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FURNACE REGULATING SYSTEM

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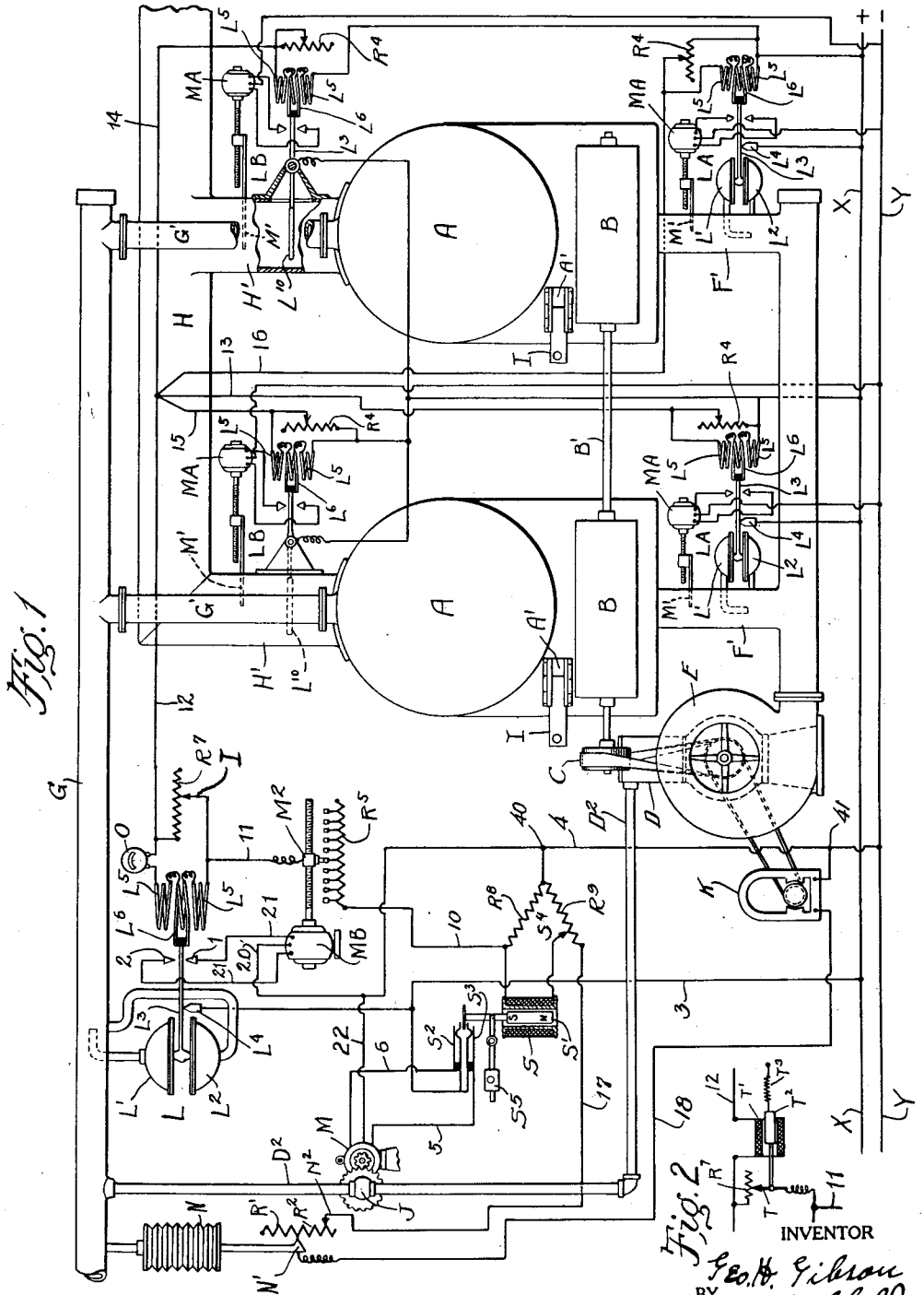


Fig. 1

Fig. 2

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UNITED STATES PATENT OFFICE

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FURNACE-REGULATING SYSTEM

Original application filed September 22, 1916, Serial No. 121,547, now Patent No. 1,537,044, dated May 5, 1925. Divided and this application filed March 17, 1925. Serial No. 16,213.

The general object of my present invention is to provide an improved apparatus for regulating combustion in furnaces and particularly in boiler furnaces. A more specific object of the invention is to provide improved means for automatically varying the rate of combustion in accordance with the boiler load; and the invention is characterized by the provisions whereby the rate of fuel feed and the rate of air feed are automatically controlled by boiler load conditions so as to vary the ratio of these two feeds on certain variations in said conditions.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification; but for a better understanding of the invention, its advantages and specific objects attained by it, reference should be had to the accompanying drawings and descriptive matter in which I have diagrammatically illustrated and described preferred embodiments of my invention.

Of the drawings:

Fig. 1 is a diagrammatic representation of a steam generating plant in which the fuel and air supplied to the combustion chambers of the boiler furnaces are automatically controlled in accordance with the present invention; and

Fig. 2 represents a modification of a portion of the apparatus of Fig. 1.

In Fig. 1, I have illustrated the use of my invention in a steam generating plant comprising two generating boilers A provided with automatic stoker mechanisms B which comprise a common operating shaft B′ shown as driven through a belt C from a steam motor D which receives its motor fluid through the branch pipe D^2 from the steam main G. The steam space of each boiler A is connected to the main G through a corresponding steam pipe G′. The stoker motor D also drives a blower E which supplies air to the under side of the grate for each boiler A, through a branch air supply pipe F′. The smoke pipes H′ from the two furnaces are connected to a common chimney connection H. Atmospheric air is supplied to the combustion chamber of each boiler above the grate through a corresponding opening or openings A′. As shown the openings A′ may be regulated in size by the dampers I.

The speed of the stoker motor D, and thereby the rate at which coal is supplied to each boiler furnace by the corresponding stoker B, is automatically proportioned to the rate at which steam is withdrawn from the boilers and to the pressure of this steam. The means which I employ for accomplishing this result comprise an electro-magnetic master flow balance L which includes a fluid pressure motor responsive to the volume of flow in the steam pipe G, and an opposing electro-magnetic motor. In the diagramamtic form illustrated, the fluid pressure motor of the device L is formed by a pressure chamber L′ connected to a Pitot tube extending into the steam supply pipe G, and a pressure chamber L^2 to which the static pressure in the pipe G is transmitted. A lever L^3 mounted on a fulcrum block L^4 is connected at one end to the opposed diaphragms or flexible walls of the chambers L′ and L^2, and carries at its other end a floating coil L^6 which in conjunction with the co-operating pair of stationary coils L^5 connected in series with the coil L^6 forms the electro-magnetic motor or dynamometer of the balance L.

An electric current is passed through the coils L^5 and L^6 of the balance from a suitable source of current, as for instance, from supply circuit conductors X and Y. As shown, one terminal of the coils L^5 is connected to the supply conductor Y by a conductor 4, a resistance R^8, a conductor 10, a rheostat resistance R^5, a rheostat contact M^2, and a conductor 11. The other terminal of the coils L^5 is connected to the supply conductor X by a conductor 12 and branches 13, 14, 15, and 16. The amount of the resistance R^5 in circuit between the conductors 10 and 11 is varied by a reversible motor MB having a threaded spindle working in a nut carrying the contact M^2.

The lever L^3 of the balancing device L controls the operation of the rheostat motor MB, causing the latter to rotate in the one direction or the other to thereby vary the

resistance R^5 in the circuit 10 as required to normally maintain the balance lever L^3 in its intermediate or neutral position in which the electro-magnetic interaction of the stationary and floating coils L^5 balances the fluid pressure differential to which the lever L^3 is subjected by the diaphragms of the chambers L' and L^2. Whenever the fluid pressure differential acting on the lever L^3 overbalances the electro-magnetic action on the lever of the coils L^5, thereby raising the coil carrying end of the lever, the latter engages a contact 2 and thereby closes one operating circuit of the motor MB and causes the latter to rotate in the direction required to reduce the amount of resistance R^5 in circuit, and thus increases the current flow through the coils L^5 to restore the balance lever L^3 to its neutral position. The energizing circuit for the motor thus closed includes a conductor 20, connecting one terminal of the motor to the conductor 4 at the point 40, a conductor 21 connecting a second terminal of the motor to the contact 2, the lever L^3, and a conductor 3 connecting the latter to the supply conductor X. When the electro-magnetic action on the lever L^3 overbalances the differential pressure action on the latter, the coil carrying end of the lever L^3 is depressed, and the lever engages the contact 1. This energizes a second circuit of the motor MB whereupon the latter is rotated in the direction to increase the resistance R^5 in the circuit, and thereby restore the lever L^3 to its normal position. The second energizing circuit for the motor MB includes the conductor 20, the conductor 21, connecting a third motor terminal to the contact 1, the lever L^3, and the conductor 3.

The operation of the apparatus shown in the drawings in so far as it has been specifically described, is as follows: The flexible walls of the chambers L' and L^2 subject the corresponding end of the lever L^3 to a downwardly acting pressure differential force which is proportional to the square of the rate of steam flow through the conduit G. The current passing through the coils of the electro-dynamometer subjects the other end of the lever L^3 to a downwardly acting electro-magnetic force which is proportional to the square of the electric current flowing through the coils. Since the motor MB is automatically controlled to cut more or less of the resistance R^5 into circuit with the coils L^5 and L^6 as required, to normally make the square of the electric current flowing through the coils proportional to the square of the steam flow through the conduit G, it follows that the current flowing through the coils L^5 and L^6 is normally proportional in strength to the steam flow through the conduit G. In consequence an ammeter O in series with the coils L^5 and L^6, as shown, gives a correct indication of the steam flow through the conduit G, and may have its scale graduated either in electric current strength units or in steam flow units.

The strength of the electric current flowing through the coils L^5 and L^6 directly determines the rate at which primary air for combustion is supplied to each furnace, and also directly determines the rate at which products of combustion are withdrawn from each furnace through the stack outlet connection H', and in consequence indirectly determines the rate at which secondary air for combustion is supplied to each furnace through the corresponding inlet A'. The means by which the foregoing results are obtained comprises a balance LA associated with each furnace primary air inlet F', and controlling a damper M' regulating the flow through said inlet, and a balance LB associated with each stack outlet H' and controlling a damper M' regulating the flow through that outlet.

Each balance LA may be, and as shown, is identical in construction with the master balance L previously described. The static pressure in each air inlet connection F' is transmitted to the pressure chamber L^2 of the corresponding balance LA, while the total (dynamic and static) pressure in the inlet connection is transmitted to the corresponding pressure chamber L'. The coils L^5 and L^6 of the left hand balance LA, as shown in the drawing, are connected in series between the conductor 12 and the supply conductor X by the conductor 13, while the right hand balance LA has its coils L^5 and L^6 connected in series between the conductor 12 and the supply conductor X by the conductor 16. The damper M' associated with each balance LA is controlled by the latter through a reversible motor MA which is directly controlled by the last mentioned balance as the motor MB is controlled by the balance L. The threaded spindle of each motor MA moves the corresponding damper M' in one direction or the other to throttle or increase the flow through the corresponding air inlet as required to make that flow proportional to the strength of the current flowing through the coils L^5 and L^6 of the corresponding balance LA and hence proportional to the steam flow through the conduit G.

The flow regulating effect of each balance LB and the damper M' associated therewith is essentially the same as that of each balance LA and its associated damper. Each balance LB differs from the balances LA primarily in that the pressure chambers L' and L^2 are dispensed with in the case of the balance LB, and the corresponding end of the lever L^3 carries a vane L^{10} which extends into the corresponding conduit H' and is there subjected to a lever turning force approximately proportional to the square of the fluid rate of flow through that conduit. The balances

LB are, because of their simplicity and sensitiveness, of especial utility where the pressure differential available as a measure of a fluid rate of flow is relatively small. The left hand balance LB has its coils L^5 and L^6 connected between the conductor 12 and the supply conductor X by a conductor 15, and a conductor 14 similarly connects the coils L^5 and L^6 of the right hand balance LB between the conductors 12 and X.

With the described arrangement the current flowing through the coils L^5 and L^6 of each of the balances LA and LB is proportional to the current flowing through the coils L^5 and L^6 of the master balance and hence to the steam flow through the main G. To attain this proportionality it is immaterial whether the coils of the various balances LA and LB are in separate parallel circuits as shown, or are all in series with one another and with the coils L^5 and L^6 of the master controller, as they are in some forms of the apparatus disclosed in my Patent No. 1,537,044, granted May 5, 1925, on my application Serial No. 121,547, filed September 22, 1916, of which the present application is a division.

A variable resistance shunt R^4 about the coils L^5 and L^6 of each of the balances LA and LB permits of a change in the proportion maintained between the air or gas flow controlled by each such balance and its control current without disturbing the ratio between the air or gas flow through the conduit regulated by any other balance LA or LB and the control current for such other balance. Similarly a resistance R^7 and a co-operating adjustable contact I forms a shunt of variable resistance about the windings L^5 and L^6 of the master balance L, which permits of an adjustment between the ratio of the total current flowing through the conductors 10, 11, and 12, to the steam flow through the main G. With less of the resistance R^7 in the shunt circuit about the master balance coils L^5 and L^6, the ratio of the current flow through the conductors 10, 11, and 12, and therefore of the supply of air to, and the withdrawal of gases from, the furnace A, to the steam flow through the main G will be larger than when there is more of the resistance in said circuit.

With any given adjustment of their resistances R^4, the two balances LA and LB for each furnace operate directly to maintain a constant ratio between the amount of primary air supplied to the conduit F′ to, and the amount of products of combustion passing through the conduit H′ from the furnace, and thereby indirectly maintain a constant ratio between the amount of primary air supplied through the conduit F′ and the amount of secondary air supplied through the opening A′, since the amount of the products of combustion withdrawn from the furnace is a definite function of the amounts of primary and secondary air supplied. The amount of secondary air passing through the opening A′ is a function of the amount by which the pressure of the atmosphere exceeds the pressure in the combustion chamber above the furnace grate. As the volume of primary air increases, the damper M′ in the conduit H′ is automatically adjusted to provide the increased suction or drop in pressure above the furnace grate necessary to cause the increased influx of secondary air required to maintain the predetermined ratio betwen the amounts of primary air and products of combustion. When the amount of primary air decreases, the pressure above the furnace grate is correspondingly raised. While the pressure in the combustion chamber above the furnace grate thus varies inversely with the amount of primary air supplied, and consequently varies inversely with the rate of steam withdrawal, the amount by which the pressure of the atmosphere must exceed the pressure in the combustion chamber above the furnace grate to give the maximum required supply of secondary air is comparatively small with properly designed apparatus, so that the apparatus operates to maintain a pressure above the furnace grate which never differs greatly from that of the atmosphere.

While the balances LA will operate to supply the proper amount of primary air for combustion to the boiler furnaces regardless of the speed of the forced draft fan E or other source of primary air under pressure, provided such source is adequate to supply the maximum demand for such air, it is a desirable feature of the invention that the fan speed varies in general with the demand for primary air. This tends to minimize the fan capacity required, and to diminish the power consumption of the fan.

In the apparatus shown, the speed of the stoker motor D is made automatically dependent both on the rate of steam flow through the main G, and on the boiler steam pressure by the following instrumentalities: A magneto K is belt-driven by the motor D, and the electromotive force generated by the magneto K is therefore proportional to the speed of the stokers B. The magneto K is connected in a circuit which includes the portion of the conductor 4 between the points 40 and 41, a resistance R^9, a conductor 17, a variable resistance R′, a manually adjustable resistance R^2, a contact N′, and a conductor 18. The contact N′ is carried by the movable end of a pressure responsive device N shown as a bellows to which the steam pressure in the main is transmitted, and which expands and contracts as that pressure increases and diminishes. When the bellows N expands, the contact N′ is moved downward, reducing the portion of the resistance R′ in series with the magneto, and when the bellows N contracts,

the amount of resistance R′ in series with the magneto K is increased.

A device responsive to small changes in electromotive force and conventionally shown as a solenoid coil S, has one terminal connected to the terminal of the resistance R^8 remote from the point 40, and has its other terminal connected to a movable contact point S^4 which may be operatively connected to the resistancse R^9 at any point along the length of the latter. The core S′ of the solenoid S closes switches S^2 and S^3 accordingly as the variations in the current flow through the solenoid S causes the core to rise above or fall below a normal intermediate position in which both switches are open. The switches S^2 and S^3 control a reversible motor M for adjusting the stoker throttle valve J. The energizing circuit connections for the motor M comprise a conductor 5 connecting one motor terminal to the switch S^3, a conductor 6 connecting a second motor terminal to a second switch S^2, a common motor terminal connected by the conductor 22 and thence through the conductor 4 to the supply conductor Y, and conductor 3 running from the supply conductor X to both switches S^2 and S^3. When the switch S^2 is closed by an upward movement of the solenoid S′, the motor is energized through conductors 22 and 6, and the motor M operates in the direction to open the valve J. When the switch S^3 is closed by a downward movement of the core S′, the motor M is energized through conductors 22 and 5 and the motor runs in the direction to close the valve J.

With the described arrangement, it will be apparent that the potential drop across the terminals of the resistance R^8 will be equal to the product of the current flowing through the conductor 10, multiplied by the amount of the resistance R^8. The potential drop across the terminals of the resistance R^8 will thus be proportional to the strength of the current flowing through the conductor 10 and the current flowing through the coils L^5 and L^6 of the balance L. The potential drop across the terminals of the resistance R^9 will similarly be proportional to the strength of the current flowing through that resistance, and hence to the electro-motive force generated by the magneto K, and consequently to the speed of the stoker motor D. Since the resistances R^8 and R^9 are each connected at one end to the other, and consequently have their connected ends at the same potential, the electromotive force impressed on the terminals of the solenoid S will be equal to the difference between the drop of electromotive force across the terminals of the resistance R^8, and the drop in potential in the portion of the resistance R^9 between the point 40 and the point at which the contact S^4 is connected to the resistance R^9. This potential difference is normally maintained at a predetermined value by the solenoid, since a movement of the core S′ in either direction will effect an operation of the motor M which will result in a change in the speed of the magneto K in the direction needed to bring the potential difference at the opposite ends of the solenoid S back to said predetermined value.

In the particular arrangement shown, the counterweight S^5 is intended to balance the weight of the core S′ and the latter is polarized. In such case the intermediate normal position of the core S′ is assumed when the terminals of the solenoid coil S are at the same potential, and no current flows through the solenoid coil. Any change in the ratio of the currents flowing through the resistances R^8 and R^9 will then cause a current to flow in one direction or the other through the solenoid S, and a consequent closure of one or the other of the switches S^2 and S^3.

So long as the steam pressure and the rate of steam flow through the main G each remain constant, after the valve J has once been adjusted into the position for maintaining the corresponding speed of the stoker motor D, the latter will operate at a constant predetermined speed. In case of a decrease in steam pressure and a corresponding contraction of the bellows N putting more of the resistance R′ in series with the magneto K, there will be a corresponding reduction in the current flow through the resistance R^9 and a consequent reduction in the potential drop across that resistance between the point 40 and the contact S^4. This will cause a current flow through the winding of the solenoid S in one direction with the result, for example, of raising the core S′ and closing the circuit of the motor M controlled by the switch S^2. This causes the motor M to open the throttle valve J as required to increase the stoker motor speed, and thereby the electromotive force generated by the magneto K, sufficiently to restore the current flow through the resistance R^9 to its former value, whereupon the solenoid core S′ will return to its normal intermediate position opening the circuit of the motor M controlled by the switch S^2 and stopping the motor. Conversely on an increase in the steam pressure, the expansion of the bellows N will cut a portion of the resistance R′ out of circuit with the magneto K. This is followed initially by an increased current flow through the resistance R^9 whereupon the resultant closure of the switch S^3 followed by a closure of the valve J reduces the speed of the stoker motor D sufficiently to again reduce the current flow through the resistance R^9 to the value at which the solenoid core S′ will be returned to its normal position again opening the switch S^3 and stopping the motor M.

On a change in the rate of steam flow through the main G and a corresponding

change in the strength of the current flowing through the coils of the master balance L, the resultant change in potential drop through the resistance R^8 tends to energize the solenoid coil S in one direction or another as required to increase or decrease the stoker speed in proportion to the increase or decrease in steam flow through the main G. If an increase or decrease in the rate of steam flow is accompanied by a simultaneous decrease or increase, respectively, in the pressure of the steam, the change in steam pressure and the change in steam flow produce cumulative effects on the speed of the stoker. Conversely the effects on the stoker speed of simultaneous changes in steam pressure and in the rate of steam generation neutralize one another to a greater or lesser extent, when the steam pressure increases and decreases as the rate of steam outflow increases and decreases, as may happen when the boiler load varies within a range in which the over-all boiler efficiency increases with the load. The particular stoker speed maintained for given load conditions may obviously be manually adjusted by varying the adjustment of the contact S^4 along the resistance R^9, and by varying the amount of resistance R^2 in the magneto circuit.

The apparatus disclosed serves to automatically vary the air feed and the fuel feed in a predetermined manner in respone to changes in conditions of boiler load so as to maintain a rate of combustion and combustion conditions enabling each boiler furnace to carry its load in an efficient and satisfactory manner. In general the air feed and the fuel feed each vary in proportion to changes in the boiler load, but since the air feed is proportional to one load condition, namely, the rate of steam delivery, while the fuel feed is dependent on two load conditions, namely, the rate of steam delivery and the pressure of the steam, certain changes in load condition result in changing the ratio of the rate of air feed to the rate of fuel feed. This inherent capacity of the apparatus to effect predetermined variations in the ratio of air feed to fuel feed in automatic response to certain changes in the load conditions is an advantageous characteristic of the invention, as it facilitates the maintenance in any given furnace installation of combustion conditions suitable for efficient and satisfactory operation under the particular conditions of operation for that installation.

The adjustable resistance shunts about the various flow balances permit of a great variety of adjustments. For example, the adjustment of the contact T along the resistance R^7 permits the ratio of steam outflow to the rate of air feed, and hence to the rate of combustion, to be varied for different load conditions. This adjustment may be effected manually with the apparatus shown in Fig. 1 and is produced automatically with the modification shown in Fig. 2. In this modification the contact T is connected to the armature core T^2 of a solenoid magnet, the winding of which is connected in series in the conductor 12. A spring T^3 opposes the electromagnetic action, and the resultant effect is to decrease the amount of resistance in circuit and hence to increase the air feed as the rate of steam outflow increases.

Various novel features of construction and arrangement disclosed but not claimed herein are claimed in my Patent No. 1,537,044, granted May 5, 1925, on an application filed September 22, 1916, of which this application is a division.

While in accordance with the provisions of the statutes, I have illustrated and described the best form of embodiment of my invention now known to me, it will be apparent to those skilled in the art that changes may be made in the form of the apparatus disclosed without departing from the spirit of my invention as set forth in the appended claims and that in some cases certain features of my invention may be used to advantage without a corresponding use of other features.

Having now described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. The combination with a boiler furnace having a regulable fuel feed and a regulable air feed, of provisions for the automatic control of said feeds comprising a device responsive to steam pressure, a device responsive to the rate at which steam is withdrawn from the boiler, means co-operating with one of said devices to vary both of said feeds on, and in proportion to the changes in the steam condition to which the last mentioned device is responsive, and means co-operating with the other device effecting an adjustment in one of said feeds relative to the other feed on changes in the steam condition to which said other device is responsive.

2. The combination with a boiler furnace having a regulable fuel feed and a regulable air feed, and provisions for the automatic control of said feeds comprising a device responsive to steam pressure, a device responsive to the rate at which steam is withdrawn from the boiler, means co-operating with the last mentioned device to vary both of said feeds on changes in the rate at which steam is withdrawn from the boiler, and means co-operating with the first mentioned device effecting an adjustment in the fuel feed relative to the air feed on changes in the steam pressure.

3. The combination with a boiler furnace having a regulable fuel feed and a regulable air feed, of provisions for the automatic control of said feeds comprising a device responsive to steam pressure, a device responsive to the rate at which steam is withdrawn

from the boiler, means including provisions responsive to the rate of air feed cooperating with one of said devices to jointly control both the air feed and the fuel feed, and means whereby the other device adjusts the ratio between said feeds on changes in the steam condition to which the device is responsive.

4. Means for maintaining a predetermined ratio between two variable quantities one of which is a fluid rate of flow, comprising in combination a balance including a fluid pressure motor responsive to said fluid rate of flow and an opposing electro-magnetic motor, and an electrical circuit into which said electro-magnetic motor is connected and from which it is energized and which includes means for maintaining a current flow in a portion of said circuit proportional to the second variable, means responsive to the current distribution in different portions of said circuit for adjusting one of said variable quantities and means actuated by said balance for adjusting the ratio between said fluid rate of flow and the energizing current for said electro-magnetic motor.

5. In a boiler furnace combustion control system having a regulable fuel feed and a regulable air feed, and means for automatically varying said feeds in response to changes in boiler load conditions, the improvement which consists in a resistance, means for passing an electric current through said resistance proportional to the boiler steam pressure, a second resistance, means for passing an electric current therethrough proportional to the rate at which steam is delivered, and means responsive to changes in the respective potential drops in the two resistances for varying the ratio of air feed to fuel feed.

6. The combination with a boiler furnace having a regulable fuel feed and a regulable air feed, of means automatically responsive to the boiler steam pressure and rate of steam delivery for automatically varying the fuel and air feed at different rates on, and in proportion to the changes in which said means are responsive, and other means for adjusting the rate of fuel feed to air feed.

7. The combination with a boiler furnace having a regulable fuel feed and a regulable air feed, of means automatically responsive to the boiler steam pressure and to the rate of steam delivery for automatically varying the air and fuel rates of feed on, and in proportion to general increases and decreases in boiler loads, and for varying the relative rates of air and fuel feed in response to predetermined changes in boiler load conditions.

8. The method of operating a furnace, which includes supplying fuel and air in a definite ratio at a given furnace load, and varying such ratio with changes in the furnace load substantially as described.

9. The method of operating a battery of furnaces, which includes supplying fuel and air to each furnace in a definite ratio at a given load, and automatically varying such ratio with variations in the load of the battery substantially as described.

10. The method of operating a battery of furnaces, which includes supplying fuel and air to each furnace in definite proportions at a given load, automatically varying such proportions with variations in the load of the battery, and supplementally varying the fuel air ratio of a furnace in the battery to compensate for its individual characteristics while leaving it susceptible to said automatic variation substantially as described.

Signed at New York city, in the county of New York, and State of New York, this 14th day of March A. D. 1925.

GEORGE H. GIBSON.