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FUEL-FIRED FURNACE***F23N 3/00* (2006.01)*F23J 15/08* (2006.01)(52) **U.S. Cl.**CPC *F23G 7/065* (2013.01); *F23J 15/08*
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Procedes Georges Claude**, Paris (FR)(57) **ABSTRACT**(21) Appl. No.: **13/642,683**(22) PCT Filed: **Mar. 30, 2011**(86) PCT No.: **PCT/FR11/50703**

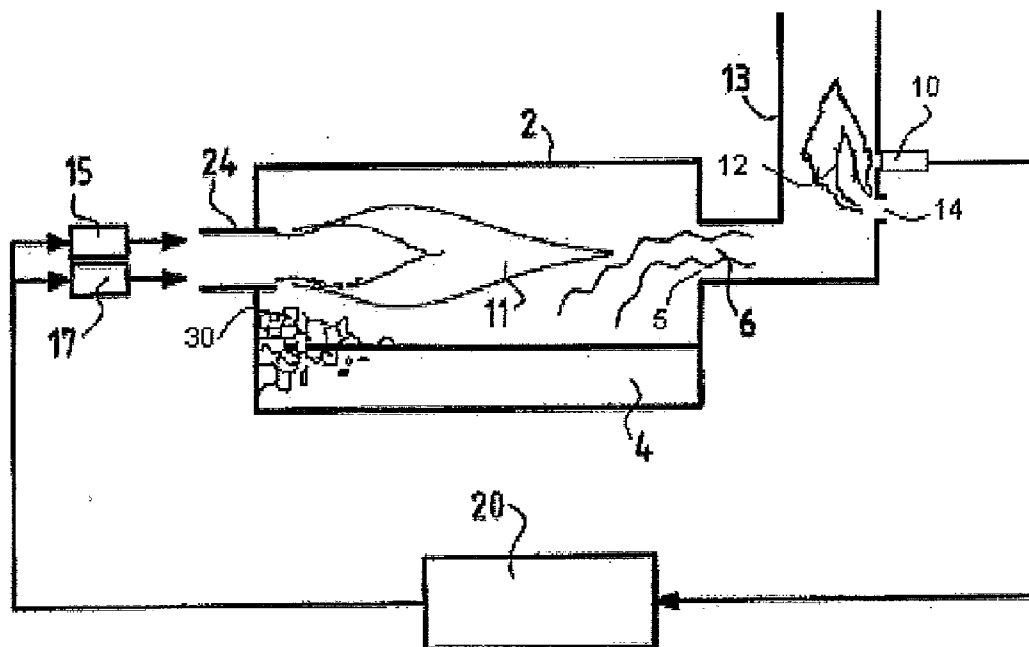
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Fuel-fired furnace and a method for operating it, in which method: a main oxidizing agent is injected at a controlled flow rate into the combustion chamber of the furnace; the combustible material is burnt in the combustion chamber with the main oxidizing agent, producing thermal energy and flue gases at a temperature higher than 600° C.; the flue gases are removed via an exhaust duct, said removed flue gases possibly containing residual materials that could be oxidized, the exhaust duct being equipped with an inlet for a diluting oxidizing agent downstream of the combustion chamber; the residual materials that could be oxidized are burnt with the diluting oxidizing agent by means of a flame at the inlet for the diluting oxidizing agent; the flame intensity inside the exhaust duct is detected; and the flow rate at which the main oxidizing agent is injected into the combustion chamber is controlled according to the detected flame intensity.



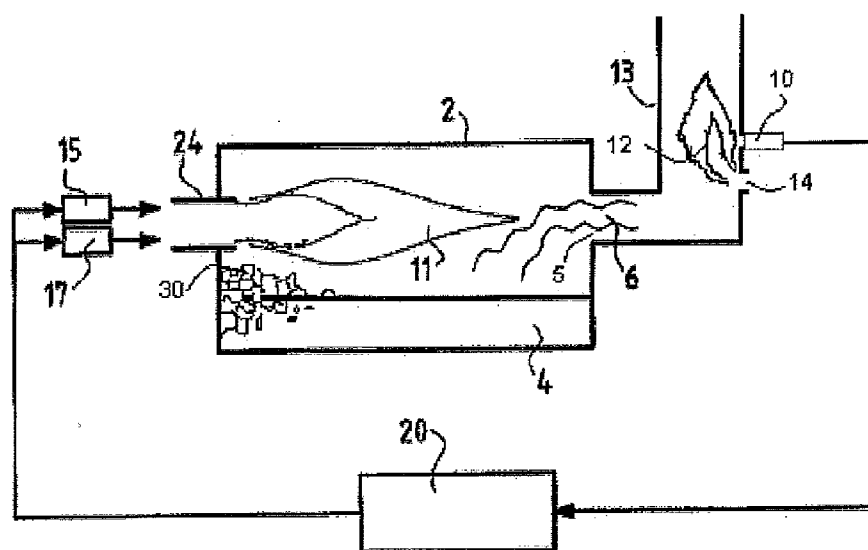


FIG.1

FUEL-FIRED FURNACE AND METHOD FOR CONTROLLING COMBUSTION IN A FUEL-FIRED FURNACE

[0001] The present invention relates to the regulation of the combustion in fuel-fired furnaces.

[0002] Fuel-fired furnaces are commonly used in industry for the generation of thermal energy and for treatment of materials at a high temperature.

[0003] The terminology "fuel-fired furnace" designates a furnace, such as a smelting furnace or an incinerator, wherein at least part of the thermal energy is produced in the combustion chamber of the furnace by the combustion of a fuel with an oxidizing agent which is present in the oxidizer. Thus, the terminology "fuel-fired furnace" also covers furnaces wherein at least part of the thermal energy is produced by combustion without a visible flame, which is often known as "flameless combustion".

[0004] The fumes which are generated by the combustion, generally containing CO_2 , CO and H_2O , are discharged from the combustion chamber of the fuel-fired furnace at a temperature higher than 600°C . by a discharge duct.

[0005] In theory, a maximum amount of thermal energy is generated by the combustion when the combustion is stoichiometric, i.e. when the oxidizing agent is injected into the combustion area in a quantity which corresponds to the quantity of oxidizing agent necessary for the complete combustion of the fuel which is present in the combustion area. In this case, the carbon which is present in the fuel is entirely oxidized into CO_2 , and the hydrogen which is generally present in the fuel is entirely oxidized into H_2O , etc. In industrial practice, however, it is found that a slight excess of oxidizing agent is necessary in order to obtain complete combustion of the fuel.

[0006] Insufficient injection of oxidizing agent gives rise to a drop in the performance of the furnace as a result of non-combustion or partial combustion of the fuel. An excess of oxidizing agent which is too great also gives rise to a drop in performance of the furnace (for example: loss of thermal energy which is greater via the discharged fumes, and, in the case of oxy-combustion, discharge together with the fumes of part of the oxygen which has not participated in the combustion, with the oxygen having a cost which is not negligible).

[0007] Amongst the other disadvantages of an excessively great flow rate of oxidizing agent, mention can be made in particular of a greater level of oxidation of the load, in the case of a load which can be oxidized, as is the case in a furnace for smelting of metals which can be oxidized, such as aluminum, and certain reheating furnaces. It is known in particular to operate fuel-fired furnaces with an arrangement of over- or under-stoichiometry, in order to prevent or limit a reduction or oxidation which is detrimental to the load by the atmosphere in the combustion area. Thus, for certain applications, the optimum combustion differs from the stoichiometric combustion.

[0008] Optimized operation of a fuel-fired furnace is generally possible in fuel-fired furnaces wherein the fuel and oxidizing agents added and the compositions of these are perfectly controlled.

[0009] However, in a large number of industrial applications of fuel-fired furnaces, the quantity and/or the composition of the combustible material available in the combustion area is controlled badly or only slightly.

[0010] This is for example the case in:

[0011] fuel-fired furnaces wherein the load contains a variable quantity and/or quality of combustible materials, such as, for example, waste incinerators and secondary smelting furnaces for recycling of metals;

[0012] in fuel-fired smelting furnaces wherein the load contains inherent and/or added combustible materials, and wherein the load releases these combustible materials in an uncontrolled manner into the combustion area which is generally situated above the load, such as, for example, secondary smelting furnaces for the recycling of metals;

[0013] in fuel-fired furnaces for post-combustion of the fumes obtained from furnaces such as the above-described types, for example post-combustion chambers of arc furnaces for secondary smelting of steel.

[0014] From JP-A-1314809 and JP-A-2001004116, it is known to equip an incinerator with a camera which faces towards the interior of the combustion chamber, and to regulate the post-combustion inside the combustion chamber above the main combustion according to the image obtained of the combustion inside the chamber.

[0015] From WO-A-2005/024398, it is known to measure the quantities of chemical species contained in a gas obtained from a metal treatment furnace, such as an electric arc furnace or a converter, by collecting part of the gas to be analyzed, cooling it to less than 300°C ., and measuring the quantity of CO and/or CO_2 present in the gas by means of the coherent light signal emitted by a laser diode, said process permitting measurement of said quantities with a response time of less than 10 seconds, and control of the furnace in real time.

[0016] WO-A-03/056044 describes a process for smelting of aluminum wherein solid aluminum is introduced into a furnace, the aluminum is smelted in order to form an aluminum bath, the variations of concentration of carbon monoxide (CO) and the temperature of the discharged fumes from the furnace are detected, the formation of aluminum oxides on the surface of the aluminum bath is deduced therefrom, and the smelting process is regulated according to the formation of aluminum oxides.

[0017] However, the measurement of the concentration of certain types of chemicals in the fumes of a fuel-fired furnace is made difficult by the nature and quantities of pollutants, such as soot, in said fumes.

[0018] WO-A-2004/083469 describes a process for smelting of aluminum, wherein the ratio of fuel to oxidizing agent injected by a burner into the fuel-fired furnace is regulated according to the temperature of the fumes in the fume discharge duct provided with an inlet for air known as "dilution air".

[0019] In a process of this type, the flow rate of dilution air can vary according to different parameters (size of the openings, speed of extraction of the fumes, state of the fume ducts, flow rate of the other flows of fumes collected by the same extractor). This variable flow rate can have an influence on the temperature of the fumes in the discharge duct, and thus have an impact on the regulation of the furnace. Daily variations (day and night) and seasonal variations (summer and winter) in the temperature of the dilution air, which is generally ambient air, can also have an impact on the temperature of the fumes in the discharge duct.

[0020] The object of the present invention is to provide regulation of the combustion in a fuel-fired furnace which does not have the disadvantages of the above-described known processes.

[0021] The present invention thus relates to a process for operation of an improved fuel-fired furnace. According to this process, an oxidizing agent, which is known as the main "oxidizing agent", is injected at a regulated flow rate into a combustion chamber of the fuel-fired furnace. Combustible material is burned in the combustion chamber together with the main oxidizing agent thus injected, thus producing in the combustion chamber thermal energy and fumes with a temperature higher than 600° C. The fumes thus produced are discharged from the combustion chamber by a discharge duct. This discharge duct is provided with an inlet for an oxidizing agent known as the "dilution oxidizing agent", which is typically, but not necessarily, ambient air, downstream from the combustion chamber, such that the dilution oxidizing agent comes into contact with the fumes at a temperature of 600° C. or even higher. When the fumes still contain materials which can be oxidized, i.e. when the combustion of combustible material in the combustion chamber is not complete, a flame is thus obtained at the level of the inlet for the dilution oxidizing agent inside the discharge duct. In fact, the contact between the dilution oxidizing agent and the materials which can be oxidized in the fumes at a high temperature generate auto-combustion of said materials which can be oxidized, such as CO and/or H₂, which are present in the discharged fumes. According to the invention, there is detection of the flame intensity inside the discharge duct, and therefore downstream from the combustion chamber, and the injection flow rate of the main oxidizing agent into the combustion chamber is regulated according to the intensity of detected flame.

[0022] In particular, the combustible material can be introduced into the combustion chamber in a controlled manner, for example by injection of a jet of fuel into the combustion chamber by means of a lance or burner. The combustible material can be present in the load, and can thus be introduced into the combustion chamber together with the load. The combustible material can also be introduced into the combustion chamber by a combination of controlled introduction and introduction together with the load into the combustion chamber.

[0023] Advantageously, the injection flow rate of the main oxidizing agent injected into the combustion chamber is reduced when the flame intensity thus detected is lower than a predetermined lower limit, and the flow rate of the main oxidizing agent injected into the combustion chamber is increased when the flame intensity thus detected is higher than a predetermined upper limit.

[0024] The presence of materials which can be oxidized, such as CO, in the fumes, is thus detected by the intensity of their combustion with the dilution oxidizing agent by means of a flame detector which returns a signal indicating the intensity of the combustion/of the flame inside the discharge duct: (a) a high intensity being the sign of a significant presence of materials which can be oxidized in the discharged fumes, and (b) a low intensity being the sign of a low presence of materials which can be oxidized in the discharged fumes.

[0025] The invention thus makes it possible to determine the level of the presence of materials which can be oxidized in the fumes, and to apply in real time correction of the regulation of the combustion in the combustion area.

[0026] The predetermined lower and upper limits are established in accordance with the nature of the combustion process in the combustion chamber, as previously described. When the combustion process is aimed at complete combustion of the combustible material in the combustion chamber, the predetermined lower limit is very low, but higher than zero. By this means, it is assured that the injection flow rate of the main oxidizing agent is neither excessive nor too low for the combustion process in the combustion chamber.

[0027] The invention makes it possible in particular to compensate for imperfect knowledge of the content of combustible material in the furnace load (typical case for recycling furnaces), the quality of the combustible material, and/or its release in the combustion chamber, by means of adaptation in real time of the regulation of the flow rate of the main oxidizing agent, and, as described hereinafter, optionally also the flow rate of fuel injected into the combustion chamber.

[0028] Another advantage of the invention is that it can be implemented by means of a flame intensity detector which is inexpensive and simple to put into use.

[0029] In certain combustion processes, the content of materials which can be oxidized in the discharged fumes can have frequent variations, but often with a short duration. According to one embodiment, the flame intensity inside the discharge duct is detected during predetermined durations $\Delta t1$ and $\Delta t2$. The injection flow rate of the main oxidizing agent into the combustion chamber is reduced when the detected flame intensity has remained lower than the lower limit during the predetermined duration $\Delta t1$. Similarly, the injection flow rate of the main oxidizing agent into the combustion chamber is increased when the detected flame intensity has remained higher than the upper limit during the predetermined duration $\Delta t2$. Thus, excessive fluctuations in the combustion process are avoided. Another possibility is (a) to reduce the injection flow rate of the main oxidizing agent into the combustion chamber when the mean value of the detected flame intensity during the predetermined duration $\Delta t1$ is lower than the lower limit, and (b) to increase the injection flow rate of the main oxidizing agent into the combustion chamber when the mean value of the detected flame intensity during the predetermined duration $\Delta t2$ is higher than the upper limit. In practice, the predetermined durations $\Delta t1$ and $\Delta t2$ are typically identical.

[0030] According to one embodiment, the main oxidizing agent and the combustible material are injected into the combustion chamber at regulated flow rates, the combustible material is burned in the combustion chamber together with the main oxidizing agent, thus producing in the combustion chamber thermal energy and fumes at a temperature higher than 600° C., and the fumes thus produced are discharged from the combustion chamber by a discharge duct. As previously stated, the discharged fumes can contain residual materials which can be oxidized. The discharge duct is provided with an inlet for dilution oxidizing agent downstream from the combustion chamber. The residual materials which can be oxidized from the fumes are burned together with the dilution oxidizing agent, thereby obtaining a flame inside the discharge duct at the level of the inlet for dilution oxidizing agent. According to the invention, the flame intensity inside the discharge duct is detected and the injection flow rate of the main oxidizing agent into the combustion area is regulated according to the detected flame intensity.

[0031] It is also possible to regulate the injection flow rate of the main oxidizing agent and the injection flow rate of

combustible material into the combustion chamber according to the detected flame intensity.

[0032] Advantageously, the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber is reduced when the detected flame intensity inside the discharge duct is lower than a predetermined lower limit, and the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber is increased when the detected flame intensity is higher than a predetermined upper limit.

[0033] In particular, it is possible (a) to reduce the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the detected flame intensity is lower than the lower limit during a predetermined duration Δt_1 , and (b) to increase the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the detected flame intensity inside the discharge duct is higher than the upper limit during a predetermined duration Δt_2 . It is also possible (a) to reduce the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the mean value of the detected flame intensity inside the discharge duct during the predetermined duration Δt_1 is lower than the lower limit, and (b) to increase the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the mean value of the detected flame intensity during the predetermined duration Δt_2 is higher than the upper limit.

[0034] The ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber can be modified by changing the injection flow rate of the main oxidizing agent relative to the predetermined injection flow rate of combustible material, or by changing (a) the injection flow rate of the main oxidizing agent and (b) the injection flow rate of combustible material. It should however be noted that the injection flow rate of combustible material into the combustion chamber is often regulated according to the thermal energy requirement in the combustion chamber.

[0035] According to one embodiment, the combustion chamber is equipped with at least one lance for the injection of a regulated flow rate of the main oxidizing agent. The combustion chamber can also be equipped with at least one burner for the injection of a regulated flow rate of the main oxidizing agent and a regulated flow rate of combustible material. The combustion chamber can also comprise at least one such lance and at least one such burner.

[0036] The process can be a batch process, a semi-batch process or a continuous supply process.

[0037] The combustion chamber can be the combustion chamber of an arc furnace, a rotary furnace, a fixed smelting furnace, a reheating furnace, a boiler, or a post-combustion chamber for gaseous effluents, etc.

[0038] The process can be a process for smelting or vitrification, and in particular a process for secondary smelting of scrap metals, a process for combustion of solid, liquid or gaseous waste, a process for post-combustion of gaseous effluents, or a process for reheating, such as reheating of metallurgical products, etc.

[0039] The inlet for the dilution oxidizing agent is typically an inlet for ambient air into the discharge duct (air gap), but can also be an injector for the oxidizing agent, such as an injector for air enriched with oxygen, or for oxygen.

[0040] The flame detector is advantageously an optical detector, and in particular an optical detector selected from amongst ultraviolet detectors, infrared detectors, and visible radiation detectors. The detector is preferably an infrared or an ultraviolet detector.

[0041] In order to avoid interference by the combustion, known as the main combustion, which takes place inside the combustion chamber, the flame is detected inside the discharge duct, preferably in a location which is sheltered from the main combustion.

[0042] In order better to separate the area of detection inside the discharge duct from the main chamber, the discharge duct can be provided with a bend. The detection of the flame then takes place preferably downstream from this bend. The inlet for the dilution oxidizing agent is advantageously situated immediately upstream, in, or downstream from the bend, such that the flame which is generated by the combustion of the materials which can be oxidized in the fumes together with the dilution oxidizing agent takes place at least mainly downstream from the bend.

[0043] When the furnace has a geometry which prevents interference between the main combustion and the flame detector, or if the furnace comprises elements which form a screen between the main combustion and the flame detector, a bend of this type is not necessary.

[0044] The present invention also relates to a fuel-fired furnace which is designed for implementation of the above-described process.

[0045] Thus, the invention relates more particularly to a fuel-fired furnace comprising a combustion chamber, and means for the injection of the main oxidizing agent at a regulated flow rate into this combustion chamber, and a duct for the discharge of fumes from said combustion chamber. The discharge duct comprises an inlet for the dilution oxidizing agent downstream from the combustion chamber. The fuel-fired furnace according to the invention also comprises a detector to detect a flame intensity in the discharge duct at the level of the inlet for the dilution oxidizing agent. The detector is positioned and oriented such as to prevent the main combustion from vitiating the detected flame intensity.

[0046] In particular, the discharge duct can comprise a bend as previously stated. With reference to the process according to the invention, the flame detector is then preferably positioned downstream from this bend.

[0047] Advantageously, the inlet for the dilution oxidizing agent is positioned immediately upstream, in, or downstream from the bend of the discharge duct.

[0048] The furnace advantageously comprises a control unit which is connected to the detector, and to the means for injection of the main oxidizing agent. This control unit is programmed to:

[0049] compare the detected flame intensity by the detector inside the discharge duct, with a predetermined lower limit and a predetermined upper limit;

[0050] reduce the injection flow rate of the main oxidizing agent into the combustion chamber by the means for injection of the main oxidizing agent, when the detected flame intensity is lower than the predetermined lower limit; and

- [0051] increase the injection flow rate of the main oxidizing agent into the combustion chamber by the means for injection of the main oxidizing agent, when the detected flame intensity is higher than a predetermined upper limit.
- [0052] More particularly, the control unit can be programmed to:
- [0053] reduce the injection flow rate of the main oxidizing agent into the combustion chamber when the detected flame intensity is lower than the lower limit for a predetermined duration $\Delta t1$ and/or when the mean value of the detected flame intensity during a predetermined duration $\Delta t1$ is lower than the lower limit for the predetermined duration $\Delta t1$; and
- [0054] increase the injection flow rate of the main oxidizing agent into the combustion chamber when the detected flame intensity is higher than the upper limit for a predetermined duration $\Delta t2$ and/or when the mean value of the detected flame intensity during the predetermined duration $\Delta t2$ is higher than the upper limit for a predetermined duration $\Delta t2$.
- [0055] The furnace according to the invention can also comprise a means for the injection of combustible material at a regulated flow rate into the combustion chamber.
- [0056] In this case, the fuel-fired furnace preferably comprises a control unit which is connected (a) to the detector, (b) to the means for injection of the main oxidizing agent into the combustion chamber, and (c) to the means for injection of combustible material into the combustion chamber. This control unit is programmed (i) to compare the flame intensity detected by the detector inside the discharge duct with a predetermined lower limit and a predetermined upper limit, (ii) to reduce the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the detected flame intensity is lower than the predetermined lower limit, and (iii) to increase the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the detected flame intensity is higher than a predetermined upper limit.
- [0057] According to a preferred embodiment, the control unit is more particularly programmed to:
- [0058] reduce the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the detected flame intensity inside the discharge duct is lower than the lower limit during a predetermined duration $\Delta t1$, and/or when the mean value of the detected flame intensity is lower than the lower limit during the predetermined duration $\Delta t1$; and
- [0059] increase the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the detected flame intensity is higher than the upper limit during a predetermined duration $\Delta t2$, and/or when the mean value of the detected flame intensity is higher than the upper limit during the predetermined duration $\Delta t2$.
- [0060] In order to vary the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber, the control unit will advantageously vary the injection flow rate of the main oxidizing agent according to the injection flow rate of

the combustible material. It is however also possible for the control unit to vary the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material, by regulating the injection flow rate of the main oxidizing agent and the injection flow rate of the combustible material. In this case, the control unit can for example, in the case of a flame intensity which is lower than the predetermined lower limit, reduce the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material, by increasing the injection flow rate of combustible material to an injection flow rate of the main oxidizing agent which remains unchanged.

[0061] The means for injection of the main oxidizing agent of the furnace can comprise one or a plurality of lances for injection of the main oxidizing agent into the combustion chamber.

[0062] The means for injection of combustible material of the furnace can comprise one or a plurality of lances for the injection of combustible material into the combustion chamber.

[0063] The furnace can also comprise one or a plurality of burners for the injection of combustible materials and of the main oxidizing agent into the combustion chamber. A burner of this type firstly forms part of the means for injection of the main oxidizing agent, and secondly of the means for injection of combustible material into the furnace.

[0064] The furnace according to the invention can be a furnace for a batch process, for a semi-batch process, or for a continuous process.

[0065] In particular, the furnace can be an arc furnace, a rotary furnace, a fixed smelting furnace, a reheating furnace such as a reheating furnace for metallurgical products, a boiler, or a post-combustion chamber for gaseous effluents, etc.

[0066] The furnace can be a furnace for smelting or vitrification, and in particular a secondary smelting furnace for scrap metals, or an incinerator for solid, liquid or gaseous waste, etc.

[0067] The inlet for the dilution oxidizing agent is typically an inlet for ambient air into the discharge duct (air gap), but can also be an injector for the oxidizing agent, such as an injector for air enriched with oxygen, or an oxygen injector.

[0068] The flame detector is preferably an optical detector, and in particular an optical detector selected from amongst ultraviolet detectors, infrared detectors, and visible radiation detectors.

[0069] The combustible material which is injected into the combustion chamber can be a gaseous, liquid or solid fuel (for example: natural gas, liquid fuel, propane, bio-fuel, powdered coal), or a combination of several fuels. This combustible material can be injected in addition to the combustible material which is introduced into the combustion chamber together with the load, and can be mixed together with the load before the load is introduced into the combustion chamber, and/or it can form an intrinsic part of the load.

[0070] The main oxidizing agent can be air, air enriched with oxygen, pure oxygen (which by definition has an oxygen content of 88% to 100% by volume), or a mixture of oxygen and recycled fumes. In the latter cases (air enriched with oxygen, and in particular pure oxygen or a mixture of oxygen and recycled fumes), there is the benefit of a reduced volume of fumes and consumption of fuel.

[0071] The invention is particularly useful for fuel-fired furnaces which are used for the secondary smelting of metals.

Secondary smelting designates the smelting of recycled materials or materials which are obtained from primary metallurgy (for example: cast iron which is obtained from a blast furnace).

[0072] The metals considered are for example: cast iron, lead, aluminum, copper, or any other metal which can be smelted in a fuel-fired furnace.

[0073] The metal load can also be loaded into the furnace mixed with combustible materials consisting of a high proportion of carbon (plastic, coke, etc.). These combustible materials can be present in the metal load (for example in the case of recycling of aluminum) and/or added intentionally to the load for the requirements of the smelting process (for example in the case of the de-oxidation reaction for the recycling of lead).

[0074] The present invention and its advantages will become more clearly apparent from the following illustrative example provided with reference to FIG. 1, which represents schematically a fuel-fired smelting furnace according to the invention.

[0075] The furnace is more particularly a rotary furnace for the secondary smelting of lead with a combustion chamber 2 with a capacity of 15 t.

[0076] The furnace is equipped with a natural gas/oxygen burner 24 which generates the flame 11 in the combustion chamber 2. The power of the burner 24 and the ratio of oxygen to natural gas are controlled by the automatism of the furnace (control device 20 connected to the oxygen flow rate regulator 15 and to the natural gas flow rate regulator 17) according to the progress of the heating cycle, as described hereinafter.

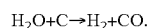
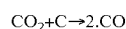
[0077] The load 30 is constituted by lead waste obtained from crushed motor vehicle batteries. A significant part of this lead is in the form of an "paste" of lead oxide (PbO, PbO₂, etc.) and lead sulfate (PbSO₄, etc.). To this metal load there are added materials which are necessary for the reduction of the oxides, which are partly constituted by coke (comprising a high content of carbon) and are also known as "reagents".

[0078] The lead recycling process consists of heating the load 30, then keeping the load hot in contact with the reagents in order to obtain liquid lead 4 and slag which fixes the impurities and sulfur which are present in the lead sulfate.

[0079] The furnace functions discontinuously. The combustion chamber 2 is loaded at the beginning of each cycle. The burner 24 is then lit, and its power is modulated by the control device 20, such that the temperature of the load follows a heating cycle which has been determined empirically.

[0080] During the heating step, a substantial part of the carbon which is present in the solid load 30 reacts with the atmosphere of the rotary combustion chamber 2 which is constituted substantially by the hot fumes produced by the burner 24.

[0081] This reaction produces CO and H₂ from the following reaction between part of the fumes and part of the carbon of the load, the mechanisms of which can be presented schematically as follows:



[0082] In order to limit the formation of CO in the atmosphere of the chamber 2, it is possible to pre-regulate the burner 24 so as to inject an excess of oxygen into the chamber 2. However, the level of reaction of the carbon which is present in the solid load 30 with the atmosphere of the furnace varies according to the different parameters of the process,

such as, in particular, the composition of the load which varies according to the origin of the batches to be recycled.

[0083] For a 15 t load, the power of the burner 24 will be regulated for example to between 1 and 1.5 MW, according to the progress of the heating cycle. In the middle of the cycle, the burner is for example regulated for a power of 1.3 MW with the following flow rates:

[0084] natural gas 130 Nm³/h

[0085] pure oxygen 270 Nm³/h.

[0086] An analysis of the fumes 6 discharged from the chamber 2 reveals the following composition:

[0087] CO₂: 56%/CO: 25%/H₂: 4% remainder N₂.

[0088] The CO and H₂ of the fumes burn together with the dilution air in the flame 12 inside the flue 13 which comprises a bend downstream and in the vicinity of the chamber 2. The dilution air is ambient air which enters into the flue 13 via the opening 14 which is provided for this purpose downstream from the bend. This dilution air permits the combustion of the CO into CO₂ and the cooling of the fumes before the filtering (not illustrated) which precedes the discharge of the fumes. An excessively high level of CO in the fumes 6 has several disadvantages:

[0089] incomplete combustion of the CO in the flue 13, and thus emission of residual CO in the flue 13;

[0090] a very significant increase of the temperature of the fumes in the flue 13, which does not allow passage of fumes into the filter downstream (not illustrated), thus giving rise to the forced drop in power of the burner 24, or even stoppage of the burner 24 at a safety temperature, in order to permit filtering and compliance with the environmental standards; and

[0091] excess consumption of fuel, and therefore a drop in the energy performance in the furnace, since the reactions CO₂+C→2.CO and H₂O+C→H₂+CO are endothermic.

[0092] The detection according to the invention, by means of the UV detector 10 from the range D-LX100 sold by the company Durag, of the intensity of flame 12 from the combustion of the mixture CO+H₂ with the dilution air just after the outlet 5 from the furnace, makes it possible to correct the regulation of the burner 24 by acting on the ratio of oxygen to natural gas. For this purpose, the detector 10 transmits to the control device 20 a signal corresponding to the detected flame intensity.

[0093] The bend of the flue 13 and the positioning of the UV detector 10 relative to said bend assures that the UV detector 10 detects only the intensity of flame 12 inside the flue 13, without interference of the UV radiation of the combustion inside the combustion chamber 2.

[0094] In particular when the intensity of this combustion in the flue 13 exceeds an upper limit which is predetermined experimentally, the invention makes it possible for example to:

[0095] increase, by means of the oxygen flow rate regulator 15, the flow rate of oxygen to 340 Nm³/h, and to maintain the flow rate of natural gas unchanged at 130 Nm³/h;

[0096] decrease, by means of the fuel flow rate regulator 17, the flow rate of fuel to 95 Nm³/h, and to maintain the flow rate of oxygen unchanged at 270 Nm³/h; and

[0097] modulate the two flow rates by increasing the flow rate of oxygen to 300 Nm³/h by means of the regulator 15, and by reducing the flow rate of natural gas to 110 Nm³/h by means of the regulator 17.

[0098] In the three cases, the burner **24** injects 70 Nm³/h of oxygen which is in excess relative to the initial regulation. This excess of oxygen is then available for the combustion inside the furnace **2**, of the combustible materials released by the load.

[0099] As soon as the flow rate of combustible material released by the load decreases, further to the development of the cycle, the intensity of the combustion of CO and H₂ in the flue **13** decreases, and the intensity of flame **12** as detected by the detector **10** thus also decreases.

[0100] It is then possible to reduce the flow rates of oxygen and natural gas of the burner **24** progressively to the initial or predetermined basic flow rates, and thus to reduce the ratio of oxygen to natural gas.

[0101] This regulation of the ratio of oxygen to natural gas is carried out dynamically according to the intensity of the post-combustion of the fumes in the flue **13** (detected intensity of flame **12**).

[0102] The energy performance of the furnace **2** is thus significantly improved, and efficient treatment of the fumes, and in particular filtering of the fumes, is assured.

1-15. (canceled)

16. A process for operation of a fuel-fired furnace comprising a combustion chamber, comprising the steps of:

injecting a main oxidizing agent at a regulated flow rate into the combustion chamber;

burning a combustible material in the combustion chamber together with the main oxidizing agent, thus producing in the combustion chamber thermal energy and fumes at a temperature higher than 600° C.;

discharging the fumes from the combustion chamber by a discharge duct, said fumes discharged being able to contain residual materials which can be oxidized, the discharge duct being provided with an inlet for a dilution oxidizing agent downstream from the combustion chamber;

burning the residual materials together with the dilution oxidizing agent with a flame inside the discharge duct at the level of the inlet for the dilution oxidizing agent; wherein the flame intensity of said flame inside the discharge duct is detected and the injection flow rate of the main oxidizing agent into the combustion chamber is regulated according to the detected flame intensity.

17. The process of claim **16**, wherein:

the injection flow rate of the main oxidizing agent into the combustion chamber is reduced when the detected flame intensity is lower than a predetermined lower limit; and the injection flow rate of the main oxidizing agent into the combustion chamber is increased when the flame intensity thus detected is higher than a predetermined upper limit.

18. The process of claim **16**, wherein:

the injection flow rate of the main oxidizing agent into the combustion chamber is reduced when the detected flame intensity is lower than the lower limit during a predetermined duration Δt_1 or when the mean value of the detected flame intensity during the predetermined duration Δt_1 is lower than the lower limit; and

the injection flow rate of the main oxidizing agent into the combustion chamber is increased when the detected flame intensity is higher than the upper limit during a predetermined duration Δt_2 or when the mean value of the detected flame intensity during the predetermined duration Δt_2 is higher than the upper limit.

19. A process for operation of a fuel-fired furnace comprising a combustion chamber, comprising the steps of:

injecting a main oxidizing agent and combustible material at regulated flow rates into the combustion chamber;

burning the combustible material in the combustion chamber together with the main oxidizing agent, thus producing in the combustion chamber thermal energy and fumes at a temperature higher than 600° C.;

discharging the fumes from the combustion chamber by a discharge duct, said fumes discharged being able to contain residual materials which can be oxidized, said discharge duct being provided with an inlet for a dilution oxidizing agent downstream from the combustion chamber;

burning the residual materials together with the dilution oxidizing agent with a flame inside the discharge duct at the level of the inlet for the dilution oxidizing agent, wherein:

the flame intensity inside the discharge duct is detected; and

the injection flow rate of the main oxidizing agent, and optionally the injection flow rate of combustible material, into the combustion chamber, is regulated according to the detected flame intensity.

20. The process of claim **19**, wherein:

the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber is reduced when the detected flame intensity is lower than a predetermined lower limit; and

the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber is increased when the detected flame intensity is higher than a predetermined upper limit.

21. The process of claim **20**, wherein:

the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber is reduced when the detected flame intensity is lower than the lower limit during a predetermined duration Δt_1 , or when the mean value of the detected flame intensity during the predetermined duration Δt_1 is lower than the lower limit; and the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber is increased when the detected flame intensity is higher than the upper limit during a predetermined duration Δt_2 , or when the mean value of the detected flame intensity during the predetermined duration Δt_2 is higher than the upper limit.

22. The process of claim **20**, wherein the injection flow rate of combustible material into the combustion chamber is varied according to the thermal energy requirement in the combustion chamber.

23. The process of claim **16**, wherein the flame intensity is determined by means of an optical detector selected from the group consisting of ultraviolet detectors, infrared detectors, and visible radiation detectors.

24. A fuel-fired furnace comprising:

a combustion chamber;

a burner or lance adapted and configured to inject a main oxidizing agent at a regulated flow rate into the combustion chamber;

a duct for the discharge of fumes from said combustion chamber, said duct comprising an inlet for a dilution oxidizing agent downstream from the combustion chamber; and

a detector to detect a flame intensity at the inlet for the dilution oxidizing agent inside the discharge duct.

25. The fuel-fired furnace of claim **24**, also comprising a control unit which is connected (a) to the detector, and (b) to the burner or lance, the control unit being programmed to:

compare the flame intensity detected by the detector with a predetermined lower limit and a predetermined upper limit;

reduce the injection flow rate of the main oxidizing agent into the combustion chamber by the burner or lance, when the detected flame intensity is lower than the predetermined lower limit; and

increase the injection flow rate of the main oxidizing agent into the combustion chamber by the burner or lance, when the detected flame intensity is higher than a predetermined upper limit.

26. The fuel-fired furnace of claim **25**, wherein the control unit is programmed to:

reduce the injection flow rate of the main oxidizing agent into the combustion chamber when the detected flame intensity is lower than the lower limit for a predetermined duration $\Delta t1$ or when the mean value of the detected flame intensity during the predetermined duration $\Delta t1$ is lower than the lower limit; and

increase the injection flow rate of the main oxidizing agent into the combustion chamber when the detected flame intensity is higher than the upper limit for a predetermined duration $\Delta t2$ or when the mean value of the detected flame intensity during the predetermined duration $\Delta t2$ is higher than the upper limit.

27. The fuel-fired furnace of claim **24**, wherein the burner or lance is a burner and the burner is adapted and configured to inject combustible material at a regulated flow rate into the combustion chamber.

28. The fuel-fired furnace of claim **27**, also comprising a control unit which is connected to the detector and the burner, the control unit being programmed to:

compare the flame intensity detected by the detector with a predetermined lower limit and a predetermined upper limit;

reduce the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the detected flame intensity is lower than a predetermined lower limit; and

increase the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the detected flame intensity is higher than a predetermined upper limit.

29. The fuel-fired furnace of claim **28**, wherein the control unit is programmed to:

reduce the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the detected flame intensity is lower than the lower limit during a predetermined duration $\Delta t1$, or when the mean value of the detected flame intensity is lower than the lower limit during the predetermined duration $\Delta t1$; and

increase the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the detected flame intensity is higher than the upper limit during a predetermined duration $\Delta t2$, or when the mean value of the detected flame intensity is higher than the upper limit during the predetermined duration $\Delta t2$.

30. The fuel-fired furnace of claim **24**, wherein the flame detector is selected from amongst optical detectors, and preferably from amongst ultraviolet detectors, infrared detectors, and visible radiation detectors.

31. The fuel-fired furnace of claim **24**, wherein:

the burner or lance is a lance; and

the furnace further comprises a lance adapted and configured to inject combustible material at a regulated flow rate into the combustion chamber.

32. The fuel-fired furnace of claim **31**, also comprising a control unit which is connected (a) to the detector, (b) to the lance for injection of the main oxidizing agent, and (c) to the lance for injection of combustible material, the control unit being programmed to:

compare the flame intensity detected by the detector with a predetermined lower limit and a predetermined upper limit;

reduce the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the detected flame intensity is lower than a predetermined lower limit; and

increase the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the detected flame intensity is higher than a predetermined upper limit.

33. The fuel-fired furnace of claim **32**, wherein the control unit is programmed to:

reduce the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the detected flame intensity is lower than the lower limit during a predetermined duration $\Delta t1$, or when the mean value of the detected flame intensity is lower than the lower limit during the predetermined duration $\Delta t1$; and

increase the ratio between the injection flow rate of the main oxidizing agent and the injection flow rate of combustible material into the combustion chamber when the detected flame intensity is higher than the upper limit during a predetermined duration $\Delta t2$, or when the mean value of the detected flame intensity is higher than the upper limit during the predetermined duration $\Delta t2$.

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