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FURNACE TEMPERATURE CONTROL

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The present invention relates to furnace control systems and more particularly to a system for controlling the temperature in an open-hearth or other regenerative furnace in such a manner that the metal will be heated at a maximum rate with a minimum of damage to the furnace.

In the use of furnaces of this type it is customary to raise the metal to some desired temperature in the shortest possible time and with the least possible fuel. In heating the furnace charge, however, care must be exercised not to raise the furnace temperature too high, since if this is done the furnace walls will be damaged and expensive and time consuming repairs will be necessary. In furnaces of this type it has been customary heretofore to control the furnace in response to the hottest temperature in the regenerator system, usually near the slag pockets, or to depend upon the experience of the operator. The various prior art methods of control are satisfactory to a certain extent but none of these methods takes into consideration the heat potential against the furnace roof. Furthermore, it has been found that the temperature of the furnace wall, particularly the roof, is a good criterion of the maximum temperature to which the furnace may be raised. In operation of furnaces of this type, fuel and air are supplied through one end of the furnace while exhaust gases are removed from the other end. After the exhaust passages have been heated and the intake passages have been cooled down by the flow of gases, to some predetermined extent, the furnace is reversed. This means that the fuel and air are supplied through the end that was formerly used for the exhaust thereby preheating the combustion supporting air. During each reversal of the furnace the temperature momentarily drops but rapidly rises to its desired point and any control system that is used in a furnace of this type must take into account this dropping of temperature so that the fuel supply will not be increased at this time, causing the temperature to overshoot its mark when the flame from the new end is started. During the melting and refining periods in the operation of an open-hearth furnace large volumes of combustible gas are liberated from the charge. The burning of these gases rapidly raises the temperature of the furnace above the danger point and unless the normal supply of fuel is reduced at this time the furnace is liable to be damaged due to the excess heat. My control system also compensates for the heat liberated by the combustible gases during the periods that the gas is liberated and burning.

It is an object of my invention to provide a furnace control system which will regulate the supply of fuel to a regenerative furnace in ac-

cordance with the temperature of one of the furnace walls. It is a further object of my invention to provide in this furnace control system a means for automatically preventing opening of the fuel valve during the time that reversal is taking place and for a short period of time thereafter.

It is a further object of my invention to automatically reduce the supply of fuel to the furnace when the temperature of a wall of that furnace rises some predetermined amount above the normal value thereof.

The description of my furnace temperature control system will be in connection with an open-hearth furnace. This is merely used, however, for descriptive purposes and it is not to be taken as limiting the use of my invention to a furnace of this type. This is true because this control system is adapted to be used with various other types of furnaces.

The various features of novelty which characterize this invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, however, its advantages and specific objects obtained with its use, reference should be had to the accompanying drawing and descriptive matter in which is illustrated and described a preferred embodiment of the invention.

In the drawing:

Fig. 1 is a more or less diagrammatic view of the furnace showing the fuel and air supply connections and the controls therefore; and

Fig. 2 is a wiring diagram showing the various parts of my control system.

Referring first to Fig. 1, there is shown a furnace 1 of the open-hearth type in which a charge of metal is to be heated. This furnace is supplied with fuel, either liquid or gas, through a pipe 2 that is provided with an adjustable valve 3. This pipe divides into branches 4 and 5 each of which is used to supply fuel to one end of the furnace. Air to support combustion of the fuel is supplied through a duct 6 and branches 7 and 8, each of which contain a checker work, to the respective ends of the furnace. When fuel and air are being supplied to one end of the furnace, say through branches 4 and 7 respectively, the gases of combustion pass out the opposite side of the furnace through branch 8 and an exhaust stack 9. In order to direct the fuel and air to the proper end of the furnace there is provided a valve 10 in the fuel line and a valve 11 in the air line which valves are actuated in unison by a manually operated lever 12. The arrangement is such that when the furnace is to be fired from its left end the lever 12 is thrown to the left thus directing fuel from pipe 2 to branch 4 and directing air from duct 6 through branch 7.

The gases of combustion will then be exhausted through ducts 8 and 9.

The temperature of this furnace is measured from the roof by means of some suitable temperature responsive device, shown herein as a thermocouple 13. This device can also take the form of a radiation pyrometer, an optical pyrometer or another suitable device depending upon the temperature at which the metal is to be maintained. The selection of the type of the temperature measuring device will also depend upon the temperature range through which it operates. The measurement of the temperature of the roof of the furnace by the device 13 is recorded through some suitable measuring system and instrument such as the potentiometer type of instrument shown at 14. A valve operating motor 15 is then energized for rotation in a direction to open or close the fuel valve 3 depending upon the value of the temperature as recorded by the potentiometer 14.

The manner in which these operations are carried out is best shown from the wiring diagram in Fig. 2. It will be seen in that figure that the instrument 14 contains a conventional potentiometer mechanism in which the voltage from a battery 16 is impressed across a resistance 17. The E. M. F. produced by the measuring element 13, which is shown in this case by way of example only as a thermocouple, is balanced against a portion of the current from the battery 16 which balance is measured by a galvanometer 18. As the temperature of the furnace roof varies the galvanometer will be unbalanced in one direction or the other to energize a motor 19 for rotation in one direction or the other, which motor serves to rebalance the potentiometer mechanism. This is accomplished by having the motor rotate a threaded shaft 20 upon which a pen carriage, 21 is mounted such carriage carrying a contact 22 that is electrically connected to the thermocouple 13 and in engagement with the resistance 17. Therefore, as the shaft 20 is rotated in one direction or the other the pen carriage 22 will be moved up or down scale to rebalance the galvanometer 18 by inserting more or less of the resistance 17 in the thermocouple circuit. The pen carriage also carries a pen 23 which serves to make a record of the value of the temperature upon a suitable chart 24.

Movement of the pen carriage, the position of which is a measurement of the value of the temperature of the furnace roof, is also used to operate the supply of fuel to the furnace. This is accomplished by having a normally balanced electrical network unbalanced in proportion of the position of the pen carriage, which unbalance serves to energize the valve adjusting motor 15 for rotation in one direction or the other. Rotation of this motor serves to adjust the valve and simultaneously rebalance the network. The control system includes a variable resistance 25 located in the instrument parallel to the potentiometer resistance 17 and another variable resistance 26 connected in circuit therewith which is located at some point suitably near the motor 15. These resistances 25 and 26 are each provided with sliders or contacts 27 and 28 respectively, the former of which is attached to and movable with the pen carriage and the latter of which is moved by the valve motor. In operation, as the pen carriage moves it will adjust the contact 27 along the resistance 25. This unbalances the network and causes the induc-

tance of one of the coils 30 to exceed that of the other coil thereby raising or lowering the armature 31, depending upon the direction of unbalance, to move a contact 32 carried by the armature into engagement with either of a pair of cooperating contacts 33 or 34 as the case may be. This is to be described in detail below. Engagement of contact 32 with contact 33 or 34 serves to energize the motor 15 which then moves contact 28 in a direction to rebalance the electrical network while simultaneously adjusting the valve 3.

The chart 24 of the potentiometer is driven by a constant speed motor 34 that also serves to drive an interruptor switch 35 which is located in the circuit of valve motor 15. The switch 35 is mounted on a support 36 that is pivoted at its left end and is provided on its lower surface with a cam edge that is periodically engaged by a roller on the end of an arm 37 which is rotated by the motor 34.

In the control of a furnace of the type disclosed herein it is often necessary to slow down the speed at which the control valve is opened or closed. This is accomplished by inserting the interruptor switch 35 in the motor circuit. This interruptor switch is continually opened and closed, and by adjusting the proportion of the closed to the opened periods, the length of time the motor is energized for each cycle may be adjusted. To this end the switch support 36 may be shifted relative to its pivot in order to vary the time that the rod 37 is in engagement with the support during each rotation of the former.

The common terminal of motor 15 is supplied with current from one side of the supply line through a conductor 38, interrupter switch 35, and a conductor 39. The other side of the line is connected through conductor 40, manual-automatic switch 41 and conductor 42 to the contact 32. From the contact 32 the motor 15 is energized through its field 15a, that serves to open the valve 3, through contact 33, conductor 43, timer switch 44, conductor 45, manually operated switch 46 and conductors 47 and 48. The purpose of the timer switch 44 will be described below. From contact 32 the motor is energized through its field 15b, that serves to close the valve 3, through contact 34, conductor 49, manually operated switch 50 and conductor 51.

In the operation of a furnace of the type shown herein the furnace is periodically reversed or fired from first one end and then the other. When this occurs there is a momentary drop in the temperature of the furnace and unless some provision is made to take care of this the control system will call for an increase in fuel, with a consequent over shooting of the temperature, when the furnace starts to fire normally from the other end. In order to overcome this disadvantage, a timer is inserted in the control circuit which will prevent opening of the fuel valve for a predetermined time after the reversal has taken place. To this end a conventional motor driven timer 52 is inserted in the line, the timer serving to prevent energization of the field 15a, that operates to open the control valve, for some predetermined time after reversal takes place. This timer is set in operation by opening the switch 53. Thereafter the timer will retain contact 44 open for whatever length of time it is set. This length of time will be sufficient for the furnace to normally regain its temperature after which the switch 44

is closed and the valve motor is permitted to be operated in the usual manner. The switch 53 is open to reset the timer and start it operating each time that a reversal takes place. This is accomplished by mounting a cam 54 on the control lever 12 so that as the control lever is moved from one side to the other to reverse the furnace, the switch 53 will be actuated.

The operation of the control system should be apparent from the above description but a summary of its operation will now be given.

As the temperature of the furnace roof varies the potentiometer circuit will be unbalanced causing the galvanometer 18 to deflect in one direction or the other to energize motor 19. This motor will then rotate shaft 20 to shift the pen carriage 21 and make a record of the change, simultaneously rebalancing the potentiometer circuit. This same movement of the pen carriage will move contact 27 along resistance 25 to unbalance the control network, thereby causing core 31, if the temperature was increasing, to be lowered to engage contact 32 with contact 34. The motor 15 is then energized intermittently for periods of time depending upon the adjustment of the switch 35 and will operate to close the control valve 3 to bring the temperature back to normal and will simultaneously adjust contact 28 and rebalance the control bridge circuit. If the temperature continues to increase the core 31 will again be lowered to bring contacts 32 and 34 into engagement to thereby energize motor field 15b and cause a further closing movement of the valve 3. On the other hand if the furnace roof temperature is falling, the contacts 32 and 33 will be engaged to energize motor field 15a to open the valve 3.

At times during the heating of the metal some abnormal condition may occur which will cause the temperature of the roof to rise appreciably, thus endangering the furnace walls. When such an abnormal condition occurs the fuel valve should be closed, and to this end my present control system is provided with the following features. Mounted in the instrument 14 adjacent the shaft 20 is a switch 55 that is on a pivoted support 56, which support has its lower surface in the form of a cam engaged by a cam roller 57 mounted on the pen carriage. Thus, as the temperature of the furnace rises unduly the pen carriage will move to the right to accomplish two things. Such a movement will first shift contact 27 along resistance 25 to unbalance the control network in a direction to energize field 15b of the valve motor to start to close the valve. Movement of the pen carriage at this time will also bring roller 57 into engagement with the cam edge of support 56 to move the same counterclockwise to close switch 55. This latter operation will short out the interrupter switch 35, thereby permitting the motor 15 to be continuously energized to close the valve 3 as long as the temperature is too high. This switch 55 and its support 56 may be adjustably positioned relative to the pen carriage so that it will be closed after the temperature has risen any predetermined amount above the normal for which the instrument has been adjusted. To this end the support 56 is pivoted to a projection extending downwardly from a block 56A. This block is provided with an elongated opening whereby it may be adjustably fastened to the frame of the machine.

In any control system of the type disclosed herein it is desirable if not essential that the

control valve should be adjusted manually at various times, such as when the furnace is being started up. To this end switches 41, 46 and 50 are provided. The switch 41 is shown in the position for automatic control. When this switch is moved to the right it will break the circuit between wires 40 and 42 and will close the circuit between wires 58 and 59 which, in effect, shorts out switches 35 and 55 so that the common line 39 of the motor 15 is directly connected with one side of the supply line through conductors 38, 59, switch 41, and conductors 58 and 39. Thereafter, the motor can be run in a direction to open the valve by moving switch 50 to its left hand position. This serves to connect conductor 48 directly with conductor 40 and to the other side of the supply line. The motor 15 can also be run in a direction to close the valve by moving switch 46 to its left hand position. This serves to connect conductors 51 and 40 of the other side of the supply line.

In the operation of the system of this type the resistance 25 is generally but not necessarily adjusted so that a narrow throttling range is obtained. By this it is meant that the resistance 25 is so formed that a small movement of the pen carriage will move the contact 27 from one end to the other of the resistance 25 and thereby run the motor 15 to completely open or shut the valve 3. Such operation means that if the temperature is low and rising, just prior to the time that the temperature reaches the control point the valve 3 will begin to be closed. Conversely if the temperature is high and falling just prior to the time the temperature reaches the control point the valve 3 will again begin to be opened. It is often desirable to have the control valve operated automatically through only a small portion of its full range of movement. This can also be accomplished by properly adjusting the effective length of the resistor 25. In such a case the switches 46 and 50 when operated will run the motor 15 an amount to completely open or close the valve 3.

From the above description it will be seen that I have provided a control system for a furnace which is responsive to the temperature of a wall of that furnace and which system serves to adjust the fuel supply valve in accordance with this temperature. I have also provided a system in which the adjustment of the fuel valve is in steps and in which the adjustment of a fuel valve in an opening direction is positively prevented during reversal of the furnace. The control can be adjusted in a closing direction at any time and is also adjusted in a closing direction continuously in response to an abnormal rise in the furnace wall temperature.

While in accordance with the provisions of the statutes, I have illustrated and described the best form of this invention now known to me, it will be apparent to those skilled in the art that changes may be made in the form of the apparatus disclosed without departing from the spirit of this invention as set forth in the appended claims, and that in some cases certain features of this invention may sometimes be used to advantage without a corresponding use of other features.

Having now described this invention, what I claim as new and desire to secure by Letters Patent is:

1. In a temperature control system for a regenerative furnace adapted to be supplied with fuel from any one of a plurality of points, the

combination of fuel regulating means, an element to measure the furnace temperature, means to intermittently adjust said fuel regulating means in response to the temperature of the furnace as measured by said element, means to render said adjusting means continuous in operation upon the attainment of a furnace temperature a predetermined amount above normal, means to shift the supply of fuel to the furnace from one point to another and means to render ineffective the operation of said fuel regulating means in a fuel increasing direction for a predetermined time after the shifting of the fuel supply takes place.

2. In combination with a regenerative furnace adapted to be supplied with fuel from any one of a plurality of points, means to increase and decrease the supply of fuel to the furnace, means operative in response to variations in the temperature of a furnace wall to adjust said supply means, means to shift the supply of fuel to said furnace from one point to another, and means operable upon a shift in the fuel supply of the furnace to render said fuel supply means ineffective to increase the supply of fuel for a predetermined time after the shifting takes place.

3. In an open hearth furnace control system in which the furnace is provided with two ends and is adapted to be supplied with fuel from either end, means to adjust the supply of fuel thereto, means to reverse the supply of fuel to said furnace from one end to the other, an element responsive to the temperature of the roof of said furnace to adjust said fuel supply in an increasing or decreasing manner depending upon whether the furnace roof temperature is below or above normal respectively, and means operative in response to furnace reversal to render said fuel supply adjusting means inoperative to increase the fuel supply for a predetermined time.

4. In a regenerative furnace control system in which the furnace is adapted to have fuel supplied from one of two points, the combination of means to regulate the supply of fuel to said furnace, means to measure the temperature of a wall of said furnace, mechanism responsive to the measurement made by said measuring means to adjust said regulating means to increase or decrease the supply of fuel to the furnace, means to render the regulating means intermittent in operation, means to reverse the supply of fuel from one point to the other, and means to render said regulating means ineffective to increase the supply of fuel for a predetermined time after a reversal takes place.

5. In a regenerative furnace control system, means to supply fuel to the furnace from a plurality of points, means to control the supply of fuel to said furnace, means to measure the temperature of a wall of said furnace, means to regulate said supply means in response to a measurement made by said measuring means in response to an increase or decrease in the temperature of the wall of the furnace with respect to a predetermined temperature, means to control the operation of said supply from one or the other of said points, and means operated by operation of said control means to render said fuel supply means inoperative to increase the supply of fuel for a predetermined time after reversal.

6. In an open hearth furnace having a plurality of ends and adapted to be supplied with fuel

from one end at a time, the combination of a valve to regulate the supply of fuel to the furnace, means to measure the roof temperature of the furnace, means operative in response to the measurement of the roof temperature to adjust said valve in an opening or closing direction, means to render intermittent the operation of said valve, means to supply fuel from one to another of the furnace ends, and means responsive to operation of said supply means to prevent said valve from being operated in an opening direction for a predetermined time after said supply means has been operated.

7. In an open hearth furnace temperature control system in which the furnace is heated from opposite ends alternately at periodic intervals by the injection of fluid fuel and oxidizing gases into said furnace, the combination of a fuel supply, a valve to regulate the supply of fuel, means to reverse the operation of said furnace, an element responsive to the roof temperature of said furnace, mechanism operative in response to measurements made by said element to adjust said valve in an opening or closing direction as the roof temperature is below or above a normal value, means to render the operation of said valve intermittent, means responsive to an increase of the roof temperature a predetermined amount above normal to produce continuous operation of said valve in a closing direction, and means operated by said reversing means to render said valve inoperative to be adjusted in an opening direction for a predetermined time after reversal takes place.

8. A furnace temperature control system comprising means to measure the temperature of the furnace, a valve through which fuel is supplied to the furnace, a motor to operate said valve, a proportioning control system for said motor operated by said measuring means to produce an adjustment of the valve in accordance with the temperature of the furnace, means to render the operation of said motor periodic during normal operation of the same while said control system is being operated by said measuring means, and means operated by said measuring means to energize continuously said motor for rotation in a direction to close said valve upon the attainment of a predetermined temperature.

9. A furnace temperature control system comprising means to measure the temperature of the furnace, means including a motor operated valve to control the supply of fuel to said furnace, a balanced electrical control system, means operated by said measuring means to unbalance said system as the furnace temperature changes, relays operated upon unbalance of said system to energize the motor for said valve in one direction or the opposite direction depending upon the direction of system unbalance to adjust said valve in a direction to return the furnace temperature toward normal, means simultaneously operated by said motor to rebalance said control system, means to render the operation of said motor periodic when the furnace temperature is below some predetermined maximum and while said control system is being unbalanced by said measuring means, and means operated by said measuring means to energize continuously said motor for rotation in a direction to close said valve if the furnace temperature exceeds said maximum.

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