MINIMUM SCALE REHEATING FURNACE
AND MEANS RELATING THERETO

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References Cited
UNITED STATES PATENTS
1,843,336 2/1932 Pike et al. ................................ 432/122
2,334,050 11/1943 Waltz ..................................... 432/138
2,417,063 3/1947 Cooper ..................................... 432/138
2,730,998 1/1956 Birkner ..................................... 110/28 F
3,063,878 11/1960 Wilson .................................... 432/11
3,197,184 7/1965 Navez et al. .............................. 432/138

ABSTRACT
A ferrous work reheating furnace wherein high fuel efficiency is achieved with minimum scale formation. The work is initially heated in an atmosphere which is slightly oxidizing, the work being in a temperature range where scale formation does not readily occur. The work is then placed in a slightly reducing atmosphere after it reaches a predetermined elevated temperature. A unique arrangement is provided wherein a continuous reheating process takes place utilizing a protective atmosphere generated by hot air burners during the high temperature phase. These burners have a low air to fuel ratio and the gases are caused to flow toward the location where the work is introduced. The combustibles within the gases are combusted through the introduction of air into the portion of the furnace nearest the charge end. Additional efficiency is gained by using the spent gases to preheat combustion air for the burners.

4 Claims, 3 Drawing Figures
MINIMUM SCALE REHEAT I NG FURNACE AND MEANS RELATING THERETO

This is a division of U.S. Pat. application Ser. No. 235,610, filed Mar. 17, 1972.

BACKGROUND OF THE INVENTION

This invention relates to reheating furnaces and particularly to means and methods for reducing scale formation in the reheating of ferrous work.

In the reheating of ferrous work such as ingots, billets, blooms, slabs, etc., preparatory to working by rolling, forging, bending, stamping, and the like, a consistent problem has been to prevent surface oxidation, commonly referred to as scaling. Many methods have been devised for prevention of scale on ferrous workpieces. One such method is to rapidly heat the work to the desired temperature so that the time at which scale may be formed is kept at a minimum. This method has not proven satisfactory. Another method has involved the use of radiant heat to raise the temperature of the work and the use of an inert atmosphere about the workpieces. Obviously, the provision of an inert atmosphere has inherent expenses and the cost of heating radiantly is higher than heating by direct combustion. Still other methods have involved the heating of ferrous work in an atmosphere rich in combustion products, those gases rich in combustibles being subsequently combusted in a heat exchange relationship to preheat the combustion air and/or to supply heat to the walls of the furnace to obtain radiant heat. Although this latter method has shown some success in reducing scale formation, its efficiency is not high as transfer of heated gases leads to high heat losses.

It is an object of this invention to provide a method for reheating metallic work in such a way that scale formation is kept to a minimum.

It is another object of this invention to provide a method of reheating ferrous work that is efficient and economical.

It is still another object of this invention to provide means for reheating ferrous work in such a way that scale formation is minimized.

It is a further object of this invention to provide means for reheating ferrous work in such a way that a high degree of efficiency and economy is achieved.

It is a still further object of this invention to provide means and methods for fully utilizing the heat content in fuel within a reheating furnace through complete combustion.

It is still another object of this invention to provide methods and means for recovering the BTU values in gases rich in combustibles by using a controlled amount of combustion air.

These and further objects will appear from the following portions of the specification and the drawing, wherein:

FIG. 1 is a partially schematic, plan cross-sectional view of a rotary hearth furnace utilizing the principles of the instant invention;

FIG. 2 is a cross-sectional view taken along the line 2—2 of FIG. 1; and

FIG. 3 is a plan view in detail showing means for introducing air into a portion of the furnace shown in FIG. 1.

SUMMARY OF THE INVENTION

Ferrous work is placed into a continuous furnace wherein the work and the atmosphere within the furnace move countercurrent to one another. Protective gas rich in combustibles and at a temperature from 3,000°F to 3,400°F is introduced to one end of the furnace. The high temperature, rich gas is generated by preheated air burners operated at low air to gas ratios. As the gas moves through the furnace, it tends to raise the temperature of the work to the desired level and the gas itself tends to cool. In order to heat the ferrous work and to utilize the rich gases in the most efficient manner, air is introduced to the furnace in a controlled fashion at a location a substantial distance from the location where the rich gas is introduced into the furnace. As the air mixes with the rich gas, combustion takes place and the nature of the atmosphere changes from a reducing atmosphere to a slightly oxidizing atmosphere. Since the work is at a relatively low temperature where the air is introduced, scale formation will not form readily.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing, a rotary hearth reheating furnace is shown generally at 10 and comprises an inner wall 12, an outer wall 14, a bottom seal member 16 and a roof 18 which in combination with a work W conveying rotary hearth 20 produce an enclosure. The rotary hearth 20 has means for rotation 21, including a driving motor 23, the rotary hearth moving in a counterclockwise direction as seen in FIG. 1. It will be understood that the description of the invention as it applies to a rotary hearth furnace is for illustrative purposes only and that the principles of the invention may be applied to other types of continuous furnaces.

The outside wall 14 has a charge opening 22 through which work may be inserted to be placed upon the rotary hearth 20 and a discharge opening 24 through which the work may be removed after treatment. A partition wall 25 extends radially from the inner wall 12 to the outer wall 14 intermediate the openings 22 and 24 to segregate their respective areas. The roof 18 of the furnace 10 has an opening 26 therein which receives a flue 28. The flue 28 leads to a stack 32 about which is located an annular jacket 34, which jacket has an opening 36 at the upper end thereof that receives an air inlet pipe 38. An air blower 40 is connected to the inlet pipe 38 thereby directing air through the jacket 34 and in contact with the stack 32. The annular jacket 34 also has an opening 42 at its lower end and the lower opening receives an air outlet pipe 44 through which air from the jacket is able to pass.

As shown in FIG. 1, the furnace 10 is segregated into six zones: 1, 2, 3 and 4, the charge zone and the discharge zone. Zones 1 and 2 have burners 46 and 47, respectively, located within the roof 18 portion of their respective zones. Zones 3 and 4 also receive burners 48 and 49, respectively, within the roof 18 thereof. The burners 48 and 49 in zones 3 and 4 are preheated air, flat flame burners which are able to produce an atmosphere high in combustibles. These types of burners are well known in the art and readily available. The burners in zones 1 and 2 may be of the same type, although it is not necessary. The burners in zones 3 and 4 must provide a protective atmosphere during the time that
the work \( W \) is at the scale formation temperature; whereas, the burners in zones 1 and 2 are used primarily for the purpose of bringing the furnace zones 1 and 2 to the operating temperature during start-up, after which the use of the burners is discontinued, unless supplemental heat is required in some operations or situations. For this reason, it is not necessary to use as expensive a burner in zones 1 and 2 as is required in zones 3 and 4.

A burner 50 is also located at the discharge zone of the furnace, this burner also being of the flat flame type which is able to produce a protective atmosphere. The burners of each zone are connected to natural gas headers 51, which in turn are supplied with gas by a main gas line 53. Each of the sets of burners 46 through 49 have valve units associated therewith, the gas delivered to the burners in zone 1 being metered by valve 52, in zone 2 by valve 54, in zone 3 by valve 56 and in zone 4 by valve 58. In zone 1, the burners 46 are connected to an air line 60 which provides the combustion air to these burners. The burners 47 in zone 2 are connected to an air line 62, the air lines 60 and 62 being in communication with an air header 64 which receives air from a blower 66. Each of the air lines 60 and 62 is provided with a valve 68 and 70, respectively, in order to control the quantity of air passing therethrough. The burners 48 in zone 3 are provided with air by a line 72 which is confluent with an air line 44 leading from the annular jacket 34. Another air line 74 branches off the initial air line 72 to provide air to the burners 49 in zone 4. Still another air line 76 branches off from air line 44 to provide air to the burner 50 in the discharge zone. A valve 78 is provided in line 72 to meter the amount of air supplied to the burners 48, a valve 80 is provided in line 74 to meter the amount of air supplied to the burners 49 and another valve 82 is provided in line 76 to meter the amount of air to the burner 50 in the discharge zone.

The flue 28 is also provided with a burner 77 which receives gas from a line 79 connected to the gas header 51 of zone 1. A valve 81 is located within the flue line 79 to control the amount of gas to the flue burner 77.

Received within the outer side wall 14 are a pair of tangential air inlet pipes 84 and 86, one tangential air inlet pipe 84 supplying air to zone 1 and the other tangential air inlet pipe 86 providing air to zone 2. An air line 88 provides air to the tangential air inlet 84 in zone 1 and another air line 90 is connected to a main header 91 which receives air from the blower 66. An air completion control unit 89 is connected with header 91. The air line 88 is provided with a valve 92 and the air line 90 is provided with a valve 94, each serving the function of controlling the amount of air flowing through their respective air lines. A stack nozzle 93 supplies air to the flue 28, there being an air line 95, with a valve 97, connected to the air header 64 and to a blower 99.

A pair of thermocouples 96 and 96' are located in the first zone, a pair of thermocouples 98 and 98' are provided in the second zone, a pair of thermocouples 100 and 100' are provided in the third zone, a pair of thermocouples 102 and 102' are provided in the fourth zone and a thermocouple 104 is provided in the discharge zone. Additionally, a thermocouple 106 is provided in the flue 28. Each of these thermocouples is provided to measure the temperature within each of their respective zones, one thermocouple, 96', 98', 100' and 102' in each zone, serving as a high limit thermocouple and one thermocouple, 96, 98, 100 and 102, in each zone as a temperature control when there is a pair of thermocouples in a zone. Control units are provided to control the flow of gas and air to the zones thereby individually controlling the temperature. Each of the thermocouples, or pairs of thermocouples, has the appropriate circuitry and instruments associated therewith which control the amount of gas and air supplied, these being a control unit 108 to serve the thermocouples 96 and 96' and valves 52, 68 and 92 associated with zone 1, a control unit 110 associated with the thermocouples 98 and 98' and valves 54, 70 and 94 of zone 2, a control unit 112 associated with the thermocouples 100 and 100' and valves 56 and 78 of zone 3, a control unit 114 associated with the thermocouples 102 and 102' and valves 58 and 80 of zone 4 and a control unit 115 associated with the thermocouple 104 and valves 59 and 82 of the discharge zone. A flow computer control unit 116 is operatively connected to control units 108, 110, 112, 114 and 115 to provide overall temperature and atmosphere control as will be described hereinafter.

In operation, work is charged into the furnace through opening 22 and moves on the rotary hearth 20 in a counterclockwise direction as seen in FIG. 1. During initial operation, all the burners 46–50 are ignited, the burners in zones 3 and 4 maintaining an atmosphere rich in combustibles whereas the burners in zones 1 and 2 bring the zones up to a temperature in the range of 1,800°–2,300° F. The burners 49 in zone 4 operate at a low air/gas ratio to maintain an atmosphere rich in combustibles under normal conditions. The air/gas ratio in zone 4 will normally be maintained from 5/1 to 6/1, depending upon the temperature of operation and the type of work being processed. Temperature in this zone 4 is sensed by the thermocouple 102 which controls the zone 4 air control valve 80. The air flow to this zone is also metered by zone 4 control unit 114. This unit 114 activates zone 4 gas control valve 58 to allow gas flow to zone 4 at the preset air to gas ratio. Zone 4 has a high limit thermocouple 102' which shuts down furnace gas supply in case of zone overheating.

The burners 48 in zone 3 also operate at a low air/gas ratio to maintain an atmosphere rich in combustibles. The air/gas ratio in zone 3 will normally be maintained from 6/1 to 8/1, again depending upon the temperature of operation and the type of work being processed. Temperatures in this zone are sensed by a thermocouple 100 which controls the zone 3 air control valve 78. The air flow to this zone is also metered by the zone 3 control unit 112. This unit 112 activates zone 3 gas control valve 56 to allow gas flow to zone 3 at the preset air to gas ratio. Zone 3 has a high limit thermocouple 100' which shuts down furnace gas supply in case of zone overheating.

Preheated air is supplied to zones 3 and 4 from the blower 40, the air flowing from recuperator jacket 34 into the preheat air line 44. The air is preferably preheated to a temperature of approximately 1,000° F. The burners 48 in zone 3 are provided with preheated air by the air line 72 which is confluent with the air line 44 leading from the annular jacket 34. The air line 74 branches off the initial air line 72 to provide preheated
air to the burners 49 in zone 4. The air line 76 branching from air line 44 provides preheated air to the burner 50 in the discharge zone. The discharge burner 50 normally operates at a low air/gas ratio and is controlled via discharge burner control unit 115.

The total air and gas flow supplied to burners 49 of zone 4 and burners 48 of zone 3 is calculated by the flow computer unit 116. This flow computer unit 116 determines the additional amount of air which must be supplied to the furnace system to complete combustion of all fuel. A signal is relayed to the completion air control unit 89 which permits delivery of the required amount of air to complete combustion in zone 1, zone 2, and/or the flue gas stack 28. Completion air is supplied via blower 66 to header 91. Completion air is conducted to zone 2 through completion air line 90 which is a branch of completion header 91. The temperature in zone 2 is sensed by the thermocouple 98 which activates zone 2 completion air valve 94 through zone 2 control unit 110. Completion air enters zone 2 through the tangential air inlet pipe 86. Under normal operation, zone 2 temperature can be maintained by the addition of completion air through inlet pipe 86. The air entering zone 2 mixes with the combustible gases generated in zones 3 and 4 by burners 48 and 49, respectively. The mixing action of completion air and combustible gases results in combustion causing a subsequent heat release. The rate of mixing is controlled by the air inlet pipe diameter and correct sizing results in desirable heat distribution within zone 2. Under normal conditions, zone 2 temperature requirements can be maintained by controlling zone 2 completion air flow to obtain the required amount of heat through burn-down of downstream, relative to the rotation of the hearth, combustible atmosphere. Under special conditions of hold or start-up, additional heat in zone 2 may be required. This heat is obtained through operation of zone 2 burners 47. The zone 2 temperature control unit 110 actuates zone 2 combustion air valve 70, which allows combustion air delivery to burners 47. The zone 2 combustion gas is controlled by a zone 2 gas valve 54 backloaded to zone 2 combustion air line 62. The pressure created in air line 62 by air flow opens valve 54 in zone 2 combustion gas line 51. The zone combustion air and gas is conducted to zone 2 burners 47 where subsequent ignition occurs at the individual burners. The control unit 110 will actuate combustion air valve 70 until zone temperature requirements can be maintained exclusively by zone 2 completion air burn-down. At this time, zone 2 burners 47 will be shut off by full closing of zone combustion air valve 70 and gas valve 54. Zone 2 has a high limit thermocouple 98* which will shut down all furnace gas in the case of zone overheat.

Temperature in zone 1 is maintained by a control sequence identical to that explained above for zone 2. Completion air is supplied to zone 1 through air line 88 and enters zone 1 chamber through the tangential air inlet pipe 84. Zone temperature is sensed via thermocouple 96 which actuates completion air control valve 92 through zone 1 control unit 108. When required, additional heat is supplied to zone 1 through burners 46. Zone 1 combustion air is controlled by zone 1 combustion air control valve 68 actuated by the control unit 108. Air pressure developed in zone 1 combustion air line 60 actuates the zone 1 combustion gas valve 52 to allow gas to burners 46. Subsequent ignition of combustion air and gas at zone 1 burners 46 allows additional heat release in zone 1. Zone 1 has a high limit thermocouple 96* which will shut down all furnace gas in the case of zone overheat. As a rule, the amount of air supplied to zone 1 is controlled so that the temperature of the work W does not exceed 1,400°F.

As in zone 2, additional heat through burners is not required at normal operating conditions. In normal cases, all heat requirements are maintained through burn-down of the combustible atmosphere gas resulting from the admission and mixing with zone 1 completion air. Also, under the normal conditions, all the completion air delivered from completion air blower 66 will be distributed evenly in zone 1 and zone 2 completion air nozzles 84 and 86, respectively. In this case, gases leaving zone 1 through flue 28 will be completely burned down. This results by achieving final stoichiometric air to gas ratios in the burndown process of zones 1 and 2.

In hold conditions, where the heat demand in zones 1 and 2 are reduced, all completion air will not be required through completion air nozzles 84 and 86. In this case, excess completion air is directed along completion air line 64 to the stack air line 95. A stack completion air control valve 97 is operated via completion air control unit 89 to allow excess completion air to enter the stack at stack nozzle 93. At this condition, the burn-down of the combustible gases is completed by mixing of completion air and combustible gases within the stack, downstream of stack nozzle 93. Additional air may be added through stack nozzle 93 via the dilution air blower 99. The amount of dilution air needed to maintain safe gas temperatures within the stack 32 is sensed by stack gas thermocouple 106. This activates dilution air control valve 97.

The hot air burners 48 and 49 generate a protective atmosphere in zones 3 and 4, respectively. By operating at an air to fuel ratio of from 5/1 to 6/1 in zone 4 and a ratio of 6/1 to 8/1 in zone 3 which air/gas ratios result in a protective gas containing 30 to 22 percent and 22 to 8 percent combustibles, respectively. The rich gases are drawn into zone 2 by the effect of flue 28, and the air jets from pipes 84 and 86, thereby setting up a flow of gases in a clockwise direction to yield a counterflow between the work and the gas.

After the burners are in operation sufficiently long to raise the temperature to the required degree, the burners in zones 1 and 2 are discontinued. Air is introduced through the tangential pipes 84 and 86 to complete combustion of the rich gas. This completion air mixes with the combustibles in the gas coming from zone 3 to ignite the same, thereby providing heat to the work W as it is being conveyed through the furnace 10. The quantity of air supplied is such that the atmosphere within zone 2 is still relatively neutral with respect to the oxidizing characteristics of the work; whereas, the atmosphere in zone 1 will be slightly oxidizing. Since the temperature of the work in zone 1 is relatively low, there will be no appreciable scale formation despite the slightly oxidizing nature of the atmosphere. Overall, enough completion air is added to achieve complete combustion of the rich gases within the furnace.

The products of combustion are withdrawn from the furnace by the flue 28 and escape through the stack 32 to the atmosphere. As the flue products escape through the stack 32, they come into heat exchange relationship with atmosphere air directed through the jacket 34 by
action of the blower 40 in cooperation with line 38. Provisions are made for additional cold air to be added in the stack 32 through stack nozzle 93. This air is required, under certain operating conditions, for incineration or cooling of the flare products.

After the air traveling through the annular jacket 34 is heated, it escapes through the outlet 42. This preheated air then becomes the source of oxygen for the burners 48, 49, 50 in zones 3, 4 and the discharge zone, respectively. The air is preheated up to a temperature of 1,000° F. It is an important feature of this invention that the air is preheated so that the temperature within zones 3, 4 and the discharge zone may be sufficiently high while still maintaining a gas rich in the products of combustion. Without the preheated air, the burners would not have the ability to achieve the desired high temperature in these latter zones.

Within zones 1 and 2 it is desirable to combust, as completely as possible, the combustible products remaining in the gas after they have passed through zone 3 without having an excess of air. In order to do this, it would be advantageous to introduce the air in a fashion such that there is complete mixing of the fuel and air. It is an important feature of this invention that an air injection system is used for completing the combustion of the rich gases entering zone 2 from zone 3 which accomplishes this goal. The air enters the furnace through tangential pipes 84 and 86 directed upstream, relative to the rotation of the hearth, towards the charge end of the furnace 10. The two tangential pipes 84, 86 are located at the downstream ends of their respective zones relative to the hearth rotation. When the air enters the furnace 10, the air jet spreads out at a constant rate and continually entrains the surrounding hot gases. The mixing rate of the air with the rich gases determines the rate of combustion or burndown. Burndown will continue until all air or combustible gas has been used.

The entrainment ratios of a free circular jet is determined by the initial jet diameter and the distance the jet has traveled. The term "free" circular jet is used here to designate a jet which enters a chamber, or environment, where no physical shapes, or bodies, are present to substantially impede or alter its natural characteristics. Once a free circular jet has been established, its behavior at points downstream are quite predictable. Its shape, size and the amount of surrounding fluid it has entrained can be calculated by accurate expressions. By being able to control the entrainment ratio of the air jet, the control of the burndown rate and subsequent control of the atmosphere condition is achieved. A long mixing length is desirable since the heat release accompanying mixing could be distributed over longer lengths of the furnace, resulting in better temperature uniformity. The angle or direction of the jet is determined by its natural expansion and entrainment length. From Fig. 3 it can be seen that this angle may be adjusted to give impingement on the inside furnace wall 12 at the maximum mixing length. This is done since the downstream flow conditions created by the furnace shape automatically cause distortion of the jet gases into the relatively rich outer atmosphere. This arrangement combined with the natural mixing of the gases as they proceed towards the charge end results in uniform atmosphere distribution by the time the gases reach a downstream nozzle or the furnace flare.

The direction of the nozzle is determined by aiming the jets so as to obtain impingement on the inside furnace wall at the same cross section where roof impingement occurs. After traveling approximately two-thirds of the way through each zone 1 and 2, the gas is completely entrained. Correct nozzle location, size and direction are necessary to insure favorable atmosphere conditions.

The furnace shown and described is able to reheat ferrous work with a minimum of scale formation while economically utilizing the thermal units associated with the gaseous fuel. In such a furnace, 6 inches x 6 inches ferrous billets have been reheated to 2,300° F. at a rate of 10.5 tons per hour, its scale loss being less than 0.1 percent by weight. This compares with a scale loss of 2 to 3 percent in reheating furnaces that do not use measures to provide a protective atmosphere. With regard to usage of natural gas, it was found that steel may be elevated to 2,300° F. at a rate of approximately 2.0 MM BTU per ton which compares favorably with 2.5 MM BTU per ton in a normal reheating furnace operating with cold air.

What is claimed is:

1. A method of reheating metallic work in a rotary hearth furnace, comprising: placing the work upon the hearth through a charge opening in the furnace and rotating the hearth in a direction to deliver the work at a discharge opening in the furnace, introducing a first quantity of air and combustible gas having an air to gas ratio of from 0.5 to 0.6 and a temperature of 2,000° to 3,400° F. into a first zone at the discharge end of the furnace, introducing a second quantity of air and combustible gas having an air to gas ratio of from 0.6 to 0.8 into a second zone continuous with and on the upstream side of the first zone relative to the rotative movement of the hearth, directing in an unrestricted manner the flow of gases from the first and second zones into the movement of the hearth, introducing a first quantity of cool completion air in an unrestricted manner into a third zone of the furnace continuous with and on the upstream side of the second zone, introducing a second quantity of cool completion air in an unrestricted manner into a fourth zone continuous with and on the upstream side of the third zone, controlling the amount of completion air introduced into the fourth zone so that the atmosphere is slightly oxidizing in the fourth zone and the temperature of the work does not exceed a relatively cool predetermined value, directing said quantities of completion air introduced into said third and fourth zones in a counter direction to the movement of the hearth, and withdrawing the atmosphere of the furnace at a region in said fourth zone adjacent the charge opening in the furnace.

2. The method of claim 1 wherein said steps of introducing said completion air into said third and fourth zones includes entraining said completion air with said air and gases discharged from said second zone by a free circular jet directed tangentially to the inside wall of said rotary hearth furnace to achieve effective burndown of said first and second quantities of air.

3. The method of claim 2 including measuring the total quantity of combustible gas and air added to the first two zones and controlling the air added to the third and fourth zones in response to the measurement.

4. The method of claim 2 including the step of preheating the air added to the first and second zones by placing the air in a heat exchange relationship with the atmosphere withdrawn from the furnace.

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