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(54) Furnace waste gas combustion control

(57) A furnace waste gas combustion control system includes an exhaust gas analyser 80 and control apparatus 82 for analysing components of the exhaust gas and initiating control over fuel/oxygen and/or air supply, thereby to ensure complete combustion of undesirable components in the exhaust gas G.

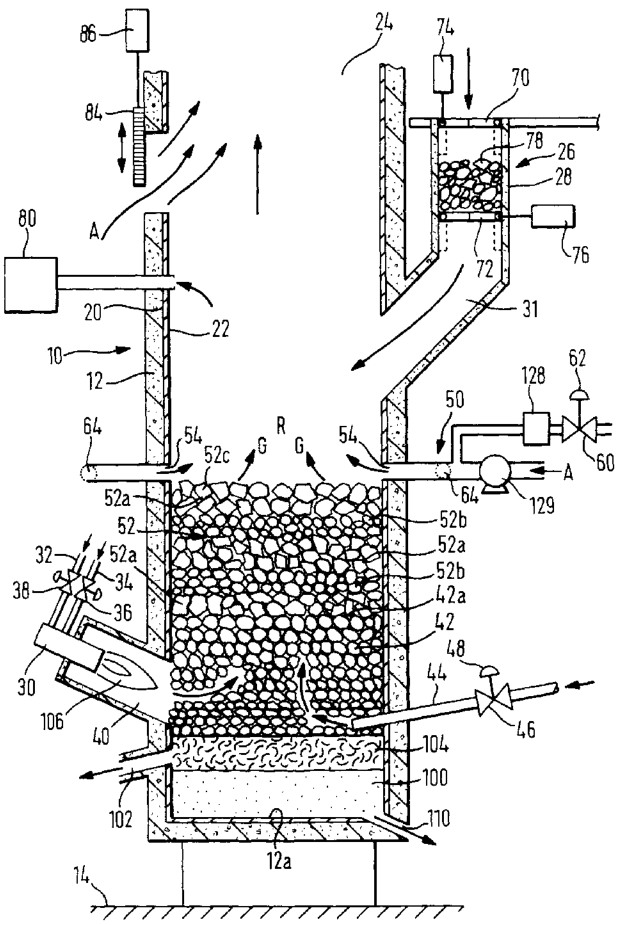

FIG. 1

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Description

The present invention relates to an apparatus and method of operating a coke consuming furnace and relates particularly, but not exclusively, to a waste gas combustion control system for a cupola or similar furnace.

Cupolas are widely used in foundries to melt pig iron, scrap iron and steel scrap or mixtures thereof. In order to operate a conventional cupola, a red hot bed of coke is established at its bottom. The coke bed is maintained at the desired temperature by supplying an air blast through tuyeres which direct the air at relatively low velocity into the bed. A charge comprising alternate layers of metal to be melted and coke is fed into the shaft of the cupola. Hot gases created by the exothermic reaction of the air blast with the coke bed flow upwards through the shaft of the cupola and heat the metal by convection sufficiently for a region of molten metal to be created immediately above the coke bed. The molten metal percolates through the coke bed and is superheated by radiation from the coke. From time to time molten metal is tapped off from the bottom of the cupola into a ladle for use in the foundry. Alternatively, the molten metal may be continuously tapped and collected in a suitable receiver. Although the coke in the bed is progressively consumed by the reaction with the oxygen component of the air blast, the coke layers in the charge will replenish the bed and the coke bed is maintained at an adequate depth throughout the operation of the cupola. It is also conventional to include within the charge limestone or other slag-forming agent, ferrosilicon or other suitable ferroalloys so as to improve the metallurgical properties of the metal during the melting operation.

Whilst the above mentioned cupola provides a relatively efficient method of melting scrap iron, it does suffer from one major disadvantage, mainly that there is emitted from the top of the cupola a visible smoke or fume which is heavily laden with particles. Although it is possible to treat such smoke or fume to reduce its content of particles so as to render it less suitable for discharge to the atmosphere, the cost of so doing is high.

A cupola which aims to at least reduce the above mentioned disadvantages is described in EP-A-0554022 which provides a method of operating a vertical shaft furnace comprising, establishing a hot coke bed in a bottom region of the furnace; charging the furnace with metal to be melted and with coke; burning at least one stream of fuel with a stoichiometric excess of oxygen over that required for complete combustion of the fuel and thereby forming a hot gas mixture including oxygen; introducing the hot gas mixture into the shaft furnace and allowing it to pass upwardly through the charge in the furnace, oxygen for the hot gas mixture thereby reacting with the coke charge such that a part of the coke charge is consumed, heat being provided to the metal via the hot gas mixture and by said reaction between the oxygen and the coke being sufficient to melt the metal without there being an air blast supplied to the furnace, and the molten metal so formed flowing downwardly under gravity through the hot coke bed; introducing at least one jet oxygen or oxygen-enriched air into the said hot coke bed so as to maintain the bed at a temperature sufficient to superheat the molten metal as the molten metal passes through the hot coke bed; and discharging superheated molten metal from the furnace.

The apparatus of the above mentioned patent provided that the significant reduction in visible fume emitted therefrom, in comparison with conventional hot blast and cold blast cupolas, was attributable to an ability (through the combustion of said at least one stream of fuel) to generate a high temperature of oxygen-containing gas mixture. This gas mixture is typically produced at a temperature of from 900°C to 1100°C. Such temperatures are well in excess of those at which the air enters the shaft of a conventional hot blast or cold blast cupola. This high temperature is conducive to the creation of conditions in which gas-borne particles of coke and the like are more readily oxidised to gaseous products than in conventional arrangements, with the result that the amount of visible fume emitted from the cupola shaft is significantly reduced.

It is an object of the present invention to improve still further the cleaning up of exhaust gases emitted from such cupolas.

Accordingly, the present invention provides a method of operating a coke consuming furnace comprising the steps of establishing a hot coke bed towards the bottom of the furnace; charging the furnace with metal to be melted, thus establishing a layer of metal to be melted immediately above the hot coke bed; introducing an oxygen-containing gas stream into the hot coke bed, thereby to react with the coke such that part of the coke charge is consumed, an exhaust gas produced and heat provided to the metal by said reaction such as to melt the metal; allowing molten metal so formed to flow downwardly under gravity through the hot coke bed and extracting said molten metal from the furnace; characterised by the further steps of determining the temperature, and measuring at least one of the CO, CO_2 or O_2 component levels within the exhaust gas and altering the oxygen concentration within the exhaust gas by introducing in a controlled manner a further quantity of oxygen-containing gas at one or more points positioned, below, in or above the charge thereby to cause any exhaust gas CO to react with the introduced O_2 to form CO_2, and combustion destruction of carbon particles or other combustibles within said exhaust gas.

Preferably, a measured component comprises CO and the further quantity of oxygen-containing gas is increased in proportion to any increase in the quantity of detected CO over and above a predetermined level, which is preferably less than 1%, and more preferably about 200ppm.

The CO component level may be measured at the furnace exhaust gas outlet.

The method may comprise measuring the O_2 component level within the exhaust gas, and adjusting the quantity of oxygen-continuing gas introduced so as to maintain the O_2 level within the range 5% to 15%, more preferably between 8% and 10%. Again, the O_2 component level may be measured at the furnace exhaust gas outlet.

The oxygen-containing gas is preferably introduced into the furnace above the upper surface of the charge within the furnace, and directly into the exhaust gas. Suitably, this oxygen-containing gas is air or air-enriched with between 1% and 10% O_2, preferably between 2% and 4% O_2.

Advantageously, the method includes the step of monitoring the exhaust gas temperature and initiating control over a heating means for raising the temperature thereof should it be monitored as falling towards a predetermined value.

Preferably, the predetermined value of exhaust gas temperature is equal to or greater than 500°C.

Preferably, control is initiated over a heating means in the form of an air or oxy/fuel burner also employed for creating a hot oxygen rich exhaust gas which is directed for passage upwardly through the coke charge thereby to allow some excess oxygen to react with the coke charge such that part of the coke charge is consumed and heat is generated in excess of that necessary for metal melting and thereby causes a rise in the exhaust gas temperature.

Preferably, control is initiated over said heating means in advance of the exhaust gas temperature reaching said predetermined minimum temperature and the rate of supply of any fuel/air and/or oxygen thereto is controlled in accordance with a predetermined operating characteristic.

Advantageously, the method includes the step of introducing a further charge of coke and metal into the furnace whilst excluding or substantially excluding any ingress of air therewith.

Conveniently, the method includes the step of introducing the further charge through a lock hopper having inner and outer doors and said charge is isolated from the external atmosphere before the inner doors are opened and the charge introduced to the furnace.

The said exhaust gas temperature to be determined is preferably measured at a point substantially level with the lowermost portion of the charge door through which charges of metal and coke are introduced into the furnace. These charges are preferably added so as to maintain the mean upper surface of the charge in the furnace at least 1m, and preferably 2m, below the lowermost portion of the charge door, oxygen-containing gas being introduced into the exhaust gas above the upper surface of the charge in the furnace. This allows the carbon monoxide in the upwardly-moving exhaust gas sufficient time to react with the introduced oxygen to form carbon dioxide; the addition of oxygen-containing gas is controlled, by monitoring the exhaust gas temperature at the lowermost edge of the charge door, so that between 25% and 100% of the carbon monoxide is converted to carbon dioxide. Preferably 50% to 90% of the carbon monoxide is converted to carbon dioxide, leaving at least a small amount of carbon monoxide in the exhaust gas at the level of the lowermost edge of the charge door; this is advantageous, since it is difficult to ensure that the charge door is perfectly sealed, and therefore a small amount of air can be allowed to enter the furnace through the charge door, and the amount of this air can be maintained sufficiently small as to react with the small amount of carbon monoxide remaining in the exhaust gas so as to convert substantially all of it to carbon dioxide.

Additionally or alternatively, the exhaust gas temperature is measured at the exhaust gas outlet from the furnace, the further quantity of oxygen-containing air being introduced into the exhaust gas in proportion to the measured temperature being less or greater, respectively, than a predetermined range. This predetermined range is 600°C to 900°C, preferably 650°C to 850°C.

In systems in which the exhaust gas is conveyed through ductwork to a dust collection device, the temperature of the exhaust gas passing through the ductwork may be measured and air admitted into the ductwork at a point upstream of the furnace exhaust gas outlet and downstream of the location at which the said temperature is measured in order to control the temperature at which the exhaust gas enters the dust collection device.

The present invention will now be more particularly described by way of example only with reference to the accompanying drawings in which:

Figure 1 is a cross sectional view of a cupola in accordance with the present invention;

Figure 2 is a schematic representation of the control system of the present apparatus;

Figure 3 is a diagrammatic representation of a cupola according to the present invention in combination with a filtration system; and

Figure 4 is a diagrammatic representation of a further embodiment of a cupola in accordance with the present invention, in combination with filtration system.

Referring to Figure 1, a cupola 10 comprises a vertical shaft 12 extending from a floor 14 and towards an exhaust gas outlet 16 (best seen in Figure 3). The shaft 12 is defined by a cylindrical wall 20 formed of a refractory brick with an inner refractory lining 22 typically of a silica-based refractory. The top of the cupola 10 forms an outlet 24 for hot gases. The cupola 10 has a charge door arrangement shown generally at 26 which comprises a lock hopper and chute arrangement 28, 31 to be described in detail later herein. The cupola 10 is further provided with a plurality of oxy/fuel burners one of which is shown at 31. Each burner comprises a supply of oxygen and fuel 32, 34 and suitable control valves 36, 38 for controlling the flow thereof to burner 30. Each burner is positioned for creating a hot combustion exhaust gas stream in a plenum chamber 40 adjacent the coke bed 42 thereby to allow for the production of a fully developed exhaust gas stream prior to its introduction into the coke bed for reasons which will be described later in detail later herein. Towards the bottom of coke bed 42 there is provided a lance 44 for the introduction of oxygen, oxygen-enriched air or natural air to the base of the coke bed 42. A suitable control valve 46 and actuator 48 are provided when initiating and maintaining control over the flow to lance 44. A further oxygen supply arrangement 50 is provided immediately above the level of any charge 52 within the cupola itself. Arrangement 50 comprises a plurality of apertures 54 circumfrentially spaced around the circumference of the cupola for allowing the introduction of air or oxygen-enriched air (up to 50% but preferably between 20 and 30% oxygen) into the exhaust gas G virtually as soon as it passes from charge 52. As shown in Figure 1, the arrangement 50 might conveniently comprise supply pipe 56 connected to a source of liquid oxygen (best seen in Figure 2) and a control valve and actuator arrangement 60 and 62 respectively which controls the flow of oxygen to an annular supply duct 64 from which each of inlets 54 are fed. The lock hopper arrangement 26 comprises a first and second pair of doors 70, 72 and suitable actuators 74, 76. In use, the lower doors 72 are moved to their closed position and a charge 78 of scrap metal and coke is passed through open doors 70 which are then closed therebehind. Once the charge is loaded into the lock hopper and the doors closed therebehind little if any air will be drawn into the cupola when the charge is introduced. Consequently, little if any cooling of the furnace exhaust gas G will take place during the introduction of a fresh charge. The advantages of this arrangement are explained in more detail later herein. An exhaust gas analyser, shown schematically at 80 is provided for analysing the exhaust gas and determining one or more of the temperature, carbon monoxide, carbon dioxide and oxygen component levels thereof. The analyser itself is operably linked to a central control apparatus shown at 82 in Figure 2 which initiates control over the flow of fuel and/or oxygen into the apparatus in a manner to be described in detail later herein. Means, shown schematically in the form of opturator door 84 and actuator 86 are provided for allowing or inhibiting the introduction of ambient air into the exhaust gas at a point downstream of the oxygen injection thereby to facilitate dilution thereof and the reduction in its temperature.

In order to operate the cupola 10 of Figures 1 and 2, a bed of silica sand is established on the floor 12a of the furnace up to the level of the bottom of a tap hole 102 from which slag 104 can be removed from the furnace. The coke bed 42 is then established to a level 42a above the burner 30 by introducing coke into the cupola 10 through lock hopper 26. The bed 42 is then ignited by burner 30 or by means of a gas poker (not shown) which can be introduced into the bed 42 through a bottom door (not shown) in the side of the cupola 10. Next, normal operation of burner or burners 30 is commenced such as to produce a hot exhaust gas 106 within the plenum chamber 40 and then introducing this into the hot coke bed 42. Burners 30 are capable of being operated with excess air or oxygen, that is to say with air or oxygen at a rate in excess of the stoichiometric requirement for complete combustion of the fuel. The walls of the cupola are pre-heated by hot combustion products from burners 30 for a period of up to 30 minutes. During this period no excess air is supplied to the burners 30. Five minutes before the end of this period, injection of pure oxygen into the coke bed 42 via lances 44 is commenced. The injection of oxygen into the coke bed 42 accelerates the rate of combustion of the coke and causes it temperature to rise rapidly. During the final 5 minutes of pre-heating the coke bed is made up again to the level at which combustion was commenced. At the end of pre-heating, the cupola 10 is loaded through lock hopper 26 with a charge 78 comprising scrap iron and coke and possibly steel, ferrosilicon and limestone or other slagging agent. This charging is performed such that layers of metal alternate with layers of coke. The top layer of the charge is arranged to be below the level of inlets 54.

In operation of the cupola 10 to melt the ferrous metal, the combustion air to burner 30 is preferably enriched in oxygen. In addition, the burners 30 are operated with up to 100% excess air or enriched air/oxygen. The flame 106 of each burner 30 quickly extends into plenum chamber 40 such that a hot gas mixture including oxygen leaves each flame and ascends the cupola 10, thereby heating the ferrous metal by convection. In addition, the oxygen in the hot gas mixture reacts with coke to generate additional heat. The resulting hot gas mixture emanating from the top of the charge will typically have a temperature well in excess of 500°C and normally above 750°C comprises a number of components to be described in detail later herein. The molten metal in the lowest of the layers begins to melt by virtue of being heated by the hot gas mixture leaving the burners 30. A region of molten metal is thus created and the limestone reacts with ash in the coke to form a slag. The molten metal falls under gravity into the coke bed 42 and trickles therethrough. Typically, the molten metal is in a super heated state as it encounters coke bed 42. During its residence in bed 42 the molten ferrous metal is further superheated by radiant heat emanating from the coke which is maintained at a suitably high temperature by the continuous injection of oxygen at high velocity through lances 44. A small amount of the coke is dissolved in the molten ferrous metal, thereby increasing its carbon content to a predetermined level. In addition, the silicon also dissolves in the ferrous metal. If desired, the carbon level of the ferrous metal can be further enhanced by direct introduction of graphite into the molten metal through a port (not shown) specially adapted for this purpose. If the temperature of the molten metal is sufficiently high, there will also be a reduction of silica at the interface between the coke and molten slag 104 with the result that additional silicon is incorporated into the molten ferrous metal. The molten metal and the slag 104 may be run off through respective holes 110 and 102. It can therefore be appreciated that the charge will gradually sink downwards through the cupola 30. In addition, the reaction between the oxygen and the coke in bed 42 will cause gradual erosion of the bed. However, the height of the bed is restored each time melting of a layer of metal is completed since the next coke layer then merges with bed 42. In order to enable molten metal to be produced throughout a chosen period of time, fresh charges are periodically loaded into the cupola through lock hopper 26. It has been observed that tap temperatures in the order of 1500°C have been maintained over a period of time, whilst being able to operate the cupola with a maximum rate of production of molten metal some four times in excess of a minimum rate.

Turning now more specifically to aspects of the present invention, it will be appreciated that the off-gas G from the top of bed 52 will contain a number of different components. Typically, this exhaust gas will include carbon monoxide, carbon dioxide, nitrous oxide, sulphur dioxide, carbon particles and other combustibles. These component levels, together with the temperature of the exhaust gas, are monitored by exhaust gas analyser 80 positioned above the top of the charge bed itself. As best seen in Figure 2, exhaust gas analyser 80 is operably linked to a central control apparatus shown schematically at 82. The controlled apparatus 82 is operably linked for initiating control over valves 46, 60, 36 and 38 via actuators 48, 62,120 and 122. The rate of oxygen and/or fuel supplied to various portions of the cupola 10 may therefore be controlled in accordance with predetermined operating requirements. Also shown in Figure 2 are sources of oxygen or oxygen-enriched air 124 for supply to valves 46, 60 and 36 together with a source of fuel 126 for supply to valve 38. If the source of oxygen is a liquefied source, vaporisers 128, 130 and 132 are provided downstream of their respective valves 60, 46 and 36 to allow the vaporisation of the oxygen prior to its delivery. The source of fuel 126 may be liquid or gaseous and hence, where appropriate, a pump 140 may be provided for pumping the fluid to valve 38. Each of actuators 74, 76 and 86 are operably connected to central controller 82 which initiates operation thereof in a manner described in detail later herein.

Operation of the control system shown generally in Figure 2 comprises the steps of monitoring the various components of the exhaust gas and adjusting the flow of oxygen, fuel and/or air as and when necessary. In more detail, the control system 82 must achieve two main functions. Firstly, it must operate such as to ensure the exhaust gas G entering region R (adjacent inlets 54) is above the auto ignition temperature of any of the exhaust gas components so as to facilitate the complete combustion thereof. Secondly, it must ensure that sufficient free oxygen is available within this region to facilitate combustion or reaction of the undesirable components. The temperature of the exhaust gas within region R can be maintained in any one of a number of different ways. For example, the apparatus can be operated so as to increase the quantity of fuel and/or oxygen or oxygen-enriched air to burner 30, thereby creating an increase in the temperature of the gas stream emanating therefrom or providing excess oxygen to the coke bed for reaction therein and the production of extra heat. This gas mixture is typically produced at a temperature of from 900°C to 1100°C and causes a consequential increase in the temperature of coke bed 42 and hence exhaust gas G. To some extent, the exhaust gas temperature can be increased by supplying additional oxygen through inlet 54 such as it reacts exothermically with any carbon monoxide contained in the exhaust gas. This heating effect is however not as significant as the prior mentioned method. Preferably, the control apparatus 82 is operable to monitor the temperature of the exhaust gas and initiate control so as to raise the temperature thereof in advance of the temperature falling below a predetermined value. Modern control systems well known to those skilled in the art and therefore not described in detail herein, may be employed to ensure efficient and accurate temperature control is achieved without wasting fuel and/or oxygen. Side by side with the temperature control steps, control system 82 is employed to monitor one or more of the remaining component levels and initiate further control over the system to ensure destruction of any undesirable components. For example, the level of carbon monoxide in the exhaust gas can be monitored and the oxygen supply adjusted accordingly. When excess carbon monoxide exists the exhaust gas effectively produces a reducing atmosphere and, when the CO is reduced to low levels, all the combustibles are essentially removed burning (provided the temperature in region R is above the auto ignition temperature thereof. The reaction of carbon monoxide with oxygen is exothermic and is easily mixed with the further carbon dioxide being emitted in the exhaust gas. Once a carbon monoxide has been reacted to CO_2, any further oxygen introduced into region R is available for the combustion destruction of any carbon particles or other combustibles within the exhaust gas. Control of any additional oxygen over and above that required to react carbon monoxide to carbon dioxide is particularly important as oxygen is expensive and any wasting thereof has a significant impact on the economic operation of the cupola itself. In practice the control system 82 is operated so as to ensure substantially complete reaction of carbon monoxide to carbon dioxide, substantially complete combustion of any carbon particles or other combustibles in the exhaust gas by the supply of additional oxygen whilst eliminating the supply of oxygen over and above this requirement. If the oxygen level in region R is too high, the control system automatically adjusts the supply rate thereby eliminating wastage thereof. This process, in combination with the maintenance of a temperature in region R equal to or greater than that of the auto ignition temperature of the undesirable component in the waste gas G is effective to result in an exhaust gas having virtually no visible smoke.

Whilst it will be appreciated that control of the oxygen supply can be initiated upon detection of any particular carbon monoxide level, it has been found that levels of 100 to 1000 ppm and preferably 500 ppm are particularly convenient levels to employ in the control system. Also, whilst it will be appreciated that the auto ignition temperature is different for each component, components such as simple oils and the like can be destroyed at temperatures as little as 500°C. Consequently, if it is desirable to ensure destruction of just simple components, the temperature in the region R may be maintained at or above a temperature as low as 500°C. Combustion of more complex components may require a much higher temperature and hence operation up to and including 1100°C in region R is also encompassed by the present invention. Simple oils and the like need only 200 to 300°C.

Referring now to Figure 4, an apparatus comprising a cupola 10 in combination with a dust collection device, or filtration system 150 which is in accordance with the present invention is shown. Three exhaust gas analysers 80a, 80b and 80c are provided. The first exhaust gas analyser 80a measures the temperature T_1 of the exhaust gas in the furnace, as will be further described below. The second exhaust gas analyser 80b measures the temperature T_2 of the exhaust gas, its carbon monoxide content and its oxygen content, all at a point adjacent the furnace exhaust gas outlet 24. The third analyser 80c measures the exhaust gas temperature T_3 in the ductwork leading from the furnace outlet 24 to the inlet to the dust collection device 150.

In normal operation of the apparatus of Figure 4, the composition of the exhaust gas immediately above the surface of the charge 52 is principally carbon monoxide and nitrogen; the amount of carbon monoxide is dependent on the ratio of the coke to charge, the carbon monoxide level usually being between 15% and 30%. The temperature of the exhaust immediately above the charge 52 is normally over 750°C.

Oxygen-containing gas is admitted via arrangement 50 as described above. This gas is air, preferably air enriched with between 1% and 10% oxygen, more preferably 2% to 4% oxygen, the precise amount of oxygen enrichment being calculated to ensure that between 25% and 100% (and preferably between 50% and 90%) of the carbon monoxide is converted to carbon dioxide. It is advantageous to provide a slightly sub-stoichiometric amount of oxygen in the gas admitted through arrangement 50, so that most but not all of the carbon monoxide is converted to carbon dioxide. This allows for the remaining carbon monoxide to be converted to carbon dioxide by reacting with any air which leaks into the furnace 10 via the charge door 26a; it is more convenient and/or less difficult and expensive to allow for a small amount of air leakage through the charge door 26a, than to provide an air-tight sealing arrangement thereat.

The $CO \rightarrow CO_2$ reaction occurring above the surface of the charge 52 raises the temperature of the exhaust gas and the measured temperature T_1 is indicative of the extent to which that reaction has been completed. As is explained above, the control apparatus 82 is operative to adjust the furnace conditions to achieve a predetermined temperate measurement T_1 which is indicative of the extent of completion of the $CO \rightarrow CO_2$ reaction. In the event T_1 falls unduly, allowing the charge to combust so that the charge level falls will encourage T_1 to rise. The furnace is charged so as to maintain a set distance D between the lower edge of the charge door and the upper surface of the charge 52. This distance is preferably 2m, and in any event not less than 1 m, in order to allow nearly all combustion of the carbon monoxide with the gas injected through arrangement 50 to form carbon monoxide to take place before the upwardly-rising exhaust gas reaches the lower edge of the charge door 26a.

The ingress of air through the charge door 26a is reduced and/or controlled by the design of the lock hopper 26 or other suitable known device and by balancing the draft on the stack 160 so as to reduce the negative pressure at the furnace outlet 24, as is known in the art. Preferably the charge door 26a is made as small as possible, in order to be able more accurately to predict/control the ingress of air therethrough.

The addition of more air into the exhaust region allows the substantial completion of the $CO \rightarrow CO_2$ reaction. This exothermic reaction also consists in the combustion of other combustibles within the exhaust gas.

The second exhaust gas analyser 80b measures the temperature and carbon monoxide and oxygen levels in the exhaust gas at or adjacent the furnace outlet 24. The temperature level should be in the range 600°C to 900°C, preferably 650°C to 850°C. The carbon monoxide level should be less than 1%, preferably less than 200ppm (although in practice it has been found that a carbon monoxide level of about 100ppm can be consistently achieved using the method of the present invention). The oxygen level should be in the range 5% to 15%, and preferably between 8% and 12%. In order to achieve/maintain these levels, the oxygen-containing gas admitted through arrangement 50 is varied, by varying the volume of air admitted and/or by varying the amount of oxygen-enrichment thereof; allowing a certain amount of air to enter the ductwork via arrangement 90 will also have some small effect on the temperature and composition of the exhaust gas, however, in practise these are primarily adjusted by varying the oxygen-containing gas admitted through arrangement 50.

Maintaining the exhaust gas temperature and composition levels within the ranges stated above (as measured at the furnace outlet 24) ensures that substantially all of the carbon monoxide is converted to carbon dioxide and nearly all other combustibles such as fine coke particles, droplets of oil, greases and other hydrocarbons and their vapours emitted from the cupola 10 are burned before the exhaust gas enters the dust collection device 150. the CO level in the exhaust gas at the furnace outlet 24 is indicative of the extent to which the other combustible components have been burned. A low CO level is also desirable in itself, to avoid the risk of fire or an explosion resulting from the $CO \rightarrow CO_2$ reaction in the device 150. The volatile constituents, which are largely the cause of undesirable smoke and odour, are, when solid or liquid in form, generally smaller than 20µm, and the above method of operation substantially eliminates all such small particles leaving only 'grits' (ie particles greater than 20µm in size) to be dealt with by the dust collection device 150. since the dust collection device 150 need only deal with such 'grits' (eg oxides of iron, silicon or aluminium and large particles of carbon), and not with smaller particles or other volatile and potentially dangerous and/or undesirable constituents, the device 150 may be simpler in design and hence less expensive. Moreover, the combustion of the volatile constituents of the exhaust gas reduces condensation and the risk of fire or explosion in the dust collection device 150.

The actuation of the air-admitting arrangement 90 is primarily in response to the temperature T_3 measured by analyser 80c, the amount of air admitted being varied so as to control the temperature of the exhaust gas entering the dust collecting device 150, in combination with the cooling of the exhaust gas by conduction with the ductwork as it flows towards the device 150, so as to ensure the exhaust gas entering the device 150 does so at a predetermined temperature, or within a predetermined temperature range, thus allowing the device 150 to operate efficiently. The air admitted via arrangement 90 is able to cool the exhaust gas efficiently, since as described above the processes of combustion are substantially complete by the time the exhaust gases reaches the furnace outlet 24; the addition of air via arrangement 90 is therefore only beneficial, and there is no risk that this might cause fire or an explosion.

It has been found that the method in accordance with this invention is applicable to all types of furnace, including both conventional cupola furnaces and cupola furnaces of the type described in EP-A-0554022.

Claims

1. A method of operating a coke consuming furnace comprising the steps of:

establishing a hot coke bed towards the bottom of the furnace;

charging the furnace with metal to be melted and coke, thus establishing a layer of metal to be melted immediately above the hot coke bed;

introducing an oxygen-containing gas stream into the hot coke bed, thereby to react with the coke such that part of the coke charge is consumed, an exhaust gas produced and heat provided to the metal by said reaction such as to melt the metal;

allowing molten metal so formed to flow downwardly under gravity through the hot coke bed and extracting said molten metal from the furnace;

characterised by the further steps of:
determining the temperature and measuring at least one of the, CO, CO_2 or O_2 component levels within the exhaust gas and altering the oxygen concentration within the exhaust gas by introducing in a controlled manner a further quantity of oxygen-containing gas at one or more points positioned, below, in or above the charge thereby to cause any exhaust gas CO to react with the introduced O_2 to form CO_2, and combustion destruction of carbon particles or other combustibles within said exhaust gas.

2. A method as claimed in Claim 1 including the step of introducing a further charge of coke and metal into the furnace whilst excluding or substantially excluding any ingress of air therewith.

3. A method as claimed in Claim 2 in which the further charge is introduced through a lock hopper having inner and outer doors and said charge is isolated from the atmosphere before the inner doors are opened and the charge introduced to the furnace.

4. A method as claimed in Claim 2 or Claim 3 wherein the said exhaust gas temperature is measured at a point substantially level with the lowermost portion of the charge door through which charges of metal and coke are introduced into the furnace.

5. A method as claimed in any one of Claims 2 to 4 comprising charging the furnace so as to maintain the upper surface of the charge therein at least 1 m,

preferably 2m, below the lowermost portion of the charge door through which charges of metal and coke are introduced into the furnace.

6. A method as claimed in any preceding Claim comprising measuring the CO component level within the exhaust gas and introducing a further quantity of oxygen-containing gas in proportion to any increase in the measured CO over a predetermined level.

7. A method as claimed in Claim 6 in wherein the predetermined CO level is less than 1%, and preferably 200ppm.

8. A method as claimed in Claim 6 or Claim 7 wherein the CO component level is measured at the exhaust gas outlet from the furnace.

9. A method as claimed in any preceding Claim comprising measuring the O_2 component level within the exhaust gas and increasing or reducing the further quantity of oxygen-containing gas introduced in proportion to the measured O_2 component level being less or greater, respectively, than a predetermined range.

10. A method as claimed in Claim 9 wherein the predetermined O_2 range is 5% to 15%, and preferably 8% to 10%.

11. A method as claimed in Claim 9 or Claim 10 wherein the O_2 component level is measured at the exhaust gas outlet from the furnace.

12. A method as claimed in any preceding Claim wherein the further quantity of oxygen-containing gas is introduced into the furnace above and in proximity to the upper surface of the charge within the furnace and into the exhaust gas.

13. A method as claimed in Claim 12 wherein the oxygen-containing gas is air enriched with between 1% and 10% O_2 preferably between 2% and 4% O_2.

14. A method as claimed in any preceding Claim comprising measuring the exhaust gas temperature within the furnace and initiating control over a means for raising the temperature thereof should it fall towards a predetermined value.

15. A method as claimed in Claim 14 in which the predetermined value is equal to or greater than 500°C.

16. A method as claimed in Claim 14 or Claim 15 wherein the means for raising the temperature comprises the means for introducing said further quantity of oxygen-containing gas.

17. A method as claimed in Claim 14, Claim 15 or Claim 16 comprising initiating a heating means in the form of a burner for introducing a quantity of heating gas either directly or indirectly into the exhaust gas.

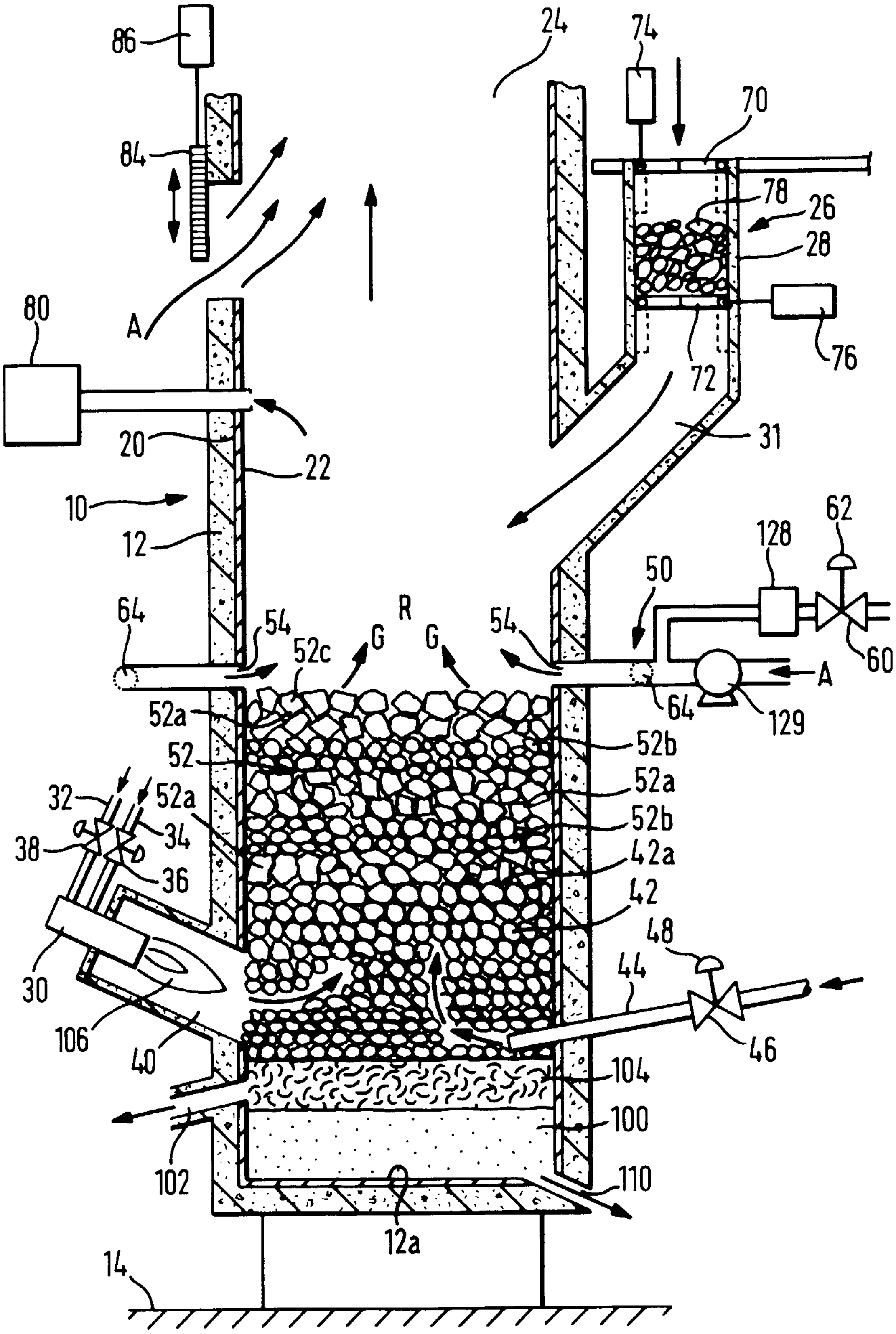
18. A method as claimed in Claim 16 in which control is initiated over a heating means in the form of a burner also employed for creating a hot oxygen rich exhaust gas which is directed for passage upwardly through the coke charge thereby to allow some excess oxygen to react with the coke charge such that part of the coke charge is consumed and heat is generated in excess of that necessary for metal melting and thereby causes a rise in the exhaust gas temperature.

19. A method as claimed in Claim 17 in which control is initiated over said heating means in advance of the exhaust gas temperature reaching said predetermined minimum temperature and the rate of supply of any fuel and/ or oxygen and/or air thereto is controlled in accordance with a predetermined operating characteristic.

20. A method as claimed in any preceding Claim comprising measuring the exhaust gas temperature at the furnace exhaust gas outlet and increasing or reducing the further quantity of oxygen-containing gas introduced into the exhaust gas in proportion to the measured temperature being less or greater, respectively, than a predetermined range.

20. A method as claimed in Claim 19 wherein the predetermined range is 600°C to 900°C, preferably 650°C to 850°C.

21. A method as claimed in any preceding Claim wherein the exhaust gas is conveyed through ductwork to a dust collection device, the method comprising measuring the temperature of the exhaust gas passing through the ductwork and admitting air into the ductwork at a point upstream of the furnace exhaust gas outlet and downstream of the location at which the said temperature is measured in order to control the temperature at which the exhaust gas enters the dust collection device.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64
54
52c
G
G
54
60
A
64
129
52a
52b
52
52a
32
52a
52b
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34
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42
48
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44
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46
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104
100
102
110
12a
14

FIG. 1

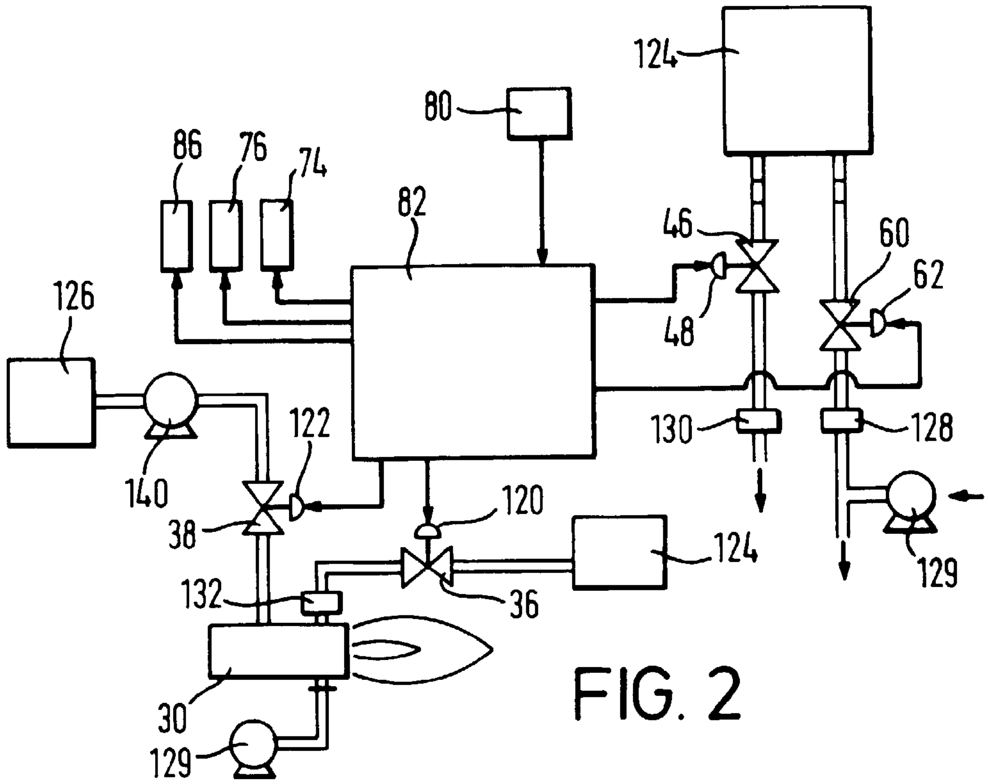
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FIG. 2

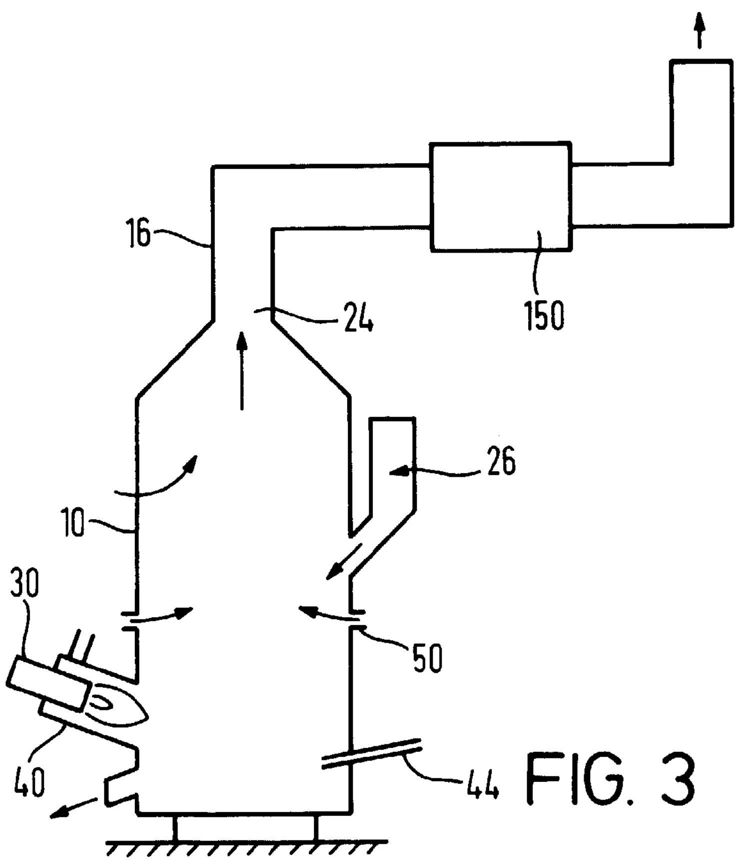
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FIG. 3

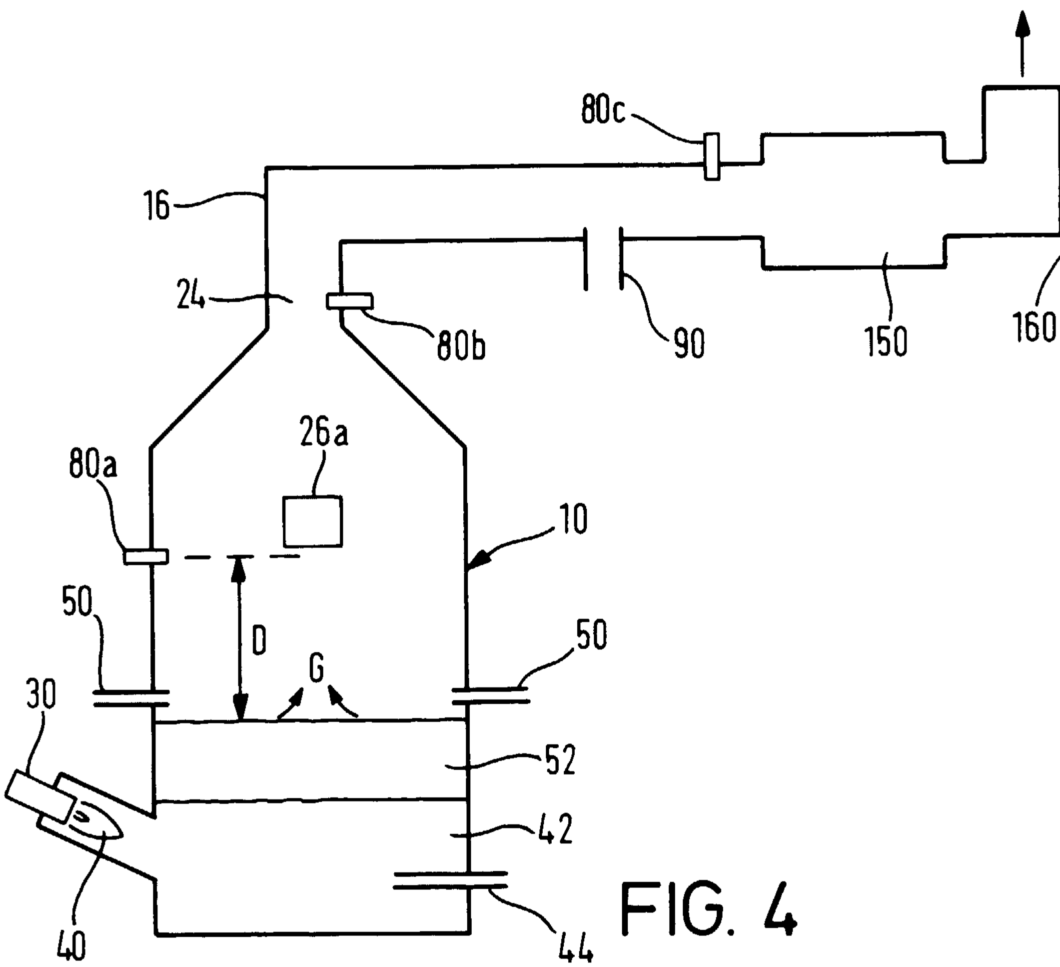

FIG. 4