Sept. 14, 1943. W. A. MORTON 2,329,211

CONTINUOUS HEATING FURNACE AND METHOD OF OPERATING THE SAME

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Fig. 1.

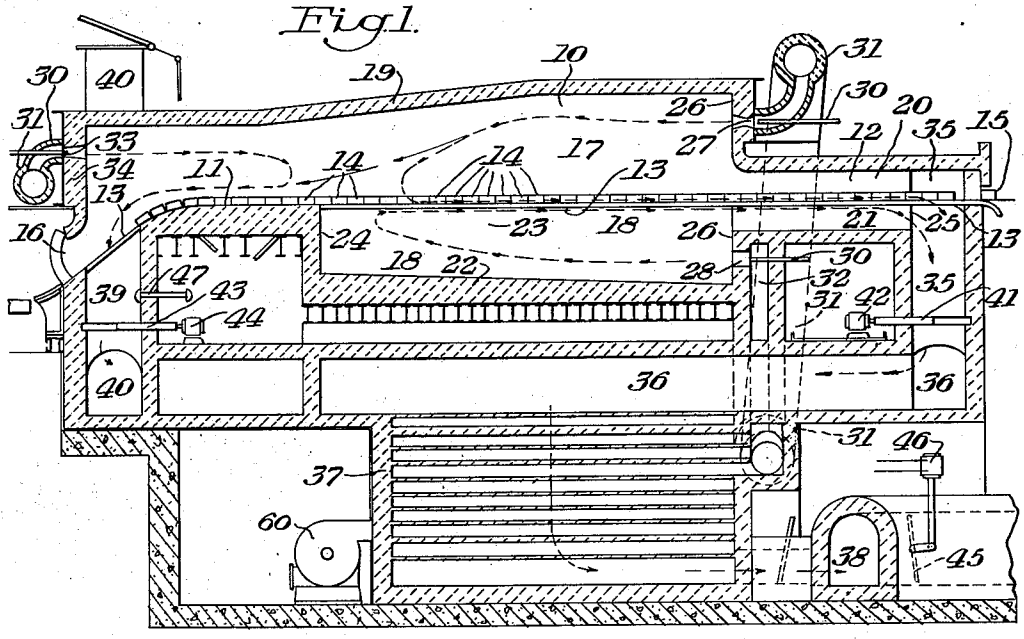
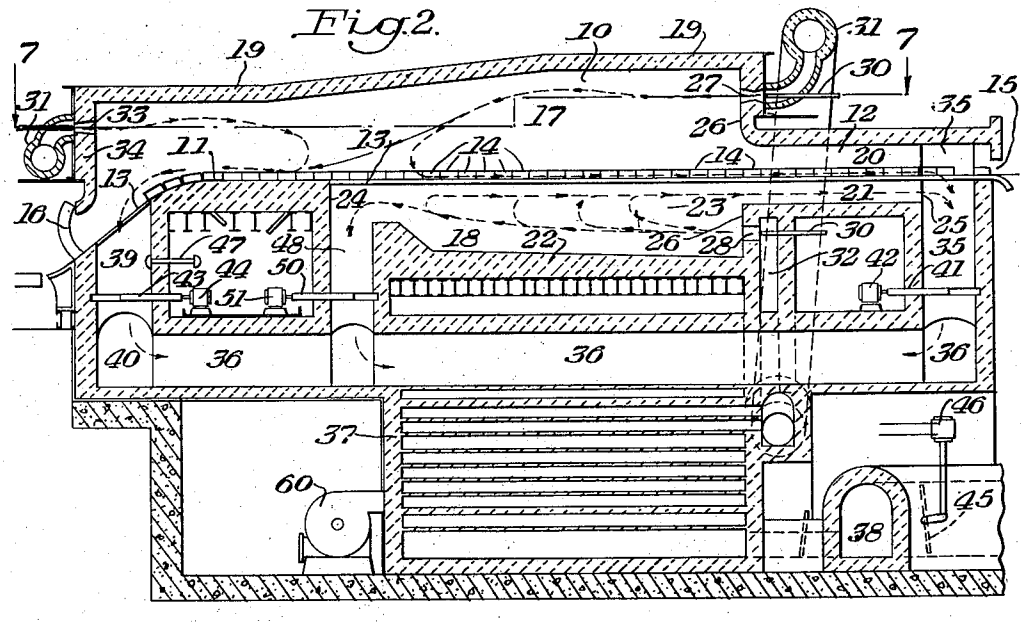


Fig. 2.



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CONTINUOUS HEATING FURNACE AND METHOD OF OPERATING THE SAME

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Fig. 3.

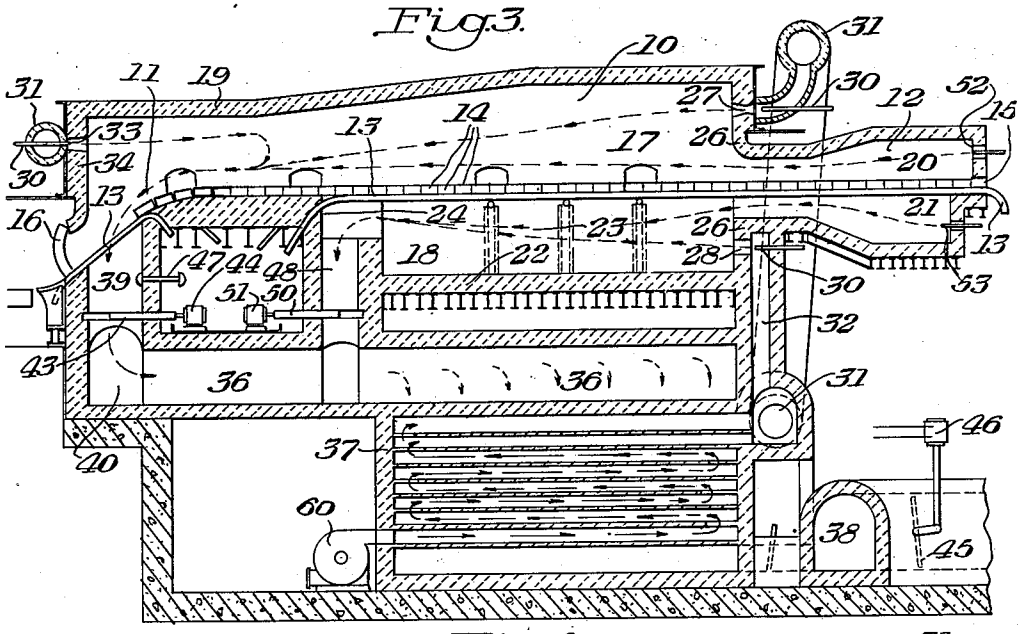
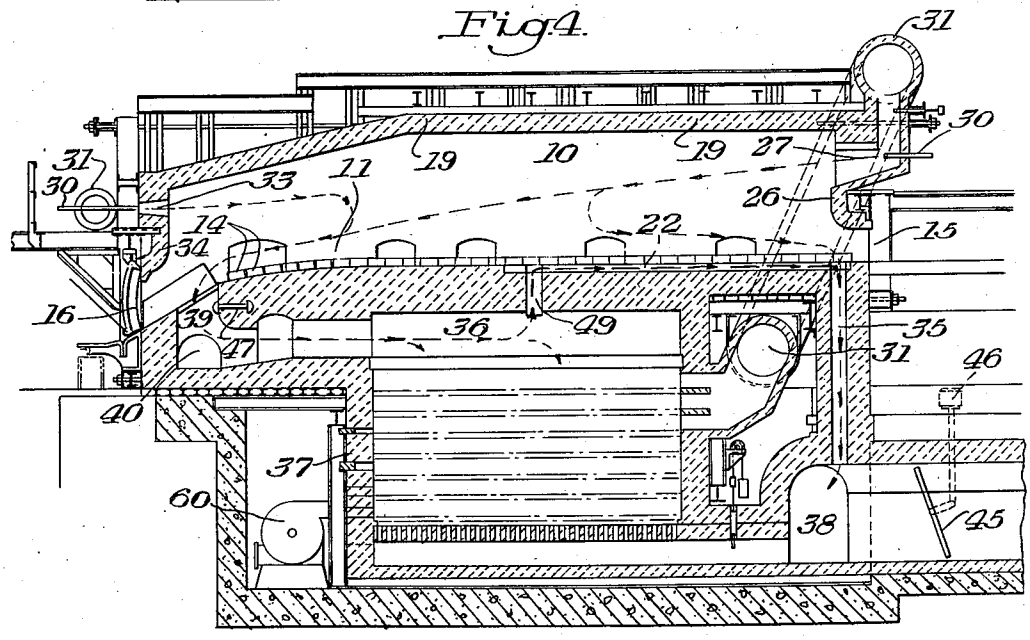


Fig. 4.



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CONTINUOUS HEATING FURNACE AND METHOD OF OPERATING THE SAME

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Fig. 5.

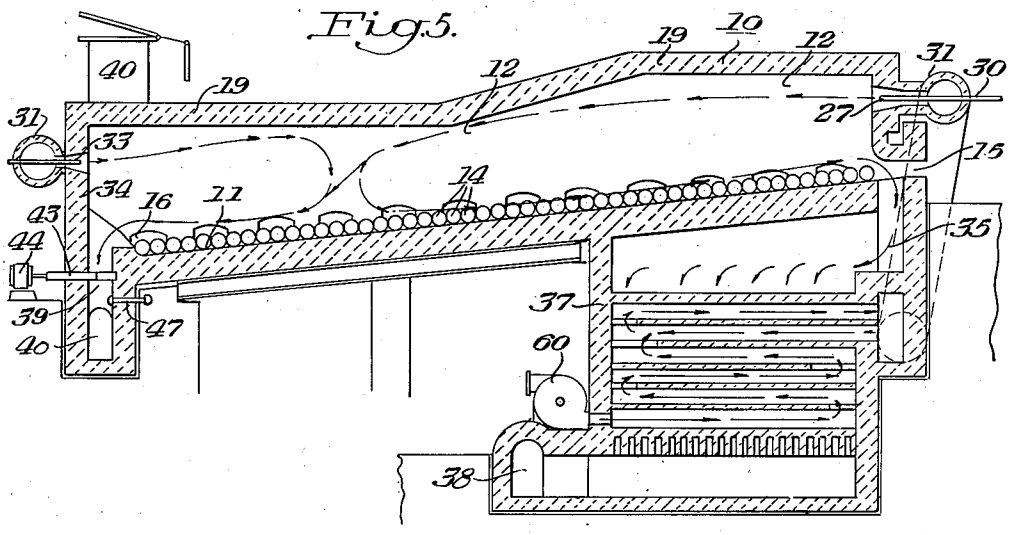
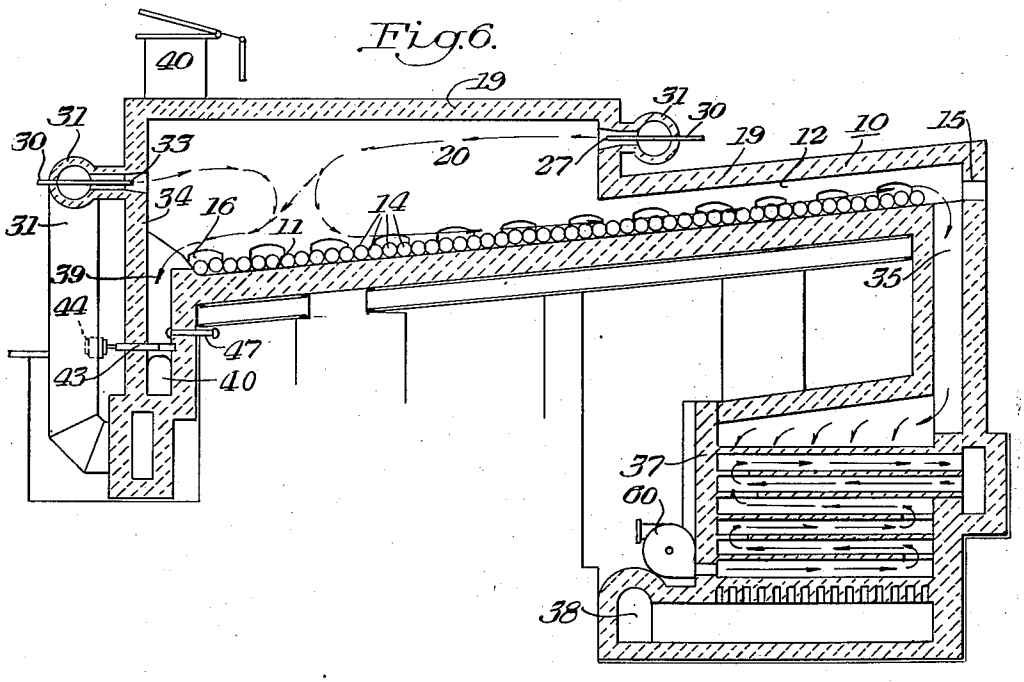


Fig. 6.



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CONTINUOUS HEATING FURNACE AND METHOD OF OPERATING THE SAME

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Fig. 7.

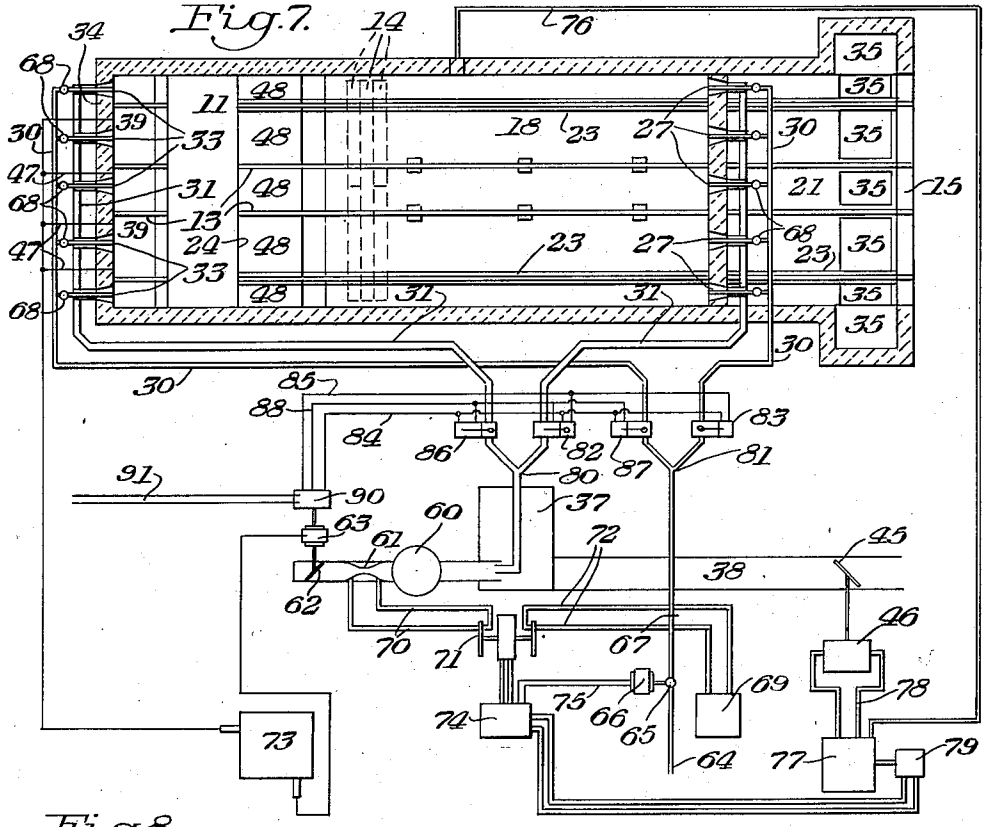
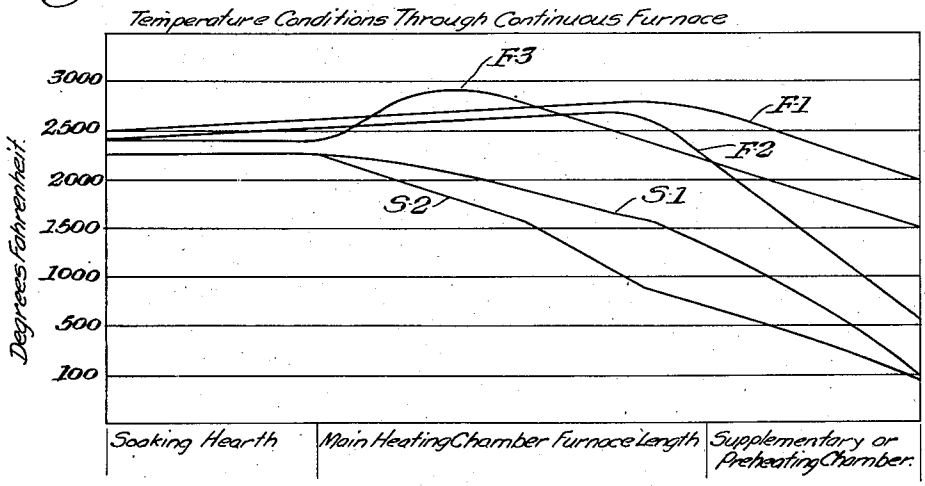


Fig. 8.



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Patented Sept. 14, 1943

2,329,211

UNITED STATES PATENT OFFICE

2,329,211

CONTINUOUS HEATING FURNACE AND METHOD OF OPERATING THE SAME

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Application May 31, 1940, Serial No. 337,987

49 Claims. (Cl. 263—2)

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

In the steel industry a continuous type heating furnace is employed for heating billets, ingots, blooms, slabs, rails and the like, to a predetermined temperature, preparatory to rolling or performing other operations thereon.

This type of furnace may be made up of two chambers, namely a heating chamber and the extension or preheating chamber.

The furnace chamber generally extends to the charging end of the furnace for the waste gases which preheat the steel. This preheating operation is a direct function of the rate of firing in the main heating chamber and it is not independent thereof and can therefore not be controlled.

The material to be heated continuously passes from the charging end of the furnace, then through the preheating chamber, then through the heating chamber, and across the soaking chamber, by which time it is uniformly heated and discharged from the other end of the furnace.

It has been customary to fire this character of furnace by direct radiation from the flames adjacent the articles at one or more positions throughout the furnace, but it is impractical to control the atmosphere with this method of firing. High carbon and alloy steels are principally affected and decarburization takes place.

Variations in furnace temperature and undesirable furnace atmosphere conditions tend to break the original scale of oxidation from the surface of the material and an undesirable tight thin secondary scale forms thereon. Conditions of this character in heating create surface defects in the steel when worked. Again heating by direct radiation from flames adjacent the steel produces streaked heating in the steel which is detrimental when rolling.

In one direct radiation type heating furnace the flames are produced from burners adjacent the discharge end (Patents 1,789,966; 1,912,933, and 1,944,729) and flow over the steel in the opposite direction of its travel for the full length of the furnace. The hottest portion of the flames are adjacent the soaking hearth and the cool gases are discharged adjacent the steel charging end. With this type of furnace it is difficult to maintain the desired temperature of the steel before it is discharged and also virtually impossible to vary the rate of production and maintain the desired critical final steel temperature. This obviously creates the tendency of over-heating the steel. This is especially true if there is any interruption or change of the speed of travel of the steel moving through the furnace. The rate of heat exchange at the charging end of the furnace is low and is dependent upon the fixed or permissible rate of firing the heating chamber. In view of the fact that the hottest flame is adjacent the discharge end it is impossible to employ more than 50% of the available preheated air from the high temperature waste heat gases and thus the furnace operation is inefficient. Each of these factors interferes with the heating of the steel and especially high carbon and alloy steels.

When the burners delivering a direct radiation type heating flame are placed adjacent both the discharging and the charging end of the furnace (Patents 1,476,142; 2,133,673, and 2,157,221) and the waste gases are roved adjacent the center of the furnace chamber, the efficiency is increased somewhat by reason of the fact that there is a greater heat exchange at the charging end than in the type of furnace referred to above. However it is impossible to control the furnace atmosphere in the preferred manner. The discharge end of this type of furnace is heated by direct radiation, making it difficult to control and equalize the temperature across the steel when it is discharged, resulting in local overheating and producing some of the difficulties as described above.

In both of these methods of heating by a direct radiating flame, cold air is drawn into the furnace at the discharge end. This air chills the steel causing the heavy original scale to contract and break away and produce an undesirable condition.

A third type of furnace, which employs a direct radiating heating flame, introduces the flame at the charging end of the furnace and the gases flow to the opposite end (Patent 1,530,239). This type of furnace avoids some of the above mentioned difficulties but it is not equipped with a soaking hearth and it is impossible to control the furnace atmosphere or to separately control the critical temperature of the steel when discharged.

The burner of another type of furnace is positioned so that the flame directly impinges the steel at an angle and is divided, the smaller portion traveling with the steel across the soaking hearth and the larger portion traveling against

the movement of the steel to the charging end. (Patent 2,056,904.) Since the gases are withdrawn from the furnace at both ends, the atmosphere of the furnace may be controlled to some degree. However the direct impingement of the flame on the steel limits the firing temperature and streaked heating is pronounced. All of the other disadvantages mentioned above are also present to a degree.

The principal object of this invention is the provision of an improved character of furnace and the method of operating the same to overcome these objectionable features and characteristics.

Another object is the provision of a method for uniformly heating the steel by diffused radiation firing.

Another object is the provision for local regulation of the temperature of the steel on the soaking hearth independently of the principal firing of the heating chamber. This method of operation maintains the steel on the soaking hearth at its proper rolling temperature while the fuel supplied to the heating chamber is varied or completely shut off. This is exceptionally advantageous during periods in which the mill is shut down temporarily for repairs or changes of mill rolls.

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

Another object is to provide for an automatic control system which regulates the temperature and furnace atmosphere conditions during normal operation, and during mill delays or reduced rates of production automatically stops the firing of the principal burners for the heating chamber and transfers the fuel to the auxiliary burners for holding the steel on the soaking hearth at rolling temperature during such delays, at any selected rate of firing.

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

Another object is to provide a supplementary chamber for preheating sensitive high carbon and alloy steels at a predetermined rate prior to their entry into the main heating temperature.

Another object is to pass the steel through a furnace in which the atmosphere adjacent the steel is a non-oxidizing atmosphere, differing from the normal uncombined combustibles.

Another object is the provision for an improved character of firing flame which enables control of the furnace atmosphere and the use of a higher than normal percentage of the waste heat recovery and which also enables one to vary the position of the maximum thermal input within the furnace.

Another object is to combine the flow of all the gases of combustion as they pass over the steel on the soaking hearth to obtain a diffusion of the total heat of the flames, to thereby equalize the temperature along the steel.

Another object is the provision for introducing and withdrawing the heating medium at the same end of the furnace.

Another object is the provision for introducing and withdrawing the heating medium at both ends of the furnace.

Another object is the provision of means for controlling the percentage of input and withdrawal of the heating medium adjacent each end of the furnace.

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

The accompanying drawings disclose a practical embodiment illustrating the principles of this invention wherein:

Fig. 1 is a sectional view taken longitudinally of a furnace fired with three redirected flames.

Fig. 2 is a sectional view taken longitudinally of a furnace fired with three flames, two of which are redirected.

Fig. 3 is a sectional view taken longitudinally of a furnace fired with three principal flames, wherein only the soaking chamber flame is redirected and two independent flames are provided for preheating.

Fig. 4 is a sectional view taken longitudinally of a furnace fired with two flames, the flame supplying heat to the soaking chamber being redirected.

Fig. 5 is a sectional view taken longitudinally of the furnace having a sloping hearth and fired with opposed redirected flames, the main furnace chamber flame normally supplying approximately 90% of the heat delivered to the furnace.

Fig. 6 is a sectional view of a furnace having a sloping hearth similar to that shown in Fig. 5 and which is provided with a preheating chamber.

Fig. 7 is a diagrammatic view illustrating the circuits for automatically controlling the temperature of the air and fuel delivered to a furnace such as that illustrated in the previous figures, and the furnace pressure control for the same. The outline of the furnace used to illustrate these controls is taken on the line 7—7 of Fig. 2.

Fig. 8 is a graph illustrating the temperature characteristics of the furnace disclosed herein which includes the preheated air delivered to the furnace, the furnace temperature, and the temperature of the steel as it passes therethrough.

Referring to Fig. 1, the furnace illustrated therein comprises three principal elements, the main heating chamber 10, the soaking hearth 11 in one end of the main heating chamber, and the preheating chamber 12. Water cooled skids 13 extend through the preheating and heating chambers for supporting the material 14 to be heated which is charged through the opening 15 and is shoved in the usual manner, through the preheating chamber, the heating chamber and over the soaking hearth, from whence it is discharged through the opening 16. The soaking hearth 11 is a solid hearth. The openings 15 and 16 are closed with suitable doors.

The main heating chamber 10 is divided by the steel charge 14 into upper and lower independent chambers 17 and 18. The chamber 17 above the steel is formed by the enclosing roof structure 19. The height of these chambers may be determined by the formula governing the expansion of gases from 60° F. to 2500° F. with the assumption that the average furnace temperature will reach the latter amount, and thus by employing the proper firing rate, the furnace pressure is maintained constant.

The roof structure above the soaking hearth 11 may also be determined in the same manner.

The preheating chamber 12 is likewise divided by the steel charge 14 into the upper and lower

independent chambers 20 and 21. Each of these chambers connect with the independent chambers 17 and 18 of the main heating chamber and thus form continuous upper and lower independent chambers in these two sections of the furnace.

The lower chamber 18 is below the plane of the hearth and is enclosed by the sub-floor 22 and the continuous outside walls 23, which carry the outer skids 13, and which extend from the intermediate transverse wall 24 adjacent the soaking hearth 11 to the charging end of the preheating chamber 12 as indicated at 25.

The rear wall 26 of the furnace, through which the preheating chamber 12 opens, is provided with two rows of burners 27 and 28 for firing the chambers 17 and 18 respectively. The burners are supplied with fuel transmitted through the conduits 30 and with preheated air transmitted through the conduits 31 and 32. Burners are provided between the walls 23 and the side walls of the furnace as shown in Fig. 7. However a portion of the flames of these burners may pass upwardly over the ends of the steel to the chamber 17.

The soaking hearth 11 is locally heated as desired by a flame issuing from the row of burners 33 in the front wall 34 of the furnace. Ordinarily these burners are operated only during mill delays, during which time the preheated air and fuel are transferred from the burners 27 and 28 to the burners 33 which are described below in relation with the furnace control and operation.

It will be noted that each of the burners 27, 28 and 33 are substantially horizontally disposed and that they are spaced further from the plane of the hearth than they are from the roof or the floor. The reason for this arrangement is to provide a flame that travels outwardly in a path substantially parallel with the steel until its velocity is reduced to such an extent that the draft, which is induced in the vicinity of each burner, redirects the path of movement of the products of combustion. Combustion is substantially complete in each flame before it is redirected by the draft forces and the hottest part of the flame does not impinge directly on the steel. Thus the products of combustion of each flame blanket the steel on its return path of movement to the flues. In this manner the atmosphere surrounding the steel may be controlled to prevent local overheating, excess oxidation and decarburization of the steel.

The hottest portion of the flame is along the initial path of projection. Thus the steel is heated by radiation from this portion of the flame and by convection from the products of combustion passing back over the steel. The radiant heat energy reflected from the roof and directly effective from the flame must pass through the products of combustion flowing back over the steel. The radiant heat energy is thus diffused as it passes through the products of combustion, thereby uniformly heating the steel laterally across the furnace, and the detrimental effects of direct heating from initial flame combustion are eliminated. Again the efficiency of the heat exchange is increased by the extension of the flame length and the location of the area of the highest rate of heating may be accurately controlled.

This method of heating utilizes direct radiation and in addition direct convection in combination to accelerate the normal heating rate and at the same time facilitates equalization of heating across a furnace heated by a series of transverse burners. The change in direction of motion of the heating gases tends to diffuse them by turbulence and eliminates any variation of the several gaseous streams after they are united by the return movement.

During normal operation of the furnace a portion of the products of combustion from the flames issuing from the burners 27 divides from the main body of the gases and travels over the steel on the soaking hearth 11 and is discharged at the front of the furnace. The paths of the gases are indicated in each of the views by dotted lines.

Flues 35 are positioned just inside the charging opening 15 for drawing off the main portion of the products of combustion from the upper chambers 17 and all of the products of combustion from the lower chamber 18. These waste gases are selectively drawn through the independent upper and lower chambers 20 and 21 of the preheating chamber 12 in their travel to the flues 35 and thus regulably preheat the steel to any desired temperature for delivery into the heating chamber. If this chamber were not added at the rear of the furnace the gases would pass directly from the chambers 17 and 18 to the vertical flues 35 which direct them through the horizontal flue 36, the recuperator 37 or other heat absorbing device, to the main flue 38, from whence they are ordinarily directed to a stack. If desired the gases may be carried directly to the stack and the air preheater omitted.

That portion of the products of combustion from the burner 27 which flows over the steel on the soaking hearth 11 is drawn down past the steel discharge opening 16 into the flues 39 where they may be discharged directly to the short, damper controlled auxiliary stack 40.

During mill delays when the firing is instantaneously switched from the burners 27 and 28 at the rear of the furnace to the burners 33 at the front of the furnace the flames project over the soaking hearth and when their velocity is diminished the products of combustion are redirected back over the steel, as described above, and are discharged down past the steel discharge opening 16 through the flues 39 to the stack 40 as described above.

The flues 35 and 39, which direct the gases from the plane of the hearth, may in each case be a single flue or may comprise a plurality of smaller flues, depending upon the character of the furnace structure. In the latter case they usually open into a single connecting flue 36 at their lower ends.

The flues or outlets are thus positioned in the vicinity of the burners and the gases discharged from the furnace chambers pass both the charging and discharging openings 15 and 16, thus carrying away any cold air that may filter into the furnace and preventing its access to the hot steel on the hearth even when the doors are open.

The steel is thus protected from cold air and is blanketed by the products of combustion. This avoids surface temperature variations which would tend to break the original scale of oxidation from the surface of the steel and thereby avoids the formation of the thin tight secondary scale which is highly objectionable. The removal of the heavy scale deposited on the hearth, which would necessitate shutting down the furnace is also avoided.

This character of flame provides uniform heating of the steel and permits accurate control of the heating cycle.

The flue 35 may be controlled by the damper 41 which in turn may be operated by the servomotor 42. The flue 39 is likewise controlled by the damper 43 operated by the servomotor 44. The main flue 38 which leads to the stack is controlled by the damper 45 operated by the servomotor 46.

The rate of preheating the steel may be controlled by damper 41 to regulate the quantity of waste heat leaving the charging end of the furnace.

A pyrometer 47 is placed in the flue 39 for registering the temperature of the gases flowing off the steel in the soaking hearth.

In Fig. 2 a greater portion of the gases passing from the lower independent heating chamber 18 are carried off by the flue 48 in the center of the furnace, which is controlled by the damper 50 operated by the servomotor 51, to the horizontal flue 36. The balance of the products of combustion of the flame issuing from the burner 28 passes back along the steel through the lower preheating chamber 21 and is discharged out the flues 35, thus forming a thinner layer of waste gas which prevents the flames from coming directly in contact with the steel.

The preheating chamber 12 in Fig. 2 is much the same as in Fig. 1.

The flues 39 carrying the gases over the soaking hearth 11 are connected with the horizontal flue 36. In order to prevent uncontrolled migration of the gases, which might upset the firing conditions therein, the dampers may be regulated to produce a draft of .04 inch of water in the flues 35 and 48 and a draft of .06 inch of water in the flue 39.

In Fig. 3 the independent chambers 20 and 21 of the preheating chamber 12 are fired directly by the upper and lower rows of burners 52 and 53, respectively, which control the rate at which it is desired to preheat the steel prior to delivery in the main heating chamber. The products of combustion from the flames of these burners pass into the main heating chambers 17 and 18, because combustion is substantially complete when these flames pass into the main heating chambers and their products of combustion blanket the steel from initial flames of combustion in chambers 17 and 18 to produce substantially the same effect as that obtainable with the structure illustrated in Fig. 1.

The hottest part of the flames issuing from the main burners 27 and 28 is thus prevented from heating the steel by direct radiation. The preheated steel is thus subjected to diffused radiant heat energy from the furnace surfaces and the flames in both the upper and lower chambers. When combustion of the flames from the burners 27 and 28 is substantially complete the products of combustion from both the preheating burners and the main burners combine and equalize in temperature as they continue to blanket the steel with an inert atmosphere of uniform temperature until it is discharged.

In the case of the structure illustrated in Fig. 3 any cold air that may filter into the furnace through the charging opening 15 aids in supporting the combustion of the preheating flames and the free oxygen is substantially all consumed before the gases pass out of the preheating chamber. Thus the infiltration of the cold air does not have an opportunity to injure the heated steel which is not at a critical temperature adjacent the point of entry and such air is usable in this design of furnace.

The hot gases of combustion from the lower preheating chamber 21 form a protective layer between the steel and flames from the burners 28 in the chamber 18. The products of combustion of the flames issuing from the burners 28 mix with the products of combustion from the preheating chamber 21 and pass down flues 48 out of the chamber 18. Gases from the chamber 17 travel along, blanketing the steel over the soaking hearth and finally pass down outlets 39. All flues or outlets are provided with independent damper control as described above and are further subject to common damper regulation by furnace pressure control.

The heat delivered to the soaking hearth from the redirected flames of the burners 33 is preferably applied only during mill delay or interruption of normal operation. At the time of interruption the heat will be automatically turned on by means of the control system which is herein described. The burners 33 may or may not be used at any time, depending upon the changing conditions within the furnace, but these burners are always subject to independent automatic control when desired.

As previously described the radiant heat of the flames from the burners 33 must pass through the previously produced blanketing gases to the steel and as the forward velocity of the flame diminishes the flame is returned by draft in the flue 39 and the gases therefrom mingle with the other products of combustion and travel down past the discharge opening 16 through the flue 39, the horizontal flue 36, to the recuperator.

The furnace illustrated in Fig 4 is not provided with a preheating chamber 12 nor a lower heating chamber 18. However the burners 27 and 33 function in the same manner as that just described in connection with Fig. 3. This view illustrates some of the details of an actual furnace structure of the charging and fired type, whereas the previous views are relatively diagrammatic.

A portion of the gases flowing through the horizontal flue 36 are drawn up the passageway 49 through the floor 22 and pass over the ends of the steel into chamber 10 to form a blanketing protection through which the radiant heat from the flame issuing from the burners 27 must pass to heat the steel. These gases are drawn off at the rear of the furnace through the flues 35 which in this instance pass directly to the stack 38. Thus the same effect is produced in this furnace as that described in relation to the previous furnaces.

In Figs. 5 and 6 a sloping hearth is provided for receiving cylindrically shaped articles 14 wich are to be heated. These articles are charged through the rear opening 15 and are progressively rolled down the hearth manually. Entrance to the furnace chamber is gained through the doors along the side walls. The steel is discharged laterally through the opening 16 in the side wall of the furnace.

In Fig. 5 the burner 27 supplies the heating chamber 10 in the same manner as that described with reference to Fig. 1. The characteristics of the flame are such that it travels into the furnace chamber for a considerable distance and the greater portion flows back up over the

steel and is discharged through the flues **35** while the remaining portion flows over the soaking hearth **11** and out the flues **39** to the auxiliary stack **40**. The roof **19** being substantially horizontal is economical to construct and because of the sloping hearth the heating chamber **10** progressively increases in volume towards the front of the furnace. The roof over the lower end of the hearth **11** is also horizontal and the connecting roof, which slopes from one roof level to the other, restricts the inner end of the heating chamber **10**. The slope of the connecting roof thus aids in redirecting the flame from the burner **27** by the restriction. The blanketing gases traveling back up over the steel are discharged downwardly through the flue **35** to the recuperator **37**.

The slope of the hearth enlarges the volume of the chamber over the soaking hearth **11** toward the front of the furnace, thus aiding in redirecting the flame from the burner **33** during mill delays, and causing the burned gases to travel down over the steel on the hearth and thus blanket it from direct radiation. These gases are discharged through the flue **39** to the auxiliary stack **40**.

The quantity of gas passed out the stack **40**, during normal operations when the burners **33** are shut down, will be merely sufficient to provide a measure of the final heated temperature of the steel prior to discharge which has not been provided for in this manner for this or any other purpose in this type of furnace.

In the furnace illustrated in Fig. 5 the gases are preferably distributed so that 90% pass out the flues **35** and 10% pass out the flues **39**. The same proportions are also preferable for the furnace illustrated in Fig. 6. The roof of the furnace shown in Fig. 6 is desired to provide the largest chamber for approximately 60% of the furnace length at the front of the furnace and the smallest chamber for approximately 40% of the furnace for the smallest chamber which in this instance is the preheating chamber **12**. In each instance the recuperator **37** is connected to the outlets of the chamber containing the largest firing proportion, which in Fig. 6 is the preheating chamber **12** and is connected through the flue **39** to the recuperator in the same manner as that described in relation to Figs. 1 and 2.

In both of these structures the steel is protected by the blanketing layer of products of combustion and any infiltration of cold air at the charging or discharging openings is carried along with waste heat gases and cannot produce any detrimental effect on the steel.

Fig. 7 is a diagrammatic view showing the automatic control circuits for operating any one of the above described furnaces. The furnace outlined is shown as a plan view of the hearth shown in the furnace of Fig. 2 which is representative of each of the furnace structures comprising this invention. Independent preheating burners **52** and **53** are employed only in the furnace shown in Fig. 3. These preheating burners for all practical purposes may be fed by branch lines from the main burners and therefore may be considered auxiliary to the main burners **27** and **28** insofar as the controls are concerned. It may or may not be desirable to provide the preheating burners with preheated air and to avoid perplexity they are not illustrated in Fig. 7.

60 represents the blower for delivering air to the recuperator **37** where it is preheated and directed to the burners **27** and **28** or to the burners **33**. 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 **27** and **28** or to the burners **33**. 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 **39** has a direct relation to the temperature of the steel on the soaking hearth which the gases have just passed over, whether these gases are coming from the main burners **27** during normal operation or from the burners **33** 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 **27** and **28**, and the preheating burners, if any, for normal operation of the furnace. The other branch line connects with the burners **33** 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 **27** and **28** or the mill delay burners **33**. 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 **33** 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 **33** continue to control the temperature of the steel on the soaking hearth **11** 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 soaking hearth and cold steel is charged into the rear of the furnace, the gases discharged through the flues **39** 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 **27, 28** and **33** 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 preheating and main heating chambers 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 **33**. 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 and the preheating chamber 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. 8 shows the temperature conditions throughout the continuous furnaces disclosed above. The upper curve **F1** represents the temperature of the furnace throughout its length when it is being used for low carbon steel. **F2** 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 **S1** and **S2**. Obviously more low carbon steel may be heated, but high 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 **F3** in Fig. 8. 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 gradually 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.

If the preheating chamber be eliminated these curves start at the charging end of the heating chamber but they assume substantially the same character as that illustrated. If the preheating chamber and the main heating chamber are shut down because of the interruption of mill operations the furnace remains closed and the steel ceases to move therethrough. The temperature of these chambers and the steel therein slowly lowers while the temperature of the steel in the soaking chamber is maintained at the proper amount. After many hours under these conditions there is a uniform gradation in the steel temperature from the inlet end of the soaking chamber to the charging door **15**.

The supplementary preheating chamber may or may not be used, depending upon the type of steel or rate of production desired. It is obvious however that when a high rate of production is desired from low carbon steels, the supplementary chamber may be operated at a very high temperature, thereby increasing the temperature of the steel prior to its entry into the main heating chamber. In the case of special steels requiring a controlled preheating cycle, the rate of temperature rise in the steel may be controlled independently of the rate of firing in the heating zone. The prior art does not disclose furnaces which have this function. In Patent No. 2,157,221, of which the present inventor is a co-patentee, the center outlet prevents the gases of the preliminary burner from protecting the steel and also prevents regulation of the bottom heating chamber independently of the top chamber. I prefer to use a substantial portion of the heating cycle for preheating but generally this will be less than half or the furnace investment will be improperly distributed.

I claim:

1. The method of heating billets and the like in a continuous furnace which comprises causing heating flames which produce radiant heat energy to travel from both ends of the furnace and toward each other in lines substantially parallel to the path of the billets, interposing between the billets and the heating flames a blanketing layer of non-oxidizing gases through which the radiant heat energy passes to heat the billets and withdrawing the non-oxidizing gases after they have passed over the billets about to be discharged.

2. The method of heating billets and the like in a continuous furnace which comprises causing heating flames to travel from both ends of the furnace and toward each other in lines substantially parallel to the path of the billets, interposing between the billets and the heating flames a blanketing layer of non-oxidizing products of combustion through which the radiant heat energy of the flames passes to heat the billets and withdrawing the non-oxidizing gases after they have passed over the billets about to be discharged.

3. The method of heating billets and the like in a continuous furnace which comprises causing heating flames to travel from both ends of the furnace and toward each other in lines substantially parallel to the path of the billets, interposing between the billets and the heating flames a blanketing layer of non-oxidizing products of combustion originating from the heating flames and withdrawing the non-oxidizing gases after they have passed over the billets about to be discharged.

4. The method of heating billets and the like in a continuous furnace which comprises causing heating flames to travel in lines substantially parallel to the path of the billets and above and below the same, and interposing between the billets and the heating flames blanketing layers of non-oxidizing products of combustion originating from the heating flames.

5. The method of heating billets and the like in a continuous furnace which comprises causing heating flames to travel from both ends of the furnace and toward each other in lines substantially parallel to the path of the billets and redirecting the non-oxidizing products of combustion of the flames from the discharge end to

travel between the billets and the heating flames to provide a blanket through which the radiant heat energy of the heating flames travels to heat the billets.

6. The method of heating billets and the like in a continuous furnace which comprises causing heating flames to travel in lines substantially parallel to the path of the billets and above and below the same and redirecting the non-oxidizing products of combustion from said flames to travel between the billets and the heating flames to provide blankets above and below the billets through which the radiant heat energy of the heating flames travels to heat the billets.

7. The method of firing a continuous furnace for heating billets and the like which comprises causing heating flames which produce radiant heat energy to travel in the direction of the travel of the billets in the furnace, dividing the non-oxidizing products of combustion from the heating flames and controlling the division of the products to cause a portion of the products to travel with the billets and in contact therewith toward the discharge end of the furnace to blanket the same and redirecting another portion to travel in the reverse direction between the parent flames and the billets to form a blanket through which the radiant heat of the flames passes to heat the billets by regulating the withdrawal of the products from both ends of the furnace.

8. The method of firing a continuous furnace for heating billets and the like which comprises causing heating flames to travel above and below the billets in the direction of their travel in the furnace, dividing the non-oxidizing products of combustion from the heating flames and causing portions of the products to travel with the billets and redirecting other portions to travel in the reverse direction between the parent flames of the billets to form blankets above and below the billets through which the radiant heat of the flames passes to heat the billets.

9. The methods of firing a continuous furnace for heating billets and the like which comprises causing heating flames to travel with the billets to preheat the same before their entry into the heating chamber of the furnace, causing other heating flames to travel with the billets as they travel in the heating chamber while interposing the non-oxidizing products of combustion of the preheating flames between the second mentioned flames and the billets to provide a blanket through which the radiant heat energy passes from the second mentioned flames to heat the billets.

10. The method of firing a continuous furnace for heating billets and the like which comprises causing heating flames to travel with the billets above and below the same to preheat the billets before their entry into the heating chamber of the furnace, causing other heating flames to travel with the billets both above and below the same as they travel in the heating chamber while interposing the non-oxidizing products of combustion of the preheating flames between the second mentioned flames and the billets to provide a blanket through which the radiant heat energy passes from the second mentioned flames to heat the billets.

11. The method of firing a continuous furnace for heating billets and the like which comprises causing heating flames to travel in the direction of the travel of the billets in the furnace, dividing the non-oxidizing products of combustion from the heating flames and causing a portion of the products to travel with the billets and in contact therewith toward the discharge end of the furnace and redirecting another portion to travel in the reverse direction between the parent flames and the billets to form a blanket through which the radiant heat of the flames passes to heat the billets, causing additional flames to travel in the opposite direction to the above mentioned flames, and redirecting the non-oxidizing products of combustion of the last mentioned flames to travel with the billets to provide a blanket through which the radiant heat energy of the last mentioned flames pass to soak the billets.

12. The method of firing a continuous furnace for heating billets and the like which comprises causing heating flames to travel with the billets to preheat the same before their entry into the heating chamber of the furnace, causing other heating flames to travel with the billets as they travel in the heating chamber while interposing the non-oxidizing products of combustion of the preheating flames between the second mentioned flames and the billets to provide a blanket through which the radiant heat energy passes from the second mentioned flames to heat the billets, causing additional flames to travel in the opposite direction to the second mentioned flames, and redirecting the non-oxidizing products of combustion of the last mentioned flames to travel with the billets to provide a blanket through which the radiant heat energy of the last mentioned flames pass to soak the billets.

13. The method of controlling the operation of a continuous furnace for heating billets and the like which comprises regulating the intensity of heat supplied to the furnace in response to variations in the temperature of the discharged gases in the flue after they have flowed off the heated billets at the discharge end of the furnace.

14. The method of controlling the operation of a continuous furnace for heating billets and the like, which comprises regulating the quantities of fuel and air supplied to the furnace in response to variations in the temperature of the discharged gases in the flue after they have flowed off the heated billets at the discharge end of the furnace.

15. The method of controlling the operation of a continuous furnace for heating billets and the like, which comprises regulating the intensity of heat supplied to the furnace in response to variations in the temperature of the products of combustion in the flue after they have passed in contact with the heated billets at the discharge end of the furnace.

16. The method of controlling the operation of a continuous furnace for heating billets and the like by combined fuel and air which comprises regulating the supply of one of the heating elements in response to variations in the temperature of the products of combustion in the flue after they have passed in contact with the heated billets at the discharge end of the furnace, and regulating the supply of the other heating element in response to the supply of the first mentioned heating element.

17. The method of controlling the operation of a continuous furnace for heating billets and the like and which is arranged to be fired at both ends which comprises regulating the quantities of heat supplied to either end in response to the temperature of the products of combustion in the flue after they have passed in contact with

the heated billets at the discharge end of the furnace.

18. The method of controlling the operation of a continuous furnace for heating billets and the like and which is arranged for firing adjacent both ends which comprises during normal operation heating the billets by firing adjacent the charging end of the furnace, and, during a temporary cessation of travel of the billets within the furnace, maintaining the heat of the billets adjacent the discharge end of the furnace by firing adjacent the discharge end.

19. The method of controlling the operation of a continuous furnace for heating billets and the like and which is arranged for firing at both ends, which comprises during normal operation heating the billets by firing adjacent the charging end of the furnace, and, during a temporary cessation of travel of the billets within the furnace, maintaining the heat of the billets adjacent the discharge end of the furnace by firing adjacent the discharge end, and regulating the quantity of firing in either instance in response to the temperature of the products of combustion passed in contact with the heated billets adjacent the discharge end of the furnace.

20. The method of controlling the operation of a continuous furnace for heating billets and the like and which is arranged for firing at either end, which comprises during normal operation heating the billets by firing adjacent the charging end of the furnace, and in case of a temporary cessation of travel of the billets in the furnace as the furnace temperature tends to rise above a predetermined degree switching the firing to the discharge end of the furnace, and upon resumption of travel of the billets again switching the firing to the charging end of the furnace.

21. The method of heating billets and the like while passing them through a continuous furnace having a preheating portion and a main heating portion, which comprises causing heating flames to travel in the direction of the movement of the billets to preheat the billets as they pass through the preheating portion, and causing heating flames to travel in the same direction to heat the preheated billets as they pass through the main heating portion.

22. The method of heating billets and the like while passing them through a continuous furnace having a preheating portion and a main heating portion, which comprises causing heating flames to travel in the direction of the movement of the billets above and below the same to preheat the billets as they pass through the preheating portion, and causing heating flames to travel in the same direction above and below the billets to heat the preheated billets as they pass through the main heating portion.

23. The method of heating billets and the like while passing them through a continuous furnace having a preheating portion, a main heating portion and a soaking hearth, which comprises causing heating flames to travel in the direction of the movement of the billets to preheat the same as they pass through the preheating portion, causing heating flames to travel with the billets in the main heating portion to heat the preheated billets, and saturating the heated billets with heat from the products of combustion of the preheating and heating flames while the billets are passed over the soaking hearth.

24. The method of heating billets and the like while passing them through a continuous furnace having a preheating portion, a main heating portion and a soaking hearth, which comprises causing heating flames to travel in the direction of the movement of the billets and above and below the same to preheat the same as they pass through the preheating portion, causing heating flames to travel with the billets in the main heating portion and above and below the same to heat the preheated billets, and saturating the heated billets with heat from that portion of the products of combustion of the heating flames above the billets while the billets are passed over the soaking hearth.

25. The method of heating billets and the like while passing them through a continuous furnace having a preheating portion, a main heating portion and a soaking hearth, which comprises causing heating flames to travel in the direction of the movement of the billets to preheat the same as they pass through the preheating portion, causing heating flames to travel with the billets in the main heating portion to heat the preheated billets, saturating the heated billets with heat from the products of combustion of the preheating and heating flames while the billets are passed over the soaking hearth, and regulating the temperature of the soaked billets by the temperature of the saturating products of combustion after they have traveled over the billets.

26. In a continuous furnace for heating billets and the like and through which the billets are caused to pass from the charging end to the discharge end, means for introducing heating flames at the charging end of the furnace which travel in the same direction as the billets for preheating the same, and means for introducing additional heating flames in the same direction as the preheating flames for heating the preheated billets to an elevated temperature.

27. In a continuous furnace for heating billets and the like and through which the billets are caused to pass from the charging end to the discharge end, means for introducing heating flames above and below the billets at the charging end of the furnace which travel in the same direction as the billets for preheating the same, and means for introducing additional heating flames above and below the billets and in the same direction as the preheating flames for heating the preheated billets to an elevated temperature.

28. In a continuous furnace for heating billets and the like and through which the billets are caused to pass from the charging end to the discharge end, means for introducing heating flames at the charging end of the furnace which travel in the same direction as the billets for preheating the same, means for introducing additional heating flames in the same direction as the preheating flames for heating the preheated billets to an elevated temperature, a soaking hearth over which the billets travel before they are discharged from the furnace, and means for withdrawing the products of combustion of said flames over the billets on the soaking hearth and discharging them from the furnace.

29. In a continuous furnace for heating billets and the like and through which the billets are caused to pass from the charging end to the discharge end, means for introducing heating flames above and below the billets at the charging end of the furnace which travel in the same direction as the billets for preheating the same, means for introducing additional heating flames above and below the billets and in the same direction as the

preheating flames for heating the preheated billets to an elevated temperature, a soaking hearth over which the billets travel before they are discharged from the furnace, means for withdrawing the products of combustion of the upper flames over the billets on the soaking hearth and discharging them from the furnace, and means for independently withdrawing the products of combustion of the lower flames ahead of the soaking hearth.

30. In a continuous furnace for heating billets and the like and through which the billets are caused to pass from the charging end to the discharge end, means for introducing heating flames at the charging end of the furnace which travel in the same direction as the billets for preheating the same, means for introducing additional heating flames in the same direction as the preheating flames for heating the preheated billets to an elevated temperature, a soaking hearth over which the billets travel before they are discharged from the furnace, means for withdrawing the products of combustion of said flames over the billets on the soaking hearth and discharging them from the furnace, and means responsive to the temperature of the products of combustion passing from the soaking hearth for controlling the final heated temperature of the billets.

31. In a continuous furnace for heating billets and the like and through which the billets are caused to pass from the charging end to the discharging end, means for introducing flames and withdrawing the products of combustion thereof adjacent the discharge end of the furnace, and means for introducing other flames and withdrawing the products of combustion thereof adjacent the charging end of the furnace.

32. In a continuous furnace for heating billets and the like and through which the billets are caused to pass from the charging end to the discharging end, means for introducing flames and withdrawing the products of combustion thereof adjacent the discharge end of the furnace, and means for introducing other flames and withdrawing a portion of the products of combustion thereof adjacent the charging end of the furnace and withdrawing the remainder of said products adjacent the discharge end of the furnace.

33. In a continuous furnace for heating billets and the like, the combination of a main heating chamber, a preheating chamber connected to the main heating chamber, a hearth extending from the charging end of the preheating chamber through the main heating chamber for supporting the billets, means for introducing heating flames at the charging end of the preheating chamber, and separate means for introducing heating flames at the charging end of the main heating chamber, and outlet means for withdrawing the products of combustion of said heating flames adjacent to the discharge end of the furnace.

34. In a continuous furnace for heating billets and the like, the combination of a main heating chamber having a soaking hearth adjacent the discharge end, a preheating chamber connected to the other end of the main heating chamber, a hearth extending from the charging end of the preheating chamber through the main heating chamber for supporting the billets, means for introducing heating flames at the charging end of the preheating chamber, and separate means for introducing heating flames at the charging end of the main heating chamber and at the discharge end of the main chamber, and outlet means for withdrawing the products of combustion of said heating flames adjacent the discharge end of the furnace.

35. In a continuous furnace for heating billets and the like, the combination of an elongated chamber through which the billets pass from the charging end to the discharge end, means for introducing heating flames into the furnace, a flue for withdrawing the products of combustion adjacent the discharge end of the furnace, and pyrometric means in said flue responsive to variations in temperature in the withdrawn products after they have entered the flue and arranged to regulate said flame introducing means.

36. In a continuous furnace for heating billets and the like, the combination of a furnace chamber having a soaking hearth adjacent the discharge end over which the billets pass, means for heating said billets as they pass through said chamber, an outlet adjacent the discharge end of the furnace for conducting the products of combustion after they have passed over the billets on the soaking hearth, heat responsive means in said outlet for controlling the heat supplied to the furnace chamber to regulate the temperature of the billets on the soaking hearth.

37. In a continuous furnace for heating billets and the like, the combination of a furnace chamber through which the billets pass from the charging end to the discharge end and having a soaking hearth adjacent the latter end, means for heating the furnace chamber from adjacent the charging end during normal operation, means for heating the billets on the soaking hearth during a cessation of the billets in the furnace, an outlet adjacent the discharge end of the furnace chamber for conducting the products of combustion after they have passed over the billets on the soaking hearth, heat responsive means in said outlet for controlling the heat delivered to the furnace to regulate the temperature of the billets on the soaking hearth, and means for selectively transferring the application of the heat to a selected end of the furnace when the quantity of heat delivered to the furnace reaches a predetermined rate of flow.

38. The method of heating billets and the like which comprises causing heating flames to travel in lines substantially parallel to the path of the billets to be heated, and blanketing both the upper and lower surfaces of the row of billets from the heating flames with layers of non-oxidizing gas consisting of the products of combustion of said heating flames.

39. In a continuous furnace for heating billets and the like, the combination of a furnace chamber through which the billets travel from the charging end to the discharging end, burners at the charging end of the furnace chamber for introducing heating flames to heat the billets as they enter the furnace chamber, burners at the discharge end of the furnace chamber for introducing heating flames to soak the billets before they leave the furnace chamber, an outlet for the discharge of products of combustion from the furnace chamber, and means responsive to the temperature of the products of combustion in said outlet for regulating said heating flames.

40. In a continuous furnace for heating billets and the like, the combination of a furnace chamber through which the billets travel from the charging end to the discharging end, burners at the charging end of the furnace chamber for introducing heating flames to heat the billets as they enter the furnace chamber, burners at the

discharge end of the furnace chamber for introducing heating flames to soak the billets before they leave the furnace chamber, and means for withdrawing products of combustion adjacent the discharge end.

41. In a continuous furnace for heating billets and the like, the combination of a furnace chamber through which the billets travel from the charging end to the discharge end, burners at both ends of the furnace chamber for introducing heating flames in lines substantially parallel to the path of the billets, means for maintaining a flow of non-oxidizing gases between the heating flames and the billets, and a flue at the end of the furnace for withdrawing the non-oxidizing gases flowing over the billets about to be discharged.

42. In a continuous furnace for heating billets and the like, the combination of a furnace chamber through which the billets travel from the charging end to the discharge end, burners at both ends of the furnace chamber for introducing heating flames in lines substantially parallel to the path of the billets, means for maintaining a blanketing layer of non-oxidizing products of combustion between the heating flames and the billets, and a flue at the end of the furnace for withdrawing the non-oxidizing products of combustion flowing over the billets about to be discharged.

43. In a continuous furnace for heating billets and the like, the combination of a furnace chamber through which the billets travel from the charging end to the discharge end, burners at both ends of the furnace chamber for introducing heating flames in lines substantially parallel to the path of the billets, means for maintaining a blanketing layer of the non-oxidizing products of combustion, originating from the heating flames, between the billets and the heating flames, and a flue at the end of the furnace for withdrawing the non-oxidizing products of combustion flowing over the billets about to be discharged.

44. The method of heating billets and the like in a continuous furnace, which comprises causing heating flames to travel, in lines substantially parallel with the travel of the billets, from both the charging end and discharging end of the furnace, interposing a blanket of non-oxidizing gases between the billets and the flames traveling from the charging end of the furnace, and reversing the direction of travel of the products of combustion of the flames traveling from the discharge end of the furnace to interpose a blanket of non-oxidizing gases between the billets and said last mentioned flames.

45. The method of heating steel billets to rolling temperature which comprises passing the steel through a heated furnace atmosphere, then heating the steel from above during the final portion of its travel through the furnace over a solid refractory hearth, and heating the hearth from below by passing the waste gases from the furnace in contact with the underside of the hearth.

46. In a continuous furnace for heating billets and the like and through which the billets are caused to pass from the charging end to the discharge end, means for introducing heating flames at the charging end of the furnace which travel in the same direction as the billets for heating the same, a soaking hearth in the furnace over which the billets pass before they leave the furnace, a gravity discharge slope at the end of the hearth down which the billets slide as they leave the furnace, and flues opening from said slope for withdrawing the products of combustion of said flames over the billets on the soaking hearth and directing them to the underside of the hearth to heat the same.

47. In a continuous furnace for heating billets and the like and through which the billets are caused to pass from the charging end to the discharge end, means for introducing heating flames at the charging end of the furnace which travel in the same direction as the billets for heating the same, heat exchange means below said furnace, a soaking hearth in the furnace over which the billets pass before they leave the furnace, said hearth also forming the top wall of the heat exchange means, and flues at the discharge end of the furnace for withdrawing the products of combustion of said flames over the billets on the soaking hearth and directing them to the heat exchange means under the hearth.

48. In a continuous furnace for heating billets and the like and through which the billets are caused to pass from the charging end to the discharge end, means for introducing heating flames above and below the billets at the charging end of the furnace which travel in the same direction as the billets for heating the same, heat exchange means below said furnace having a stack flue connection, a soaking hearth in the furnace over which the billets pass before they leave the furnace, flues at the discharge end of the furnace for withdrawing the products of combustion of said flames over the billets on the soaking hearth, flues ahead of the soaking hearth for independently withdrawing the products of combustion of the flames below the billets, both of said flues directing the products of combustion to said heat exchange means, and damper means in all of said flues for separately regulating the draft therein.

49. The method of operating a continuous furnace for heating billets and the like which comprises the steps of moving the billets through the furnace from the charging end to the discharge end, introducing the heating flames at the charging end of the furnace and exhausting products of combustion at the discharge end of the furnace to heat the billets as they pass therethrough, and regulating the flow of gases over the billets at both ends of the furnace to provide a greater quantity of gases flowing over the billets at the charging end than at the discharge end so that the surface temperature of the billets does not exceed the temperature of the body of the billets at the time of their discharge from the furnace.

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