G. H. GIBSON.

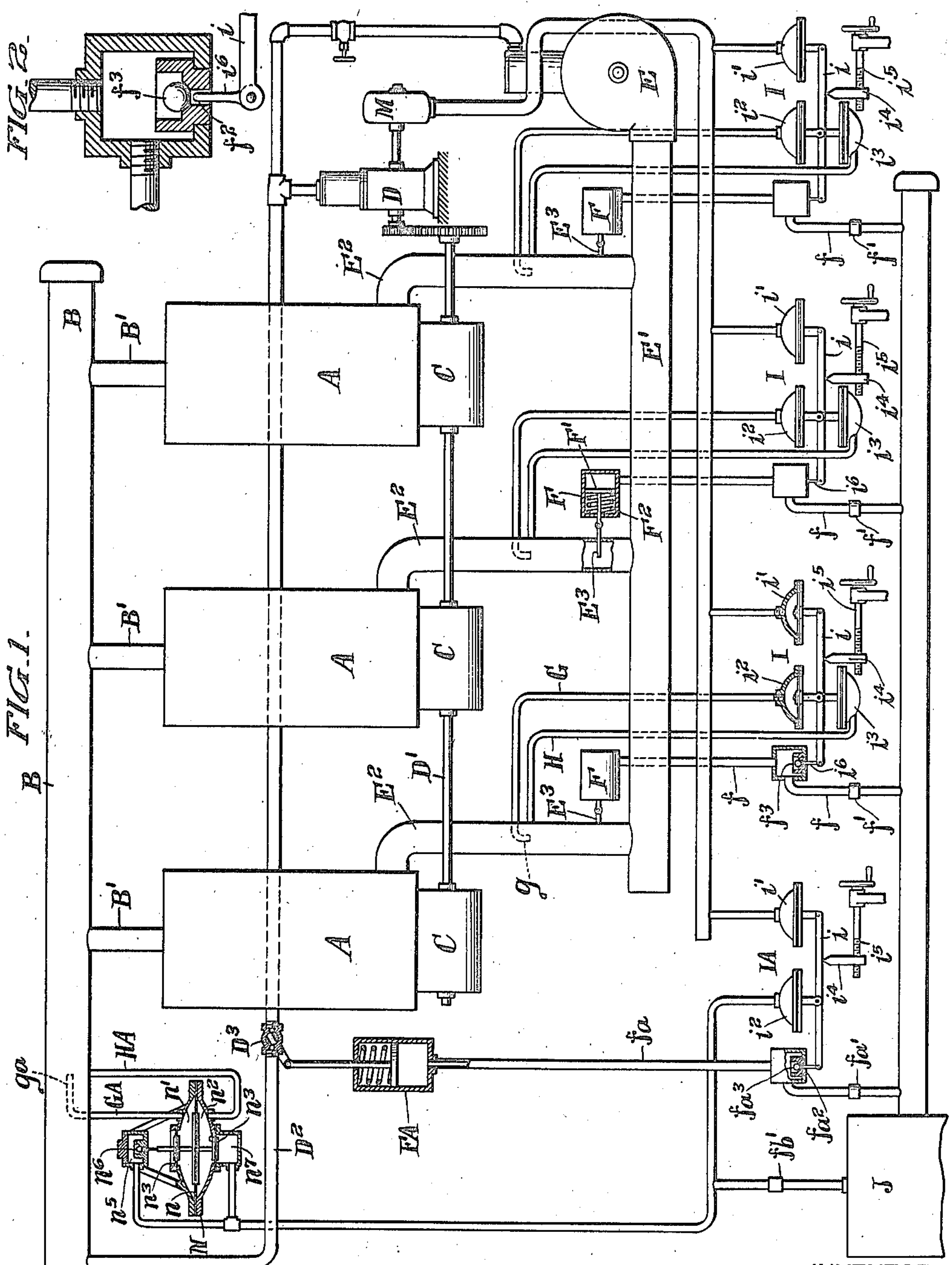
FURNACE REGULATION.

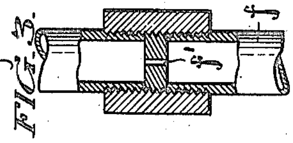
APPLICATION FILED OCT. 3, 1914.

1,167,343.

Patented Jan. 4, 1916.

4 SHEETS—SHEET 1.





WITNESSES

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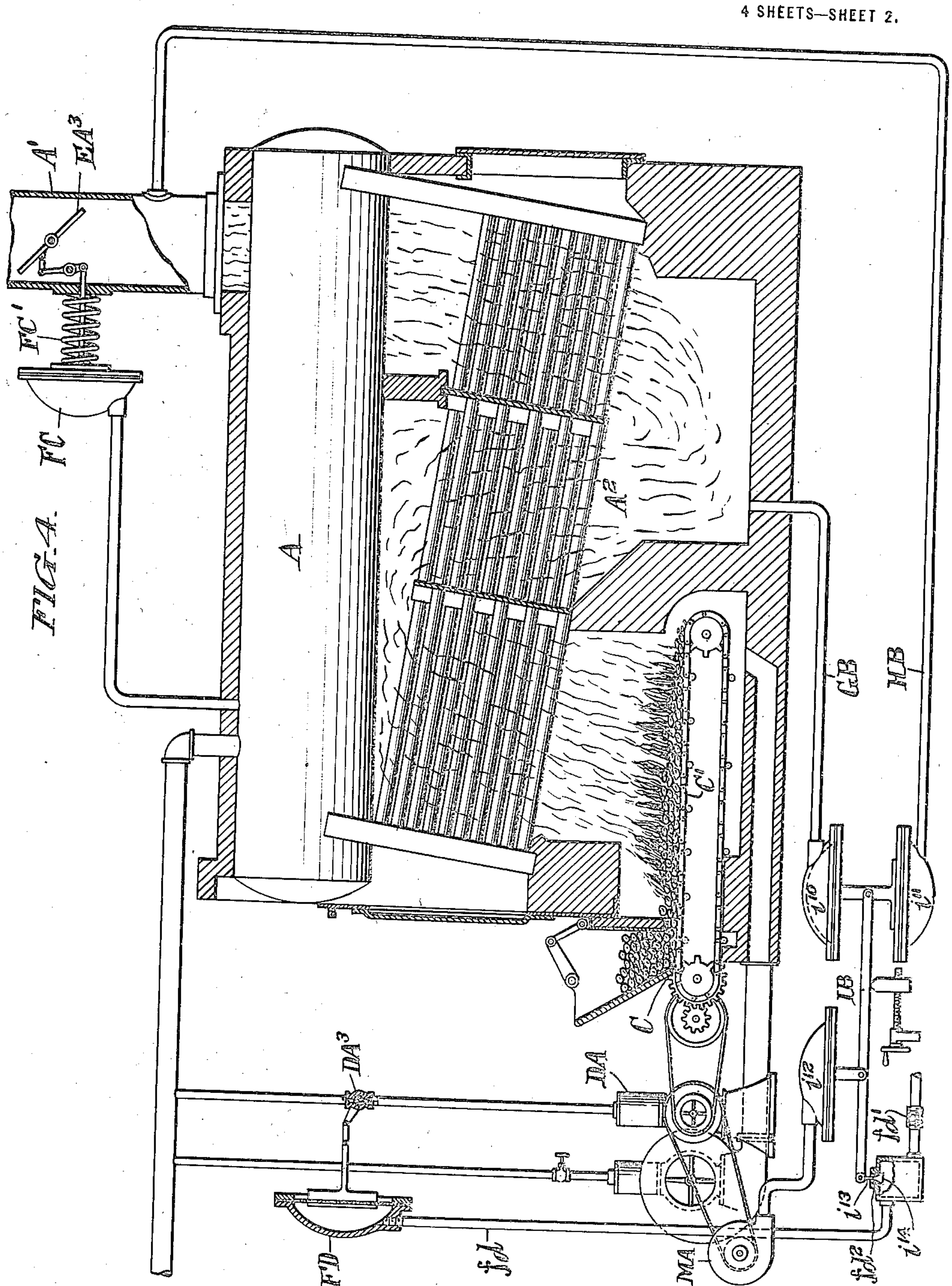
4 SHEETS—SHEET 2.

FIG. 4.



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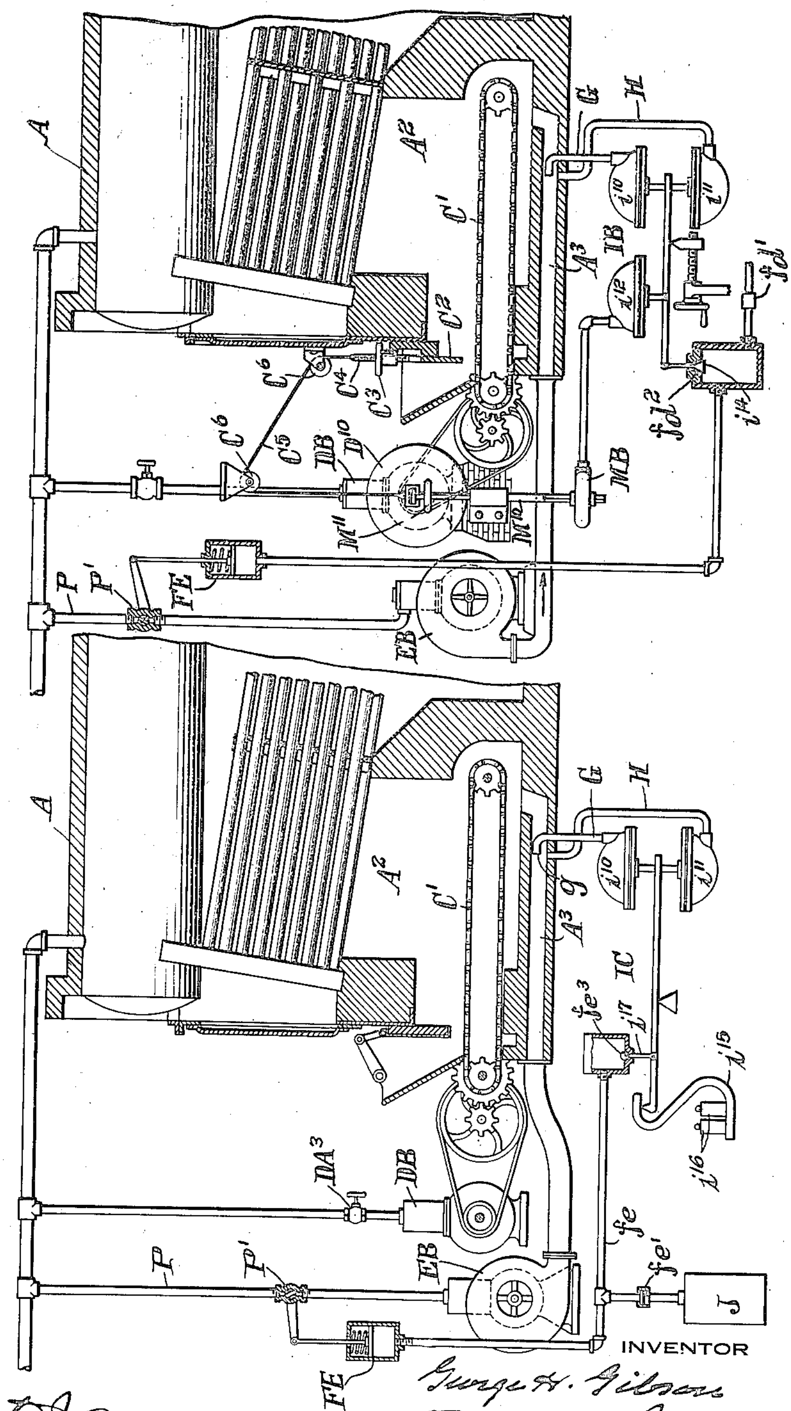
4 SHEETS—SHEET 3.

FIG. 6.

FIG. 5.



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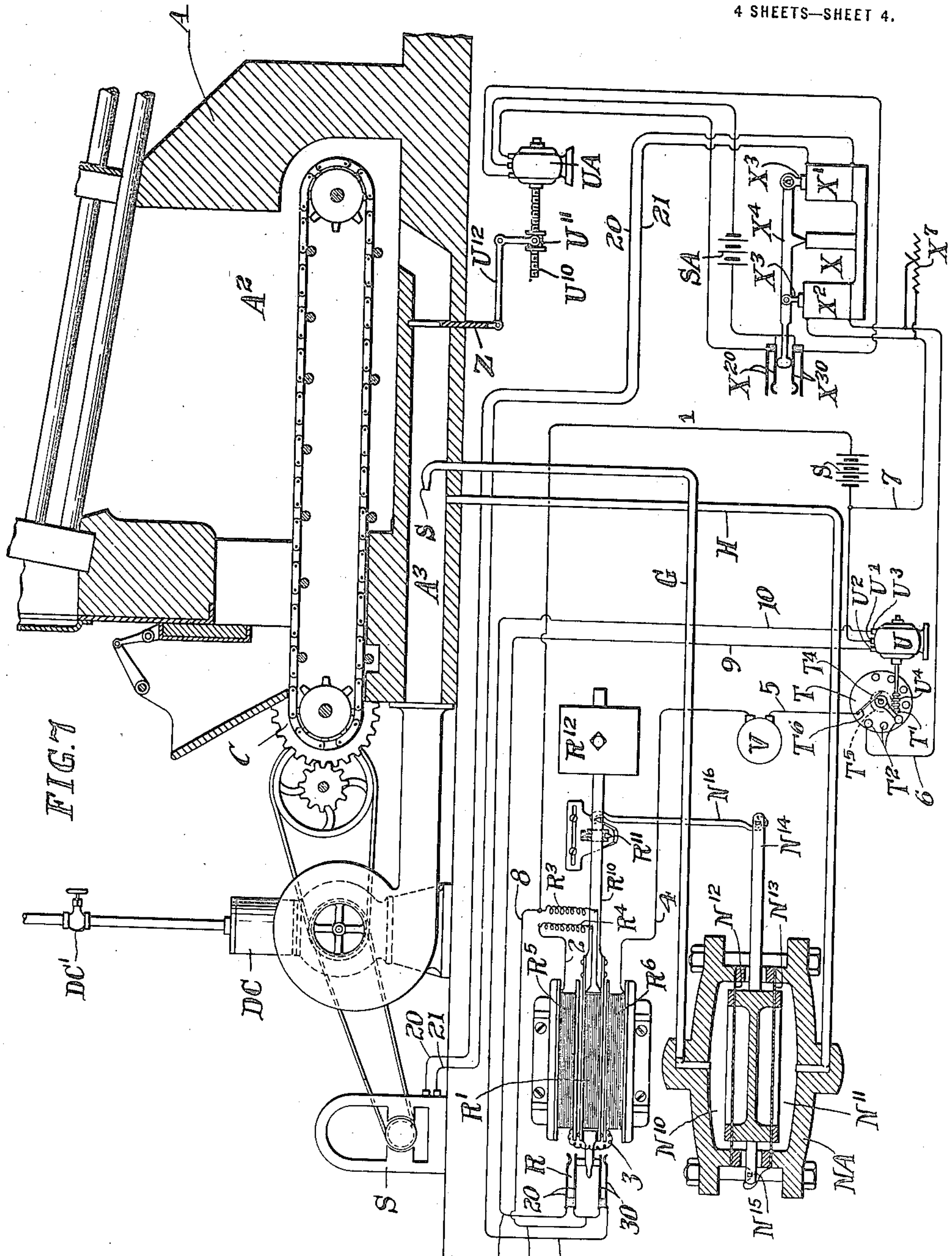

FIG. 1

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FURNACE REGULATION.

1,167,343. Specification of Letters Patent. Patented Jan. 4, 1916.

Application filed October 3, 1914. Serial No. 864,734.

To all whom it may concern:

Be it known that I, GEORGE H. GIBSON, a citizen of the United States of America, residing in 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 true and exact description, reference being had to the accompanying drawings, which form a part thereof.

The general object of my present invention is to provide efficient and satisfactory means for automatically controlling the combustion in furnaces, and particularly in steam generating furnaces.

A more specific object of my invention is to provide effective means whereby the fuel fed to the furnace, and the air for the combustion of the fuel fed to the furnace, are correctly and automatically proportioned to one another.

In preferred embodiments of my invention the fuel and air are not only automatically porportioned to one another, but are fed at a rate varying with and depending on service conditions. For instance, they may be fed to the furnace at a rate varying with the rate at which steam is withdrawn from the boiler, or varying inversely with the pressure of the steam generated by the boiler.

My invention also comprises novel means for insuring a proper load distribution among the different boilers of a steam generating plant comprising a plurality of separate boilers delivering steam into the same distribution system.

The various features of novelty characterizing 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 of the advantages possessed by it, reference should be had to the accompanying drawings and descriptive matter, in which I have illustrated and described several forms in which my invention may be embodied.

Of the drawings: Figure 1 is a diagrammatic representation of a steam generating plant comprising a plurality of boiler furnaces all delivering steam to a common distribution system, and having provisions for automatically maintaining a predetermined ratio between the amount of fuel and the amount of the air to support the combustion of the fuel, fed to each boiler furnace, and also having provisions for varying the amounts of fuel and air fed to each of the different boilers of the battery in proportion to the rate at which steam is withdrawn from the plant as a whole; Fig. 2 is a large scale sectional elevation of one detail of the apparatus employed in Fig. 1; Fig. 3 is a large scale sectional elevation of another detail of the apparatus employed in Fig. 1; Fig. 4 is a diagrammatic representation of a steam generating plant embodying a modified form of my invention; Fig. 5 is a diagrammatic representation of a plant similar in numerous respects to, but different in other respects from, the plant shown in Fig. 4; Fig. 6 is a somewhat diagrammatic representation illustrating a special construction which may or may not be utilized in such plants as shown in Figs. 1 and 4; and Fig. 7 is a diagrammatic representation of a portion of a boiler plant, comprising electro-magnetic means for maintaining the volume of draft proportional to the stoker feed.

In the embodiment of my invention illustrated diagrammatically in Fig. 1, there are three steam generating boilers A, which may be duplicates of one another, and which deliver steam through pipes B′ to the common steam main or header B. Fuel is fed to each boiler by an individual mechanical stoker C; the various stokers being driven through the common shaft D′ and suitable gearing by the motor D. The air necessary to support combustion in each furnace A is provided through a corresponding branch pipe E^2 from a main air supply pipe E′, which, as shown, receives air from the blower or rotary pump E. The flow of air through each branch pipe E^2 is controlled as shown by a slide damper E^3. Each slide damper E^3 is actuated by a fluid pressure motor F, which comprises, as shown, a cylinder, a piston F′ working therein, and a spring F^2 tending to move the piston in the direction to sold the damper F^3 wide open.

Associated with each pressure motor F are means for automatically maintaining a pressure against its piston F′ in a direction opposing the action of the spring F^2 such that the flow of air through the corresponding pipe E^2 will be proportional to the speed of the stoker motor D, and hence to the rate at which fuel is supplied to the corresponding furnace. The means shown for accomplishing this purpose comprise mechanism by which a force, which is a function of the rate of flow through each air conduit E^2, is opposed to a force which is a similar function of the speed of the stoker engine, in a balancing mechanism or comparator, which on a change in the ratio between these two forces varies the pressure acting against the piston F′ of the corresponding motor F and thereby opens or closes the connected damper E^3 as required to restore the ratio between two forces to a predetermined value. The particular form of means illustrated in Fig. 1 for accomplishing this result, comprises a fluid pressure balancing device or comparator I, consisting of a lever i pivoted on a fulcrum block i^4, which is advantageously adjustable, as by means of the threaded rod i^5 passing through the fulcrum block. The lever i is connected at one end to a flexible diaphragm forming one wall of a pressure chamber i'. The pressure chamber i' is connected to the outlet of the rotary pump M, shown as driven by the stoker engine D. At the opposite side of the fulcrum block i^4 from the chamber i' a similar pressure chamber i^2 has its diaphragm wall connected to the lever i, so that the pressure exerted against the lever by the diaphragm of the chamber i^2 opposes the thrust on the lever of the diaphragm of the chamber i'. As shown, the chamber i^2 is connected by a pipe G to a Pitot tube g located in the corresponding air conduit E^2. A static pressure pipe H is connected to the conduit E^2 adjacent the Pitot tube g and extends from there to a pressure chamber i^3 which has a flexible diaphragm connected to the lever i so as to directly oppose the latter in its action on the lever i. The cylinder of each damper actuating pressure motor F is connected through a corresponding branch pipe f to a compressed air reservoir J, or other source of pressure fluid. Each branch pipe f is formed with a restricted orifice f' (see Fig. 3), and between the orifice f' and the motor F is formed with a vent or leakage orifice f^2 (see Fig. 2), controlled, as shown, by the normally closed ball valve f^3. The ball valve f^3 is arranged to be lifted off its seat by a finger i^6 carried by the lever i whenever the effect of the pressures within the chambers i' and i^3 on the lever i exceeds the effect of the pressure in the chamber i^2.

The difference between the pressures transmitted to the chambers i^2 and i^3 will be a function of the rate of air flow through the corresponding conduit E^2, and this pressure differential will in practice be approximately proportional to the square of the rate of air flow through the conduit. Similarly, the pressure maintained in the closed discharge pipe of the pump M will be a function of the rate at which the stoker motor D operates, and in practice may be made approximately proportional to the square of the speed of rotation of the stoker motor. When the ratio of air flow to stoker speed increases above the predetermined value, the finger i^6 permits the valve f^3 to close the port f^2, and when this ratio diminishes, the valve f^3 is lifted off its seat, permitting leakage out of the pipe f through the port f^2. The pressure in the motor F and the piping f at the outlet side of the restricted port f' tends to rise to an equality with the pressure in reservoir J when the valve f^3 is seated, and when the latter is off its seat tends to fall to an equality with atmospheric pressure. As the pressure in motor F falls the damper E^3 opens permitting a greater air flow through the pipe E^2. This increase of air flow tends to shift the lever i to permit the valve f^2 to seat and thereby increase the pressure in motor F and close the damper E^3. It will be understood, of course, that the pressure in the reservoir or supply source J should be at least as great as the maximum pressure needed in the motor adjustment.

Inasmuch as it is the difference between the pressures in the chambers i^2 and i^3, and not simply the static pressure in the pipe E^2, to which the lever i is subjected, variations in the resistance to flow through the combustion chamber due to varying thicknesses and varying degrees of perviousness of the fuel bed and other varying conditions of operation will not prevent the maintenance of the proper gaseous flow through the combustion chamber. While, if the boiler furnaces A are similar in type and capacity, the gaseous flow through each combustion chamber should ordinarily be the same as through each of the others at all times, this does not mean that the different dampers E^3 should all be open to the same extent at any one time. On the contrary, with a comparatively open fuel bed in one furnace and a less pervious fuel bed in another, the damper E^3 for the first chamber would be less widely open than the damper E^3 for the other furnace. It will be understood, of course, that in the arrangement described, the blower E and the piping connecting it to the different furnace chambers should be of such capacity that the flow through each conduit E^2 will increase and decrease as the corresponding damper E^3 is opened and closed throughout the entire range of damper adjustment.

It will be apparent that the apparatus already described operates to maintain a predetermined ratio between the air and fuel supplied to each furnace, and that this ratio does not depend upon whether the speed of the motor D, and consequently the fuel rate of feed, is manually or automatically controlled. It is quite desirable in some cases, however, to automatically proportion the feed of the fuel and of the air supporting combustion to the rate at which steam is withdrawn from the boilers, and means for accomplishing this result are shown in Fig. 1. This means comprises a throttle valve D^3 in the branch pipe D^2 through which steam is supplied from the steam main B to the stoker motor D for operating the latter, fluid pressure motor FA for operating the valve D^3, and a balancing mechanism IA subjected to the opposing action of a force proportional to the square of the rate of steam flow through the conduit B, and of the delivery pressure of the pump M, and means actuated by the balancing mechanism IA for varying the pressure of the motive fluid supplied to the motor FA as required to maintain a predetermined ratio between said force and pressure.

The balancing device IA is generally similar to the balancing device I heretofore described, except that the fluid pressure chamber i^3 acting on the lever i is dispensed with, and the fluid pressure chamber i^2 is subjected to a fluid pressure which is proportional to the difference between the velocity and static heads, or pressures, in the pipe B, but which may be different from, and in practice is substantially smaller than either of these pressures. As shown, the pipe GA leads from the Pitot tube ga to the chamber n' of a fluid pressure analyzer or differential pressure device N. The static pressure pipe HA leads from pipe B to the chamber n^2 of the device N. The chambers n' and n^2 are separated by a flexible diaphragm n, and opposed wall portions of the two chambers, n' and n^2, are formed by two flexible diaphragms n^3. The two diaphragms n^3 are similar to one another in size, but are smaller than the central diaphragm n. All three of the diaphragms n, n^3, which are coaxial, are connected by a central stem, which is provided at its upper end with an extension adapted to unseat the ball valve n^6 normally closing a leakage port from a chamber n^5. The latter is connected by suitable piping to a chamber n^7 separated from the chamber n^2 by the corresponding small diaphragm n^3. The chambers n^5 and n^7 are also connected to the pressure chamber i^2 and this chamber and the connecting piping receive pressure fluid from the source J through the restricted port fb'. It will be apparent, therefore, that the pressure maintained in the chamber n^7 will be proportional to the excess of the pressure in the chamber n' over that in the chamber n^2 of the device N, for the balancing pressure in the chamber n^7 will be increased or diminished by the closing and opening of the valve n^6 as the diaphragms n and n^3 move in one direction or the other from their neutral positions. The pressure motor FA receives pressure fluid through the branch pipes fa and restricted port fa', and the pressure in the piping fa at the outlet side of the restricted port fa' is controlled by the balancing device IA acting on the ball valve fa^3 normally closing the leakage port fa^2.

By using the pressure analyzer N in the manner described, it becomes unnecessary to subject the pressure balancing device IA to the high temperatures and pressures of the steam pipe B. It will, of course, be understood, however, that the pressure balancing device IA might comprise a fluid pressure chamber i^3 as is found in the balancing device I, and in this case the chambers i^2 and i^3 of the balancing device IA might be connected directly to the pipes GA and HA, respectively.

With the arrangement described for controlling the valve D^3 it will be apparent that the motor D will be supplied with steam as required to maintain its speed proportional to the velocity flow through the steam main B. It will also be observed that the supply of fuel and of the air supporting the combustion of the fuel to the combustion chamber of each of the different boilers in proportion to the rate at which steam is withdrawn from the battery of boilers as a whole. This tends to equalize the amount of work done by the different boilers.

In the modified form of apparatus illustrated in Fig. 4, the escape of the gaseous products of combustion from the combustion chamber A^2 of the boiler is controlled by a damper EA^3 located in the chimney or breeching A′ of the boiler, and opened and closed, as the pressure of the steam generated by the boiler diminishes and increases, by the fluid pressure motor FC, which, as shown, comprises a flexible diaphragm acted against on the one side by the steam pressure and on the other side by a spring FC′. As shown in Fig. 4, the stoker motor DA driving the mechanical stoker C, feeding solid fuel to the boiler A, is governed by means of the steam supply throttle valve DA^3 operated by the pressure motor FD, and the latter is controlled by a pressure balancing device IB, generally similar to the devices I and IA heretofore described. As shown, the device IB comprises opposed pressure chambers i^{10} and i^{11} connected by the pipes GB and HB to the combustion chamber A^2 and the smoke outlet A′, respectively; and also comprises a fluid pressure chamber i^{12} connected to the discharge from the blower MA operated by the stoker motor DA. The diaphragm of the pressure chamber i^{12} acts on the lever of the balancing device IB to oppose the action of the diaphragm of the pressure chamber i^{10}, and to assist the action of the diaphragm of the pressure chamber i^{11}. The lever of the balancing device IB carries a finger i^{13}, terminating in a valve i^{14} controlling the leakage port fd^2 from the piping fd' through which pressure fluid passes from a suitable source to the pressure motor FD. The leakage port fd^2 is located between the pressure motor FD and the restricted port fd' in the pipe fd.

It will be apparent that with the apparatus shown in Fig. 4 the passage of air into the combustion chamber A^2 is indirectly controlled by the damper EA^3 in the smoke outlet A' in response to the steam pressure generated by the boiler, and thereby tends to maintain a predetermined steam pressure. The supply of fuel to the combustion chamber, however, is proportional to the gaseous rate of flow through the combustion chamber into the smoke outlet, which is a function of the difference between the pressures transmitted by the pipes GB and HB, and is not directly dependent on the setting of the damper EA^3, or the perviousness of the fuel bed.

In some cases it may be desirable to automatically maintain a constant rate of air flow into the combustion chamber of a boiler, as where the manual or automatic mode of firing employed insures a uniform rate of fuel introduction into the combustion chamber. One arrangement for this purpose is illustrated in Fig. 5, wherein the balancing device IC employed comprises chambers i^{10} and i^{11}. The chamber i^{10} is connected by pipe G to the Pitot tube g in the draft inlet A^3 of the furnace. The chamber i^{11} is connected by the static pressure pipe H to the inlet A^3. The blower MA of Fig. 2 is omitted, however, and the pressure chamber i^{12} of Fig. 4 is replaced by the scale pan i^{15}, on which are placed weights i^{16} which determine the gaseous rate of flow through the combustion chamber and may be varied to vary this rate of flow. The finger i^{17} of the balancing device IC acts against the leakage valve fe^3 regulating the pressure in the pressure motor FE governing the throttle valve P' in the steam supply pipe P of the steam engine driving the draft blower EB.

With the apparatus shown in Fig. 5, a given rate of fuel feed to the combustion chamber A^2 may be maintained by a proper setting of the supply valve DA^3 in the steam supply pipe for the stoker engine DA, and with any given rate of fuel feed, the proper rate of air flow through the combustion chamber may obviously be had by placing the proper weights i^{16} on the scale pan i^{15}.

The blower fans M and MA are conventionally illustrated in Figs. 1 and 4, as operated at a speed directly proportional to the speed of the stoker engine. In practice, however, with the common type of stokers, such as are illustrated in Figs. 4, 5 and 6, the rate at which fuel is fed into the combustion chamber depends upon two factors; namely, the speed of travel of the chain grate C', and the height of the gage or feed gate C^2. The effect of an adjustment of the gate C^2 in apparatus such as is shown in Figs. 1 and 4, can be compensated for by a corresponding adjustment of the lever fulcrums of the balancing devices I of Fig. 1, or of the balancing device IB of Fig. 4. The effect of this adjustment of the feed gate may well be automatically compensated for, however, by the means for the purpose shown in Fig. 6. This means comprises a gearing connecting the stoker motor DB to the fan MB and provisions for automatically adjusting this gearing as the gate C^2 is adjusted. As shown, a friction disk D^{10}, rotated by the stoker engine, drives the blower MB by means of a friction roller M^{11} and connected to the blower MB by a shaft M^{10} which is arranged to slide through the blower to permit the roller M^{11} to be moved toward and away from the center of the disk D^{10}. Such movement of the roller M^{11} is brought about by means of the cord C^5 running over the pulleys C^6 and connected to the feed gate C^2, or rather as shown to the bolt C^4 on which is threaded the hand-wheel C^3 for raising and lowering the gate C^2. With the arrangement shown in Fig. 6, it will be apparent that the speed of the blower MB will be proportional to the product of two factors, one of which is the speed of the stoker engine DB and the other of which is proportional to the elevation of the feed gate C^2.

In the apparatus illustrated in Figs. 1 to 6, inclusive, fluid pressure balancing devices (I and IA, &c.) form the means through which the forces to be equilibrated act against one another, and through which one of said forces may be adjusted when necessary to preserve or restore the balance. In its broader aspects, however, my present invention is not dependent upon the form or general character of the equilibrating mechanism, and in Fig. 7 I have illustrated an embodiment of my invention in which electrical balancing and controlling mechanism is employed. As shown in Fig. 7, the speed of the stoker motor DC is independently controlled through the valve DC', and is connected to and drives a magneto S at a proportional speed, so that the electric current generated by the magneto will be proportional in strength to the speed of the stoker motor. The terminals of the magneto S are connected by conductors 20 and 21 to the terminals of one coil X' of an electro-magnetic balancing device X. The latter controls the draft regulating damper Z in a manner hereinafter described. The balancing device X comprises, as shown two cylindrical coils X' and X^2, each receiving a solenoid X^3 carried by the corresponding end of a lever X^4 pivoted between the axes of the coils.

Associated with the apparatus of Fig. 7 already referred to are means for maintaining an electric current flow through the coil X^2 proportional in intensity to the volume of draft through the furnace. This means as shown comprises a differential pressure device NA having two spaced apart chambers N^{10} and N^{11}, adjacent wall portions of which are formed by similar flexible diaphragms N^{12} and N^{13}. The chamber N^{10} is connected by a pipe G to a Pitot tube *g* projecting into the draft inlet passage A^3 of the furnace, and the static pressure in this passage adjacent the point at which the Pitot tube is located, is transmitted to the chamber N^{11} through the pipe H. The diaphragms N^{12} and N^{13} are connected to the opposite sides of a lever N^{14} which has a stationary fulcrum support N^{15} at one end, and at the other end is connected by means of a link N^{16} to a lever R^{10}. The lever R^{10} is pivoted on an adjustable fulcrum R^{11} and carries at one end an adjustable counterweight R^{12} and at the other end carries the floating coil R′ of an electro-dynamometer R, of the Kelvin balance type. Coöperating with the floating coil R′ of the electrodynamometer are upper and lower stationary coils R^5 and R^6. The electric current passing in series through the coils R′, R^5 and R^6 is supplied by a suitable source, conventionally illustrated as a battery S, and the intensity of this current is regulated as required to maintain the lever R^{10} in its neutral position by means of a rheostat T, which is adjusted by a motor U. The rheostat T, as conventionally illustrated, comprises a contact arm T′ sweeping over a series of contact studs T^2, connected in series by the usual resistance sections. The arm T′ is carried by a shaft T^4, which also carries a gear T^5 in mesh with the worm U^4 carried by the shaft of the motor U. The motor U is reversible, and runs in one direction when a suitable source of electric current is connected to its terminals U′ and U^3, and in the opposite direction when current is supplied to the terminals U′ and U^2.

The circuit connections are as follows: A conductor 1 leads from one side of the battery S to the flexible terminal R^3 of the floating coil R′. The other flexible terminal R^4 of the coil R′ is connected by the conductor 2 to one terminal of the stationary coil R^5. The second terminal of the stationary coil R^5 is connected by the conductor 3 to one terminal of the stationary coil R^6. A conductor 4 connects the second terminal of the coil R^6 to one terminal of the ammeter V, and the other terminal of the latter is connected by the conductor 5 and brush T^6 to the movable contact arm T′ of the rheostat T. The contact stud T^2 at one end of the row of studs T^2 is connected by the conductor 6 to one terminal of the balance coil X^2. The other terminal of the balance coil X^2 is connected by the conductor 7 to the opposite side of the battery S from that to which the conductor 1 is connected. The conductor 1 is connected by a conductor 8 to one of a pair of contacts 20, and to one of a pair of contacts 30. The second of the pair of contacts 20 is connected to the motor terminal U^2 by a conductor 9, and the second of the contacts 30 is connected by a conductor 10 to the motor terminal U^3. The motor terminal U′ is connected to the conductor 7. In the neutral position of the floating coil R′ of the balance R, the two contacts 20 are out of engagement with one another, and this is true also of the two contacts 30. When the floating coil R′ moves upward, as it does on an increase in the volume of draft through the passage A^3, the contacts 20 are closed, thus energizing the winding of the motor of which U′ and U^3 are the terminals, whereupon the motor U is operated in the direction to move the contact arm T′ clockwise, and thus decrease the number of resistance sections in circuit. This, by increasing the strength of the current flowing through the coils R′, R^5 and R^6, tends to restore the floating coil to its neutral position. On a decrease in the volume of draft, the decrease in the differential of the pressures in the chambers N^{10} and N^{11} results in a closure of the contacts 30, and this causes the motor U to rotate the arm T′ in the counter-clockwise direction, increasing the number of resistance sections in circuit, and correspondingly reducing the current flow through the dynamometer coils R′, R^5 and R^6.

Inasmuch as the difference between the pressures in the chambers N^{10} and N^{11} will be proportional to the square of the rate of air flow or volume of draft through the passage A^3, while the electro-magnetic interaction due to the current in the coils R′, R^5 and R^6 is proportional to the square of the strength of the electric current flowing through these coils is in linear proportion to the volume of draft or rate of air flow through the passage A^3, hence a simple ammeter V will furnish direct and proportional readings of the volume of draft.

The lever X′ of the balancing device X is adapted to engage and close a normally separated pair of contacts X^{20} on a movement of the lever resulting from an increase in the ratio of the current passing through the coil X^1 to the current passing through the coil X^2, and on a diminution in this ratio, to engage and close a pair of normally separated contacts X^{30}. When the contacts X^{20} are closed, a circuit is thereby established which includes a source of current, as the battery SA, and the winding of a motor UA, which causes the latter to rotate in the direction in which its threaded spindle U^{10} moves the nut U^{11} to the right. This shifts the lever U^{12} so as to lower the damper Z, and permit a greater flow of air into the combustion chamber A^2 of the furnace, whereby the pull of the coil X^2 will be increased sufficiently to return the lever X^4 to its normal position. Conversely, when the ratio of the speed of the stoker motor to the volume of draft decreases, the lever X^4 is shifted to close the contacts X^{30} and thus close the second circuit of the motor UA, whereupon the latter is rotated in the opposite direction, and the damper Z moved toward its closed position. It will be understood, of course, that the current generated by the magneto S may or may not be the equal in strength to the current flowing through the coil X^2 of the balance X, when the balance lever X^4 is held in its neutral position. The ratio between these two currents necessary to maintain the balance X in its neutral position may be adjusted, as for instance by shunting the coil X^2 by a variable resistance X^7, as shown.

While the electric and fluid pressure controlling devices illustrated are full equivalents of one another in many respects, each possesses certain advantages over the other for use in certain conditions. For instance, with an electrical balancing device of the Kelvin dynamometer type, the electric current passing in series through the stationary and floating coils may be made to vary in linear proportion to the velocity of air flow, or steam flow, so that an ordinary ammeter will directly indicate the rate of flow of the air or steam. With the fluid pressure apparatus shown, however, the pressures balanced are proportional, not to the rates of flow, but to the squares of the rates of flow, so that simple pressure gages will not give direct proportional indications of the rate of flow. The fluid pressure balancing devices are simpler, however, than the electrical apparatus, and can be used under conditions unsuitable for the use of the electrical apparatus.

In the appended claims hereto I have used the term "volume of draft" as a means for defining draft quantitatively; (*i. e.* cubic feet or pounds of gaseous fluid) flowing through the combustion chamber; instead of defining the draft by the pressure differential between stack and atmospheric pressures, or in some analogous manner.

In all of the forms of apparatus illustrated, except that shown in Fig. 4, provisions are made for automatically maintaining a standard or predetermined volume of draft notwithstanding variations in fuel bed resistance or variations in other draft affecting conditions. In the form of apparatus shown in Fig. 5, the standard or predetermined volume of draft is a constant for any given setting of the apparatus, while with the forms illustrated by the drawings other than Figs. 4 and 5, however, the standard or predetermined ratio between the rate of fuel feed and the volume of draft, notwithstanding variations in one or the other of these quantities in response to other conditions. On a variation in the draft from the predetermined standard the draft regulating mechanism tends to produce a compensating adjustment in the draft controlling device which is progressive in the sense that the device continuously undergoes adjustment until the draft returns to the standard.

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 may be made in the forms of apparatus disclosed without departing from the spirit of my invention, and that under some conditions certain features of my invention may be used 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. In a furnace a draft regulating device and in combination therewith means responsive to the volume of draft controlling said device and tending on a departure in the volume of draft from a predetermined standard to effect a progressive compensating adjustment of said device continuing until the draft returns to said standard.

2. In a furnace, the combination of means responsive to the rate at which fuel is fed into the furnace, means responsive to the volume of furnace draft and means jointly controlled thereby for regulating the ratio of fuel feed to the volume of draft.

3. The combination with a steam generating boiler, of a mechanical stoker therefor, means automatically responsive to the rate at which said stoker operates, means automatically responsive to the volume of boiler draft and a device jointly controlled by both of said means for regulating the draft.

4. In a steam generating plant, the combination of means responsive to the rate at which steam is withdrawn from the plant, and coöperating means including a fuel feeding device, a draft regulating device, and a device responsive to the volume of draft for regulating the fuel feed and volume of draft in accordance with the rate at which steam is withdrawn from the plant.

5. In a boiler plant comprising a plurality of boiler furnaces, means separately regulating the combustion in the different furnaces and controlling means therefor including a device responsive to the joint rate of steam delivery from said furnaces, for proportionately varying the rate of com-

bustion in the different furnaces according to variations in said rate of steam generation.

6. In a boiler plant comprising a plurality of boiler furnaces, the combination of means responsive to the joint rate of steam generation of the furnaces and means including a device responsive to the volume of draft of each boiler furnace for correspondingly varying the rate of combustion in each of said furnaces in response to variations in said joint rate of steam generation.

7. In a boiler plant comprising a plurality of boiler furnaces, the combination of means responsive to the joint rate of steam generation, means, one for and responsive to the volume of draft of each boiler furnace, and draft regulating devices, one for each boiler furnace, and each jointly controlled by the corresponding draft responsive means and the first mentioned means.

8. In a furnace, the combination of a mechanical stoker comprising a variable speed fuel feeding device and an adjustable feed gate, a draft regulating device and controlling means therefor responsive both to the speed of said feeding device and the setting of said gate.

9. In a furnace, the combination of a mechanical stoker, means for maintaining a fluid pressure which is a function of the rate at which fuel is fed, means for maintaining a differential pressure which is a function of the volume of furnace draft, a fluid pressure device in which the first mentioned pressure is balanced against said differential pressure and draft regulating means controlled by said device.

10. The combination with a steam generating boiler, of means responsive to the amount of steam being withdrawn from the boiler, means responsive to the rate at which combustion occurs, and means controlled jointly by the two first mentioned means for adjusting the combustion rate.

11. The combination with a steam generating boiler of means automatically responsive to the volume of boiler draft, means automatically responsive to another varying condition of operation in the boiler and a draft regulating motor jointly controlled by both of said means whereby a predetermined relation between the volume of said draft and said other condition of operation is maintained as the latter varies.

12. In a furnace, the combination of a draft regulating motor and controlling means therefor, comprising a balancing mechanism, means for subjecting said mechanism to opposing forces one of which is a function of the volume of draft, and means actuated by said balancing mechanism controlling said motor whereby the draft is varied as required to maintain said balancing mechanism in its neutral condition.

13. In a furnace, the combination of a draft regulating motor, a device responsive to the volume of draft and controlling means for said motor actuated by said device for progressively operating said motor as required to maintain a predetermined volume of draft notwithstanding variations in the resistance to the draft occurring in the furnace.

14. In a furnace the combination of fuel feeding mechanism, air supplying means and means for automatically proportioning the supply of air to the rate at which fuel is fed comprising means for generating a force which is a function of the rate at which fuel is fed, means for generating a force which is a function of the rate at which air is supplied and balancing means acted upon by said forces.

15. In a furnace burning solid fuel, mechanism for effecting an efficient combustion comprising in combination means for supplying fuel to the combustion chamber of the furnace at a regulated rate, means for adjusting the volume of furnace draft, and means responsive to the volume of draft and automatically controlling the adjustment of one of the previously mentioned means, whereby variations in the ratio of fuel feed to the volume of draft may be compensated for.

16. In a furnace, a draft regulating device and in combination therewith means for creating a pressure differential which is a function of the volume of draft, and means for utilizing said pressure differential on the occurrence of a variation therein from a predetermined standard to effect a progressive compensating adjustment of said device continuing until said pressure differential returns to said predetermined standard.

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Witnesses:
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