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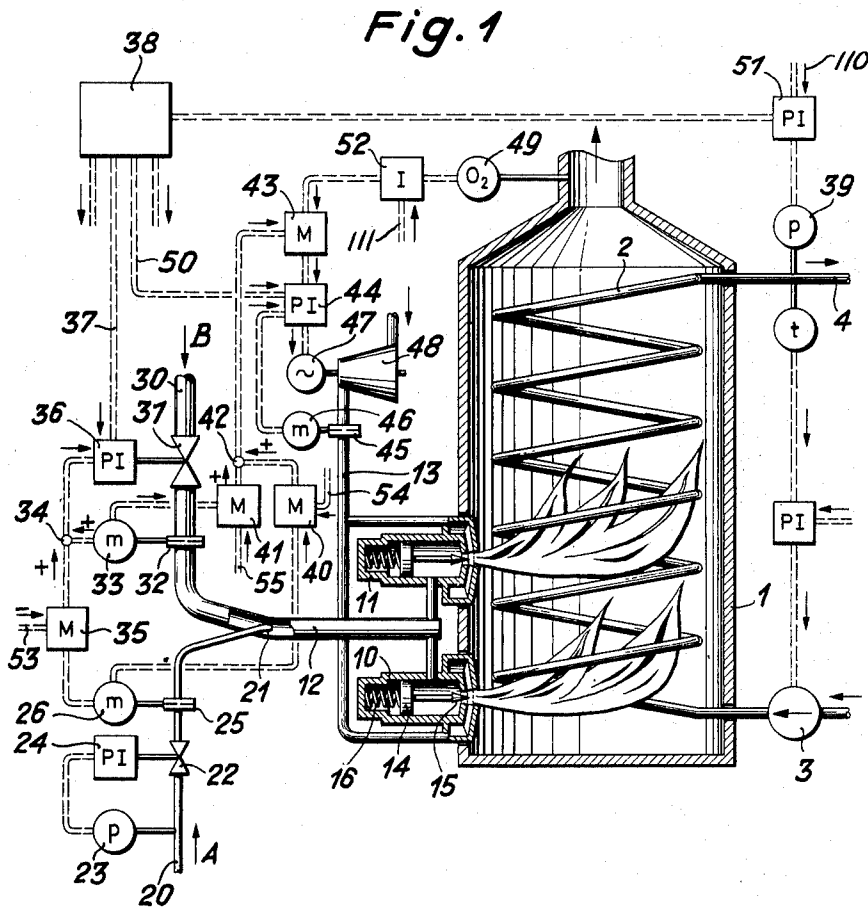
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3,241,597

METHOD OF FIRING WITH FLUID FUELS

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4 Sheets-Sheet 1



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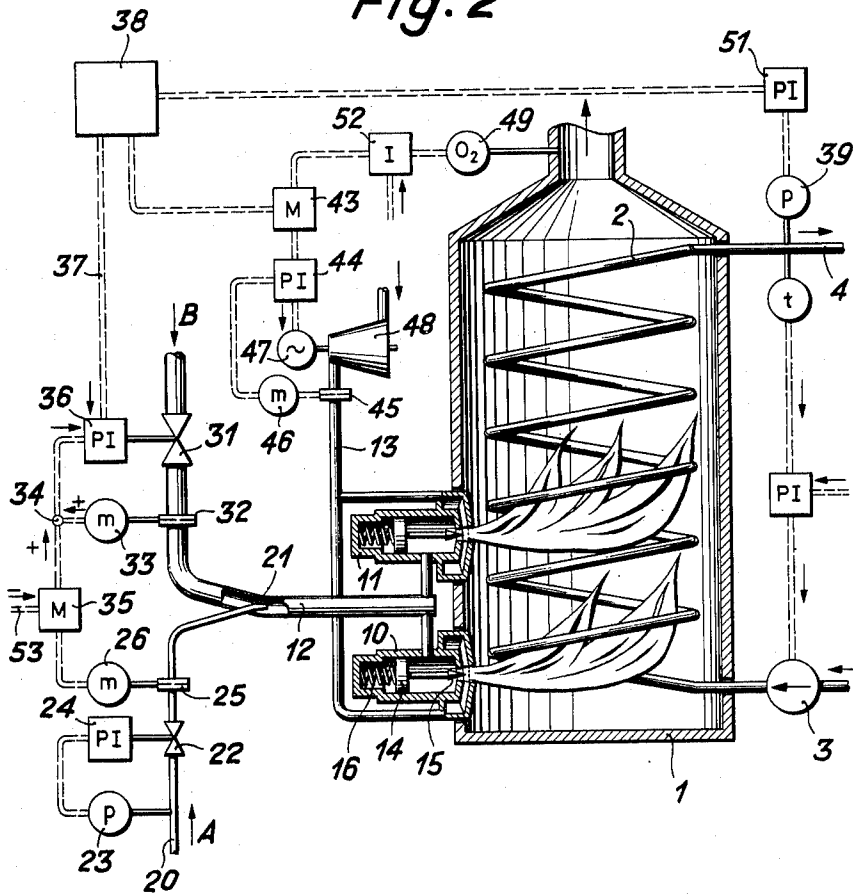
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Fig. 2



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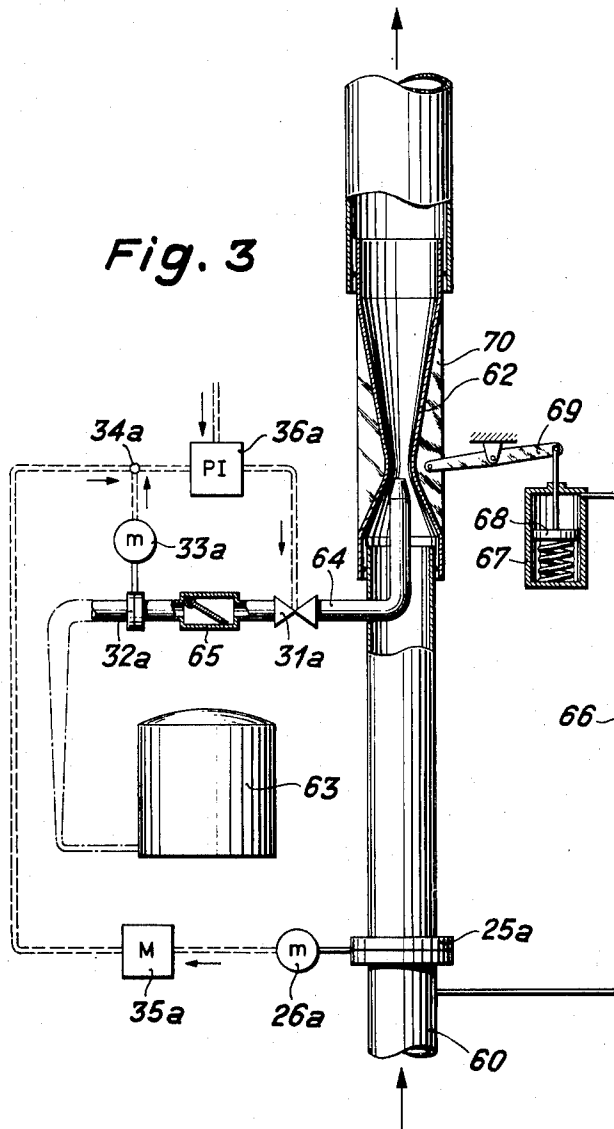
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4 Sheets-Sheet 3



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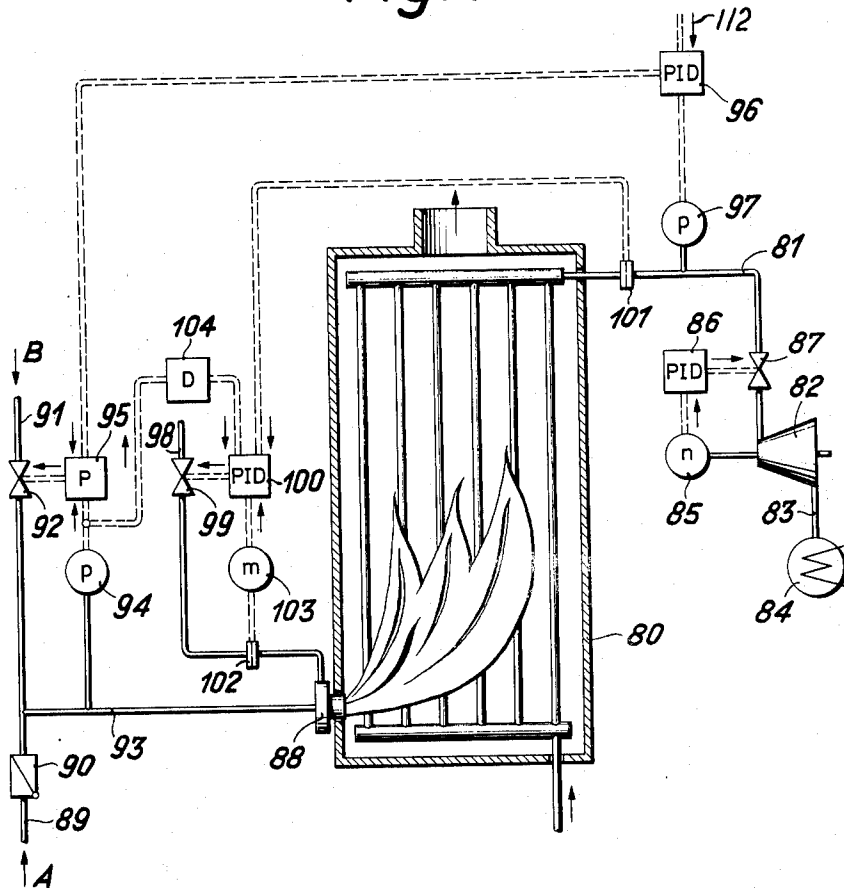
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Fig. 4



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METHOD OF FIRING WITH FLUID FUELS

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3 Claims. (Cl. 158—117.5)

The present invention pertains to a method and means for operating a firing apparatus fed with at least two separate fluid fuels, for use in particular for firing a steam generator or gas turbine, in which at least one basic fuel is to be burned at the rate at which it arrives at the location of the firing apparatus.

The term "fluid fuels" is to be understood as including gaseous fuels such as methane, blast furnace gas, etc., liquid fuels such as crude oil and the various fractions obtained therefrom by distillation, and also finely divided solid fuels such as anthracite or soft coal in pulverized form.

The invention comprises a process in which at least one supplementary fuel is mixed to the continuously arriving basic fuel in a quantity corresponding to the heat output desired, this mixture being then supplied for burning.

The apparatus of the invention for carrying out this method is characterized by the provision of means for adjusting the quantity of the supplementary fuel in accordance with the heat output required, and by the provision of means for mixing the supplementary fuel with the basic fuel continuously supplied.

The invention finds advantageous application particularly in cases where there is to be burned in a firing mechanism a basic fuel of a type which cannot be economically stored, i.e. when the storage of such fuel is possible only at unreasonable costs, or when the quantity of the basic fuel to be consumed per unit time is set by an agreed program or contract relating, for example, to the terms of supply of the basic fuel. The term "basic" is here used in the sense of primary, or fundamental, and not in the chemical sense which distinguishes between basic and acidic. The basic fuel can take the form of a gas such as blast furnace gas which is to be consumed in the firing mechanism of a steam generator at the rate of its arrival or supply, which rate of arrival may be subject to variations with time. Moreover, the basic fuel may vary with time in regard to its heating value. According to the invention, a freely available supplementary fuel is to be added to and mixed with the basic fuel, the quantity so added being adjusted prior to mixture so that the required heat output will be obtained notwithstanding possible variation with time of this required heat output.

According to one preferred form of the method of the invention, the rates of flow of the constituent fuels to be mixed, i.e. of the basic and supplementary fuels, are measured, and a signal derived from the rate of flow of one or more of the fuels is corrected by means of a signal derived from the heat value of one or more of the fuels or from the combustion air requirements thereof. The rate of flow signals and the corrected signal thus obtained are combined into a sum signal, and the rate of delivery to the burner of at least one of the free-

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ly available supplementary fuels is adjusted in accordance with this sum signal.

In one embodiment of the invention especially useful in the case of basic and supplementary fuels which have approximately the same heating values and approximately the same densities, the dynamic or total pressure of the fuel mixture is measured and the rate of flow (i.e. rate of delivery to the burner) of the freely available supplementary fuel is varied in accordance with the pressure value so measured. Such an embodiment possesses the advantage of great simplicity.

By reason of the mixture of the fuels, a correspondingly reduced number of burners will be required as compared with separate firing of the separate fuels. Accordingly the invention provides a further advantage in that the firing mechanism may be of reduced dimensions and may require only a small space.

The invention will now be described in further detail with reference to the accompanying drawings in which:

FIG. 1 is a schematic representation of a once-through forced circulation steam generator including firing apparatus according to the invention;

FIG. 2 is a diagram similar to that of FIG. 1, likewise showing a once-through forced circulation steam generator including firing apparatus according to the invention but in which, in contrast to the embodiment of FIG. 1, no adjustment is made of the supply of combustion air as a function of the measured rates of delivery of the fuels;

FIG. 3 is a diagram showing apparatus for mixture of fuels which may be used in the invention; and

FIG. 4 is a schematic representation of a further steam generator having a firing apparatus according to the invention in which the adjustment of the rate of supply of the supplementary fuel is made as a function of the total pressure of the mixture of fuels.

In FIG. 1 a once-through forced circulation steam generator having a fire enclosing chamber 1 is provided with a tube system 2, fed from a feed pump 3. The fresh steam leaves the steam generator at the line 4. Two burners 10 and 11 are provided in the wall of the generator and these are fed with a mixture of fuels via a line 12. The air necessary for combustion of the mixture is supplied to the burners through line 13. The burners comprise each a piston 14 in a cylinder, this piston carrying a throttling cone 15 and bearing against a spring 16. This insures that, irrespective of the rate at which the fuel mixture passes through the burner, it will pass through the burner opening and into the combustion chamber with a specified minimum streaming velocity. By variation of the characteristics of the spring 16, the pressure at the burner can be suitably related to the load.

The fuel mixture in FIG. 1 comprises two components. One component A, assumed to be supplied at a given fixed or time variable rate not subject to control, arrives via a line 20 and passes to a mixing device 21. For example, there may be here employed blast furnace gas. A desired pressure is maintained in the line 20 by means of a valve 22, this valve being controlled from a pressure value signal generator 23 via a control device or servo mechanism 24 which may, for example, have a proportional and integral mode of operation. Such a device will hereinafter be termed a P-I controller. A perforated diaphragm 25 is located downstream of the valve 22 and the pressure differential across diaphragm 25 is supplied

to a device 26 which generates a signal representative of the rate of flow of fuel A through line 20.

The freely available supplementary fuel component B such as methane for example arrives at a line 30 which contains a valve 31 and a perforated diaphragm 32. By "freely available" it is here meant that fuel B can be delivered to and accepted and consumed by the firing apparatus of FIG. 1 at any rate over a range of rates which may be stated for example in cubic feet or pounds per minute, this rate being precisely adjusted in accordance with the invention to match, for example, such factors as a changing load on the steam generator or a changing heat value of one or more of the fuel components. Thus, the quantity of fuel B consumed in unit time is subject to control by the apparatus of and in accordance with the method of the invention, whereas the quantity of fuel A consumed in unit time, whether fixed or variable, is a datum, not subject to control.

The operating pressure drop at diaphragm 32 is supplied to a rate of flow signal generating device 33 whose output is superposed at 34 with an output signal from the rate of flow signal generating device 26, as corrected in a multiplying organ 35. The sum signal so obtained operates as a control signal, i.e. as an actual value signal representative of the current rate of consumption of components A and B, on a P-I controller or servo 36 which drives the valve 31. The controller 36 receives its reference or desired value signal via a line 37 from a load demand representative signal generating device 38. This demand signal generator 38 receives as input a signal coming from the pressure measuring device 39 which measures the pressure in the fresh steam line 4, as modified in the P-I controller 51 by the reference input signal arriving on line 110. The rate of flow signal generating devices 26 and 33 additionally deliver their outputs to signal multiplication elements 40 and 41 respectively, whose outputs in turn are summed at the junction point 42. This sum signal is then supplied via the multiplying device 43 as a reference value to a P-I controller 44. Controller 44 controls the supply of air to the burners 10, with the help of a perforated diaphragm 45 and a rate of air flow signal generator 46. Specifically, the controller 44 adjusts the operation of a motor 47 which drives a blower or compressor 48. The multiplying device 43 receives a correction signal via an integrally operating controller 52 from a device 49 which generates a signal representative of the oxygen content of the combustion products at the exhaust stack. An advance signal derived from the load demand device 38 is applied to the controller 44 via a line 50, the controller 44 affecting the motor 47 upon a change in load either proportionally, or for example, proportionally and differentially.

The firing system of FIG. 1 operates in the following manner: Upon a departure of the pressure in the fresh steam line 4 from a desired value, the load demand device 38 shifts its setting. As a consequence the servo 36 receives a new reference value to which the actual value sum signal from summing device 34 is to be compared for control of valve 31. In addition, the advance signal to the controller 44 is changed so that the quantity of fuel component B passed through the line 30 and the quantity of combustion-supporting air passed through line 13 will be changed substantially simultaneously. The actual quantities (i.e. rates of flow) of the two fuel components A and B are indicated by the devices 26 and 33 and the signal from the device 26 is so corrected in the multiplying device 35 as a function of the relative heat values of the two components that the sum signal formed at the junction point 34 is always proportional to the heat value of the gas mixture. A factor signal representative of these heat values is supplied at line 53. The corrected heat value signal output from multiplier 35 is then at once compared in controller 36 with a desired or reference value (in line 37) so that any departure or divergence

between the two operates on the valve 31, after a delayed transformation in the controller 36. The outputs of the rate of flow measuring devices 26 and 33 are separately multiplied in the devices 40 and 41 with factors corresponding to the combustion air requirements of fuel components A and B respectively, signals representative of these factors being supplied at input signal lines 54 and 55. The sum signal formed at the junction point 42 is then applied to the controller 44 as a reference or desired value signal for the combustion air, this reference value being optionally subjected to correction in the multiplication device 43 as a function of the output signal from the oxygen measuring device 49 and of the reference input signal applied to controller 52 at line 111.

Upon a change in the physical characteristics of either or both of the fuel components, the factors supplied via signal lines 53, 54 and 55 to the multiplying devices 35, 40 and 41 are suitably altered. In the case assumed, the first of these factors represents in the line 53 the ratio of the heat values of the two components whereas the second and third factors represented by the signals in lines 54 and 55 represent respectively the combustion air requirements of the two fuels A and B.

It is also possible in a manner analogous to that involved in the formation of the reference value signal for the combustion air control, to insert between the rate of flow signal generator 33 and the junction point 34 a multiplying device similar to the device 35. With such a construction, the signal input at line 53 and the corresponding input to the multiplying device inserted between elements 33 and 34 would represent respectively the heat values of the fuel components A and B individually. In such a construction it is possible to dispense with one of the multiplying devices 40 and 41, the other then being adjusted to operate as a function of the ratio of the combustion air requirements of the two fuels.

The embodiment of FIG. 2 is the same as that of FIG. 1 except that in FIG. 2 the quantity of air supplied to the burners is not adjusted as a function of the individual fuel arrival rates. Thus, there is in FIG. 2 no input to the multiplier 43 representative of the measurements at 25 and 32. Rather, the reference value for controller 44 is set simply by a signal from the load demand device 38, as corrected in multiplier 43 by the oxygen signal generator 49. This embodiment has the advantage of great simplicity. It is wholly satisfactory insofar as the total required combustion air varies approximately proportionally to the required heat output.

FIG. 3 shows a mixing device for the fuels having fuel flow rate regulating means similar to that of FIGS. 1 and 2. The mixing device proper takes the form of an ejector 62. This may be used with especial advantage when the basic fuel arrives at a high pressure such as, for example, ten atmospheres. The highly pressurized basic fuel is supplied via the line 60 to the ejector 62 while the supplementary fuel, the quantity of which can be varied at will, is supplied to the ejector from a container 63 via a line 64 containing not only a control valve 31a but a check valve 65. Adjustment of the quantity of supplementary fuel is carried out in a manner similar to that described in connection with FIGS. 1 and 2 so that a description of this control is believed to be unnecessary. For clarity all elements of the structure of FIG. 3 which correspond in function with elements of FIGS. 1 and 2 are identified in FIG. 3 with the same reference characters as in FIG. 2 except that the letter *a* has been appended thereto. The valve 22 of FIG. 1 which serves to preserve a desired pressure in line 20 is omitted in FIG. 3 since the ejector 62 is adjustable. The pressure of the basic fuel is communicated via a line 66 to the spring loaded piston 68 in cylinder 67, this piston being coupled via a two-armed lever 69 with a fin 70 attached to the ejector tube 62 proper. The ejector tube 62 is thus movable axially with respect to the nozzle at the end of tube 64. The construction shown makes it possible to operate

with only a small degree of compression of the supplementary fuel.

Of course, the valve 31 of FIG. 1, rather than the valve 22, might be omitted in construction employing the adjustable ejector of FIG. 3.

FIG. 4 shows a steam generator 80 from which a fresh steam line 81 leads to a turbine 82. The steam outlet 83 from the turbine is connected to a condenser 84. A revolution counter or tachometer 85 is connected to the turbine shaft and this counter operates via a proportionally, integrally and differentially operating controller 86 on the setting of the valve 87 in line 81.

In the firing system for the steam generator of FIG. 4 there is shown only one burner 88. The basic fuel A is supplied via a line 89 containing a check valve 90 and the supplementary fuel B is supplied via a line 91 which contains a regulating valve 92. The fuel mixture is fed to the burner 88 via a line 93. The dynamic or total pressure of the fuel mixture is measured in a measuring device 94 and from this device an actual value signal is supplied to a proportional controller 95. The output of the controller 95 adjusts the setting of the valve 92. Formation of the reference value signal for the controller 95 occurs in the controller 96 which receives its input signals from a pressure measuring device 97, measuring the steam pressure in the line 81, and from the reference input signal line 112. The combustion air is adjusted as a function of the steam outputs of the steam generator. Compressed air is supplied to the burner 88 via a line 98. This line contains a control valve 99 which is adjusted by means of a proportionally, integrally and differentially operating controller 100. The reference value signal for this controller is generated from the rate of steam flow measuring device 101 in the fresh steam line 81 whereas the actual value signal is obtained from a measurement diaphragm in the diaphragm 102 and associated signal generator 103.

The mode of operation of the firing system of FIG. 4 is as follows: If for example the load on the turbine declines, the valve 87 will be reset in the direction which closes it by operation of the revolution counter 85 and the controller 86. Thereupon pressure will rise in the line 81 and this will produce a corresponding change in the reference value signal applied from the fuel controlling device 96 to the controller 95, the change in pressure being measured at the device 97. The controller 96 will via the proportionally operating controller 95 effect a re-setting of the valve 92, and hence a reduction in the quantity of supplementary fuel supplied. Only after a certain time delay will there occur a corresponding change in the reference value signal to the air controller 100, arriving from the steam rate of flow measuring device 101. In addition however, a transient signal will be supplied from the signal line between pressure measuring device 94 and controller 95, this signal being applied to the air controller 100 via a differentiating element 104 so that an immediate adjustment of the air supply can occur upon a change in operating conditions.

The invention may also find application, with suitable change of the components illustrated, if in place of a single basic fuel plural basic fuels or plural supplementary fuels are to be employed.

From the foregoing it will be seen that there has been described a method and apparatus for generating heat by the combustion of fuel, in which at least two separate fluid fuels are employed. One of these fuels, termed the basic fuel, is delivered for firing at a rate which, while it may be variable with time, is not subject to control in accordance with the requirements for heat to be generated nor in accordance with changing heat values of that fuel. On the contrary, the basic fuel must be consumed as fast as it is delivered to the combustion means,

and conversely no means are available for adjusting the rate of delivery thereof, either upward or downward. In contrast the rate of delivery of the supplementary fuel is subjected to control, and it is so controlled, according to the invention, to match a desired heat output, in spite of fluctuations in that desired heat output, or in the heat value of one or both of the fuels.

While the invention has been described herein in terms of a number of preferred embodiments, the invention itself is not restricted thereto, comprising rather all variations and modifications which may be made upon the embodiments described within the spirit and scope of the appended claims.

I claim:

1. A method of operating a fire for the combustion of first and second fluid fuels supplied to the fire at variable rates subject to control, said method comprising the steps of supplying both of said fuels and a combustion supporting medium to a firing point, generating first and second signals representative respectively of the rates of flow of said first and second fuels to said firing point, modifying one of said signals in accordance with variations in the heat value of at least one of said fuels, summing the other of said signals and said modified signal, generating a third signal representative of the load demand on said fire, and controlling the rate of flow of said second fuel by comparison of said summed signals with said third signal.

2. A method of operating a fire with at least two fluid fuels of which one is supplied at a variable rate subject to control, said method comprising the steps of supplying both of said fuels and a combustion supporting medium to a firing point, developing first and second signals representative of the rate of flow of said two fuels to said firing point, summing said signals, modifying at least one of said signals in accordance with variations in the requirement of at least one of said fuels for combustion-supporting medium, developing a third signal representative of the load demand on said fire, controlling the supply of the other of said fuels by comparison with each other of said summed and third signals, and controlling the supply of combustion-supporting medium by comparison with each other of said modified and third signals.

3. A method of operating a fire for the combustion of a mixture comprising first and second fluid fuels supplied to the fire at variable rates subject to control, said method comprising the steps of supplying both of said fuels and combustion supporting medium to a firing point, generating first and second signals representative respectively of the rates of flow of said first and second fuels to said firing point, modifying one of said signals in accordance with variations in the heat value of at least one of said fuels, summing the other of said signals and said modified signal, generating a third signal representative of the load demand on said fire, controlling the rate of flow of said second fuel by comparison of said summed signals with said third signal, mixing said fuels before delivery to said fire, and controlling the supply of combustion-supporting medium to said fire in accordance with at least one of said first and second signals.

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