March 15, 1932. E. X. SCHMIDT 1,849,335

METHOD AND APPARATUS FOR PROPORTIONING FLUIDS USED IN COMBUSTION PROCESSES

Filed Nov. 5, 1927 2 Sheets-Sheet 1

Fig. 1

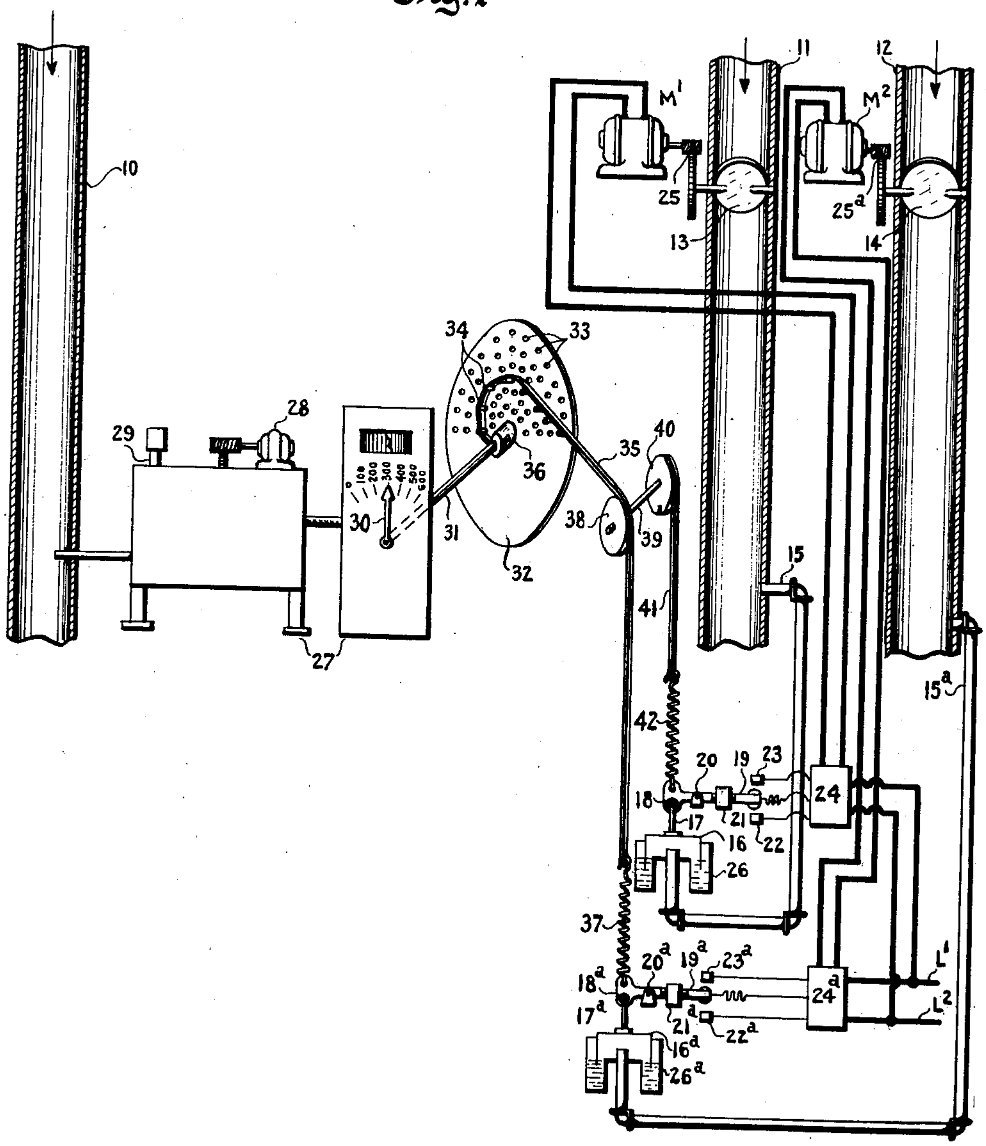

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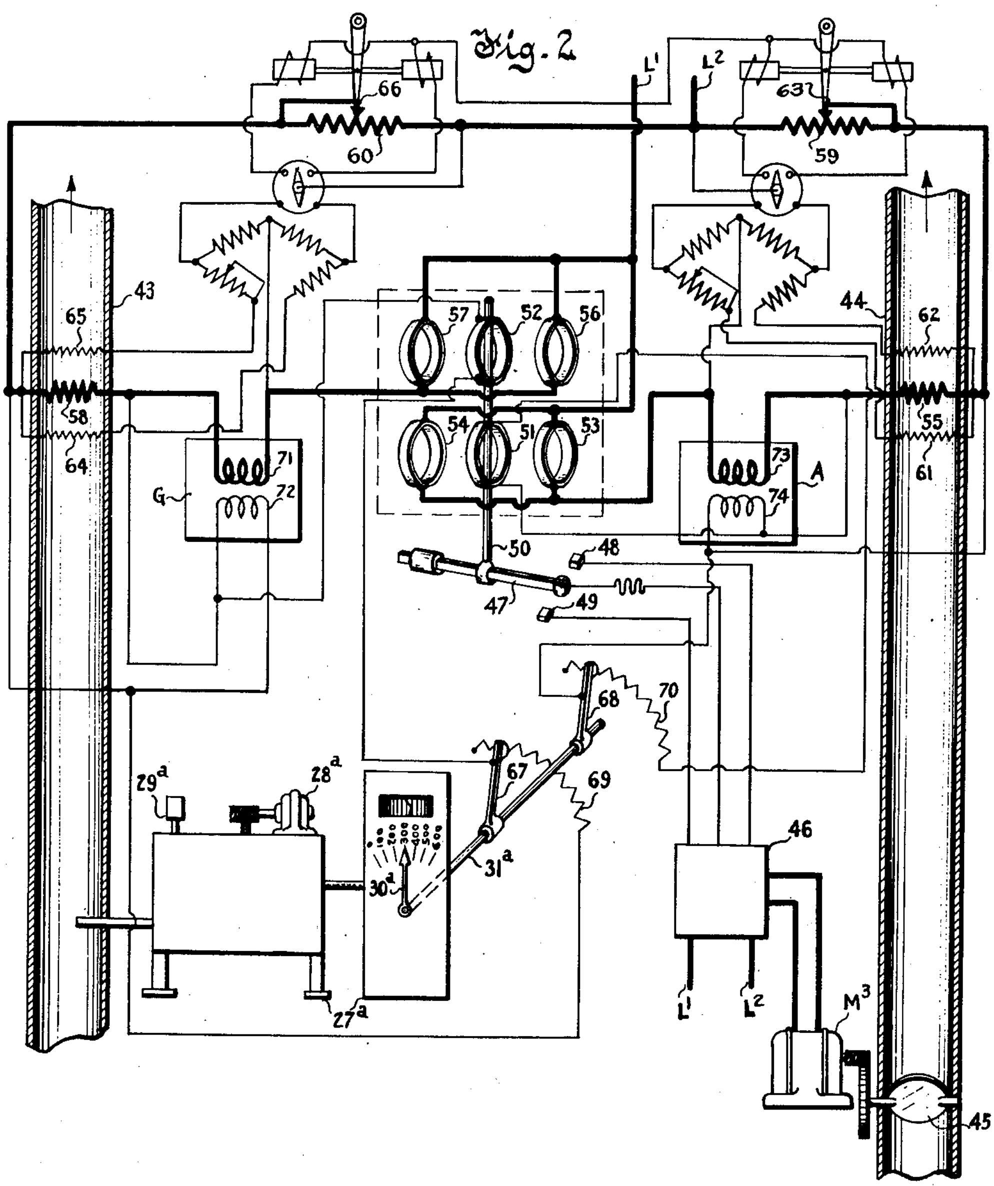
Fig. 2



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UNITED STATES PATENT OFFICE

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METHOD AND APPARATUS FOR PROPORTIONING FLUIDS USED IN COMBUSTION PROCESSES

Application filed November 5, 1927. Serial No. 231,290.

This invention relates to methods of and apparatus for proportioning flowing fluids, and the invention more particularly relates to improved methods and apparatus for proportioning fluids used in combustion processes.

It has heretofore been proposed in combustion control systems to provide for automatically maintaining a predetermined volumetric proportionality between the rate of supply of a combustible fluid or fluid mixture and the air or other fluid employed to support and assist in the combustion thereof. Moreover, in the patent to Wilson, No. 1,437,626, dated December 5, 1922, it is proposed to vary the proportionality of the gas and air to maintain a fixed proportionality between the weights of combustible gas and oxygen.

Combustion control systems of the type just mentioned are sufficiently accurate in operation in cases where the total heating value per unit volume of the combustible fluid remains constant or is maintained constant. However, it is now generally desired in the operation of coke ovens and the like to employ a lower grade of fuel gas therefor,—to permit sale of as much as possible of the higher grade coke oven gas. This condition results in variation in quality of the fuel supplied to the coke ovens, due to the variable amount of coke oven gas sold for other purposes; and fuel supplied to the coke ovens may therefore vary in quality all the way from producer gas of low heating value to coke oven gas of relatively high heating value; or a mixture of such gases may be employed.

As is well understood in the art, and as evidenced by the prior art patents such as Wilson No. 1,437,626 aforementioned, a definite amount of air is required for each unit volume of combustible fluid of a given quality or total heating value per unit volume to insure perfect combustion thereof; and assuming that the quality of such combustible fluid remains constant and that said fluid and the combustion air are supplied under like conditions of temperature, pressure and saturation, it is obvious that satisfactory results may be obtained if the proportionality of the fluid and air is maintained substantially constant.

Under conditions herein contemplated, however, the total heating value per unit volume of the combustible fluid may vary throughout a wide range, due to the use of one or another of a plurality of combustible fluids, or of a mixture of such fluids. For example, assume that in a combustion control system the rate of fuel requirement is 60,000,000 B. t. u. per hour. If coke oven gas having a total heating value of 600 B. t. u. per cubic foot is used, 100,000 cubic feet per hour must be supplied, whereas the amount of air required for perfect combustion of such gas would be about 543,000 cubic feet per hour. On the other hand if water gas having a total heating value of 310 B. t. u. per cubic foot is used, 193,500 cubic feet per hour must be supplied,—whereas the amount of air required would be about 450,000 cubic feet per hour.

Upon comparison of the two examples just mentioned it will be seen that in order to satisfy the fuel requirement in the second case the rate of flow of gas was increased 93.5 per cent (as compared with the first case), whereas the air requirement for perfect combustion was decreased 17.3 per cent. 17.3 per cent represents approximately the maximum change in air requirement between the highest and lowest qualities of artificial fuel gas. For carbureted water gas of various heating values up to 600 B. t. u. per cubic foot the air requirement per B. t. u. approximately follows the straight line relation of the air requirement per B. t. u. of mixtures of uncarbureted water gas and coke oven gas. Producer gas with a heating value of 110 B. t. u. per cubic foot requires approximately the same amount of air per B. t. u. as that required for uncarbureted water gas.

It will be apparent from the foregoing that in order to insure perfect combustion of the combustible fluid it is necessary that the volumetric rate of flow of air must be varied not only in accordance with variations in the volumetric rate of flow of such combustible fluid, but also in accordance with variations in the quality or total heating value per unit volume of the latter.

Accordingly my invention contemplates the employment of means comprising a calorimeter which cooperates with the other elements of the combination to superimpose upon the controlling effects of the latter a controlling effect which is a function of the total heating value per unit volume of the combustible fluid, whereby maximum combustion efficiency or other desired calorific effects of the combustion may be insured.

An object of the invention is to provide novel methods of proportioning and regulating the rates of flow of a combustible fluid or fluid mixture and air to insure the aforementioned perfect combustion conditions.

Another object is to provide simple and efficient apparatus for carrying out such methods, among others.

Other objects and advantages of the invention will be apparent or will be specifically pointed out in the course of the following description.

The accompanying drawings diagrammatically illustrate certain embodiments of the invention, by way of example; but it will be understood that the invention is susceptible of embodiment in other forms without departing from the spirit and scope thereof as defined in the appended claims.

In the drawings, Figure 1 illustrates diagrammatically a combustion control system wherein it may be assumed that the combustible fluid is supplied at a constant volumetric rate per unit of time, and in which the volumetric rates of flow of primary and secondary air are normally maintained of predetermined constant value, but subject to variation in accordance with changes in the total heating value per unit volume of the combustible fluid, and

Fig. 2 illustrates a modified form of the invention wherein electrical means are provided for normally maintaining a predetermined proportionality between the volumetric rates of flow of the combustible fluid and the air employed to support and assist in combustion thereof,—in combination with calorimetric means for effecting variation in the rate of flow of air in accordance with variations in the total heating value per unit volume of the combustible fluid, and in accordance with variations in air requirements due to changes in composition of the combustible fluid.

As will be pointed out in detail hereinafter, the volumetric rate of flow of the combustible fluid may also be subject to control in accordance with the determinations of the calorimeter to provide for so-called total heat control,—that is, control of the volumetric rate of flow of the combustible fluid in such manner that the total number or value of heat units supplied per unit of time will be maintained constant.

Referring first to Fig. 1, the numeral 10 designates a conduit through which it may be assumed that a combustible fluid is caused to flow, in the direction of the arrow, at a constant volumetric rate per unit of time. Any suitable means well known in the art may be employed for effecting such flow of the combustible fluid. Numeral 11 designates a conduit through which the primary combustion air is adapted to flow and 12 designates a conduit through which the secondary combustion air is adapted to flow. The arrows indicate the direction of flow of the primary and secondary air from any suitable source or sources.

The rates of flow of the primary and secondary air are normally maintained substantially constant through the medium of adjustable valves 13 and 14, respectively. Thus I provide a pipe 15 which leads from conduit 11 at the outlet side of valve 13 to the interior of a prover bell 16 or the like to subject the latter to the pressure conditions obtaining within the outlet end of said conduit. Prover bell 16 is provided with a link or rod 17 pivoted at 18 to one end of a movable contactor 19, which is pivoted at 20 to a suitable fixed support. Contactor 19 is provided with a weight 21 which is adjustable to normally effect neutral positioning of said contactor under predetermined pressure conditions within the conduit 11. On opposite sides of contactor 19 are stationary contacts 22 and 23 adapted when engaged by said contactor 19 to control a reversing relay illustrated diagrammatically at 24 to selectively provide reverse circuit connections for a motor M^1,—the latter when energized for operation in either direction respectively being adapted through suitable worm and pinion gearing 25 to effect movement of valve 13 in a direction and to a degree corresponding with the direction and duration of operation of said motor. The power supply lines for the motor are indicated at L^1, L^2.

It will be apparent from the foregoing that the means just described normally acts automatically to insure a predetermined constant rate of flow of primary combustion air through conduit 11, depending upon the particular adjustment of the weight 21. The rate of flow of secondary combustion air through conduit 12 is likewise subject to automatic control in accordance with the direction and duration of operation of a motor M^2;—the gearing interposed between valve 14 and motor M^2, and the various control elements for the latter being in all respects similar to those aforedescribed, and being designated by like reference numerals with the exponent "a" added. As shown the prover bells 16 and 16^a are sealed by bodies of liquid within the containers 26 and 26^a, respectively.

Thus assuming a constant volumetric rate of flow of the combustible fluid through conduit 10, it will be remembered that the means aforedescribed will likewise tend to maintain the volumetric rates of flow of primary and secondary air substantially constant and, of course, proportional to the rate of flow of combustible fluid. With the weights 21 and 21^a properly adjusted, the aforedescribed arrangement would result in maximum combustion efficiency of the combustible fluid,—provided the quality or total heating value per unit volume of such fluid remained or were maintained constant. However, as aforestated it is contemplated that the quality or total heating value per unit volume of the combustible fluid will vary throughout a wide range, depending upon the particular quality of gas or mixture of gases which is passed through the conduit 10. Accordingly I provide means for modifying the control of the rates of flow of primary and secondary air to insure maximum combustion efficiency of the combustible fluid under conditions of variation in quality or total heating value per unit volume of the latter.

Said means as shown may comprise a calorimeter which is illustrated diagrammatically at 27, said calorimeter preferably being of the type disclosed in Patent No. 1,625,-277, granted April 19, 1927, to H. N. Packard. As described in said patent the calorimeter is provided with means driven by a suitable motor 28 for effecting withdrawal of a continuous sample of the combustible fluid from conduit 10, and supplying said sample, together with predetermined proportions of combustion air and cooling air to the burner 29, for combustion of the fluid sample and combustion air and absorption by the cooling air of the heat so liberated. The arrangement is preferably such that the fluid sample and combustion air and cooling air are supplied under like conditions of temperature, pressure and saturation; whereby the indicating and recording element 30 of the calorimeter is adapted to show the instantaneous quality or total heating value per unit volume of the fluid flowing through conduit 10. The actuating means for the indicating and recording element 30 is fully described in the aforementioned Patent No. 1,625,277; and since the same forms no part of the present invention, further description thereof is deemed unnecessary herein.

As will be apparent, the element 30 moves in a direction and to a degree accurately corresponding to variations in the quality or total heating value per unit volume of the combustible fluid flowing through conduit 10. I therefore attach, either directly or indirectly, to the operating shaft 31 of element 30 a disk or wheel 32,—said disk having a plurality of radially arranged sets of perforations or sockets 33 adapted to receive removable pins or plugs 34, which may therefore be arranged in any desired predetermined relation to form a curved or cam surface. One end of a flexible element 35 is attached to the hub 36 of disk 32 and the other end of said element is preferably attached to a coiled spring 37. The end portion of element 35 adjacent to hub 36 is carried by the pins 34 on disk 32, and said element is further adapted to ride over and in driving engagement with a wheel or pulley 38. Spring 37 is attached to the contactor 19^a at a point to the left of the pivot 20^a. The controlling effect of the prover bell 16^a upon the position of contactor 19^a is thus modified in accordance with variations in the degree of tension upon the spring 37; whereas such tension is subject to control in accordance with variations in the quality or total heating value per unit volume of the fluid flowing in conduit 10, and such variations have an effect corresponding to the arrangement of the pins 34 on disk 32.

Fixed to the wheel 38 by means of a shaft 39 and movable therewith is a second wheel 40,—said last mentioned wheel having attached thereto one end of a flexible element 41 which is adapted to be wound around the periphery of said wheel, the other end of said element being connected through the medium of a coiled spring 42 with the end of contactor 19 to the left of pivot 20. Variations in the quality or total heating value per unit volume of the combustible fluid passing through conduit 10 will therefore cause like variations in the tension of springs 37 and 42; which in turn will result in proportional variations in the respective volumetric rates of flow of the primary and secondary air through conduits 11 and 12 to provide for maximum combustion efficiency of the fluid in conduit 10 when burned.

In the combustion control system illustrated in Fig. 2 the numeral 43 designates a conduit through which a combustible fluid is adapted to flow, in the direction of the arrow. The numeral 44 designates a conduit through which the combustion air flows, in the direction of the arrow. The volumetric rate of flow of combustion air through conduit 44 is subject to control by an adjustable valve 45, and the means now to be described are operable automatically to normally maintain a predetermined proportionality between the volumetric rates of flow of the combustible fluid and the combustion air. Said means as shown comprises a reversible motor M^3 adapted to be supplied with energy from lines L^1, L^2; the reverse circuit connections for said motor being subject to control by a relay illustrated diagrammatically at 46. Energization of relay 46 for effecting operation of motor M^3 in reverse directions selectively is in turn subject to control by an oscillating contactor 47 adapted to cooperate with stationary contacts 48 and 49. contactor 47 is rigidly attached to a rod or shaft 50 for support thereby, said shaft being rotatably supported in suitable bearings, not shown.

Also fixed to shaft 50 in spaced relation to each other are a pair of wattmeter coils 51 and 52; coil 51 being biased to move in a clockwise direction under the magnetic influence of a pair of wattmeter coils 53 and 54, which are connected in circuit in parallel with each other and in series with the heating element 55 of an electric fluid meter of the type disclosed in the patent to C. C. Thomas, No. 1,222,492, dated April 10, 1927. On the other hand, coil 52 is biased in a counterclockwise direction under the magnetic influence of a pair of wattmeter coils 56 and 57, which are connected in circuit in parallel with each other and in series with the heating element 58 of another electric fluid meter. The coils 51 and 52 thus act in opposition to each other in their effect upon the position of contactor 47, so that in the event that the torque of one coil predominates over the other said contactor 47 will be moved in one direction or the other to engage the stationary contacts 48 and 59 selectively.

Upon engagement of contactor 47 with one of said contacts 48 or 49 the relay 46 is energized to complete circuit for operation of motor M^3 in one direction or the other, whereby the valve 45 is operated to vary the rate of flow of air or other fluid in conduit 44 in such manner as to cause equalization of the torque of coils 51 and 52. The operation of the aforementioned electric fluid meters per se is well understood in the art, and is described in detail in Patent No. 1,222,492 aforementioned. Hence the diagrammatic illustration thereof herein is deemed sufficient. It may be noted, however, that a variable resistance 59 is connected in series with the heating element 55, whereas a variable resistance 60 is connected in series with the heating element 58. The heating element 55 and its resistance 59 are connected, in parallel with heating element 58 and its resistance 60, to line L^1, L^2; the arrangement being preferably such that the value of the resistances 59 and 60 included in circuit with the respective elements 55 and 58 is varied to cause variation in the energy input to the respective elements, whereby a predetermined contstant temperature rise of the gas, air or other fluids flowing through the respective conduits 43 and 44 is maintained.

Thus the heating element 55 is provided on each side thereof with thermometer resistances 61 and 62, said resistances being connected in a well known manner in the Wheatstone bridge circuit of the electric meter to normally insure a predetermined rise in temperature of the air or other fluid flowing in conduit 44 as the result of heating of said fluid by element 55. In other words, assuming that it is intended to provide for a ten degree rise in temperature of the fluid in its passage between thermometer resistances 61 and 62, such rise will be maintained only while the rate of energy input to heating element 55 is maintained constant and also only while the rate of fluid flow through conduit 44 remains constant.

On the other hand, if the rate of fluid flow were increased for any reason the temperature rise of the fluid as measured by thermometers 61 and 62 would obviously be decreased, and such decrease would cause unbalancing of the Wheatstone bridge to a corresponding degree. The metering mechanism would thereupon act to adjust the contactor 63 to decrease the amount of the resistance 59 included in circuit with element 55, whereby the energy input to the latter would be increased sufficiently to provide the predetermined temperature rise of the fluid. The increased current thus permitted to pass through element 55 and coils 53 and 54 connected in circuit therewith would vary the torque upon coil 51, and assuming the torque of coil 52 to remain constant during the interval, contactor 47 would be caused to move in a clockwise direction to cause energization of relay 46 with resultant energization of motor M^3 in a manner to cause movement of valve 45 toward closed position. In the foregoing manner the rate of flow of fluid through conduit 44 is controlled to normally maintain the same of substantially constant predetermined value.

Similarly the electric fluid meter comprising the heating element 58 is provided with thermometer resistances 64 and 65 which are arranged in the well known Wheatstone bridge circuit, as described in connection with thermometer resistances 61 and 62. Thus, assuming a given adjustment of the contactor 66 of adjustable resistance 60 to provide for a predetermined constant input of energy to heating element 58 the Wheatstone bridge is adapted to remain balanced so long as the rate of flow of gas or other combustible fluid through conduit 43 remains constant. However, if the rate of flow of combustible fluid through said conduit is subject to variation through control of known means for providing a constant rate of flow of heat units per unit of time through said conduit, it will be seen that any variation in the volumetric rate of flow of said fluid will cause unbalancing of the Wheatstone bridge with consequent adjustment of contactor 66 to vary the rate of energy input to said heating element 58 whereby the predetermined temperature rise of the fluid is again provided and the balance of the Wheatstone bridge restored. Such variation in the value of the energy input to heating element 58 causes a like variation in the value of the torque upon the wattmeter coil 52, as will be obvious.

Thus if the rate of flow of fluid through conduit 43 has decreased the torque upon the coil 52 will likewise decrease, and assuming normal torque conditions upon the coil 51 the latter will predominate to cause movement of contactor 47 in a clockwise direction to engage contact 49, with consequent energization of relay 46 and operation of motor M^3 in a direction to cause partial closure of valve 45. On the other hand, if the rate of flow of fluid in conduit 43 has increased, the contactor 66 will be automatically adjusted to increase the energy input to element 58, whereupon the torque of coil 52 will predominate over the torque of coil 51 to cause movement of contactor 47 in a counterclockwise direction into engagement with contact 48, with consequent energization of relay 46 to effect operation of motor M^3 in the reverse direction to cause opening movement of valve 45, thereby increasing the rate of flow of fluid in conduit 44.

The system shown in Fig. 2 as thus far described therefore operates in a manner to normally maintain a predetermined porportionality between the volumetric rate of flow of the fluid in conduit 44 with respect to the volumetric rate of flow of fluid in conduit 43. As heretofore pointed out, however, it is found that combustible fluids of different qualities or total heating values per unit volume require different proportions of combustion air to provide for maximum combustion efficiency thereof; and I therefore provide means for superimposing upon the aforementioned control of the rate of flow of fluid through conduit 44 a controlling effect which is a direct function of the quality or total heating value per unit volume of the combustible fluid flowing through conduit 43.

Said means as shown may comprise a calorimeter of the general character illustrated and described in connection with Fig. 1,—said calorimeter and the parts thereof having been given reference numerals corresponding to those of Fig. 1, with the exponent "a" added. Thus the calorimeter 27^a is adapted to withdraw a continuous sample of combustible fluid from the conduit 43, said sample being supplied to the burner 29^a along with predetermined portions of combustion air and cooling air, preferably under like conditions of temperature, pressure and saturation. The arm 30^a of the indicating and recording element of the calorimeter is operable automatically in a direction and to a degree corresponding with variations in the total heating value per unit volume of the fluid flowing in conduit 43 as aforedescribed. Attached to the operating shaft 31^a of said arm 30^a for movement therewith are a pair of contact elements 67 and 68 adapted for co-operative engagement with the adjustable resistances 69 and 70.

As shown the wattmeter coil 52 is connected, in series with resistance 69, across the terminals of heating element 58; whereby the degree of energization of coil 52 is dependent upon the value of potential across the terminals of said heating element 58 and also dependent upon the position of the contact element 67 of the resistance 69. Similarly, the wattmeter coil 51 is connected in series with resistance 70, across the terminals of heating element 55; whereby the degree of energization of coil 51 is dependent upon the value of potential across the terminals of said heating element 55 and also dependent upon the position of the contact element 68 of the resistance 70. I have diagrammatically illustrated a meter G for indicating the total volumetric flow of combustible fluid through conduit 43, said meter comprising essentially a current coil 71 connected in series with the heating element 58 and a voltage coil 72 connected across the terminals of said heating element. I have also illustrated a similar meter A for indicating the total volumetric flow of fluid through conduit 44, said meter comprising essentially a current coil 73 connected in series with the heating element 55 and a voltage coil 74 connected across the terminals of said heating element. Said meters G and A as will be understood, are of the well known wattmeter type, and further description thereof is deemed unnecessary. Also it is to be understood that meters G and A may be omitted if desired.

As aforeindicated, any variation in the quality or total heating value per unit volume of the combustible fluid or fluids flowing in conduit 43 will effect corresponding movement of the contact arms 67 and 68 with consequent variation in the degree of energization of wattmeter coils 52 and 51, respectively; whereby the controlling effect of contactor 47 is modified in accordance with such variations in quality to thereby insure proper proportionality of the volumetric rate of flow of air or other fluid flowing in conduit 44 with respect to the volumetric rate of flow of combustible fluid in conduit 43, to provide for maximum combustion efficiency of the latter when burned.

I have herein specifically described the adaptation of my invention to a combustion control system in which a calorimeter is utilized to insure the desired uniform or maximum combustion efficiency by regulating the volumetric rate of flow of combustion air in such manner that variations in the total heating value per unit volume of the combustible fluid, velocity of flame propagation, and other calorific effects incident to changes in the quality or composition of the combustible fluid, will not affect the desired combustion process. Nevertheless, it will be apparent to those skilled in the art that the function of the calorimeter herein need not be limited to the attainment of maximum thermal efficiency. For example, it may be desirable in some cases to insure a maximum constant value of the flame temperature, or a maximum constant value of heat distribution; whereas in accordance with my invention it is possible to so adjust or regulate automatically the volumetric rate of flow of combustion air by means of the calorimeter that the particular phase of the combustion which is of greatest importance is maintained of predetermined constant value.

What I claim as new and desire to secure by Letters Patent is:

1. The method of proportioning fluids used in combustion processes, which comprises the step of normally effecting a flow of combustible fluid and a flow of fluid to support combustion thereof in predetermined volumetric proportions, and varying the rate of flow of said last mentioned fluid individually in response to variations in the total heating value per unit volume of said combustible fluid per se.

2. The method of proportioning fluids used in combustion processes, which comprises effecting separate flows of fluids one of which is combustible and the other of which is adapted to support combustion thereof, normally maintaining a predetermined proportionality between the volumetric rates of flow of said fluids, and varying individually the relative rate of flow of said second mentioned fluid in response to variations in value of a calorific effect of combustion of said first mentioned fluid per se to thereby provide for substantially perfect combustion of said first mentioned fluid.

3. The method of proportioning flowing fluids, which comprises effecting a flow of combustible fluid, effecting a predetermined proportional flow of fluid to support combustion thereof, ascertaining the instantaneous total heating value per unit volume of said combustible fluid, and varying individually the rate of flow of said second mentioned fluid in response to variations in such total heating value per unit volume of said combustible fluid.

4. The method of proportioning flowing fluids, which comprises effecting a flow of combustible fluid, effecting a predetermined proportional flow of a fluid to support combustion thereof, utilizing a continuous sample of said combustible fluid to ascertain the total heating value per unit volume thereof, and varying individually the rate of flow of said second mentioned fluid in response to variations in such total heating value per unit volume of said combustible fluid whereby a predetermined calorific effect of the combustion is insured.

5. In apparatus for proportioning fluids used in combustion processes, in combination, means for supplying a fluid for combustion, means for supplying another fluid in predetermined volumetric prooprtionality to said first mentioned fluid to support and assist in combustion thereof, and means for varying individually the rate of flow of said second mentioned fluid in response to variations in a calorific effect of combustion of said first mentioned fluid per se.

6. In apparatus for proportioning fluids used in combustion processes, in combination, means for effecting separate volumetrically proportioned flows of fluids, one of said fluids being combustible and other of said fluids being adapted to support and assist in combustion thereof, and means operable automatically in response to variations in certain calorific effects of combustion of said first mentioned fluid per se to vary individually the relative rate of flow of said other of said fluids.

7. The method of proportioning fluids used in combustion processes, which comprises effecting a flow of combustible fluid, effecting a volumetrically proportioned flow of air to support combustion of said fluid, determining the instantaneous total heating value per unit volume of said combustible fluid, and varying individually the rate of said flow of air in response to variations in said total heating value.

8. The method of proportioning fluids used in combustion processes, which comprises effecting separate flows of fluids one of which is combustible and another of which is adapted to support combustion thereof, ascertaining the relative volumetric rates of flow of said fluids respectively and subjecting one of said fluid flows to rate control in response to variations in the rate of flow of the other of the same to thereby normally maintain a predetermined volumetric proportionality between said rates of flow, withdrawing a continuous sample of said combustible fluid and subjecting the same to calorimetric means to ascertain the instantaneous total heating value per unit volume thereof, and additionally varying individually the rate of flow of said second mentioned fluid in response to variations in such total heating value to thereby insure a substantially perfect volumetric proportionality between said flows of fluids for the purpose set forth.

9. In apparatus for proportioning fluids used in combustion processes, in combination, means for effecting a flow of combustible fluid, means for effecting a volumetrically proportioned flow of air to support combustion of said fluid, means for determining the instantaneous total heating value per unit volume of said combustible fluid per se, and means for varying individually the rate of said flow of air in response to variations in said total heating value to provide for

substantially perfect combustion of said combustible fluid.

10. In apparatus for proportioning flowing fluids used in combustion processes, in combination, means for regulating the flow of one fluid, means controlling said means and tending to render the flow of said fluid volumetrically proportional to the flow of another fluid, and means automatically operable in response to variations in a combustion calorific value of said second-mentioned fluid to supplementally and individually vary the rate of flow of said first-mentioned fluid.

11. In apparatus for proportioning fluids used in combustion processes, in combination, means for measuring the relative rates of flow of a plurality of flowing fluids one of which is combustible and the other of which is adapted to support combustion thereof, means controlled by said means to vary the rate of flow of said second-mentioned fluid individually in accordance with variations in the rate of flow of said first-mentioned fluid, and means for modifying the control so effected in response to variations in a combustion calorific value per unit volume of said first-mentioned fluid per se.

12. In apparatus for proportioning fluids used in combustion processes, in combination, means for measuring the relative rates of flow of a plurality of flowing fluids, means controlled by said means to vary the rate of flow of one of said fluids individuallly in accordance with variations in the rate of flow of the other of the same, and means for modifying the control so effected in response to variations in the total heating value per unit volume of said second-mentioned fluid per se.

13. In apparatus for proportioning fluids used in combustion processes, in combination, means for measuring the relative rates of flow of a plurality of flowing fluids, means controlled by said means to vary the rate of flow of one of said fluids in accordance with variations in the rate of flow of the other of the same, and means for modifying the control so effected in response to variations in the total heating value per unit volume of a combustible mixture including said second-mentioned fluid.

14. In apparatus for proportioning fluids used in combustion processes, in combination, a plurality of conduits through which fluids are adapted to flow, one of said fluids being combustible and another of said fluids being adapted to support combustion thereof, electrical means for measuring the relative volumetric rates of flow of said fluids, means controlled by said means for controlling the volumetric rate of flow of one of said fluids to normally maintain a predetermined volumetric proportionality between said rates of flow, and calorimetric means for determining the quality or total heating value per unit volume of said combustible fluid, said second-mentioned means being also subject to control by said calorimetric means to effect variation in the proportionality of said fluids in response to variations in said total heating value.

In witness whereof, I have hereunto subscribed my name.

EDWIN X. SCHMIDT.