This invention relates to the heating of steel forging stock to forging temperature by advancing the work through a furnace chamber having a heating zone whose temperature is maintained substantially higher than the desired leaving temperature of the work so that the work must be advanced through the furnace at a predetermined rate to avoid being overheated in said zone. In a heating system of this type, in case the demand for heated work is suddenly interrupted, the highly heated refractory lining which forms the furnace chamber contains enough heat to overheat the work if it is left in the furnace hence there is presented the problem of how to save the heated work from damage while retaining it in the furnace; and it is with the solution of this problem in a relatively simple and practical way that the present invention is primarily concerned.

For a consideration of what I believe to be novel and my invention, attention is directed to the drawing, the following portion of the specification, and the claims appended thereto.

In the accompanying drawing forming part of this specification,

Fig. 1 is a schematic representation of the method and apparatus involved in the present invention.

Fig. 2 is a longitudinal vertical sectional view of the type of furnace schematically shown in Fig. 1.

Fig. 3 is a transverse view of the furnace shown in Fig. 2.

Fig. 4 is a view similar to Fig. 3 with some modifications.

Fig. 5 is a detail view of apparatus for the furnace of Fig. 2.

Fig. 6 is a chart showing pertinent chemical and heat balance information.

Fig. 7 is a schematic representation of alternate apparatus for admission of atmosphere premix gas to the furnace, which may be substituted for a portion of the showing of Fig. 1.

Fig. 8 is a schematic electrical diagram showing control apparatus for the furnace.

This application is a continuation in part of my copending application Serial No. 98,543, filed June 11, 1949, now Patent No. 2,693,952, issued November 9, 1954. This invention is well adapted for use in connection with the furnace disclosed in my application filed May 19, 1949, Serial No. 94,216, now Patent No. 2,691,513, issued October 12, 1954, and will therefore be described in that connection.

In its preferred form, the furnace chamber is cylindrical in transverse cross section and is defined by a structure embodying an inner annular refractory lining 6, the structure being supported on a pair of longitudinally extending girders 7 in a manner to permit free thermal expansion and contraction of said structure thereon, as indicated by the rollers 8, with reference to the anchored end 10 of the structure. The charge or work entering the furnace is at the left as viewed in Fig. 2.

In Fig. 1, the furnace is diagrammatically indicated by the three aligned rectangular figures A, B and C, respectively, to indicate three successive heat zones in the furnace chamber. In Fig. 1, the charge end of the furnace is at the left hand end 11 of zone A and the discharge end is at the right hand end 12 of zone C.

If the entire work piece 13 (see Figs. 2 and 3) must be heated to forging temperature, the pieces will ordinarily be pushed through the furnace on elevated skid rails 14. On the other hand, if the work pieces are elongated bodies 15 (see Fig. 4) of which only one end requires to be heated, said pieces will project into the furnace through a longitudinally extending slot in the side wall thereof from any preferred support and conveying means 16 outside of the furnace chamber.

Heat is produced in the furnace chamber by longitudinally extending rows of nozzles or burners 20 arranged to fire tangentially thereto into so that the flame of combustion may flow along the curved surface of the refractory lining 6 whereby to constitute said furnace a source of radiant heat for heating the work pieces advancing through the furnace. Two such rows of burners will ordinarily suffice.

The nozzles, or burners 20 are manifolded into groups 21, 22 and 23 corresponding to the heating zones A, B and C, the respective groups being so manifolded at 24, 25 and 26 respectively. To minimize explosion hazards, each manifold has its own air and fuel mixing device 27, 28 and 29 respectively. The main gas supply line is indicated at 30 and the main air supply line for air under pressure is indicated at 32. Shut-off valves for these lines are indicated at 37 and 19, respectively.

Branch fuel lines 33, 34 and 35 conduct the fuel to the several mixing devices and branch air lines 36, 37 and 38 conduct the air thereto. Each branch air line is provided with a control valve 42, 43 and 44, respectively.

The relative proportions for air and gas to each mixing device are automatically maintained by a gas governor 40 in each branch gas line, the governor being responsive to changes in pressure in the associated branch air line through a connecting pipe 41 in a manner to vary the gas flow in accordance as the air flow is varied. Ratio control means of this type are well known in the art.

The final heat zone C is not a soaking zone where the temperature of the work pieces is equalized but is a heating zone wherein the thermal head is maintained substantially higher, say 400° F. higher, than the discharge temperature, say 2300° F., of the work pieces. When the demand for heated work is at a maximum, the heat input to the zones A and B is at a maximum. When the production demand for heated work is reduced, the rate of advance of the work pieces through the furnace must be correspondingly reduced. This presents the problem of how best to control the furnace to avoid overheating of the work and to prevent excessive scale formation on the work due to longer time in the furnace.

This problem is solved not by reducing the thermal head of the final heat zone C but by controlling the heat input to the first heat zone A and then to the next heat zone B to such degree as may be necessary to insure that by the time the work piece has passed through the final high temperature heat zone C, it will not have been at scaling temperature substantially longer than when the work was being advanced through the furnace at maximum production rates with maximum heat input to zone A as well as the other zones B and C. The characteristic of effecting such heat input control to the first zone A comprises a heat sensing element 45 mounted to be responsive to changes in temperature within the final heat zone C and more especially to the temperature of the work pieces in said zone. The said heat sensing element 45 operates a control instrument 46 which in turn operates a valve adjusting means 47 associated with the heat input control valve 42 for zone A to reduce the heat input to zone
A as operating conditions may require. If still further reduction of heat input is required a valve adjusting means 48 associated with the control valve 43 for zone B is next operated on by the instrument 46 as will now be readily understood. It is preferred to separate zone A from the next succeeding zone B by means of a transversely extending heat shield 49 so that radiant heat in zone A is localized to that zone. The heat input to zone C to maintain the desired elevated temperature therein is determined by the setting of the control valve 44 for said zone. Hand setting of said valve 44 will ordinarily suffice but automatic control means may be employed.

The apparatus thus far described is substantially the same as that disclosed in my aforesaid application Serial No. 94,216.

To permit the already heated work to be retained in the furnace without damage by overheating and without excessive scale formation thereon in case the demand for heated work is suddenly interrupted, this invention introduces into the furnace for contact with the highly heated refractory lining thereof a mixture of gases which when heated by said refractory will react endothermically and thereby rapidly lower the temperature of the surface of said refractory, the said mixture of gases (hereinafter sometimes called "atmosphere gas premix") being of such character that the reaction products will serve as a protective atmosphere for the heated work to reduce the formation of scale thereon to a minimum. The atmosphere gas premix is formed according to Fig. 1, outside of the furnace chamber in a mixing device 51 to which air under appropriate pressure is delivered by a supply pipe 52 having a control valve 53 and to which fuel gas under appropriate pressure is delivered by a supply pipe 54, having a control valve 55. The relative proportions of the air and fuel gas thus delivered to said mixing device 51 are controlled in any preferred way. Since the work in zone C is already at elevated temperature therefore requires immediate protection against overheating, it is into zone C that the mixture from the mixing device 51 is preferably introduced whereby to rapidly cool the refractory lining of that zone and to supply a protective atmosphere to surround the hot work in that zone. The mixing device 51 therefore delivers to the manifold 26 for the burner group 23 associated with the zone C so that the mixture may enter said zone tangentially and therefore be rapidly heated to reaction temperature as it flows in contact with the highly heated curved boundary surface of said zone. To reduce draft through the burner assembly to a minimum the fuel supply to the furnace is shut off, the normally open flue dampers 67 and 68 and the door 71 are closed, it being understood that it is desirable to maintain a Plenum of protective atmosphere in the furnace chamber during that time to reduce the formation of scale on the heated work to a minimum.

The loss of heat from the furnace through its walls, its water-cooled work support ralls 14, and the application of the atmosphere gas premix rather quickly cools the furnace chamber to a temperature below which the work is not overheated, and by substantially simultaneously closing the furnace chamber and generating a work-protecting atmosphere within the furnace, a relatively small quantity of atmosphere gas can effectively reduce and substantially eliminate air infiltration into the furnace chamber and consequent oxidation of the surface of the work during such temporary delays.

While a simultaneous shutting off of the firing system, shutting off the air inlet system and closing of the furnace chamber is desirable for fullest benefit from this atmosphere protection and avoidance of overheating of the work, in practice a short delay after stopping the firing and closing the furnace chamber is desirable to insure purging of the burner manifold piping and thus to avoid backfire. It is thus preferred to slightly delay actual closing of the furnace chamber and inlet of atmosphere premix gas for safety reasons.

In Fig. 2 the flue dampers 67 and 68 are shown as hingedly connected to an edge of the respective flues. An alternate way of operating the flues is illustrated in more detail in Fig. 6 where flue damper 68 is supported on two pairs of hinged arms 72 and 73. The lower ends of the arms 72 and 73 extend beyond the furnace structure and aligned with a flue 81 of the furnace so that as a hydraulic cylinder 76 is actuated through valve 77 by energizing the solenoid coil 78 thereof, the valve is moved from the position as shown to its second position and is thus actuated toward the position shown in dashed lines, moving the damper 68 from the open position as shown to a closed position shown in dashed lines atop the flue 81. If desired, the flue dampers 67, 68, and the door 71 may be internally cooled by streams of coolant water supplied through flexible conduits, not shown.

When the size of the piping and valves in the combustion, air and fuel lines becomes so large that it is difficult to automatically close the air lines, it may be preferred to stop the combustion air blower 82 and provide an independent source of air for atmosphere. This is particularly advantageous where power interruptions may be experienced and a high pressure plant air storage system is available. Such an atmosphere system is illustrated in Fig. 7, where high pressure plant air, perhaps up to 150 pounds per square inch, is delivered to air supply conduit 83, through solenoid valve 84 and to an inspirator 85 wherein atmospheric air is aspirated and delivered to a mixer 86 at about 30 p.s.i. Fuel gas such as natural gas is delivered from fuel supply conduit 87 through solenoid valve 88, pressure governor 91 and to the mixer 86. The governor is loaded by a small condit 92 to the mixture conduit 93 downstream of the mixer 86, to maintain zero gas pressure at the throat of the mixer 86 which is preferably of the venturi type as is well known, thus providing the desired proportioning of fuel and air for producing an atmosphere in the furnace chamber. The mixture in conduit 93 passes through mixture valve 94 and inlet pipe 95 to a nozzle 96 for the discharge zone of the furnace; zone C in Figs. 1 and 2. A second stream of mixture, or atmosphere premix, may pass through inlet pipe 99 and valve 97 therein, and inlet nozzle 98 into zone B of the furnace. By reducing the number of atmosphere premix nozzles, a higher inlet velocity is obtainable, hence improved wall contact is obtained, and it is not then necessary to use inlet nozzles as are used for combustion premix gas. It may be desirable to use a plurality of atmosphere premix nozzles 96 and 98, but generally with 30 p. s. i. in the premix line, one or two each of such nozzles will suffice to provide the furnace chamber is sufficiently closed as by doors and flue dampers.

An electrical control system for coordinating the illustrated atmosphere producing apparatus with the furnace operations is illustrated in Fig. 8 wherein a 110 volt control circuit is illustrated. A two position atmosphere push button 101, shown in off, or open, position is wired in series with a safety contact 102 in a relay operated from a contact in the temperature control instrument, not shown and the solenoid coil 103 of a relay 104. The relay operating contact in the temperature control instrument is set to close the relay above 1400° F. and to open it below 1400° F. so that atmosphere premix cannot be delivered to the furnace when it is above 1400° F., thus eliminating an explosion hazard. The safety contact 102 is shown in its safe, or hot position, closed.

The relay 104 operates three contacts 105, 106 and 107. Contact 105 is normally closed, and its series with a normally open contact 108 in a limit switch 109 is depressed when the damper 68 is in open position, and the operating coil 112 of an air blower relay 113. Thus
the combustion air blower 82 cannot be started or operated unless the damper 68 is in open position, off the flue 81. When the push button 101 is depressed to actuate the atmosphere producing control system, the combustion air blower 82 is stopped.

Contact 106 operated by the relay 104 is normally closed in a circuit with a coil 114 in the main fuel gas valve 31, hence when the atmosphere push button 101 is depressed, relay 104 is actuated and contact 106 is opened, thus breaking the circuit to the coil 114 of the main gas valve 31 and shutting down the nozzles 20 which supply combustion premix to the furnace chamber for heating the same.

Contact 107 is operated by the relay 104 and is normally open. When the relay 104 is actuated, contact 107 is closed, making a circuit to a coil 116 in a timer 115. The timer 115 is adjusted to run for a short period of time such as 50 seconds, sufficient to allow the furnace chamber to purge itself and the residual air in the combustion air piping to draw the last bit of fuel gas from the gas manifolds. When the timer 115 trips out, it closes a normally open contact 117 therein, which is in series with a contact 118 which is closed when the push button 101 is depressed, thus making a circuit to solenoid 78 and a hydraulic valve 77 from its position to open the damper 68 as shown to its second position to close the damper 68. A similar solenoid and hydraulic valve, not shown, is also actuated by closing of contacts 117 and 118 to close the other flue damper 67. Solenoid 122 operates a similar four-way hydraulic valve for a door operating hydraulic cylinder, not shown to close the discharge door 71 of the furnace simultaneously with the closing of the flue dampers.

While the timer 115 is preferably a clock mechanism, especially where 25 cycle electric current is used and upon stopping of the power to the air blower, the blower air pressure drops rapidly, it is equally satisfactory to use other timing means. For example, when the blower 31 is driven by a 60 cycle current motor which characteristically coats after stoppage of power supply, a pressure switch may be placed in the main air manifold 38 and adjusted to close a contact 117 therein after a drop in air pressure therein to a pressure attained in about 30 seconds.

When the solenoid 78 is actuated and the flue damper 68 is moved from its open position off the flue as shown in solid lines in Fig. 6 to the position shown in dashed lines in Fig. 6, the furnace is formed normally without an atmosphere and a normally open contact 123 therein. This makes a circuit through a contact 124 which, like contact 102, is closed above 140°F, in the temperature control instrument, and energizes a solenoid 125 for the atmosphere gas valve 86 in pipe 87 and solenoid 126 for the atmosphere air valve 84 in the auxiliary air supply pipe 83. If desired, the mixture valve 94 may also be operated by a solenoid wired in parallel with solenoids 125 and 126.

The above described control circuit is designed to coordinate the closing of the heating chamber by flue dampers and suitable doors, where desirable or necessary, and to provide a time delay between the stopping of the firing system for heating the furnace and the closing of the furnace chamber. This allows the furnace chamber and fuel supply pipes to be completely purged of unburned fuel before the atmosphere gas premix is admitted thereto, and automatically stops any increase in temperature or fuel values upon closing of the furnace, thus containing the generated atmosphere within the heating chamber and reducing the quantity thereof required to protect the surface of the work therein.

The reaction produced by scrubbing the atmosphere premix on the wall of the furnace chamber is an endothermic reaction since more heat is required to bring the gas to furnace temperature than is supplied from the partial combustion reaction which generates the atmosphere, but a greater cooling effect from the water cooled rails 14 and from normal heat loss from the furnace walls is obtained thus reducing the time the work which is temporarily retained in the furnace is held above scaling temperature.

Figure 5 illustrates some chemical and thermal properties of varying ratios of the atmosphere gas premix. The ordinate is the ratio of air to methane and the abscissa is the reacting or equilibrium temperature. Curve 61 shows the thermal equilibrium mixtures of air and methane at various temperatures. Mixtures falling below the curve at a given temperature will normally proceed to the same, the proportionate distance of a point from the curve is an indication of the quantity of heat absorbed in the reaction.

Curves 62 shows the temperatures at which the gases resulting from the reaction to equilibrium of a gas mixture of the air to gas ratio indicated will be in equilibrium with FeO, any richer premix resulting in an atmosphere reducing to FeO and a leaner premix resulting in an atmosphere oxidizing the FeO. Curve 63 shows the same information with regard to FeO and the point 64 lies on a similar curve for FeO. In the application of the present invention an atmosphere gas premix is chosen that is reducing to the several forms of scale, thus constituting a protective atmosphere, and at the same time having a high capacity to absorb heat in an endothermic reaction. The preferred ratio is 1:1 or ½:1 air to methane gas, thus allowing a maximum cooling effect without the bad effects of carbon deposition or sooting characteristic of rich air-gas mixtures. The mixture is admitted to the refractory wall in relatively small or thin streams for improved heat contact therewith for sufficient time to insure substantially complete reaction before passing to the center of the furnace, thereby the work from further oxidation while cooling the furnace and to a desired temperature. An illustration of the beneficial effects obtained in the practice of the present invention the following may be cited:

Work was heated, in a furnace whose walls were maintained at 2700°F, to a core temperature of 2200°F. The scale formed in normal operation at 50% of the furnace design production rate was 0.010 inch on a 23 lb. piece of work, and after holding in an atmosphere in accordance with this invention for 25 minutes the scale was 0.008 inch. After reheating a corresponding piece to forging temperature, the scale was 0.017 inch. A similar work piece was heated to forging temperature, then cooled out in a nitrogen atmosphere to 2100°F, and allowed to return to temperature in 30 minutes and was found to have 0.56" scale.

It is preferred to admit the atmosphere forming gas to the furnace chamber through a series of laterally extending relatively small inlet ports tangent to the inner surface of said chamber whereby to produce in the chamber a plurality of laterally spaced streams of said gas and which collectively form a relatively thin layer of the gas next to said surface with the resultant more rapid cooling of said surface by endothermic reaction as will now be readily understood.

Since the preferred type of high heat head forging furnace illustrated in Fig. 1 utilizes a series of laterally extending burner ports which are tangent to the refractory wall, and those burners, or nozzles, are turned off when the work is temporarily retained in the furnace, the same ports 20 may be used to deliver the atmosphere gas mix to the furnace. It is sometimes preferred, however, to utilize an independent atmosphere premix inlet system such as shown in Fig. 7, and in either case the atmosphere premix inlet system is coordinated with the damper and/or door controls as hereinbefore described.

I claim:
1. In a furnace for heating work to elevated temperatures, the combination which comprises structure defining a cylindrical furnace chamber having refractory walls wherefrom work may be advanced from a charge
end to a discharge thereof for heating the work; said structure defining at least one flue intermediate said ends for discharging products of combustion from the furnace chamber, damper means for closing said flue, burner means for firing into said chamber to heat the refractory walls thereof to constitute the same a source of radiant heat tending to overheat the work; burner stop means for shutting off the burner means; atmosphere means for admitting to the furnace chamber next adjacent the refractory wall thereof a stream of gaseous mixture which will be heated to reaction temperature by contact with said wall, cool the wall, and generate a protective atmosphere for preventing oxidation of the work in the furnace chamber and control means connected to said damper means, said burner stop means, and said atmosphere means operable to operate the burner stop means, actuate the damper means to close said flue, and actuate the atmosphere means to admit said gaseous mixture to the furnace chamber, so that the work may be retained temporarily in the furnace chamber after the burner stop means is actuated while oxidation of the work is inhibited, said control means including an electrical control circuit comprising a first relay, a stop switch for closing a circuit to the first relay to energize the same, a burner stop means control circuit, contact means in the first relay for interrupting the burner stop means control circuit whereby to shut-off the burner means, a timer relay, contact means in the first relay for closing a circuit to the timer relay to actuate the same, a flue damper control circuit, timer contact means in the timer relay for actuating the flue damper control circuit to cause the flue damper to close after a delay period set by the timer relay, and a control circuit for actuating the atmosphere means after the flue damper is closed to cause the gaseous mixture to be admitted to the furnace after said delay period.

2. In the combination according to claim 1, at least one door for closing an end of the furnace chamber, and means comprising a control circuit for closing said door, the timer contact means being adapted to actuate the door closing means through its control circuit to close the door after said delay period.

3. In a furnace for heating work to elevated temperature and comprising wall means forming a heating chamber wherein work may be advanced for heating, and heating means for normally maintaining said wall means at an elevated temperature tending to overheat the work, the improvement which comprises atmosphere means for supplying an atmosphere premix gas to the heating chamber, closure means for closing the heating chamber, and coordinating means connected to the heating means, the closure means, and the atmosphere means, for substantially simultaneously shutting off the heating means, actuating the closure means to close the heating chamber, and actuating the atmosphere means to deliver atmosphere premix gas to the heating chamber.

4. A furnace according to claim 3 wherein the coordinating means comprises time delay means for delaying the closure of the heating chamber after the heating means is shut off.

5. A furnace according to claim 3 wherein the coordinating means comprises time delay means for delaying the actuation of the atmosphere means after shutting off the heating means.

6. A furnace according to claim 3 and comprising thermostat means responsive to heating chamber temperature for preventing the supply of atmosphere premix gas premix below a predetermined chamber temperature.

7. In a furnace for heating work to an elevated temperature and comprising wall means forming a heating chamber wherein work may be advanced for heating, and heating means for normally maintaining said wall means at an elevated temperature tending to overheat the work, the improvement which comprises atmosphere means for supplying an atmosphere premix gas to the heating chamber to prevent oxidation of the work when it is retained in the heating chamber temporarily, closure means for closing the heating chamber, and a control circuit connected to said heating means, said atmosphere means, and said control circuit including a source of voltage, a series circuit including a switch and a first relay coil connected across said source, a second series circuit including a normally-closed contact of said first relay coil, and a control for operating said heating means connected across said source, a third series circuit including a normally-open contact of said first relay coil, and the coil of a time delay relay connected across said source, a fourth series circuit including a normally-open contact of said time delay relay and a control for operating said closure means connected across said source, and a fifth series circuit including a normally-open contact of said first relay coil, and the coil of a time delay relay, connected across said source.

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