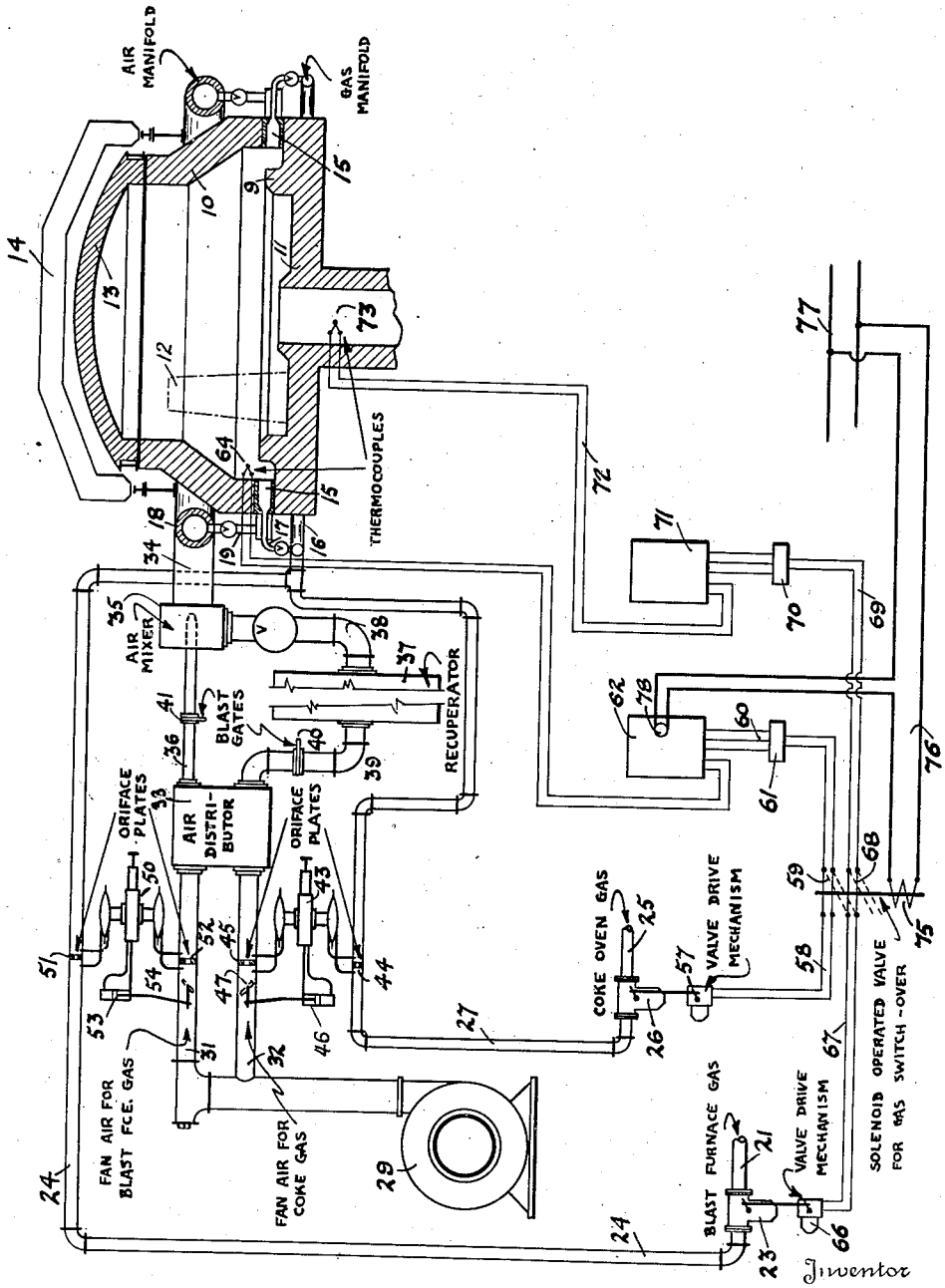
Aug. 18, 1942. LE ROY KELLS 2,293,550

METHOD AND APPARATUS FOR CONTROLLING HEATING FURNACES

Filed Sept. 9, 1939



Inventor

LE ROY KELLS

By Francis J. Klempay

Attorney

Patented Aug. 18, 1942 2,293,550

UNITED STATES PATENT OFFICE

2,293,550

METHOD AND APPARATUS FOR CONTROLLING HEATING FURNACES

Le Roy Kells, Salem, Ohio, assignor to Salem Engineering Company, Salem, Ohio, a proprietorship

Application September 9, 1939, Serial No. 294,123

7 Claims. (Cl. 236—15)

This invention relates to a method and apparatus for controlling the supply of fuel and air to an industrial heating furnace which has as its primary function the controlled heating of metal objects. Thus the invetnion is applicable to heating furnaces of the ingot soaking pit, annealing, continuous pusher billet heating and other types of similar character. In furnaces of the kind mentioned heat is absorbed in the ingots, billets and other articles from the fuel burner sources or sources and the hot gaseous products of combustion, after giving up some of their heat, pass to the cooler zones of the furnaces and thence in certain installations through recuperators employed to preheat primary air for combustion and for other purposes, such as the heating of particular zones of the furnace.

The control of the operation of heating furnaces of the general type mentioned, irrespective of the character of the furnace and the use to which it is put, involves a nicety of balance between various operating factors, since care must be taken to insure the adequate and uniform heating of the articles placed in or moving through the furnace in order that they may reach a condition suitable for further working as they leave the furnace without being overheated while insuring protection to the furnace parts, including the recuperators, against damaging high temperatures. The problem is particularly difficult in furnaces of the continuous type where interruption in the travel of the material being heated frequently occurs, since in this circumstance the total heat withdrawn from the furnace by the metal is erratic and the heat radiated by the articles standing in the furnace contributes to the absorption of heat by the walls and other elements of the furnaces.

In accordance with the present invention the control of the operation of the furnace is such that the material in the furnace will be uniformly heated to the accurate temperature required while the possibility of overheating the material is definitely eliminated. In addition, the control of the furnace is such that the maximum radiating or heat emitting capacity of the furnace is fully utilized, while any probability of damage to the furnace parts because of overheating is reduced to a minimum. It is, therefore, the primary object of the invention to provide an improved method for the control of the operation of an industrial heating furnace which will result in the more economical and accurate heating of the ingots, billets and the like, while the loss due to overheated material and damage to the furnace parts is kept to a minimum.

The above object is accomplished by the present invention by controlling the operation of the furnace by means of two or more temperature responsive devices positioned in different temperature zones of the furnace, as in the zone of highest temperature or the combustion zone and the zone of lowest temperature as in the flue. A thermo-couple or other temperature responsive device in the hot zone of the furnace is employed primarily to determine the quality of the fuel consumed in the combustion chamber, thereby insuring the maintenance of an efficient temperature in such chamber at all times, while a thermo-couple or other temperature device positioned in the cooler zone of the furnace, as in the flue, controls primarily the quantity of the fuel consumed in the furnace, thereby insuring sufficient total heat input for efficient operation of the furnace and adequate heating of the material placed therein. To prevent overheating of the material and the furnace in certain circumstances, as when a particular batch of material remains in the furnace for an abnormal length of time, the thermo-couple in the hotter zone is arranged to withdraw the control of the thermo-couple in the cooler zone when the temperature in the hot zone rises above a predetermined maximum value. Thus the maximum temperature existent in the furnace is controlled at all times, thereby preventing damage to the material in the furnace because of overheating.

Another object of the invention is the provision of an improved method for the control of the operation of an industrial heating furnace in which economical gaseous fuel, such as blast furnace gas, may be satisfactorily employed in such manner that substantial economies may be effected in the operation of the furnace. It is also an object of the invention to provide a fuel feeding and control arrangement for such a furnace in which the economical blast furnace gas may be used as a fuel, while the advantages of the control system outlined above may be retained. These objects are accomplished, in accordance with the invention, by supplying both gases of high and low calorific values to the burners, the gas of low calorific value being preferably blast furnace gas and the rich gas being preferably either natural or coke oven gas.

The proportioning of the gases consumed is normally responsive to the relation existing between the temperature in the hot and cold zones of the furnace, the total quantity of the blast furnace gas supplied being determined by the temperature existing in the cold zone and the quantity of coke oven gas supplied being determined by the temperature existing in the hot zone. Due to the very low calorific value of the blast furnace gas, large quantities of such gas will be consumed while a relatively small quantity of the coke oven gas will be supplied and therefore the thermo-couple in the hot zone of the furnace will normally control the quality of the gas while the thermo-couple in the cold zone

will normally control the general quantity of the gas.

These and other objects and advantages of the invention will become apparent from a consideration of the following detailed specification and the accompanying drawing disclosing a representative adaptation of the invention. By way of example, the invention is disclosed as applied to a circular ingot heating furnace commonly termed a soaking pit and the single view of the drawing is a cross-sectional view of the furnace and a schematic representation of the fuel feeding and control system constructed according to the principles of the invention.

Referring now to the drawing, reference numeral 10 indicates a circular ingot heating furnace having a circular hearth 11 to receive the ingots 12 and having a cover 12 removable by a cover crane 14. Immediately outward of the hearth 11 but spaced inwardly from the outer wall of the furnace is a circular bridge wall 9 behind which is positioned a series of circumferentially spaced burners 15 positioned in the outer wall of the furnace. A fuel ring or manifold 16 encircles the furnace 10 adjacent to and preferably below the burners 15, fuel conducting tubes 17 interconnecting the manifold ring 16 with the respective burners 15. Also encircling the furnace 10 and preferably above the burners 15 is the air ring or manifold 18 which is connected to the various burners by means of the conduits 19.

The fuel gas of low calorific value is supplied to the manifold 16 from a source 21 through valve 23 and tube 24. The fuel gas of high heat content or coke oven gas is supplied to the manifold 16 from a source 25 through valve 26 and tube 27. Air for combustion is supplied under pressure from a blower 29 which discharges into the header 30. A pair of parallel branches 31 and 32 communicates with the header 30 and discharges into an air distributor 33. The air thus provided is supplied to the manifold 18 through a conduit 34 from an air mixer 35. A portion of the air reaching the mixer 35 from the distributor 33 passes through a conduit 39, recuperator 37 and conduit 38 connecting with the mixer. A gate or valve 40 is positioned in the conduit 39 to determine the quantity of air passing through the recuperator. The remaining portion of air reaching the mixer 35 from the distributor 33 passes through a tube 36 leading directly from the distributor to the mixer. A valve or gate 41 in the tube 36 controls the quantity of air which so passes directly into the mixer.

To maintain the proper ratio of air to gas, regardless of whether coke oven gas or blast furnace gas or any proportion of the two is being burnt in the furnace, a proportioning regulator is installed between each gaseous fuel supplying tube and one of the branches leading from the air supplying header 30. Thus a regulator, indicated generally by the reference numeral 43, which is preferably an "Askania" ratio regulator, is so positioned that the forces tending to move one of its balancing diaphragms is responsive to the flow of gas through the tube 27, an orifice plate 44 being positioned in the tube 27 to enable the rate of flow therein to be sensed, while the other balancing diaphragm of the regulator is responsive to the rate of flow of the air through the branch 32, an orifice plate 45 being positioned in the branch 32 and pressure lines leading from opposite sides of the orifice plate to opposite sides of the diaphragm. In a manner well understood in the art, the governing position of the nozzle of the regulator proportioning the fluid pressure admitted above and below the piston in cylinder 46 is controlled by the position of the diaphragms above mentioned in such manner that variations in the relative rate of flow of the fluids in the conduits 27 and 32 will be reflected by changes in the pressures above and below the piston in cylinder 46 and, therefore, in the position of valve 47 controlled by the cylinder 46. The regulator operates in such manner that the quantity of air supplied through branch duct 32 is always proportional to the quantity of gas flowing through tube 27. If no gas flows through tubes 27, no air flows through branch duct 32 and, if a maximum quantity of fuel flows through tube 27, a maximum quantity of air is allowed to flow through duct 32.

Likewise, a regulator 50, which is identical with the regulator 43, is positioned between the fuel supply tube 24 and the branch air duct 31 to control the flow of air through the duct 31 in response to the amount of flow of the gas through tube 24. An orifice plate 51 is positioned in the tube 24 and a similar plate 52 is positioned in the duct 31. Air flow in the duct 31 is controlled by a valve 54 operated by a balanced fluid pressure cylinder 53, the pressures of which are controlled by the diaphragms in the regulator 50. Thus the supply of air passing through the distributors 33 and mixer 35 into the manifold 18 is always correctly proportional to the amount of fuel supplied, regardless of the character of the fuel supplied.

The quantity of the coke oven gas supplied to the manifold 16 is controlled by the valve 26 operated by a balancing valve drive mechanism 57, which in turn is energized through circuit 58 from a relay unit 61. For a purpose to be later described, a switch 59 is incorporated in the circuit 58 to normally connect the valve drive mechanism 57 with the relay 61 and which is operative to connect the relay 61 with a circuit 67 controlling the operation of a second balanced valve drive mechanism 66, which in turn operates the valve 23 controlling the flow of blast furnace gas to the manifold 16. Relay 61 is controlled through circuit 60 by a controller 62 which is preferably a "Micromax" indicating and recording controller of the Leeds & Northrup Company. The controller, which is of the beater type, has its galvanometer in circuit with the thermo-couple 64 positioned in the combustion zone of the furnace 10 adjacent the wall 9 and intermediate its adjacent burner 15. As is well understood in the art, the valve controlling system described is of the type which proportions the rate of flow of the gas through tube 27 in accordance with the extent of deviation from normal of the temperature existent at the location of the thermo-couple 64.

A controller 71, similar to the controller 62, is coupled through circuit 72 with a thermo-couple 73 positioned in the central flue of the furnace 10 and through relay 70, circuit 69, switch 68 and circuit 67, normally controls the actuation of the balanced valve drive mechanism 66, which actuates the valve 23. The controller 71 and its ancillary equipment is operative to proportion the flow of fuel through tube 24 in proportion to the extent of deviation from normal in the temperature existent at the location of thermo-couple 73.

The operation of the fuel feeding and control arrangement thus far described should be readily apparent. The thermo-couple 64 in the hot or

combustion zone of the furnace normally controls the supply of coke oven gas or other gas of high calorific value through the controller 62 and valve drive mechanism 67. In operation, if the hearth is cold or a quantity of cold steel has just been charged, the large deviation from normal in the temperature of the furnace adjacent the thermo-couple 64 will result in large quantities of the rich gas reaching the burners and the flame from the burners will be bright and intensely hot. As the gas passes through tube 27, regulator 43 will automatically introduce the correct amount of air for its combustion into the distributor 33. The hearth will therefore be rapidly brought up to the proper temperature required for the efficient operation of the furnace and the rapid heating of the steel placed therein.

To insure the uniform and rapid heating throughout the extent of the furnace the thermo-couple 73, normally controlling the flow of the gas of low calorific value, such as blast furnace gas, to the burners, is positioned in the cold zone of the furnace at a location substantially removed from the location of the thermo-couple 64. Thermo-couple 73, through circuit 72, controller 71, relay 70 and valve drive mechanism 66, controls the operation of valve 23 which regulates the amount of such gas furnished to the burner and, since such gas burns with a long low temperature flame, the burning of large quantities of such gas in the furnace results in large volumes of long relatively low temperature flames in the furnace which may propagate to substantially the position of the thermo-couple 73, thereby insuring substantial heating of the furnace and the material placed therein throughout the extent of the furnace.

As stated above, although the invention is disclosed specifically as applied to a circular ingot heating furnace, the invention is capable of many other adaptations as, for example, in large capacity pusher furnaces where the material entering end of the furnace is maintained at a relatively low temperature, for example 850°, while at the material leaving end of the furnace a temperature of 1400° is desired to be maintained. The burners and the combustion area would be positioned adjacent the last mentioned end and a thermo-couple, corresponding to the thermo-couple 64 in the specifically disclosed embodiment, would be employed in such zone adjacent the burners to control the supply of rich gas to the burners, while a thermo-couple, corresponding to the thermo-couple 73, would be employed adjacent the material entering end of the furnace to control the supply of gas of low calorific value to the burners. Likewise, in the adaptation of the invention to annealing furnaces where a baffle wall is employed between the combustion chamber and the material being annealed, the thermo-couple normally controlling the supply of high quality gas is placed in the combustion chamber, while the thermo-couple normally controlling the supply of low quality gas is placed in the compartment holding the material being annealed.

To prevent overheating of the furnace and the material placed therein and to enable the furnace to be satisfactorily operated while using the maximum amount of economical low quality gas and the minimum amount of the high quality gas switches 59 and 68 are interposed in the circuits leading from the relay units 61 and 70, respectively, which in turn are controlled by the controllers 62 and 71, respectively. Switches 59 and 68 are operated simultaneously from one limiting position to another limiting position by the solenoid 75 and when in one position connect the relays 61 and 70 with their respective valve drive mechanisms 67 and 66. When the switches are in the other of their limiting positions, switch 59 interconnects relay unit 61 with the valve drive mechanism 66 while the switch 68 disconnects relay 70 and controller 71 from any further control.

Solenoid 75 is energized from a suitable line source of current 77 through circuit 76 having a switch or contacts 78 incorporated therein. Switch 78 is built into the controller 66, being actuated by the position of the circuit balancing mechanism of the controller in such manner that upon the attainment of a predetermined minimum temperature in the combustion chamber of the furnace, as sensed by the thermo-couple 64, the switch 78 will be closed thereby energizing solenoid 75. Therefore, upon the attainment of a pre-determined desired temperature in the combustion zone of the furnace or other preselected zone of high temperature, the switch 59 by moving to the dotted position shown in the drawing connects controller 62 through relay 61 with the valve drive mechanism 66 controlling the flow of blast furnace gas or other gas of low quality of the furnace. Simultaneously, switch 68 is moved to open position, as indicated by the dotted lines of the drawing, thereby disconnecting controller 71 and consequently thermo-couple 73 from any further control.

The operating range of the valve drive mechanism 67 and the valve 26 controlling the supply of coke oven or other high quality gas to the furnace and the adjustment of the regulator 62 are so adjusted and correlated that the supply of such gas is entirely shut off upon the attainment of the above mentioned predetermined temperature required for the closing of switch 78. It should, therefore, be apparent that upon the attainment of the predetermined minimum temperature in the hot zone of the furnace, as sensed by the thermo-couple 64, the furnace is then operated exclusively on the economical low quality fuel. Experience and trial determine the minimum temperature to be maintained in the combustion or high temperature zone of the furnace for efficient operation of the furnace. So long as the temperature of such zone is above such minimum temperature, the low quality gas is used exclusively for the maintenance of such temperature. If, however, cold steel is charged into the furnace or the load increased, as in the case of a continuous furnace, and the low quality gas is incapable of maintaining the pre-determined temperature in the high temperature zone of the furnace, controller 62 through switch 78 de-energizes solenoid 75 thereby allowing switches 59 and 68 to return to their original positions and again allowing high quality gas to be supplied to the furnace. The intense heat of such gas rapidly raises the temperature of the furnace to its preselected minimum value.

It should be observed that the employment of the control switching arrangement above described eliminates any possibility of the overheating of the furnace and its contents. Due to the character and construction of the furnace itself and the quantity and condition of the steel contained therein as well as the location and nature of the surroundings of the low temperature thermo-couple in the furnace, it may happen, in the absence of such a switching arrangement, that the thermo-couple in the high temperature zone would be satisfied and the supply of high quality

gas shut off while the thermo-couple in the low temperature zone would not be up to temperature and would be feeding large quantities of the low quality gas to the furnace, whereby the high temperature zone of the furnace and material adjacent thereto may become unduly overheated. By withdrawing the control by the thermo-couple in the low temperature zone when a predetermined temperature is reached in the high temperature zone, any possibility of the overheating of the furnace and its contents is eliminated.

The above specifically described embodiment of the invention should be considered as illustrative only as obviously many changes may be made therein without departing from the spirit or scope of the invention. For example, it should be apparent that control instrumentalities other than the specific controlling apparatus disclosed may be employed for the performance of their respective functions.

What I claim is:

1. The method of operating a material heating furnace which consists of normally supplying a gaseous fuel mixture to the burners of said furnace, said gaseous fuel mixture consisting of variable portions of high and low quality gases, controlling the quantity of high quality gas in accordance with the temperature existing in a high temperature zone of said furnace, controlling the quantity of low quality gas in accordance with the temperature existing in another zone of said furnace, withdrawing the supply of high quality gas when the temperature in said first mentioned zone reaches a predetermined degree and simultaneously shifting the control of the supply of low quality gas to effect the control in accordance with the temperature existing in said first mentioned zone.

2. The method of operating a material heating furnace having gaseous fuel burners which consist of supplying high quality gas to said burners in accordance with the deviation from a predetermined value of the temperature of the combustion chamber of said furnace, controlling the supply of low quality gas to said burners in accordance with the temperature existing in a colder zone of said furnace, withdrawing the supply of high quality gas to said burners when said predetermined temperature is attained in said combustion zone and simultaneously shifting the control of the supply of low quality gas to effect such control in accordance with the temperature of the combustion zone.

3. The method of heating material which consists of passing hot gaseous products of combustion over said material from a combustion area adjacent one end of said material, normally controlling the temperature in said area, normally controlling the volume of such gases in accordance with the temperature existing at the other end of said material, and shifting the control of the volume of such gases to thereafter effect the same in accordance with the temperature existing in said area upon the attainment in said area of a predetermined temperature.

4. Apparatus for controlling the operation of a material heating furnace having gaseous fuel burners and high and low temperature zones comprising means to supply high quality gas to said burners, means to supply low quality gas to said burners, means responsive to the temperature of said high temperature zone normally in control of the supply of high quality gas, means responsive to the temperature of the low temperature zone normally in control of the supply of low quality gas, means responsive to the attainment of a predetermined temperature of said first mentioned zone to shut off the supply of high quality gas, to simultaneously render said second mentioned control ineffectual and to simultaneously connect said first mentioned temperature responsive means with the means to control the quantity of low quality gas supplied to said burners.

5. Apparatus of the character described comprising a gaseous fuel burner, a combustion zone adjacent said burner, a low temperature zone associated with but spaced from said first mentioned zone, means including a modulating valve to supply high quality gas to said burner, means including a modulating valve to supply low quality gas to said burner, a thermo-couple in said first mentioned zone, a proportioning regulator interconnected between said thermo-couple and said first mentioned modulating valve to control the opening of said first mentioned valve in accordance with the temperature sensed by said thermo-couple, a second thermo-couple in said low temperature zone, a second regulator for controlling the opening of said second mentioned valve in accordance with the temperature sensed by the thermo-couple in said low temperature zone, and means associated with said first mentioned regulator to render ineffectual the control by said second mentioned regulator and to interconnect said first mentioned regulator with said second mentioned valve upon the attainment of a predetermined temperature at the location of said first mentioned thermo-couple.

6. The method of operating a metal heating furnace having fuel burners and an adjacent zone normally maintained at a high temperature and a second zone spaced from said first mentioned zone and normally maintained at a lower temperature, which consists of normally controlling the intensity of the flame issuing from said burners in accordance with the temperature existent in said adjacent zone, normally controlling the length of said flame in accordance with the temperature existent in said second zone, withdrawing said last mentioned control upon the temperature in said first mentioned zone exceeding a predetermined maximum, and thereafter controlling the length of said flame in accordance with the temperature existent in said first mentioned zone.

7. The method of operating a material heating furnace which consists of normally supplying a gaseous fuel mixture to the burners of said furnace, said gaseous fuel mixture consisting of variable portions of high and low quality gases, controlling the quantity of high quality gas in accordance with the temperature existing in a high temperature zone of said furnace, controlling the quantity of low quality gas in accordance with the temperature existing in another zone of said furnace, withdrawing the supply of high quality gas when the temperature in said first mentioned zone reaches a predetermined value and thereafter controlling the quantity of low quality gas in accordance with the temperature existent in the first mentioned zone.

LE ROY KELLS.