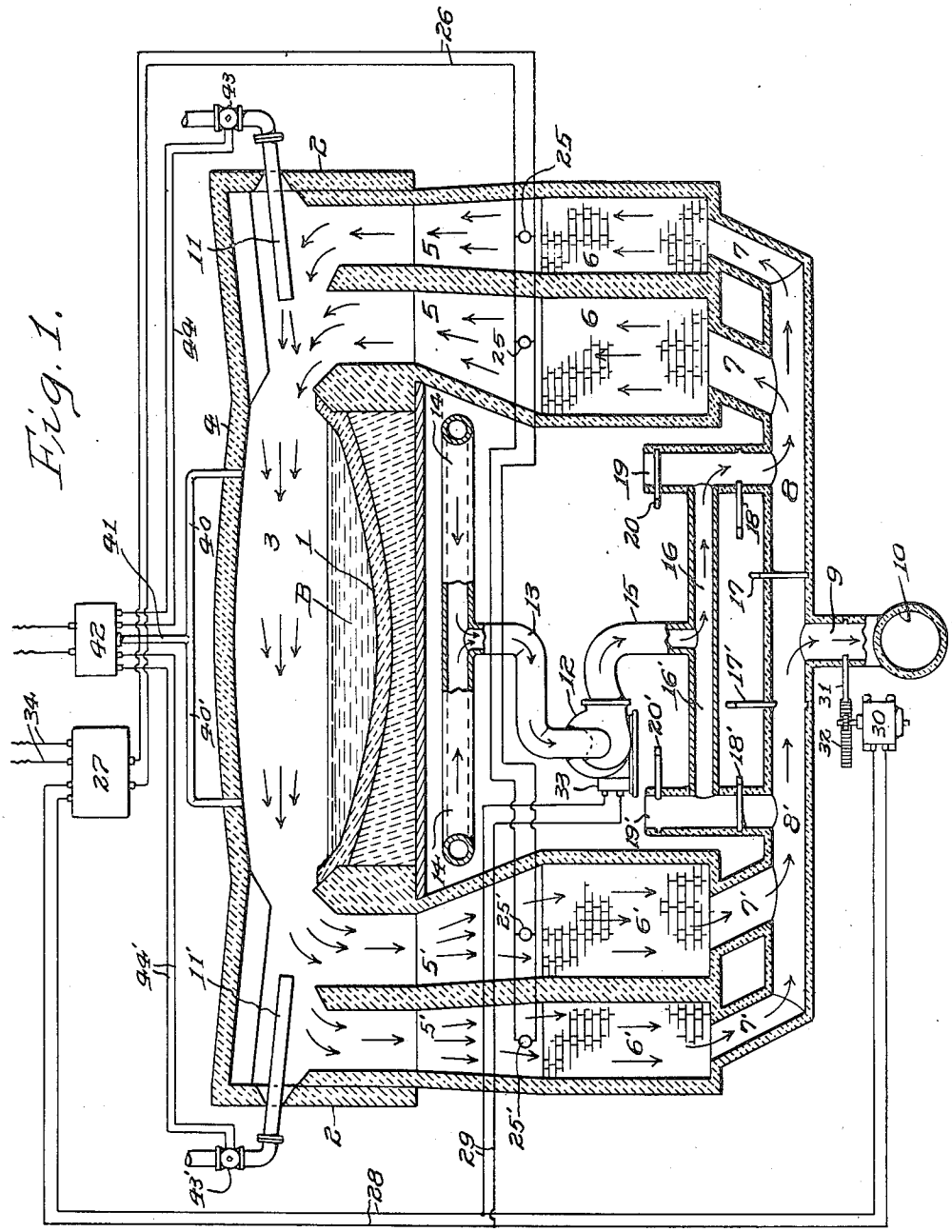
May 30, 1933. P. E. LEISS 1,911,831

METHOD OF AND APPARATUS FOR CONTROLLING FURNACES

Filed Aug. 25, 1930 2 Sheets-Sheet 1

Fig. 1.




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METHOD OF AND APPARATUS FOR CONTROLLING FURNACES

Filed Aug. 25, 1930 2 Sheets-Sheet 2

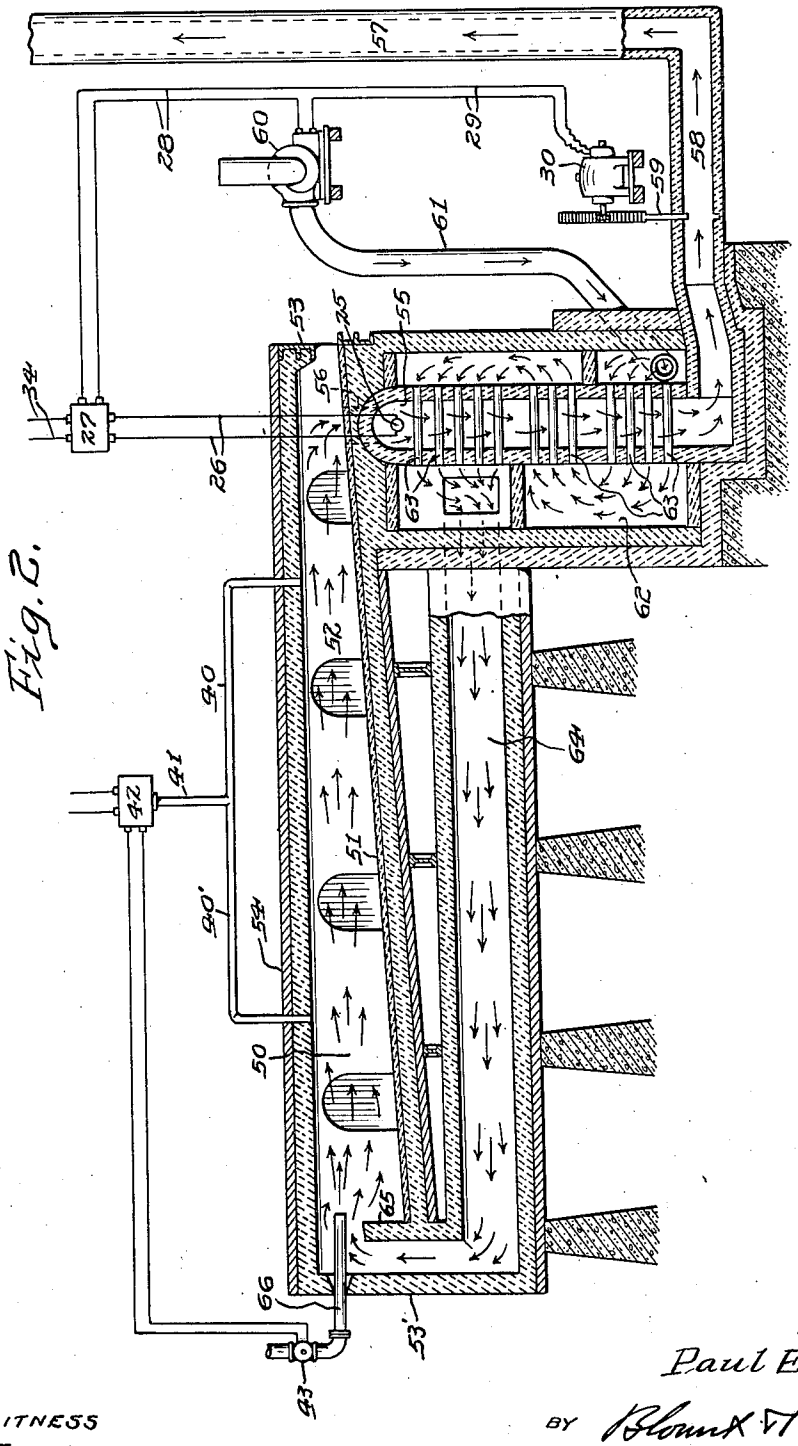



Fig. 2.

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Patented May 30, 1933 1,911,831

# UNITED STATES PATENT OFFICE

PAUL E. LEISS, OF YOUNGSTOWN, OHIO

## METHOD OF AND APPARATUS FOR CONTROLLING FURNACES

Application filed August 25, 1930. Serial No. 477,553.

My invention relates to industrial furnaces of the regenerative or recuperative type such, for example, as those used for making or heating steel, a principal object of the invention being to provide an improved method of furnace control adapted to automatically regulate the supply of fuel and the volume of air for combustion so as to reduce to a minimum the various fuel losses which ordinarily occur in manually operated and controlled furnaces, with consequent maintenance of higher thermal efficiencies than has heretofore been possible.

It is a further object of the invention to provide a method of furnace control, as well as apparatus suitable for effecting such control, adapted to automatically maintain the furnace at the most desirable operating temperatures and pressures consistent with a high rate of production and reasonable operating life of the refractories.

Other objects, advantages, novel steps, operations and arrangement of apparatus comprehended by or incident to the invention are hereafter more particularly pointed out or will be apparent to those skilled in the art from the present specification.

With a given type of furnace, the operator is always confronted with the problem of so regulating the internal pressures and temperatures as to obtain the maximum rate of production from a minimum amount of air and fuel yet without subjecting the refractory material embodied in the furnace to such excessive wear and tear as would unduly reduce the operative life of the furnace and thus correspondingly raise the cost of the product through resulting expense for furnace repair or replacement.

The present invention is directed toward the solution of this problem through the provision of a novel method of automatically maintaining with a high degree of accuracy, the furnace temperatures and pressures at those points which are most conducive to maximum efficiency of operation, the method, to this end, comprehending the automatic regulation of such temperature and pressure through control of the air and fuel supplied to the furnace in correspondence with variations in the average mean temperature and pressure therein, so that upon any material variation from the normal or desired operative temperature or pressure the supply of air and fuel will be promptly adjusted so as to restore the predetermined desired operating conditions.

It will be of assistance in obtaining a proper understanding of the invention to first briefly advert to certain conditions incident to the operation of furnaces of the class to which it relates and more especially as they occur in a regenerative open hearth furnace. Thus, during the process of melting down and refining the charge, the quantity of fuel actually necessary is variable, for when the furnace is first charged the temperature of the combustion chamber, regenerators and stack is reduced and more fuel can be burned to advantage than in the later stages of the heat, but while the furnace is being charged and until such time as the charge is melted down (particularly when light scrap is charged), the quantity of fuel being used cannot be judged with reasonable accuracy from looking into the furnace, so that frequently more fuel is fed than can properly be utilized or an amount insufficient to maintain the maximum rate of production under the operating conditions present.

As the heat progresses the rate of heat absorption decreases and the fuel supply should be gradually reduced, but it is virtually impossible in practice to effect this reduction with even a fair degree of accuracy; consequently the fuel supply is frequently not reduced at all but only the air, or the fuel supply is increased and the air supply kept constant with the result that either unburned fuel or excess air must be heated to the temperature of the furnace with consequent absorption of heat from the melting chamber and a cooling effect on the charge so that there is always a waste of fuel and, in addition, the refractories beyond the melting chamber are frequently damaged, especially where the fuel supplied is excessive.

An additional reason which tends to enhance the difficulty of accurately determin-

ing the proportions of air and fuel to be supplied for proper combustion at any given time during operation is that with certain types of fuel such, for example, as coke oven gas, the flame at the high temperatures employed cannot be clearly seen, thus rendering it impossible for the operator to correctly judge the proper proportions of air and gas.

Moreover, whenever during the open hearth process iron ore is added to the bath and also during the period of the lime boil, considerable quantities of combustible gases are evolved so that the need for the regular full fuel supply is temporarily reduced, but as it is extremely difficult for the operator to manually regulate the latter with sufficient accuracy and speed to compensate for the presence of the said evolved gases, the full saving in fuel which would be theoretically possible if complete advantage were taken thereof is rarely attained, while frequently their presence, by increasing the amount of available fuel, results in undue temperatures and ensuing damage to the refractories.

Finally it is known that the best operating results are obtained where the pressure in the furnace, as determined by the stack draft, is either slightly positive or slighly negative, the preferred condition, in a given furnace, being that at which the flame is directed most efficiently; consequently only sufficient stack draft to produce this result and to insure the burning of sufficient fuel to maintain the required temperature is desirable.

Various methods of regulating and controlling a furnace in the light of the conditions to which I have thus briefly referred have therefore been suggested, but as far as I am aware all of them are open to some inherent disadvantage. Thus, it has been proposed to control the furnace pressure directly by the stack draft, the stack damper being adjusted so as to change the draft with a view to maintaining a constant pressure in the furnace, or cold air being supplied to the stack flue so as to bring about a corresponding regulation of the stack draft and in turn the furnace pressure. In other methods, the air supply is regulated in accordance with the quantity or volume of the fuel supply, but this system is open to the objection that if the latter is decreased when combustible gases are being evolved from the bath itself, the air supply is also necessarily reduced in proportion, so that advantage is not taken of the evolved gases. Still other methods operate on the principle of varying the fuel supply directly in accordance with the furnace temperature itself. As will hereafter more fully appear, my method differs from all of these as well as all other methods with which I am familiar and is capable of effecting a much more accurate and satisfactory control.

I have found that under a given set of operating conditions the drop in temperature from the exit end of the combustion chamber of a regenerative furnace is gradual to the top of the regenerators, and at that at any point therebetween the temperature bears a constant relation to the average temperature within the furnace proper. Moreover, for all practical purposes within the limits ordinarily met in commercial operation, the stack temperature and stack draft are proportional, and the stack draft is also proportional to the furnace temperature, reduced draft being reflected in less fuel being burned and therefore lower temperatures in the furnace, and vice versa provided the furnace pressure and other conditions remain the same. Additionally, after any reversal of the furnace, the temperature of the incoming air and therefore the temperature of the refractories on the incoming end will gradually decrease, while at the same time the temperature of the refractories on the outgoing end will gradually increase; however, the average sum of the temperatures of the refractories and/or gases at both ends is substantially constant with a given temperature in the furnace itself. Thus, the aforesaid average bears a constant relation to the average temperature in the furnace which, in turn, is proportional to the stack draft, and the present invention is largely predicated on this fact.

As I have stated, the invention is applicable to both regenerative and recuperative furnaces and comprehends the provision of a novel method or system of furnace control as well as apparatus suitable therefor, although other apparatus may be utilized if preferred. I shall therefore first refer to one manner of practising the invention by means of said apparatus in connection with a regenerative open hearth furnace of the type usual in the steel industry and then to the practice thereof in connection with a recuperative furnace of the type such as is frequently used for heating steel billets or the like, Fig. 1 in the accompanying drawings being a diagrammatic view showing the said apparatus in operative combination with the former type of furnace and Fig. 2 similarly showing the apparatus in operative combination with the latter type, only so much of the furnace proper being shown in each of the said figures as is requisite for an adequate comprehension of the invention.

Referring now more particularly to Fig. 1 of the drawings there is shown therein in longitudinal section a typical regenerative open hearth furnace adapted to be fired with liquid fuel such as tar or oil. The furnace comprises the usual hearth 1, in which is disposed the bath B, end walls 2, front and

back walls 3 and roof 4. From each end of the furnace ports and passages 5, 5, 5′, 5′ lead to the checker chambers 6, 6, 6′, 6′ of usual construction and which in practice are generally located to one side of the hearth. From each of these chambers passages 7, 7, 7′, 7′ communicates with flues 8, 8′ in turn uniting in a flue 9 leading to the stack 10. The liquid fuel necessary for operation is introduced to each end of the furnace through the ordinary burners 11, 11′ while at least a portion of the total air requisite for combustion is desirably furnished through the medium of fan 12 arranged to draw air from a conduit 13 communicating with branch conduits 14 respectively extending to the vicinity of and preferably above the checker chambers at both ends of the furnace whereby the air passing into the conduits is slightly preheated prior to its passage to the fan. From the fan the air is directed through a conduit 15 having branches 16, 16′ respectively connected with the flues 8, 8′, said flues being provided on opposite sides of the stack flue 9 with the usual reversing gas valves 17, 17′ and said conduits with the usual reversing air valves 18, 18′, the reversal of the furnace being effected by suitable operation of these several valves in the ordinary way. Each of the conduits 16, 16′ may also be provided with a port 19 or 19′ communicating with the atmosphere outside the furnace and controlled by a valve 20 or 20′, as the case may be, to thereby supplement the supply of air furnished by the fan. The various parts to which reference has just been made are commonly found in one form or another in open hearth regenerative furnaces of the liquid fuel type and thus require no further or extended description, particularly as the specific form and construction thereof form no part of the present invention.

In accordance with one manner of practising the invention, I dispose at some suitable point in each of the passages 5, 5, 5′, 5′ and thus between the throats of the furnace and the several checker chambers, thermally actuated temperature indicating units such as thermo-couples 25, 25′ and respectively interconnect them in a circuit 26 leading to a control element 27. This element in turn is suitably connected, as by wires 28, 29, with a motor 30 suitably arranged to actuate the usual stack damper 31, as by a rack and pinion connection 32, or in any other convenient way, and with the motor 33 of the fan 12, current being supplied to the control element 27 from a power line 34. The control element may be of any suitable type satisfactory for the performance of its intended function, namely, to effect control of the motors 30, 33 in correspondence with the temperature of the indicating units 25, 25′, so that when the latter are reduced in temperature below their predetermined setting, the fan will be operated to increase the amount of air normally supplied to the furnace at such setting and the motor 30 will be actuated to open the damper more widely so as to increase the draft through the furnace beyond that normally occurring at such setting. Control elements adapted for the performance of these functions are well known and, in one form or another, are supplied by various makers, so that the precise type utilized in the carrying out of my invention is merely a matter of choice.

It will be noted that in the form of the apparatus now being described I make use of four indicating units respectively located between the ports at the ends of the furnace and the adjacent checker chambers and that the said units are connected in parallel so that an average reading of all of them will be reflected in the control element 27. The employment of four units will ordinarily be preferred where the furnace comprises a like number of passages to the checker chambers, but where a larger or smaller number of passages are provided a correspondingly increased or decreased number of units will generally be utilized, while under some circumstances it may be preferred to install two or more units into each passage or to connect the units in series instead of in parallel, the ultimate purpose, whatever arrangement be adopted, being to impart to the control element 27 an average reading or indication of a plurality of units respectively and preferably installed adjacent opposite ends of the furnace in the path of the incoming air and outgoing gases where the furnace is of a liquid fuel type or in the path of the incoming air and gas and outgoing gases where it is of the gas fired type. Under certain conditions, instead of using thermo-couples or the like located directly in the path of the gases, pyrometers of the radiation type may be employed and arranged so as to register the temperature of the refractories adjacent the ends of the furnace and impart to the control element 27 the average of their several readings.

It will thus be apparent that irrespective of the particular type of devices employed for indicating the temperature adjacent the incoming and outgoing ends of the furnace, the average reading thereof will be communicated to the control element 27 to in turn actuate the fan and stack draft damper in accordance with variations in such mean or average temperature. Thus when the said mean temperature falls below a predetermined point to which the several units 25, 25′ are set, the fan will be actuated to increase the volume of air entering the furnace and the stack damper 31 will be opened beyond its normal position so as to increase

the draft therethrough. In a similar way should the mean temperature of the furnace increase beyond the predetermined point, the control element 27 will operate the fan 12 to decrease the volume of air passing through the furnace and likewise actuate the damper 31 so as to decrease the draft therethrough with the resulting reduction of the internal temperature.

It will be apparent from the fact, as hitherto explained, that as the drop in temperature from the exit end of the combustion chamber of the furnace is gradual to the top of the regenerators and at any given point bears a constant relation to the actual average or mean furnace temperature, the units 25, 25′ may be disposed at any point between the ends of the furnace and the top of the checker chambers, for irrespective of their particular disposition within the limits stated, their average or mean reading will bear a constant relation to the average interior temperature of the furnace adjacent the hearth.

Moreover since the average of the pressures in the several passages leading from the throats of the furnace bears a direct relation to the average or mean temperature in the furnace, a reduced draft or pressure being reflected in less fuel being burned and therefore lower temperature in the furnace and vice versa, pressure actuated indicating units may be utilized if preferred in place of thermo-couples, pyrometers or like thermally actuated units, and the average or mean reading of the several pressure actuated units suitably communicated to the control element 27, so it will operate in like manner to increase the draft and air supplied when the average or mean temperature in the furnace falls below a predetermined point and to decrease the draft and air supplied when said temperature rises above such predetermined point; within the scope of my invention, therefore, either thermally actuated indicating units or pressure actuated indicating units may be employed for operating the element 27 in accordance with fluctuations in the average or mean temperature in the furnace as determined, through the medium of the indicating units, by the average or mean temperature in the passages leading from the ends of the furnace (or adjacent said passages when the temperatures of the refractories are measured) or by the average or mean pressure in said passages.

It will of course be appreciated that the average or mean temperature at which it is desired to maintain the furnace under any given set of operating conditions will be determined in accordance with the various factors which must always be considered in obtaining maximum efficiency of operation with reasonable refractory life, and to some of which I have hereinbefore referred. Thus, for example, while a high temperature is desirable in the interest of rapidity of production, its inimical action on the refractories of the furnace must also be taken into consideration and a compromise effected by which a maximum productive rate may be maintained without excessive deterioration of the furnace itself. These factors as well as others entering into the permissible furnace temperatures to be employed are well known to those familiar with the industry and in any given case will be determinative of the normal or predetermined setting of the indicating units 25, 25′.

In accordance with my invention, in addition to the provision of means for automatically regulating the stack draft and air supply as above described, I provide other means operative in conjunction therewith for controlling the supply of fuel so as to effect automatic regulation of the same in correspondence with the requirements of the furnace at any given time during operation. This regulation of the fuel supply is effected in accordance with the average pressure in the hearth rather than in accordance with the particular pressure at any point thereof, and to this end I provide in the roof of the furnace adjacent each end of the hearth and, if desired at other points above the latter preferably symmetrically located with respect to its center, suitable ports from which conduits 40, 40′ are extended to a central conduit 41 communicating with a pressure actuated control device 42 which may be of any suitable form and construction adapted for the performance of its intended function, numerous devices of this character being on the market and in commercial use. This device is interconnected with suitably disposed control valves 43, 43′ respectively adapted to control the admission of fuel to the burners 11, 11′. The control valves may be of any desired type and if electrically actuated are respectively connected with the control element 42 by leads 44, 44′ or if mechanically actuated by suitable mechanical means, the arrangement in either case being such that after the control element 42 is adjusted to a desired normal furnace pressure, any subsequent variation in such pressure as determined by the average or mean pressure in the conduits leading from the furnace to the control element will be effective through the control element to vary the rate of admission of fuel to the furnace by changing the setting of whichever of the valves 43, 43′ controls the burner through which fuel is then being admitted. Thus, when the mean or average pressure in the furnace rises above the predetermined normal as, for example, when combustible gases are being

evolved from the bath, the fuel supply entering through the burner at the incoming end of the furnace is proportionately reduced through the operation of the control element 42 and fuel control valve at that end, so that the evolved gases can be burned along with the reduced quantity of liquid fuel without unduly increasing the temperature of the furnace, and it therefore results that material advantage can be taken of heat units in the said evolved gases with consequent saving in the total amount of liquid fuel required for the entire heat. In like manner, when the pressure drops below the desired point, the control element operates one of the valves 43, 43′ to increase the fuel supply and thereby bring about a restoration of normal conditions.

Under some conditions it may be deemed preferable to arrange the control element to operate a single main valve or pump in a main fuel pipe from which branches respectively lead to the burners 11, 11′ so that when one or the other burner is shut off in the usual way, depending on which end of the furnace is being fired, the fuel supply to the other and active burner will be controlled in accordance with the setting of the main valve or the operation of the pump as determined by the control element 42.

It will thus be apparent that in accordance with my invention control of the furnace is automatically effected in accordance with the mean or average temperature and pressure therein so as to maintain throughout the operative cycle a satisfactory and efficient balance between the fuel, air and draft with consequent substantial maintenance throughout the furnace of the temperature and pressure most satisfactory for efficient operation. Since this control is determined by the average or mean temperature and pressure throughout the furnace, reversals of the latter are not in themselves effective to alter the normally balanced condition to which I have referred for if, when the furnace is being fired from one end, the temperature there is somewhat different than at the opposite end, a corresponding condition obtains after reversal, and the average or mean temperature and/or pressure condition in the furnace is thus not effected.

While it is believed my improved method of controlling the furnace operation by means of apparatus of the general character of that heretofore described will be readily understood by those familiar with the art, brief reference to certain aspects thereof at this point may nevertheless be desirable. The normal or desired furnace temperature having been determined, the units 25, 25′ are set thereto and the control element 27 properly adjusted in correspondence therewith and the control unit 42 also adjusted to the desired furnace pressure. Now assuming that the charge on the hearth is relatively cold as at the initiation of the heat and that the furnace is being fired from the right hand end when viewed as in Fig. 1, fuel will pass thereinto through the burner 11 and air through the ports and passages 5, 5 being heated as usual in the adjacent checker chambers 6, 6. Since the furnace charge is relatively cold and therefore highly heat absorptive, the temperature of the units 25′ will also be relatively low with consequent lowering the average or mean temperature of the several units to a point below the desired operating temperature of the furnace, with the result that the control element 27 will be actuated so as to open the stack damper 31 more widely and also increase the speed of operation of the fan with resulting introduction of a greater quantity of air to the right hand end of the furnace. Due to the increased opening of the stack damper effected as just described, the mean or average pressure in the furnace will naturally decrease and the control element 42 will thus be actuated so as to open the valve 43 more widely and admit a greater quantity of fuel. The combustion of the increased quantity of air and fuel so admitted will promptly operate to raise the furnace temperature with corresponding elevation of the temperature of the outgoing gases in the path of which the units 25′ are disposed, thereby raising the mean temperature and pressure until a point of equilibrium is reached corresponding to that at which the various indicating units and control devices are set, after which the desired normal conditions of operation within the furnace are automatically maintained without disturbance thereof when the furnace is reversed as heretofore explained.

The principles of the invention are equally applicable for use in controlling the temperatures and pressures in recuperative furnaces, that is, those in which there is no periodic reversal of the direction of movement of the gases, and in Fig. 2 of the drawings I have diagrammatically shown a typical furnace of that type in longitudinal central section with the apparatus of my invention operatively associated therewith.

In accordance with the usual design of recuperative heating furnaces, I have diagrammatically shown substantially in longitudinal central section a furnace comprising a heating chamber 50 having an inclined hearth 51, side walls 52, end walls 53, 53′ and roof 54, the furnace being adapted to be charged through a door in the end wall 53 adjacent the more elevated end of the hearth. Beneath the latter is a vertically extending recuperative chamber 55 communicating with the heating chamber through ports 56 at its upper end and with the stack 57 through a flue 58 extending between the

lower end of the chamber and the lower end of the stack, this flue being provided with a damper 59 for controlling the draft therethrough. The air necessary for combustion is driven by a fan 60 through a conduit 61 to the lower part of a chamber 62 surrounding the recuperative chamber and provided with horizontal baffles or partitions which are effective to cause the air to circulate through the usual pipes 63 in the recuperative chamber and finally to enter a conduit 64 extending beneath the hearth to a point adjacent the end wall 53′ where it turns upwardly so as to direct the heated air over a bridge wall 65 into the adjacent end of the heating chamber in the usual way. The fuel necessary for combustion is also introduced into this end of the heating chamber in any suitable way, for example, through the medium of a burner 66 when the fuel is of liquid character. As the precise details of construction and arrangement of the furnace form no part of the present invention, further reference thereto would be superfluous.

In order to effect the desired control of the stack damper 59 and the air fan 60 in accordance with the principles of the invention, I dispose in the upper part of the recuperative chamber or at any other convenient point between that end of the hearth from which the waste gases are drawn and the stack damper, an indicating unit 25 or a plurality of such units connected together in series or parallel, the unit or battery of units being in turn connected with a control element 27 by leads 26. Current is supplied to the control element from the line 34 and the element in turn is connected as heretofore described with the fan 60 and motor 30 or other means actuating the stack damper 59 by the leads 28, 29. I also provide the furnace roof with spaced ports which communicate respectively through conduits 40, 40′ with a main conduit 41 extending to the pressure actuated control element 42 which is connected, as by the leads 44, with a suitable valve 43 controlling the admission of fuel to the burner 66. While it will be usually preferred to utilize thermally actuated units such as thermo-couples or pyrometers in or adjacent the recuperative chamber for indicating the temperature therein, pressure actuated units may be utilized if desired as hitherto explained, for the pressure in that chamber bears a direct relation to the temperature in a recuperative furnace just as the pressure in the passages to the checker chambers bears a like relation to the temperature in a regenerative furnace.

After the control and indicating units are adjusted to the temperature and pressure at which it is desired to operate the furnace, it will be apparent that, in the manner already explained, variations in the temperature will be reflected in the mean or average temperature of the indicating units so as to operate the control element 27 to bring about automatic adjustment of the fan and of the stack damper so as to temporarily feed more air to the furnace and increase the draft thereof. In like manner, variations in mean or average pressure in the furnace are reflected in the control element 42 with resulting adjustment of the fuel supply, so that both the desired temperature and pressure are continuously and automatically maintained throughout the range of operating conditions encountered.

While I have herein referred more particularly to the use of my invention in connection with the control of liquid fuel fired furnaces, it will be apparent that it may be employed with equal facility for controlling pressure and temperature in furnaces employing gas or other suitable fuel as the fuel medium, the apparatus in such cases being arranged to control the supply of fuel in any convenient way through the medium of the control element 42 in correspondence with fluctuations in mean or average pressure within the furnace, and further, that while electrically actuated control devices will usually be found most convenient, mechanically actuated ones may be utilized if preferred so long as they are satisfactorily operative for the performance of their respective functions.

As I have heretofore pointed out, the average or mean of the temperatures of the incoming air and of the outgoing or exhaust gases, as well as the average or mean temperature of the refractories adjacent their respective paths, bears a direct relation to the average or mean temperature within the furnace and, additionally, the average of the pressures of said air and gases likewise bears a direct relation thereto. Consequently, it is merely a matter of choice whether the average or mean of the temperatures of the air and exhaust gases, or of said refractories, or of said pressures is employed as a basis for effecting regulation of the draft and air supply in the control of the furnace. Therefore while in the appended claims I have referred to the average or mean of the temperatures of the incoming air and of the exhaust gases, I do not desire or intend to thereby exclude the utilization of the average or mean either of the temperatures of the said refractories, or of the said pressures in lieu thereof, since both of said averages or means, within the purview of my invention, are the full equivalents of the average or mean of the temperatures of the said air and gases and thus may be substituted therefor or employed in place thereof without departing from the spirit and scope of the invention as defined by the said claims.

Having thus described my invention, I claim and desire to protect by Letters Patent of the United States:

1. In a method of furnace control, the step of regulating the temperature within the furnace by changing the fuel feed and air supply in accordance with the average of the temperature of the incoming air supplied to support combustion and of the outgoing burned gases.

2. In a method of furnace control, the step of regulating the temperature within the furnace by changing the fuel feed and air supply in accordance with the average of the temperatures of the incoming air supplied to support combustion as it passes into the furnace and of the burned gases as they pass out of the furnace on their way to the stack.

3. In a method of furnace control, the step of adjusting the quantity of air supplied to support combustion in accordance with the average of the temperatures of said air as it passes into the furnace and of the burned gases as they pass out of the furnace.

4. In a method of furnace control, the steps of regulating the pressure within the furnace and changing the fuel feed and the volume of air supplied to support combustion in accordance with the average of the temperatures of said incoming air adjacent its point of entry into the furnace and of the burned gases adjacent their point of exit from the furnace to thereby maintain a substantially constant predetermined temperature within the furnace.

5. The method of furnace control which comprises the steps of determining the average of the temperatures of the incoming air supplied for combustion prior to its entry into the furnace and of the burned gases after their exit from the furnace, regulating the volume of said air and the draft through the furnace in accordance with the average of said temperatures and simultaneously regulating the quantity of fuel supplied to the furnace in correspondence with the average pressure within the furnace, to thereby substantially maintain a predetermined operative pressure and temperature within the furnace during the heat.

6. The method of furnace control which comprises the steps of adjusting the volume of air supplied for combustion and the draft through the furnace in correspondence with the average of the temperatures of the incoming air before it enters the furnace and of the burned gases after they leave the furnace and prior to their entry to the stack and simultaneously adjusting the quantity of fuel supplied in correspondence with the average pressure within the furnace, to thereby substantially maintain the operating temperature and pressure within the furnace respectively at predetermined points.

7. The method of controlling the operating temperature and pressure in an open hearth furnace during the heating of the charge, which comprises the steps of effecting continuous determination of the average of the temperatures adjacent the opposite ends of the furnace, utilizing said determination as a basis for the control of the volume of air supplied for combustion and of the draft through the furnace, and simultaneously continuously effecting a determination of the average pressure within the furnace and utilizing said determination as a basis for the control of the fuel supplied for combustion.

8. That method of control of an open hearth regenerative furnace during the heating of the charge, which comprises the steps of continuously determining the average of the temperatures adjacent the opposite ends of the furnace and the average pressure within the furnace and then respectively utilizing said averages as bases for the control of the volume of air supplied for combustion and of the draft through the furnace and for regulation of the quantity of fuel supplied for combustion.

9. That method of control of an open hearth furnace which comprises the steps of continuously determining during a heat the average of the temperatures adjacent the opposite ends of the furnace and the average pressure within the furnace and then automatically regulating the volume of air supplied for combustion and the draft through the furnace in correspondence with fluctuations in the average of said temperatures and simultaneously automatically regulating the quantity of fuel supplied for combustion in accordance with fluctuations in said average pressure to thereby substantially maintain a predetermined normal operating condition within the furnace hearth.

10. In a method of furnace control, the step of utilizing throughout the operating cycle the temperature of the burned gases after they pass from the furnace as a factor in automatically controlling the volume of air supplied for combustion and simultaneously regulating the quantity of fuel supplied for combustion in correspondence with fluctuations in the average pressure within the furnace.

11. In combination with a furnace, control apparatus comprising means operative to determine the average of the temperatures of the air supplied for combustion prior to its entry into the furnace and of the burned gases after their exit from the furnace, a control element actuated by said means and mean actuated from the control element for regulating the volume of said air in correspondence with said determination.

12. In combination with a furnace, control apparatus comprising means operative to determine the average of the temperatures of

the air supplied for combustion prior to its entry into the furnace and of the burned gases after their exit from the furnace, a control element actuated by said means and means actuated from the control element for regulating the volume of said air and the draft through the furnace in correspondence with said determination.

13. In combination with a furnace, control apparatus comprising a plurality of indicating units disposed in the path of the incoming air supplied for combustion and of the burned gases after their exit from the furnace, means interconnecting said indicating units, a control element arranged for actuation in accordance with the average of the readings of said units and connected therewith, and means interconnected with said control element and operative thereby for regulating the volume of air supplied for combustion and the draft through the furnace in accordance with said average as reflected in said control element.

14. In combination with a furnace, control apparatus comprising means operative to determine the average of the temperatures adjacent but beyond opposite ends of the furnace hearth, a control element interconnected with said means and adapted for actuation thereby and means interconnected with and adapted for actuation by the control element operative to vary the draft through the furnace and the volume of the air supplied for combustion in correspondence with fluctuations in the said average of said temperatures.

15. In combination with a furnace, control apparatus comprising a plurality of indicating units adapted to determine the average of the temperatures adjacent but beyond the opposite ends of the furnace hearth, a control element interconnected with said units and adapted for actuation in accordance with fluctuations in said average, means interconnected with said control element and operable thereby to vary the volume of air supplied for combustion and the draft through the furnace in correspondence with said fluctuations and means for regulating the quantity of fuel normally supplied for combustion in correspondence with fluctuations in pressure within the furnace, said means comprising a pressure actuated control element, means for reflecting in said element the average pressure within the furnace and means actuated by said control element for directly controlling said fuel supply.

16. In a method of furnace control, the step of utilizing throughout the operating cycle the temperature of the burned gases after they pass from the furnace as a factor in automatically controlling the volume of air supplied for combustion and the draft through the furnace and simultaneously regulating the quantity of fuel supplied for combustion in correspondence with fluctuations in the average pressure within the furnace.

17. That method of control of an open hearth furnace which comprises the steps of continuously determining, during a heat and at points respectively adjacent the opposite ends of the furnace, the average of the temperatures of the incoming air and of the exhaust gases and also the average pressure within the furnace, and then respectively and simultaneously automatically controlling the amount of air supplied for combustion and the draft through the furnace in accordance with said average temperature and the amount of fuel supplied for combustion in accordance with said average pressure so as to maintain a substantially predetermined operating temperature and pressure within the furnace throughout the heat.

In witness whereof I have hereunto set my hand this 21st day of August, 1930.

PAUL E. LEISS.