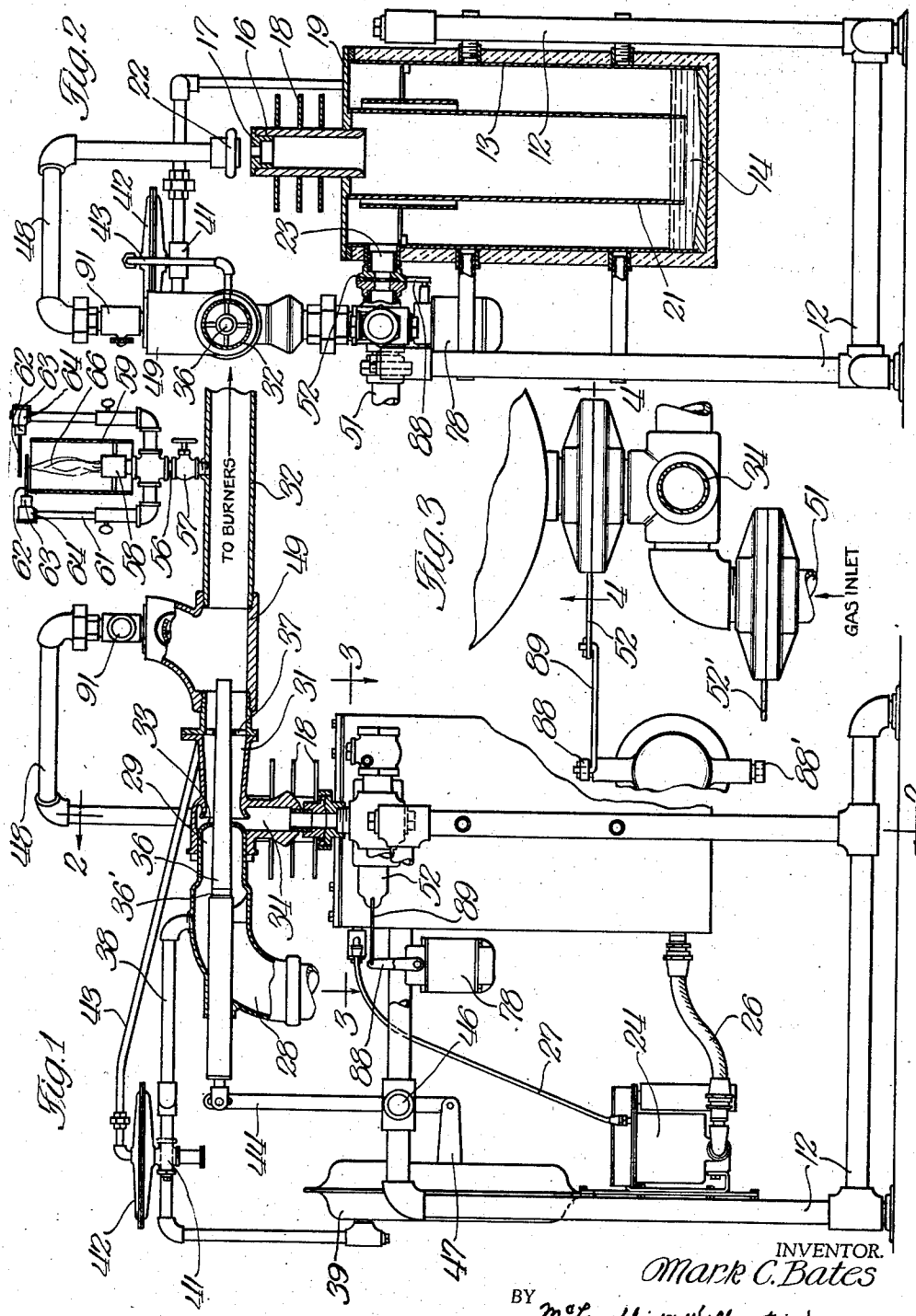
Jan. 2, 1945. M. C. BATES 2,366,170

CONTROL METHOD AND APPARATUS

Filed Oct. 12, 1940 4 Sheets-Sheet 1




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CONTROL METHOD AND APPARATUS

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Fig. 4

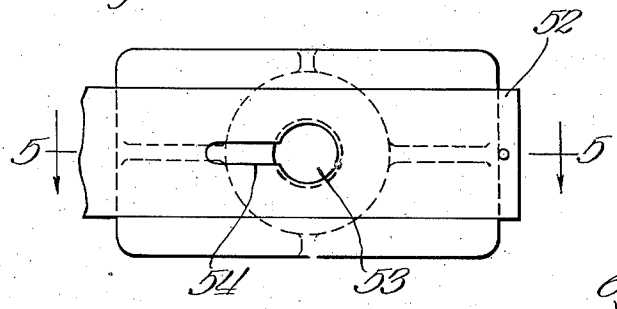



Fig. 5

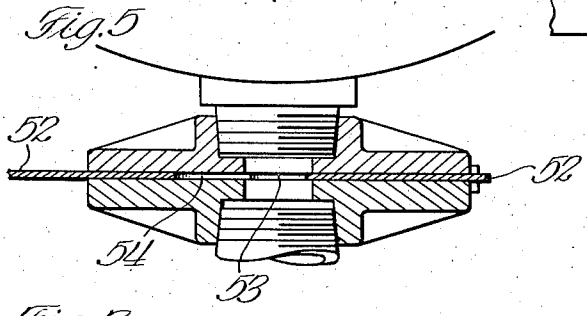



Fig. 6

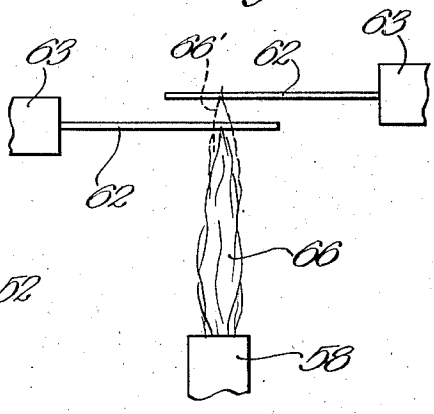
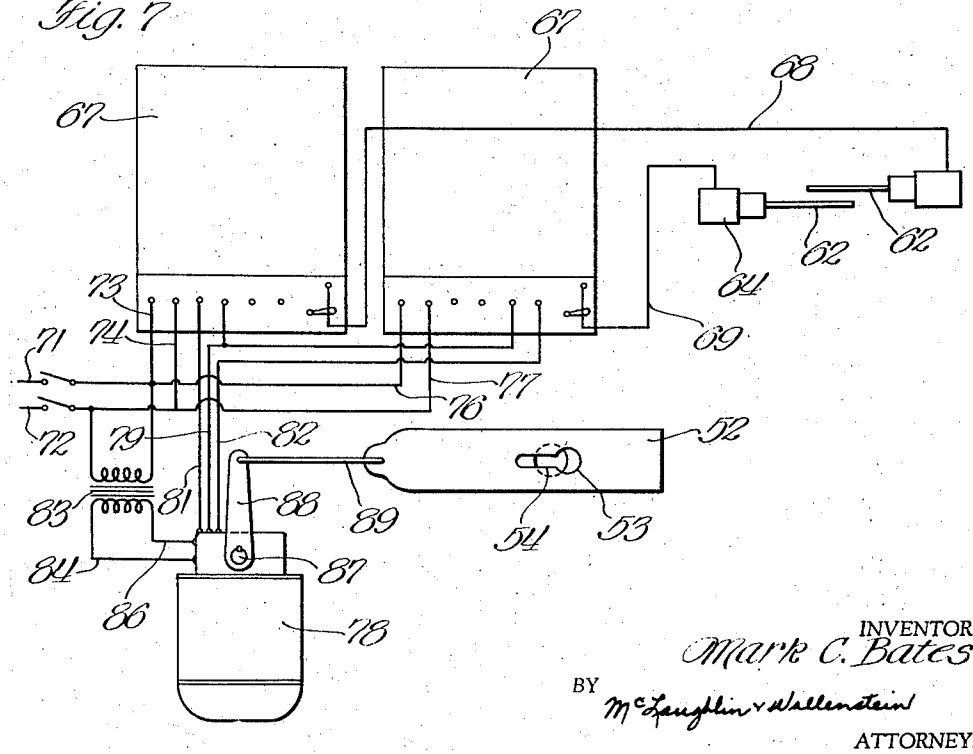



Fig. 7




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CONTROL METHOD AND APPARATUS

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Fig. 8

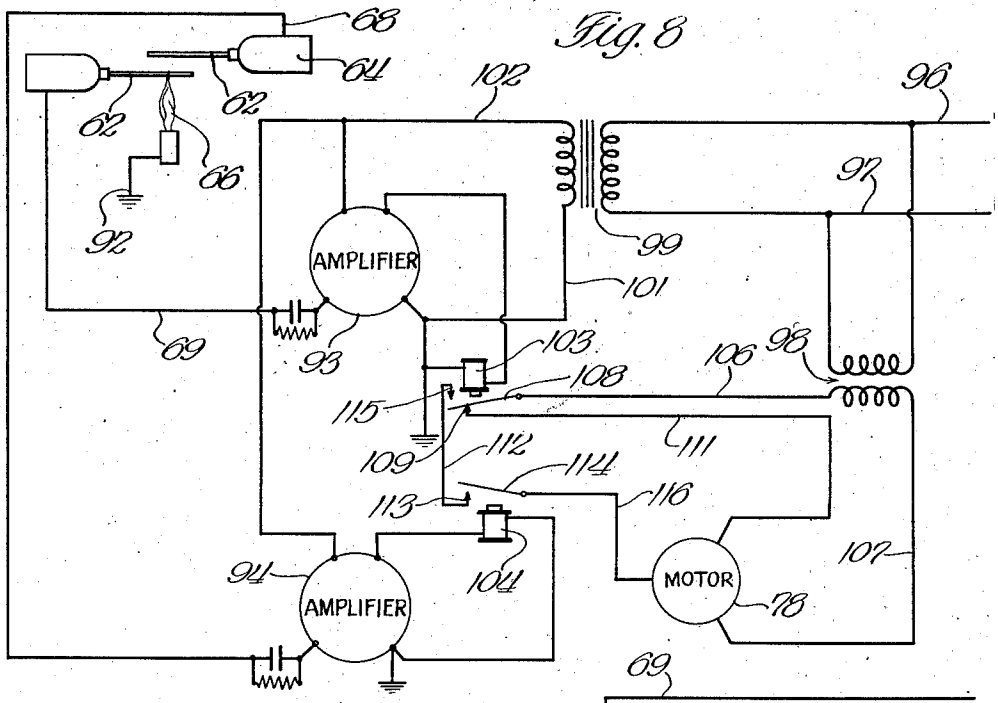



Fig. 9

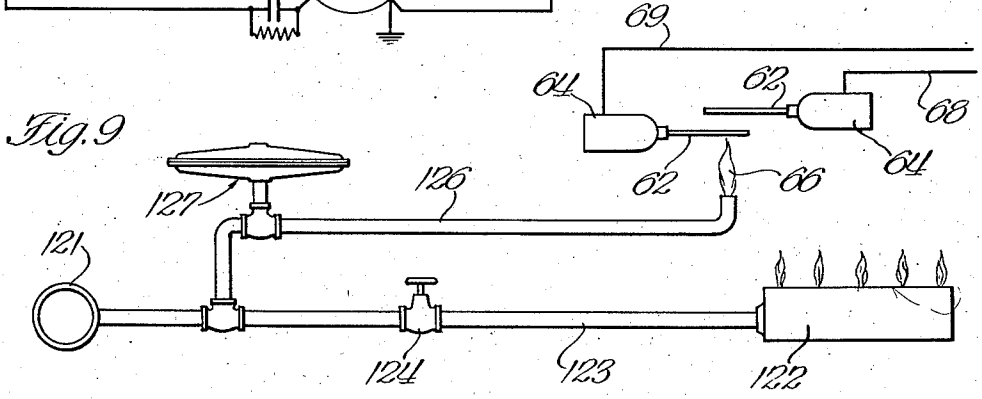
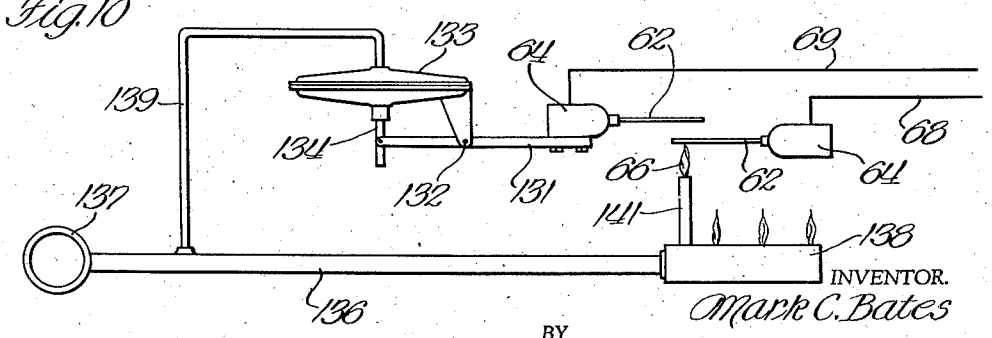



Fig. 10



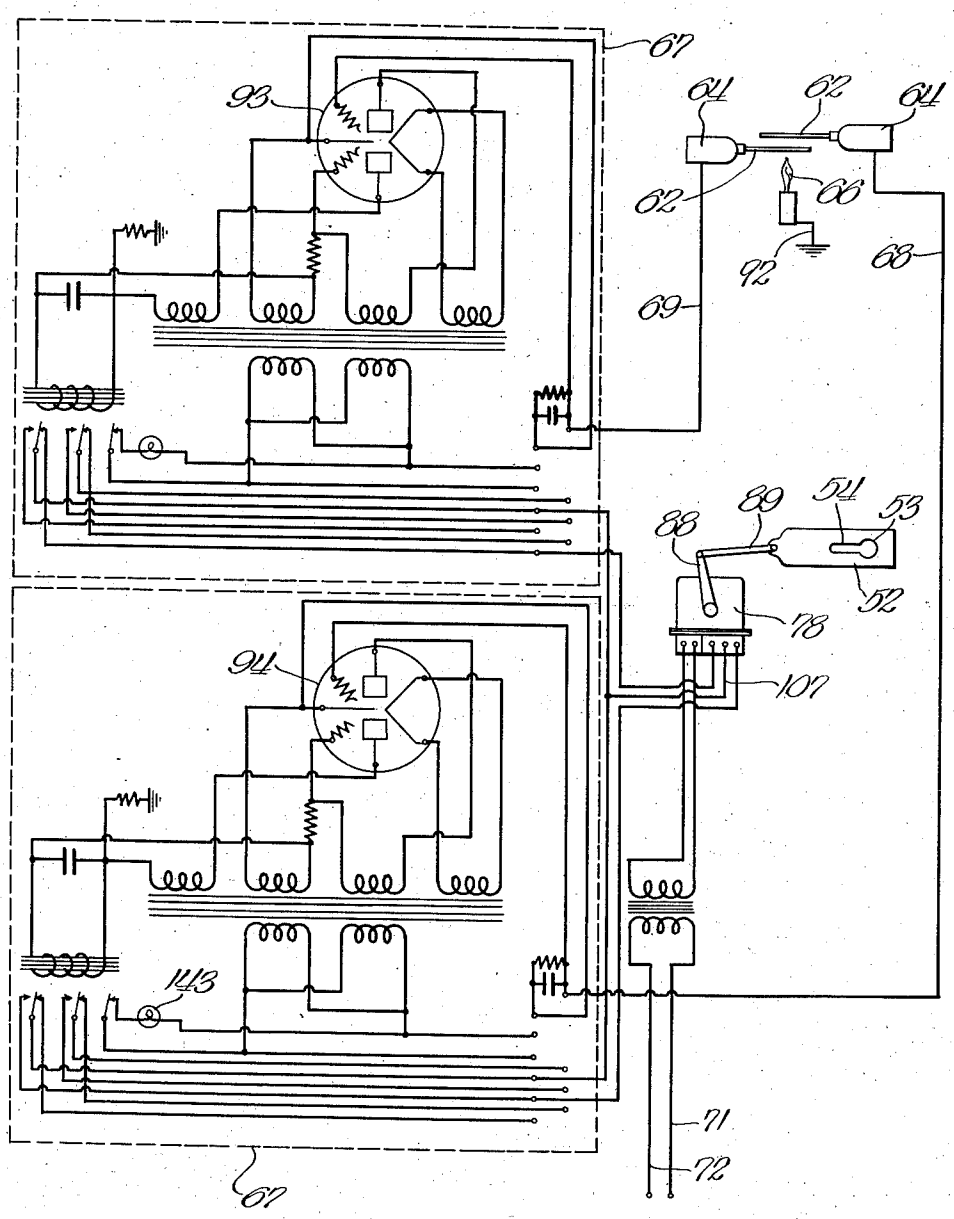

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CONTROL METHOD AND APPARATUS

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Fig. 11




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2,366,170

# UNITED STATES PATENT OFFICE

2,366,170

## CONTROL METHOD AND APPARATUS

Mark C. Bates, Chicago, Ill.

Application October 12, 1940, Serial No. 360,89[illegible]

11 Claims. (Cl. 236—15)

My invention relates in general to control equipment. It relates more in particular to a method of and means for controlling combustion of commercial fuels, particularly to controlling the quality of a flame produced by burning a vaporous fuel, such as commercial gas or a vaporized liquid hydrocarbon.

The demands of industry have required increasingly accurate control of combustion and the quality of combustion products. Some processes may require an oxidizing flame, others, a substantially neutral flame, or, still others, a reducing flame, it being understood, of course, that the gaseous combustion products will have the same general quality. Industrially, the flame may require control because of an operation which is being performed, which operation will require control of a furnace atmosphere as to its oxidation character, reduction character, etc. At times also, the control of the character of combustion in industrial establishments is primarily for the purpose of promoting efficiency in the burning operation. Even in non-industrial applications, such as in ordinary home heating establishments, attempts are made to control the character of combustion in order that the most efficient use of the fuel may be made.

Demand for more accurate control of combustion has manifested itself in the development of improved combustion apparatus, quality control mechanism, the use of powdered solid fuel, apparatus for premixing gas and air, and the like. In general, given constant conditions, some apparatus for controlling quality functions fairly well at least over a minor range in the demands for the combustible product. Various uncontrolled or uncontrollable conditions, however, must be reckoned with. When premixed gas and air are employed, and the quality controlled by metering the gas and air, any change in the B. t. u. content of the gas being supplied immediately results in a change in the quality of the mixed fuel and air. As an example, many commercial gas lines deliver a mixture of natural gas and water gas. Theoretically, these gases should diffuse in such a way as to produce a homogeneous, uniform product. Actually, however, because of a certain amount of stratification or for other reasons which need not be considered, mixtures of gases delivered through pipe lines almost always show evidence of varying B. t. u. content, indicating that at one time the mixed product being supplied to the combustion equipment is richer in the high B. t. u. content gas and at another time is richer in the lower B. t. u. content gas. The same problem of nonuniformity occurs where, as in certain industrial plants, a gas storage tank is provided into which by-product gas from various sources in the industrial establishment is delivered, such as coke oven gas and the like. Here the B. t. u. content of the stored gas will vary depending upon the source of the various gases contained therein.

Another source of error so far as quality control is concerned arises by virtue of the fact that, in all quality control apparatus, various factors are encountered which will cause a change in quality depending upon the demands for fuel. As an example, where mixing apparatus is employed, making use of a Venturi throat and a forcing nozzle, surface friction and eddy currents result in considerable variation in the proportion of air and gas delivered to the manifold, when the volume is very high as compared to the time when the volume is very low. The Pitot tube, for example, is accurate only within certain limits, and, above and below the range at which it is accurate, it will either pass less gas or more gas as compared to the proportion of air than it will through the range at which it is found to be accurate. Even when the quantity of fuel being burned in a gas premix device is fairly constant, changed atmospheric conditions may cause a change in quality of combustion.

The above are merely representative of the principal causes for variation in the quality of combustion. Those skilled in the art are aware of other factors to be considered, and of the difficulty, if not impossibility, of controlling the quality of combustion by means of ordinary available mechanical metering apparatus, particularly when the range between high and low turn down or high and low demands is great.

The principal object of the invention is to provide an improved method of and means for controlling combustion.

Another object is the provision of a combustion control system which may be utilized with usual types of equipment for burning various types of fuels.

A still further object is the provision of combustion control means which may be used to supplement control devices of the general type discussed hereinabove and overcome their deficiencies with respect to extremes of fuel demands, atmospheric changes, inequalities in the character of the fuel, and the like.

In general, I secure the objects of my present invention by providing a control flame which may comprise a load burner or part of a load

burner, but is preferably independent of the load burner, and differentially operate air and fuel metering apparatus in response to changes in the quality of the flame from an established normal. Preferably, I mount a pair of electrodes in a position to be contacted by such flame, connect the electrodes into an electrical circuit of which the flame is adapted to form a part, and through such circuit control the position of quality control equipment in response to the relative position of the flame with respect to the electrodes. While the features of the invention may be applied to controlling manifold pressure, for example, or in other ways to control the quantity of fuel delivered, it has its most useful application to controlling the quality of the fuel. The control equipment, therefore, preferably comprises valve means for metering the fuel, and this is preferably operated through an electrically driven, reversible prime mover, actuated in response to electrical impulses delivered through the circuit in response to the position of the flame, it being borne in mind that, pressure being constant, the length and sometimes the width of a flame varies with the proportion of fuel as compared to the proportion of air. If a flame is lean, that is to say, contains an excess of air and is therefore oxidizing, it will be short, and, as the proportion of fuel is increased, the flame lengthens. I preferably utilize in connection with the control equipment, therefore, means for maintaining constant volume of fuel delivered to the flame utilized for control purposes, or provide means whereby to correct for differential volume. With respect to the circuit employed, I preferably use a grounded circuit, thereby making it unnecessary to insulate electrically the burner associated with the controlling flame, and, due to the fact that the flame itself is rather a poor conductor, I preferably insulate the electrodes to permit a minimum of leakage to ground, and amplify the current passing through the flame to provide adequate power for operating associated apparatus. As a further measure of control, I preferably utilize commercial voltage on the actual prime mover used to change the position of a quality damper or the like and control the delivery of commercial current to the prime mover by actuating a relay or series of relays in response to energization of that portion of the circuit which includes the flame.

The invention is shown in the drawings as applied to several different types of equipment. Additional objects and features of the invention will be apparent from a consideration of such drawings, taken with the following detailed description. In the drawings,

Fig. 1 is a fragmentary elevational view, partly in section, showing the application of the invention to the type of vaporizing apparatus shown in French Patent No. 2,113,252, the apparatus being modified, however, as to some of its structure and having associated therewith a commercial gas inlet utilizable in a manner made clear in the detailed description;

Fig. 2 is a vertical sectional view, partly in elevation, taken substantially along the line 2—2 of Fig. 1, looking in the direction of the arrows;

Fig. 3 is a plan sectional view, partly in elevation and with the parts partially broken away to conserve space, the section being taken on the line 3—3 of Fig. 1, looking in the direction of the arrows;

Fig. 4 is an enlarged sectional view taken on the line 4—4 of Fig. 3;

Fig. 5 is a sectional view taken on the line 5—5 of Fig. 4;

Fig. 6 is a fragmentary view, partly schematic, showing the relation of the control flame to the electrodes;

Fig. 7 is a diagrammatic view showing some circuit features and the relation of some of the apparatus utilized in accordance with one embodiment of the invention;

Fig. 8 shows the general arrangement of the circuit employed where a reversing motor is used to control the position of the quality control damper or the like;

Fig. 9 shows more or less schematically a modified type of installation;

Fig. 10 shows still another type of installation; and

Fig. 11 is a detailed circuit diagram showing one complete form of circuit which may be used with a reversing motor for actuating a quality control damper or the like.

Reference may be made first to Figs. 1 to 5, inclusive, showing the application of the invention to the general type of vaporizing apparatus disclosed in French patent identified hereinabove. This form of equipment is utilizable for the vaporization of relatively heavy liquid hydrocarbons, premixing the vapor so formed with air, and delivering the resulting combustible mixture to suitable load burners used, for example, to heat a bake oven, perform a carburizing operation, anneal metal parts, roast coffee, bake enamel, anneal glass lenses, or the like operations performed in industrial establishments. Commercially, this form of equipment is employed exclusively for the burning of fuel oil, or as stand by equipment for the utilization of fuel oil when commercial gas is either not available because of peak load conditions or is less economical to use. As will be shown, the premixing portion of the equipment may be employed to premix gas and air, or for the purpose of premixing liquid fuel vapor and air. The form of mixing device utilized will deliver a combustible fuel of constant quality over a fairly wide range of demand. At very high fuel demands and at very low fuel demands, the quality may suffer, or the quality may be changed slightly due to differences in the B. t. u. content of the fuel utilized.

In order that those skilled in the art may understand the application of the invention to this form of equipment, I shall first generally describe the structure and functioning thereof.

As shown, the device comprises a frame 12 carrying a heat insulated pot 13 adapted to contain a body of liquid fuel 14. At the top of the pot 13 is a firing tube 16 having a heat resisting cap 17 and flanged as at 18 to facilitate dissipation of local heat. A readily removable cap 19 carries a down-coming tube 21 which reaches below the level of fuel 14. A pilot burner 22, provided with a combustible mixture in a manner to be described, faces downwardly toward an opening in the cap 17, and delivers hot products of combustion to a point below the level of fuel 14. These hot products of combustion vaporize a portion of the liquid fuel and deliver it to an outlet 23 situated near the top and at one side of the pot 13. The fuel level is maintained by suitable means, such as a float valve 24, the fuel being delivered through a line 26 from a suitable source, and equal pressure con-

ditions being maintained by a pressure equalizing line 27. In this way, conditions maintained are constant and the proportion of oil vaporized is generally proportional to the amount of hot products of combustion delivered to the pot 13.

Air under pressure is delivered to a line 28 connected with a forcing nozzle 29, and this forcing nozzle delivers air under pressure to a Venturi tube 31 which is immediately connected to a manifold 32, leading, as shown by the legend in Fig. 1, to suitable burners. The portion at 33, immediately in advance of the venturi 31 and extending partly within the venturi, comprises a mixing chamber, and this is connected through a passageway 34 to the outlet passageway 23 of the vaporizer pot. Thus, air delivered through the forcing nozzle has the effect of entraining vapor and, as a result, a mixture of air and vapor is delivered to the manifold. As already pointed out, over a fair range of demands, this construction alone will provide constant quality, that is to say, the proportion of air to vapor will remain constant. For the purpose of extending the range, however, and providing a more complete control, additional apparatus, distinct from that relating to the present invention, is conventionally used.

Inserted through the forcing nozzle is a control bar 36 tapered at its forward end where it extends through the forcing nozzle, and being held centrally of the forcing nozzle by having its front end supported in a centrallizing bearing 37 and its rear end extending through a supporting boss on the elbow comprising the air line 28. It will be noted that the member carrying the bearing 37 is apertured to pass the combustible mixture to the manifold, the construction being such that a minimum of resistance is presented to the passage of gases. The position of the control bar 36 is adjustable in response to load demands, and it will be noted that there is a shoulder 36' which may bear against the end of the forcing nozzle and substantially entirely close the same so that little or no air is delivered. This provides for extreme turn down and it is at extreme turn down that some of the problems of quality control make themselves particularly manifest. For controlling the position of the bar 36, an air line 38 is connected at one side of the diaphragm contained in a housing 39 through a valve 41. The valve 41 is actuated by a diaphragm contained in a housing 42, the position of which diaphragm is controlled in response to manifold pressure, a line 43 being connected between the manifold and one side of the diaphragm. This general arrangement of controls is disclosed in Faverty Patent No. 2,122,683, and may be consulted by those skilled in the art for a more detailed explanation of structure. The functioning of this portion of the device, as illustrated in the drawings, is as follows:

Should some burners connected with the manifold 32 be turned off through manual or in response to automatic control, there is an immediate tendency for the manifold pressure to increase, and this affects the position of the diaphragm in the housing 42 and results in partially closing the valve 41. This decreases the pressure at the left side of the diaphragm in the housing 39, with the result that a bell crank lever 44, pivoted at 46 and pivotally connected to support 47 which in turn is connected to the diaphragm, moves in a clockwise direction and forces the bar 36 inwardly. This shuts off some of the air being delivered through the forcing nozzle, and, as a result, this air entrains less vapor, with the result that the manifold pressure, despite the lessened demand, is held substantially constant. On the other hand, if more burners are turned on, the reverse process takes place, but the manifold pressure still remains substantially constant.

Before taking up in detail the features of the present invention, I wish to call attention to the fact that the pilot burner is provided with combustible mixture through a line 48 connected, as shown, to a special cast structure 49 disposed immediately between the manifold 32 and the Venturi tube 31 and, therefore, in effect comprising a portion of the manifold. I wish also to call attention to the fact that a gas line 51 may, through the series of connections illustrated in Fig. 3, be employed for delivering gas in place of vapor to the outlet 34 and thence to the mixing chamber. Between the outlet 23 and the outlet 34, I provide a quality control valve 52, shown more in detail in Figs. 4 and 5. This is a sliding type of valve having a central opening 53 to permit maximum flow of vapor, and a slotted portion 54 connected therewith, whereby, when the valve is moved in a right hand direction, looking at Fig. 4, the amount of vapor allowed to pass is gradually diminished. Obviously the valve may be moved to entirely close off the supply of vapor should this be necessary. Between the gas inlet 51 and the outlet 34, I also provide a similar valve 52', having substantially the identical construction and functioning in substantially the same manner. These two valves may be manually controlled, or controlled in response to the position of the bar 36. I utilize these valves, however, conjointly with the control device now to be described for the purpose of positively controlling quality independently of the demands for fuel and independently of the B. t. u. content of the fuel.

Connected to the manifold 32 is a fuel line 56 shown provided with a valve 57 and leading to a burner 58. The burner has a shield 59 open at the bottom but having the effect of protecting the flame against the effect of stray air currents. At the sides of the burner are a pair of adjustable supports 61 for supporting electrodes 62. These electrodes are, as previously noted, heavily insulated electrically and preferably also thermally. As shown, insulation 63 is provided around the electrodes, and a suitable supporting cap 64 connected to the support 61 maintains the electrodes rigidly in any position to which they are adjusted. Suitable means is provided, not shown in Fig. 1, for electrically connecting the electrodes into a circuit. The electrodes are mounted in spaced relation vertically above a flame 66. The manifold 32, for reasons previously pointed out, will have a constant pressure, and, therefore, a unit volume per unit of time relation is established so far as the burner and its flame are concerned. The result is that the length or height of the flame 66 will be determined by the relative proportions of air and fuel. If the mixture is lean, the flame 66 will be short, and, if the mixture is rich, the flame 66 will be long. I utilize this fact to control the quality, placing the electrodes so that the bottom electrode is just touched by the flame and the upper electrode is above the tip of the flame when the flame is burning the quality of fuel which I wish to maintain in the manifold for delivery to the load burners. I provide electrical connec-

tions and apparatus so constructed and arranged that, if the mixture for any reason becomes lean and the flame, being shortened, no longer contacts the lower electrode, the control apparatus will function to provide a greater proportion of fuel with respect to air; and, if the flame becomes rich and contacts the upper electrode, then the opposite adjustment will be made and the flame will be brought back to a point where it touches the lower electrode but not the upper electrode. The limits of adjustment or, we might say, the tolerances permitted are determined by the space between the electrodes, it being understood, of course, that there are some limits to this adjustment if we wish to avoid having the apparatus continuing to function either one direction or the other. I find, however, that quite close adjustments may be made, for example, one-eighth to one-quarter inch distance between the electrodes, and the system will work very satisfactorily without excessive numbers of operations.

Reference may now be had to Figs. 6 and 7, as well as Figs. 1 to 5, inclusive, for the purpose of bringing out more in detail the arrangement of the electrical apparatus. In Fig. 6, I indicate the two electrodes 62 with the flame 66 shown in full lines and running just up to the lower electrode 66, and a portion of the flame 66' indicated in dotted lines and just touching the upper electrode 62. The flame, in general, will be maintained between the two electrodes, that is to say, between the upper limits of the full line portion shown in Fig. 6 and the upper limit of the dotted portion 66'.

I may employ, in connection with the present invention, a standard form of device 67, indicated schematically in the drawings, comprising amplifying apparatus actuating a relay to close or open a line circuit in response to the flow of current through that portion of the circuit connected to the amplifying apparatus. This general form of standard equipment is manufactured by several manufacturing establishments, such as the Wheelco Instrument Company and Minneapolis-Honeywell Regulator Company. The equipment is shown in their usual catalogs and is well known to the industry generally. As shown in Fig. 7, I connect one electrode 62 through a conductor 68 to one of the instruments 67 and the other through a conductor 69 to the other instrument 67. A commercial electric line, comprising conductors 71 and 72 provided with usual switch means, is connected through conductors 73 and 74 to one instrument 67 and through conductors 76 and 77 to the other instrument 67. Extending to a motor 78 is a conductor 79, common to both instruments 67, and lines 81 and 82 lead to the motor from the two instruments 67 individually, whereby to permit individual control of the motor through the medium of the two instruments. The circuit, as shown, also includes a transformer 83 disposed between the line comprising the conductors 71 and 72 and conductors 84 and 86 leading to the motor. By means of this circuit arrangement, a standard type of reversing motor 78 may be employed, capable of being controllably operated in either direction in response to energization of a circuit through the instruments 67. There are several different types of motor which may be operated in this manner, such, for example, as Barber-Colman motor E. Y. C. C. 524, a commercially available, well-known reversing motor conventionally operated on 25 volts. It is, of course, obvious that other types of reversing motors, operating on regular line voltage, may be employed.

The motor 78 is adapted to drive a shaft 87 in either direction. This shaft carries an arm 88 connected through a link 89 to the quality control valve 52 (see Figs. 1 and 3). Thus, by means of a circuit such as described in connection with Fig. 7, utilizing substantially standard, readily available equipment, employed, however, in a novel way, the position of the valve 52 may be adjusted. Considering Figs. 1 to 3, inclusive, further, it will be seen that, as shown, the equipment is connected to operate on oil vapor. If the equipment is to be operated with gas, however, the link 89 shown in Fig. 3 is removed and a suitable link, corresponding to link 89, is connected between arm 88', also carried by the shaft 87, and the valve 52' inserted in the gas line. The valve 52 may be entirely closed in order to close off the vapor outlet 23, and the pilot burner line may be closed off by closing valve 91. Thus, the equipment may be changed over to gas operation and the control of the present invention may still be utilized through simple adjustments such as described. If the change-over, for any reason, should result in the flame 66 being either longer or shorter because of the character of fuel, or, if, for any reason, any adjustment is desired in the control apparatus, the position of the electrodes 62 is readily adjusted by adjusting the support 61.

Fig. 8 shows generally a type of circuit which is suitably utilized with my invention. One end of the flame 66 is grounded at 92. One electrode 62 is connected to an amplifying device 93, such as any suitable radio amplifying tube, and the other electrode is connected to an amplifying device 94. Any suitable means may be used to assure electron flow in the flame circuit. The drawings show a conventional arrangement of choke coil and condenser connected in parallel in the conductors leading from the electrodes. This is adequate to provide a partially rectified current, and to permit the spilling over of electrons from the electrode 62 to ground when contact is made by the flame. The purpose of the circuit arrangement is to drive in either direction the motor 78, indicated schematically in the drawings. The commercial voltage line, comprising conductors 96 and 97 is connected to one side of a transformer 98 and also to one side of a transformer 99. The transformer 99, through conductors 101 and 102, supplies current to the amplifiers 93 and 94 which may be of any suitable type and are illustrated schematically in the drawings. Through suitable conductors, as shown, the amplified voltage is delivered from the amplifier 93 to a solenoid 103, and the amplified voltage from amplifier 94 is delivered to a solenoid 104. Each line is grounded to provide a return lead to the burner. The secondary of transformer 98 has its leads connected to conductors 106 and 107. Conductor 107 leads directly to the motor, while conductor 106 is connected to armature 108 associated with the solenoid 103. Normally, armature 108 makes contact with the contact point 109 leading through conductor 111 to the motor 78. A conductor 112 is connected between a contact point 113, adapted to be engaged by an armature 114, and a contact point 115 adapted to be engaged by armature 108. Conductor 116 leads to the motor 78 and is electrically connected to armature 114. The motor 78 is a conventional three-line type,

conductor 107 being common to two circuits including either conductor 116 or conductor 111.

The functioning of this arrangement, with the device as previously described, is as follows: When the flame 66 is in contact with the lower electrode 62, a circuit is established, including the solenoid 103, and armature 108 is drawn away from the contact 109, and the circuit to the motor 78 is opened. Should the flame 66 fall below the lower electrode 62, however, then solenoid 103 becomes de-energized and the armature 108 makes contact with contact member 109. This establishes a circuit which includes conductor 107, the secondary of transformer 98, conductor 106, armature 108, contact point 109, conductor 111, and the windings of motor 78. The flame being below the electrode 62, the motor should operate in a direction to open the valve 52, and, accordingly, the motor is so mounted with respect to the apparatus that the valve 52 would move in a left hand direction when looking at Figs. 3 and 4 and permit a greater proportion of fuel to be delivered to the manifold through the mixing chamber. If the equipment shown in Figs. 1 to 3, inclusive, were adjusted to burn commercial gas, the same result obviously would take place. This would cause the flame 66 to elongate due to the increased amount of fuel, and, when it reached the lower electrode 62, the solenoid 103 will be energized, drawing up armature 108, thereby opening the circuit previously identified, and stopping the motor. Should the flame become too rich and reach the upper electrode 62, then the solenoid 104 would be energized, drawing armature 114 to it and engaging the contact point 113. This would result in the completion of a circuit including conductor 117, the secondary of transformer 98, conductor 105, armature 108, contact 115 (armature 103 is actuated because the flame is in contact with the lower electrode 62), conductor 112, contact 113, armature 114, conductor 116, and the windings of motor 78. This causes the motor to be driven in the opposite direction to move valve 52 in a right hand direction looking at Figs. 3 and 4, and therefore decrease the supply of fuel delivered to the mixing chamber.

The circuit described is simplified, for the purpose of illustrating the principles involved, it being understood that any of the usual means for balancing a circuit of this general type may be used. Employing the principles explained, I have been able to obtain extremely accurate control of quality. The motor used in the circuit may be a conventional three-conductor motor wound so as to operate in either direction as determined by which pair of conductors form the circuit. I wish to point out, also, for the further guidance of those skilled in the art, that the electrodes employed may be suitably of the type produced by the Wheelco Instrument Company and known as the B. B. type. I have used this form of electrode with very good results, but other suitably constructed electrodes may, of course, be employed.

In Fig. 9, I show the application of the invention to another form of installation wherein a manifold 121, supplied, for example, with premixed gas and air, delivers a combustible mixture to a load burner 122 fed by a line 123 and controlled by a valve 124 of suitable type, either manually or in response to the control by thermally responsive equipment. Leading from the line 123 is a control burner line 126, the pressure on which is maintained constant by pressure regulating apparatus shown generally by the reference character 127. Electrodes 62 are associated with the control flame 66. The leads 68 and 69 from the electrodes extend to the controlling circuit described in connection with Figs. 7 and 8, or other suitable controlling circuit embodying the same principles. This form of installation may be utilized in those instances where no attempt is made to control within close limits the pressure on the manifold 121. It is obvious, of course, also that the leads or conductors 68 and 69, and the circuit and electrical apparatus associated therewith, may be utilized in this form of installation to control either the quality of the fuel in the manifold, the pressure of the fuel in the manifold, or both. Indeed, any usual controlling or recording device may be responsive to the position of the flame, as, for example, where it is deemed essential to record operating characteristics over a period of time, the recording mechanism may be associated with the same circuit, if desired. In the same connection, I wish to point out also that I may associate with the control device means for entirely shutting off both the air and fuel delivered to the burners, if desired. For example, looking at Fig. 1, the bar 36 may be caused to move to the right to wedge the shoulder 36' against the opening of the forcing nozzle to shut off the air, and the valve 52 may be operated to entirely close off the admission of the gas or vapor being employed. This is simply accomplished by energizing a relay in response to the motor 78 moving as far as possible in one direction. For example, if the flame 66 should be extinguished, as, for example, should it comprise a pilot flame or be mounted on the same line with a pilot flame, used to ignite a main burner, then the motor 78, when the circuit of Fig. 8 is employed, would continue to operate in the direction which it would normally take to lengthen the flame 66. Since the flame 66 would be extinguished and would not lengthen, motor 78 would continue to operate until it closed a suitable set of contacts energizing a solenoid or set of solenoids which would then be responsive to entirely shut off both the air and fuel, or the latter alone, as a safety feature. I do not, however, deem this an important feature of my present invention since the same result may be accomplished in other ways; the matter indicates, however, the versatility of the control of the present invention for substantially any purpose where it is desirable or necessary to control combustion.

In Fig. 10, I illustrate still another form of the invention wherein the upper electrode 62 is mounted on a bell crank arm 131 pivoted at 132 and adapted to move in a counterclockwise direction when a diaphragm contained in housing 133 is forced downwardly to move longitudinally a rod 134 to which the bell crank arm 131 is also pivoted. A line 136 connected to a manifold 137 and delivering fuel to a load burner 138 is connected to one side of the diaphragm by a pressure line 139. The lower electrode may be mounted stationary or it may also be associated with the arm 131 depending upon the accuracy of control desired. A control burner 141 provides a controlling flame 66 which functions in the manner previously described. The controlling flame 66 may comprise a part of the load burner, or may in itself be the load burner, depending upon the installation. The feature of this form of the invention is that the electrodes may be

moved with respect to the flame 66 in response to pressure on the manifold, and it is unnecessary to provide either a separate controlling flame supplied with combustible fuel at a constant pressure. It will be noted that, if the pressure increases on the line 136, the flame, even if of constant quality, will become elongated. If the flame is elongated due to increased pressure, the diaphragm in the housing 133 will be moved downwardly and, through the mounting shown, the electrode 62 will be moved its normal distance away from the flame to compensate for the elongation thereof due to increased pressure. Should the flame be elongated, however, independently of pressure, as, for example, due to the mixture becoming too rich, then the electrodes 62 will not move, the upper electrode will be contacted by the flame, and, through the conductor 69, the circuit will be energized to bring out proper control and leaning of the mixture in the manner described.

For the further understanding of those skilled in the art, I show in Fig. 11 a complete electrical circuit such as employed in a standard commercial type of instrument 67 previously referred to in connection with the description of Fig. 7. I deem it unnecessary to describe this particular circuit in detail, the parts previously described being identified by reference characters so that the relationship of the parts and the various connections are clear to those skilled in the art familiar with conventional showings of electrical circuits. I might add that the transformer arrangement is somewhat modified, resistances and condensers are shown for balancing the circuit, and a separate set of conductors is shown associated with relay apparatus for controlling pilot lights 143 which, while conventionally used, are not essential so far as the operation of the control equipment is concerned.

From the above description, it should be clear to those skilled in the art that my invention is not limited to use with any particular kind of apparatus or with any specifically detailed type of electrical apparatus and circuit arrangement associated therewith. While the use of two electrodes, each connected into a separate portion of the circuit so as to provide substantially a balanced arrangement, is advantageous and preferred for substantially all types of installations, I may employ only a single electrode or more than two electrodes while still utilizing the same novel features. By employing a single electrode, and driving a control motor in one direction when the flame touches the electrode and in the opposite direction when the flame is out of contact with the electrode, I may control quality in substantially the same manner. The use of a single electrode in the manner described, however, has the disadvantage that the motor will at all times be moving in either one direction or the other. In the case of two electrodes, however, if conditions are maintained constant, the flame tip will reach a point between the two electrodes and stay there with the result that the motor may not be actuated at all for a relatively long period of time. There is also the factor of lag to be considered, as, for example, in the case where there may be only a momentary increase or decrease in the proportion of fuel delivered. If only a single electrode is used, a temporary unstable condition is more apt to let the motor overrun and produce faulty adjustment in the opposite direction. More than two electrodes may be employed to further stabilize the operation and eliminate the results of lag in extreme cases by, for example, operating a second motor for controlling an additional valve, to speed up the motor, or to compensate for changed load conditions in a system which does not provide for substantially constant manifold pressure. As an example, in place of a mechanical correction for changed pressure of the type shown in Fig. 10, I may, for example, employ three electrodes, the two lower of which would be utilized on low manifold pressure and the two upper of which on high manifold pressure. I deem these to be representative of obvious modifications which those skilled in the art will understand, given the principles on which my invention is based, and a general consideration of these modifications facilitates an understanding of those principles.

In pointing out the general features of the invention hereinabove, I made the statement that means were provided, responsive to change in the character or quality of the control flame, for differentially operating air and fuel metering apparatus. This obviously may involve operating either or both the air and fuel metering apparatus. The detailed description, including, as it does, the use of flame contacting electrodes for operating a motor in either direction, is not to be construed as indicating that the general principles of the invention cannot be carried out in other ways. It will be apparent that, as the length of a flame varies, other factors, such as color, vary. It is not essential, therefore, that a flame contacting electrode operate the circuit. A photo cell, responsive to flame length, may be used, for example, by interposing a prism or other light forming means, to focus light from the flame onto the cell. I may also employ cells responsive to color variations. In any case, the same general circuit arrangement may be used.

I wish to point out, also, that by the term electric motor, I do not wish to confine myself to the use of the ordinary motor construction using a stator and rotor. The quality control apparatus may be operated by any electrically actuated prime mover, employing, for example, solenoids or similar magnetic devices.

I have described the invention in considerable detail illustrating several different forms of installation, including, in the case of Figs. 1 to 3, inclusive, detailed apparatus, so that those skilled in the art will have no difficulty in fully understanding both the construction and operation as applied to different types of installations. Those skilled in the art will understand, however, that the invention is not limited to the particular kinds of installation shown but may be used for the purpose of controlling combustion of any of the usual forms of fuel in substantially any of the usual forms of combustion equipment. It seems to have its greatest value, however, where premixed air and vaporous fuel (gas or vaporized oil) are delivered to load burners, and a separate control flame, burning a constant volume of the premixture, differentially actuates the air and fuel metering apparatus in response to the length of the control flame. Substantially constant quality is thereby preserved on the load burners. Any tendency for the quality to change is immediately effective to vary the quality of the control burners. The apparatus then acts to again establish the normal predetermined quality. This is adjustable by positioning the electrodes ac-

cordingly, and the normal established may be rich, neutral or lean, as determined by the demands of an installation.

The term "vaporous fuel," as employed in the claims, is not intended to be limited to a true vapor, but rather to include any fuel which burns with the general characteristics of a vapor. The above specification is believed clearly to bring out the characteristics which are, in general, found in a flame resulting from the burning of a vapor, which characteristics are utilized in the manner defined in the claims, in the practice of the invention described.

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

1. The method of controlling the proportion of fuel to air in a combustion system, whereby to control the quality of combustion, which comprises providing a pair of electrodes at a flame tip spaced unequal distance therefrom, connecting said electrodes into electrical circuits including said flame, either or both of said circuits being energized by the flame touching either or both electrodes, controlling the delivery of fuel to said system in response to energization of either or both of said circuits in such a manner as to place the tip of said flame between the electrodes, and controlling said flame and electrodes to correct for any differences in flame length due to the quantity of fuel being burned in the system.

2. In combustion apparatus, means to provide a controlling flame, means to deliver a constant volume of combustible mixture to said flame providing means, whereby the length of said flame is proportional to the quality of said combustible mixture, a pair of electrodes, each having its longitudinal axis crosswise of the axis of the flame, one electrode positioned so as to be touched by the tip of the flame when the combustible mixture is of a desired quality, and the other spaced therefrom and in the path of said flame if elongated, means for controlling the quality of the combustible mixture, and electrical circuit means including said electrodes for adjusting the quality control means to maintain the flame substantially with its tip in contact with the first mentioned electrode but not in contact with the second mentioned electrode.

3. In combustion apparatus, a flame adapted to be maintained at predetermined length but variable as to length in response to quality of a combustible mixture supplied thereto, two electrodes spaced from each other along the flame path, one of which is adapted to be contacted by said flame, and means responsive to the relative positions of said flame and electrodes for maintaining, at predetermined quality, the combustible mixture delivered to said flame, said means operating to maintain one electrode in the flame and one out of the flame when the flame has one quality, both said electrodes being in the flame when the quality of the flame changes.

4. In combustion apparatus, a manifold, a burner supplied with fuel from said manifold for producing a control flame, valve means for controlling the delivery of fuel to said manifold, a reversing motor connected to said valve means for opening and closing said valve means as determined by the direction of movement of said motor, a pair of spaced electrodes positioned near said flame, one or both of which are adapted to be contacted thereby depending upon the volume of the luminous portion of the flame, circuit means, including said electrodes, said circuit means including relays for energizing said motor to drive in either direction, the said circuit being so arranged that, when neither electrode is contacted by the flame, a relay is actuated to energize said motor to move in one direction; when both electrodes are contacted by the flame, a relay is actuated to energize said motor to move in an opposite direction, and, when only a single electrode is contacted by the flame, said circuit means acts to deliver no current to the motor, whereby the effect is substantially to maintain said flame in contact with only a single electrode.

5. In combustion apparatus, a control flame, means to deliver a constant quantity of combustible mixture thereto, whereby said flame will vary in length as quality of said combustible mixture is changed, load burner means supplied with the same combustible mixture as that delivered to said control flame, and means responsive to the length of said flame for controlling the quality of combustible mixture delivered to said load burner means.

6. The method of operating a combustion system, comprising a manifold, and means to deliver air and vaporous fuel thereto separately whereby to premix the same in predetermined relationship in said manifold, which method comprises burning a uniform volume of the premixed air and vaporous fuel to produce a control flame, whereby said flame is adapted to change in character only in response to a change in the said predetermined relationship between air and vaporous fuel, providing means for detecting a change in the character of said flame indicating a change in the said predetermined relationship of air and vaporous fuel, and differentially operating said delivery means in response to the change in the character of said flame to return the same to its predetermined character, whereby the relation of air to vaporous fuel premixed in said manifold is controlled.

7. The combination, with a combustion system, of means for maintaining substantially a predetermined relationship between the proportion of air and fuel burned, which combination comprises a manifold, means for delivering air and vaporous fuel to the manifold to produce a premixed combustible vaporous product, valve means for separately metering at least one of the products air and vaporous fuel, load burner means adapted for burning the said vaporous product in accordance with load demands, a control burner for producing a control flame, means for delivering a constant volume of vaporous product to said control burner whereby the character of said control flame is unaffected by varying pressures in said manifold, a reversing motor connected to drive said valve means in either direction, separate circuits including windings of said motor, the energization of one of which will drive said motor in one direction, and the energization of the other of which will drive said motor in an opposite direction, means for closing one motor circuit in response to a change of character of said flame in one direction, and means for closing the other of said circuits in response to change in the character of said flame in another direction, whereby to maintain substantially constant characteristics of said flame.

8. In a combustion system, a manifold, means for delivering air to the manifold, and means for delivering vaporous fuel to the manifold, whereby to produce a premixture of air and fuel,

load burners for burning said premixture, a burner, means for delivering a constant volume of the premixture to said burner whereby to produce a control flame, the length of which is affected by quality only, a pair of electrodes mounted in spaced relation along the path of the control flame, and electric circuit means, including said electrodes and the flame, for differentially operating the air and fuel delivery means, said circuit being ineffective when the flame contacts only one electrode, whereby the relative proportions of air and fuel will substantially be maintained such that said flame will touch only one electrode and a predetermined quality of fuel will be delivered to the load burner, and whereby any deviation from the established predetermined quality will immediately be corrected.

9. A system as defined in claim 8, including means for independently adjusting the positions of said electrodes whereby the quality of the premixture may be determined by their position, as well as the degree of departure from the predetermined mixture effective to operate said control means.

10. A system as defined in claim 8, wherein said circuit means includes grounded voltage carrying circuits including said electrodes and said flame, means for amplifying electric current flowing in either of said circuits when closed by the flame contacting the electrode of the circuit, prime mover means for controlling said air and fuel delivery means, an electric circuit including the prime mover, and relays operated by the said amplified circuit for controlling the energization of the prime mover circuit.

11. In a combustion system, a pair of spaced electrodes adapted to be successively contacted by a flame as said flame lengthens, means for producing a flame the length of which, with respect to the position of the electrodes, is responsive only to change in the quality of the combustile mixture delivered to it, energized circuits including each electrode, an amplifying circuit for each electrode circuit, a metering device, a motor connected to operate said metering device, said motor having one set of windings to drive the same in one direction, and another set of windings for driving the same in an opposite direction, two relays, each effective to control energization of one set of motor windings, and connections established by operation of said relays through amplified current in the amplifying circuits, whereby when neither electrode is in contact with the flame and neither relay operated, one set of motor windings is energized; when on electrode is in contact with the flame and one relay is energized, neither set of motor windings is energized; and when the electrodes are both in contact with the flame and both relays are energized, the said other set of motor windings are energized.

MARK C. BATES.