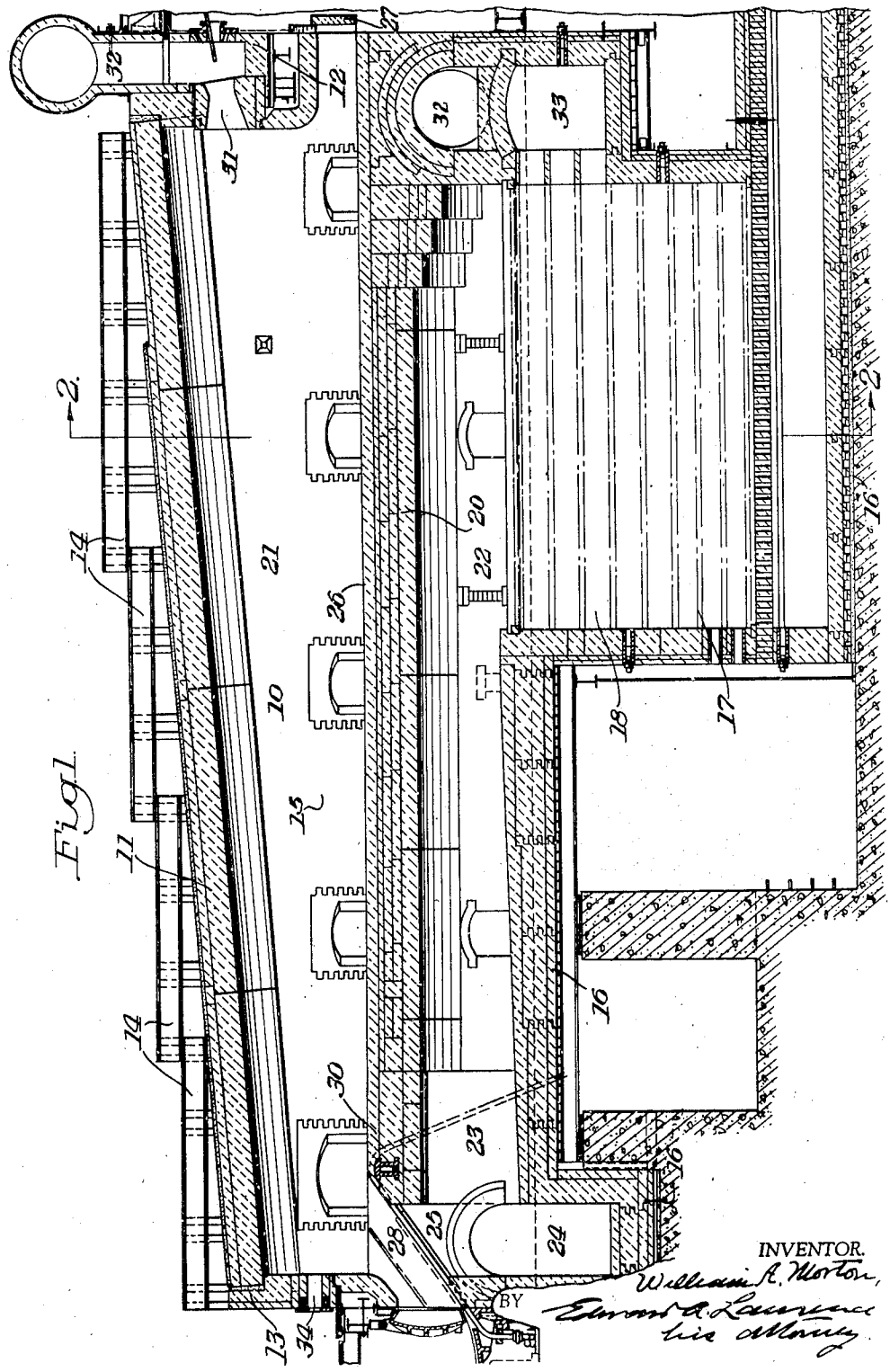
Oct. 12, 1948. W. A. MORTON 2,451,349

CONTINUOUS HEATING FURNACE AND METHOD OF OPERATING THE SAME

Filed Jan. 12, 1943 3 Sheets-Sheet 1

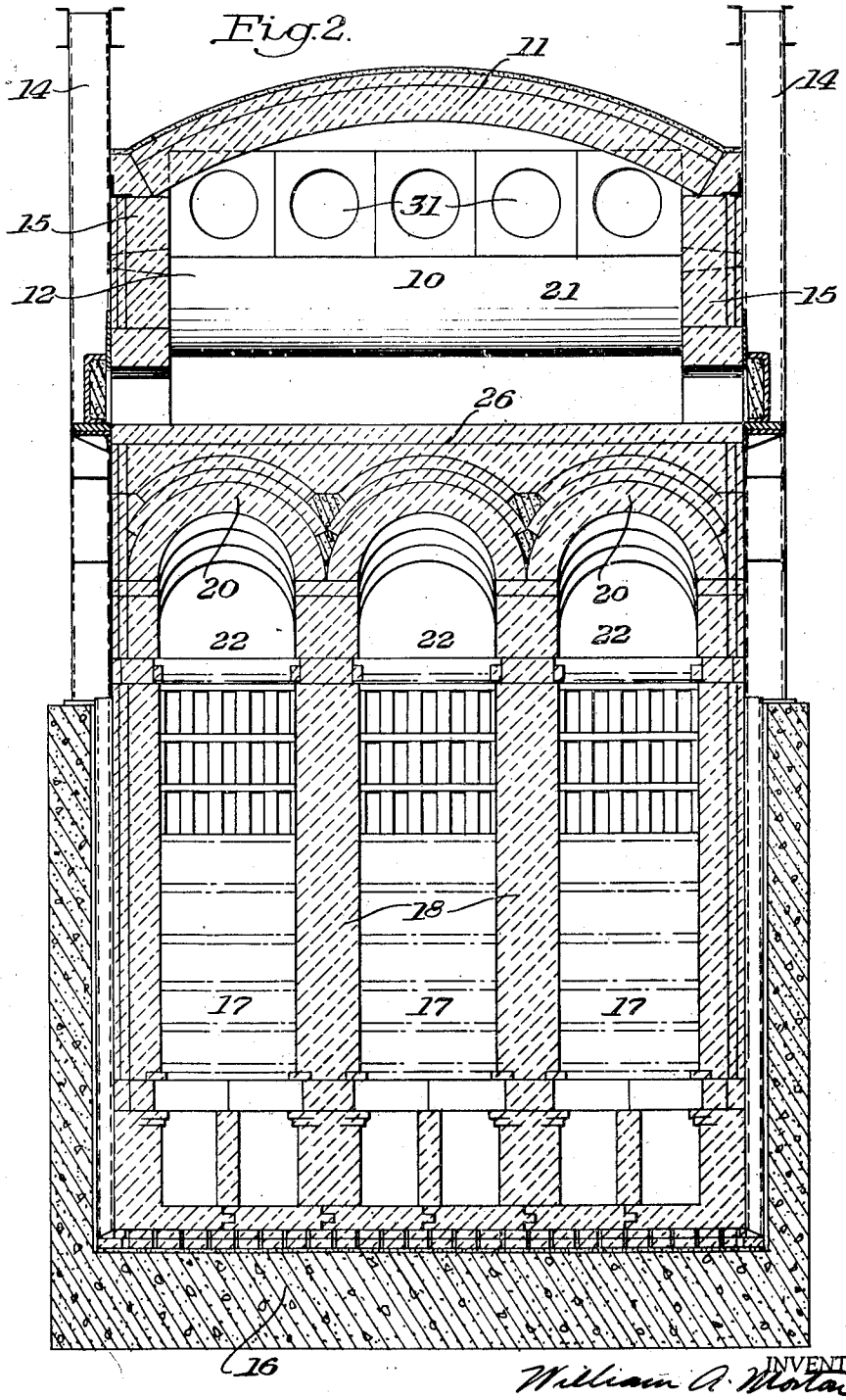


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CONTINUOUS HEATING FURNACE AND METHOD OF OPERATING THE SAME

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Fig. 2.



INVENTOR.
William A. Morton.
BY Edmund B. Lawrence
his Attorney

Oct. 12, 1948. W. A. MORTON 2,451,349

CONTINUOUS HEATING FURNACE AND METHOD OF OPERATING THE SAME

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Fig. 3.

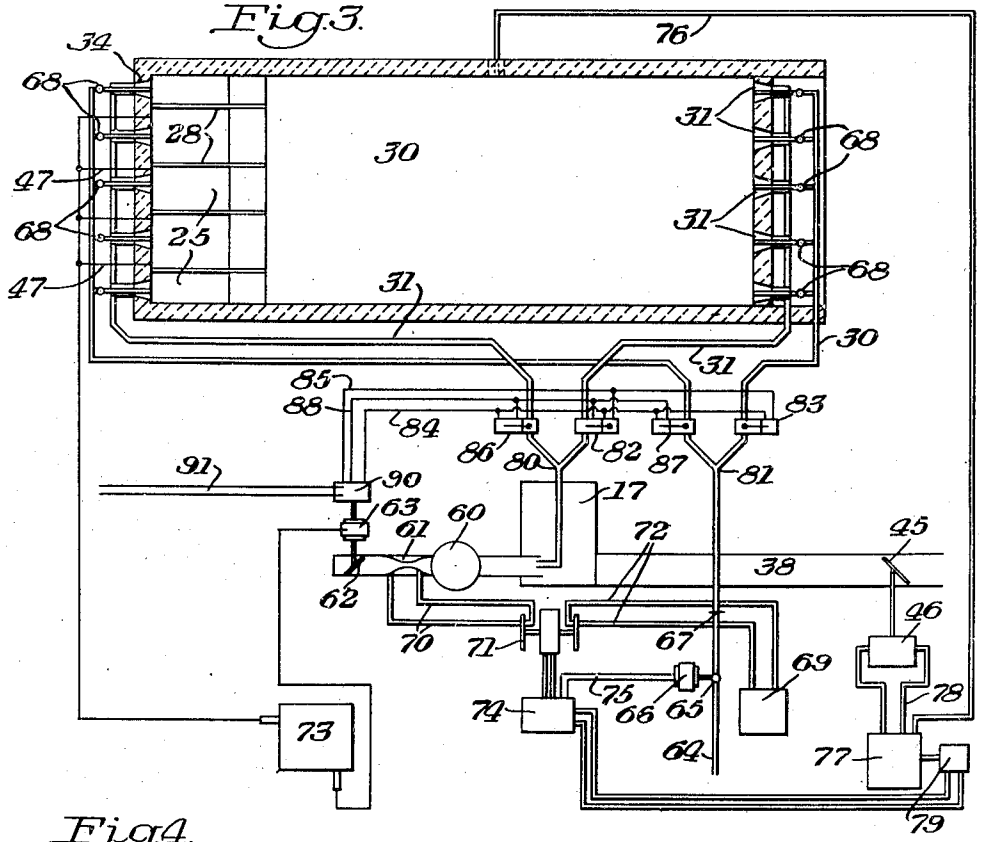
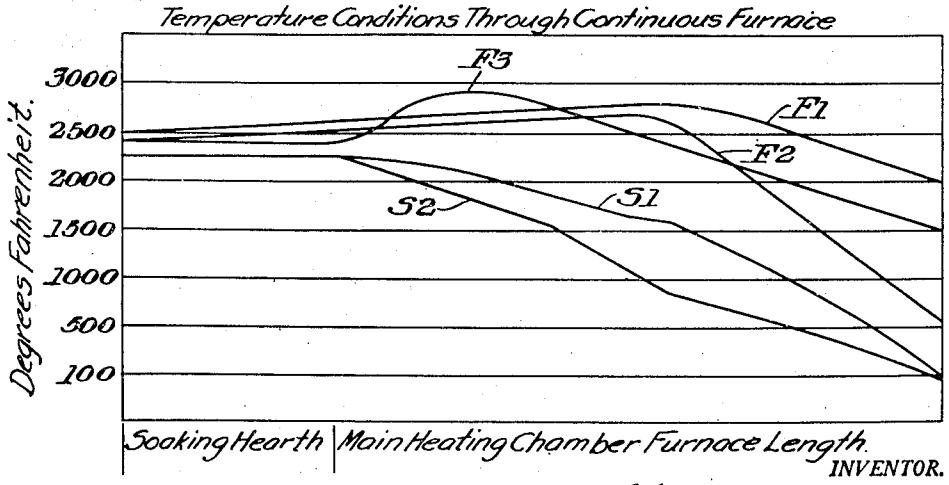


Fig. 4.



INVENTOR.

William A. Morton,

BY

Edmund A. Laurence

his attorney

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2,451,349

CONTINUOUS HEATING FURNACE AND METHOD OF OPERATING THE SAME

William A. Morton, Mount Lebanon, Pa., assignor, by mesne assignments, to Amsler Morton Corporation, Pittsburgh, Pa., a corporation of Delaware

Application January 12, 1943, Serial No. 472,098

15 Claims. (Cl. 263—39)

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This invention relates generally to heating furnaces and more particularly to heating furnaces of the type wherein articles are heated as they are moved therethrough and the method of operating the same.

This invention is a continuation in part of United States Letters Patent No. 2,329,211 for Continuous heating furnace and method of operating the same.

The principal object of this invention is the provision of an improved character of continuous furnace and the method of operating the same.

Another object is the provision of independent local regulation of the temperature of the steel as it travels through the furnace or rests on the soaking hearth section. This method contemplates the operation of burners adjacent the discharge end of the furnace chamber to maintain the steel on the soaking hearth at its proper rolling or working temperature during mill delays or shutdowns when little or no heat is required of the burners at the charging end.

Another object is the provision for automatically controlling the temperature of the steel as it is discharged regardless of the rate of production, or rate of firing the heating chamber, or during mill delays.

Another object is the provision of a method for controlling the rate of heating of the steel in the furnace in proportion with the rate of production without endangering the thermal or physical characteristics of the steel in the critical heating range.

Another object is the provision of a method for varying the position or location of the maximum thermal input within the furnace chamber.

Another object is the provision for introducing the heating medium at both ends of the furnace chamber and withdrawing all the products of combustion from the discharge end of the furnace.

Another object is the provision of a continuous furnace having a solid hearth the under side of which is heated to prevent heat absorption from the steel lying thereon, thereby reducing the temperature differential between the furnace temperature and the waste gases below the hearth. This improvement increases the efficiency of the furnace by lowering the losses and reducing the fuel consumption.

Another object is the provision of heating the hearth of a continuous furnace to reduce the temperature gradient from the top to the bottom of the steel lying on the hearth.

Another object is the provision of a recuperator

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the roof of which is employed as a hearth for a continuous furnace to stop heat loss from the steel as it is heated when passing along the hearth.

Other objects and advantages appear in the following specification and claims.

A practical embodiment illustrating the principles of this invention is shown wherein:

Fig. 1 is a vertical sectional view of the continuous furnace comprising this invention.

Fig. 2 is a cross sectional view taken on the line 2—2 of Fig. 1.

Fig. 3 is a diagrammatic view illustrating the circuits for automatically controlling the furnace operation.

Fig. 4 is a graph illustrating the temperature of the furnace and the steel being heat treated as it passes therethrough.

Referring to Figs. 1 and 2 of the drawing, the furnace illustrated therein comprises the furnace chamber 10 enclosed by the roof 11 which has a gradual slope downwardly from the rear or charging end wall 12 to the front or discharge end wall 13. The roof is arched transversely and is supported exteriorly by the steel beams 14 which are assembled in sections forming steps from the front to the rear of the furnace. The side walls 15 of the furnace extend to the foundation 16 beneath the furnace. The foundation 16 is irregular because substantially half of the length of the furnace chamber encloses the heat exchangers or recuperators 17. It is more economical to construct three independent heat exchangers 17 than it is to combine them into one large heat exchanging chamber and the three recuperators shown have sufficient capacity collectively to function under the overloads that the heating chamber is capable of handling. Thus the intermediate vertical divisional walls 18 shown in Fig. 2 enclose the centermost recuperator and the outer recuperators are enclosed between the exterior side walls 15 and the intermediate vertical walls 18.

The roof 20 of the recuperators 17 horizontally divides the furnace chamber 10 into two chambers, the main heating chamber 21 above the roof 20 and the recuperator chamber 22 below the roof 20. The recuperator chamber 22 is divided longitudinally of the furnace into three separate passages 23 by the intermediate vertical walls 18 which are extended to the front of the furnace where the passageways 23 are connected to the transverse passage 24 and the vertical outlets 25.

A solid hearth 26 is laid on the top of the roof 20. This hearth extends from the charging door

27 to the gravity discharge slope 28 at the front of the furnace. The top of the division walls forming the outlets 25 are inclined and carry water-cooled skids which form the rails of the gravity discharge slope 28 upon which the steel slides as it is being discharged from the hearth in the furnace chamber. A short section 30 adjacent the front end of the hearth 26 serves as the soaking part of the hearth.

That portion of the rear wall 12 above the hearth 26 is provided with a row of large burners 31 which are supplied with preheated air by the duct 32 that extends around both sides of the furnace and is connected to the common air collector 33 that receives preheated air from each of the recuperators 17. Blowers are provided at the front of the recuperators to force the air therethrough where it is preheated and conveyed to the burners.

A row of burners 34 are positioned in the front wall 13 of the furnace for the purpose of heating the steel during mill delays or during periods when the mill is shut down for roll changes, repairs or the like. These burners may also be supplied with preheated air from the collector 33 through ducts similar to the ducts 32. The control mechanism which automatically supplies and regulates fuel fed to the furnace in accordance with the temperature demands of the furnace together with transfer of the firing from the rear burners 31 to the front burners 34 are shown in Figs. 3 and 4.

60 represents the blower for delivering air to the recuperator 17 where it is preheated and directed to the burners 31 and 34. A Venturi tube 61 is inserted in the blower inlet which is controlled by the damper 62 operated by the servo motor 63.

The fuel is supplied through the conduit 64 and its flow is controlled by the regulating valve 65 which is operated by the motor 66. When the fuel passes from the valve 65 it must flow through an orifice plate 67 and then continues through the supply conduit to the burners 31 and 34. Each of these sets of burners is provided with a hand-operated valve 68 for independently adjusting the flow of fuel to each of the burners. The flow of fuel may be read by the meter 69.

The burners are preferably of the induction type and the preheated air in the common ducts while it is induced it is also proportioned by the fuel ratio control. This is important to maintain the proper furnace atmosphere throughout furnace operations.

Fluid pressure lines 70 connect each side of the Venturi throat 61 to one diaphragm of the air-fuel regulator 71 for registering by pressure the quantity of air flowing to the recuperator. Fluid pressure lines 72 also connect each side of the orifice 67 in the fuel line to the other diaphragm of the air-fuel regulator and register the quantity of fuel delivered to the furnace. The quantities of air and fuel are thus kept proportional by means of this ratio regulator control which is operated by differential pressures created by the flow of air and the quantity of fuel is maintained proportional. The quantity of air is previously determined by the temperature of the furnace.

The temperature of the gases being discharged from the furnace through the flue 25 has a direct relation to the temperature of the steel on the soaking hearth 30 which the gases have just passed over, whether these gases are coming from the main burners 31 during normal operation or from the burners 34 during mill delays. When

the furnace temperature is approximately 2500° F. the steel on the soaking hearth will be approximately 200° F. less. This difference may vary slightly but for purpose of control the waste gases always bear a direct relation to the steel temperature whereby the furnace control system may be accurately operated.

The temperature of the gases discharged from the furnace is measured by the pyrometer 47 and registered in the recording potentiometer temperature control 73. This control in turn operates the servo motor 63 for opening and closing the damper 62 and thereby regulates the amount of air delivered to the furnace for controlling the temperature.

Any change in the quantity of air delivered to the recuperator is registered as differential pressures in the air-fuel regulator 71 which actuates the ratio control 74 for automatically maintaining a predetermined ratio of air and fuel flow by operating the fuel valve 65 by means of the servo motor 66. The servo motor 66 may be operated by fluid pressure through the control lines 75. When the proper quantity of fuel is delivered to the furnace for maintaining the predetermined ratio of air and fuel a balance will be created between the diaphragms of the regulator 71 by the pressure differentials registered across the restricted orifices in the air and fuel lines.

The pressure of the furnace naturally varies with the rate of production and the rate of firing. In order to maintain the furnace at a predetermined pressure an atmosphere connection in the furnace is made through the conduit 76 to the pressure regulator 77 for carrying pressure impulses thereto. These impulses are relayed through the furnace pressure control device which opens a high pressure valve in lines 78 to open ports in the opposite ends of the fluid operator motor 46 for regulating the main damper 45 in the flue 38 leading to the stack. The furnace pressure regulation is supplemented by a suitable hand control, whereby the pressure to be automatically maintained may be predetermined and adjusted.

The fluid pressure controls may be supplied with fluid from the reservoir 79, which is connected to a source of fluid pressure.

The control system automatically maintains this continuous type furnace at a predetermined temperature and under proper pressure and atmosphere conditions. The location of the pyrometer 47 which registers the temperature of the gases, which bear a direct relationship to the steel temperature, is important and is made possible and practical for the first time in continuous furnace practice.

During normal mill operation the potentiometer temperature control 73 of the furnace control regulates the flow of air delivered to the furnace and the regulator 71 proportions the flow of fuel with the quantity of air being delivered to the furnace. The air and fuel lines are each provided with the Y connections 80 and 81, respectively, for conducting the air and fuel to one of two branch lines. One branch line connects with the main burners 31 for normal operation of the furnace. The other branch line connects with the burners 34 for operation during mill delays.

Each of these branch lines is controlled by a solenoid operated valve which preferably has a spring return action for closing the valve. This arrangement provides a safety feature in case of a power failure. The valves 82 and 83, in air and fuel branch lines respectively, control the lines

leading to the main burners at the rear of the furnace and are electrically energized through the common return wire 84 and the control wire 85. The valves 86 and 87, in the air and fuel branch lines respectively, control the lines leading to the mill delay burners at the front of the furnace and are electrically energized through the common return wire 84 and the control wire 88. These control wires are connected with the selection switch 90 which in turn is operated by the servo motor 63. The switch 90 is provided with electrical energy from any suitable source such as indicated by the wires 91.

The switch 90 selectively energizes either set of valves for controlling the normal operating main burners 31 or the mill delay burners 34. This selection is determined automatically by the temperature of the furnace. The furnace controls are adjusted to provide the proper firing conditions for the desired rate of reduction. With this adjustment normal operation of the furnace is automatically continued by moving the steel therethrough at the chosen predetermined rate of speed. If hot steel is not taken from the furnace at the normal rate, by feeding cold steel thereto, the furnace temperature will quickly rise. This rise in temperature is immediately registered by the pyrometers 47 in the potentiometer temperature control 73 which energizes the servo motor 63 to reduce the quantity of air delivered to the furnace. The reduction of air thus automatically reduces the quantity of fuel through the regulator 71 and the air fuel ratio control 74. As the quantity of heat energy delivered to the furnace is reduced, the furnace temperature falls to normal.

If no steel is taken from the furnace the temperature rises very fast and initiates the automatic operation just described. When the potentiometer control 73 reduces the quantity of air delivered to the furnace to a predetermined amount, such as 50%, then the servo motor 63 throws the switch 90, thereby selectively changing the firing from normal operation at the rear of the furnace to the mill delay burners 34 at the front of the furnace by deenergizing and closing the air and fuel valves 82 and 83 and energizing and opening the air and fuel valves 86 and 87.

The waste gases from the redirected flames of the mill delay burners 34 continue to control the temperature of the steel on the soaking hearth 30 and the automatic controls continue to function in the same manner. The fuel consumption during mill delays is naturally materially less than that required for normal furnace operation because the small amount of steel on the soaking hearth is all that is maintained at rolling temperature. Again this steel is not overheated and is always ready for use.

When mill operations are resumed, hot steel is discharged from the coaking hearth and cold steel is charged into the rear of the furnace, the gases discharged through the flues 25 become cooler because the furnace temperature drops due to increased absorption of heat by the cooler steel moved onto the soaking hearth and into the furnace. The pyrometer 47 then actuates the potentiometer temperature control 73 which in turn energizes the servo motor 63 for operating the damper 62 to increase the quantity of air delivered to the furnace. The air-fuel ratio regulator 71 and the control 74 are operated by the change in the quantity of air delivered to increase the quantity of fuel delivered to the furnace. When the quantity of air delivered to the furnace reaches

a predetermined amount the servo motor 63 actuates the selection switch 90 which deenergizes the valves 86 and 87, causing them to close and energize the valves 82 and 83, causing them to open and thereby transfer the firing from the front to the rear of the furnace. Thus the furnace has been restored to normal operation for continued mill production.

The selection switch 90, which controls the transfer of firing from normal operation to mill delay operation, may be designed to operate the transfer valves in the branch lines when 50% of the normal amount of air is delivered to the furnace as stated above. When the transfer is being made from mill delay operation to normal operation of the furnace this selection switch 90 may be made to operate when the quantity of air delivered to the furnace reaches 40%. 50% or 60% as desired. This adjustment is advantageous in the control system as different fuels and different characters of furnaces may require faster or slower pick up to return them to normal operation.

Again the transfer valves 82, 83, 86 and 87 may be arranged to proportion the quantity of air and fuel between the rear and front of the furnace, in which case the burners 31 and 34 will all be firing at the same time and a greater differential will be provided between the complete transfer of the firing from one end of the furnace to the other.

This automatic control system may be applied to furnaces of this type other than that disclosed herein. However it is particularly advantageous for use with these furnace structures.

If it be necessary to turn off the burners in the main heating chamber because the mill is shut down for roll change or repairs, the steel on the soaking hearth may thus be kept at rolling temperature automatically by means of this control system which mechanically transfers the firing operation from the main burners to the mill delay burners 34. When the mill is again ready for hot steel the furnace is prepared to deliver it immediately from the soaking hearth and the burners in the main furnace automatically resume operation in response to initiation of cold steel charging creating a fuel demand. This represents a material advance in the continuous furnace art.

The graph illustrated in Fig. 4 shows the temperature conditions throughout the continuous furnaces disclosed above. The upper curve F_1 represents the temperature of the furnace throughout its length when it is being used for low carbon steel. F_2 represents the temperature of the furnace when heating alloy or high carbon steels. The respective temperature of the low carbon and high carbon steels as they pass through the furnace under these conditions is represented by the curves S_1 and S_2. Obviously more low carbon steel may be heated under the particular conditions or safe controlled rates of temperature acceleration in the same furnace safely for the first time.

The temperature of an ordinary continuous type of furnace such as that found in the prior art is illustrated as curve F_3 in Fig. 4. In such continuous type furnaces the temperature within the main heating chamber is highest between the center of the chamber and a soaking chamber, whereas in this improved furnace with above disclosed method of firing the same, the highest temperature is adjacent the charging end of the main heating chamber and the temperature grad-

ually diminishes to the discharge end of the furnace, thereby providing a preferred state of thermal equilibrium, in that the gases, steel and furnace parts are substantially uniform across the furnace. In ordinary continuous type furnaces these temperature conditions are not attained.

Particular attention is directed to the fact that the burners **31**, which are the only source of heat supply during the normal operation of the furnace, are located at the rear of the furnace just above the opening through which the billets or the like are charged into the heating chamber **21**. The steel charged into the furnace is either cooled from being exposed during previous working steps or is cold because it is being initially heated. Thus the newly introduced steel is cold when it is introduced into the main heating chamber **21** and the heating flames issuing from the burners **31** provide the highest temperature at the charging end of the furnace. This results in the greatest heat absorption by the steel as it enters the heating chamber. As the steel moves to the front of the furnace the rate of heat absorption gradually decreases because the temperature of the burning gases flowing to the front of the furnace is decreasing and the steel slowly moving concurrently therewith is increasing in temperature. Thus the temperature differential between the gas and the steel becomes lower and the rate of heat absorption by the steel becomes correspondingly less.

Under selected firing conditions with the proper thermal load which determines the rate of production of a given furnace, the heat input is designed to bring the steel up to the desired temperature when it reaches the soaking hearth and the temperature of the gases passing over the steel moving along the soaking hearth is sufficient to supply the losses and maintain the steel at the desired temperature. Thus the heat absorption by the steel is complete before it passes over the soaking hearth and when on the soaking hearth the temperature of the steel becomes uniform throughout. The products of combustion delivered to the recuperators are thus higher than the products of combustion being discharged from a chamber of a furnace where the highest flame temperature is adjacent the front of the chamber, near or over the soaking hearth, and the products of combustion are discharged from the center or the rear of the chamber.

A solid hearth furnace is ordinarily employed for heating steel of irregular lengths and thickness. In some instances the steel may be too short to span the water-cooled skids in a continuous furnace wherein the top and bottom of the steel is heated at the same time. Again long slabs or billets that are only three and one-half inches or less in thickness cannot be heated in a continuous furnace having water-cooled skids for carrying the steel over an exposed lower combustion chamber because they will sag and become deformed.

The object is to provide a solid hearth continuous furnace in which steel of irregular lengths and thickness may be heated as well as heavy slabs and billets of the character that is normally heated from above and below when traveling on water-cooled skids. It is impractical to heat thick billets in a continuous furnace having a solid hearth because the underside of the hearth is open to the atmosphere and heat is continuously absorbed by the hearth from the steel, making the temperature of the bottom of the billet

resting on the hearth materially lower than that of the top of the billet. The minimum rolling temperature for soft steel is approximately 2150° F. and the temperature of a billet ten inches thick in a furnace atmosphere of approximately 2450° F. will be 2250° F. at the top and 1900° F. at the bottom, a differential of 350° F. Continued soaking will not permit the billet to have a uniform temperature because heat is being continuously conveyed from the billet by the solid hearth. The temperature of the surface of the solid hearth is approximately 1800° F. and the underside of the hearth being exposed to the atmosphere is approximately 300° F. Thus the differential in temperature of the hearth is approximately 1500° F. It is therefore impossible to raise the temperature of the underside of the billet to rolling temperature because these temperature differentials are excessive and it would require a furnace temperature that would be destructive to the upper surface of the steel to have rolling temperature at the bottom.

By the heating of the underside of the hearth as described above, the temperature differentials of the steel and the hearth are reduced materially, which permits this continuous furnace to be used for heating heavy slabs and billets, as well as irregular lengths and thickness. For example, the top of a billet seventeen inches thick moving through a furnace atmosphere of 2450° F. has a temperature of 2250° F. and the bottom has a temperature of approximately 2200° F., producing a temperature differential of 50° F. in the heavy billet. The whole of the billet is therefore above the required rolling temperature. The gases at the soaking hearth **30** are approximately 2450° F. and they are all discharged at the front end of the chamber **10** passing down the outlets **25** and through the passageways **23** along the underside of the hearth heating it for the full length thereof. The products of combustion from this furnace are discharged at a higher temperature than that of an ordinary solid hearth furnace since there are no heat losses through the hearth from the main heating chamber. The gases in passageways **23** and the recuperator chamber **22** are approximately the same as that discharged from the furnace chamber except for a small gradation normally expected. The temperature of the underside of the hearth is approximately 2400° F. and the heat actually flows up through the solid hearth supplying some heat to the bottom of the billet lying in full contact therewith. The surface of the solid hearth has a higher temperature than the underside of the billet because the heat flows from the hearth to the billets. The temperature of the hearth is believed to be approximately 2250° F. and the temperature differential of the hearth, from the underside to the top, is approximately 150° F. The billets must be kept in contact with the hearth to be heated thereby and to maintain a lower differential through the steel.

By heating the solid hearth in this manner the rate of production is increased one-third and the heat losses of the furnace are materially reduced, making the overall efficiency higher. These advantages actually make an inoperative furnace structure operative for thick heavy slabs and billets.

I claim:

1. The method of operating a continuous furnace having a continuous solid hearth over which billets and the like are moved for reheating which comprises the steps of moving the billets on the

hearth through the furnace chamber from the charging end to the discharge end, introducing heating flames at the charging end of the furnace chamber and causing all of the gases thereof to move concurrently with the billets to the discharge end of the furnace chamber, exhausting all of the products of combustion at the discharge end of the furnace chamber, regulating the flow of the heating planes to produce a gradation of temperature in the furnace chamber from the charging end to the discharge end thereof to thermally treat the billets, and heating the hearth to prevent absorption of heat from the billets and to maintain a low temperature gradient between the top and bottom of the billets.

2. The method of claim 1 in which the heating of the hearth is accomplished by directing the products of combustion to the underside thereof.

3. In a continuous furnace for heating billets and the like and having a continuous solid hearth over which the billets are caused to pass from the charging end to the discharge end, burners at the charging end of the furnace for introducing heating flames which travel in the same direction as the billets for heating the same, a portion of the continuous hearth providing a soaking hearth in the furnace over which the billets pass before they leave the furnace, and flues at the discharge end of the furnace for withdrawing all of the products of combustion of said flames over the billets on the soaking hearth and directing them to the under side of the hearth to heat the same.

4. A continuous furnace for heating billets and the like comprising a solid floor extending substantially the full length of the furnace and dividing the interior thereof into an upper and lower independent chambers, the upper surface of the floor providing a continuous hearth on which the billets are caused to move from the charging end to the discharge end of the furnace, a heat exchanger beneath the floor in the lower chamber and to which all of the products of combustion from the upper chamber are directed.

5. The structure of claim 4 which also includes burners for introducing heating flames into one end of said upper chamber, and means at the other end of the upper chamber for the passage of the products of combustion to the lower chamber.

6. In the structure of claim 4 which also includes burners for introducing heating flames at the charging end of the upper furnace chamber, and means at the discharge end of the furnace for conducting the products of combustion from the upper chamber to the lower chamber.

7. In the structure of claim 4 which also includes burners for introducing heating flames into the upper chamber, means at one end of the furnace for conducting the products of combustion from the upper chamber to the lower chamber, and flue means for drawing the products of combustion through the lower chamber for substantially the full length of the floor and through the heat exchange to discharge.

8. The method of operating a continuous furnace provided with a heating chamber having a continuous solid hearth extending from the charging end of the chamber to adjacent the discharge end of the same, which comprises moving the billets over the hearth, introducing heating gases at the charging end of the chamber and causing all of said gases to travel concurrently with the billets to the discharge end of the chamber, and withdrawing all of the heating gases from the chamber at the discharge end thereof, and regulating the flow of the heating gases to produce a uniform graduation of temperature in the furnace chamber from the charging end to the discharge end thereof.

9. The method of claim 8 which also includes the regulation of the flow of the gases over the billets to prevent the surface temperature of the billets from exceeding the body temperature thereof when discharged from the chamber.

10. The method of claim 8 which also includes the control of the temperature of the heating gases to regulate the rate of heat absorption of the billets as they traverse the chamber.

11. The method of operating a continuous furnace provided with a heating chamber having a continuous solid hearth extending from the charging end of the chamber to adjacent the discharge end of the same, which comprises moving the billets over the hearth, introducing heated gases at the charging end of the chamber and causing all of said gases to travel concurrently with the billets to the discharge end of the furnace, withdrawing all the heated gases at the discharge end of the furnace, and causing the gases discharged from the heating chamber to travel beneath the hearth and in contact with the under surface of the same toward the charging end of the furnace to prevent the hearth from absorbing heat from the billets and thus maintain a low temperature differential between the top and bottom of the billets.

12. In a continuous furnace for heating billets and the like, the combination of a chamber defined by side and end walls, a roof and a continuous solid hearth extending from the charging end of the chamber to adjacent the discharge end of the same and along which the billets are caused to travel from the charging end of the chamber to the discharge end of the same, means for introducing heating gases at the charging end of the chamber to travel therein toward the discharge end concurrently with the billets, and means for withdrawing all the heating gases at the discharge end of the chamber.

13. In a continuous furnace for heating billets and the like, the combination of a chamber defined by side and end walls, a roof and a continuous solid hearth extending from the charging end of the chamber to adjacent the discharge end of the same and along which the billets are caused to travel from the charging end of the chamber to the discharging end of the same, means for introducing heating gases at the charging end of the chamber to travel therein toward the discharge end concurrently with the billets, means for withdrawing all the heating gases at the discharge end of the chamber, and means for returning all the heating gases toward the charging end of the furnace in contact with the under surface of the hearth to heat the latter and maintain a low temperature differential between the top and bottom of the billets.

14. In a continuous furnace for heating billets and the like, the combination of a chamber defined by side and end walls, a roof and a continuous solid hearth extending from the charging end of the chamber to adjacent the discharge end of the same and along which the billets are caused to travel, means for introducing heating gases at the charging end of the chamber to travel therein concurrently with the billets, means for withdrawing all the heating gases at the discharge end of the chamber, a passage beneath the hearth

extending from the discharge end of the furnace and communicating with the discharge end of the chamber to receive the gases from the latter, a heat-exchanger to which the passage conducts said gases, the hearth forming the roof of the heat-exchanger to maintain a low temperature differential between the top and bottom of the billets, and means for exhausting the spent gases from the heat-exchanger.

15. The method of operating a continous furnace having a continuous solid hearth in the furnace for heating billets and the like which consists in the steps of moving the billets through the furnace chamber from the charging end to the discharge end, introducing heating flames at the charging end of the furnace chamber and causing all of the gases thereof to move concurrently with the billets over the hearth to the discharge end of the furnace chamber, exhausting all of the products of combustion at the discharge end of the furnace chamber, regulating the flow of the heating gases to produce a uniform gradation of the temperature in the furnace chamber from the charging end to the discharge end

thereof, and directing the discharge products of combustion to the underside of the hearth to maintain a low temperature differential and reduce heat absorption from the billets and the gases in the furnace chamber.

WILLIAM A. MORTON.

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