COMBUSTION AIR SYSTEM FOR CONTINUOUS HEATING FURNACE

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The present invention relates to continuous reheating furnaces employed in the processing of metal in slabs or other large size bodies requiring uniform temperature throughout the mass thereof preparatory to further processing into desired shapes.

More specifically, the invention is concerned with a combustion air system providing regulated volumes of heated air under pressure to each of a series of heating zones employed in maintaining controlled temperatures within continuous heating furnaces through which the metal slabs are progressively advanced and discharged therefrom at a preselected temperature.

The construction and operation of such continuous reheating furnaces are well known, as are the applications of the burners and control devices employed in delivering measured quantities of combustion air and fuel thereto. However, because of the substantially greater input of fuel on modern furnaces that are rated at higher capacities per square foot of hearth area, with correspondingly higher demands for preheated air, it has become more advantageous and economically feasible to design the air-preheating heat-exchangers as multiple parallel components rather than as single units.

The provision of means for collecting the preheated air from more than one heat-exchanger, preferably in the form of a recuperator, and subsequently delivering it to each of the heating zones with assurance of uniformly regulated pressure, has hitherto presented a problem due to the variable resistances in the individual heat-exchangers and in the ductwork associated therewith. These variable resistances tend to cause fluctuations in temperatures and pressures of the preheated combustion air, thereby making it extremely difficult to regulate the airflow required to maintain the desired accurate fuel-air ratio. The improved apparatus of the present invention accomplishes an equalizing of these temperatures and pressures at a point just ahead of the usual combustion air supply manifold of each bank of burners, whereby a self-regulating balanced combustion air system is readily established and maintained.

One object of the present invention is to provide a solution of the problem as set forth above.

Another object of the present invention is to provide means for conveying the said combustion air longitudinally of the furnace and delivering it in uniformly regulated volumes to each of the burners in said bank of burners.

These and further objects will be made apparent from the following specification and the drawings forming a part thereof, wherein:

FIG. 1 shows a longitudinal vertical section through a conventional form of reheating furnace, and

FIG. 2 shows a perspective view of the combustion air distributing system for the banks of burners spaced longitudinally of the furnace of FIG. 1.

Each manifold 14 of the drawings, the furnace 65 in longitudinal cross-section indicated generally at 1 is provided with a pre-heating section 2, heating section 3 and soaking section 4. Extending longitudinally through said furnace sections are the usual spaced skids 5 upon which the slabs being heated (not shown) are moved.

To the right of FIG. 1 is shown an outlet 6, there being an outlet 6 on each side of the furnace, for combustion gases and leading to the stack 7 for discharge from the furnace. Suitably mounted within the respective heating zones are the upper and lower banks of burners 8 and 9 of the pre-heating section 2, 10 and 11 of heating section 3 and a single bank of burners 12 in soaking section 4.

Adjacent the pre-heating section 2 and combustion gas outlets 6 are the heat exchangers 13 through which the waste combustion gases pass to the stack 7 and adjacent thereto are the heat-exchangers' recuperative air boxes 14.

Referring now to FIG. 2, comprising a perspective view of the combustion air distribution system, the waste gas heat exchangers 13 have the air boxes 14 mounted thereon and in heating contact with them. Boxes 14 comprise hollow closed members having a plurality of conduits 15 connecting the interior thereof with the interior of a cold air manifold 16 having an inlet 17 connected with a suitable blower fan (not shown). Manifold 16 has one end 18 closed so that cold air entering from inlet 17 and building up therein is uniformly passed through conduits 15 at each side thereof into spaced air boxes 14 and from each box 14 the air passes through conduits 19 into an adjacent hot air manifold 20 provided with closures 21 and 22 at opposite ends thereof. The air flowing through the air boxes is by-passed through a multiplicity of recuperator tubes 14A (FIG. 1) and exhausted in heat-exchanger chambers 13. Each closure 22 of manifolds 20 has a pressure bleed-off valve 23 connected therewith for venting heated air to the atmosphere during periods when safe temperatures for the metallic components of the heat-exchangers are exceeded. Further description of the bleed-off valves appears in the following specification.

Extending downwardly from each manifold 20 is a riser having a top portion 24 feeding air to the burners above the skid line (5, FIG. 1) and a bottom portion 25 feeding air to burners below skid line 5. Extending downwardly from each riser portion 24 is a duct 26 and below each duct 26 is a forwardly extending duct 27 connected with each riser portion 25. The outer ends of ducts 26 are connected by a transverse header 28 and intermediate the header 28 and riser is a second header 29 connecting both ducts 26. Intermediate the ends of header 29 and extending longitudinally of the furnace 1 are ducts 30. Each duct 30 connects the mid-portions of header 29 with the mid-portions of a burner manifold (31 and 31A) and intermediate the ends of each duct 30 is mounted a flow metering orifice and in downstream position a suitable form of air control valve (36A or 36B).

Each manifold 31 and 31A has its mid-portion at the point of connection with duct 30 of maximum cross-sectional area and tapering in opposite directions therefrom to a minimum cross-sectional area at the end closure walls 32 thereof. The mid-portion of header 29 has connection to a duct 35 which extends into the mid-portions of manifolds 31B. Duct 35, adjacent the manifold, has mounted therein a suitable air control valve assembly 36. The outer ends of lower ducts 27 are connected by a transversely disposed header 33. Oppositely disposed ducts 34 extending longitudinally of furnace 1 connect the mid-portions of header 33 with burner manifolds 31C and 31D. Each of the connector ducts 30, 34 and 35 is provided with an air flow-metering orifice assembly located between the air control valve assembly in the duct and the connection of said duct to the respective transverse header.

Each of the burner manifolds 31, 31A, 31B, 31C and 31D by means of the maximum hollow cross-sectional area at its mid-point and at the point of juncture with the connecting ducts, which cross-sectional area decreases towards both closed end portions, creates a back pressure from both said manifold end portions. Each burner
The manifold has a plurality of longitudinally spaced openings in one face thereof from each of which extends a hollow conduit 37 that connects with and feeds combustion air to a burner of the bank of burners supplied with air from the manifold. Due to the particular varied cross-sectional area of each manifold, conditions thereby established during air flow, the flow of air may be controlled at a value substantially the same for the several conduits 37 spaced along the manifold.

Each said conduit or pipe 37 preferably includes a valve 38 therein for separate control of combustion air volume supplied to the associated burner. As shown in FIG. 2, the manifolds 31, 31A and 31B supplying air to burners above the line of passage of the slabs through the furnace, have the conduits 37 depending therefrom. The manifolds 31D and 31C supplying air to the burners below the said line of passage are inverted and the conduits 37 extend upwardly therewith.

The invention has been disclosed herein as related to a furnace having five combustion zones, each of the five banks of burners defining one combustion zone. The air-preheating and distributing system of the invention can be readily adapted to furnaces having a greater or lesser number of combustion zones by an appropriate modification in the number of headers, manifolds and banks of burners, as desired. The disposition of the ducts and other component parts of the system will be largely determined by furnace design. As shown in FIGS. 1, 2, and 3, the direction of flow of the warm combustion gases through the furnace chamber is counter-current to the direction of movement of the metal through the furnace, and the location of the waste gas flues conveniently determines the location of the heat exchanger 13, 14, 14A. The conduits or ducts 26 feeding air to the burners in the upper portions of the pre-heating, heating and soaking sections are located above the furnace with the manifolds 31, 31A and 31B spaced longitudinally of the center line of the furnace. Similarly the manifolds 31C and 31D supplying air to the burners in the lower portions of the pre-heating and heating sections are located below the heating section of the furnace.

Referring now to FIG. 2 of the drawing, the single inlet duct 17 from a suitably located blower (not shown, but conventional in the art) supplies cold air to a cold air manifold 16 located in this case at the longitudinal center line of the furnace. The pressure of air delivered to the system is controlled at one point, as by means of a butterfly valve or a set of movable louvres. The louvres may be mounted either in the inlet or in the outlet of the blower fan, while the butterfly valve may be mounted in the duct 17. Control means (not shown, but known to the art) operate the louvres, or the butterfly valve, to regulate automatically the pressure and the quantity of the cold air flowing in the duct 17. From manifold 16 the air to be heated flows in equal amounts into each recuperator box 14 and through tubes 14A and thence into the adjacent hot air manifold 20. In this manner, regulated volumes of heated air are supplied from the manifolds 20 to the riser ducts 24, 25. Similarly the longitudinally extending ducts 26 and 27 supply heated air at substantially uniform volumes and pressures to the opposite ends of the cross-over or transverse headers 28, 29 and 33 respectively connected thereto and from which the air is supplied to the manifolds 31, 31A, 31B, 31C and 31D.

The volume of air supplied by each of said manifolds to its respective bank of burners will, of course, be varied in accordance with the firing rates of the five combustion zones of the furnace, as determined by the grade of metal within the furnace as well as the mass of metal passing through the furnace at any given interval of time.

The automatically operated louvres or butterfly valve, mentioned above, comprise a single control means which regulate the flow and volume of the air delivered to the system, while the individually controlled valve means 36, 56, 36A, 36B, 36C and 36D regulate the air pressure from the headers 28, 29 and 33 to their associated manifolds 31, 31A, 31B, 31C and 31D.

It is well known in the art of processing metals, particularly steels, both in rolling and forging that uniformity of temperature throughout the entire body of the work-piece is desirable, and that steels of different carbon content and alloys require different working temperatures. Consequently, the individual burners of each bank of burners are equipped with individual adjustable controls for both fuel and combustion air. The combustion air differs in temperature as the temperature of the air over headers, each receiving air at opposite ends thereof, and delivering the air through air orifice devices and control valves to the manifolds, insures that air at regulated pressure is delivered to each manifold. Each manifold supplying air from each connect duct (30, 34 and 35) to a bank of burners, by reason of having its greatest cross-sectional area at the connection to its duct (30, 34 or 35) and diminishing therefrom towards the closed ends of the manifold, will maintain substantially uniform pressure throughout the length of the manifold and at each air outlet therefrom to the individual burners.

When the firing rate of the furnace is reduced, the volume of combustion air flowing in the system is correspondingly reduced, causing a rise in the temperature of the air and in the metallic components of the heat-exchangers. If and when this rise in temperature reaches a predetermined temperature, the thermostatic devices (not shown, but well known in the art) are arranged to open the bleed-off valves 23 and 24 and to allow an increased flow of cold air through the heat-exchangers protecting them from dangerous over-heating. Thermostatic devices (not shown, but well known in the art) are arranged to open the bleed-off valves, in order to prevent the temperature of the air and heat-exchanger bodies from reaching excessive temperatures. As such temperature drops to a safe value, the bleed-off valves close.

While the invention is particularly designed for continuous furnaces whose combustion air is preheated in two heat-exchangers, there will be cases where the improvements may be applied to furnaces equipped either with a single heat-exchanger, or with more than two heat-exchangers. These and other modifications are contemplated within the terms of the appended claims.

1. A continuous slab-heating furnace having an elongate heating chamber for a row of steel slabs, a plurality of combustion zones located in spaced relation with respect to each other in said heating chamber, each combustion zone having a bank of burners, a combustion air manifold and a fuel supply pipe connected to the burners of each combustion zone, a heat-exchanger, means for delivering combustion air through said heat-exchanger, two ducts extending longitudinally of the furnace, said ducts being connected to said heat-exchanger for delivering heated combustion air in two separated streams along the furnace, a plurality of headers extending transversely of the furnace and being connected adjacent their opposite ends severally to the two ducts for establishing a supply of heated air derived from both of said streams, a connector duct extending from each of said combustion air manifolds to one of said headers, whereby each header is adapted to supply heated combustion air to the burners respectively associated with the manifolds, and means comprising a metering orifice and a valve arranged in spaced relation in each connector duct for regulating the flow of heated combustion air from the header to the associated manifold and its burners.

2. A continuous furnace having an elongate heating chamber for a row of articles to be heated to working temperature, a plurality of combustion zones located in spaced relation longitudinally of said chamber, a bank of burners for each combustion zone, a combustion air manifold and a fuel supply pipe connected to the burners of
each combustion zone, a flue for the hot products of combustion of the furnace, recuperators arranged in the path of flow of said hot products of combustion, means for propelling combustion air through said recuperators, two ducts connected to said recuperators and being spaced apart transversely of the furnace for leading hot combustion air from the recuperators to the combustion zones of the furnace, a plurality of transverse headers inter-connecting said two ducts, a connector duct for hot combustion air extending between each combustion air manifold and one of said transverse headers, and means comprising a metering orifice and a valve spaced downstream therefrom in each of said connector ducts for controlling the flow of hot combustion air from said transverse headers to their associated combustion air manifolds.

3. In a system for the balanced distribution of combustion air to a continuous furnace having at least two combustion zones each having a bank of burners, two laterally spaced air ducts adapted for extending longitudinally of the furnace from a supply of air under pressure, two headers spaced apart longitudinally of said air ducts, each header being connected at its opposite ends to the ducts for substantially equalizing the pressures of the air delivered to the header by said ducts, an elongate manifold for each bank of burners, said burner manifolds being substantially parallel to and spaced from said headers severally, air delivery pipes severally connecting the burners of each bank to its associated burner manifold, valves in said pipes for controlling the quantity of air flow to each burner from its manifold, a connector duct extending from intermediate the ends of each header to its associated burner manifold, and means for controlling air flow from said headers to their burner manifolds comprising a metering orifice and a valve arranged in spaced relation in each connector duct.

4. In a system for the balanced distribution of combustion air to a continuous furnace having at least two combustion zones each having a bank of burners, two laterally spaced air ducts adapted for extending longitudinally of the furnace from a supply of air under pressure, two headers spaced apart longitudinally of said air ducts, each header being connected at its opposite ends to the ducts for substantially equalizing the pressures of the air delivered to the header by said ducts, an elongate manifold for each bank of burners, said burner manifolds being substantially parallel to and spaced from said headers severally, air delivery pipes severally connecting the burners of each bank to its associated burner manifold, valves in said pipes for controlling the quantity of air flow to each burner from its manifold, a connector duct extending from intermediate the ends of each header to its associated burner manifold, and means for controlling air flow from said headers to their burner manifolds comprising a metering orifice and a valve arranged downstream therefrom in each connector duct.

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