Jan. 10, 1939. C. W. PAYN 2,143,820

COMBUSTION EFFICIENCY METHOD AND APPARATUS

Filed March 12, 1937 2 Sheets-Sheet 1

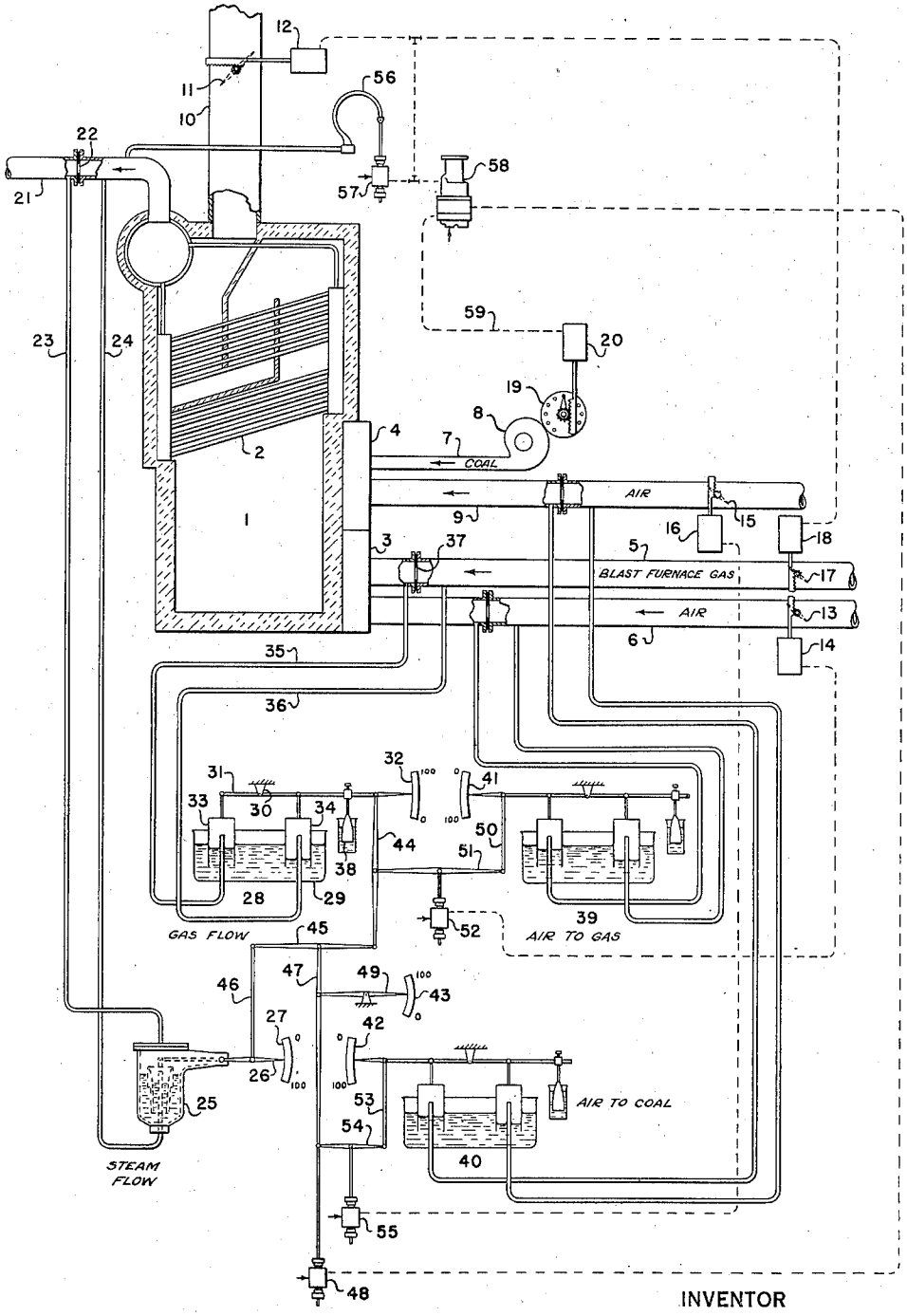


FIG. 1

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COMBUSTION EFFICIENCY METHOD AND APPARATUS

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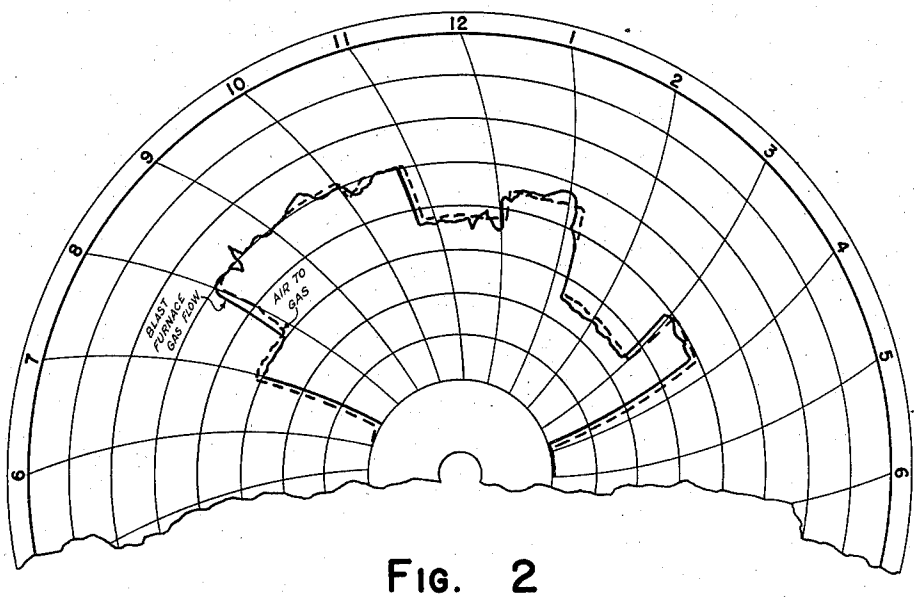


FIG. 2

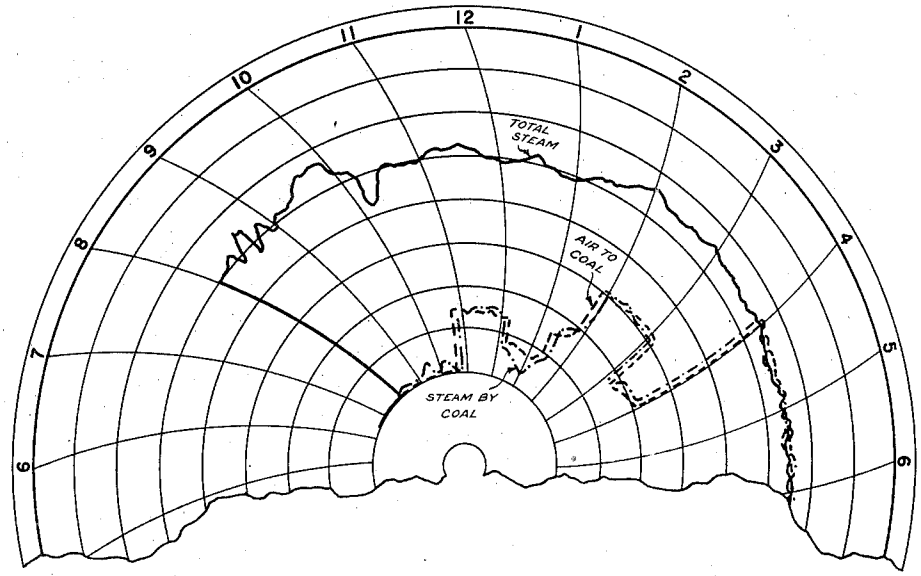


FIG. 3

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Patented Jan. 10, 1939

2,143,820

UNITED STATES PATENT OFFICE

2,143,820

COMBUSTION EFFICIENCY METHOD AND APPARATUS

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Application March 12, 1937, Serial No. 130,549

14 Claims. (Cl. 236—1)

This invention relates to combustion efficiency apparatus, and especially to the use of such apparatus in the control of the supply of air for combustion to the furnace of a vapor generator or to heating furnaces in general, wherein the elements of combustion react to liberate heat, and where a plurality of fuels may be fed to the furnace simultaneously and in any proportion.

Ordinarily a single fuel is burned in the furnace and an indication of combustion efficiency may be had through obtaining the relation existing between a measure of the air flow and a measure of output, such for example as vapor outflow from the vapor generator. Such indication of combustion efficiency may then be utilized as a guide for either manually or automatically controlling the supply of air for promoting combustion.

In the combustion of a single fuel at different rates of output and at a predetermined desirable excess of air, a definite rate of flow of products of combustion will result for each rate of output. The value of the rate of flow, or its flow effect, or the relation such as previously referred to, may be calculated for any given fuel; but when a plurality of fuels are burned simultaneously in a furnace, and in varying proportions, the resulting volume of products of combustion will vary not only with the percentage of excess air, and the rating developed, but also with the character of the fuels burned and the proportioning of the several fuels.

Dissimilar fuels have not only different calorific values, but due to their difference in composition require a different theoretical amount of air for perfect combustion. Furthermore, the percentage of excess air providing optimum combustion conditions will vary from one fuel to another. For example, when burning blast furnace gas the theoretical amount of air for perfect combustion will differ decidedly from that required when burning pulverized coal, and furthermore the excess of air required for optimum combustion conditions in the burning of blast furnace gas will differ from the excess required in the burning of pulverized coal. Again the theoretical and excess air required for the combustion of tar or other fuels will differ from that for blast furnace gas or pulverized coal.

If two or more dissimilar fuels are burned simultaneously in a furnace and in varying proportions, a difficult problem exists in the proper proportioning of air for combustion to the furnace to obtain optimum combustion conditions. It is therefore a primary object of the present invention to control the supply of air for combustion in the most efficient manner, regardless of the rating developed or the proportionality of fuels supplied.

It is a further object of the invention to provide a relation indicator for indicating, as a guide to manual or automatic control of the supply of air, the relation instantaneously existing between certain measures of fuel, of the air, and of the output of the furnace or some variable factor in the operation of the furnace, taking into account the proportionality and characteristics of the various fuels, and furthermore the excess air at which the fuels are desirably burned.

I have chosen as illustrative of my invention to describe a particular example, wherein it is desired to produce vapor by means of a vapor generator from the combustion of blast furnace gas until the available rate of supply of the blast furnace gas is not sufficient to maintain steam pressure and satisfy steam flow demand, and to thereafter supplement the heat liberation by the supplying of pulverized coal. It will be understood that the pulverized coal may be supplied to and burned in the furnace regardless of the rate of supply of blast furnace gas, but that in the particular example which I have chosen to describe it is advantageous to make use of the blast furnace gas alone, so long as it is available in sufficient quantity.

Two dissimilar fuels, such as blast furnace gas and pulverized coal, when separately burned, have a different calorific value, a different demand for air for theoretical combustion and a different percentage of excess air for most economical combustion. When simultaneously burned in varying proportions the total air supplied to the furnace must be properly proportioned to the total of the two fuels burned, regardless of amount or proportionality.

Where a single fuel is being burned, it is feasible to compare a measure of output, such as rate of steam flow, with a measure of the products of combustion passing through the furnace to control, or assist in the control, of the supply of air to the fuel for combustion. However, when a plurality of dissimilar fuels are being simultaneously burned the difference in flow effect of the products of combustion makes it not a simple matter to compare total steam flow against total air flow for the control of air supply. In other words the total flow of the products of combustion is not in such case an accurate indication of the efficiency of combustion and of the amount of excess air which is being utilized in connection with either or both of the fuels.

By my invention I directly measure the amount of air supplied for combustion of each of the fuels. I measure one of the fuels and proportion to that fuel the correct amount of air for its combustion under optimum conditions. Insofar as the other fuel is concerned, I determine a variable in the operation of the unit, which is indicative of the second fuel, and compare to such variable the rate of supply of air for combustion of the second fuel.

In the drawings:

Fig. 1 represents a sectional elevation of a steam generator and its related heating furnace showing fuel and air supplying means as well as the system and apparatus of my relation indicator and control system in somewhat diagrammatic fashion.

Figs. 2 and 3 represent chart records depicting pen traces from the apparatus of Fig. 1.

I illustrate at 1 a furnace arranged for heating a steam generator 2 through the combustion within the furnace 1 of gaseous fuel and air fed thereto through one or more burners 3 and pulverized coal and air fed thereto through one or more burners 4. Each of the various burner entrances to the furnace 1 is surrounded by an air box in common manner.

To the burner or burners 3 blast furnace gas is supplied through a conduit 5 and air to support the combustion of the blast furnace gas through a conduit 6.

To the burner or burners 4 pulverized coal is supplied through a pipe 7 by an exhauster or blower 8 and air to support combustion of the pulverized coal is supplied through a conduit 9.

It is to be understood that the two fuels mentioned, namely, pulverized coal and blast furnace gas, are used as illustrative only, and the invention might equally as well be applied to a plurality of similar or different fuels.

The vapor generator is provided with an uptake 10 in which is positioned a damper 11 under the control of a pneumatic actuating device 12.

While the positioning of the damper 11 will control the suction upon the furnace and thereby to some extent the total supply of air for combustion of both the gas and coal, still it is contemplated that the two air supply lines 6, 9 will be fed from a forced draft duct or other constant source of supply. The rate of supply of air to the burner 3 for support of combustion of the gas is under the control of a damper 13, positioned in the conduit 6, through the agency of a pneumatic actuator 14. The supply of air to the burner 4 for support of combustion of the coal is under the control of a damper 15, positioned in the conduit 9, through the agency of a pneumatic actuator 16.

The supply of blast furnace gas through the conduit 5 is controlled by the positioning of a valve 17, in the conduit 5, under the agency of a pneumatic actuator 18, while the rate of supply of pulverized coal is varied through speed control of the exhauster 8 by means of a rheostat 19 under the control of a pneumatic actuator 20.

Steam generated in the boiler 2 passes therefrom through a conduit 21, in which is positioned a pressure differential creating device, such as an orifice 22, for causing a drop in pressure bearing a definite and known relation to the rate of flow of steam through the conduit and providing in general a measure of the steam outflow from the generator.

Connected to the conduit 21 at opposite sides of the orifice 22 by means of pipes 23, 24 I show a rate of flow meter 25 having an indicator 26 adapted to cooperate with an index 27 for advising the rate of flow of steam. Such a meter is illustrated as a known type having a non-uniform diameter liquid sealed bell whose wall is of material thickness whereby the quadratic relation between differential pressure across the orifice and rate of flow therethrough is converted to a linear relation, to the end that positioning of the indicator 26 relative to the index 27 is by equal increments directly proportional to the rate of flow of steam from the boiler. It will be understood that this is the total steam produced by the boiler through the combustion of both blast furnace gas and pulverized coal, regardless of in what proportion the two fuels are being burned.

At 28 I designate in general a gas flow meter comprising primarily a liquid holding casing 29 relative to which is located a pivot support 30. A beam 31 is adapted to be positioned around the pivot 30 in angular movement, and such movement or positioning is indicated by a projection at one end of the beam 31 relative to an index 32.

From the beam 31 at opposite sides of the pivot 30 are suspended liquid sealed bells 33, 34 to the under sides of which is led respectively through pipes 35, 36 the pressure existing on opposite sides of an orifice 37 in the gas conduit 5, thus producing a pressure differential between the points of connection bearing a known relation to the rate of flow of gas through the conduit 5. Such pressure differences when applied to the underside of the liquid sealed bells 33, 34 react on the beam 31 as a resultant force tending to rotate the beam around its pivot 30. This rotation is opposed by a displacer 38 suspended from the beam 31 within a second liquid, preferably mercury, and the displacer of a shape parabolic in function through whose agency the positioning of the beam 31 in rotation around the pivot 30 (as indicated on the index 32) is by increments directly proportional to the rate of flow of gas to the burner 3.

Displacer 38, while in general of parabolic functional shape, may have its shape modified therefrom and furthermore the displacer is provided with means for being moved along the beam 31 relative to the pivot 30 to vary its moment arm. The general arrangement and purpose of the displacer 38 is to counterbalance or counteract the resultant force acting upon the beam 31 of the pressure differential effective upon the bells 33, 34, whereby a desired relation is obtained between increments of indicator movement over the index 32 and increments of differential pressure existing across the orifice 37.

As rate of gas flow increases, the system comprising the beam 31, bells 33, 34 and displacer 38, will tend to move in a counterclockwise direction around the pivot 30. Such a tendency to rotate will be opposed by the lifting of the displacer 38 from the mercury, producing an increasing weight upon the beam 31 adjacent the bell 34 to counteract the tendency for counterclockwise rotation.

Similar meters 39 and 40 are adapted to indicate the rate of supply of air to the gas burner and the rate of supply of air to the coal burner upon indexes 41 and 42 respectively.

In the operation of this system I find it preferable to burn all of the blast furnace gas which is available and if this does not provide sufficient heat to make the necessary steam flow and maintain desirable steam pressure, then to supplement

through the supplying of pulverized coal. The air to support combustion for the blast furnace gas and that to support combustion of the pulverized coal is separately supplied, metered, and controlled.

I desirably determine and allocate that portion of the steam flow generated by each of the different fuels. Inasmuch as it is not feasible to directly separately measure the steam flow produced by each of the fuels, I have found it satisfactory to determine the total steam flow generated as by the meter 25, and to so calibrate the meter 28 as to indicate the steam flow equivalent of the gas supplied. In other words, the indicator beam 31 may indicate relative to the index 32 in terms of gas flow or of equivalent steam flow after the meter 28 has been calibrated and adjusted throughout its range of operation. I then subtract the gas equivalent steam flow from the total steam flow and indicate upon an index 43 the coal equivalent steam flow.

Inasmuch as the steam flow produced by the gas at different ratings may not be a straight line, but a curved relation, such relation can be found by test and the meter 28 calibrated to take care of proper indication in terms of gas equivalent steam flow. Variables such as boiler efficiency at different ratings and with different percentages of excess air at different ratings may also be taken into account in the calibration and adjustment. It is known that it may be desirable to operate with a somewhat different excess air at one rating than at another, but such optimum conditions may be predetermined and incorporated in the calibration of the meter 28. The moment arms of the bells 33, 34, the moment arm of the displacer 38 and its shape, may all be adjusted in calibration to produce the desired results.

Such variables as boiler efficiencies at different ratings and with different combinations of fuels can properly be taken care of through adjustments in calibration under different conditions also.

From the gas flow meter arm 31 is pivotally suspended a link 44, to the other end of which is pivotally connected one end of a floating beam 45. The other end of the beam 45 is positioned by the indicator arm 26 through the agency of a connecting link 46 pivotally joined thereto.

Intermediate the ends of the floating beam 45 is pivotally suspended a link 47 carrying at its lowermost end the stem of a pilot valve 48. The vertical positioning of the link 47 is indicated through the agency of an indicator 49 upon the index 43. The indication relative to the index 43 is then a resultant of the indications on 27 and 32. The arrangement is such that if all of the steam being generated as shown upon the index 27 is generated by gas fuel, then the reading on the index 32 will be the same as on the index 27, and the reading on the index 43 will be at zero. This is true regardless of whether there is zero steam flow and zero gas flow, or some definite maximum steam flow and maximum gas flow. The maximum steam flow for full utilization of gas fuel will in the present embodiment be something less than full steam flow indication on the index 27 to take care of additional steam flow generated by pulverized coal beyond the availability of maximum gas flow. If it were expected that half of the maximum steam flow could be generated by all of the available blast furnace gas and the other half of maximum steam flow by pulverized coal, then when the index 32 read maximum, and with no pulverized coal being burned, the steam flow index 27 should read 50% of maximum, and the index 43 should read zero. Under such conditions, if the pulverized coal is then supplied up to its maximum, the steam flow meter should read to maximum on the index 27 and the index 43 should read at 50% of its possible travel.

With a condition of all pulverized coal being burned and no blast furnace gas, then the steam flow meter should read at 50% of index 27, the gas flow meter 28 should read at zero, and the index 43 should read at 100.

A link 50 is pivotally suspended from the indicator beam of the meter 39 and is joined at its lower end with one end of a floating beam 51, the opposite end of which is positioned by the link 44. Intermediate the ends of the beam 51 is suspended the stem of a pilot 52, which is positioned responsive to ratio between gas fuel rate of supply and rate of supply of air for combustion of the gas fuel. If the two are in proper ratio, then the pilot 52 will not be displaced from predetermined position, while if the air supplied for promoting combustion of the gas fuel is not in proper relation thereto the pilot will be displaced, either vertically upwardly or downwardly from predetermined neutral position.

In like manner a link 53 is pivotally suspended from the indicator beam of the air meter 40 and together with the link 47 serves to position a floating beam 54 to which is pivotally attached the stem of a pilot 55. Thus the pilot 55 is positioned in accordance with the ratio between steam flow representative of coal feed and the air supplied for the combustion of such coal.

For optimum combustion efficiency the air supplied through the conduit 6 is proportioned in definite relation to the gas supplied through the conduit 5, and such proportioning takes into account the theoretical air required for combustion of the gaseous fuel as well as the excess of air desirable at different rates of operation. Also characteristics such as varying efficiency throughout the range of operation, calorific value of the fuel, etc. From the gas flow—air flow relation as determined by the position of the beam 51, I utilize the air loading pressure established by the pilot valve 52 to position a pneumatic actuator 14 for positioning the damper 13 and thus regulating the supply of air for combustion of the gas fuel.

In like manner the position of the floating beam 54 is determined by the relation between steam equivalent of the coal burned and the air supplied for combustion of the coal. The pilot valve 55, positioned by the beam 54, establishes an air loading pressure effective upon the pneumatic actuator 16 for positioning a damper 15 to control the supply of air through the conduit 9 for combustion of the pulverized coal.

It will be observed that I have provided two relation indicators which may be utilized independently or in combined fashion in the manual or automatic regulation of combustion efficiency. The indicator arms need not necessarily indicate relative to separate indexes 32, 41, 27, 43, or 42, but may readily be adapted to move relative to a common index or may comprise correlated pen tracings upon recording charts; it only being necessary in a contemplation of my invention that the various measures of fuel, air, and steam flow, be simultaneously observable for comparison as to desirable relation or departure therefrom. For example, the indexes 32, 41 of gas flow and

its related air flow need not be separate indexes as illustrated in Fig. 1, but may comprise correlated pen traces on a single recording chart as illustrated in Fig. 2. Herein the solid line indicates blast furnace gas flow, or equivalent steam flow by the combustion of blast furnace gas, and the dash line indicates the rate of supply of air for combustion of the gas. Most desirable operation of the entire unit would be for the two pen traces to coincide throughout their operation, but I have illustrated in Fig. 2 a more practical condition wherein the traces cross and recross and lead or lag each other slightly upon wide variations in rating. Furthermore, I have somewhat separated the pen traces in Fig. 2, for if they were shown as coinciding, they could not be distinguished one from the other.

In similar manner the indications on the indexes **27**, **42**, **43** may comprise correlated pen traces upon a single recording chart as illustrated in Fig. 3. In this figure I have indicated by a solid line the total steam flow equivalent to the indication **27** and produced by the combustion of both pulverized coal and blast furnace gas. I indicate by dash line the air supplied for combustion of the coal as measured by the meter **40** and indicated at **42**. I indicate by dot-dash line the steam produced by the combustion of the pulverized coal and equivalent to the indication on index **43**.

In Fig. 3 the record of steam flow by coal and air for combustion of the coal will be kept together at all times for optimum combustion efficiency. The sum of the steam flow by blast furnace gas on Fig. 2 and steam flow by pulverized coal on Fig. 3 should equal the total steam flow of Fig. 3. That is, the reading on index **32** when the gas firing is producing steam, plus index **43**, should equal the reading of index **27** (Fig. 1).

If all of the steam is being produced by gas then index reading **32** will equal index reading **27** and index reading **43** should be zero. Index **32** should equal index **41** and index **42** should be zero.

If there is no gas being used, but all coal, then index **32** should read zero, as well as index **41**, while index **27** should equal index **43** and index **42**. In this latter condition all three records of Fig. 3 should coincide and the records on Fig. 2 should read zero.

As gas flow increases, thereby moving **32** toward its maximum (gas flow meter having been calibrated empirically to deflect proportionally to steam flow) index **43** moves toward zero proportionally to the difference between the total steam flow and the gas flow until all of the steam is being produced by gas and **43** reads zero.

Proper calibration and adjustment require that the meters be adjusted by firing the boiler completely on coal and adjusting the air to the coal for optimum condition of combustion efficiency throughout the range of operation. Then to fire the unit completely on gas and adjust the air to the gas throughout its range of operation.

When all of the steam is being produced by gas then the steam flow by pulverized coal, namely, indicator **43**, should ride on zero along with the air flow for coal **42**. However, if indicator **43**, or the dot-dash record of Fig. 3, rises off the zero line for short increments of time, as for example between 8:00 A. M. and 10:30 A. M. of Fig. 3, it indicates that the total steam flow exceeds the total blast furnace gas flow and the existence of these short movements from zero warns the fireman that the heat reserve of the boiler is being drawn upon to produce the extra demand for steam and that coal supply is necessary to supplement the available blast furnace gas. It will be understood that these can exist only for a very short duration of time as they indicate steam flow which is drawing on the heat reserve of the boiler and should correspond to drops in steam pressure caused by that extra heat taken out of the boiler storage over and above that which is being put in by the burning of the gas. From this beneficial indication to the fireman that a supplemental fuel is necessary, he will then bring into operation the supplying of pulverized coal, and this will cause the indicator **43** to rise from zero to show some steam being produced by pulverized coal. From the disturbance of the coal-air relation as indicated by the pilot **55**, the air supply for the combustion of the coal, through the conduit **9** will be readjusted in proper manner.

At all times that the pen traces of Fig. 2 are together and the steam by coal-air traces of Fig. 3 are together it indicates that proper or optimum combustion conditions exist, after the initial calibration and adjustments have been made.

I have provided then a relation indicator, namely the meters **28**, **39**, which may indicate as at **32**, **41** or record as in Fig. 2 to give the instantaneous relationship between gas fuel supply (steam by gas) and air supplied for the gas combustion. In like manner I provide a relation indicator wherein proper interrelation of the indexes **27**, **42**, **43**, or the pen traces of Fig. 3, show the instantaneous value of the total steam produced by the unit as well as the steam produced corresponding to pulverized coal and the air supplied for the combustion of the coal. I may desirably incorporate these two relation indicators as a single unit wherein the various indexes may be interrelated for comparison or value determination, or wherein all of the pen traces may be in proper interrelation upon a single recording chart.

Basically, I provide the necessary information for advising either an operator or an automatic control system of the maintenance or departure therefrom of proper fuel-air relationship for each of a plurality of dissimilar fuels burned simultaneously in varying proportion. From such information the operator may manually adjust the air supply to each or both of the fuels, or as described, through the agency of pneumatic pilot valves and actuators the information may be continuously utilized in the automatic control of proper regulation of the air and thereby of combustion of the separate fuels.

I utilize the pressure of the steam generated by the boiler as a primary control of induced draft, gas supply, and of pulverized coal supply. A Bourdon tube **56** positions a pilot valve **57** responsive to value and variations in steam pressure. Through this agency an air loading pressure is established representative of steam pressure and is applied to the pneumatic actuator **12** for positioning the damper **11**, controlling the induced draft. Simultaneously this loading pressure is effective upon an air actuator **18** for positioning the damper **17** in the gas supply line **5**. The adjustment is such that for rates of steam demand below that which may be obtained by maximum available blast furnace gas the steam pressure pilot **57** will cause a throttling of the damper **17**, thus controlling gas supply

in accordance with steam demand to maintain steam pressure at desired value. When the load increases to a point that all available gas is being used, then the damper 17 is in its wide open position. An increased demand for steam and consequent falling off of steam pressure causes the air loading pressure of the pilot 57, which is also effective within a relay device 58, to be supplemented by an air loading pressure established by the pilot 48 additive in the relay 58. The resultant loading pressure by the relay 58 is effective through the pipe 59 upon the pneumatic actuator 20 for positioning the coal exhauster rheostat 19.

The pilot 48 operates on the ratio of gas flow to total steam flow, or steam by gas to total steam. Thus if the ratio of gas flow to total steam flow is small there would not be sufficient pressure from the ratio pilot 48 to assist the steam pressure operate the relay valve 58. Thus the exhauster speed will not be altered by steam pressure, but the gas flow will. If, however, the gas flow drops or is insufficient to carry the desired steam flow and pressure, then the loading pressure within 48 builds up and thus assists the master pressure operate the relay valve 58 for more coal until steam pressure is again normal. Thus the coal feed is regulated by both gas flow-steam flow ratio and by steam pressure. If gas flow increases, while steam pressure is normal, the action would be to reduce the coal feed and leave all of the firing to the gas.

When firing with all pulverized coal, the steam flow-gas flow ratio will be a maximum, so that the loading pressure from 48 will be a maximum and the exhauster speed will respond directly to master pressure.

While I have illustrated and described a preferred embodiment of my invention wherein two fuels, namely, blast furnace gas and pulverized coal, are fed simultaneously in varying proportions (from zero to maximum of either of the fuels) to the furnace of a steam generating boiler, it is to be understood that I am not to be limited thereto, for the invention contemplates broadly the burning of a plurality of fuels regardless of type or number simultaneously for the heating of a furnace and regardless of the type of furnace or the service for which its heating is to be used.

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

1. The method of controlling the air supplied for combustion of a plurality of fuels burned simultaneously in a furnace, which includes, separately supplying and measuring the air with each fuel, determining a variable in the operation of the furnace representative of the combustion of each fuel, and utilizing the variable and the air measurement in regulating the air supply to each fuel independent of the other.

2. The method of automatically operating a furnace adapted to be heated by the combustion of a plurality of dissimilar fuels burned simultaneously in varying proportion, which includes, supplying air for supporting combustion of one fuel at a rate in step with the rate of supply of that fuel, obtaining an indication of output of the furnace allocated to another fuel, and supplying air for supporting combustion of the other fuel at a rate dependent upon the indication of output.

3. The method of controlling the air supplied for combustion of a plurality of fuels burned simultaneously in varying proportion in the furnace of a vapor generator, which includes, measuring the rate of supply of one fuel, measuring the rate of supply of air to support combustion of the one fuel, controlling such air supply from an interrelation of the measures; measuring the total vapor generated, allocating a portion of the measured vapor to a second fuel, measuring air supplied to support combustion of the second fuel, and controlling air supplied to the second fuel to maintain desired relation between the last two measurements.

4. The method of controlling the air supplied for combustion of a plurality of fuels burned simultaneously in a furnace, which includes, separately obtaining a measure of the air supplied for combustion to each of the fuels, obtaining a measure of one of the fuels, obtaining a measure of total furnace output, correlating such measures, and controlling air supply from the correlation.

5. The method of controlling combustion in a furnace wherein two dissimilar fuels are simultaneously burned in varying proportion, which includes, continuously obtaining a measure of furnace output, of the rate of supply of one of the fuels, and separately of the air supplied to each of the fuels; and utilizing the measures to proportion the supply of air to the fuels for optimum combustion efficiency.

6. The method of controlling combustion in a furnace wherein two dissimilar fuels are simultaneously burned in varying proportion, which includes, continuously measuring the rate of supply of one of the fuels, measuring and proportioning air supply for combustion with the one fuel, continuously determining the value of a variable in the operation of the furnace which is representative of the rate of supply of the other fuel, and proportioning air for combustion of said other fuel in accordance with said variable.

7. The method of controlling combustion in the furnace of a vapor generator wherein two dissimilar fuels are simultaneously burned in varying proportion, which includes, continuously measuring the rate of supply of one of the fuels, measuring and proportioning air supply for combustion with the one fuel, continuously measuring rate of total vapor generation, determining the vapor generation equivalent of the one fuel and subtracting it from total vapor generation to continuously obtain rate of vapor generation equivalent to the other fuel, and measuring and controlling air supply with said other fuel in proportionate relation to its equivalent vapor rate.

8. The method of controlling combustion in a furnace wherein two dissimilar fuels are simultaneously burned in varying proportion, which includes, regulating the rate of supply of one of the fuels from an indication of output of the furnace, and regulating the rate of supply of the other of the fuels only after the availability of the first fuel is insufficient to satisfy output demands.

9. The method of operating a vapor generator having a heating furnace wherein two dissimilar fuels are simultaneously burned in varying proportion, which includes, regulating the rate of supply of one of the fuels to its maximum availability in response to a measure of vapor pressure, and utilizing vapor pressure to regulate the second fuel to supplement the first fuel upon reaching maximum available rate of supply of the first fuel.

10. The method of operating a vapor generator having a heating furnace wherein two dis-

similar fuels are simultaneously burned in varying proportion, which includes, regulating the rate of supply of one of the fuels in response to demand upon the generator, regulating the second fuel supply in response to demand upon the generator to supplement the first fuel when the first fuel has reached its maximum availability, and proportioning air to support combustion individually to the two fuels.

11. A relation indicator for a furnace adapted to be heated by the combustion of two dissimilar fuels burned in varying proportions, comprising in combination, a meter of the rate of supply of a first fuel, a meter of the rate of supply of air for combustion of the first fuel, means correlating the readings of said meters, an indicator of a variable representative of the rate of supply of the second fuel, an indicator of the rate of supply of air for combustion of the second fuel, and means correlating the readings of said indicators.

12. A relation indicator for use in regulating the combustion of two dissimilar fuels adapted to be simultaneously burned in varying proportion in a furnace, comprising in combination, means continuously indicating the relation between rate of supply of one of the fuels and rate of supply of air for combustion of said fuel, and means continuously indicating the relation between a variable representative of the rate of supply of the second fuel and rate of supply of air for its combustion.

13. In combination, a furnace, means for supplying a first fuel to the furnace, means for supplying air for the combustion of said first fuel, means adapted to continuously indicate the interrelation between the rates of supply of said first fuel and its combustion air, means for supplying a second fuel to the furnace, means for supplying air for the combustion of said second fuel, means continuously indicating the value of furnace output attributed to the second fuel, and means continuously indicating the interrelation between such furnace output value and the rate of supply of air to support combustion of the second fuel.

14. In combination, a furnace, means for supplying a first fuel to the furnace, means continuously proportioning air to the first fuel for its combustion, means for supplying a second fuel to the furnace, means continuously proportioning air to the second fuel for its combustion, and means responsive to a measure of furnace output adapted to regulate the supply of the first fuel to its maximum availability and to thereafter supplement the first fuel by the second fuel when the demand for furnace output exceeds the output capacity of the first fuel.

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