

June 30, 1925.

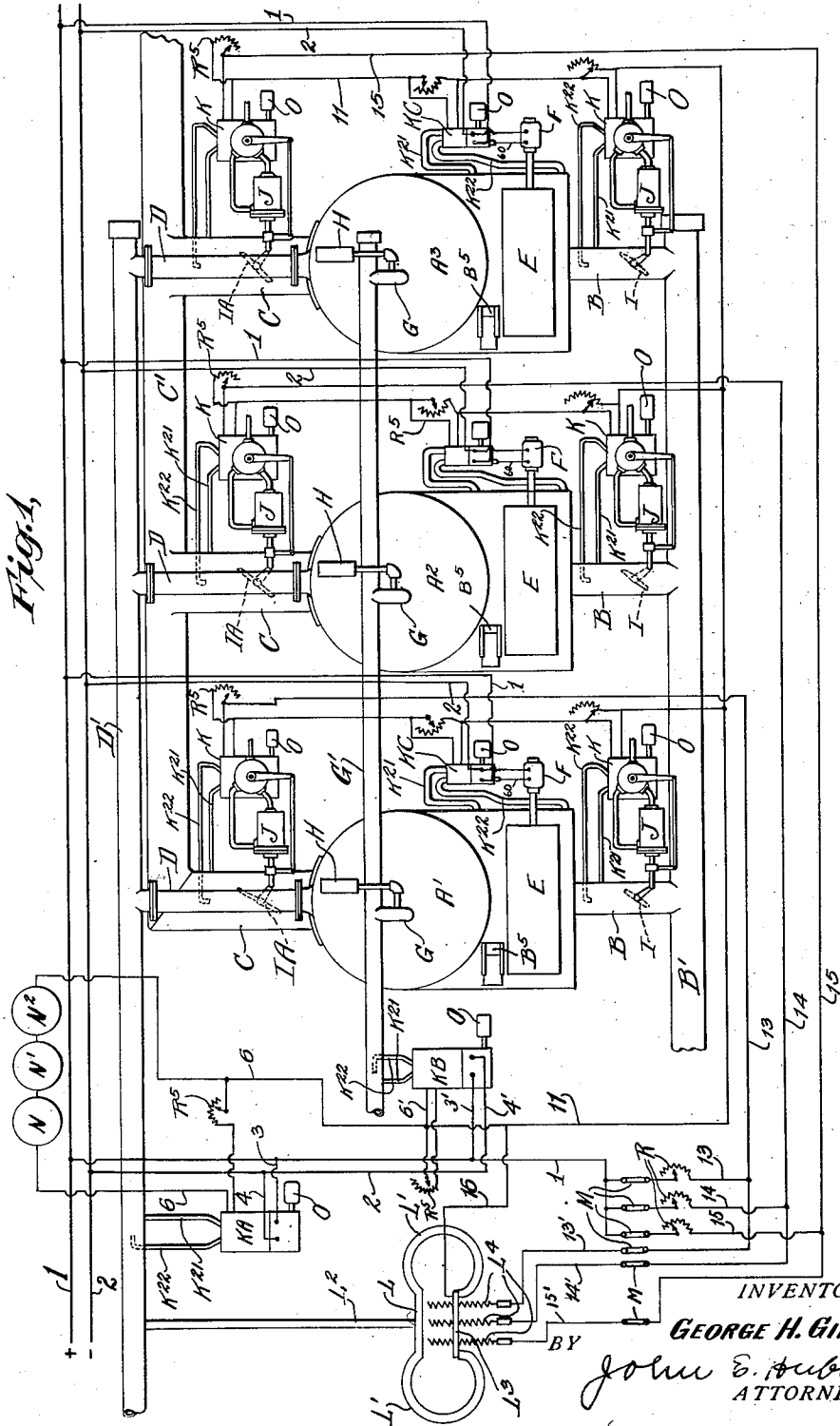
1,544,310

G. H. GIBSON

COMBUSTION REGULATION

Filed Sept. 9, 1921

2 Sheets-Sheet 1



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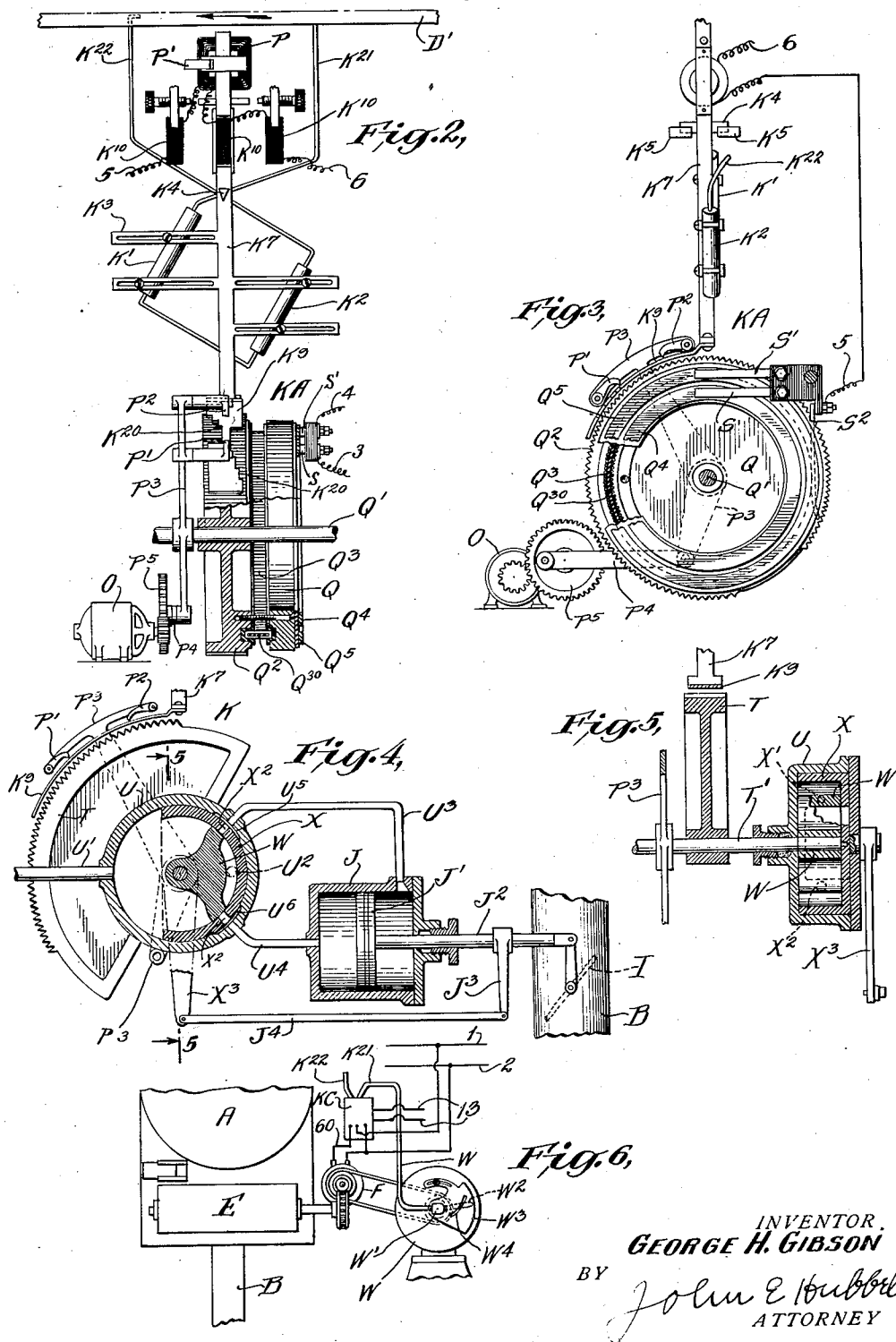
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Filed Sept. 9, 1921

2 Sheets-Sheet 2



Patented June 30, 1925.

1,544,310

UNITED STATES PATENT OFFICE.

GEORGE H. GIBSON, OF MONTCLAIR, NEW JERSEY.

COMBUSTION REGULATION.

Application filed September 9, 1921. Serial No. 499,403.

To all whom it may concern:

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

The general object of the present invention is to provide an improved method of and apparatus for regulating combustion in furnaces in automatic response to the heat requirements of the furnaces.

My present invention in its entirety is especially designed and adapted for use in regulating combustion in boiler furnaces heated by the combustion of solid fuel, but some features of my invention are useful in other furnaces and some features are useful in furnaces heated by the combustion of liquid or gaseous fuel as well as those in which solid fuel is burned.

One specific object of my invention is to provide an improved control of the supply of fuel to the furnace in automatic response to the fuel requirements of the furnace. Another specific object of the invention is to provide for the automatic regulation of the rate of combustion in boiler furnaces not only in response to the volume and pressure of the steam generated by the boilers of the regulated furnaces, but also in response to the rate at which feed water is supplied to the boilers.

In general my invention comprises provisions for automatically supplying to the furnaces fuel, and primary and secondary air for the combustion of the fuel, in proportion to the heat requirements of the furnaces, but the proportions between heat requirements and fuel and air supplies which I am enabled to maintain in accordance with the present invention are not necessarily linear proportions, as I have found it desirable in some cases to vary the supply of fuel to a furnace, and to vary the distribution of the total air supplied for combustion of the fuel into primary and secondary portions on changes in the heat requirements, at rates or proportions relative to the heat requirements which rates or proportions vary as the heat requirements vary.

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, its advantages and specific objects attained with its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described preferred embodiments of my invention.

Of the drawings:

Fig. 1 is a diagrammatic representation of a battery of boiler furnaces and regulating apparatus therefor;

Fig. 2 is an elevation partly in section of one of the automatic regulators employed in carrying out the invention;

Fig. 3 is a side elevation with parts broken away and in section of a portion of the apparatus shown in Fig. 2;

Fig. 4 is a sectional elevation of a portion of one of the automatic damper control mechanisms;

Fig. 5 is a section on the line 5—5 of Fig. 4; and

Fig. 6 is a view illustrating a modification of a portion of the apparatus shown in Fig. 1.

In the drawings A^1 , A^2 and A^3 represent boiler furnaces each of which receives air through a corresponding branch pipe B from the discharge conduit B' of a forced draft fan (not shown). The stack outlets C of the different furnaces connect to a common stack connection C', and the steam pipes D from the different boilers discharge into a common steam main or header D'. Each of the boilers receives feed water through a corresponding branch pipe G from a boiler feed pipe G'. The supply of water to each boiler is controlled by a boiler feed regulator H which may be of any usual or suitable type. Secondary air is supplied to each furnace above its fuel bed through an adjustable inlet B^s, the pressure in the combustion chamber in the furnace being regulated as hereinafter explained so as to draw into each furnace through the inlet B^s the proper amount of secondary air. Fuel is supplied to each boiler furnace by a corresponding automatic stoker E driven by an individual motor F at a rate dependent, as hereinafter explained, on the operation of a corresponding regulator KC. The vol-

ume of draft through each furnace, and the pressure conditions in the latter are regulated by a damper I in the air inlet connection B and a damper IA in the stack outlet connection C. Each of the dampers I and IA is automatically adjusted by an individual control mechanism comprising a damper actuating motor J and a regulator K.

In the embodiment of my invention illustrated in the drawings, the various regulators K automatically operate to maintain a predetermined relation between the amount of fluid flowing through the air inlet B or the stack connection C to which the regulator pertains, and the strength of an electric control current. The latter is a joint function of the rate of steam outflow through the main D', the pressure of the steam in the main D', and the rate at which feed water passes to the boilers through the supply pipe G'. Each regulator KC acts to maintain a supply of fuel to the fuel bed of the corresponding furnace which will make the pressure drop or loss of draft head through the fuel bed a function of the electric control current for the regulators K of the same furnace. The means shown for maintaining the electric control current at the proper strength comprises a master controller KA responsive to steam flow through the conduit D', a master controller KB responsive to the rate of water flow through the boiler feed line G', and a master controller L responsive to the pressure of the steam in the conduit D'.

The master controller KA as shown in Figs. 2 and 3 consists essentially of an electro-magnetic flow balance comprising a tilting differential pressure gauge to the upper end of one leg K' of which, the static pressure in the main D' is transmitted by a conduit K²¹ and to the upper end of the other leg K² of which, the total pressure in the conduit D' is transmitted by a pipe K²². The differential pressure thus impressed on the tilting pressure gauge tends to displace the sealing liquid in the gauge and thereby exerts a tilting force on the gauge which is a function of the rate of flow through the conduit D'. This tilting force is opposed by the resultant of an electro-magnetic interaction between coils K¹⁰, and an electro-magnetic interaction between a coil P and a permanent magnet P'. The electric current flowing through the coils K¹⁰ and P is automatically adjusted as required to normally maintain the balance in its neutral position by a current regulator including a resistance Q³ and mechanism for utilizing more or less of the potential impressed upon the resistance Q³ in forcing current through the coils K¹⁰ and P, as I shall now explain.

As shown the arms K' and K² of the gauge are adjustably clamped to arms K³ of a gauge frame K' having a knife-edge

pivot K⁴ resting on suitable bearing blocks K⁵. The frame K' carries one of the coils K¹⁰ and normally holds the latter midway between the other two coils K¹⁰ which are stationary. The movable and stationary coils K¹⁰ correspond in essence to the floating and movable coils of a Kelvin balance. The coil P is also carried by the frame member K' and the various coils may be so connected that the electro-magnetic pull between coil P and the stationary permanent magnet P' opposes or assists the pull of the coils K¹⁰.

Associated with, and regulated by the magnetic flow balance of the master controller KA is an electrical current adjusting device Q comprising in the form shown a supporting shaft Q' on which is loosely journaled a member Q² having ratchet teeth on its periphery. Also journaled on the shaft Q' is a ratchet oscillating lever P³. The latter is oscillated by a constantly running electric motor O through connections including a gear wheel P⁵ in mesh with a pinion carried by the motor shaft and carrying a crank pin connected by a link P⁴ to the lever P³. The latter is provided with two pawls P' and P². The pawl P' tends to engage the ratchet teeth on the periphery of the member Q² and turn the latter with the lever P³ as the latter swings in the clockwise direction as seen in Fig. 3, while on the return stroke of the lever P³, the pawl P² tends to move the member Q² in a counter clockwise direction. A pawl controller K⁹ carried by the lower end of the flow balance frame member K' prevents the simultaneous engagement of both pawls P' and P² with the ratchet teeth of the member Q² and regulates the amount and direction of movement imparted to the member Q² by the oscillatory movements of the lever P³. As shown the pawl controller K⁹ is in the form of an arc shaped strip of sheet metal fitting over a portion of the periphery of the member Q² and serving when the tilting pressure gauge is in its neutral position as shown in Fig. 2 to hold both pawls P' and P² out of engagement with the ratchet teeth on the member Q² in all positions of the lever P³. When the tilting pressure gauge is swung from its neutral position in the direction in which it moves when the steam flow through the conduit D' decreases relative to the electric current flow through the coils K¹⁰ and P, the shield K⁹ will hold the pawl P² out of engagement with the ratchet teeth on the member Q² throughout the complete stroke of the lever P³, but the pawl P' will then be permitted to engage the ratchet teeth during a portion of the movement of the lever P³ and will correspondingly adjust the member Q² in a clockwise direction as seen in Fig. 3. The portion of the movement of the lever P³ in which the pawl

P' operatively engages and adjusts the member Q² will depend upon the extent of displacement of the shield K⁹ from its neutral position owing to the shape of the correspondingly stepped or inclined side edge K²⁰ of the shield member. Similarly when the shield member is displaced to the right from its neutral position as shown in Fig. 2, the pawl P' will be held out of engagement with the teeth of the member Q² and the pawl P² will effect the adjustments of the member Q² in a counter clockwise direction as seen in Fig. 3 in steps the magnitude of which depends upon the extent to which the shield K⁹ is displaced from its neutral position.

The member Q includes a resistance element Q³ wound in a flattened helix about a ring shaped support Q³⁰. The terminals of the conductor Q³ are connected to inner and outer centrally disposed contact or slip rings Q⁴ and Q⁵. S and S' represent stationary brushes engaging the slip rings Q⁴ and Q⁵ respectively. S² is a stationary brush engaging the resistance conductor Q³. The brushes S and S' are connected by branch conductors 3 and 4 respectively to main current supply conductors 1 and 2, respectively, between which a suitable potential difference is maintained. The coils K¹⁰ and P of the master controller KA are connected in a control circuit including the portion of the resistance Q³ between the end of the latter connected to the slip ring Q⁵ and thereby to the main supply conductor 2, and the point at which the resistance is engaged by the brush S², the latter, a conductor 5 and a conductor 6. The conductor 6 is connected to a similar conductor 6' from the master controller KB. The common continuation 11' of the control conductor 6 and 6' is connected to the main supply conductor 1 through branch conductors 13, 14 and 15 in each of which is placed a manually adjustable rheostat R and a cut-out switch M.

The conductor 13 includes the windings of the two regulators K and the regulator KC for the boiler A', and the conductors 14 and 15 similarly include the windings of the regulators K and KC for the boilers A² and A³, respectively.

The master controller KB may be identical in construction and operation with the controller KA, the pressure transmitting pipe connections K²¹ and K²² of the controller KB transmitting the static and total pressures in the boiler feed line G' to the differential pressure gauge of the balance KB. The connections 3' and 4' between the master controller KB and the supply conductors 1 and 2, correspond to the connections 3 and 4 for the controller KA.

The master controller L comprises in the construction illustrated a hollow head to

which the pressure in the steam line D' is transmitted by a pipe L², and two flexible hollow curved arms L' each of which is in effect a Bourdon tube. The movable ends of the two flexible tubes L' are connected by a part L³ which serves as a movable contact member sliding over three resistances L⁴. The three resistances L⁴ are connected by conductors 13', 14' and 15' respectively to the conductors 13, 14 and 15 respectively at points between the corresponding balances K and KC and the rheostats R. The movable contact member L³ is connected to the conductor 11. In consequence of the described arrangement, the portion of the resistance L⁴ between the contact L³ and the conductor 13 forms a shunt about the balances K and KC of the furnace A', so that when the steam pressure in the pipe D' increases above normal and the contact member L³ is correspondingly depressed, the resistance of the shunt including the conductor 13' about the balances K and KC of the furnace A' is reduced and the electric current flowing through the balance K and KC of the furnace A' is correspondingly reduced. On a decrease in the pressure of the steam, the shunt resistance is increased and the effect of this is to increase the current flow through the balances K and KC. The resistances L⁴ connected to the conductors 14' and 15' respectively, form similar and similarly operated adjustable shunts about the balances K and KC of the furnaces A² and A³ respectively, which tend to increase and decrease the current flow through those balances as the pressure of the steam in the main D' decreases and increases.

Each of the regulators K comprises an electromagnetic flow balance which may be identical with the electromagnetic flow balance of the master controller KA and has its static and total pressure transmitting connections K²¹ and K²² running to the corresponding conduit B or C. In the regulators K however, the current regulator Q of the master controller KA is replaced by a regulator for the corresponding damper actuating motor J. The motor J as shown is a fluid pressure motor comprising a piston J', the stem J² of which is connected to the operating arm of the corresponding damper I or IA. Fluid under pressure is admitted to and exhausted from the opposite ends of the cylinders in which the piston J' operates through pipe connections U³ and U⁴ to a valve chest U. The valve chest U is provided with an inlet U' for a suitable motive fluid, as water under pressure, with an exhaust outlet U² and with spaced apart ports to which the pipes U³ and U⁴ are connected. Working in the valve chest U is a cylindrical valve member X provided with spaced apart ports X² which are interposed between the inner wall of the valve chest and a valve

member W of the rotary D valve type. The ports X^2 open at their outer ends into pockets or recesses U^6 and U^8 in the inner wall of the valve chest U into which the pipes U^5 and U^4 open. The valve member W is secured to the shaft T' to which is also secured a segmental ratchet T. Associated with the ratchet T of each balance K is oscillating mechanism for operating it, comprising an oscillating lever P^3 , its actuating motor pawls P^1 and P^2 and a shield K^9 carried by the frame K^7 of the gauge of the flow balance element of the regulator K whereby the gear segment T may be oscillated in one direction or another in varying degrees dependent upon the position of the flow balance of the regulator in a manner exactly similar to that in which the current regulator element Q^2 of the master controller KA is oscillated. The valve member X has an arm X^3 connected by a link J^4 , an arm J^3 , a stem J^2 to a piston J^1 .

The intended operation of each regulator K is to adjust the corresponding damper I or IA as required to maintain a predetermined ratio between the electric current flowing through the coils K^{10} and P of the balance, and the volume of primary air flowing through the pipe B, or the volume of the products of combustion flowing through the stack connection C, as the case may be. When the current flow through the branch conductor 13, for example, increases, the shields K^9 of the two balances K pertaining to the furnace A' are shifted to the left as seen in Fig. 5 and the member T of each balance is thereby adjusted through the action of the corresponding pawls P^1 in a clockwise direction to thereby permit pressure fluid to flow through the valve chest U and the pipe U^3 into the right hand ends of the corresponding cylinder J as shown in Fig. 4, while at the same time permitting the left hand end of the cylinder to exhaust through the pipes U^4 and exhaust outlets U^2 . This shifts the piston J^1 to the left as seen in Fig. 4, and opens the corresponding damper I or IA and thereby increases the flow through the corresponding conduit B or C. The adjustment of the member T in the counter clockwise direction correspondingly adjusts the damper in the closing direction. With either adjustment of the damper, the corresponding movement of the valve member X produced through the arms J^3 and X^3 and the link J^4 tends to prevent over-travel and hunting of the damper.

The stoker regulators KC may each be identical in construction and general mode of operation with the master controller KA. The pressure transmitting connections K^{21} and K^{22} of each regulator KC are connected to the furnace chamber above and below the fuel bed in the latter and hence the differential pressure gauge element of

each balance KC is responsive to the drop in draft head through the fuel bed. The coils of each regulator KC corresponding to the coils K^{10} and P of the balance KA are connected in series with the corresponding circuit conductor 13, 14 and 15, and are not connected to resistances Q^3 of the regulator. In the balance KC, the resistance Q^3 forms a part of the control mechanism for the electric motor F by which the corresponding stoker E is driven. For example, the resistance Q^3 of each regulator KC may have its terminals connected to the supply conductor 1 and 2 and one terminal of the motor F may be connected to the supply conductor 2, while the other terminal of the member is connected to the conductor 60 leading from the brush of the controller KC corresponding to the brush S of the controller KA, the connections, in any event, being such that as the electric current flows through the control circuit conductor 13 increases and decreases, the rate at which the stoker member F runs tends to increase and decrease.

With the electro-magnetic flow balance shown in Figs. 3 and 4, it is possible to maintain many different kinds of ratios between the pressure differential to which the flow balance is subjected on the one hand, and the balancing electric current on the other hand. For example, by disconnecting the coil P and setting the different pressure gauge legs K^1 and K^2 vertical, the pressure differential will vary in linear proportion with the square of the strength of the balance current and hence, in the case of the balance KA for example, the electric current flowing through the control conductor 6 will be proportional in strength to the volume of steam flow through the conduit D, since the pressure differential in that case is proportional to the square of the rate of steam flow. When the coil P is connected in circuit with the coils K^{10} as shown in Figs. 2 and 3, the magnetic pull between the coil P and the permanent magnet P^1 is proportional to the strength of the electric current and in this case with vertically disposed pressure gauge legs K^1 and K^2 , the flow balance will tend to maintain an equality between the pressure differential impressed on the gauge of the balance, and an electro-magnetic force which increases more rapidly than does the electric current flowing through the coils, but less rapidly than the square of the electric current.

The effect of securing the different differential pressure gauge legs K^1 and K^2 to their supporting frame arm K^8 in different angular adjustments is to vary the change in tilting moment produced by a given amount of displacement of the sealing liquid in the gauge. By such adjustments of the gauge legs K^1 and K^2 it is possible to

so calibrate the flow balance that the pressure differential impressed upon the gauge will vary more rapidly than does the square of the electric current by which it is balanced, or will vary less rapidly than the electric balancing current, or will vary according to some intermediate relation between the pressure differential and the electric balancing current. Much the sort of gauge adjustment obtained by changes in the inclination of the axes of the gauge legs K' and K^2 , may be secured without changing the inclination of the legs by replacing one or both of the legs K' and K^2 by others which vary in horizontal cross section along their lengths, but the adjustment by change in inclination is simpler and more flexible.

The proper relation to be maintained between the pressure differential and the strength of the balancing current in the damper controlling regulators and master controllers will depend on conditions of operation. Thus, for example, in some cases it is desirable to have the rate of combustion in linear proportion to the rate of steam generation so long as the steam pressure is constant and feed water is being introduced into the boilers at the same rate at which steam is generated. This result may be obtained by dispensing with the coils P , or disconnecting the latter, in the regulators K and master controller KA , and by an adjustment of the corresponding gauge legs K' and K^2 so that they will be vertical in the neutral positions of the various flow balances. If with constant steam pressure and with boiler feed water supplied at the same rate at which the steam is generated it is desired to have the rate of combustion increased more rapidly than does the rate of steam generation, this result may be accomplished by inclining the legs K' and K^2 of the master controller KA from the vertical as shown in Fig. 2 so that when the sealing liquid is displaced from the leg K' into the leg K^2 the change in turning moment on the gauge frame exerted by the displaced liquid will be greater than the change in the volume of displaced liquid.

In the operation of some furnaces it is desirable to increase the ratio of primary to secondary air as the rate of combustion increases. With apparatus as shown in Fig. 1 in which the ratio of primary to secondary air is obtained by maintaining a determined ratio between the volume of primary air and the volume of products of combustion, the ratio of primary to secondary air may be caused to increase with the load by a relative adjustment of gauge legs K' and K^2 of the regulators K respectively, controlling the corresponding dampers I and IA of a furnace so that as the load increases the volume of primary air passing from the furnace to the conduit B will increase at a more

rapid rate than the rate at which the volume of products of combustion leaving the furnace increases.

In the operation of some types of furnace, notably those equipped with chain stoker grates, the difference between the pressures above and below the fuel bed or loss of draft in the fuel bed is approximately proportional to the square of the volume of draft. With such a furnace the flow balance in the regulator KC does not require the coil P and should have the legs K' and K^2 of its pressure gauge vertically disposed in order to so operate the stoker motor as to maintain a fuel bed of approximately constant thickness. With a furnace equipped with an under feed stoker however the pressure drop through the fuel bed does not increase with the square of the volume of flow through the fuel bed, as would be the case if the flow resistance of the fuel bed were constant with different volumes of flow. In such a furnace the effect of increase of draft is in general to so loosen or open up the fuel bed that in some cases the pressure drop through the fuel bed increases but little more rapidly than does the volume of draft. For this case the coil P may advantageously be used in the regulator KC and the gauge legs K' and K^2 may be inclined oppositely to the direction of inclination shown in Fig. 2. Indeed in a case of this sort the coil P is not only desirably employed but may be used to furnish the entire electro-magnetic balancing force, the coils K^{10} being then dispensed with or disconnected. Much the same results obtainable with the coil P and permanent magnet P' can be obtained by replacing the permanent magnet by an electro magnet having an oversaturated core.

In addition to the variations in the characteristics of the controllers and regulators, resulting from the use or non-use of the various coils and the changes in the inclination of the gauge tube legs mentioned above, it is possible to modify the relative effect of one controller or regulator upon the others in the system by the use of adjustable resistance shunts R^5 about the electro-magnetic balance coils of the flow balance element of the controller or regulator. Similarly the rheostats R in the conductors 13, 14 and 15 permit of a modification of the effect of the master controller L on the different control circuits.

When, as will sometimes be necessary or desirable, one or more of the boilers in the battery is temporarily cut out of service, the switch M in the circuit with each of the corresponding control conductors 13, 14 and 15 and shunt conductors 13', 14' or 15' for the furnace or furnaces cut out of operation should be opened so that the master controllers KA , KB and L may continue to

exercise the proper control upon the regulators K and KC of the furnaces remaining in operation.

N, N' and N² represent electrical instruments connected in series with the conductors 6 which may be used to indicate, record and integrate the steam flow through the conduit D. When the flow balance of the master controller KA is of such character that the electric current flowing through the conductor 6 is in linear proportion to the rate of steam flow through the conduit D, the instruments N, N' and N² may be ordinary ammeters having indicating, recording and integrating provisions, respectively.

The apparatus shown in Fig. 1 embodies a substantial improvement over somewhat similar apparatus heretofore devised by me in which the rate of combustion is made proportional solely to the volume, or to the volume and pressure of the steam generated, in that provisions are made in the present case for supplementing the regulation in response to steam generation, by a regulation responsive to the rate at which feed water is introduced into the boiler. The importance of this will be recognized when it is realized that in a high pressure boiler plant a very considerable portion of the total amount of heat required to convert cold boiler feed water into steam is utilized in raising the temperature of the steam. Thus in converting a pound of boiler feed water at 60° F. into steam at 250 pounds pressure, about one half as many heat units are required to raise the temperature of the water as water to the temperature of the steam, as are required to evaporate the water after it is so heated. Even with lower pressure and higher feed water temperature the regulation of the rate of combustion solely in response to the volume and pressure of the steam generated is less accurate than may often be desirable at periods in which the demand for steam is relatively low but in which the supply of feed water may be quite rapid as frequently may be the case with fluctuating steam demands.

In Fig. 6 I have illustrated a modified form of control for the stoker motor F of the boiler furnace A' whereby the speed of the stoker is made a function of the strength of the electric current flowing through the corresponding control conductor 13. For this purpose I may advantageously employ a balance KC, but the pressure differential to which the pressure gauge of the balance is subjected in this case, is the difference between the pressure of the atmosphere and the suction or inlet pressure of a fan W driven by the stoker motor and varying in speed with the latter. As shown the pipe K²² of the balance KC shown in Fig. 6 has its outer end open to the atmosphere and the pressure transmitting pipe

K²¹ runs from the balance to the inlet W' of the fan W. The suction of the fan W may be adjusted as disclosed in my prior Patent No. 1,360,285 by means of a radial slot W² in the side of the fan housing and a rotatable damper W³ formed with a slot W⁴ intersecting the slot W² so that the intersection of the slots W² and W⁴ may be adjusted toward and away from the fan axis by rotating the damper W³.

The apparatus and modes of use disclosed herein involve various features novel with me but not claimed herein as they are disclosed and claimed in my prior applications, Serial No. 121547, filed September 22, 1916; Serial No. 247858, filed August 1, 1918; Serial No. 375728, filed April 22, 1920, and Serial No. 418087 filed the 19th of October, 1920.

While in accordance with the provisions of the statutes I have illustrated and described the best forms of my present invention now known to me, it will be apparent to those skilled in the art that changes may be made in the form of my invention without departing from the spirit of my invention as set forth in the appended claims, and that certain features of my invention may sometimes 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 method of operating a boiler furnace which consists in varying the rate of combustion therein in automatic response both to the rate at which feed water is supplied to the boiler and to the rate at which steam is withdrawn from the furnace.
2. The method of operating a boiler furnace which consists in varying the rate of combustion therein in automatic response to the rate at which feed water is supplied to the boiler and to the rate at which steam is withdrawn from the furnace, and to the pressure of the steam generated.
3. The method of regulating combustion in a furnace which consists in separately supplying primary and secondary air for combustion and varying the ratio of primary to secondary air in a predetermined relation to the rate of combustion as the latter varies.
4. The method of automatically regulating combustion in a plurality of furnaces supplying heat for one or more uses which consists in building up a controlling force by adding together elements each of which is proportional to the requirements of one of said uses, subdividing the total controlling force into proportional parts, one for each furnace, and controlling the combustion in each furnace by the corresponding part of said force.
5. The combination with a boiler furnace

of means for regulating the rate of combustion therein including provisions automatically responsive to the rate at which feed water is supplied to the boiler tending to increase and decrease the rate of combustion as the supply of feed water increases and decreases respectively.

6. The combination with a boiler furnace of means automatically responsive to the rate of steam generation, the pressure of the steam generated and to the rate at which feed water is supplied to the boiler for jointly regulating the rate of combustion.

7. The combination with a furnace having separate primary and secondary air supplies of means for increasing and decreasing the ratio of primary to secondary air supplied in automatic response to increases and decreases in the heat requirements of the furnace.

8. The combination with a furnace heated by the combustion of solid fuel on a fuel bed, of means automatically responsive both to the volume of draft through the fuel bed and to the difference between the pressure at opposite sides of the fuel bed for supplying fuel to the fuel bed at a rate increasing more rapidly than does said difference in pressure as the volume of draft through the fuel bed increases.

9. In combination with a plurality of boiler furnaces, means individually responsive to separate heat requirements of all the furnaces for maintaining electric currents corresponding in intensity to the different requirements, means for combining said currents into a single control current, separate combustion controlling circuits for the different furnaces, and means for dividing said control current among said circuits.

10. In combination with a plurality of boiler furnaces, automatic means for supplying an electrical current which is proportional to the sum of the heat requirements of all the furnaces, separate combustion controlling circuits for the different furnaces, means for dividing said current among said circuits, and means for

modifying the current in each of said circuits in response to changes in the steam pressure.

11. The combination with a boiler furnace, of means separately responsive to different heat requirements of the furnace for maintaining electric control currents corresponding in intensity to the different requirements, and means jointly controlled by said currents for regulating combustion in said furnace.

12. In a flow responsive device consisting of a tilting frame carrying a U-tube manometer subject to a pressure difference due to the flow of the fluid and also carrying electro-magnetic means for opposing the tilting action of the manometer, the improvement which consists in provisions for varying the angle at which the limbs of the manometer are attached to the frame.

13. The combination with a steam boiler having a furnace, of means for regulating the pressure of gases in the furnace, means for feeding fuel to the furnace, and means responsive both to steam conditions and to fuel bed resistance, for controlling the feed of fuel.

14. The combination with a steam boiler having a furnace, of means for controlling the flow of gases through the furnace, means for feeding fuel to the furnace, and means responsive to steam conditions and fuel bed resistance, for controlling the feed of fuel.

15. The combination with a plurality of boiler furnaces, means individually responsive to separate heat requirements of all the furnaces for maintaining electric currents corresponding in intensity to the different requirements, means for combining said currents into a single control current, and separate combustion regulating devices for the different furnaces actuated in response to changes in the strength of said control current.

Signed at New York, in the county of New York and State of New York, this seventh day of September A. D. 1921.

GEORGE H. GIBSON.