Aug. 7, 1928. 1,680,026

E. McLEAN

METHOD AND APPARATUS FOR CONTROLLING FURNACES

Filed April 14, 1924 4 Sheets-Sheet 1

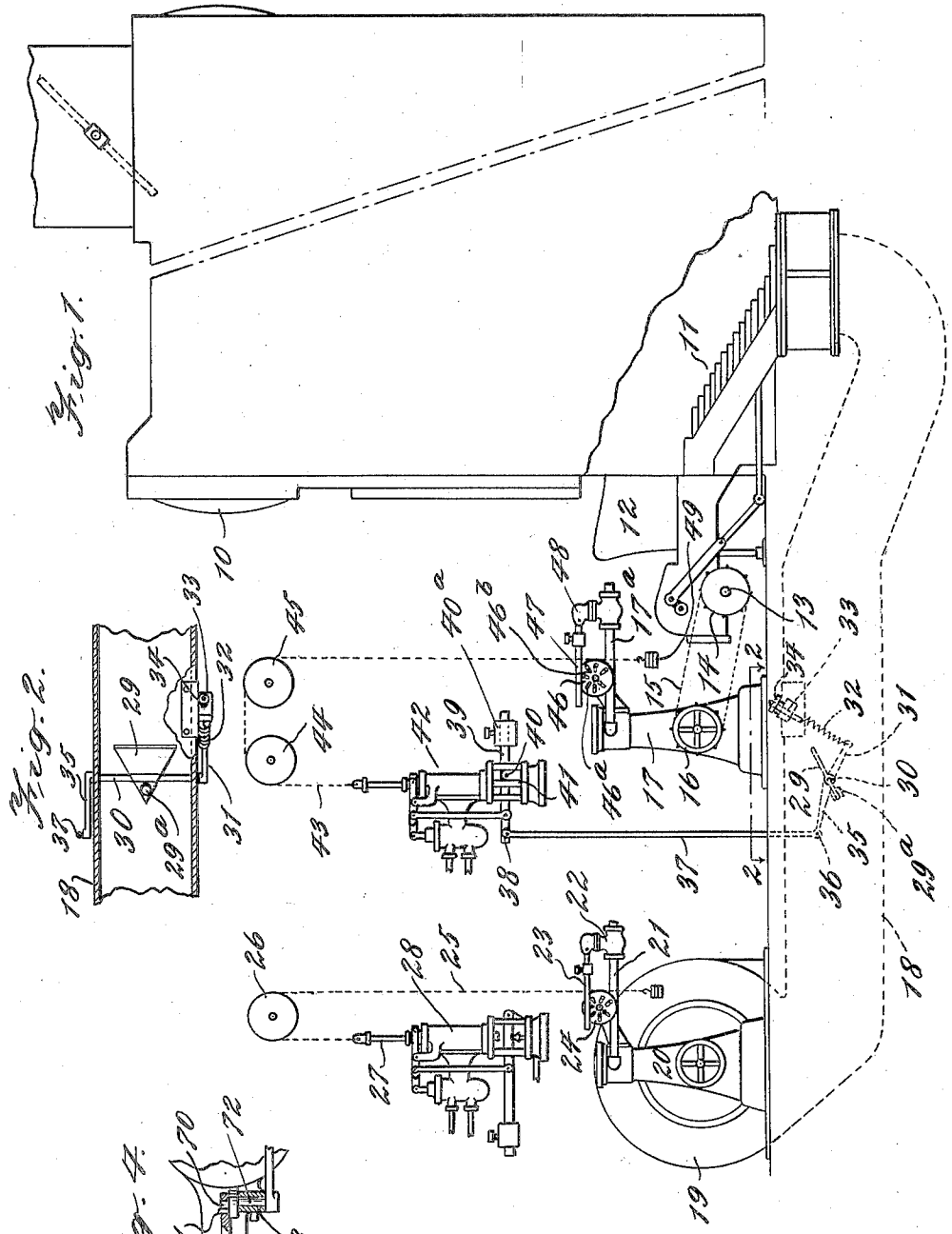


Fig. 1.

Fig. 2.

Fig. 4.

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Fig. 1a

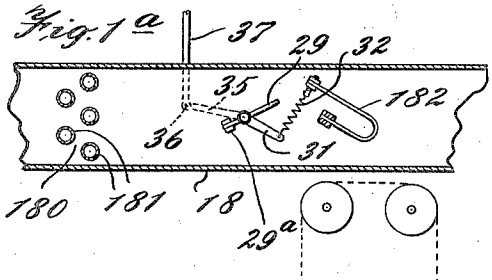
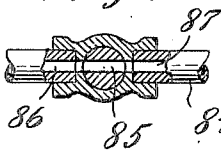


Fig. 8.

Fig. 7.



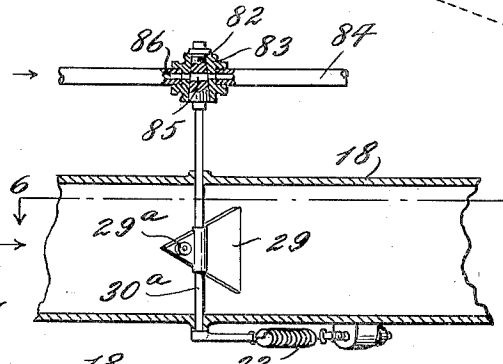
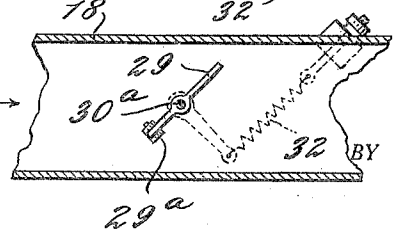


Fig. 5.

Fig. 6.



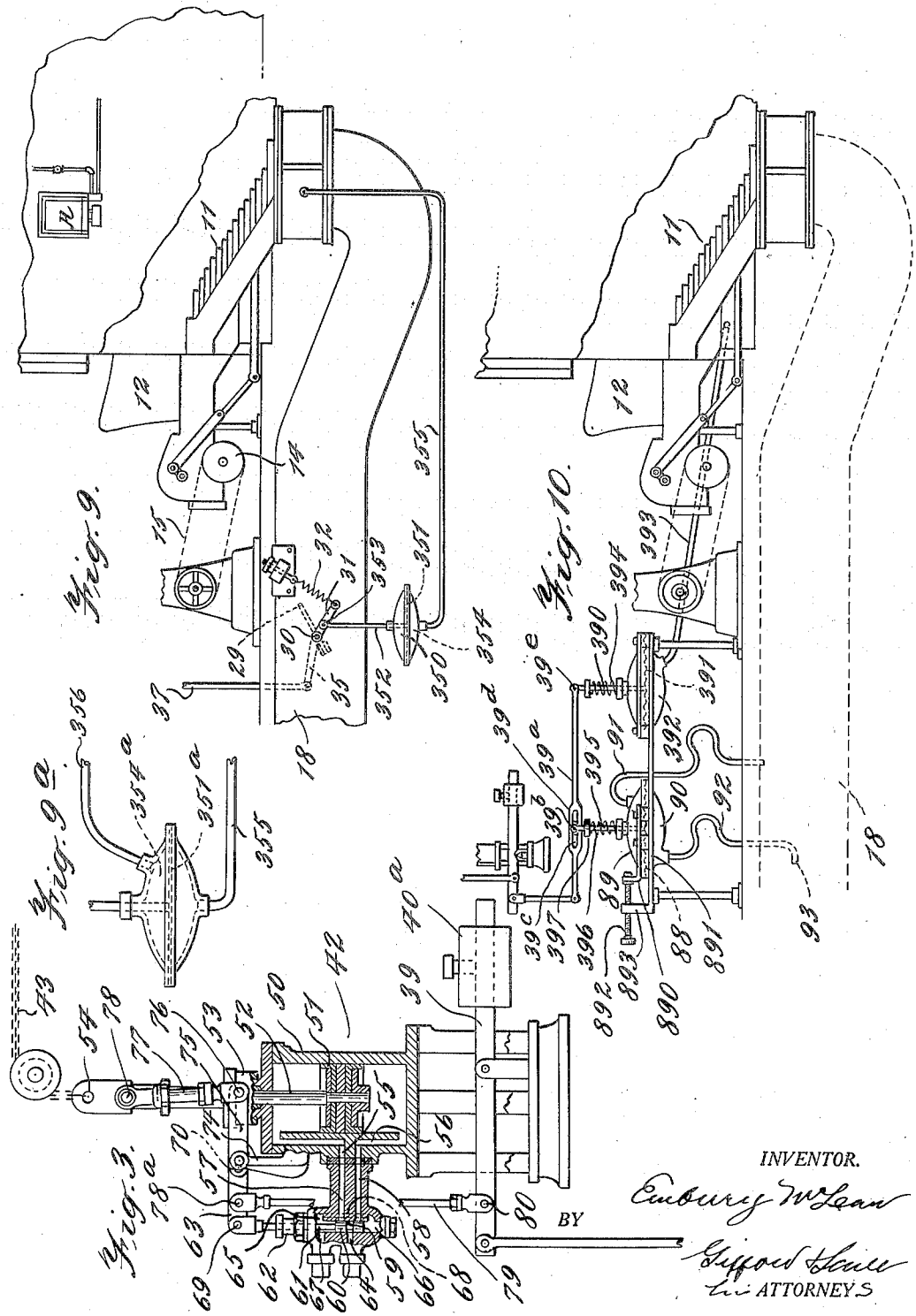
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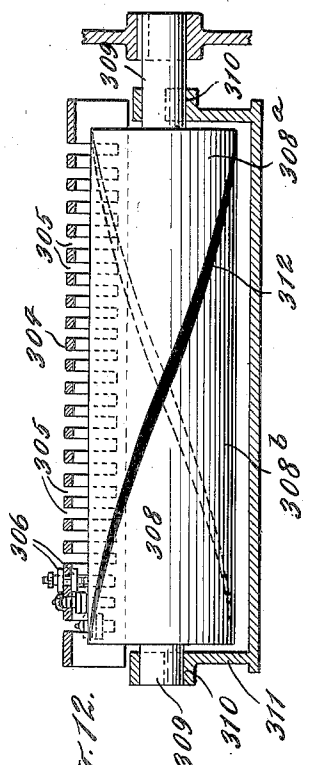


Fig. 12.

Fig. 11.

Fig. 13.

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Patented Aug. 7, 1928. 1,680,026

UNITED STATES PATENT OFFICE.

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METHOD AND APPARATUS FOR CONTROLLING FURNACES.

Continuation of application Serial No. 655,572, filed August 4, 1923. This application filed April 14, 1924. Serial No. 706,278.

My invention more particularly relates to a method and apparatus for controlling the rate of feed of fuel to the furnace in accordance with the rate of supply of air to the furnace. I am aware that various means have been used for regulating the rate of feed of fuel in accordance with the velocity of flow of gases through the boiler. All such means are defective in that the velocity of flow of the gases is affected by the temperature and by the composition of the gases, and is also affected by the resistance of the gas passage which varies with the accumulation of soot and fuel ashes on the tubes and flues. In my invention, the air used for combustion is preferably taken from the atmosphere where the temperature of the air is reasonably constant and where the same is not subject to rapid variations in temperature, such as exist in the gases passing through a steam boiler, nor is the resistance to the passage of air through the air duct varied by the accumulation of flue ashes, as is the case with gases passing through the boiler.

The present application is a continuation of my application Serial No. 655,572, which was filed in the Patent Office on August 4, 1923.

My invention will best be understood by reference to the accompanying drawings, in which I have illustrated the preferred form of apparatus for carrying out my invention, and in which Figure 1 is a diagrammatic side view of a boiler and its furance and the parts associated therewith; Fig. 1ª shows a modification of the arrangement of Fig. 1; Fig. 2 is a fragmentary sectional plan view through the air duct of Fig. 1; Fig. 3 is a vertical central section of a device for controlling the rate of feed of fuel and its operation in accordance with the supply of air to the furnace; Fig. 4 is a plan view, partially in section, of certain parts of Fig. 3; Fig. 5 is a sectional plan view showing a modified form of my invention; Fig. 6 is a section taken on the plane of the line 6—6 of Fig. 5; Fig. 7 is a section through the valve shown in Fig. 5 and at right-angles thereto, Fig. 8 is a diagrammatic side view similar to Fig. 1 and illustrating a further modification of my invention; Fig. 9 is a fragmentary view similar to Fig. 1, illustrating a modification; Fig. 9ª shows a modification of Fig. 9; Fig. 10 is a view similar to Fig. 8 showing a modification thereof; Fig. 11 is a diagrammatic view illustrating electrical means for controlling the rate of feed of fuel to the furnace in accordance with the joint action of the rate of air supply to the furnace and the pressure drop through the fuel bed; Fig. 12 is a longitudinal section through the contact member at the control station and Fig. 13 is a transverse section thereof.

Referring now to the drawings, in which I have shown several embodiments of my invention, and first to Figs. 1 to 4, 10 is a boiler of any well-known construction and provided with a furnace which is heated by fuel supplied by an underfeed stoker 11 having a hopper 12, suitable feeding means driven by a power shaft 13 being provided. The power shaft 13 carries a sprocket 14 connected by a driving chain 15 to the driving sprocket 16 on the shaft of a steam engine 17 to which steam is supplied through a pipe 17ª which may be connected to the boiler.

Air is supplied to the furnace through a duct or flue 18, a fan 19 preferably being provided to supply the air under forced draft, but it will be understood that the air may be drawn through the duct either by a chimney or an induced draft fan. The supply of air to the furnace may be controlled in any desired manner, and the control thereof constitutes no part of my invention. In the form illustrated, the fan 19 is driven by a steam engine 20 to which is connected the steam supply pipe 21. A valve 22 is interposed in the pipe 21 and is operated by an arm 23 which rests upon a cam member 24, which may be of the same character as the corresponding cam member shown more fully and described in my Patent No. 1,355,157, to which reference may be made for further details. A chain or other flexible member 25 is wound upon a disc or drum attached to the cam member 24 and pases over a pulley 26 and is connected to a piston rod 27 which is operated by a suitably controlled device, indicated, generally, at 28, and which is illustrated as a Mason compensating regulator. This regulator is of the same character as the one hereinafter described and need not be further described at the present time.

Within the air supply duct 18 is located

a member 29 shown in the form of a plate arranged transversely within the duct 18 and mounted on a shaft 30 having its bearings in the side walls of the duct. The plate 29 is shown as triangular, the major portion of the plate being located at one side of the shaft 30, and a counterweight 29ª mounted on the opposite side of said plate or vane to balance the turning moment due to gravity of said major portion, so that the plate is movable in accordance with variations in the rate of flow of air to the furnace. An arm 31 is mounted on the shaft 30 at one end thereof and outside of the casing of the duct 18. One end of a spring 32 is connected to the end of the arm 31, the opposite end of the spring being connected to an adjustable member 33, which is shown as a screw provided with a nut 34. The spring 32 tends to move the plate 29 to a position transverse of the duct and movement of the plate by the flow of air is resisted by the spring. An arm 35 is secured to the opposite end of the shaft 30 and outside of the casing of the duct 18 to the end thereof is pivoted as at 36, the lower end of a connecting link 37, the opposite end of which is pivoted, as at 38, to a lever 39 pivoted at 40 on the frame 41. The movement of the lever 39 operates a controller which I have indicated, generally, at 42, the controller, in turn, operating a chain 43 or other flexible member passing over pulleys 44 and 45 and wound around a disc (not shown) in Fig. 1 attached to a cam member 46, which cam member operates an arm 47 which, in turn, operates a valve 48 interposed in the steam supply pipe 17ª to the engine 17. The cam member preferably comprises bolts 46ª radially adjustable in radial slots 46ᵇ in the same manner as in my Patent 1,355,157 which issued October 12, 1920. A weight 49 is preferably attached to the end of the chain 43, as indicated. The arrangement is such that when the rate of flow of air in the duct 18 is increased, the regulator 42 will be actuated to increase the supply of steam to the engine and increase the rate of feed of fuel to the furnace, whereas on the reduction of the flow of air in the duct 18, the regulator will operate to cause the valve in the steam supply pipe 17ª to restrict the passage and decrease the amount of steam supplied to the steam engine and thus decrease the rate of feed of fuel to the furnace. The regulator 42 may be of any well-known type, but I prefer to employ what is known on the market as the "Mason compensating regulator", but without the usual diaphragm, and having the lever 39 pivoted at 40 with an adjustable counterweight 40ª to balance the lever and connecting links, the same as shown in detail in Figs. 3 and 4. As this construction is well known, I do not deem it necessary to describe the same with particularity, but in order that the operation thereof may be understood, I briefly describe the construction thereof as follows: The lever 39 controls the flow of a fluid through a motor cylinder for operating the chain or flexible connection 43 heretofore described. The cylinder is illustrated at 50 containing a sliding piston 51 mounted on a piston rod 52 and extending through a stuffing box 53 in one end of the cylinder and connected, as at 54, to said chain 43. Within the walls of the cylinder 50 are inlet ducts 55, 56 opening on opposite sides of the piston 51 and communicating through ducts 57 and 58 with a valveway 59 within which reciprocates a double-headed piston valve 60 on a piston rod 61 extending through a stuffing box 62 on a casing of the piston valve and operable by means of a lever 63, as will be presently described. Entering the valveway 59 is a supply opening 64 leading from a suitable source of fluid pressure, for example, water, and above and below the piston valve 60 are exhaust chambers 65 and 66 leading to an exit or exhaust 67, said piston valve 60 being operable to control the flow from the inlet 64 and to the exhaust chambers relative to the said cylinder 50. When the said piston valve is in the position shown in Fig. 3, flow of motive fluid is cut off both to and from the cylinder 50, the heads of the valve closing the ports 57 and 58. When the piston valve moves downward to uncover the port 57, the motive fluid will be permitted to flow from the inlet 64 between the heads of the piston valve 60 to the passage 58 and thence through the passage 56 to the cylinder 50 below the piston 51, and, at the same time, the exhaust 67 will be connected to the upper part of the cylinder 50 through the chamber 65 and the space above the upper head of the double-headed piston valve 60. On the other hand, when the piston valve 60 moves upward, the upper portion of the cylinder 50 is connected to the inlet through the passage 57 and the space between the heads of the piston valve 60, and the lower portion of the cylinder is connected to the exhaust through the duct 58, the chamber 66 and the duct or by-pass, indicated at 68, shown in dotted lines leading to the exhaust 65. The piston rod 61 is pivotally connected at its upper end, as at 69, to one end of the lever 63, the opposite end of which is slotted, as at 70 (see Fig. 4), and receives an eccentric pin 71 on a shaft 72 having a bearing, as at 73, in a bracket 74 on the cylinder 50, the opposite end of said shaft 72 being rigidly connected to a lever 75, which, in turn, is pivoted, as at 76, to one end of a link 77, the other end of which is pivoted, as at 78, to the piston rod 52. The lever 63 is connected, as at 78ª, to one end of a link 79, the other end of which link is connected, as at 80, to the lever 39. When the lever 39 is ro-

tated clockwise about its pivot 40, due to an increased flow of gases in the duct 18, the upward movement of the link 79 rotates the lever 63 about its pivot, thereby moving the piston rod 61 upward. This causes fluid under pressure to be admitted to the upper end of the cylinder 50, thereby moving the piston 51 downwardly and correspondingly moving the chain 43 in a direction to open the valve 48 and thus admit more steam to the engine and speed up the stoker to deliver a correspondingly greater amount of fuel to the furnace. The downward movement of the piston 51 and the piston rod 52 causes the link 77 to move downward, thereby rotating the lever 75 and through connections 70 and 71 raises the adjacent end of the lever 63 which, acting on the connection 78^a as a fulcrum, moves the double-headed piston valve 60 toward the position to shut off the parts 55 and 56. The stoker thus maintains its increased rate of speed while the increased amount of air is supplied to the furnace. On a downward movement of the link 37, due to a decreased flow of air to the furnace through the duct 18, the amount of steam supplied to the stoker engine 17 is corespondingly decreased in a manner which will be evident from the foregoing description. By adjusting the positions of the bolts 46^a in the slots 46^b of the cam member 46, the relation of the rate of supply of fuel to the furnace to the rate of air supply may be varied in any desired manner from minimum to maximum rates of air supply.

Now, if for any reason, a thin fuel bed or a hole in the fuel bed occurs, the resistance is reduced and the flow of air through the fuel bed increased. The combustion due to the imperfect fuel bed is not complete, but notwithstanding this, the increased flow of air will tend to increase the rate of combustion and maintain the steam pressure. The action of the increased flow of air on the vane regulator will be to increase the feed of fuel, which will increase the thickness of the fuel bed and tend to fill up any hole that may have been formed. This increase in resistance of the fuel bed will, in turn, reduce the quantity and velocity of air flowing to the furnace, which, in turn acts on the coal feeding mechanism, gradually reducing the rate of feed. This reduction in rate of fuel feed and the reduction in supply of air, due to increased resistance, continue until the normal fuel bed is reached, at which point the rate of feed of fuel is equal to the consumption of fuel, and the furnace will operate normally until some change in the rate of air supply occurs. In adjusting the operation of the fuel feed control by the deflecting air vane, applicant's preferred method is to establish a desired or normal fuel bed, which would have a certain resistance. Normally the resistance of the fuel bed varies with the thickness thereof. If the resistance of fuel bed is greater than this amount, the apparatus is adjusted to reduce the rate of fuel feed more than the reduction in supply of air, due to the increased fuel bed resistance, and conversely if the fuel bed is thinner than normal, or has a lower resistance than normal, the rate of feed of fuel is adjusted so that it will increase the rate of feed of fuel greater than the rate of increase in supply of air, due to the reduction in resistance from normal fuel bed. Where adjusted in this way, my apparatus will automatically maintain a fuel bed of practically normal thickness or resistance for all rates of combustion, if the same efficiency of combustion or percentage of carbon dioxide in the gases is maintained throughout the range of combustion. To the extent that combustion is imperfect, as indicated by a low carbon dioxide, the relative rate of coal feed to air feed will be greater than when the combustion is more perfect with a high carbon dioxide, so that in the first case, the fuel bed will become thicker and in the latter case the fuel bed will burn down and become thinner.

In Fig. 1^a, I have illustrated a modification in which the entering air flows over an air heater, indicated generally at 180, and comprising, in the form illustrated, pipes 181 extending transversely of the flue and through which waste heat gases, exhaust steam, or other gases from which heat is to be extracted flows. The entering air is variably heated depending upon the operation of the air heater. In this form of my invention, a thermostat 182, shown as U shaped in form, is located in the flue 18 where it is subjected to the action of the entering air after passing over the air heater, the parts being so arranged that the control of the rate of feed of fuel is in accordance with the rate of air supply, notwithstanding the fact that the temperature thereof varies. One end of the thermostat is stationary, as indicated, and to the free end thereof is adjustably attached the other end of the spring 32. Now, an increase in temperature of entering air will increase the volume, and while the specific gravity of the air is lowered, its velocity is increased, and as the moment of the vane or plate varies as the square of the velocity of the air, the vane will tend to move to the right, as viewed in Fig. 1^a. But the increase in temperature of the air tends to straighten the thermostat, stretches the spring 32, and thereby maintains the plate 29 more nearly in the position it would occupy had the temperature of the air not been increased.

I have illustrated in Figs. 5, 6 and 7 a modified form of my invention, in which variations in the rate of supply of air to the

furnace are utilized to control the rate of feed of fluid fuel to the furnace. In the form here shown, the plate 29 secured on a shaft 30ª in the air duct 18 is or may be the same as that shown in Figs. 1 and 2, the movement of the plate also being resisted by a spring 32 in the same manner. In the form of my invention here illustrated, the shaft 30ª is directly connected to a valve 82 located in a valve casing 83 which is interposed in a pipe 84 which supplies fluid fuel, such as liquid fuel, pulverized fuel and gas to the furnace. The valve member 82 is preferably in the form of a rotary conical member provided with an opening 85, which, in the position shown in Fig. 7, registers with ports 86 and 87 in the valve casing 83, the position indicated in Fig. 7 corresponding to a full supply of fluid fuel. As the air supply is reduced, the opening through the valve casing and valve member is reduced to correspondingly reduce the supply of fluid fuel to the furnace.

In Fig. 8 I have illustrated a further modification of my invention, in which many of the parts are the same as those illustrated in Fig. 1. The boiler, stoker, engine for driving the stoker and the control therefor and the Mason compensating regulator without the diaphragm, indicated generally at 42, are the same as those illustrated and described in Fig. 1 and need not further be described. The lever arm 39 associated with the regulator, however, instead of being operated by the movement of the plate 29 as in Fig. 1, is operated in accordance with the difference in the static pressure within the air supply duct 18 and the combined velocity and static pressures. For this purpose, a flexible diaphragm 88 is clamped between dished upper and lower sections 89 and 90 of a diaphragm casing, the upper section forming an upper chamber with the diaphragm 88 and the lower section 90 forming a second lower chamber with the diaphragm 88. The lower chamber communicates with the air duct 18 through a plain pipe 91, the end of which is at right angles to the direction of flow of air in the duct 18, as indicated in Fig. 8, so that the lower diaphragm chamber is subjected to the static pressure existing within the air duct 18. The upper diaphragm chamber communicates with the air duct through a pipe 92, the lower end of which is curved, as at 93, in the direction of the incoming air, so that the upper diaphragm chamber is subjected to the combined static pressure within the air duct and pressure due to the velocity of the air. The movement of the diaphragm 88, therefore, responds to variations in the velocity of the air. The diaphragm 88 is connected by a stem 94 to the end of the lever arm 39, the movement of the stem 94 moving the lever arm in the same manner as does the link 37 in Fig. 1. The downward movement of the diaphragm 88 is resisted by a compression spring 95 which is interposed between a collar 96 on the stem 94 and a seat formed by a screw-threaded lug 97 on the upward portion 89 of the diaphragm casing on which is screw-threaded a cap 98. An increase in the flow of air in the arrangement shown in Fig. 8 brings about an increase of feed of fuel to the furnace in the same manner as does the arrangement illustrated in Fig. 1, while a decrease in the rate of flow of air to the furnace produces a corresponding decrease in the rate of feed of fuel to the furnace.

Under certain conditions of operation, I prefer to control the rate of feed of fuel to the furnace jointly by the velocity of the flow of air to the furnace and the pressure drop through the fuel bed. In the embodiment of my invention illustrated in Fig. 9, the pressure above the fuel bed is maintained substantially constant by a balanced draft regulator, indicated generally in a diagrammatic way at A, and which may be the same as that more fully illustrated and described in my application Serial No. 391,779, which was filed in the Patent Office on or about June 25, 1920, and to which reference may be had for further details. When such a device is used for maintaining substantially constant pressure above the fuel bed, then a device that responds to variations in static pressure beneath the fuel bed responds also to variations in drop in pressure through the fuel bed. I have illustrated such an arrangement in Fig. 9 wherein the mechanism comprising the link 37 is controlled both by the flow of air to the furnace and by the pressure drop in the fuel bed. I have illustrated parts in Fig. 9 which are the same as corresponding parts in Fig. 1, with the same reference characters. The arm 35, one end of which is pivoted to the link 37, is secured to a shaft 30, on which is mounted a vane or plate 29, which is operated in response to the velocity of the air supplied to the furnace. The movement of the arm 35 is opposed by a spring 32. The mechanism operable in response to the pressure beneath the fuel bed, I have illustrated as comprising a diaphragm casing 350, within which is mounted a diaphragm 351 (indicated in dotted lines), the lower end of a stem 352 being attached to said diaphragm 351, and the upper end thereof being pivoted as at 353 to the arm 31 on the shaft 30. The chamber 354 formed in the casing 350 beneath the diaphragm 351 communicates with the space beneath the fuel bed by means of a pipe 355. It will be noted, therefore, that the stem 352, which is operated by the pressure beneath the fuel bed acts on the arm 31, in operation to the flow of air to

the furnace, but the parts are so constructed and arranged that the force exerted by the pressure-operated diaphragm is at all times less than that exerted by the flow of air to the furnace. With the parts constructed and arranged as illustrated in Fig. 9, and adjusted so that the deflecting plate causes normally a rate of fuel feed equal to the rate of fuel consumption, a thinning of the fuel bed, or an opening produced in the fuel bed would cause an increased flow of air to the furnace, and a reduction in the pressure beneath the fuel bed. The vane or plate 29 would, therefore, be moved clockwise from the normal position by the action of the diaphragm 351, due to a reduction in pressure under the diaphragm. This would result in increasing the rate of feed of fuel to the furnace to a rate greater than the rate of consumption and such increase in the feed of fuel would continue until the normal fuel bed was re-established. A temporary increase in depth or resistance of the fuel bed would result in the reverse operation of the parts and would establish a rate of feed less than the rate of consumption of fuel and would tend to bring the fuel bed back to its normal thickness. It is obvious, therefore, that with this arrangement, the parts can be proportioned to maintain either a normal thickness of fuel bed for all rates of combustion or they can be adjusted to maintain a thin fuel bed for a low rate of combustion or light load on the boiler and a thick or heavy fuel bed for a high rate of combustion or heavy load on the boiler, should it be desired to maintain this result.

The variations in normal feed can be secured, for example, by changing the leverage on the arm 31; that is, by moving the diaphragm 351 horizontally and changing the pivotal connection of the stem 352 to the arm 31. The same result obviously may be secured by changing the angular relation of the lever arm 31 to the vane or by varying the size of the vane.

In Fig. 9[a] I have illustrated a modification of the arrangement shown in Fig. 9, wherein the diaphragm 351[a] is subjected on its lower side to the pressure beneath the fuel bed as before, by a pipe 355 that leads to a point beneath the fuel bed. In this arrangement, however, no balanced draft device is used for maintaining substantially constant pressure above the fuel bed. By placing a closed chamber 354[a] above the diaphragm in communication with a point above the fuel bed by means of a pipe 356, the diaphragm 351[a] will respond to variations in pressure drop through the fuel bed.

In Fig. 10 I have illustrated a modification of the arrangement shown in Fig. 9, in which the control for the rate of feed of fuel responds both to the flow of air to the furnace and to the drop in pressure through the fuel bed. In the arrangement there illustrated, the parts which are the same as the corresponding parts of Fig. 9 are similarly designated. The diaphragm 88 in the casing 89, 90 is, in this case, connected to the arm 39[a] by a stem 395 which is pivoted to the arm 39[a] at an intermediate point thereof, as at 39[b]. The upward movement of the stem 395 is resisted by a coiled spring 396 under tension, which surrounds the stem, and is attached at its lower end to the stuffing box on the casing through which the stem passes, and is attached at its upper end to a collar 397 adjustably secured on said stem. The pivotal point is preferably formed by a bolt 39[b] passing through and adjustable along a slot 39[c] formed longitudinally of an enlarged part 39[d] formed on the lever 39[a], the diaphragm casing 89, 90 preferably being mounted on a frame 890 slidable along a suitable bracket 891, and adjustably secured in position preferably by means of a screw-threaded member 892, the threads of which engage the threaded opening in a stationary part 893 and the end of which engages the said frame 890. The chamber on the upper side of the diaphragm 88 is connected by a flexible pipe 91 to the duct 18, in such a way as to respond to the static pressure within the duct, while the chamber in the casing below the diaphragm 88 communicates with the duct 18 through a flexible pipe 92, the lower end of which is curved toward the inflowing air, as at 93, so that the diaphragm is subjected on its lower side both to the static pressure and the velocity pressure of the air within the duct 18, the net result being that the diaphragm is operated by the velocity of the flow of the air. The right-hand end of the arm 39[a], as viewed in Fig. 10, is pivoted, as at 39[e] to a stem 390, the lower end of which is attached to a diaphragm 391 within a diaphragm casing 392. The chamber within said casing below the diaphragm 391 communicates, by means of a pipe 393, with the space beneath the fuel bed, so that the diaphragm is subjected on its lower side to the pressure of the air beneath the fuel bed. The pressure above the fuel bed is maintained constant by a balanced draft regulator as shown in Fig. 9. The upward movement of the diaphragm 391 is preferably opposed by a spring 394, which is similar in construction and operation to the spring 396. With the arrangement illustrated in Fig. 10, the distance between the pivots 39[b] and 39[e] is so adjusted, and the relative movements of the stems 395 and 390 are such that the link 37 will move upward for an increasing velocity of air and with normal fuel bed, and will move downward with a decreasing velocity of air and normal fuel bed.

When the fan is running at a predetermined speed, a thinning of the fuel bed with

the arrangement illustrated in Fig. 10, will result in an increase in the flow of air in the duct 18, and in a reduction in the pressure beneath the fuel bed. The increase in the rate of flow of air will force the diaphragm 88 upwardly, and tend to rotate the arm 39ª about the pivot 39ᵉ, and in a direction to increase the rate of feed of fuel to the furnace. The reduction in the air pressure beneath the fuel bed will cause the diaphragm 391 to move downwardly, but the arrangement here, as respects the relation between the force exerted by the air supply and the force exerted by the variation in pressure beneath the fuel bed, is similar to that described in Fig. 9, the parts being constructed and arranged so that the force exerted in response to variations in pressure beneath the fuel bed is less than that exerted by the flow of air. The movement of the link 37, due to the action of the diaphragm 391, therefore, is less than its movement due to the action of the diaphragm 88, with the result that the feed of fuel is increased to bring the depth of fuel bed back to normal. Similarly, an increase in the depth of fuel bed would result in a decrease in the flow of air to the furnace, and in an increase in pressure beneath the fuel bed, and the operation of the parts would be the reverse of that above described. On the other hand, should there be an increase in load on the boiler, this would result in speeding up the blower, and in increasing both the flow of air to the furnace and the pressure existing beneath the fuel bed. This would result in an upward movement of the diaphragm 88, and also in an upward, but less movement, of the diaphragm 391, which would cause the left-hand end of the arm 39ª to occupy a new and higher position to bring about an increase in the rate of feed of fuel. A decrease in the load on the boiler would bring about a decrease in the speed of the blower, and the reverse operation of the parts from that above described. With this arrangement, the parts can be adjusted so that a uniform thickness or resistance of fuel bed is maintained for all rates of combustion for all loads on the boiler or if preferred, the parts can be adjusted so that a thin fire is maintained for a low rate of combustion or light load on the boiler and a thick or heavy fuel bed for high rates of combustion and a heavy load on the boiler, or the parts can be adjusted to maintain any desired relation between the rate of combustion or load on the boiler and the corresponding thickness or resistance of the fuel bed.

In Fig. 11 I have illustrated an arrangement in which electrical means are employed for controlling the rate of feed of fuel to the furnace, jointly, by the rate of flow of air thereto and the pressure existing beneath the fuel bed, which, as before stated, corresponds to the pressure drop through the fuel bed, when the pressure in the furnace is maintained constant by a balanced draft regulator, as shown in Fig. 9. Parts the same as the parts of Figs. 1 and 9 are similarly designated. In the arrangement here shown, the member which is operated in response to the flow of air in the duct 18, preferably comprises two plates or vanes 291 and 292, mounted on arms 293 and 294, secured on the shaft 30, the arms 291 and 292 being at right angles to each other, so that the effective surface acted on by the current of air is more nearly constant than would be the case with a single vane. (The arms and vanes are indicated in dotted lines.) On the shaft 30 is also mounted a contact arm 295, which is connected by a link 296, which is pivoted to a stem 297, the left-hand end of which, as viewed in Fig. 11, is attached to a diaphragm 298, mounted in a casing 299, the chamber at the left of said diaphragm communicating by means of a pipe 300 with the space beneath the fuel bed.

The movement of the arm 295 by the joint action of the flow of air to the furnace and the pressure of air beneath the fuel bed, brings about variations in the rate of feed of fuel to the furnace by electrical means, which will now be described. The arm 295 is included in an electrical circuit and constitutes a movable contact arm which engages a plurality of stationary contacts 301, which are connected by conductors 302 to stationary contacts 303, forming part of the control mechanism for the feed of fuel. The contacts in the form shown are mounted on a transversely slotted segment of a cylinder 304, the contact members being secured within the respective slots 305 by means of clamping members 306. The cylindrical segment 304 is formed of insulating material, such as fiber. Each of the contact members 303 is preferably mounted on an arm 307, which is preferably bent back upon itself, as indicated in Fig. 13, the opposite end of the arm 307 being secured to one of the clamping members 306. The various contacts 303 are, therefore, independently adjustable peripherally of the segment 304.

The contacts 303 engage a rotary contact member, indicated generally at 308, preferably provided with trunnions 309, taking their bearings as at 310. The cylinder contact member, together with the associated stationary contacts are preferably enclosed in a casing 311 (Fig. 13). The cylindrical member 308 is divided into two contact segments 308ª and 308ᵇ by insulation 312, which passes diametrically through the cylinder, but is preferably warped or spirally arranged longitudinally thereof, as indicated in Fig. 12. The two sections 308ª and 308ᵇ of the contact cylinder are connected by con-

ductors 313 and 314 to magnet coils 315 and 316, respectively, the opposite terminals of said coils being connected by a common conductor 317[a] to a battery 318, or other source of electrical energy, the opposite terminal of the battery being connected to the contact arm 295. The energization of the coil 315 causes the motor 317 to rotate in one direction and the energization of the other coil 316 causes said motor to rotate in the opposite direction. For example, the energization of the coil 315 closes switches 319, thereby closing a circuit from the supply conductors 320 with the current flowing in a given direction, and causing the motor to operate in a given direction. When the coil 316 is energized and the coil 315 de-energized, a circuit is closed to the motor 317 with the current flowing in the opposite direction, thereby causing the motor to rotate in the opposite direction. The motor actuates the contact cylinder 308 through a pinion 321, mounted on the shaft of the motor and engaging a gear 322, mounted on the shaft of the rotating contact member 308. On the shaft of the contact member is also mounted a pulley 323, on which is wound a chain 324, passing over pulleys 325, 326 and connected to an arm 327 of a rheostat 328, the movement of the arm 327 varying the amount of resistance included in a circuit, the conductors of which are indicated at 329, and which lead to the motor 330 which, through sprockets and a sprocket chain 331, operates the stoker.

By the described construction, the motor 317 controlling the rate of feed of fuel to the furnace is made to follow the movement of the arm 295. Assume, for example, that a normal rate of air is being supplied to the furnace, thereby causing the contact arm 295 to engage a certain contact 301[a]. The contact 301[a] is connected to the contact 303[a] at the controlled station, and the latter contact will at this time engage the insulating member 312 of the contact cylinder, and neither of the coils 315 or 316 are energized, nor is the motor 317 energized. Now, assuming that the arm 295 is moved counter-clockwise because of an increased rate of flow of air, than the contact arm 295 will be moved counter-clockwise into engagement with a contact 301[b] which is connected to the contact 303[b] at the controlled station. The contact 303[b], however, engages the segment 308[b] of the cylindrical contact member, thereby closing a circuit through the said member, conductor 314, coil 315, conductor 317 and battery 317, back to the arm 295 and contact 301[b]. The energization of the coil 315 closes the circuit to the motor 317 and causes the same to rotate in a given direction, thereby rotating the contact cylinder until the insulating member 312 is brought beneath the contact 303[b], when the motor will again be deenergized. At the same time, the rotation of the motor 317 through the chain or other flexible member 324, varies the amount of resistance included in the motor 330 which operates the stoker to increase the rate of feed of fuel to the furnace, corresponding to the increased rate of air supply. In case the increased rate of air supply is caused by a decrease in the depth of fuel bed, the increased rate of feed of fuel will bring the fuel bed back to normal, and all of the parts will be restored to their original position. On the other hand, should a decreased rate of air supply to the furnace occur, because of an increased depth of fuel bed, then the arm 295 would be moved clockwise, the coil 316 at the control station would be energized to close a circuit to the motor 317 in the opposite direction, thereby causing the motor to rotate in the opposite direction and until the insulating member 312 in the rotating contact member is brought beneath the stationary contact included in the newly formed circuit. The rotation of the motor correspondingly operates the arm 327 of the rheostat to again vary the resistance to the motor, but in such a direction as to decrease the rate of fuel feed. The control mechanism is thus made to follow the movement of the arm 295. Instead of the electric motor 330, it is obvious that a steam engine controlled by a suitable valve, or any other kind of motor suitably controlled could be used. With this arrangement, the parts can be adjusted so that a uniform thickness or resistance of fuel bed is maintained for all rates of combustion for all loads on the boiler or if preferred, the parts can be adjusted so that a thin fire is maintained for a low rate of combustion or light load on the boiler and a thick or heavy fuel bed for high rates of combustion and a heavy load on the boiler, or the parts can be adjusted to maintain any desired relation between the rate of combustion or load on the boiler and the corresponding thickness or resistance of the fuel bed.

By rate of combustion is meant the quantity of fuel burned in a given time.

I claim:

1. The method of operating a furnace burning solid fuel which consists in establishing a fuel bed of normal resistance for a given rate of combustion, utilizing the velocity of flow of air to the furnace caused by the supply of air to control directly the rate of feed of fuel and causing a decrease in the rate of air supply due to an increased fuel bed resistance to reduce the rate of feed of fuel more than the rate of supply of air, and an increase in the rate of air supply due to a decreased fuel bed resistance to increase the rate of feed of fuel more than the rate of supply of air.

2. The method of operating a steam boiler

and furnace burning solid fuel which consists in regulating the rate of feed of fuel to the furnace and so controlling the rate of feed of fuel as to maintain any predetermined relation between the resistance of the fuel bed and the rate of combustion.

3. The method of operating a steam boiler and furnace burning solid fuel which consists in regulating the feed of fuel in accordance with the rate of supply of air to the furnace, and so controlling the rate of feed of fuel as to maintain a desired relation between the resistance of the fuel bed and the rate of combustion.

4. The method of operating a steam boiler and furnace burning solid fuel which consists in regulating the rate of feed of fuel in accordance with the rate of supply of air to the furnace, and so controlling the rate of feed of fuel as to maintain a constant resistance of fuel bed for all rates of combustion.

5. The method of operating a steam boiler and furnace burning solid fuel which consists in regulating the rate of feed of fuel to the furnace, and so controlling the rate of feed of fuel as to maintain a thin fuel bed for a low rate of combustion and a thick fuel bed for a high rate of combustion, and intermediate thicknesses of fuel proportionate to intermediate rates of combustion.

6. The method of operating a steam boiler and furnace burning solid fuel which consists in regulating the rate of feed of fuel in accordance with the rate of supply of air to the furnace, and so controlling the rate of feed of fuel as to maintain a thin fuel bed for a low rate of combustion and a thick fuel bed for a high rate of combustion, and intermediate thicknesses of fuel proportionate to intermediate rates of combustion.

7. The method of operating a steam boiler and furnace burning solid fuel, which consists in feeding solid fuel to the furnace, and controlling the rate of feed of fuel jointly by the rate of flow of air to the furnace and the drop in pressure through the fuel bed.

8. The method of operating a steam boiler and furnace burning solid fuel, which consists in feeding solid fuel to the furnace, maintaining a substantially constant pressure of furnace gases above the fuel bed, and controlling the rate of feed of fuel jointly by the rate of flow of air to the furnace and the pressure beneath the fuel bed.

9. In combination, a furnace, means for supplying fuel thereto, means for supplying air thereto, a pivoted member operable in accordance with the flow of air to the furnace, means for yieldingly resisting the movement of said member, means operable by the movement of said member for controlling the rate of feed of fuel to the furnace during the normal operation thereof, and means for varying the feed of fuel to the furnace in accordance with variations in the temperature of the air supplied to the furnace.

10. In combination, a furnace, means for supplying fuel thereto, means for supplying air thereto, a pivoted member operable in accordance with the flow of air to the furnace, means for yieldingly resisting the movement of said member means operable by the movement of said member for controlling the rate of feed of fuel to the furnace during the normal operation thereof, and means for automatically varying the feed of fuel to the furnace in accordance with variations in the temperature of the air supplied to the furnace.

11. In combination, a furnace, means for supplying air thereto, means for feeding solid fuel thereto to maintain a fuel bed, means responsive to the rate of flow of air to the furnace caused by the supply of air for controlling directly the rate of feed of fuel, the parts being so constructed and arranged that a reduction in rate of air supply due to an increased fuel bed resistance reduces the rate of feed of fuel more than the rate of air supply and an increase in the rate of air supply due to a decreased fuel bed resistance increases the rate of feed of fuel more than the rate of supply of air.

12. In combination, a furnace, means for supplying air thereto, means for feeding solid fuel thereto to maintain a fuel bed, and means under the joint control of the velocity of the flow of air to the furnace and the pressure drop through the fuel bed for controlling the rate of feed of fuel to the furnace.

13. In a combined boiler and furnace, means for feeding solid fuel to the furnace, means for supplying air to the furnace, means responsive to variations in the rate of air supply to the furnace for varying the rate of feed of fuel to the furnace, and means for maintaining a desired relation between the resistance of the fuel bed and the rate of combustion.

14. In a combined boiler and furnace, means for feeding solid fuel to the furnace, means for supplying air to the furnace, and means responsive to variations in the supply of air to the furnace for varying the rate of feed of fuel to the furnace to maintain a constant resistance of fuel bed for all rates of combustion.

15. In a combined boiler and furnace, means for feeding fuel to the furnace, means for supplying air to the furnace, means responsive to variations in the rate of air supply for varying the rate of feed of fuel to the furnace to maintain a fuel bed varying in depth in accordance with the rate of combustion.

16. In combination, a furnace, means for supplying air thereto, means for feeding solid fuel thereto to maintain a fuel bed,

means for maintaining a substantially constant pressure above the fuel bed and means under the joint control of the velocity of the flow of air to the furnace and the pressure beneath the fuel bed for controlling the rate of feed of fuel to the furnace.

17. In a combined boiler and a furnace, means for supplying air to the furnace at varying rates, means for feeding solid fuel to the furnace in variable quantities the rate of feed being controlled jointly by the rate of air supplied to the furnace and the pressure drop through the fuel bed, and means for maintaining any desired relation between the resistance of the fuel bed and the rate of combustion.

EMBURY McLEAN.