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(54) SHAFT FURNACE AND INJECTION OF OXIDIZING AGENT THEREIN

(57) Sonic or supersonic injection of oxidizing agent in a shaft furnace presenting at least one hot-spot and/or at least one cold spot, whereby the active duration of sonic or supersonic injection of oxidizing agent in a hot-spot section is reduced and whereby the active duration of sonic or supersonic injection of oxidizing agent in a cold spot section is increased.

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Description

[0001] The present invention relates to the operation of shaft furnaces.

[0002] Shaft furnaces have been used in a wide range of processes, such as the burning of solid waste, the reduction of iron ore to produce pig iron, the melting of metals and mineral wool, etc.

[0003] Thereto, the solid charge is fed to the furnace via the top and combustion oxidant, such as air which may or may not be preheated is injected into the furnace via a number of injectors distributed around the circumference of the furnace.

[0004] In spite of the distribution of the oxidant injection around the circumference of the furnace, the combustion process is not always homogeneous across the cross-section of the furnace and hot spots can often be observed in shaft furnaces. These may arise due to asymmetry of the structure of the shaft furnace and/or due to a non-homogeneous distribution of the charge or of the composition of the charge across the cross-section of the furnace. The location of a hot spot may be constant or invariable, for example when the charge-loading system systematically creates the same non-homogeneous distribution of the charge across the furnace, or may vary over time, for example, when the nature of the charge varies over time.

[0005] The presence of one or more such hot spots and can lead to reduced furnace efficiency, a lower or less constant quality of the product of melting processes and damage to the refractory furnace wall at or near the hot-spot area.

[0006] Similarly, cold spots have also been observed in shaft furnaces. In cold spots, the temperature drops below the optimum temperature for the process taking place inside the furnace, thereby affecting the efficiency of the furnace and the quality of the product in case of melting processes. For example, the presence of a cold spot in a shaft furnace may lead to the formation of so-called "bridges" and prevent a uniform descent of the charge within the furnace.

[0007] It is known in the art to improve the efficiency of shaft furnaces by injecting a combustion oxidant with a higher oxygen content than that of air into the furnace, in particular oxygen-enriched air and substantially pure oxygen. It is also known, in that case, to inject the combustion oxidant with supersonic velocity in order to achieve sufficient penetration of the combustion oxidant into the shaft furnace in spite of the lower volumetric flow. It is, in particular, known in the art to inject oxygen-rich combustion oxidant in a pulsed or sequenced manner into the shaft furnace, whereby each of the supersonic injectors between an active phase, during which it injects combustion oxidant at supersonic velocity, and a passive phase during which it does not. Such shaft furnace operation methods are for example described in EP-A-1242781, EP-A-1739194 and DE-A-10249235.

[0008] Unfortunately, it has been observed that the use of oxygen-rich combustion oxidant does not overcome the problem of hot and cold spots and can even increase the occurrence and intensity of hot spots and their consequences.

[0009] There is therefore a need to be able to inject combustion oxidant into the shaft furnace in such a way that the occurrence and negative effects of hot and/or cold spots in the shaft furnace are reduced or even remedied.

[0010] There is in particular a need to be able to inject oxygen-rich combustion oxidant into the shaft furnace so as to increase furnace efficiency while reducing the occurrence and negative effects of hot and/or cold spots in the shaft furnace.

[0011] Thereto, the present invention proposes an improved method of injecting oxidizing agent into a vertical shaft furnace in which a combustion process takes place.

[0012] Said shaft furnace presents n injectors (at least 3), distributed around the circumference of the shaft furnace at a level or height $[h, h + \Delta h]$ of the shaft furnace. Each one of said n injectors is adapted for sonic or supersonic injection of a gaseous fluid into one of n sections of a cross-section of the shaft furnace at level $[h, h + \Delta h]$.

[0013] The n injectors and the n sections are thus in a one-to-one relationship, with each injector being associated with one of the sections into which the injector is capable of injecting the fluid, and each section being associated with one of the injectors by which the section can be supplied with the fluid. The n sections together form the internal cross-section of the shaft furnace at level $[h, h + \Delta h]$. According to the invention, the shaft furnace is part of an installation including a source of an oxidizing agent and a control unit.

[0014] The source of oxidizing agent is adapted to supply an oxidizing agent with an oxygen content higher than 21%vol and at most 100%vol, said source being fluidly connected to each of the n injectors. The oxygen content of the oxidizing agent supplied by said source is preferably at least 50%vol, more preferably at least 90% and even more preferably at least 95%vol.

[0015] The control unit is programmed to control both:

- a total amount of the oxidizing agent injected into the shaft furnace by means of the n injectors considered together and
- an amount of oxidizing agent injected into the shaft furnace by each one of the n injectors individually,

the sum of the amounts of oxidizing agent injected into the shaft furnace by each one of the n injectors at a given moment in time corresponding to the total amount of the oxidizing agent injected into the shaft furnace by means of the n injectors at said moment in time.

[0016] The control unit controls the total amount of the oxidizing agent injected by the n injectors so as to meet a demand for oxidizing agent by the combustion process which takes place in the shaft furnace.

[0017] As regards the amount of oxidizing agent injected by each individual injector of the n injectors, this is controlled by the control unit so that the injection of oxidizing agent by each one of the n injectors takes place cyclically according to a cycle with a duration t_c. During each cycle, the control unit controls the injection of oxidizing agent by each one of the n injectors so that each one of the n injectors injects oxidizing agent in a sequenced fashion, i.e. in a fashion alternating between an active phase and a passive phase. More specifically, the control unit controls the injection of oxidizing agent by each one of the n injectors so that the injection of oxidizing agent by each one of the n injectors alternates between:

(a) an active phase having an active duration t_a, whereby during the active phase the oxidizing agent is injected by the injector at an active flow rate and with sonic or supersonic velocity, and
(b) a passive phase having a passive duration t_p, whereby during the active phase either the injector injects no oxidizing agent or the injector injects oxidizing agent at subsonic velocity and at a passive flow rate which is lower than the active flow rate.

[0018] Even though, as will be explained below, the duration of the active phase t_a and the duration of the passive phase t_p may be different for different injectors, for each one of the n injectors, the sum of the duration (t_a) of the active phase and the duration (t_p) of the passive phase is equal to the duration (t_c) of the cycle of the cyclical operation of the control unit (i.e. $t_a + t_p = t_c$).

[0019] In this manner, the control unit ensures that oxidizing agent is injected at sonic or supersonic velocity in each section of the cross-section of the shaft furnace at level [h, h + Δh] at some point during cycle duration t_c.

[0020] According to a first aspect, the present invention relates to a method of injecting oxidizing agent into a vertical shaft furnace in which a combustion process takes place and whereby at least one of the n sections has been identified as a hot-spot section or as a cold-spot section.

[0021] When a section has been identified as a hot-spot section, the control unit controls the injection of oxidizing agent by the injector corresponding to the hot-spot section so that the active duration t_a of said injector is shorter than the active duration t_a of the injectors not corresponding to a hot-spot section (so that the passive duration t_p of a hot-spot section is in turn longer than the passive duration t_p of a section which is not a hot-spot section). As a consequence, the amount of oxidizing agent injected per cycle into a hot-spot section is lower than the amount of oxidizing agent injected per cycle into a section which is not a hot-spot section. This in turn makes it possible to reduce the intensity of combustion in the hot-spot section and to lower the temperature within a hot-spot section or to prevent a further increase of said temperature.

[0022] In an analogous manner, when a section has been identified as a cold-spot section, the control unit controls the injection of oxidizing agent by the injector corresponding to the cold-spot section so that the active duration t_a of said injector is longer than the active duration t_a of the injectors not corresponding to a cold-spot section (and the passive duration t_p of a cold-spot section is consequently shorter than the passive duration t_p of a section which is not a cold-spot section). As a consequence, the amount of oxidizing agent injected per cycle into a cold-spot section is higher than the amount of oxidizing agent injected per cycle into a section which is not a cold-spot section. This makes it possible to intensify the combustion in the cold-spot section and to increase the temperature within a cold-spot section or to prevent a further decrease of said temperature.

[0023] When it is known that no problems arise with cold-spot sections during the operation of the shaft furnace, the control by the control unit of the injection of oxidizing agent by injectors corresponding to cold-spot sections may be omitted from the method.

[0024] Likewise, when it is known that no problems arise with hot-spot sections during the operation of the shaft furnace, the control by the control unit of the injection of oxidizing agent by injectors corresponding to hot-spot sections may be omitted from the method.

[0025] The passive flow rate is preferably less than half the active flow rate, more preferably less than 30% and even more preferably at most 15% of the active flow rate. The reason for injecting some (subsonic) oxidizing agent during the passive phase of an injector is generally to protect the passive injector against overheating and/or to prevent the formation of solid deposits onto and into the passive injector.

[0026] In order to continuously meet the demand for oxidizing agent by the furnace, the control unit controls the number of the n injectors which is in the active phase at any one time, the other injectors of the set of n injectors being in the passive phase. Thus, when the demand or oxidizing agent is high, more injectors will be simultaneously in the active phase than when the demand for oxidizing agent is low. According to a first embodiment of this method, the active duration t_a of each of the injectors not corresponding to a hot-spot section or to a cold-spot section is identical and/or the active duration t_a of each of the injectors corresponding to a cold-spot section is identical.

[0027] The control unit may activate the start of the active phase of the n injectors so that the next injector for which the active phase starts is located in clockwise succession around the circumference of the furnace of the last injector to have started its active phase (as seen from above).

[0028] The control unit may alternatively activate the start of the active phase of the n injectors so that the next injector for which the active phase starts is located in counterclockwise succession around the circumference of the furnace of the last injector to have started its active phase (as seen from above). According to a further embodiment, when the number n of injectors is at least 5 and preferably at least 6, the control unit may activate the start of the active phase of the n injectors so that the next injector for which the active phase starts is located in a semi-circumference opposite the last injector to have started its active phase, which may result in a more even instantaneous distribution of the injectors in active phase thus avoiding that the injectors in active phase across the cross section of the shaft furnace. It may be known from experience where a hot spot or a cold spot will invariably arise in the shaft furnace. In that case, the identification of the one or more hot-spot sections is predetermined and/or the identification of the one or more cold-spot sections in the method according to the invention may be predetermined and the corresponding data stored as predetermined date in the memory of the control unit, i.e. i.e. independently from any real-time feedback from the shaft furnace. For example, only one of the n sections may thus have been identified as a hot-spot section and/or only one of the n sections may have been identified as a cold-spot section in a predetermined manner.

[0029] Likewise, the active duration t_a of an injector corresponding to a hot-spot section and/or the active duration t_a of an injector corresponding to a cold-spot section may be predetermined, in which case said active duration(s) t_a and the corresponding passive duration(s) t_p are not varied on the basis of real-time feedback from the shaft furnace.

[0030] Alternatively, the active duration t_a of an injector corresponding to a hot-spot section and/or the active duration t_a of an injector corresponding to a cold-spot section may be varied in function of real-time feedback from the shaft furnace.

[0031] According to such an embodiment, when a section has been identified as a hot-spot section, the method may advantageously further comprise a step of continuously or intermittently determining a hot-spot temperature inside the hot-spot section or of a wall element adjacent the hot-spot section. The control unit compares the thus determined hot-spot temperature with a predetermined upper hot-spot limit value. When the hot-spot temperature exceeds a predetermined upper hot-spot limit value, the control unit reduces the active duration t_a of the injector corresponding to said hot-spot section. The control unit also compares the hot-spot temperature with a predetermined lower hot-spot limit value. When the hot-spot temperature is below said predetermined lower hot-spot limit value, the control unit increases the active duration t_a of the injector corresponding to said hot-spot section.

[0032] Likewise, when a section has been identified as a cold-spot section, the method may advantageously further comprise a step of continuously or intermittently determining a cold-spot temperature inside the cold-spot section or of a wall element adjacent the cold-spot section. The control unit then compares the thus determined cold-spot temperature with a predetermined lower cold-spot limit value. When the thus cold-spot temperature is below said predetermined lower cold-spot limit value, the control unit increases the active duration t_a of the injector corresponding to said cold-spot section. The control unit also compares the cold-spot temperature with a predetermined upper cold-spot limit value and when the cold-spot temperature exceeds the predetermined upper cold-spot limit value, the control unit decreases the active duration t_a of the injector corresponding to said cold-spot section.

[0033] Obviously, the upper hot-spot limit value is higher than the lower hot-spot limit value and the upper cold-spot limit value is higher than the lower cold-spot limit value. Both hot-spot limit values are normally higher than both cold-spot limit values.

[0034] It will be appreciated that these embodiments enable a more refined response to the occurrence of hot spots and/or cold spots in the shaft furnace.

[0035] Although, as indicated above, in some cases it may be possible to predetermine that hot spots and/or cold spots will occur at certain locations, and thus to predetermine hot-spot sections and/or cold-spot sections, in many cases it will not be possible to predict when and/or where a hot spot or a cold spot may occur in the shaft furnace.

[0036] For this reason, the present invention also includes a method of injecting oxidizing agent into a vertical shaft furnace in which a combustion process takes place and whereby the occurrence of one or more hot-spot sections and/or cold-spot sections is detected in real time.

[0037] According to such an embodiment, the method further comprising the step of continuously or intermittently determining a control temperature inside each of the n sections or of a wall element adjacent each of the n sections.

[0038] Thereafter, when the method includes the identification of hot-spot sections, each control temperature is compared with a hot-spot reference temperature. When the control temperature of a section exceeds the hot-spot reference temperature, said section is identified by the control unit as a hot-spot section. Likewise, when the method (also) includes the identification of hot-spot sections, each control temperature is compared with a cold-spot reference temperature and when the control temperature of a section below the cold-spot reference temperature said section is identified as a cold-spot section by the control unit.

[0039] The hot-spot reference temperature and/or the cold-spot reference temperature are generally predetermined. However, said reference temperature(s) may also usefully be determined in real-time, for example in function of the average of the control temperatures of the n sections. The hot-spot reference temperature could then be a first predetermined number of degrees above said average or a first predetermined percentage above said average. Likewise, the cold-spot reference temperature could be a second predetermined number of degrees below the average or a second percentage below the average, whereby, when both hot-spot sections and cold-spot section are determined, the first and second predetermined number of degrees or the first and second percentage may be identical or different. The exact value of the first and/or second predetermined number of degrees or the first and/or second percentage will depend on the sensitivity to differences in temperature of the process taking place in the furnace and the furnace refractories. Indeed, differences in temperature which do not produce a noticeable detrimental effect on the process nor on the refractories do not justify the adjustment of the injection of the oxidizing agent into the furnace.

[0040] The determination of the control temperatures may be done manually or automatically. When the control temperatures are determined intermittently, this may be done manually or automatically. When the control temperatures are determined continuously, this is normally done automatically. Likewise, the comparison between the control temperatures and the reference temperature(s) may be performed by the furnace operator and the results (temperature difference or the identification of the hot- and/or cold-spot sections may be inputted into the control unit by the operator. Preferably, the control unit automatically receives the determined control temperatures, compares same with the reference temperature or temperatures and automatically identifies any hot-spot sections and/or cold-spot sections in function of said comparison.

[0041] In addition, according to a preferred embodiment:

- the control unit also selects the active duration t_a of an injector corresponding to a hot-spot section in function of the difference between the control temperature of said hot-spot section and the hot-spot reference temperature so that a greater difference between the control temperature and the hot-spot reference temperature results in a shorter active duration t_a and a smaller difference between the control temperature and the hot-spot reference temperature results in a greater active duration t_a
  and/or
- the control unit selects the active duration t_a of an injector corresponding to a cold-spot section in function of the difference between the control temperature of said cold-spot section and the cold-spot reference temperature so that a greater difference between the control temperature and the cold-spot reference temperature results in a greater active duration t_a and a smaller difference between the control temperature and the cold-spot reference temperature results in a smaller active duration t_a.

[0042] The control unit preferably has at least one information output element which discloses which of the n sections is a hot-spot section and/or which of the n sections is a cold-spot section or which of the n injectors corresponds to a hot-spot section and/or which of the n injectors corresponds to a cold-spot section. The control unit may, for example, comprise, by way of output element, a screen with a schematic representation of the cross section of the shaft furnace in which any hot-spot sections and/or cold-spot sections are highlighted. The control element may also have an output element which transmits said information to a remote hand-held or mobile device.

[0043] Typically, the cross section of the shaft furnace is substantially circular, though different cross sections, such as a rectangular cross section, is also possible.

[0044] In general, the n injectors are substantially evenly or uniformly distributed around the circumference of the shaft furnace.

[0045] The number n of said injectors is generally greater than 3. A number of up to 14 or 16 injectors may be useful. However, the number n of injectors may also be significantly higher, for example up to 24 or even up to 36.

[0046] The source of oxidizing gas may be an installation for enriching air with oxygen, typically when the oxygen content of the oxidizing gas is relatively low, for example more than 21%vol and not more than 90%vol. The source of oxidizing gas may also be an air separation unit, a reservoir of liquefied oxygen or a pipeline transporting liquefied oxygen, for example when the oxygen content of the oxidizing gas is between 90%vol and 100%vol, preferably at least 95%vol.

[0047] The control unit usefully controls the total amount of the oxidizing agent injected into the shaft furnace by means of an adjustable control valve unit. Such an adjustable control valve unit may for example control the total amount of oxidizing agent which is supplied to a gas distributor which is in fluid connection with each one of the n injectors, typically a gas supply ring which surrounds the shaft furnace.

[0048] The control unit advantageously controls the amount of oxidizing gas to each of the n injectors by means of n individual valve units, each of the n individual valve units controlling the supply of oxidizing agent to a single one of the n injectors. Said n individual valve units may, for example, be positioned on the n fluid connections between the gas distributor (or ring) and the n injectors, one individual valve unit per fluid connection.

[0049] The n individual valve units are preferably on-off valve units. When an individual valve unit is in an on-position, a first flow rate of oxidizing agent is supplied to the corresponding injector so that said injector injects oxidizing agent at said first flow rate (active flow rate) and at sonic or supersonic velocity into the shaft furnace. When an individual valve unit is in an off-position, no oxidizing agent is supplied to the corresponding injector or oxidizing agent is supplied to said corresponding injector at a second flow rate which is lower than the first flow rate so that said injector injects no oxidizing agent into the shaft furnace or injects oxidizing agent at said second flow rate (passive flow rate) and at subsonic velocity into the melting zone.The injectors are advantageously equipped with a convergent-divergent nozzle or laval nozzle.

[0050] The shaft furnace may be a waste combustion furnace. However, the invention is particularly useful when the furnace is a furnace in which a charge material, other than the fuel which is combusted with the oxidizing agent, is transformed. The invention is thus particularly useful when the shaft furnace is a glass-melting furnace, a mineral-wool-melting furnace or a metal-melting furnace.

[0051] The shaft furnace may be a cupola. The shaft furnace may also be an ironmelting blast furnace.

[0052] The present invention also relates to an installation for effecting a combustion process in a vertical shaft furnace.

[0053] This installation comprises the shaft furnace, a source of oxidizing agent and a control unit.

[0054] The shaft furnace presents n injectors distributed around the circumference of the shaft furnace at a level [h, h + Δh] of the shaft furnace , whereby n is at least 3, each injector being adapted for sonic or supersonic injection of a gaseous fluid into one of n sections of a cross-section of the shaft furnace at level [h, h + Δh].

[0055] The oxidizing agent which the source of oxidizing agent is capable of supplying has an oxygen content higher than 21%vol and at most 100%vol. Said source is furthermore fluidly connected to each of the n injectors.

[0056] The control unit of the installation according to the invention is programmed to control both (a) a total amount of the oxidizing agent injected into the shaft furnace by means of the n injectors so as to meet a demand for oxidizing agent by the combustion process and (b) an amount of oxidizing agent injected into the shaft furnace by each one of the n injectors, said control unit being more specifically programmed to control the amount of oxidizing agent injected by each one of the n injectors in accordance with any one of the embodiments of the method of the invention as described above.

[0057] The different installation features described hereabove in the context of the method, such as the number and type of injectors, the types of shaft furnace, etc, also apply to different embodiments of the installation of the invention.

Claims

1. Method of injecting oxidizing agent into a vertical shaft furnace in which a combustion process takes place, the shaft furnace presenting:

    • n injectors distributed around the circumference of the shaft furnace at a level [h, h + Δh] of the shaft furnace , with n $\geq$ 3, each injector being adapted for sonic or supersonic injection of a gaseous fluid into one of n sections of a cross-section of the shaft furnace at level [h, h + Δh],

    the shaft furnace being part of an installation including:

    • a source of an oxidizing agent having an oxygen content higher than 21%vol and at most 100%vol, said source being fluidly connected to each of the n injectors,
    • a control unit programmed to control:

        (a) a total amount of the oxidizing agent injected into the shaft furnace by means of the n injectors so as to meet a demand for oxidizing agent by the combustion process and
        (b) an amount of oxidizing agent injected into the shaft furnace by each one of the n injectors,

    whereby:

        • the control unit controls the injection of oxidizing agent by each one of the n injectors cyclically with a cycle duration t_c;
        • the control unit controls the injection of oxidizing agent by each one of the n injectors so that each one of the n injectors injects oxidizing agent in a pulsed fashion, alternating between:

            (a) an active phase having an active duration t_a and during which the injector injects the oxidizing agent at an active flow rate and with supersonic velocity, and
            (b) a passive phase having a passive duration t_p and during which the injector either injects no oxidizing agent or injects oxidizing agent at subsonic velocity and at a passive flow rate which is lower than the active flow rate,

        whereby for each one of the n injectors $t_a + t_p = t_c$;

    characterized in that:

        • at least one of the n sections is identified as a hot-spot section and/or at least one of the n sections is identified as a cold-spot section, and
        • when a section has been identified as a hot-spot section: the control unit controls the injection of oxidizing agent by the injector corresponding to a hot-spot section so that the active duration t_a of said injector is shorter than the active duration t_a of the injectors not corresponding to a hot-spot section,
        • when a section has been identified as a

cold-spot section: the control unit controls the injection of oxidizing agent by the injector corresponding to a cold-spot section so that the active duration t_a of said injector is longer than the active duration t_a of the injectors not corresponding to a cold-spot section.

2. Method according to claim 1, whereby the active duration t_a of each of the injectors not corresponding to a hot-spot section or to a cold-spot section is identical.

3. Method according to claim 1 or 2, whereby the active duration t_a of each of the injectors corresponding to a hot-spot section is identical and/or whereby the active duration t_a of each of the injectors corresponding to a cold-spot section is identical.

4. Method according to any one of claims 1 to 3, whereby either (a) the control unit activates the start of the active phase of the n injectors so that the next injector for which the active phase starts is located in clockwise succession around the circumference of the furnace of the last injector to have started its active phase or (b) the control unit activates the start of the active phase of the n injectors so that the next injector for which the active phase starts is located in counterclockwise succession around the circumference of the furnace of the last injector to have started its active phase.

5. Method according to any one of claims 1 to 3, whereby n is ≥ 5, preferably ≥ 6 and whereby the control unit activates the start of the active phase of the n injectors so that the next injector for which the active phase starts is located in a semi-circumference opposite the last injector to start its active phase.

6. Method according to any one of the preceding claims, whereby the identification of the one or more hot-spot sections is predetermined and/or whereby the identification of the one or more cold-spot sections is predetermined.

7. Method according to any one of claims 1 to 5, further comprising the step of continuously or intermittently determining a control temperature inside each of the n sections or of a wall element adjacent each of the n sections, and whereby:

- each control temperature is compared with a hot-spot reference temperature and when the control temperature of a section exceeds the hot-spot reference temperature, said section is identified by the control unit as a hot-spot section and/or
- each control temperature is compared with a cold-spot reference temperature and when the control temperature of a section below the cold-spot reference temperature said section is identified as a cold-spot section by the control unit.

8. Method according to claim 7, whereby the control unit performs the comparison between each control temperature and the hot-spot reference temperature and/or the cold-spot reference temperature.

9. Method according to claim 8, whereby:

- the control unit selects the active duration t_a of an injector corresponding to a hot-spot section in function of the difference between the control temperature of said hot-spot section and the hot-spot reference temperature so that a greater difference between the control temperature and the hot-spot reference temperature results in a shorter active duration t_a and a smaller difference between the control temperature and the hot-spot reference temperature results in a greater active duration t_a and/or
- the control unit selects the active duration t_a of an injector corresponding to a cold-spot section in function of the difference between the control temperature of said cold-spot section and the cold-spot reference temperature so that a greater difference between the control temperature and the cold-spot reference temperature results in a greater active duration t_a and a smaller difference between the control temperature and the cold-spot reference temperature results in a smaller active duration t_a.

10. Method according to any one of the preceding claims, whereby the control unit controls the total amount of the oxidizing agent injected into the shaft furnace by means of an adjustable control valve unit.

11. Method according to any one of the preceding claims, whereby the control unit controls the amount of oxidizing gas to each of the n injectors by means of n individual valve units, each of the n individual valve units controlling the supply of oxidizing agent to a single one of the n injectors.

12. Method according to any one of the preceding claims, whereby the n individual valve units are on-off valve units, whereby, when the individual valve unit is in an on-position, a first flow rate of oxidizing agent is supplied to the corresponding injector so that said injector injects oxidizing agent at said first flow rate and at sonic or supersonic velocity into the shaft furnace and whereby, when the individual valve unit is in an off-position, no oxidizing agent is supplied to the corresponding injector or oxidizing agent is supplied to said corresponding injector at a second flow rate which is lower than the first flow rate so that said injector injects no oxidizing agent into the shaft furnace or injects oxidizing agent at said second flow rate and at subsonic velocity into the melting zone.

13. Method according to any one of the preceding claims, whereby the shaft furnace is a cupola.

14. Method according to any one of claims 1 to 12, whereby the shaft furnace is an ironmelting blast furnace.

15. Installation for effecting a combustion process in a vertical shaft furnace, the installation comprising:

- the vertical shaft furnace which presents n injectors distributed around the circumference of the shaft furnace at a level [h, h + Δh] of the shaft furnace , with n $\geq$ 3, each injector being adapted for sonic or supersonic injection of a gaseous fluid into one of n sections of a cross-section of the shaft furnace at level [h, h + Δh];
- a source of an oxidizing agent having an oxygen content higher than 21%vol and at most 100%vol, said source being fluidly connected to each of the n injectors,
- a control unit programmed to control:

  (a) a total amount of the oxidizing agent injected into the shaft furnace by means of the n injectors so as to meet a demand for oxidizing agent by the combustion process and
  (b) an amount of oxidizing agent injected into the shaft furnace by each one of the n injectors,

in accordance with a methods according to any one of claims 1 to 12.

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EUROPEAN SEARCH REPORT

Application Number
EP 17 17 7494

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	AU 660 238 B2 (NIPPON KOKAN KK) 15 June 1995 (1995-06-15) * page 1, line 11 - line 14 * * page 2, line 16 - line 18 * * page 3, line 21 - page 5, line 1 * * page 6, line 15 - page 8, line 24 * * page 12, line 13 - line 17 * * page 13, line 10 - page 14, line 5 * * claims 1,8,11 * * figures 1,4 * -----	1-15	INV. C21B5/00 C21B7/16
A	WO 2008/080922 A2 (AIR LIQUIDE [FR]; JOUMANI YOUSSEF [FR]; PENFORNIS ERWIN [FR]; MORTBERG) 10 July 2008 (2008-07-10) * page 4, line 10 - line 13 * * page 10, line 3 - line 5 * * page 10, line 22 - line 26 * * figure 6 * -----	4-6	

TECHNICAL FIELDS SEARCHED (IPC)

C21B
F27B
F27D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	27 November 2017	Porté, Olivier

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 17 17 7494

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REFERENCES CITED IN THE DESCRIPTION

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