FIG. 3

FIG. 4
AFTERBURNER SYSTEM FOR CUPOLA FURNACE
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11 Claims

ABSTRACT OF THE DISCLOSURE

An afterburner system and arrangement for cupola furnaces wherein a series of burners are arranged near the charging opening of the cupola stack and ignite and comb USB the carbon monoxide gas emitted during furnace operation as it leaves the furnace. The afterburner raises the stack gas temperature thereby permitting complete combustion of high molecular weight organic compositions and minimizing the amount of free air pulled in through the charging opening.

This invention relates to afterburner systems and more particularly to afterburner systems for use on cupola furnaces.

Until a short time ago, cupola furnace stacks were allowed to discharge their effluents directly into the atmosphere and the resultant discharge was characterized by a distinctive objectionable odor and heavy black, brown or reddish smoke from which dust deposited on nearby areas. The characteristic smoke and odor were the result of iron oxide particles plus organics and hydrocarbons that were only partially combusted within the furnace itself. With the increasing furoi over air pollution many devices have been tried in conjunction with cupola furnace stacks in an attempt to eliminate the air pollution hazard. Among some of these air pollution control devices are dust collectors, to remove ash dust, and air washers to clean the particulate material. In order to completely exhaust the stack, while these devices have been helpful in removing some of the objectionable contaminants in the cupola exhaust, they have not been completely successful. As more stringent air pollution control codes were enacted limiting the amount of contaminant that can be emitted from industrial furnaces, it has become acutely necessary to devise more efficient systems and apparatus to remove a greater proportion of contaminants from cupola furnace exhausts.

Afterburners positioned high up in the cupola furnace stack have also been tried but these, however, have not been found to be entirely satisfactory. The positioning of some of the early designed afterburners high up in the stack was believed necessary in order to sustain continuous combustion since the composition of the gaseous products of combustion vary greatly and caused blowout of the early afterburner flame at lower elevations. Further, the afterburners positioned above the charging opening were burning the stack gases mixed with the unmetered air drawn in through the charging opening. Hence, the efficiency of the afterburner combustion varied constantly. Also, the air drawn in through the charging opening had a cooling effect on the stack gases and the afterburner combustion temperatures were not high enough to burn carbon monoxide and high molecular weight organic residues. The most seriously objectionable constituents in furnace exhaust gases, which cause unwanted air pollution, are carbon monoxide (resulting from incomplete oxidation within the furnace itself) and various high molecular weight organic residues. These organic residues often result from the use of scrap metal in the furnace along with materials such as coke, flux and iron. On a great deal of this scrap metal, oil and grease and other organic material including paint and like surface coatings are present in appreciable quantities.

These grease and paint resin components have a high molecular weight and are difficult to burn completely. As differences in temperature occur in different regions of the furnace itself, the burning process is not simple; and many of these organic residues are thermally cracked, decomposed and semi-oxidized to form numerous organic derivatives. Since most cupola furnaces utilize a rapid combustion process the materials do not remain in the furnace for a long period and even if the temperature is high, there is often an insufficient oxygen supply within the furnace itself to effect the transformation and complete oxidation of these high molecular weight organic products. As a result, the oils and greases are distilled and thermally cracked but do not burn to carbon monoxide and/or carbon dioxide and water vapor. Also, due to the variation in the air supply to the furnace, the amount of oxygen available for assisting in the oxidation of these materials may be limited and compounded by the high volume of other more readily oxidizable materials present in the furnace mix.

As a result, the organic residues become cracked with formations of low molecular weight derivatives which leave the furnace in an unburned state. This results in the formation of sub-micron size liquid aerosol products which are difficult to remove in any dust collection or air washing system and thus pass through these systems to contaminate the air as they pass out of the stack.

In addition, since the combustion process within the furnace is rapid, and often there is insufficient oxygen for complete combustion, an unduly large residue of carbon monoxide passes out through the stack. This carbon monoxide can pass through the air washers and dust collection systems and, while it may be cleaned and scrubbed free of solid particulate material it nevertheless is ultimately exhausted to the atmosphere.

To minimize these emissions from cupola furnaces and to minimize such organic products, special attention must be given to systems that remove such products, as these organic products in the form of aerosols catch and retain sub-micron solid particles of other types of contaminants which would normally be removed by dust collectors and air washers. But, due to the organic aerosol spray in which these particles are carried, the particles pass through the contamination control system and exhaust into the atmosphere.

Therefore, in order to eliminate these organic materials and carbon monoxide, it is necessary to complete the combustion prior to the point where the cupola exhaust enters the dust collectors and air washers.

It is therefore an object of the present invention to provide a system in cupola furnace stacks to consume the carbon monoxide.

It is another object of the present invention to provide a system for burning completely the organic residues that are normally emitted from a cupola furnace stock.

It is still a further object of the present invention to provide an afterburner for a cupola furnace to effectively oxidize carbon monoxide and to more completely combust organic residues.

It is still a further object of the present invention to provide an afterburner system for cupola furnace stacks to complete the combustion of carbon monoxide and utilize the heat from the burning carbon monoxide and the afterburner system to complete the combustion of unburned organic residues.

Yet another object of the present invention is to provide a high efficiency afterburner system for use in
cupola furnace stacks to control the emission of pollutants therefrom.

In accordance with a preferred embodiment of the present invention, a plurality of afterburner jets are spaced at varying elevations around the rear and side portions of a cupola furnace stack in the area opposite the charging opening. The burner jets are inclined at a downward angle to direct the afterburner flame into the area immediately below the charging opening. The jets include a gas fuel supply, a furnace gas supply, and an air or oxygen supply line with appropriate valving to control the combustion mixture in the afterburner according to the character of combustion products encountered in the cupola furnace.

In the specification and in the accompanying drawings there are described and shown illustrative embodiments of the invention and various modifications thereof are suggested, but it is to be understood that these are not intended to be exhaustive, but on the contrary are given for purposes of illustration in order that others skilled in the art may fully understand the invention so that they may modify and adapt it in various forms, each as may be best suited to the conditions of a particular use.

The various objects, aspects and advantages of the present invention will be more fully understood from a consideration of the following specification in conjunction with the accompanying drawings in which:

FIG. 1 is a diagrammatical elevational view showing a cupola furnace stack, the charging opening, and the positioning of the afterburners;

FIG. 2 is a fragmentary sectional view taken on line 2--2 of FIG. 1 showing a preferred spacing for the afterburners;

FIG. 3 is an enlarged detailed view partly in section showing an afterburner of the present invention; and

FIG. 4 is a diagrammatical view showing the fuel and air supply systems for an afterburner.

Referring now to FIG. 1, there is shown a stack 10 for a cupola furnace including a row of tuyeres 12, to admit oxygen which is required for the formation of the molten zone in the cupola furnace, and a charging opening 14 to allow for the introduction of the coke, iron and flux into the furnace itself.

The charge for the cupola furnace is admitted through the charging opening 14 in any suitable manner, i.e., by a mechanical charging bucket, and drops down into the stack through the melting zone. The gaseous products of combustion rise in the stack 10 from the combustion zone, adjacent the tuyere zone near the bottom of the cupola, and up through the charge and to the top of the stack, from which they escape through air washing and dust collecting systems (not shown).

Due to the incomplete combustion and the high molecular weight organic products present with the gaseous products of combustion, the gases discharged from the stack contain an undesirable high content of carbon monoxide gas as well as sub-micron organic particulate matter. Therefore, to produce a more complete combustion of the gaseous products, a plurality of afterburner elements 16 are provided. The afterburners 16 are disposed at three elevations 15, 20 and 22 respectively, around the portion 24 of the cupola stack opposite the charging opening 14 and, illustratively, are downwardly inclined at a 30° to 60° angle in order to effectively complete the combustion of the organic residues within a short distance above the cupola furnace bed. The afterburners may, of course, be installed at lower elevations and at different angles to the stack, as desired, and at varying numbers of elevations, the important consideration being to have them effectively operate just above the tuyeres, 25° to 30° above the area immediately below the charging opening. At this point the carbon monoxide is richest since it has not been diluted by air entering through the charging opening and the temperature of the gases is at their highest level in respect to the metallurgical operation of the cupola furnace. Additionally, the combined effect of the downwardly directed afterburner jets and the combustion zone formed below the charging opening forms a screen which shields the zone below the charging opening from the diluting and cooling effect of the unmetered air being drawn through the charging opening 14. Hence, the air drawn in through the charging opening passes up the stack to assist in drawing off the gaseous products of combustion.

In a normal cupola furnace operation, there is a wide deviation in temperatures of the gases above the bed which is partly due to the manner in which the furnace is operated, particularly in respect to the rate at which air is forced into the bottom of the cupola furnace through the tuyeres. By placing the afterburners near the charging opening level and angled downward so that the flame from the afterburner penetrates to levels below the opening, but still above the furnace bed, the temperature in this zone can be more closely controlled by adjusting the intensity and number of afterburners that are operating.

The afterburners in this zone advantageously provide for a more complete combustion of the carbon monoxide. This in turn elevates the stack gas temperature, due to the heat from the afterburners and from the combustion of the carbon monoxide, which results in a more complete thermal cracking of the high molecular weight organic residues and in the organic residues burning more completely. Additionally, the higher temperatures in the afterburner region preheats the charge as it descends to the furnace bed, which improves the efficiency of the metallurgical reactions in the furnace itself.

Referring now to FIG. 3, there is shown a detail of an afterburner assembly, it being understood that the other afterburners are similar. The afterburner 16 is housed in an outer rectangular or circular jacket 26 which extends into the wall 28 of the cupola stack, and through its refractory lining 30, as well as through the outer casing 32 which may be steel or brick. Afterburner jacket 26 includes an end cover plate 34 with the burner 36 extending through cover plate 34 and directed into the interior of the cupola stack through an opening 38 in the wall of the stack 10.

The burner 36 is of generally cylindrical form and has a lower sleeve portion 39 of greater diameter than an upper portion 42 and is covered within jacket 26 with a flange plate 44, carried by the exposed end 46 of the burner, which is bolted at 48, to the end plate 34 of the jacket.

A gas fuel supply line 50 supplies the fuel gas to the burner 36. An auxiliary gas supply line 52, which draws off combustible gases from a coking oven or producer gas oven, is also provided to supply a secondary supply in the event of an emergency or to utilize combustible furnace gases produced as a by-product of other plant operations so that this gas may be used as an auxiliary fuel to augment afterburner ignition. Air under pressure is supplied from a blower 54 and an air supply line 56 to the afterburner 36 to provide a jet stream through the burner element to assist in drawing the burner fuel gases into the burner and also to supply the air needed for burner combustion and to initiate mixing of air and burner fuel gas. A pilot 57 including igniters (not shown) supplies fuel to ignite the main fuel when the afterburner is started.

Additional air to support the combustion of carbon monoxide is supplied through an auxiliary air supply line 58 which communicates with an air duct 60 in the lower portion of the jacket 26. The air duct 60 is formed in the lower portion of jacket 26 by a separation plate 62 which along with the other plate 34 and the afterburner jacket 26 forms the duct. Duct 60 communicates with the interior of the stack 10 through opening 59 and thus air drawn in through duct 60 enters the cupola stack just below the
area of afterburner combustion and allows for complete mixing with the cupola furnace products to support complete combustion of the carbon monoxide.

Insulating refractory material 64 is disposed around the smaller diameter portion of the afterburner 42 and additional insulation refractory material 65 is interposed between the sleeve walls 26 and the afterburner element 36 to preclude unwanted heat transfer from the exposed portion of the burner.

Referring now to FIG. 4, there is shown a diagrammatic representation of a portion of the cupola furnace stack and one of the afterburners, it being understood that all of the afterburners function in like manner. The afterburner unit 16 is shown extending through the wall of the cupola stack 10 in the elevation of the charging opening 14, with elevated pressure air being supplied from blower 54 to the burner 16 through line 56. The fuel gas supply from line 50 is also shown leading to the burner element and this gas supply is regulated by a control system 66 which is responsive to the temperature of the products of combustion such that when the temperature within the cupola stack in the afterburner region is high the supply of gas is lessened to reduce the afterburning effect. When a greater afterburning effect is necessary, the control system 66 automatically increases the supply of gas to the afterburner thereby increasing the capacity of the afterburner to burn the products of combustion. The auxiliary furnace gas supply line 52 is similarly controlled by a control system 68 to supply gas from the auxiliary supply to the afterburner as needed. The air supply through line 58 to the afterburner jacket lining 26 is also regulated by a control unit 70 which is responsive to the carbon monoxide content of the cupola furnace exhaust in order to meter the necessary amount of air to support complete combustion of the carbon monoxide. The respective control units 66, 68 and 70 also include safety devices responsive to furnace conditions which automatically shut off the supply of air and gas in the event there is a blowout in the cupola furnace or any other hazardous condition which would be aggravated if the afterburner were to continue operating.

It is thus seen that the apparatus of the present invention provides for improved cupola furnace operation by markedly reducing the emission of carbon monoxide and unburned organic residues to reduce the air polluting effect of the furnace. Additionally, by utilizing the afterburners to combust unburned carbon monoxide the carbon monoxide is effectively used as a fuel to raise the temperature of the stack gases. This higher temperature results in the complete burning of high molecular weight organic residues and also aids in pre-heating the charge as it descends through the cupola stack to improve the efficiency of the metallurgical reaction carried out in the cupola furnace.

By orienting the afterburner jets so that the flame from the jets impinges on the area immediately below the charging opening the dilution of gases from the furnace bed by air entering through the charging door is avoided. The afterburning is accomplished before the stack gases reach the charging opening level and thus the stack gases are not cooled and diluted by the unmetered air entering at the charging opening so that a more controlled burning can be effected.

Additionally, the higher stack gas temperatures created by the afterburners and the combustion of unburned carbon monoxide activate other solid emission products such as iron oxide and create higher gas temperatures in the stack gases that enter the associated washing and scrubbing apparatus. The higher temperature gases in the spray washers as described in commonly assigned and co-pending application to Arnold et al. Ser. No. 586,812, filed Oct. 14, 1966, now abandoned in favor of continuation application Ser. No. 719,767, filed Apr. 8, 1968 and issued as Pat. No. 3,475,881 on Nov. 4, 1969, create a shock cooling effect which enhances the ability of the washing and scrubbing apparatus to remove solid particulate material.

Thus, the overall effect is to remove greater quantities of carbon monoxide and organic residues and additionally allow for more effective removal of solid particulate matter resulting in cleaner stack emission. What is claimed is:

1. In a cupola furnace having a furnace bed, a furnace stack and a charging opening within said stack at an elevation above said furnace bed, the improvement comprising:

   at least one afterburner jet directed into said stack below the top portion of said charging opening to provide heat for more complete combustion of the products of combustion from said furnace, and control means for said jet responsive to the composition of the combustion products to vary the extent of afterburning according to the composition of the products of combustion.

2. The apparatus of claim 1 wherein there are a plurality of afterburner jets spaced around the circumference of said cupola stack at the elevation of said charging opening, said afterburner jets being inclined downwardly thereby to project an afterburner flame into the stack to an elevation immediately below said charging opening whereby the afterburners give complete combustion in the gases before emanating from said cupola furnace and before said products are diluted and cooled by air entering through said charging opening.

3. The apparatus of claim 1 wherein said afterburner comprises a housing adapted to extend into the wall of said cupola stack, a generally cylindrical burner element within said housing, fuel gas supply means communicating with said burner element and means to supply a quantity of air to support afterburner combustion.

4. The apparatus of claim 3 including means to supply air to the interior of the cupola stack at an elevation below said afterburner to support combustion of the gases emanating from said cupola furnace.

5. The apparatus of claim 4 wherein said means to supply air comprises a duct within said housing positioned below said burner element and communicating with the interior of said cupola stack, said means to supply air including control means to supply metered quantities of air to said stack responsive to the composition of said gases from said cupola furnace to support a predetermined level of combustion.

6. The apparatus of claim 4 wherein said fuel gas supply means includes a first supply line adapted to deliver fuel gas to said burner element, said gas supply being responsive to control means to regulate the rate of gas supply according to a predetermined afterburner combustion level.

7. The apparatus of claim 6 including a second gas supply line adapted to deliver an auxiliary supply of fuel gas to said burner element, said second gas supply being responsive to control means to regulate the rate of gas supply according to a predetermined afterburner combustion level.

8. A method of reducing the air pollution effects of exhaust gases emanating from a cupola furnace comprising:

   combusting unburned carbon monoxide in a cupola furnace stack, said combustion process being initiated by afterburners directed into said stack below the top portion of the charging opening of said stack, utilizing heat from combustion of fuel gas supplied to the afterburner and from combustion of unburned carbon monoxide to ignite high molecular weight organics in the cupola furnace exhaust gases.

9. The method of claim 8 wherein the rate of combustion in the afterburner is varied in response to the
composition of cupola furnace exhaust gases in said cupola furnace stack.

10. The method of claim 8 which further includes adding a metered supply of air to the stack below said afterburner to support combustion and to closely control the rate of afterburner combustion.

11. The apparatus of claim 1 wherein said afterburner jet is directed to project a flame into the stack below said charging opening.

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