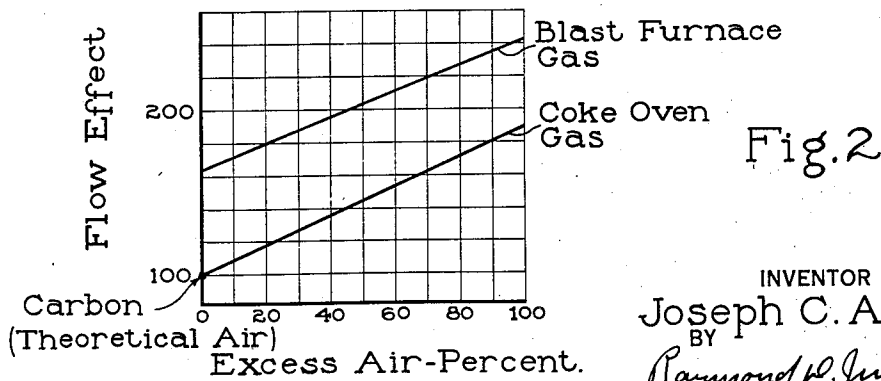
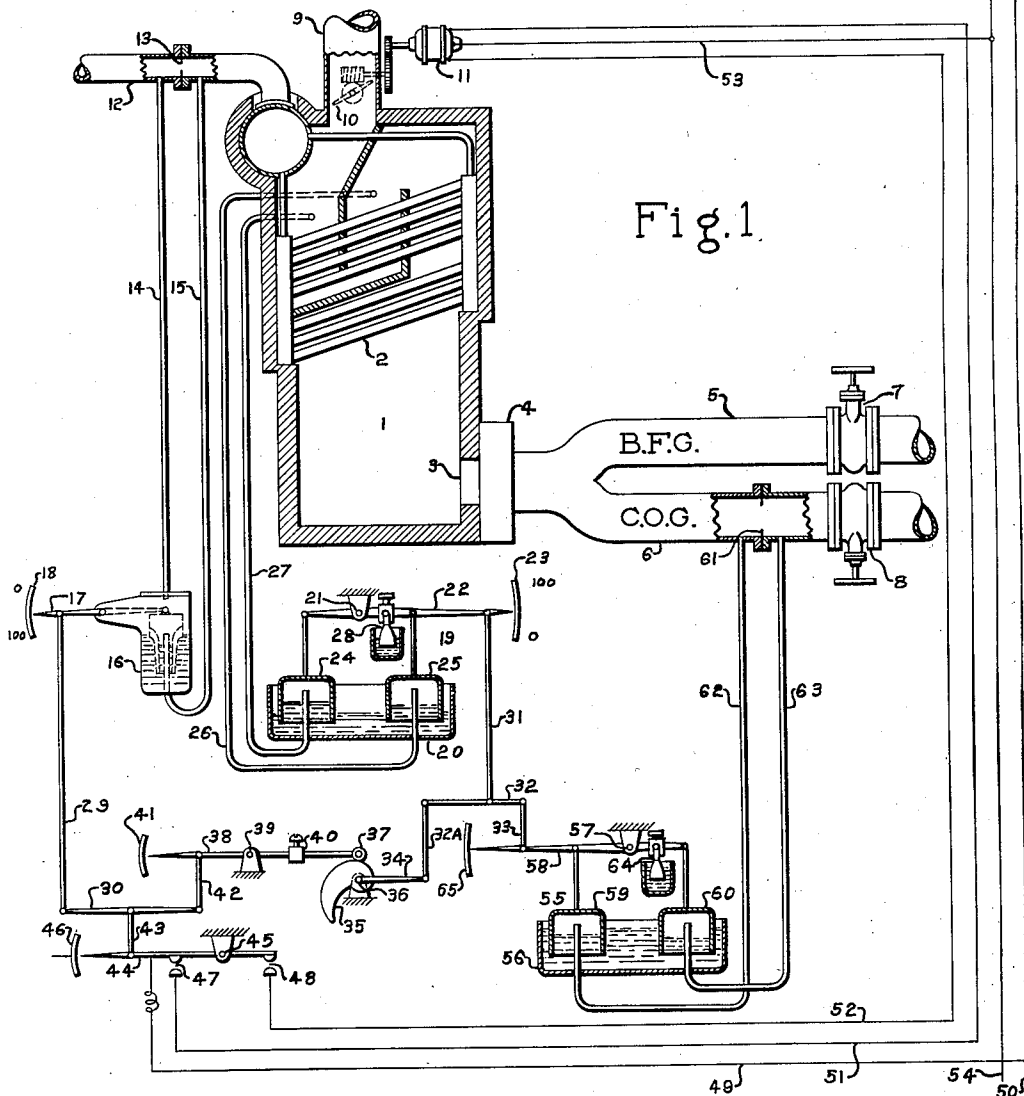


Sept. 11, 1934.

J. C. ALBRIGHT
COMBUSTION CONTROL
Filed May 9, 1932

1,972,968



INVENTOR
Joseph C. Albright.
BY
Raymond W. Jenkins.
ATTORNEY

UNITED STATES PATENT OFFICE

1,972,968

COMBUSTION CONTROL

Joseph C. Albright, Teaneck, N. J., assignor to
Bailey Meter Company, a corporation of Delaware

Application May 9, 1932, Serial No. 610,295

19 Claims. (Cl. 236—14)

This invention relates to combustion control, and especially to 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 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 a 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.

Relation indicators have been known for showing the instantaneous value of such relation, but have been used in connection with the burning of a single fuel. 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.

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 a plurality of fuels supplied simultaneously for combustion.

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 a measure of the output of the furnace or of some variable factor in the operation of the furnace and a measure of the air flow, taking into account the proportionality and characteristics of the various fuels simultaneously burned in any proportionality from zero to one hundred percent of maximum supply of each of the fuels; and furthermore, the excess air at which the fuels are burned.

Another object of the invention is to obtain a measure of the air flow for the purpose of controlling the air supply, automatically taking into account on such measure of the air flow a measure of one of the fuels where a plurality of fuels is burned simultaneously.

A still further object is to obtain a measure of one of a plurality of fuels burned simultaneously

and cause such measure to effect a compensation of a measure of the air flow in relation to a characteristic such as calorific value of each of the fuels separately so burned.

Still another object is to combine as a readable guide for manually or automatically controlling the supply of air to a furnace, indications of the air flow and of one of a plurality of fuels burned simultaneously in a furnace, giving a resultant indication of air flow compensated for proportionality of fuels burned, their calorific value, and/or other characteristics of the combustion, such for example as percentage of excess air with which the fuels are separately burned.

As a preferred embodiment of my invention, I have illustrated and will describe the invention in connection with a steam generating boiler furnace to which are fed for combustion two fuels simultaneously and in amounts which may vary from zero to maximum of either of the fuels.

In the drawing:

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.

Fig. 2 represents a graph of the flow effect of the two fuels burned.

I illustrate at 1 a furnace arranged for heating a steam generator 2 through the combustion within the furnace 1 of fuel fed thereto through a burner 3. The burner entrance to the furnace 1 is surrounded by an air box 4 in common manner. To the burner in the present embodiment is supplied two fuels simultaneously in varying amount, namely, blast furnace gas through a conduit 5 and coke oven gas through a conduit 6, the former regulated in quantity rate of flow by a regulating valve 7, and the latter by a similar regulating valve 8. The throttling control of the valves 7, 8 may be by hand or automatically from steam pressure or otherwise, as desired; the same forming no part of the present invention. It is only contemplated that the fuel supplied through the burner 3 be in the present embodiment composed of blast furnace gas and coke oven gas in varying proportions from zero to maximum rate of flow of either.

The rate of air supply entering the furnace through the air box 4 and the burner 3 is controlled by the suction exerted upon the furnace of a stack 9 having positioned therein a damper 10 through the agency of a stop-start-reversing pilot motor 11 for controlling the draft.

Steam generated in the boiler 2 passes therefrom through a conduit 12 in which is positioned a pressure differential creating device such as an orifice 13 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 12 at opposite sides of the orifice 13 by means of the pipes 14, 15 I show a rate of flow meter 16 having an indicator arm 17 adapted to cooperate with an index 18 for advising the rate of flow of steam leaving the boiler through the conduit 12. Such a meter is illustrated as a known type, having a variable diameter liquid sealed bell whose wall is of material thickness whereby the quadratic relation between differential pressure across an orifice and rate of flow therethrough is converted to a linear relation, to the end that positioning of the indicator 17 relative to the index 18 is in equal increments directly proportional to the rate of flow of steam from the boiler.

At 19 I designate in general an air flow meter comprising primarily a liquid holding casing 26 relative to which is located a pivot support 21. A beam 22 is adapted to be positioned around the pivot 21 in angular movement, and such movement or positioning is indicated by a projection at one end of the beam 22 relative to an index 23.

From the beam 22 at opposite sides of the pivot 21 are suspended liquid sealed bells 24, 25 to the undersides of which is led respectively through pipes 26, 27 the pressure existing at two points in the gas passage through the boiler 2 between which there is resistance to the flow of products of combustion, thus producing a pressure differential between the points of connection bearing a known relation to the rate of flow of the air and gases therethrough. Such pressure differences, when applied to the underside of the liquid sealed bells 24, 25 in the air flow meter 20, react on the beam 22 as a resultant force tending to rotate the beam around its pivot 21. Rotation is opposed by a displacer 28 suspended from the beam 22 within a second liquid, preferably mercury, and the displacer of a shape parabolic in function through whose agency the positioning of the beam 22 in rotation around the pivot 21, as indicated on the index 23, is by equal increments directly proportional to the rate of flow of air and gases through the boiler 2.

Displacer 28, 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 22 relative to the pivot 21 to vary its moment arm. The general arrangement and purpose of the displacer 28 is to counterbalance or counteract the resultant force acting upon the beam 22 of the pressure differential effective upon the bells 24, 25 whereby a desired relation is obtained between increments of indicator movement over the index 23, and increments of differential pressure existing between the points of connection of the pipes 26, 27 with the boiler 2.

It will be observed that the pipe 27 connecting to the boiler at a location closer to the stack than the connection of the pipe 26, leads beneath the bell 24 and exerts upon the bell 24 a suction or downward force greater than the downward force applied beneath the bell 25. This differential in pressure will tend to cause a rotation of the beam 22 in counterclockwise direction around its pivot 21. Such a tendency to rotate will be opposed by the lifting of the displacer 28 from the mercury, producing an increasing weight upon the beam 22 adjacent the bell 25 to counteract the tendency for counterclockwise rotation. The shape of the displacer 28 is made in general such

that the pressure differences exerted upon the bells 24, 25 bearing quadratic relation to the rate of flow of air and gases through the boiler 2 will be indicated directly upon the index 23 as equal increments of rate of flow.

By air flow through the furnace and boiler as measured by the air flow meter 20 I mean not only air but all of the products or gases of combustion leaving the furnace through the stack 9 and which are utilized for heating the generator 2 in their passage from the furnace to the stack. When the proper calibration and adjustments have been made, the air flow meter 20, by measuring the rate of flow of all of the air and products of combustion leaving the furnace, will indicate the rate of flow of air supplied for combustion.

It is known that a comparison of the rate of steam flow leaving the boiler as an indication of boiler output with the rate of air flow through the boiler comprises an adequate guide for manual or automatic control of the supply of air for combustion to the related furnace. I therefore connect the indicator arm 17 of the steam flow meter and the indicator arm 22 of the air flow meter through linkage for comparing the instantaneous values of the steam flow and air flow and advising a departure of the relation of instantaneous values from desired relation.

From the steam flow indicator arm 17 I pivotally suspend a link 29 pivotally joined at its lower end to one end of a freely floating beam 30. From the beam 22 I suspend a similar link 31 pivotally connected at its lower end to a floating member 32 intermediate the ends of the member 32.

One end of the floating member 32, namely (on the drawing) the righthand end, is pivotally connected to a link 33 dropped vertically downward therefrom, and whose purpose will be explained hereinafter.

The lefthand end (on the drawing) of the floating member 32 is pivotally connected through a link 32A to an extension 34 of a cam 35, which cam is adapted for rotation or angular movement around a fixed pivot point 36. The arrangement is such that assuming the link 33 stationary, then vertical reciprocation of the link 31 raises and lowers the lefthand end of the member 32 and correspondingly tends to rotate the extension 34 and cam 35 in one direction or the other in angular movement around the fixed pivot 36.

Bearing on the shaped surface of the cam 35 is a roller 37 adapted to rise and fall substantially vertically as the cam 35 moves angularly around its pivot 36. The roller 37 is carried at one end of a beam 38 pivoted intermediate its ends at a fixed pivot 39 and carrying a counterweight 40 for holding the roller 37 in engagement with the surface of the cam 35. The beam 38 at its other end forms an indicator arm adapted to cooperate with an index 41 and from the beam 38 near the lefthand end (on the drawing) is suspended pivotally connected thereto a link 42 which at its lower end is pivotally connected to the righthand end of the floating beam 30. Equal increments of vertical movement of the link 31 will result in increments of vertical motion of the link 42, related thereto according to the shaping of the cam 35.

Pivotally connected to the floating beam 30 at a point intermediate its ends is a link 43 connected to and for oscillation of a contact bar 44 around a fixed pivot 45 intermediate the ends of the contact bar. One end of the contact bar 44

forms an indicator arm adapted to cooperate with an index 46 to show departure from predetermined position in one direction or the other.

Carried by the contact bar 44 are one-half each of normally open circuited contacts 47, 48 and the contact bar is connected through a conductor 49 with a main power line 50. The other half of the contact 47 is connected through a conductor 51 with the motor 11, and the other half of the contact 48 is connected through a conductor 52 to the motor 11. The return line 53 from the motor 11 joins the other main power line 54.

The arrangement is such in general that, should the rate of steam flow from the boiler increase, such increase will be indicated through a downward movement of the indicator arm 17 relative to the index 18 and a corresponding downward positioning of the links 29 and 43, resulting in a positioning of the contact bar 44 in a counterclockwise direction around its pivot 45. This positioning causes a close-circuiting of the contact 47, completing a circuit comprising main power line 50, conductor 49, contact 47, conductor 51, motor 11 and conductor 53 to main power line 54, whereby the motor 11 is energized for rotation in a direction to increase the opening of the damper 10 and allow a greater flow of air through the boiler. Assuming that the rate of steam outflow remains the same, then the increased flow of air through the boiler effective as an increased pressure differential applied to the bells 24, 25 of the air flow meter 19 will cause an upward positioning of the indicator 22 relative to the index 23 with an upward movement of the links 31, 42 and contact bar 44 until contact 47 is open circuited, thus stopping rotation of the motor 11, for the resulting air flow is then in desired relation to the increased steam flow.

The operation is the same in reverse manner, should the rate of steam flow decrease from any value. Correspondingly, should the steam flow remain steady but for some reason such as change in wind across the top of the stack 9, the air flow through the boiler would increase or decrease, then its action upon the air flow meter 19 and the links 31, 42 would result in a positioning of the motor 11 in one direction or the other for an opening or closing of the damper 10 until again the air flow balances the steam flow in desired relation.

It will be observed that it is not necessary that the relation between air flow and steam flow be in 1 to 1 ratio, but through proper adjustment of moment arms any desired and predetermined relation may be indicated or utilized for control. Proper adjustment as to size of the bells 24, 25, shape of the displacer 28, and moment arms of the bells and displacer relative to the pivot 21 take care, for the particular design and type of boiler, of the resistance between the points of connection at a given rate of output.

The indicator arms 17, 22 need not necessarily indicate relative to separate indexes 18, 23, but may readily be adapted to move relative to a common index or may comprise co-related pen traces upon a single recording chart; it only being necessary in a contemplation of my invention that a measure of steam flow and a measure of air flow be simultaneously observable for comparison as to desired relation or departure therefrom, and with the understanding that steam flow and air flow are used merely as examples of the variable characteristics in the operation of the furnace. The positioning of the indicator arm 44 relative to the index 46 denotes the presence of or de-

parture from desired relationship between steam flow and air flow on a single index, or as above stated, the indicator arms 17, 22 may comprise pens working on a single recording chart over the same set of graduations and desirably recording at the same point on the chart when proper relationship is obtained. Furthermore, the indicated relationship between such characteristics may be utilized as a guide for manual control of the supply of air or as a part of an automatic control system.

I have described so far a steam flow meter and an air flow meter in co-relation, as would be adaptable to a boiler furnace wherein a single fuel were burned, for example, blast furnace gas alone, through the burner 3. Assuming combustion with a constant percentage of excess air regardless of rate of operation, then the differential pressure existing through the boiler 2 and effective upon the air flow bells 24, 25 is in definite quadratic relation with the rate of flow of air through the boiler. If, however, we should suddenly shift from burning all blast furnace gas to a condition of burning all coke oven gas, and in sufficient quantity of B. t. u. input to maintain the same steam flow output or B. t. u. output of the boiler, and were the coke oven gas burned with the same percentage of excess air, then the pressure differential existing across the points of connection to the boiler and impressed upon the bells 24, 25 would vary from that of the previous example. This due to the fact that for a radically different fuel the products of combustion will vary, the one from the other, and what I term the "flow effect" of the particular fuel will vary for the one fuel as compared to the other fuel.

If, for example, when burning blast furnace gas alone, the steam flow indicator read at 50% of maximum on the index 18 and the air flow indicator read at 50% of maximum on the index 23, indicating a relation of the proper air flow for the fuel burned at a desired excess air condition in the furnace, then upon a sudden shift to burning coke oven gas in proper B. t. u. quantity whereby the steam flow indicator remained at 50% of maximum on the index 18, the air flow indicator would drop to some reading, for example 48% of its maximum, thereby indicating the difference in flow effect between the products of combustion of blast furnace gas and the products of combustion of coke oven gas at the same excess air for combustion.

Likewise a change in B. t. u. value of a given fuel will cause a change in the air flow reading, assuming the same excess of air and the same boiler output or steam flow reading, for in this case a greater or lesser amount of the fuel must necessarily be burned to give the same B. t. u. output.

Desirably in the operation of the furnace and boiler, the readings of steam flow and air flow are to be kept in desired relation as a guide to hand or automatic control of air supply, and thus as in the example, if the fuel were changed suddenly from all blast furnace gas to all coke oven gas, the steam and air flow indicator arms in place of reading each at 50% of their maximum would now read 50 and 48 respectively, indicating to the operator or to the automatic control a condition which would need correction in the direction of increasing the supply of air so that the air flow indicator would come up to a unity relation with that of the steam flow. However, if the air flow were so increased as to bring the air flow indicator from 48 to 50 on its index, this

actually would result in too great a supply of air, and the excess of air for combustion would have increased over the desired value, with corresponding loss of efficiency of combustion.

- 5 What actually is desired, is that the reading of the air flow indicator arm when switching from one fuel to the other, should be compensated or moved mechanically from 48 to 50 so that to the operator or to the automatic control the proper
- 10 relationship still exists, and no correction in air supply is needed. My invention primarily contemplates such a correction of the actual air flow reading to take care of the difference in flow effect produced through the burning of different
- 15 fuels, and the compensating means which I will describe would automatically, upon the shifting of blast furnace gas to coke oven gas, mechanically move the air flow effect upon the floating beam 30 from the equivalent of its reading of 48
- 20 to an equivalent of its previous reading of 50, whereby is indicated that the proper supply of air exists through the position of the indicator 44 relative to the index 46. It is to be understood that the position of the indicator 44 relative to
- 25 the index 46 is for the guidance of the operator, or as through the contact bar 44 for the guidance of automatic control to advise that the steam flow—air flow relation is as desired, or a departure from such desirable relation.
- 30 Such a condition as I have described would occur in the sudden shifting from the burning of one fuel to that of burning another wholly. However, I contemplate the possibility of burning the two fuels simultaneously in varying proportions,
- 35 in which event I must apply as a compensation to the air flow mechanism an effect proportional to the flow effect of one of the fuels when the air flow mechanism has been calibrated for the burning of the other of the fuels, and such proportion
- 40 must be in accordance with the magnitude of the relative proportion of the two fuels burned, or desirably in proportion to the total B. t. u. input from each of the two fuels.

Referring now to the drawing, Fig. 1, I show a fuel flow meter 55 having a liquid containing

45 case 56 relative to which is located a pivot 57. Oscillatable around the pivot 57 is a beam 58 having suspended therefrom at opposite sides of the pivot 57 liquid sealed bells 59, 60.

- 50 In the conduit 6 through which is supplied the coke oven gas to the burner 3, I position a pressure differential producing device such as an orifice 61 for causing a drop in pressure bearing a definite and known relation to the rate of flow of
- 55 coke oven gas through the conduit 6 and providing a measure of the flow therethrough. At opposite sides of the orifice 61 I connect pipes 62, 63 leading respectively to the undersides of bells 59, 60 and applying to the bells and as a resultant to the beam 58 an effect proportional
- 60 to the flow of coke oven gas.

- I suspend from the beam 58 a displacer 64 adaptable for movement along the beam 58 to vary its moment-arm relative to pivot 57 and
- 65 providing a variable counterbalancing effect for the force applied to the beam by the bells 59, 60.

- The pressure at the inlet of the orifice 61 will be the greater, and effective through the pipe 63 to the underside of the bell 60, will provide an
- 70 upward force tending to rotate the beam 58 in a counterclockwise direction around its pivot 57 relative to the smaller force of the pressure on the downstream side of the orifice 61 effective through the pipe 62 upon the underside of the
- 75 bell 59. Such tendency towards counterclock-

wise rotation of the beam 58 is opposed by the pulling out of the mercury of the displacer 64. The displacer 64 is preferably shaped in quadratic function so that a pointer formed at the end of the beam 58 will move along an index 65 in

80 equal increments with increments of rate of flow of coke oven gas through the orifice 61.

I show the lower end of the link 33 pivotally connected to the beam 58 and vertically positioned thereby. It will be observed that the

85 righthand end of the floating member 32 (previously considered as fixed) is adapted for vertical positioning with and by the beam 58 as a measure of coke oven gas rate of flow. Should the link 31 be stationary, then a variation in the percentage of coke oven gas burned or supplied

90 to the burner 3 will cause a positioning of the member 32 around the lower end of the link 31 and correspondingly a vertical positioning of the link 43. Thus the link 42 may be positioned ver-

95 tically either by a change in rate of air flow by the flow meter 19 or a change in rate of coke oven gas flow by the corresponding meter 55.

Interposed between the floating member 32 and the link 42 I have shown the cam 35 and the parts

100 related thereto, which is for the purpose of allowing the fuels, regardless of their relative proportionality, to be burned with a different excess of air at one boiler rating than at another boiler rating. This may be desirable, and often is desirable

105 to protect the furnace walls or other parts from too high a combustion temperature at one rating relative to another.

It will be apparent that, considering the air flow meter 19 alone in relation to the steam flow

110 meter 16, and burning only a single fuel, namely blast furnace gas, for example, the calibration of such air flow meter through varying the moment arm of the displacer 28, etc. may be adjusted to burn the blast furnace gas at a desired excess of

115 air, for example, 15% over that theoretically required for combustion. Thus regardless of rate of B. t. u. output as indicated by the steam flow meter, the air flow meter will indicate the same

120 reading in co-relation thereto when the rate of flow of the excess air and products of combustion through the furnace is proper for the desired excess of air, with burning the right amount of blast furnace gas for the heat liberation indicated. Thus we may say that the air flow meter 19 can

125 be properly calibrated to burn blast furnace gas alone under a desired predetermined excess of air regardless of rating, and when such condition exists the air flow meter will indicate the same percentage of its maximum index as does the

130 steam flow meter in percentage of its maximum index.

Furthermore, the calibration of the coke oven gas meter 55 may be adjusted so that its related effect upon the positioning of the floating member

135 32 is in accordance with the burning of the coke oven gas at a definite predetermined percentage of excess air regardless of rating, which, for example, may be the same or a different percentage of excess air than that for which the air flow

140 meter 19 is calibrated for the burning of blast furnace gas.

Thus I might so calibrate the air flow meter 19 that when burning only blast furnace gas, the blast furnace gas is burned at an excess air per-

145 centage of 18, and so calibrate the meter 55 in its linkage effect upon the member 32 that desirably the coke oven gas were burned at an excess air percentage of 22, for example. The resultant positioning vertically of the lefthand end of the

150

member 32 would be in accordance with the proportionality of blast furnace gas and coke oven gas burned, and in accordance with the percentage of each of the two gases as multiplied by or taking into account the specific excess air at which that proportion of the total fuel were desirably to be burned. Thus the resultant movement of the lefthand end of the member 32 might be the summation of the effect of burning 25% of the fuel as blast furnace gas at 18% excess air, and 75% of the fuel as coke oven gas at 22% excess air.

If I allowed the lefthand end of the floating member 32 to be effective directly for vertical positioning of the link 42, then I would have such a condition as I have just explained, effective in relation with the steam flow as indicated relative to the relation index 46 and for positioning the contact bar 44. If the proper relation existed between B. t. u. output from the boiler as measured by the steam flow therefrom in relation to the total air flow, where a portion of the total air flow represented products of combustion of blast furnace gas at 18% excess air and products of combustion of coke oven gas at 22% excess air, then the indicator 44 would show the desired relation condition on the index 46, and the contacts 47, 48 would remain open circuited. I provide, however, through the cam 35 intermediate the member 32 and the link 42, the possibility of burning the fuels in any relative proportions; each with the same or different percentage of excess air; and the total with a different excess of air at one boiler rating than at another boiler rating. I may so shape the cam 35 that the excess of air, except for that related to the relative proportionality of the two fuels burned, is the same at one rating as at another rating; or I may so shape the cam 35 to have any desirable relationship between the excess of air at one rating and that at another rating.

To bring out more clearly the principle of my invention, I will define what I mean by "flow effect" and illustrate the same in connection with the fuels mentioned. The term "flow effect" as I use it denotes the relative effects on a differential pressure responsive device of the products of combustion produced by the burning at an equal rate of heat generation of the fuel in question and of carbon with the theoretical amount of air necessary for complete combustion, and considered at the lower heating value, and may be expressed by the formula:

$$\text{Flow effect} = \frac{21600 \times W \times \sqrt{\text{sp. vol.}}}{H}$$

Where W = Weight of products of combustion per pound of fuel.

Sp. vol. = Specific volume of products of combustion at 800° F. (considered as the average temperature at point of measurement)

H = Lower heating value of the fuel being compared to carbon

21600 = A constant which gives a flow effect of 100 when burning carbon with the theoretical amount of air.

In Fig. 2 I illustrate by means of curves the flow effect of blast furnace gas and of coke oven gas as calculated by the above formula, plotting flow effects for each of the two fuels against excess air over that theoretically required for perfect combustion.

From the formula, considering carbon burned with the theoretical amount of air necessary, we obtain a flow effect of 100. The flow effect of other fuels burned with the theoretical amount of air necessary, or at any specified percentage of excess air, may be calculated from the formula or read directly from a curve similar to that of Fig. 2, and the flow effect value so obtained may be compared to that of carbon or relative to each other.

For instance, coke oven gas burned at 20% excess air has a flow effect (from the curve) of 119. Blast furnace gas burned at 20% excess air (from the curve) shows a flow effect of 179. The relation between the two flow effects, namely $179/119=1.5$, which is the correction factor it would be necessary to apply to the air flow reading if the air flow had been calibrated and adjusted for a condition wherein coke oven gas only were being burned, and the operation were suddenly switched to a burning of blast furnace gas only. This on the assumption, of course, that the operator would desire to maintain a condition of 20% excess air for each of the two fuels.

I show the indexes 18, 23, 41, 65 each graduated from zero to 100%. If blast furnace gas alone is being burned, and at, for example, 20% excess air, then the reading on the index 18 will be the same as the reading on the index 23, showing that the air flow is correct in relation to the B. t. u. output of the boiler-furnace unit. This regardless of rate of operation between zero and 100% maximum.

If coke oven gas alone is being burned, then the reading on the index 23 will not necessarily correspond to the reading on the index 18, but the reading on the index 41 will be the same as the reading on the index 18, for the reading on the index 41 will be the reading of the index 23 compensated for the fact that there is no blast furnace gas being burned, but all coke oven gas being burned. The reading on the index 23 for this example relative to that of the preceding paragraph will be in the relation of 1.5, or the relation of flow effects; namely, $179/119$. The compensating effect upon the member 32 by the meter 55 will be 1.5, so that the reading on the index 41 will be the reading of the index 23 times 1.5. This on the assumption that the blast furnace gas and coke oven gas were each burned at the same percentage of excess air, and that the cam 35 were of uniform rise characteristic, wherein the vertical positioning of the indicator end of the beam 38 was directly proportional to the vertical movement of the left-hand end of the member 32.

If now the coke oven gas were to be burned at an excess air of 22%, and the blast furnace gas at 18%, then the correction relation would not be 1.5, but the ratio of flow effects 178 to 121 or 1.46.

If now the blast furnace gas and coke oven gas are burned simultaneously but in varying proportions, then the movement of the beam 38 relative to the index 41 is in accordance with the proportions of the two fuels burned, as well as the excess air at which each of the two fuels is burned. Furthermore, through the introduction of the cam 35 I may depart from such definite value of excess air at which each of the fuels is to be burned, and provide that the excess air be radically different at one rating than at another, regardless of the proportionality of the fuels burned at the two ratings.

I have thus broadly conceived apparatus for advising a relation between a measure of the out-

put of a furnace and a measure of the air flow through the furnace, with such relation taking into account the variation in flow effect of the products of combustion resulting from the burning of a plurality of fuels simultaneously in varying proportions in the furnace. Furthermore, the advice of the indicators and relation of indications may be used for manual or automatic control of the supply of air to the furnace. In addition, an adjustment is arranged whereby the compensating effect through the relation of indications may be varied, dependent upon and in accordance with calorific value or other variation in composition or characteristic of the burning of the individual fuels. Additionally, the fuels may be burned in any relative proportion from zero to maximum rate for each or all of the plurality of fuels and a correction dependent upon varying flow effect is effective regardless of rate of operation of the furnace.

I provide that the fuels may be burned at predetermined percentage of excess air which may differ the one fuel from another, and that at the same time, and regardless of the proportionality of the fuels as burned, the total excess of air over that theoretically required for perfect combustion may differ, one rating from another rating, in the operation of the boiler. I provide adjustments whereby such relation may be varied as desired. I primarily provide a meter for indicating the rate of flow of steam from a boiler as a measure of the output of a furnace. I further provide a meter for measuring the rate of supply of one fuel to the furnace. Still further, I provide an air flow meter for measuring the total air flow and products of combustion through the furnace, and I inter-relate the measurements and indications to the end that I advise the maintenance or departure from predetermined relation of indications for the purpose of guidance in hand or automatic control of combustion, and specifically of the supply of air for combustion to the furnace.

I illustrate and describe a control of the air supplied for combustion to a furnace through the usage of a relation between a measure of the air flow and a measure of one of a plurality of fuels burned simultaneously and in varying proportions in the furnace, and show possible manual or automatic control of the air supply from such indications, and with adjustment for changing calorific value or other characteristic for compensation of the fuels being so burned.

While I have illustrated and described a preferred embodiment of my invention wherein two fuels, namely blast furnace gas and coke oven gas, 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, obtaining a measure of furnace output, obtaining a measure of air flow, obtaining a measure of the rate of supply of one of the fuels, applying to the measure of air flow a compensating effect dependent on the measure of the one fuel, de-

termining the relation between the measure of furnace output and the compensated measure of air flow, and subjecting the air supply to control in accordance with the departure of said relation from a predetermined value.

2. The method of controlling the air supplied for combustion of a plurality of fuels burned simultaneously in a furnace, which includes, obtaining a measure of furnace output, obtaining a measure of air flow, applying to the measure of air flow a compensating effect representative of total heat supplied the furnace by one of the fuels, determining the relation between the measure of furnace output and the compensated measure of air flow, and controlling air supply from such relationship.

3. The method of controlling the air supplied for combustion of a plurality of fuels burned simultaneously in varying proportions in the furnace of a vapor generator, which includes, measuring the vapor generated, measuring the air flow, varying the value of the measure of air flow in accordance with heat input by one of the fuels to the furnace, determining the relation between the measure of vapor and the measure of air flow after the latter has been so varied, and controlling the air supply in accordance with the departure of said relation from a predetermined value.

4. The method of controlling the air supplied for combustion of a plurality of fuels burned simultaneously in a furnace, which includes, obtaining a measure of air and gases flowing through the furnace, obtaining a measure of one only of the fuels burned, correlating such measures, and controlling air supply from the correlation.

5. Apparatus for controlling the supply of air for combustion of a plurality of fuels adapted to be burned simultaneously in a furnace and which may have different heating values per unit quantity, comprising in combination, a furnace, air supplying means and means for supplying each of a plurality of fuels separately to the furnace, a meter of furnace output, a meter of air flow, a meter of one of the fuels, control means for the air supplying means, and a device cooperatively actuated by all of the meters, said control means being actuated by said device.

6. A relation indicator for use with vapor generators heated by combustion of a plurality of fuels adapted to be burned simultaneously in varying proportions, comprising in combination, a vapor outflow meter, an air flow meter, a meter for one of the fuels supplied to the furnace, and relation determining means of the vapor outflow and air flow, said fuel meter adapted to compensate the air flow meter.

7. An indicator for use with a furnace heated by combustion of a plurality of fuels adapted to be burned simultaneously in varying proportions, comprising in combination, an air flow meter having an indicator, and a meter of the rate of supply of one of the fuels, said last-named meter adapted to modify the effect of the air flow meter upon its indicator.

8. A relation indicator for use with a steam generator heated by combustion of two fuels of different heat value and adapted to be burned simultaneously in varying proportions, comprising in combination a steam flow meter, an air flow meter, a meter for one of the fuels supplied to the furnace, and relation determining means of the steam flow and air flow, said fuel meter adapted to compensate the air flow meter,

30

35

90

95

100

105

110

115

120

125

130

135

140

145

150

9. A relation indicator for use with vapor generators heated by combustion of a plurality of fuels adapted to be burned simultaneously in varying proportions, comprising in combination, a vapor outflow meter, a meter for the gaseous products of combustion flowing through the generator, a meter of one of the fuels supplied to the furnace, said fuel meter adapted to compensate the air flow meter, and relation determining means conjointly positioned by the vapor outflow meter and by the compensated air flow indication.

10. Apparatus for use in controlling the air supplied to a vapor generator heated by combustion of a plurality of different fuels burned simultaneously in varying proportion, comprising, in combination, relation determining means for vapor outflow and air flow, and means responsive to the rate of supply of one only of the fuels for providing a separate indication of air flow compensated for the said fuel supply rate.

11. An indicator for use with a furnace heated by combustion of a plurality of fuels of different heat value adapted to be burned simultaneously in varying proportions, comprising, in combination, a meter of the rate of flow of gaseous products of combustion including excess air leaving the furnace, and a rate of flow meter for one of the fuels adapted to compensate the first named meter.

12. The method of automatically operating a furnace adapted to be heated by the combustion of a plurality of different fuels burned simultaneously in varying proportions, which includes, supplying air for supporting combustion of the fuels at a rate in step with the rate of supply of one of the fuels, measuring the rate of supply of one only of the fuels and modifying the rate of supply of air in accordance with such measurement.

13. The method of automatically controlling the supply of air to support combustion of a plurality of fuels of different heat value and composition adapted to be burned simultaneously in varying proportion, which includes supplying air in desired excess relation to one of the fuels, and additionally controlling the supply of air in different excess relation to another of the fuels.

14. The combination with a furnace, of means for supplying a gaseous fuel to the furnace, means for automatically controlling the air supply for supporting combustion of said gaseous fuel in predetermined excess relation at all rates of supply of the said fuel, means for supplying simultaneously a second gaseous fuel to the furnace, a

meter of the second fuel, and means adapted to further control the supply of air to the furnace in predetermined excess relation to the second fuel varying the excess relation with rate of supply of the second fuel.

15. The method of controlling the air supplied for combustion of a plurality of fuels burned simultaneously in a furnace, which includes, measuring the products of combustion flowing through the furnace, measuring the rate of supply of one only of the fuels burned, and controlling the supply of air from the measurements.

16. A relation indicator for use with a furnace heated by combustion of two fuels of different heat value and adapted to be burned simultaneously in varying proportions, comprising in combination, a furnace output meter, an air flow meter, a meter for one of the fuels supplied to the furnace, and relation determining means of the furnace output and air flow, said fuel meter adapted to compensate the air flow meter.

17. A relation indicator for use with a furnace heated by combustion of a plurality of fuels adapted to be burned simultaneously in varying proportions, comprising in combination a furnace output meter, an air flow meter, a meter for one of the fuels supplied to the furnace, and relation determining means of the steam flow and another indication, said other indication being air flow measurement compensated by the said fuel meter.

18. The method of operating a furnace heated by combustion of a plurality of fuels simultaneously supplied to the furnace, which includes, obtaining an indication of furnace output, obtaining an indication of air supplied for combustion, obtaining an indication of rate of supply of one only of the fuels, modifying the indication of air supplied by the indication of fuel supply, and using such modified indication in relation to the indication of furnace output to show desirable relation therebetween or departure therefrom.

19. Apparatus for guiding the control of supply of air for combustion to a furnace, comprising in combination, a measuring device of furnace output, a measuring device of air supply, means for comparing the measurements relative to predetermined relation, and means responsive to a measure of one of a plurality of fuels simultaneously supplied for combustion, said means effective in modifying the measure of air flow before it is compared with the measure of furnace output.

JOSEPH C. ALBRIGHT.