduit **41** is proportioned between the burners in order to keep each burner operating within the optimum range of excess air. If the flue gas analysis indicates that the burners are not operating within the optimum range with the use of this system, the total amount of combustion air can be changed or the fuel rates can be modified. This system obviates the need for any major readjustments resulting from minor disturbances in the system.

This invention has been described with a certain degree of particularity. Certain deviations therefrom can be made without departing from the scope of the invention.

What is claimed is:

1. A control system for regulating the flow of combustion air to a burner comprising, in combination, a burner, a Y-shaped flow diverter valve for splitting a main stream of burner combustion air into two secondary streams of predetermined proportion, said valve including a control port for the application of a flow proportioning control fluid thereto, means for supplying a constant volume flow of control fluid, conduit means connecting said control fluid supply means to said control port, said conduit means passing adjacent the flame produced by said burner to provide that the control fluid pumped through said conduit be exclusively heated by the flame of said burner whereby the energy of the heated control fluid changes in proportion to a change in temperature of the flame, said control fluid being directly effective to alter the ratio of combustion air flowing in said secondary streams of said diverter valve.

2. A method of proportioning a constant volume stream of combustion air to two burners to obtain an amount of excess air at each burner within the desired range comprising dividing a combustion air stream to supply combustion air to a first burner and a second burner, heating a first stream of control fluid with the flame of the first burner, heating a second stream of control fluid with the flame of the second burner, whereby the energy of said first stream and said second stream is changed in direct proportion to a change in flame temperature of said first burner and second burner respectively; correcting, in response to a change in energy of either control stream, the flow of combustion air to said first burner and second burner in amounts directly proportional to the change in energy of the first and second control streams respectively.

3. A method according to claim **2** wherein said first heated control stream in injected into said combustion air stream at a position diametrically opposed to that at which the second heated control stream is injected into said combustion air and wherein both control streams are injected into said combustion air stream at essentially right angles thereto.

4. A method of proportioning a volume of fuel to two burners to ensure that the burners operate within the optimum range of excess air comprising dividing a stream of fuel to supply fuel to a first burner and a second burner, heating a first stream of control fluid with the flame of the first burner, heating a second stream of control fluid with the flame of the second burner, whereby the energy of said first stream and the energy of said second stream is changed in direct proportion to a change in flame temperature of said first burner and said second burner respectively; changing, in response to a change in energy of either control stream, the flow rate of fuel to said first burner and second burner in amounts inversely proportional to the change in energy of the first and second control streams respectively.

5. A method according to claim **4** wherein said first heated control stream is injected into said fuel stream at a position diametrically opposed to that at which the second heated control stream is injected into said fuel stream and wherein both control streams are injected into said fuel stream at essentially right angles thereto.

6. An apparatus for proportioning a fixed supply of combustion air between the flames of two burners comprising: a pneumatic valve through which said combustion air is channeled to a first burner and a second burner; a first fluid conduit positioned from said first burner to ensure that the control fluid to be pumped through said first fluid conduit is exclusively heated by the flame of said first burner, said first fluid conduit being attached to said pneumatic valve and positioned relative thereto to ensure that the direction of the flow of the control fluid entering said valve is at a right angle to the direction of the flow of combustion air flowing through said valve; a second fluid conduit positioned from said second burner to provide that the control fluid to be pumped through said second fluid conduit be exclusively heated by the flame of said second burner, said second fluid conduit being attached to said pneumatic valve at a position diametrically opposite of the position at which said first fluid conduit is attached to said pneumatic valve and said second fluid conduit being positioned relative to said pneumatic valve to ensure that the direction of the flow of the control fluid entering said valve is at a right angle to the flow of combustion air flowing therethrough.

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