March 6, 1934. E. S. BRISTOL 1,949,736

METHOD OF AND APPARATUS FOR COMBUSTION CONTROL

Filed March 31, 1930 2 Sheets-Sheet 1

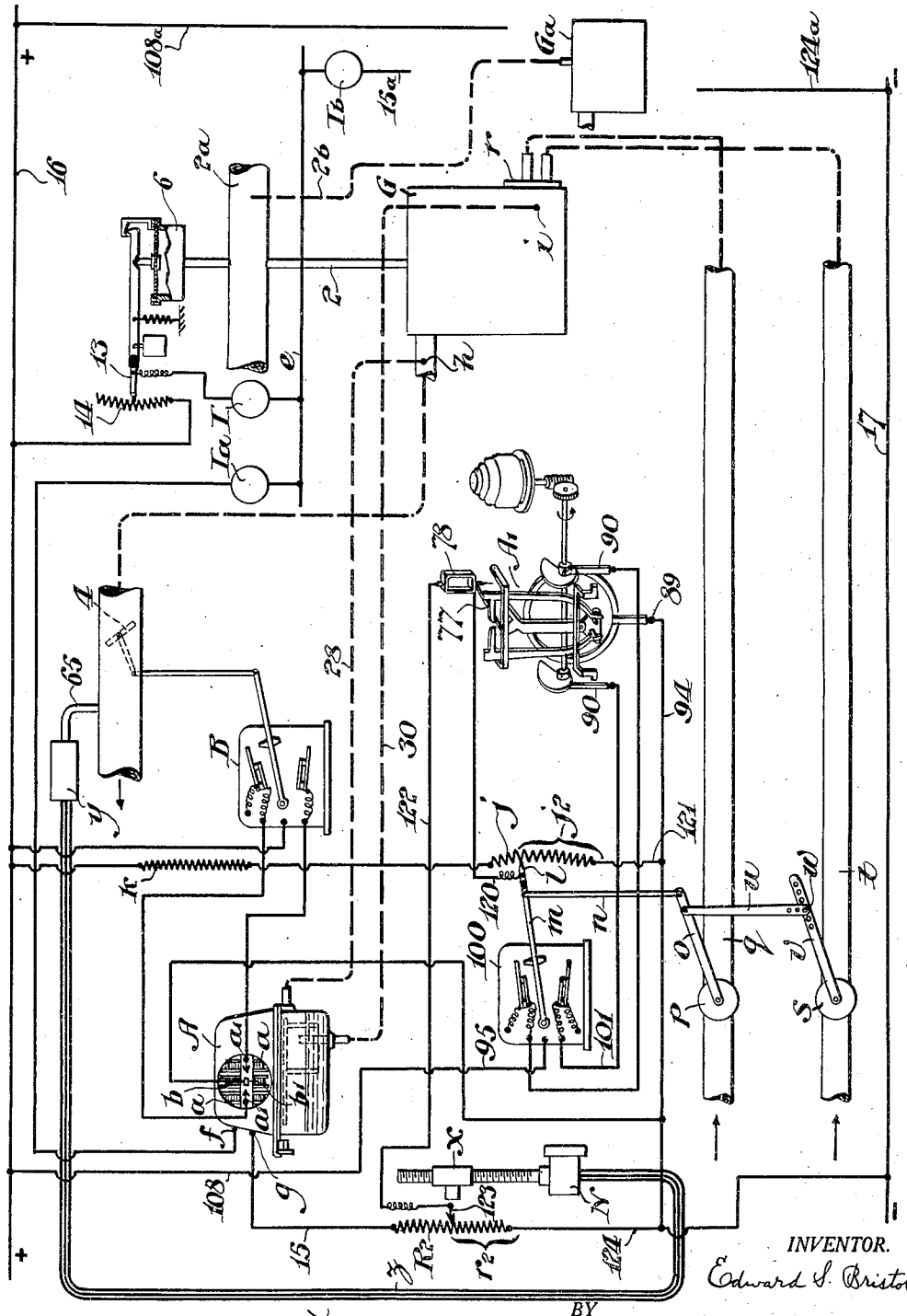


Fig. 1.

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Fig. 2

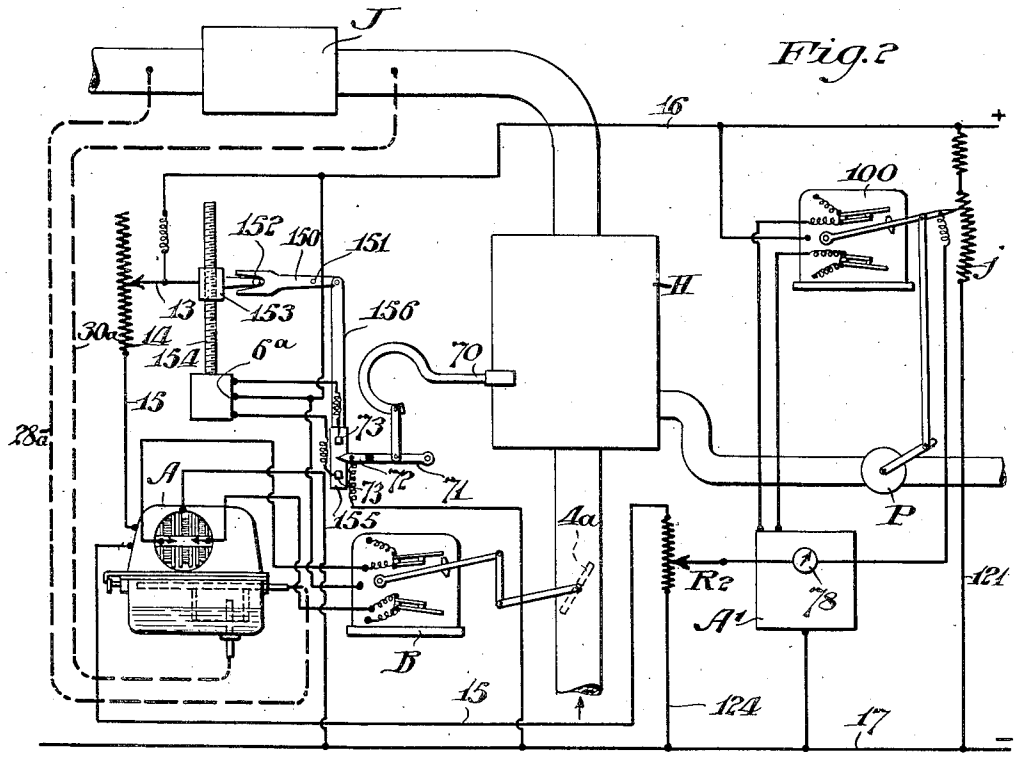
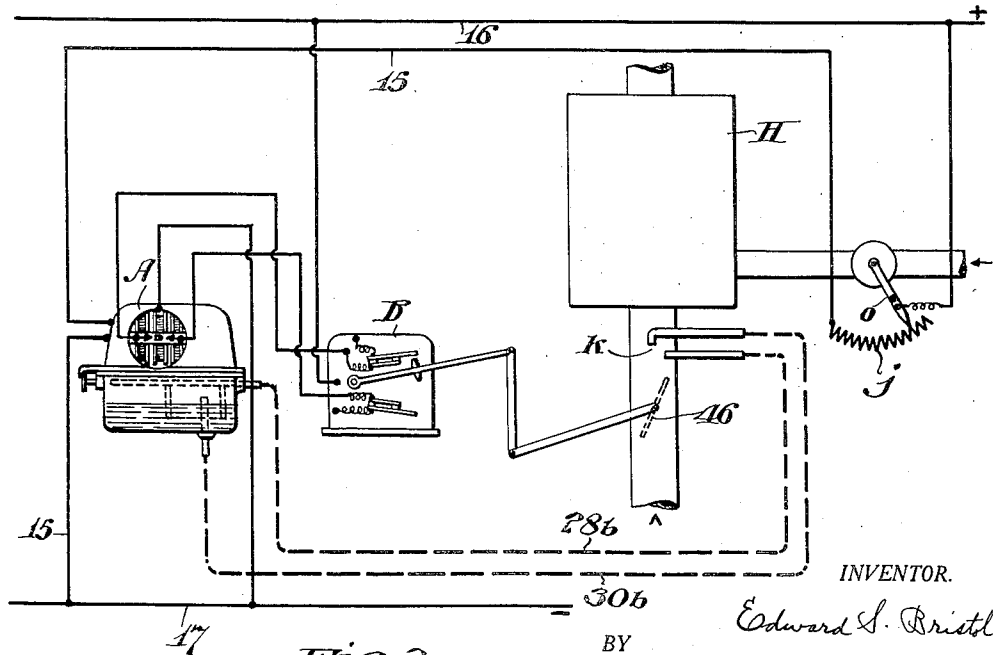


Fig. 3.



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UNITED STATES PATENT OFFICE

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METHOD OF AND APPARATUS FOR COMBUSTION CONTROL

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Application March 31, 1930, Serial No. 440,596

11 Claims. (Cl. 236—14)

My invention relates to a method of and apparatus for combustion control in a steam generator, furnace, or the like.

In accordance with my invention, there is developed and maintained a control force proportional to the required combustion rate, a second force developed dependent upon the position of a combustion-regulating element and balanced against the first force, and a third force developed dependent upon the rate of air supply for combustion and also balanced against the first force.

Further in accordance with my invention, an electromotive force is developed and varied in accordance with variations in the required combustion rate, and such force utilized to control the rate of air supply for supporting combustion.

Still further in accordance with my invention, an electromotive force is developed and varied in accordance with variations in the required combustion rate, such force utilized to control the rate of supply of an agent contributing to combustion, and such force modified in accordance with variations in a condition incident to combustion such as variations in the composition of the gases of combustion, more specifically, variations in CO_2 content of the latter.

My invention resides more particularly in a system for combustion control comprising apparatus such as a steam generator or furnace for burning fuel, suitable means regulating rate of air supply to support fuel combustion in such apparatus, adjustable means regulating rate of fuel supply to such apparatus, and means governing regulating action of the air-regulating means and including a calibrated electrical resistance adjustable with the fuel supply means, the calibration of the resistance being such as to provide for substantially correct proportionment of rate of air supply to rate of fuel supply at the various positions of adjustment of the fuel supply means.

My invention resides in the method and apparatus hereinafter disclosed and claimed.

For the purpose of illustrating my invention, several embodiments thereof are shown in the drawings, in which

Fig. 1 is a schematic showing of a system constructed and operated in accordance with my invention, and

Figs. 2 and 3 are similar views showing modifications.

In Fig. 1 is shown a combustion control system of the same general character as the system disclosed in my co-pending application Serial No. 116,776, filed June 18, 1926, and the various parts and connections have been designated by the same reference characters designating corresponding parts and connections in said application.

That part of the construction and operation of the system in Fig. 1 which is well known in the art and to which no claim is made per se, will first be described, after which the various parts and the method of operation provided thereby, which, in combination with the former constitutes my present invention, will be described.

The steam generator or fuel-burning apparatus G is connected by a pipe line 2 to the steam header 2*a*, the rate of combustion in such apparatus controlled by variations in current in an electric control circuit comprising a master control rheostat 14 connected to the voltage supply line 16, the master control bus *e*, connection 15, resistance R2, and connection 124 connected to the voltage supply line 17. A suitable fluid-pressure motor 6 is connected to header 2*a* and operates to change the position of the master control contact 13 in accordance with variations in the header pressure occurring upon variations in load demand, the arrangement being such that upon increase in load demand contact 13 is moved downwardly the proper amount to increase the current in the control circuit, this contact moved upwardly to decrease the control current upon decrease in load demand and in amount corresponding to such decrease.

The combustion rate in generator G is controlled by the stack damper 4 actuated by the damper drive unit B which may be of any suitable construction and comprises the usual reversible driving motor connected across lines 16 and 17 by an air-flow controller A comprising coils *a* and *b* connected in series with respect to each other, such series having terminals *f* and *g* whereby the same is connected as shown in series with connection 15 forming part of the control circuit. The coil *b* controls movement of a contact *b*1 and is pivotally supported for movement between coils *a* which are fixed, contact *b*1 engaging with either of the fixed contacts *a*1 to effect proper connection of the damper drive unit B across the voltage supply lines to effect operation thereof in one direction or the other as the case may be, and corresponding adjustment of damper 4. The movable coil *b* is urged in a clockwise direction by a force proportional to the current in the control circuit and which is representative of the required combustion rate in generator G, and is urged in a counter-clockwise direction by a second force balancing the first force and which is representative of the rate of

flow of the gaseous products of combustion through the generator. The second force is equal to the pressure differential between the points *h* and *i* to which controller A is connected by pipe lines represented respectively by the broken lines 28 and 30. When the control current varies in one sense or the other, controller A is out of balance and movable coil *b* moved in the corresponding direction to effect adjustment of damper 4 in such wise that the draft through generator G is changed and the pressure differential between points *h* and *i* varied in such sense that the second force referred to again balances the first force to cause return movement of coil *b* to its central or neutral position with respect to fixed coils *a* whereat contact *b*1 is out of engaging relation with the fixed contact *a*1 it had just engaged. The construction and manner of operation of the air-flow controller A is described in detail in my co-pending aplication 234,410, filed November 19, 1927.

Coming now to description of the various parts and connections which, in combination with those just described, provide for my present improved method of and system for combustion control, a resistance *j* is connected through the series resistance *k* across lines 16 and 17, and is provided with an adjustable contact *l* carried by the arm *m* of a motor drive unit 100 similar to unit B and which is connected by connections 95 and 101 to the fixed contacts 90 of a controller or control mechanism indicated generally by reference character A1 and which is shown as being of the general type described in detail in Patent 1,332,182 of February 24, 1920, to Leeds. Controller A1 comprises the fixed contact 89 connected to supply line 17 by connection 94, and the galvanometer 78 having the usual needle 77. The galvanometer is connected to contact *l* by connection 120, and to the adjustable tap or contact 123 associated with resistance R2 by connection 122. That part or section *r*2 of resistance R2 below contact 123 in any position of adjustment thereof, connection 122, galvanometer 78, connection 120, contact *l*, that part or section *j*2 of resistance *j* below contact *l* in any position of adjustment thereof, connection 121 and connection 124, constitute a balanced circuit, the voltage across resistance section *j*2 acting in opposition to and balanced against the voltage across resistance section *r*2. As is well known, when galvanometer 78 of controller A1 is connected in a circuit of the character shown and balanced conditions exist, the needle 77 is at rest in a neutral position whereat the controller is non-effective with respect to the various parts controlled thereby, but upon unbalancing of the circuit in one sense or the other, the needle deflects in the corresponding direction to effect controlling action of the controller in the proper sense such that electrical connection is made between contact 89 and one of the contacts 90, and motor drive unit 100 accordingly connected across lines 16 and 17 for operation in the proper direction. In the present system, upon increase in load demand and operation of master controller 14 in the usual manner to effect corresponding increase in the control current, the drop across resistance section *r*2 increases in amount directly proportional to the degree of increase in the control current, whereby the galvanometer circuit is out of balance and needle 77 deflected to cause operation of motor drive unit 100 in such direction that the associated arm *m* is rotated in a counter-clockwise direction to effect upward adjustment of contact *l* and corresponding increase in the voltage drop across resistance section *j*2 until such drop balances the increased drop across resistance section *r*2. Needle 77 then returns to neutral position. The arm *m* is connected by a link *n* to an arm *o* adjustable to control rate of combustion in generator G by controlling rate of fuel supply thereto. In the embodiment of my invention shown, arm *o* controls the position of a suitable rotary valve *p* in an oil supply line *q* leading to the burner structure *r*, the oil pressure on the supply side of the valve being substantially constant. There is, therefore, a definite position of valve arm *o* for each value of control current flowing through resistance R2 since any variation in such current will cause unbalancing of the galvanometer circuit and corresponding adjustment of contact *l*, as explained, to adjust the oil supply valve while at the same time changing the amount of resistance section *j*2 in the proper sense to rebalance the galvanometer circuit.

Resistance *j* is calibrated in such wise that for any voltage drop across resistance section *r*2 the movement of arm *m*, necessary to change the amount of resistance section *j*2 so that the galvanometer circuit will again be balanced, places valve arm *o* in a new and corresponding position whereat there is substantially correct proportionment between the new rate of air supply called for and the new rate of fuel supply. In other words, the calibration of resistance *j* is such as to provide for proportionment of rate of air supply to rate of fuel supply at the various positions of adjustment of the fuel supply means such as the oil valve *p*. From the foregoing it will be seen that the voltage drop across resistance section *j*2 represents a force which is balanced against the control force proportional to the required combustion rate and which is represented by the current value in the control circuit.

A valve *s* controlling supply of steam to burner *r* from a steam line *t* may be connected by a link *u* to the oil valve arm *o* for movement therewith, the link and valve arm *v* provided with suitable openings as indicated for any desired adjustment of the connecting pin *w* to obtain proper proportionment between oil supply and steam supply to burner *r*.

The proportionment between rate of air supply and rate of fuel supply may be changed by adjusting contact 123, and such adjustment may be effected automatically in accordance with any suitable index of combustion efficiency such as CO_2 content of the flue gases, furnace temperature, or ratio of boiler steam flow to air flow. In the system shown, contact 123 is adjustable by suitable screw-and-nut mechanism *x* driven by a reversible pilot motor N controlled by a CO_2 compensator unit or system indicated generally by reference character *y* and which may be of the same general type disclosed in Patent No. 1,753,319, of April 8, 1930, to Schofield et al. The compensator system is connected in the usual manner to the exhaust stack by connection 65. The pilot motor N and connection 65 correspond to and are designated by the same reference characters as such motor and connection in said patent. The necessary electrical connections between system *y* and motor N are disposed in a suitable cable *z*.

The action is such that upon varation in the CO_2 content in either sense the compensating unit or system *y* responds to effect operation of motor N in the proper direction to adjust contact

123 until the proportion of rate of air supply to rate of fuel supply is changed to such value whereat the CO_2 content is again normal.

It will be understood that a CO_2 compensator of any suitable construction or type may be used and that instead of responding to variations in CO_2 content of the flue gases, the compensating system may be of another type and responsive to furnace temperature, ratio of boiler steam flow to air flow, or any other suitable index of combustion efficiency.

The valve *p*, instead of controlling rate of oil supply, may be a throttle valve for a steam turbine or engine driving suitable fuel feed supply mechanism for generator G or a draft fan. Further, the link *n*, instead of being connected to valve arm *o*, may be connected directly to a suitable speed-regulating rheostat for an electrically driven auxiliary.

As indicated to the right of the drawing, a second complete steam-generating system, including generator G*a* and the connections 2*b*, 108*a*, 15*a* and 124*a*, corresponding to the connections for generator G designated by similar reference numerals, may be connected as shown to supply lines 16 and 17 and the master control bus *e*, and controlled by the master controller 14.

Suitable indicating, recording or integrating ammeters I, I*a* and I*b* may be connected as shown in the control circuit, ammeter I operating to register the strength of the total control current and ammeters I*a* and I*b* operating to register the strength of the current in the respective control circuits for generators G and G*a*. Other steam-generating systems may be connected in a similar manner and controlled by the master controller 14.

In the system shown in Fig. 2, the arrangement and manner of operation is the same generally as that in Fig. 1, except that the contact 13 of master controller 14 is adjusted by a reversible electric motor 6*a* in response to variations in the temperature in a heating furnace H from a predetermined standard. For this purpose, a suitable pressure bulb thermometer 70 is associated with the furnace as indicated, and is responsive to the temperature of combustion therein or the temperature of the product being heated in the furnace. The action is such that upon variation in the furnace temperature or temperature of the heated product in either sense from a predetermined standard, arm 71 is moved in one direction or the other to engage a movable contact 72 with one or the other of the associated contacts 73. Motor 6*a* is thereby connected across lines 16 and 17 for operation in the proper direction to vary the control current and effect adjustment of damper 4*a* through the agency of the air-flow controller A and the associated damper drive unit B. Through the reduction lever 150 pivoted at 151 and having the bifurcated end shown receiving lug 152 carried by the nut 153 on screw 154 driven by the motor, and the insulating block 155 on which contacts 73 are mounted, and which is connected by link 156 to lever 150, the contacts 73 are moved simultaneously upon operation of the motor and in such direction that the contact engaged by movable contact 72 is moved out of engaging relation with the latter. The combustion rate is accordingly varied in the proper sense until temperature conditions in furnace H are again restored to normal, whereupon contact 72 is returned to its intermediate position shown out of engaging relation with the contact 73 it had just engaged.

In this modification, the controller A is shown as being responsive through connections 28*a* and 30*a* to the pressure differential between points in the stack at the inlet and outlet ends of a waste heat boiler J through which the gases of combustion pass. The various units, parts and connections in this figure are designated by the same reference characters designating corresponding units, parts and connections in Fig. 1.

In Fig. 3 adjustment of the oil valve arm *o* is manual, and the air-flow controller A made responsive, through connections 28*b* and 30*b* and a suitable Pitot tube arrangement K, to variations in rate of air supply to furnace H. As in the systems in Figs. 1 and 2, the resistance *j* is calibrated so that for each manual adjustment of arm *o* to vary the rate of fuel supply, variation in current in the control circuit 15 is such as to effect adjustment of damper 4*b*, by drive unit B and controller A, to provide proper proportionment between the rate of air supply and the new rate of fuel supply.

Various changes such as in the size, shape, and arrangement of the parts may be made without departing from the spirit of my invention or the scope of the claims.

What I claim is:

1. In a system of the character described, apparatus for burning fuel, an electrical control circuit, means responsive to current conditions in said circuit and operable in accordance with variations in such conditions to control rate of air supply to support fuel combustion in said apparatus, adjustable means controlling actual rate of fuel supply to said apparatus and operable upon adjustment to vary such rate, and adjustable resistance means forming part of said circuit and having a contact mechanically coupled to said last-named means to effect variation in current conditions in said circuit simultaneously with variation in the actual rate of fuel supply.

2. In a system of the character described, apparatus for burning fuel, a closed conduit for supplying fluid fuel to said apparatus, means regulating rate of air supply to support fuel combustion in said apparatus, valve structure for controlling the rate of flow of fluid fuel through said conduit, and means governing regulating action of said air-supply means and including calibrated electrical resistance means adjustable concurrently with said valve structure, the calibration of said resistance means being such as directly to provide for proportionment of rate of air supply to actual rate of fuel supply at the various positions of adjustment of said fuel supply means.

3. In a system of the character described, apparatus for burning fuel, a voltage supply line, an electrical control circuit connected across said line, means operable to vary the resistance in said circuit in accordance with variations in load demand on said system, means controlling rate of air supply to said apparatus in accordance with variations in such resistance, adjustable means controlling actual rate of fuel supply to said apparatus, a balanced circuit comprising part of said control circuit, means responsive to conditions of unbalance in said circuit and operable upon occurrence of such conditions to effect adjustment of said fuel supply means, adjustable resistance means connected across said line and forming part of said balanced circuit, and means for effecting adjustment of said resistance means concurrently and

in accordance with adjustment of said fuel supply means.

4. A combustion control system comprising means for producing a force whose magnitude is a function of the rate of supply of a component of a combustible mixture, movable structure for controlling the supply of another component of said mixture, means for producing a second force whose magnitude is determined by the position of said structure, means for producing a third force whose magnitude is representative of a desired rate of combustion, means responsive to unbalance of said first and third forces for controlling the rate of supply of said first component, and means responsive to unbalance of said second and third forces to change the position of said structure, a change in magnitude of said third force effecting substantially simultaneous and measured responses of both responsive means.

5. A combustion control system comprising a source of current, a regulator for controlling the supply of combustion air responsive to unbalance between forces which are direct functions of the actual rate of supply of air and current from said source, a resistance variable in accordance with changes of a combustion effect to vary the current through said regulator to effect corresponding changes of combustion air, adjustable valve structure in a fuel supply line, and means for changing the position of said structure in accordance with said combustion effect and to maintain proper relations of fuel and air comprising a pair of resistances, one of which is traversed by substantially constant current and has an adjustable contact coupled to said valve structure, and the other of which is traversed by current of magnitude determined by said first resistance, and means connected between said contact and a point of the other of said pair of resistances responsive to unbalance of potentials thereof to effect movement of said valve structure and said contact.

6. A combustion control system comprising a pair of resistances having adjustable contacts, valve structure in a fuel supply line coupled to one of said contacts, means responsive to unbalance of the potentials of said contacts to change the positions of said valve structure and coupled contact, means responsive to changes in a combustion effect for changing the current through one of said resistances to unbalance said potentials, and means responsive to change in combustion efficiency for changing the position of the other of said adjustable contacts.

7. A combustion control system comprising a pair of resistances having adjustable contacts, valve structure in a fuel supply line coupled to the contact of one of said resistances, means responsive to unbalance of the potentials of said contacts to change the positions of said valve structure and coupled contact, a regulator for controlling the supply of combustion air responsive to unbalance between forces which are direct functions of the rate of supply of air and control current traversing the other of said resistances, means responsive to changes in a combustion effect to vary the current through said regulator to change the rate of supply of air and to unbalance said potentials to change the position of said valve structure, and means responsive to change in combustion efficiency to change the position of the other of said contacts thereby to vary the ratio of fuel to air.

8. A combustion control system comprising a fixed resistance traversed by current of substantially constant magnitude, a second fixed resistance, a third resistance adjustable to vary the current traversing said second fixed resistance in accordance with changes of a combustion effect, and means responsive to difference in potential between points of said first and second resistances to effect a change in the rate of supply of a component of a combustible mixture.

9. A combustion control system comprising a source of current, a regulator for controlling the supply of combustion air, traversed by current from said source and responsive to unbalance between forces which are direct functions of said current and the rate of supply of air, adjustable valve structure in a fuel supply line for controlling the rate of supply of fuel, and an adjustable resistance in circuit with said source and said regulator and having its adjustable element coupled to said valve structure whereby change in position thereof changes the current through said regulator to effect a corresponding measured change in the rate of supply of air.

10. A combustion control system comprising a fixed resistance traversed by current of substantially constant magnitude, a second fixed resistance, a third resistance adjustable to vary the current traversing said second resistance in accordance with changes of a combustion effect, valve structure for controlling the rate of supply of a component of a combustible mixture, an adjustable contact for said first resistance coupled to said valve structure, and means connected between said contact and a point of said second resistance and responsive to unbalance of the potentials thereof for concurrently changing the positions of said contact and said valve structure.

11. In the art of combustion control, the method which comprises varying an electromotive force in accordance with the changes in position of valve structure controlling the rate of flow of fluid fuel, and varying the rate of supply of combustion air solely in accordance with said force to maintain the ratio of the rates of flow of air and fluid fuel substantially constant.

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