Jan. 13, 1925. 1,522,877

G. H. GIBSON

FURNACE REGULATION

Original Filed Nov. 9, 1915 4 Sheets-Sheet 1

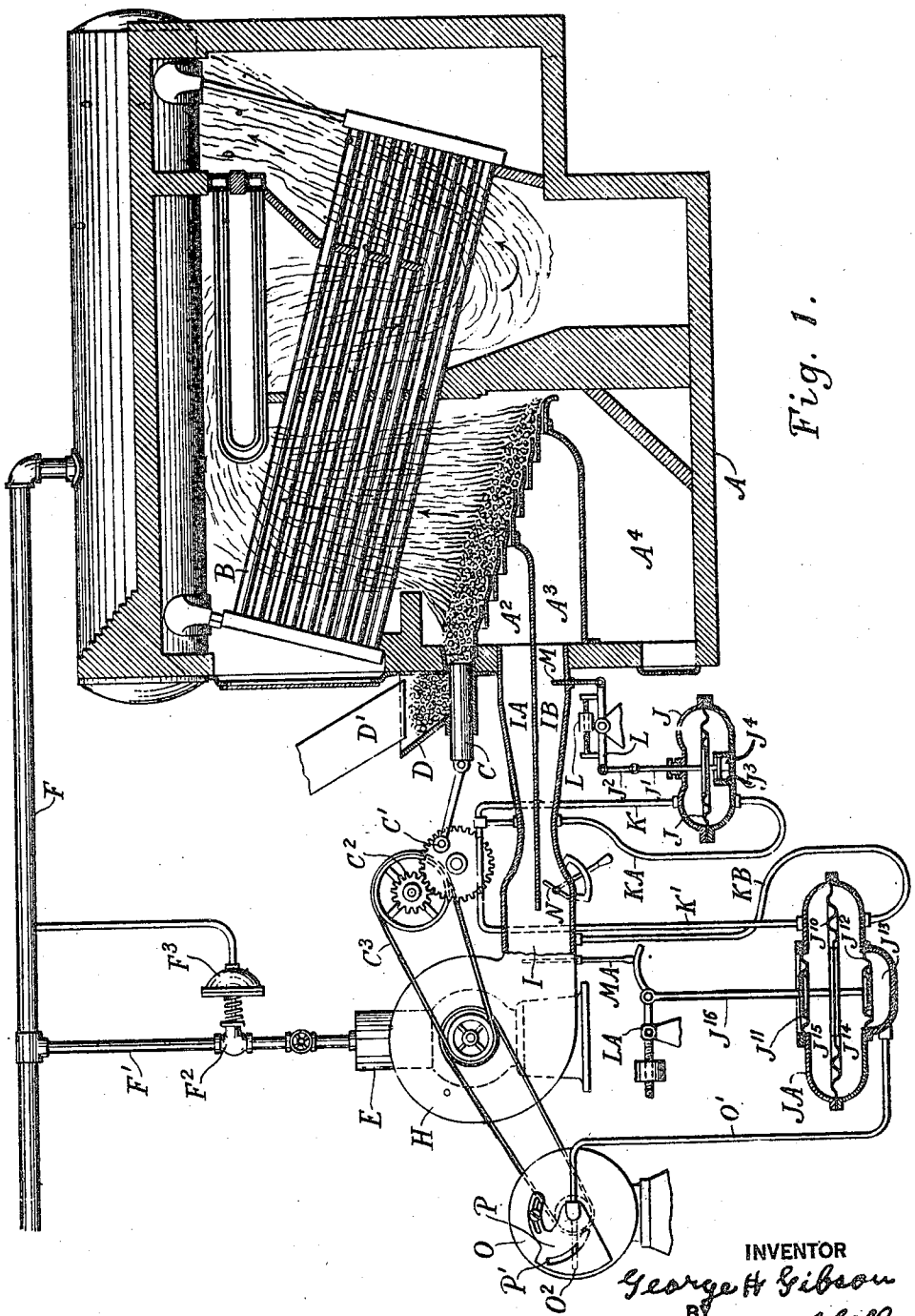


Fig. 1.

INVENTOR
George H Gibson
BY
John E. Hubbell
his ATTORNEY

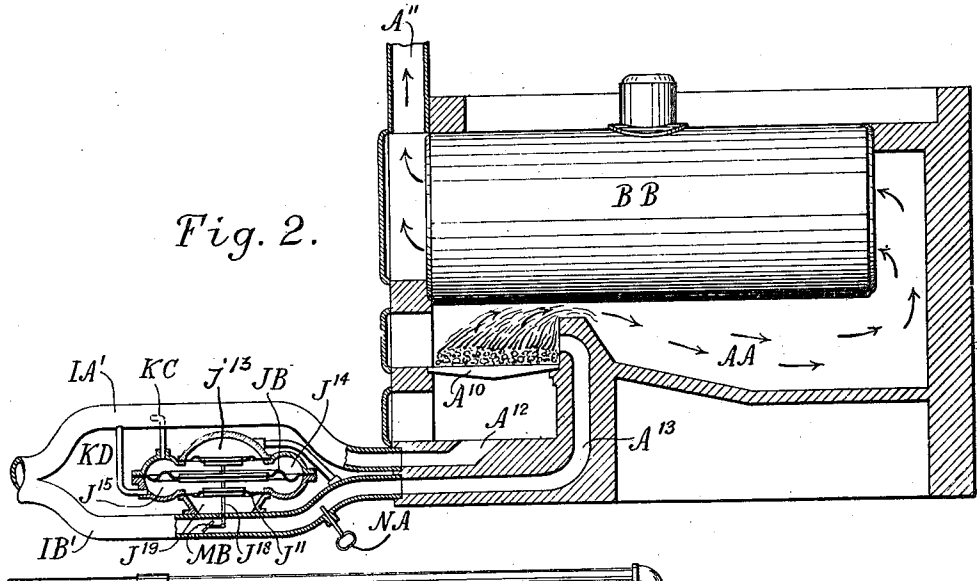
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FURNACE REGULATION

Original Filed Nov. 9, 1915 4 Sheets-Sheet 2

Fig. 2.



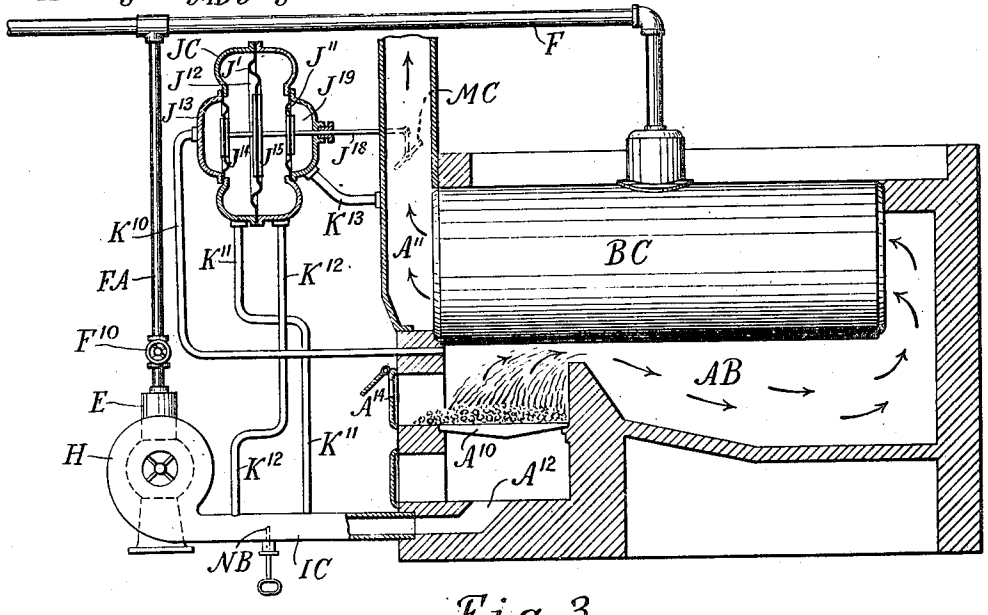


Fig. 3.

INVENTOR
George H Gibson
BY
Colin E. Dubbell
his ATTORNEY

Jan. 13, 1925. 1,522,877

G. H. GIBSON

FURNACE REGULATION

Original Filed Nov. 9, 1915 4 Sheets-Sheet 3

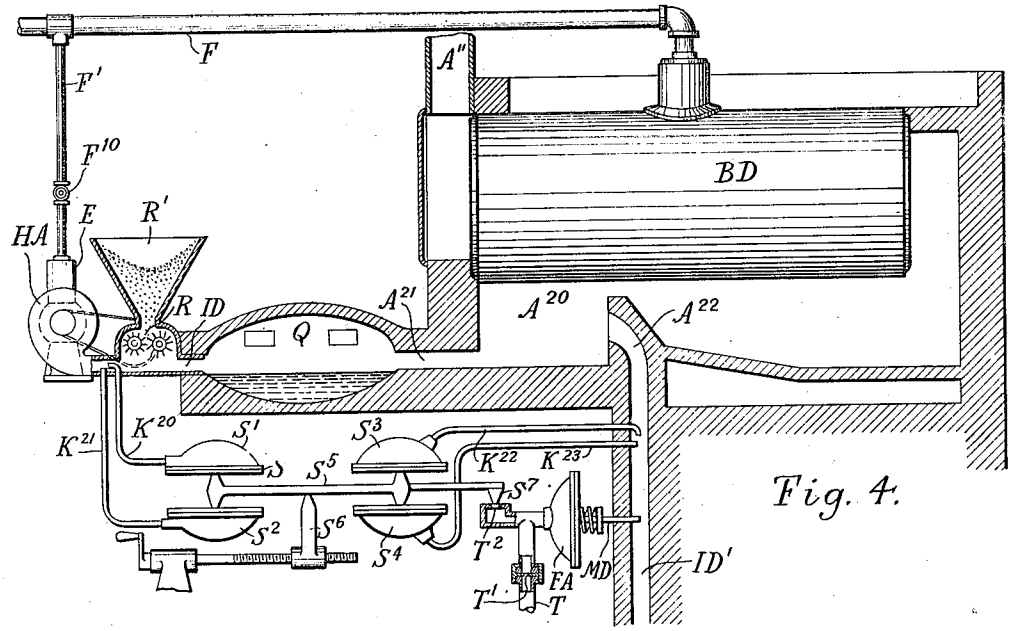


Fig. 4.

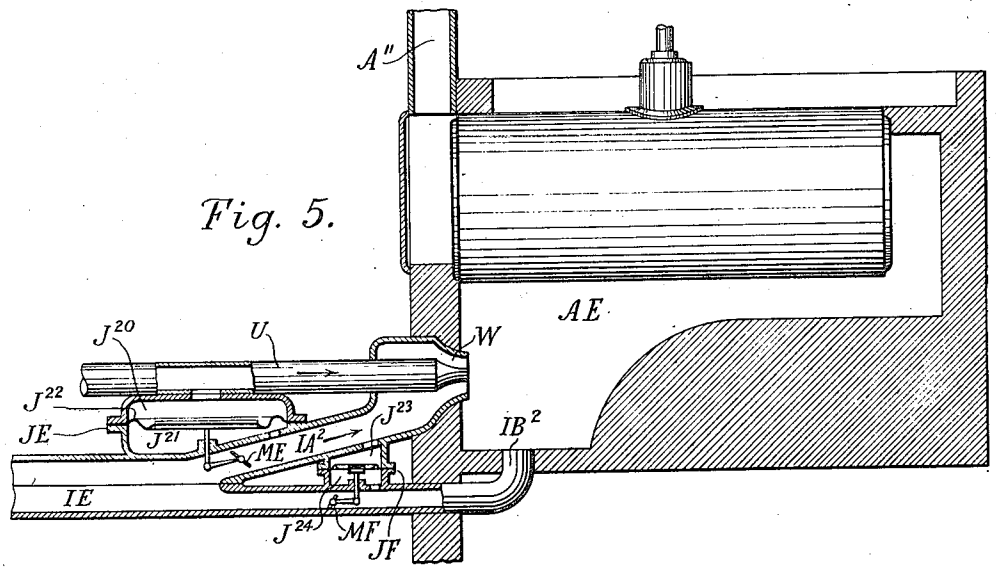


Fig. 5.

INVENTOR
George H. Gibson
BY
John E. Hubbell
his ATTORNEY

Jan. 13, 1925. 1,522,877

G. H. GIBSON

FURNACE REGULATION

Original Filed Nov. 9, 1915 4 Sheets-Sheet 4

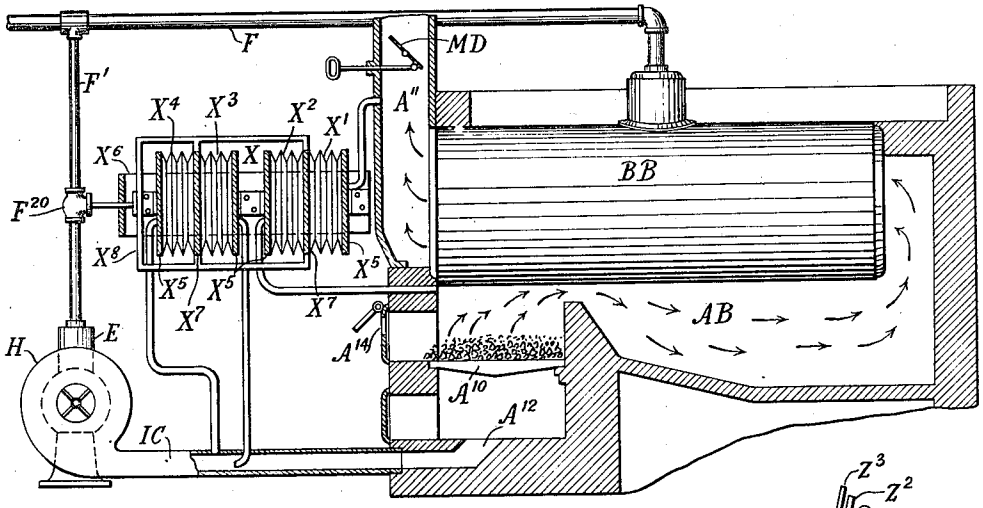


Fig. 6.

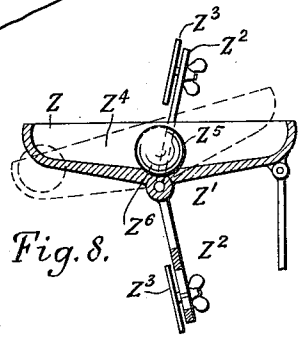


Fig. 8.

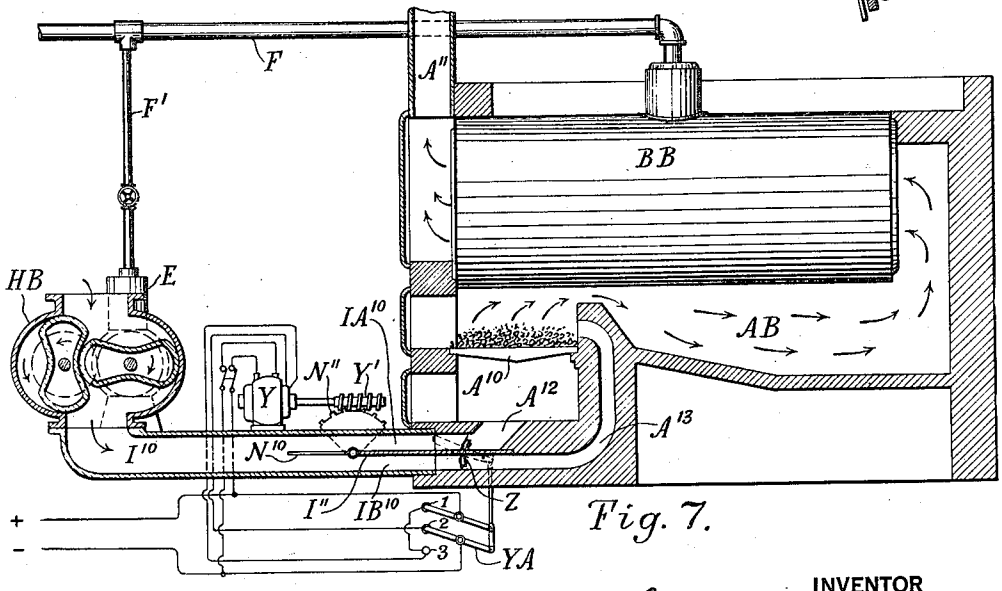


Fig. 7.

INVENTOR
George H. Gibson
BY
John E. Hubbell
his ATTORNEY

Patented Jan. 13, 1925. 1,522,877

UNITED STATES PATENT OFFICE.

GEORGE HERBERT GIBSON, OF MONTCLAIR, NEW JERSEY.

FURNACE REGULATION.

Original application filed November 9, 1915, Serial No. 60,623. Divided and this application filed April 22, 1920. Serial No. 375,728.

To all whom it may concern:

Be it known that I, GEORGE H. GIBSON, a citizen of the United States, and resident of Montclair, in the county of Essex and State of New Jersey, have invented certain new and useful Improvements in Furnace Regulation, of which the following is a specification.

The primary object of my present invention is to provide an improved method of, and means for regulating the supply of air for combustion to the combustion chambers of boiler and other furnaces. An important specific object of my invention is to provide satisfactory means for supplying primary and secondary air in definite relative proportions to the combustion space of a furnace when the character of the furnace or its mode of use make it necessary or desirable to provide the two proportioned air supplies to the combustion space of the furnace for its most satisfactory or efficient use; and my invention comprises novel means effective to automatically maintain a predetermined ratio between the rates of flow of the two streams of air.

The need for accurately proportioned supplies of primary and secondary air to the combustion space of a furnace is experienced in connection with many different kinds of furnaces. For instance, where air is passed through a sufficiently deep bed of fuel on an ordinary grate, the gaseous product rising from the fuel bed is substantially a producer gas. For the complete and efficient combustion of this producer gas, a definite quantity of secondary air should be supplied to the combustion space of the furnace above the fuel bed.

In fuel beds fed by ordinary automatic stokers the traveling fuel bed is, in effect, divided into two sections in one of which the coal is subjected to a coking operation whereby the volatile matter is distilled out of the coal, and in the other of which the coke residue of the coal from which the volatile constituents have been distilled is burned to ash. The rate at which air is fed into the coking section of the fuel bed is a practical measure of the rate at which combustible gas is generated in and passes away from this section. The second section may advantageously be supplied with a sufficient excess of air for the complete combustion in the space above the fuel bed, of the combustible gas rising from the first section of the fuel bed. The efficient operation of a furnace equipped with a stoker of this type requires the two supplies of air to be carefully proportioned to one another as well as to the quantity of coal consumed.

In burning oil or pulverized coal it is commonly found desirable to provide primary air to facilitate the introduction of the fuel into the combustion space and its initial combustion, and to provide a secondary supply of air to complete combustion, and for the most efficient operation the two supplies of air should be proportioned to one another.

The provision of two proportioned supplies of air is also of prime importance in cases where solid fuel is burned initially with an insufficient supply of air in order to get a reducing flame and is subsequently burned with more air to supply heat in another portion of the apparatus.

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. For a better understanding of the invention, however, and the advantages possessed by it, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described the preferred embodiments of my invention.

Of the drawings:

Fig. 1 is a diagrammatic elevation partly in section, of a steam generating plant having provisions for passing regulated and proportioned streams of air through two zones or sections of a fuel bed maintained by an automatic stoker;

Fig. 2 is a diagrammatic representation of a portion of a steam generating plant provided with means for supplying proportioned amounts of air to the furnace chamber above and below the fuel bed;

Fig. 3 is a view taken similarly to Fig. 2 of apparatus accomplishing the same general purpose but in a somewhat different manner;

Fig. 4 is a diagrammatic elevation partly in section illustrating the use of my invention in a plant in which powdered coal is burned with a restricted amount of air to supply a reducing flame to a reverberatory

furnace, and the combustion of the reducing flame gases is thereafter completed and the heat of these gases utilized in supplying heat to a boiler;

Fig. 5 is a diagrammatic elevation partly in section illustrating the application of my invention to a furnace in which liquid or gaseous fuel is burnt;

Fig. 6 is a view taken similarly to Fig. 3, illustrating a modified form of mechanism for obtaining the same general kind of furnace regulation;

Fig. 7 is a view taken similarly to Fig. 2 and illustrating a modified form of apparatus for obtaining the same kind of furnace regulation; and

Fig. 8 is a sectional view of a detail employed in Fig. 7.

In the construction shown in Fig. 1, I have illustrated the application of my invention to a steam generating plant of the kind in which an automatic stoker is employed to continuously feed fuel on to the inclined grate A′ of a furnace A. The ashes and cinders fall off the lower edge of the grate A′ into an ash pit A^4. As shown, the grate A′ is perforated to permit the passage through the fuel bed of primary and a secondary air from the air chambers A^2 and A^3 respectively beneath the grate. The air supplied to the chamber A^2 does not completely burn the fuel on the portion of the grate A′ adjacent to the chamber A^2. The air is supplied to the chamber A^3 in excess of that required to burn to ashes the coke fuel on the section of the grate A′ adjacent the air chamber A^3. The excess or free air in the gaseous products rising from the lower section of the fuel bed completes the combustion of the gasified fuel products issuing from the upper section as the commingled products pass into and through the spaces beneath the tubes of the water tube boilers B shown as heated by the fuel burnt on the grate A′.

In the conventional form illustrated, the stoker comprises a reciprocating plunger C which withdraws coal from the hopper D supplied to the latter through a chute D′ and forces it into the upper head of the fuel bed in successive relatively small charges. As shown the plunger C is reciprocated through the crank C′, suitable intermediate gearing C^2, and a belt C^3 by the engine E which is shown as directly conected to, and driving the forced draft blower H. As shown, the engine E receives steam through the branch pipe F′ from the main steam supply pipe F leading from the steam drum of the boiler B. The amount of steam supplied the engine E and hence the speed of the latter is regulated by the pressure generated in the boiler. The regulating means comprising a regulating valve F^2 and a diaphragm device F^3 subject to the steam pressure and tending to open and close the valve F^2 accordingly as the steam pressure falls and rises. The outlet pipe I from the blower H is connected to the chambers A^2 and A^3 by branch conduits IA and IB which are shown as comprising each a Venturi section. With this arrangement it will be apparent that the difference between the pressures at the small cross section portions of the conduits IA and IB will be a function of the ratio between the rates of flow through the two conduits. By maintaining a predetermined ratio between these pressures it is therefore possible to maintain a predetermined ratio between the rates of flow through the two branch conduits. This is accomplished with the apparatus shown by means of a damper M and a fluid pressure device J controlling the damper, divided into two chambers by a flexible diaphragm j. The device J comprises a casing with one chamber connected by the pipe K to the small diameter portion of the conduit IA, and the other chamber connected by the pipe K^A to the small diameter portion of the conduit IB. The diaphragm j is connected by a stem j' and link j^2 to a lever L on which the damper M which is vertically movable rests. A weight L′ adjustably mounted on the lower L forms a means for bringing the damper lever and connected diaphragms into balance. A dash pot piston j^3 working in the dash pot chamber j^4 prevents the damper regulating means from hunting. An adjustment of the ratio of the rates of flow in the conduits IA and IB may be had by the manually adjusted damper N.

Advantageously the flow controlling provisions already referred to are combined with means for proportioning the total amount of air supplied to the furance to the fuel supplied to the furnace. As shown, the means for accomplishing this result comprise a small blower O which is driven by the engine E and therefore is driven at a speed proportional to the rate at which coal is fed into the combustion space of the furnace by the stoker plunger C. The blower O is formed with a central inlet connected by the pipe O′ to the chamber j^{13} of a fluid pressure damper regulating device JA. As shown, the blower O is formed with a radial slot O^2 and is provided with an adjustable damper P formed with an inclined slot P′. By adjusting the damper F, the outlet from the blower O formed by the intersection of the slots O^2 and P′ can be moved toward or away from the axis of the blower with the effect of decreasing or increasing the suction of the pump. The fluid pressure device JA comprises three chambers J^{13}, j^{14} and j^{15}. The chamber j^{14} is separated from the chamber j^{13} by the flexible diaphragm j^{12}. The chambers j^{14} and j^{15} are separated by a

flexible diaphragm j^{10} substantially larger in area than the diaphragm j^{12}. The outer wall of the chamber j^{15} is formed with a central opening closed by a diaphragm j^{11} of the same area as the diaphragm j^{12}. A central stem j^{16} connected to the diaphragm j^{10}, j^{11} and j^{12}, is connected to a lever LA on which rests the vertically movable damper MA projecting into the conduit I at a point between the blower and the division of the conduit into its branches IA and IB. The chamber j^{15} is connected by a pipe K′ to the small diameter portion of the conduit IA and the chamber j^{14} is connected by the pipe KB to the conduit I and thus serves to transmit the static pressure of the conduit I to the chamber j^{14}.

With the arrangement described it will be apparent that the damper MA will automatically be adjusted to preserve a constant ratio between the differential of the static pressures in the body of the pipe I and at the small cross section portion of the conduit IA on the one hand, and the pressure in the chamber j^{13} on the other hand. The latter pressure is a function of the stoker speed of operation, and the differential pressure referred to is a function of the rate at which air is supplied to the furnace. The device JA operates therefore to proportion the total amount of air supplied to the furnace to the amount of coal supplied. The device J operates, as will be readily apparent to those skilled in the art, to maintain a predetermined ratio between the amounts of air supplied to the furnace through the conduits IA and IB. This ration may be adjusted by the adjustment of the manually controlled damper N.

In the modification illustrated in Fig. 2, a fire tube boiler BB is shown in a hand fed furnace AA with a stack outlet A^{11}, and a fuel supporting grate A^{10}, and with an air inlet A^{12} for primary air opening to the ash pit underneath the grate, and with an inlet or channel A^{13} in the furnace bridge wall for supplying secondary air to the combustion space above the grate. To automatically proportion the amounts of primary and secondary air, a damper regulating device JB is employed. The device JB is essentially the same as the device JA with the exception that it comprises an extra chamber j^{19} separated from the chamber j^{15} by the diaphragm j^{11}. The chamber j^{19} is formed with a port communicating with the secondary air conduit IB′ at the inlet side of a damper NA therein which may be manually adjusted to vary the ratio of primary and secondary air to be maintained. The chamber j^{13} is connected to the conduit IB′ at the outlet side of the damper NA. The chamber j^{14} of the device JB is connected to a Pitot tube KC in the primary air supply conduit IA′, and a pipe KD transmits the static pressure of the conduits IA′ to the chamber j^{15}. In the diagrammatic illustration of Fig. 2, the stem j^{18} connecting the three diaphragms of the device JB passes through, but does not fill the opening between the chamber j^{19} and the conduit IB′ into the latter where it operates a damper MB. As shown, the damper MB is of the pivoted or butterfly type. It is to be observed, however, that in practice the damper of flow regulating valve operated in this manner should, in general, be of a more perfectly balanced type than is a butterfly valve.

In the modification illustrated in Fig. 3, the boiler BC and its furnace A^b are shown as substantially the same as the boiler BB and furnace AA of Fig. 2 with the exception that in Fig. 3 no air passage A^{13} is formed in the bridge wall. As conventionally illustrated in Fig. 3, the secondary air is supplied to the combustion chamber above the fuel bed through an air inlet A^{14} in the front of the boiler. In practice it will be understood that in a boiler of this type the air admitted to the combustion chamber above the fuel bed may not only pass through inlet ports formed in the boiler housing for the purpose, but also through leaky joints and cracks in the masonry and iron work of the boiler housing. In the arrangement shown in Fig. 3, the primary air is forced into the ash pit through the conduit IC and inlet A^{12} by the forced draft fan H driven by the engine E and the rate of combustion may be controlled by varying the speed of the blower which may be accomplished by the manual adjustment of the throttle valve F^{10} in the steam supply pipe FA of the engine E. A manually adjustable damper NB in the conduit IC is employed to regulate or adjust the ratio of the primary and secondary air. A device JC and a damper MC operated thereby and located in the stack outlet A^{11} are employed to directly maintain a predetermined ratio between the amounts of primary air supplied to the furnace and the total products of combustion issuing from the furnace and thereby, since the volume of the total products of combustion is a definite function of the amounts of primary and secondary air supplied the apparatus shown in Fig. 3 thus operates indirectly to maintain under varying conditions of operation the ratio between primary and secondary air fixed by the adjustment of the damper NB. The device JC, as shown, is substantially like the device JB of Fig. 2, and operates to maintain a balance between the pressure differential which is a joint function of the flow through the boiler tubes and the resistance to flow of those tubes and a pres-

sure differential which is a joint function of the ratio of flow past the damper NB and the resistance to flow of that damper.

The amount of secondary air entering the combustion chamber through the inlet A^{14} and any leaky joints in the boiler housing is a direct 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 regulator JC adjusts the damper MC as required 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 between the amount of primary air and products of combustion. When the amount of primary air decreases the pressure above the furnace grate is correspondingly raised. The pressure in the combustion chamber above the furnace grate thus varies inversely with the rate at which primary air is supplied, with the rate at which secondary air is supplied and consequently, with the rate of combustion.

For this purpose the chamber j^{13} is connected to the combustion space of the boiler immediately above the fuel bed by the pipe K^{10} while the chamber j^{19} is connected by the conduit K^{13} to the stack outlet A^{11} below the damper MC. The differential of the pressures in the chambers j^{13} and j^{19} is a function of the loss of head due to the passage of the entire body of heating gases through the boiler tubes and hence is a function of the volumetric rate of flow of these gases. The chamber j^{15} is connected by a pipe K^{11} to the conduit IC at the outlet side of the damper NB. The chamber j^{14} is connected by the pipe K^{12} to the conduit IC at the inlet side of the damper NB. The difference between the pressures in the chambers j^{14} and j^{15} due to the frictional resistance to the flow of air past the damper NB is a function of the rate of flow of the primary air through the conduit IC. It will be apparent without further explanation that when the valve F^{10} is manipulated to increase or decrease the output of the blower the device JC is actuated to correspondingly open or close the damper MC and thus to correspondingly increase or decrease the amount of secondary air which will be drawn into the furnace and out through the stack. Similarly, a momentary increase in the amount of secondary air admitted such as may occur when a firing door is left open, operates to effect a closure of the damper MC and thus restores the normal ratio between the two rates of flow. It will be observed that the valve N of Fig. 1, the valve NA of Fig. 2 and the hinged valve controlling the port A^{14} of Fig. 3 each serves as a regulating damper on adjustable constriction in a passageway through which air is passed into the combustion chamber of the furnace, and that the differential of the pressures at the opposite sides of each of these dampers depends upon and is controlled by the setting of a corresponding control valve, namely: the valve M of Fig. 1, the valve MB of Fig. 2 and the valve MC of Fig. 3. Each of these control valves is automatically actuated by a mechanism responsive to a pressure differential to thereby automatically maintain a differential between the pressures at the opposite side of the corresponding regulating damper, which varies in predetermined relation with the load carried by the boiler.

In the modification illustrated in Fig. 4, the boiler BD is a waste heat boiler receiving the partially cooled heating gases from a reverberatory metallurgical furnace Q through the air inlet A^{21} opening to the supplementary combustion space A^{20} below the boiler BD. The gaseous products for heating the reverberatory furnace are formed by the combustion of powdered coal blown into the furnace with primary air in amount sufficient for the combustion of the coal to a reducing flame, HA representing the blower and RR the powdered fuel feeding device. The latter is driven by the same engine which drives the blower HA and serves to feed the pulverized fuel at the proper rate from the hopper R′ into the conduit ID leading from the blower outlet to the furnace Q. Secondary air to complete the combustion of the gaseous products from the reverberatory furnace is supplied to the combustion chamber A^{20} through the air inlet A^{22}.

The quantity of primary air and the rate of combustion in this case is controlled by the manually actuated steam supply valve F^{10} in the steam supply line F for the engine E driving the blower HA. A damper MD in the secondary air supply line ID′ is automatically actuated to proportion the secondary air to the primary air. The proportioning mechanism employed for this purpose might be generally like the proportioning mechanism shown in Fig. 1 or Fig. 3, but as actually shown in Fig. 4 it comprises a pair of pressure chambers S′ and S^2 having opposed flexible diaphragms acting in opposite directions on one end of a lever S^5 pivoted on a fulcrum block S^6. A pipe K^{20} connects a Pitot tube facing the direction of flow in the conduit ID to the chamber S′. A pipe K^{21} transmits the static pressure of the conduit ID to the chamber S^2. At the opposite side of the fulcrum S^6 the lever S^5 is acted upon in opposite directions by the opposed flexible wall portions of two pressure chambers S^3 and S^4. The chamber S^3 is connected by a pipe K^{22} to a Pitot tube located in and facing the direction of flow in the conduit ID′, while a con-

duit K^{23} transmits the static pressure in the conduit ID′ to the chamber S^4. The damper MD is operated by a fluid pressure damper operating device FA which receives pressure fluid through the pipe T and the restricted orifice T′ in the latter from a suitable source. The pressure in the device FA, and consequently the position of the damper MD is a function of the leakage through the orifice T^2 which is throttled more or less depending on the position of the lever S^5 by a valve S^7 carried by the lever S^6.

With the apparatus shown in Fig. 4 the differential of the pressures in the chambers S′ and S^2 is a function of the rate of flow through the conduit ID, and the differential of the pressures in the chambers S^3 and S^4 is a function of the rate of flow through the conduit ID′. The device S operates to vary the pressure to which the operating device FA is subjected and consequently to vary the opening of the damper MD as required to maintain the predetermined ratio between the primary and secondary supplies of air. The apparatus shown in Fig. 4 may be made more sensitive than the apparatus shown in the other figures for the reason that the diaphragms or flexible wall portions of the pressure chambers S′, S^2, S^3 and S^4 need have but very little movements, for the extent of movement of the damper MD is not dependent upon the mere extent of movement of the diaphragm or flexible wall portions of the pressure chambers.

In Fig. 5 I have illustrated the use of my invention in maintaining a predetermined ratio between two fluid streams, one of fuel and one of primary air, so as to secure and maintain a definite mixture composition and also in dividing a stream of air into definitely proportioned branch streams of primary and secondary air. In the arrangement shown in Fig. 5, AE represents the combustion chamber of a steam generating plant. Gaseous or liquid fuel is supplied to the burner W through the conduit U, and primary air is also supplied to the burner W through the branch IA^2 of the main air supply conduit IE. A second branch IB^2 of the air supply conduit IE supplies secondary air to the combustion chamber AE. The amount of primary air supplied to the burner W is fixed by the adjustment of a damper ME and the latter is automatically adjusted to preserve the desired ratio between the quantity of gaseous or liquid fuel and the primary air by the differential pressure device JE. The device JE comprises a casing divided into chambers j^{20} and j^{21} by a diaphragm j^{22} which is connected to the damper ME. The chamber j^{20} is open to the conduit U and the chamber j^{21} is open to the conduit IA^2. With gas or liquid fuel the rate of discharge of both the fuel and the air through the burner W will ordinarily be a function of the corresponding supply pressure, and with the apparatus shown in Fig. 5, the damper ME will be adjusted to maintain a predetermined ration between the pressure in the primary air supply conduit IA^2 at the outlet side of the damper ME, and the pressure in the fuel supply conduit U. The proper ratio of secondary to primary air is obtained by means of the damper MF in the conduit IB^2 and its differential pressure controlling device JF which is essentially the same as the device JE. The two chambers j^{23} and j^{24} of the device JF are open to the conduits IA^2 and IB^2 at the outlet sides respectively of the dampers ME and MF. It will be understood, of course, that the modes of draft regulation similar or analogous to those already described may be carried by different means from those already described, and Figs. 6 and 7 are examples of modifications which may thus be made.

In Fig. 6 I have illustrated apparatus differing from that shown in Fig. 3, but adapted to give the same kind of regulation. In Fig. 6, the total rate of combustion is controlled by the flue damper MD which as shown, is adapted for manual actuation. The ratio of primary and secondary air is regulated by the balanced valve F^{20} in the steam supply pipe F′ for the engine E driving the blower H. The controlling means for the valve F^{20} comprises four bellows chambers K′, K^2, K^3 and K^4. The chambers X′ and X^2 have opposed ends walls X^5 rigidly connected to the stationary frame X^6, and a common floating end wall X^7 mechanically connected to the movable frame X^8 by which the valve F^{20} is operated. Similarly the bellows chambers X^3 and X^4 have opposed end walls X^5 rigidly connected to the stationary frame X^6 and a movable intermediate wall X^7 connected to the movable frame X^8. The chambers X′ and X^2 are connected to the smoke stack A^{11} and the combustion chamber AB above the grate A^{10}, respectively, and the chamber X^3 is connected to a Pitot tube in the air supply conduit IC while the chamber X^4 has the static pressure of the conduit IC transmitted to it. The chambers X′ and X^2 thus subject the frame X^8 to a differential force which is a function of the total volume of flow out of the combustion chamber, while the chambers X^3 and X^4 subject the frame X^8 to an opposing differential force which is a function of the flow of air through the conduit IC to the under side of the grate.

It will be obvious, of course, that more positive of powerful means for setting up the air flow or operating the dampers than those already referred to in detail may be employed if and when this seems desirable. This is illustrated for example in Figs. 7

and 8 which show a modified form of apparatus for accomplishing the same regulation as is intended to be secured with the apparatus of Fig. 2. In Fig. 7 the blower HB employed is of the positive rotating piston type. The discharge conduit I^{10} leading from the blower outlet to the primary and secondary air admission passages A^{12} and A^{13} respectively, of the furnace is divided adjacent its discharge end by the partition I^{11} into branches IA^{10} and IB^{10}. A pivoted damper N^{10} controls the division of the air discharged by the blower between the branches IA^{10} and IB^{10}. This damper is shown as operated by the reversible electric motor Y having a worm Y′ on its shaft in mesh with the gear segment N^{11} secured to the arbor of the damper N^{10}. The means shown in Fig. 7 for starting, stopping or reversing the motor Y in response to changes in the distribution of flow through the channels IA^{10} and IA^{11} comprises a switch YA for opening, closing and reversing the armature connections of the motor Y, and an operating device Z for operating this switch. The device Z comprises an axle Z′ pivoted in the wall between the channels IA^{10} and IA^{11} and provided with arms Z^2 projecting into each of these channels and each carrying an adjustable vane Z^3. Preferably provisions are made to restrict racing or undesirable oscillation of the vanes Z^3, and this is accomplished in the form shown by turning the two arms backwards so that the vanes make an angle a little less than 180° with one another. The device Z also comprises a portion formed with a race-way Z^4 for a rolling weight in the form of a ball Z^5. In the neutral condition of the apparatus, the ball Z^5 rests in a central cavity Z^6 in the raceway Z^4, and the arms of the switch YA do not contact with any of the cooperating switch contacts 1, 2 or 3. An excess flow through the channel IA^{10}, and a consequent tilting of the member Z in a clockwise direction causes the switch arms of the switch YA to be moved into engagement with the contacts 1 and 2 which has the effect of starting the motor Y with such direction of rotation that the damper N^{10} is turned clockwise to cut down the flow through the channel IA^{10}. When the desired ratio of flow is restored, the member Z assumes a neutral position and the motor stops. Similarly when the flow through the channel IB^{10} becomes excessive, the member Z is tilted to move the arms of the switch YA into the position in which they engage the contacts 2 and 3 and thus causes the motor to be operated in the direction to adjust the damper N^{10} so as to restrict the flow through the channel IB^{10}. When the member Z is turned from any position previously occupied by it sufficiently to displace the weight Z^5 from its previous position, the shifting of the weight insures an extent and rapidity of turning movement of the member minimizing sparking at the switch contacts. The particular construction shown in Fig. 1 and claimed generically but not specifically herein, is claimed specifically in my Patent No. 1,360,285, granted November 30, 1920, of which this application is a division.

While in accordance with the provisions of the statutes I have illustrated and described the best forms of my invention now known to me, it will be apparent to those skilled in the art that changes can be made in the form of my invention without departing from its spirit, and that some features of my invention can be used without a corresponding use of other features of the invention.

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

1. In a furnace having primary and secondary air supplies, the combination of means jointly responsive to the amounts of primary and secondary air supplied, and flow controlling means actuated by the first mentioned means to regulate the ratio of primary air to secondary air.

2. In a furnace having primary and secondary air supplies, the combination of fluid pressure means jointly responsive to the rates of flow of the primary and secondary air, and flow controlling means actuated by the first mentioned means to regulate the ratio of primary air to secondary air.

3. In a furnace having primary and secondary air supplies, the combination of fluid pressure means for creating a differential pressure which is a function of the ratio of the volumes of flow of the primary and secondary air and flow controlling means actuated thereby on a variation from said ratio from a predetermined standard to affect a compensating adjustment in said ratio.

4. The mechanism for maintaining a predetermined ratio between the amounts of primary and secondary air supplied to a combustion furnace which comprises means for creating a pressure differential which is a measure of the rate of flow of primary air, means for creating a pressure differential which is a measure of the rate of flow of secondary air and flow adjusting means controlled by said pressure differentials.

5. Mechanism for maintaining a predetermined ratio between the amounts of primary and secondary air supplied to a combustion furnace comprising means responsive to the amount of primary air and secondary air supplied and flow adjusting apparatus controlled by said means and regu-

lating the quantity of secondary air supplied.

6. The combination with a furnace having primary and secondary air supplies, of fluid pressure controlled mechanism regulating the relative amounts of primary air and secondary air supplied to the furnace, and means for subjecting said mechanism to a controlling pressure which is a function of the amount of primary air supplied, and to a controlling pressure which is a function of the amount of secondary air supplied.

7. In a furnace having a fuel bed and having provisions for supplying primary air to the furnace chamber at one side of the fuel bed, and for supplying secondary air to the furnace chamber at the opposite side of the fuel bed, the combination therewith, of means responsive to the volume of flow of the primary air supplied for regulating the relative amounts of primary and secondary air supplied.

8. In a furnace having a fuel bed and a primary air supply connection opening to the furnace chamber at one side of the fuel bed and a secondary air supply connection supplying air to the opposite side of the fuel bed to burn the combustible gases issuing from the bed on that side, the combination therewith, of means responsive to the volume of flow of primary air supplied to the furnace chamber, and means controlled by the last mentioned means for regulating the relative amounts of primary and secondary air supplied.

9. The method herein described of regulating furnaces operating under forced draft which consists in varying the pressure in the furnace chamber inversely with the varying rates of combustion.

10. The method herein described of regulating furnaces of a vapor generator operating under forced draft which consists in varying the pressure in the furnace chamber inversely with the varying demand on the generator.

11. The method herein described of regulating furnaces operating under forced draft which consists in maintaining in the furnace chamber a pressure less than atmospheric pressure and varying inversely with the varying rates of combustion.

12. The method herein described of regulating furnaces of a vapor generator operating under forced draft which consists in maintaining in the furnace chamber a pressure less than atmospheric pressure and varying inversely with the demand on the generator.

13. The method herein described of regulating furnaces which consists in discharging gases from the furnace in quantities proportional to varying rates of combustion and supplying air to the furnace at such rates that the pressure in the furnace will vary inversely with the rates of combustion but at such a rate as to maintain under such varying rates of combustion pressure below atmospheric pressure.

14. The method herein described of regulating furnaces of a vapor generator operating under forced draft which consists in discharging gases from the furnace in quantities proportional to varying demands on the generator and supplying air to the furnace at such rates that the pressure in the furnace will vary inversely with the demands on the generator but at such a rate as to maintain under such varying demands on the generator a pressure below atmospheric pressure.

15. The combination with a combustion chamber, means for supplying air thereto and means for maintaining therein a pressure below atmospheric pressure and for automatically varying such pressure inversely with varying rates of combustion.

16. The combination with the combustion chamber of a vapor generator operating under forced draft, means for supplying air thereto and means for maintaining therein a pressure below atmospheric pressure and for automatically varying such pressure inversely with varying demands on the generator.

17. The combination with a combustion chamber, of a blower for supplying air thereto, means for establishing therein a pressure below atmospheric pressure and means for varying such pressure inversely proportional to varying rates of combustion.

18. The combination with a combustion chamber, of a blower for supplying air to said chamber, means for establishing therein a pressure below atmospheric pressure and for varying such pressure inversely to varying rates of combustion, said means comprising appartus for varying the exhaust of gases from the furnace and substantially simultaneously so varying the supply of air to the furnace that the pressure in the furnace will not exceed a minus pressure.

19. In combination with a furnace, means for varying the escape of gases from the furnace in quantities graduated between the extremes, a blower, and means for varying the supply of air to the furnace from the blower in such quantities so graduated between the extremes as to maintain a pressure in the furnace inversely proportional to the graduated quantities of gases discharged from the furnace, the parts being so automatically controlled that minus pressures are maintained in the furnace.

20. A combustion controlling system comprising a combustion chamber, a passageway for the air and gases through and including said chamber, a damper in said passageway regulating the flow of air to

the combustion chamber, and means for controlling the differential in pressure at the damper whereby the quantity of air flowing past the damper is controlled.

21. A combustion controlling system comprising a combustion chamber, a passageway for the air and gases through and including said chamber, a damper in said passageway regulating the flow of air to the combustion chamber, and means for controlling the relation between the differential in pressure at the damper and the area of the damper opening.

22. The method of regulating furnaces which consists in controlling a constriction in the passageway for the air and gases through the furnace and in controlling the differential in pressure at the point of constriction.

23. The method of controlling furnaces which consists in regulating the flow of air to the furnace by varying a constriction in the passageway for the air and gases through the furnace and in controlling the differential in pressure at the point of constriction.

24. The method of regulating the flow of gas under pressure through a passageway which consists in controlling a constriction in the passageway for the gas and in controlling the differential in pressure at the point of constriction.

25. The method of regulating the flow of gas under pressure through a passageway which consists in regulating the flow of gas by varying a constriction in the passageway and in controlling the differential in pressure at the point of constriction.

26. An apparatus of the class described comprising a conduit, a damper in the conduit, means to adjust the position of the damper to vary the area of the conduit at the damper, and means for controlling the differential in pressure at the damper whereby the quantity of gas flowing past the damper is controlled.

27. An apparatus of the class described comprising a conduit, a damper in said conduit regulating the flow of gas therethrough, and means for controlling the relation between the differential in pressure at the damper and the area of the damper opening.

28. An apparatus of the class described comprising a conduit, a pair of dampers located at different points in the conduit, means for varying the position of one of said dampers to vary the damper opening, and means controlled by the differential in pressure effecting the flow through said damper opening, acting to vary the position of the other damper to maintain constant the said differential in pressure.

29. The combination with a furnace having separate primary and secondary air supplies of means automatically responsive to variations in the ratio of primary air to secondary air supplied for adjusting one of said supplies in a direction tending to maintain said ratio constant.

30. The combination with a furnace burning fuel on a grate and having separate primary and secondary air supplies of means for automatically adjusting one of said supplies on changes in fuel bed resistance in the direction required to maintain a constant ratio of primary air to secondary air supplied notwithstanding such changes.

Signed at New York in the county of New York and State of New York this 17th day of April A. D. 1920

GEORGE HERBERT GIBSON.