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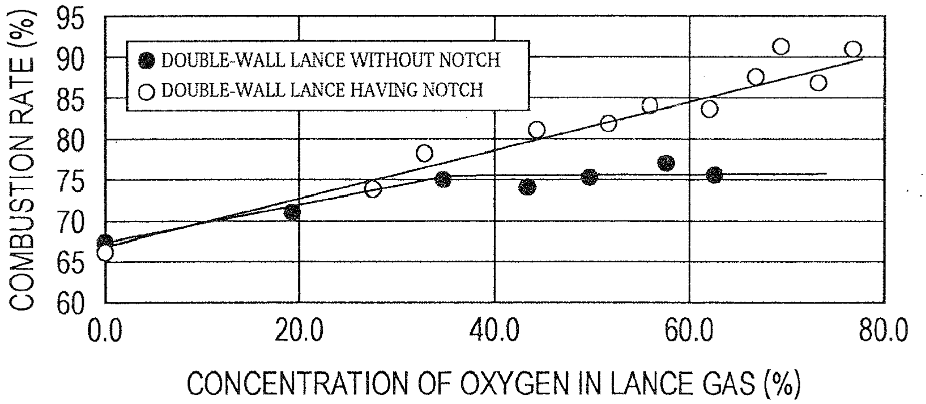
(54) **DOUBLE WALL LANCE**

(57) A lance 4 for injecting a fuel through a tuyere 3 is a double tube. Pulverized coal is injected through an inner tube 21 of the double wall lance 4. Oxygen is injected through an outer tube 22 of the double wall lance 4. Notches 23 are formed in a injecting front end of the inner tube 21 of the double wall lance 4. The concentration of oxygen in a gas composed of a carrier gas for the pulverized coal and a gas injected through the outer tube is 35% by volume or more. Even in an operation using pulverized coal having a volatile matter content of 25 mass% or less at a high pulverized coal ratio of 150 kg/t or more, the combustion temperature can be increased, and consequently CO_2 emissions can be reduced. The specific oxygen consumption can be suppressed by decreasing the oxygen concentration to less than 70% by volume. The notches 23 may be circumferentially evenly spaced in the inner tube 21 of the double wall lance 4 and further improve combustion efficiency.

FIG. 9



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Description

[Technical Field]

[0001] The present invention relates to a method for operating a blast furnace that includes injecting pulverized coal through a blast furnace tuyere to increase the combustion temperature, thereby improving productivity and reducing CO_2 emissions.

[Background Art]

[0002] Considering recent global warming due to increased carbon dioxide emissions, it is also important for the iron industry to reduce CO_2 emissions. In blast furnaces, coke and pulverized coal injected through a tuyere are used as main reducing materials. Because of the difference in carbon dioxide emissions in pretreatment, the use of pulverized coal rather than coke can reduce CO_2 emissions. For example, Patent Literature 1 discloses that the combustion efficiency can be improved by using pulverized coal having a volatile matter content of 25 mass% or less at a pulverized coal ratio of 150 kg/t-pig iron or more, supplying the pulverized coal and oxygen to a lance for injecting a fuel through a tuyere, and increasing the oxygen concentration in the lance to 70% by volume or more. It is also proposed in Patent Literature 1 that in the case of a single-tube lance a mixture of oxygen and pulverized coal is injected through the single-tube lance, and in the case of a double wall lance pulverized coal is injected through an inner tube of the double wall lance, and oxygen is injected through an outer tube of the double wall lance. The pulverized coal ratio is the mass of pulverized coal used per ton of pig iron.

[0003] Patent Literature 2 discloses that a reaction between pulverized coal and oxygen is promoted by dispersing the pulverized coal utilizing asperities formed on an outer tube of a double wall lance.

[0004] Patent Literature 3 discloses that in a double wall lance for injecting pulverized coal through an inner tube thereof and oxygen through an outer tube thereof the contact between pulverized coal and oxygen is improved by shortening the inner tube relative to the outer tube, that is, placing a pulverized coal injecting front end of the inner tube upstream from an oxygen injecting front end of the outer tube in the injecting direction.

[Citation List]

[Patent Literature]

[0005]

[PTL 1] Japanese Patent No. 4074467

[PTL 2] Korean Patent Laid-Open Publication No. 2002-00047359

[PTL 3] Japanese Unexamined Patent Application Publication No. 6-100912

[Summary of Invention]

[Technical Problem]

[0006] Although much air is blown through a tuyere, a lance may be exposed to a high temperature. Thus, the supply of a mixture of a high concentration of oxygen and pulverized coal to a single-tube lance as described in Patent Literature 1 is unrealistic from a safety standpoint. With a demand for a further reduction of CO_2 emissions, it is desirable to increase the pulverized coal ratio to 170 kg/t-pig iron or more, for example. At a high pulverized coal ratio of 170 kg/t or more, however, even when pulverized coal is injected through an inner tube of a double wall lance and oxygen is injected through an outer tube thereof as described in Patent Literature 1, the combustion temperature levels off, and the combustion efficiency cannot be increased.

[0007] A gas flowing through an outer tube of a double wall lance also functions to cool the outer tube. In the presence of an obstacle that interferes with the gas flow, such as the asperities formed on the outer tube in Patent Literature 2, a heat load is applied to a slow flow region, possibly causing wear damage, such as cracking or a melting loss. Such wear damage may induce backfire or clogging of a lance. An increase in the amount of pulverized coal inevitably causes a problem of abrasion of a raised portion due to pulverized coal injected through an inner tube.

[0008] Although shortening the front end of the inner tube of the double wall lance relative to the outer tube of the double wall lance as described in Patent Literature 3 may improve the contact between pulverized coal and oxygen, an oxygen flow suppresses the dispersion of pulverized coal, and the combustibility of pulverized coal is not sufficiently improved.

[0009] The present invention has paid attention to these problems and aims to provide a blast furnace operation method for increasing the combustion temperature and thereby reducing CO_2 emissions.

[Solution to Problem]

[0010] In order to achieve this object, the present invention provides a blast furnace operation method described below.

(1) A blast furnace operation method, including preparing pulverized coal having a volatile matter content of 25 mass% or less;
preparing a double wall lance for injecting the pulverized coal and a combustion-supporting gas through a tuyere, the double wall lance having an inner tube and an outer tube;
blowing hot air through the tuyere;
circumferentially forming a plurality of notches in a injecting front end of the inner tube of the double wall lance, the notches being cut in the axial direction;

injecting the pulverized coal together with a carrier gas through the inner tube at a pulverized coal ratio of 150 kg/t-pig iron or more; and
injecting the combustion-supporting gas through the outer tube of the double wall lance,
wherein the concentration of oxygen in a gas composed of the carrier gas and the combustion-supporting gas is 35% by volume or more.

(2) The blast furnace operation method according to (1), wherein the notches are circumferentially evenly spaced in the front end of the inner tube of the double wall lance.

(3) The blast furnace operation method according to (2), wherein the ratio of the total width of the notches to the internal circumference of the inner tube of the double wall lance is more than 0 and 0.5 or less.

(4) The blast furnace operation method according to (3), wherein the ratio of the total width of the notches to the internal circumference of the inner tube of the double wall lance is 0.05 or more and 0.3 or less.

(5) The blast furnace operation method according to (4), wherein the ratio of the total width of the notches to the internal circumference of the inner tube of the double wall lance is 0.1 or more and 0.2 or less.

(6) The blast furnace operation method according to (2), wherein each of the notches has a depth of more than 0 mm and 12 mm or less.

(7) The blast furnace operation method according to (6), wherein each of the notches has a depth of 2 mm or more and 10 mm or less.

(8) The blast furnace operation method according to (7), wherein each of the notches has a depth of 3 mm or more and 7 mm or less.

(9) The blast furnace operation method according to (2), wherein the ratio of the number of the notches to the maximum number of notches is more than 0 and 0.8 or less, wherein the maximum number of notches is an integer part of a quotient obtained by dividing the internal circumference of the inner tube of the double wall lance by the width of one of the notches.

(10) The blast furnace operation method according to (9), wherein the ratio of the number of the notches to the maximum number of notches is 0.1 or more and 0.6 or less.

(11) The blast furnace operation method according to (10), wherein the ratio of the number of the notches to the maximum number of notches is 0.2 or more and 0.5 or less.

(12) The blast furnace operation method according to (1), wherein the combustion-supporting gas is oxygen, and part of oxygen for enrichment is injected into a blast through the outer tube of the double wall lance.

(13) The blast furnace operation method according to (1), wherein the pulverized coal has a volatile matter content of 3 mass% or more and 25 mass% or less.

(14) The blast furnace operation method according to (1), wherein the combustion-supporting gas injected through the outer tube of the double wall lance has an outlet flow velocity in the range of 20 to 120 m/sec.

(15) The blast furnace operation method according to (1), wherein the pulverized coal ratio is 170 kg/t-pig iron or more.

(16) The blast furnace operation method according to (1), wherein the pulverized coal ratio is 170 kg/t-pig iron or more, and the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas is 35% by volume or more and less than 70% by volume.

(17) The blast furnace operation method according to (16), wherein the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas is 40% by volume or more and 65% by volume or less.

(18) The blast furnace operation method according to (17), wherein the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas is 45% by volume or more and 60% by volume or less.

(19) The blast furnace operation method according to (15), wherein the pulverized coal ratio is 170 kg/t-pig iron or more and 300 kg/t-pig iron or less.

(20) The blast furnace operation method according to (16), wherein the pulverized coal ratio is 170 kg/t-pig iron or more and 300 kg/t-pig iron or less.

(21) The blast furnace operation method according to (1), wherein the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas is 35% by volume or more and less than 70% by volume.

(22) The blast furnace operation method according to (21), wherein the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas is 40% by volume or more and 65% by volume or less.

(23) The blast furnace operation method according to (22), wherein the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas is 45% by volume or more and 60% by volume or less.

(24) The blast furnace operation method according to (1), wherein the pulverized coal ratio is 150 kg/t-pig iron or more and 300 kg/t-pig iron or less.

(25) The blast furnace operation method according to (1), wherein the pulverized coal ratio is 150 kg/t-pig iron or more and less than 170 kg/t-pig iron.

(26) The blast furnace operation method according to (1), wherein the pulverized coal ratio is 150 kg/t-pig iron or more and less than 170 kg/t-pig iron, and the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas is 35% by volume or more and less than 70% by volume.

(27) The blast furnace operation method according to any one of (1) to (26), wherein at least one selected from the group consisting of waste plastics, refuse-derived fuels, organic resources, scrap woods, and CDQ coke dust is added to the pulverized coal.
(28) The blast furnace operation method according to (27), wherein the pulverized coal accounts for 80 mass% or more, and at least one of the waste plastics, refuse-derived fuels, organic resources, scrap woods, and CDQ coke dust is used.

[Advantageous Effects of Invention]

[0011] In a blast furnace operation method according to the present invention in which a lance for injecting a fuel through a tuyere is a double tube, the method includes injecting pulverized coal together with a carrier gas through an inner tube of the double wall lance, injecting a combustion-supporting gas through an outer tube of the double wall lance, and forming notches in a injecting front end of the inner tube of the double wall lance, wherein the concentration of oxygen in a gas composed of the carrier gas and the combustion-supporting gas in the double wall lance is 35% by volume or more. Even in an operation using pulverized coal having a volatile matter content of 25 mass% or less at a high pulverized coal ratio of 150 kg/t or more, the combustion temperature can be increased, and consequently CO_2 emissions can be reduced. When the pulverized coal ratio is 170 kg/t or more, the specific consumption of a combustion-supporting gas, such as oxygen, can be reduced by decreasing the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas in the double wall lance to less than 70% by volume.

[0012] The notches circumferentially evenly spaced in the front end of the inner tube of the double wall lance improve the diffusion of pulverized coal and the combustion-supporting gas and further improve combustion efficiency.

[0013] Injecting part of oxygen for enrichment into a blast as a combustion-supporting gas through the outer tube of the double wall lance can prevent excess oxygen supply without disturbing the gas balance in the blast furnace.

[Brief Description of Drawings]

[0014]

[Fig. 1] Fig. 1 is a longitudinal sectional view of an embodiment of a blast furnace to which a blast furnace operation method according to the present invention is applied.
[Fig. 2] Fig. 2 is an explanatory view of the combustion state when only pulverized coal is injected through the lance illustrated in Fig. 1.
[Fig. 3] Fig. 3 is an explanatory view of the combustion mechanism of pulverized coal in Fig. 2.
[Fig. 4] Fig. 4 is an explanatory view of the combustion mechanism in the case that pulverized coal and oxygen are injected.
[Fig. 5] Fig. 5 is an explanatory view of a combustion experimental apparatus.
[Fig. 6] Figs. 6(a) to 6(c) are explanatory views of the concentration of a pulverized coal flow.
[Fig. 7] Figs. 7(a) and 7(b) are detail views of a injecting front end of the lance illustrated in Fig. 1.
[Fig. 8] Figs. 8(a) and 8(b) are explanatory views of the pulverized coal flow of the lance illustrated in Fig. 7 and a lance formed of a straight tube.
[Fig. 9] Fig. 9 is a graph of the relationship between the concentration of oxygen in a lance gas and the combustion rate at a pulverized coal ratio of 150 kg/t-pig iron or more and less than 170 kg/t-pig iron.
[Fig. 10] Fig. 10 is a graph of the relationship between the concentration of oxygen in a lance gas and the combustion rate at a pulverized coal ratio of 170 kg/t-pig iron or more.
[Fig. 11] Figs. 11(a) to 11(c) are explanatory views of the shape of a notch in an inner tube viewed in the radial direction.
[Fig. 12] Figs. 12(a) and 12(b) are explanatory views of the angle θ made by a center of a front end and a center of a lower end of a notch.
[Fig. 13] Fig. 13 is an explanatory view of an experiment on the contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal.
[Fig. 14] Fig. 14 is an explanatory view of the contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal as a function of the notch width.
[Fig. 15] Fig. 15 is an explanatory view of the contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal as a function of the notch depth.
[Fig. 16] Fig. 16 is an explanatory view of the contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal as a function of the number of notches.
[Fig. 17] Fig. 17 is an explanatory view of the contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal as a function of the width of a tetragonal notch or a triangular notch.
[Fig. 18] Fig. 18 is an explanatory view of the relationship between the flow velocity at a lance outlet and the lance surface temperature.

[Description of Embodiments]

[0015] A blast furnace operation method according to an embodiment of the present invention will be described below with reference to the accompanying drawings.

[0016] Fig. 1 is an overall view of a blast furnace to which a blast furnace operation method according to the present embodiment is applied. As illustrated in the figure, a tuyere 3 of a blast furnace 1 is coupled to a blow pipe 2 for blowing hot air, and a lance 4 is inserted in the blow pipe 2. A combustion space called a raceway 5 is disposed over a coke layer in front of the tuyere 3 in a hot air blowing direction. Combustion and gasification of a reducing material occur mainly in this combustion space.

[0017] Fig. 2 illustrates the combustion state when only pulverized coal 6 is injected as a solid reducing material through the lance 4. The pulverized coal 6 is injected from the lance 4 into the raceway 5 through the tuyere 3. The volatile matter and fixed carbon of the pulverized coal 6 burn together with coke 7. After the volatile matter is released, an aggregate of carbon and ash, which is generally called char, is discharged from the raceway as unburned char 8. The hot air velocity in front of the tuyere 3 in the hot air blowing direction is approximately 200 m/sec. An oxygen zone extends approximately 0.3 to 0.5 m from a front end of the lance 4 into the raceway 5. Thus, it is necessary to increase the temperature of pulverized coal particles and improve the efficiency of contact with oxygen (dispersibility) during a period substantially on the order of 1/1000 second.

[0018] Fig. 3 illustrates the combustion mechanism in the case that only the pulverized coal (PC in the figure) 6 is injected into the blow pipe 2 through the lance 4. Particles of the pulverized coal 6 injected into the raceway 5 through the tuyere 3 are heated through radiative heat transfer from flames in the raceway 5. The temperature of the particles increases rapidly through radiative heat transfer and conductive heat transfer. The particles start to decompose at a temperature of 300°C or more. The volatile matter of the particles ignites and forms a flame. The combustion temperature reaches a temperature in the range of 1400°C to 1700°C. After the volatile matter is completely released, the char 8 remains. Since the char 8 is mainly composed of fixed carbon, a combustion reaction is accompanied by a carbon dissolution reaction, such as a solution-loss reaction or a hydrogen gas shift reaction.

[0019] Fig. 4 illustrates the combustion mechanism in the case that the pulverized coal 6, together with a combustion-supporting gas oxygen 9, is injected into the blow pipe 2 through the lance 4. The pulverized coal 6 and the oxygen 9 are simply injected parallel to each other. For reference, a dash-dot-dot line in the figure indicates the combustion temperature in the case that only the pulverized coal is injected as illustrated in Fig. 3. Simultaneous injecting of the pulverized coal and oxygen promotes mixing of the pulverized coal and oxygen in the vicinity of the lance and accelerates the combustion of the pulverized coal, thereby increasing the combustion temperature in the close vicinity of the lance.

[0020] On the basis of such findings, a combustion experiment was performed with a combustion experimental apparatus illustrated in Fig. 5. Imitating the interior of a blast furnace, an experiment furnace 11 is filled with coke, and the interior of a raceway 15 can be observed through an observation window. A lance 14 is inserted in a blow pipe 12. As a hot air blown from an air-heating furnace to the blast furnace, a hot air produced by a combustion burner 13 can be blasted into the experiment furnace 11 at a predetermined blast rate. The oxygen enrichment level of the blast air can be controlled with the blow pipe 12. One or both of pulverized coal and oxygen can be injected into the blow pipe 12 through the lance 14. An exhaust gas from the experiment furnace 11 is separated into an exhaust gas and dust in a separator 16 called cyclone. The exhaust gas is sent to an exhaust gas treatment system, such as an auxiliary combustion furnace. The dust is collected in a collecting box 17.

[0021] The pulverized coal is composed of fixed carbon (FC) 71.4%, volatile matter (VM) 19.5%, and ash 9.1%. The blast conditions include a blast temperature of 1200°C, a flow rate of 300 Nm^3/hr, a blast velocity of 130 m/sec at a front end of the tuyere, and an oxygen enrichment of 6% (an oxygen concentration of 27.0%, an enrichment of 6.0% relative to an oxygen concentration of 21% in air). With respect to the pulverized coal injecting conditions, the lance 14 was a double wall lance, pulverized coal was injected through an inner tube of the double wall lance, and oxygen was injected as a combustion-supporting gas through an outer tube of the double wall lance. Pulverized coal was carried by a carrier gas. The carrier gas for pulverized coal was nitrogen. The solid-gas ratio of pulverized coal to a carrier gas for carrying pulverized coal ranges from 10 to 25 kg/Nm^3 in the case that a powder, that is, pulverized coal is carried by a small amount of gas (high concentration transport) or 5 to 10 kg/Nm^3 in the case that pulverized coal is carried by a large amount of gas (low concentration transport). In addition to nitrogen, the carrier gas may also be air. An experiment was conducted with a focus on variations in pulverized coal flow at a pulverized coal ratio in the range of 100 to 180 kg/t. When oxygen was injected as a combustion-supporting gas, part of oxygen for enrichment was included in the blast so as not to change the total amount of oxygen blown into the furnace. The combustion-supporting gas may also be an oxygen-enriched air.

[0022] The present inventors found the following in this experiment. When pulverized coal is injected through the inner tube of the double wall lance, and a combustion-supporting gas, that is, oxygen is injected through the outer tube of the double wall lance, the combustion temperature is increased by increasing the oxygen concentration in an operation at a low pulverized coal ratio of less than 150 kg/t even if the pulverized coal has a volatile matter content of 25 mass% or less. In an operation at a high pulverized coal ratio of 150 kg/t or more, however, the combustion temperature is not increased by increasing the oxygen concentration. When the pulverized coal ratio is 150 kg/t or more, the combustion temperature levels off at an oxygen concentration of approximately 35% by volume. As described below, this is because pulverized coal injected through the inner tube of the double wall lance localizes (or is concentrated) in the center of a blast flow and rarely or does not come into contact with oxygen injected through the outer tube of the double wall lance. The present invention is the same as the related art in that pulverized coal is injected through an inner tube of a double wall lance and a combustion-supporting gas, for example, oxygen is injected through an outer tube of the double wall lance. However, in the present invention, notches formed in a injecting front end of an inner tube of a double wall lance can improve the diffusion of pulverized coal and a combustion-supporting gas and thereby promote contact between the pulverized coal and the combustion-supporting gas and increase the combustion temperature. Even if the notches are formed in the injecting front end of the inner tube of the double wall lance, when the pulverized coal ratio is 170 kg/t or more, the combustion temperature also levels off at an oxygen concentration of 70% by volume or more in the lance. Thus, an oxygen concentration of more than 70% by volume does not contribute to high combustion efficiency and results in an increased specific oxygen consumption. Unlike a projection, such as a baffle, which suffers wear damage due to collision with pulverized coal, the notches formed in the inner tube of the double wall lance have no wear damage trouble.

[0023] Fig. 6(a) illustrates the pulverized coal flow in an operation at a low pulverized coal ratio of less than 150 kg/t. Since the lance is a straight tube having a constant diameter in the experiment, the dispersion width of pulverized coal is substantially constant. The pulverized coal flow has a substantially uniform concentration within the dispersion width at such a low pulverized coal ratio. In an operation at a high pulverized coal ratio of 150 kg/t or more, however, as illustrated in Fig. 6(b), pulverized coal is concentrated in the center of the dispersion width. In particular, in an operation at a high pulverized coal ratio of 170 kg/t or more, pulverized coal is highly concentrated in the center of the pulverized coal flow. Since oxygen is injected through the outer tube of the double wall lance, pulverized coal concentrated in the center of the pulverized coal flow does not come into contact with oxygen, and such unburned pulverized coal injected into the furnace interferes with aeration in the blast furnace. Even if the amount of oxygen blown is increased to promote contact with oxygen, when the amount of oxygen blown exceeds a certain threshold, as illustrated in Fig. 6(c), the pulverized coal flow is further concentrated in the center of the surrounding oxygen flow. Thus, the contact with oxygen is not substantially promoted, and the combustion temperature levels off as described later.

[0024] Fig. 7 illustrates the details of a injecting front end of the double wall lance 4 according to the present embodiment. Fig. 7(a) is a longitudinal sectional view, and Fig. 7(b) is a cross-sectional view taken along the line A-A in Fig. 7(a). In the present embodiment, as illustrated in Fig. 7, notches 23 are formed in a injecting front end of an inner tube 21 of the double wall lance 4. Pulverized coal 6 and a combustion-supporting gas oxygen 9 diffuse through the notches 23. This allows efficient contact between the pulverized coal 6 and the oxygen 9 and increases the combustion temperature. When the inner tube 21 has an inner diameter of approximately 16 mm, four notches 23 each having an approximately 5 mm x 5 mm square cross section are circumferentially evenly spaced in the inner tube 21 at intervals of 90 degrees. An outer tube 22 is a straight tube. The shape of the notches 23 is not limited to the shape described above and may be triangular or U-shaped as described below. The number of the notches 23 is also not limited to four.

[0025] As illustrated in Fig. 8(a), the pulverized coal 6 and the combustion-supporting gas oxygen 9 can diffuse through the notches 23 formed in the injecting front end of the inner tube 21 of the double wall lance 4 and come into contact with each other, thereby increasing the combustion temperature. In a known double wall lance 4 having no notch in a injecting front end of an inner tube 21, as illustrated in Fig. 8(b), pulverized coal 6 is concentrated in a central portion of a combustion-supporting gas oxygen 9. This results in poor contact between the pulverized coal 6 and the oxygen 9, and the combustion temperature levels off. As described above, unlike a projection, such as a baffle, which suffers wear damage due to collision with pulverized coal, the notches 23 formed in the inner tube 21 of the double wall lance 4 have no wear damage trouble.

[0026] Fig. 9 shows the combustion temperature represented by the combustion rate under the conditions that the pulverized coal ratio is 150 kg/t, the volatile matter of the pulverized coal is 25 mass% or less, the blast conditions are fixed, the oxygen enrichment ratio is fixed, and the injecting front end of the inner tube 21 of the double wall lance 4 has the notches 23 or no notch. In both cases, pulverized coal is injected through the inner tube of the double wall lance 4, and a combustion-supporting gas oxygen is injected through the outer tube of the double wall lance 4. As is clear from the figure, in the case of the double wall lance 4 having no notch in the inner tube 21, the combustion temperature levels off when the concentration of oxygen in a gas composed of the carrier gas for carrying pulverized coal and the combustion-supporting gas in the lance is 35% by volume or more. Thus, in the case of the double wall lance 4 having no notch in the inner tube 21, the combustion temperature is not increased at an oxygen concentration of 35% by volume or more. In contrast, in the case of the double wall lance 4 having the notches 23 in the inner tube 21, the combustion temperature increases even when the concentration of oxygen in a gas composed of the carrier gas and the combustion-supporting gas is 35% by volume or more. This means that the pulverized coal flow from the double wall lance 4 is not concentrated at a pulverized coal ratio of 150 kg/t or more and less than 170 kg/t.

[0027] Even in the case of the double wall lance 4 having the notches 23 in the inner tube 21, however, when the pulverized coal ratio is 170 kg/t or more, as illustrated in Fig. 10, the combustion temperature levels off when the concentration of oxygen in a gas composed of the carrier gas and the combustion-supporting gas in the lance is 70% by volume or more, and the combustion temperature is not increased at an oxygen concentration of more than 70% by volume. Thus, when the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas in the lance is 70% by volume or more, the combustion efficiency is not improved at a pulverized coal ratio of 170 kg/t or more, although the specific oxygen consumption increases. Thus, even in the case of the double wall lance 4 having the notches 23 in the inner tube 21, the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas is 35% by volume or more and less than 70% by volume, preferably 40% by volume or more and 65% by volume or less, more preferably 45% by volume or more and 60% by volume or less, at a pulverized coal ratio of 150 kg/t or more and less than 170 kg/t or a pulverized coal ratio of 170 kg/t. The upper limit of the pulverized coal ratio is 300 kg/t or less, preferably 250 kg/t or less.

[0028] The shape of the notches 23 in the inner tube 21 viewed in the radial direction may be tetragonal as illustrated in Fig. 11(a), triangular as illustrated in Fig. 11(b), or U-shaped as illustrated in Fig. 11(c). The size of the notches 23 is represented by the opening width of the notches 23 and the depth of the notches 23 from the opening to the bottom thereof. As illustrated in Fig. 12, the angle θ made by the center of the front end and the center of the lower end of each of the notches 23, more specifically the angle θ of a line segment between the center of the opening and the center of the bottom of each of the notches 23 with respect to a chord of the opening preferably ranges from 30 to 90 degrees. An experiment was performed on the contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal while the notch shape, particularly the notch size, was changed. In the experiment, as illustrated in Fig. 13, smoke was emitted from an inner tube and an outer tube of a double wall lance, that is, a pulverized coal flow path and an oxygen flow path. The area of an overlap between the smoke emitted from the pulverized coal flow path and the smoke emitted from the oxygen flow path was determined as a contact area between oxygen and pulverized coal in an image analysis. The dispersion width of the pulverized coal was determined from the spread angle of the smoke emitted from the pulverized coal flow path. The experiment was mainly performed on notches having a tetragonal shape when viewed in the radial direction of the inner tube.

[0029] First, Fig. 14 illustrates the contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal as a function of the notch width. The notch width was represented by the ratio of the total width of the notches to the internal circumference of the inner tube. The contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal were represented by ratios based on the case of the inner tube having no notch. As is clear from the figure, the contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal increased with increasing notch width. However, the dispersion width of the pulverized coal began to decrease at a certain notch width. This is probably because although the degree of mixing between oxygen and pulverized coal increases with increasing notch width, an excessively large notch width results in an inflow of oxygen into the inside of the double wall lance in the radial direction, thereby suppressing the dispersion of pulverized coal. Thus, the ratio of the total width of the notches to the circumference of the inner tube is preferably more than 0 and 0.5 or less, more preferably 0.05 or more and 0.3 or less, still more preferably 0.1 or more and 0.2 or less.

[0030] Fig. 15 illustrates the contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal as a function of the notch depth. The notch depth was represented by the depth itself. The contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal was represented by ratios based on the case of the inner tube having no notch. As is clear from the figure, the contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal increased with increasing notch depth. However, the dispersion width of the pulverized coal began to decrease at a certain notch depth. This is probably because although the degree of mixing between oxygen and pulverized coal increases with increasing notch depth, an excessively large notch depth results in the stabilization of a flow at the front end of the lance, thereby suppressing the dispersion of pulverized coal. Thus, the notch depth is preferably more than 0 and 12 mm or less, more preferably 2 mm or more and 10 mm or less, still more preferably 3 mm or more and 7 mm or less.

[0031] Fig. 16 illustrates the contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal as a function of the number of notches. The number of notches was represented by the ratio of the number of the notches to the maximum number of notches. The contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal were represented by ratios based on the case of the inner tube having no notch. The maximum number of notches is an integer part of a quotient obtained by dividing the internal circumference of the inner tube of the double wall lance by the notch width, more specifically the maximum number of notches having a predetermined width in the inner tube. As is clear from the figure, the contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal increased with increasing number of notches. However, the dispersion width of the pulverized coal began to decrease at a certain number of notches. This is probably because although the degree of mixing between oxygen and pulverized coal and the dispersibility of the pulverized coal increase with increasing number of notches, an excessively great number of notches results in an increased ratio of oxygen flowing through the inner tube, thereby suppressing the dispersion of pulverized coal. Thus, the ratio of the number of the notches to the maximum number of notches is preferably more than 0 and 0.8 or less, more preferably 0.1 or more and 0.6 or less, still more preferably 0.2 or more and 0.5 or less.

[0032] Fig. 17 illustrates the contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal as a function of the width of a tetragonal notch or a triangular notch. In Fig. 17, the experimental results for the triangular notch is superimposed on Fig. 14. The notch width was represented by the ratio of the total width of the notches to the internal circumference of the inner tube. The contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal were represented by ratios based on the case of the inner tube having no notch. As is clear from the figure, in both cases of the tetragonal notch and the triangular notch, the contact area between oxygen and pulverized coal and the dispersion width of the pulverized coal increased with increasing notch width. However, the dispersion width of the pulverized coal began to decrease at a certain notch width. This is probably because although the degree of mixing between oxygen and pulverized coal increases with increasing notch width as illustrated in Fig. 14 also in the case of the triangular notch, an excessively large notch width results in an inflow of oxygen into the inside of the double wall lance in the radial direction, thereby suppressing the dispersion of pulverized coal. Thus, the ratio of the total width of the notches of any shape to the circumference of the inner tube is preferably more than 0 and 0.5 or less, more preferably 0.05 or more and 0.3 or less, still more preferably 0.1 or more and 0.2 or less.

[0033] With an increase in combustion temperature, the outer tube of the double wall lance tends to be exposed to a high temperature. The lance is a stainless steel pipe, for example. Although a lance is sometimes surrounded by a water jacket and is cooled with water, a front end of the lance cannot be surrounded by the water jacket. In particular, it was found that a front end of an outer tube of a double wall lance that cannot be cooled with water is likely to change its shape with heat. When a lance is deformed or bent, this makes it difficult to blow a gas or pulverized coal into an intended portion or replace the consumable lance. A pulverized coal flow may be changed and hit a tuyere, thereby causing damage to the tuyere. A bent outer tube of a double wall lance may block a gap between the outer tube and an inner tube of the lance. A blockage in the outer tube may result in a melting loss of the outer tube of the double wall lance or may cause damage to a blow pipe. Deformation or wear damage of a lance makes it difficult to achieve the desired combustion temperature and decrease the specific consumption of a reducing material.

[0034] In order to cool an outer tube of a double wall lance, which cannot be cooled with water, the outer tube must be cooled with a gas flowing inside the outer tube. In the case that an outer tube of a double wall lance is cooled by dissipating heat into a gas flowing inside the outer tube, the flow velocity of the gas probably affects the lance temperature. Thus, the present inventors measured the lance surface temperature while changing the flow velocity of a gas injected through an outer tube of a double wall lance. In the experiment, oxygen was injected through the outer tube of the double wall lance, and pulverized coal was injected through an inner tube of the double wall lance. The flow velocity of a gas was changed with the amount of oxygen injected through the outer tube. An oxygen-enriched air may be used instead of oxygen. 2% or more, preferably 10% or more, oxygen-enriched air is used. An oxygen-enriched air is used not only for cooling but also in order to improve the combustibility of pulverized coal. Fig. 18 shows the measurement results.

[0035] The outer tube of the double wall lance was a steel pipe called 20A schedule 5S. The inner tube of the double wall lance was a steel pipe called 15A schedule 90. The lance surface temperature was measured while changing the total flow velocity of oxygen and nitrogen injected through the outer tube. The terms "15A" and "20A" refer to the nominal outer diameter of a steel pipe according to JIS G 3459. 15A denotes an outer diameter of 21.7 mm, and 20A denotes an outer diameter of 27.2 mm. The term "schedule" is the nominal thickness of a steel pipe according to JIS G 3459. 20A schedule 5S denotes a thickness of 1.65 mm, and 15A schedule 90 denotes a thickness of 3.70 mm. In addition to a stainless steel pipe, plain steel may also be used. In this case, the outer diameter of a steel pipe is specified in JIS G 3452, and the thickness of the steel pipe is specified in JIS G 3454.

[0036] As indicated by a dash-dot-dot line in the figure, the lance surface temperature decreases in inverse proportion to the flow velocity of a gas injected through the outer tube of the double wall lance. In a double wall lance formed of a steel pipe, a double wall lance surface temperature of more than 880°C results in creep deformation and a bending of the double wall lance. Thus, when the outer tube of the double wall lance is a 20A schedule 5S steel pipe, and the double wall lance surface temperature is 880°C or less, the outlet flow velocity in the outer tube of the double wall lance is 20 m/sec or more. So long as the outlet flow velocity in the outer tube of the double wall lance is 20 m/sec or more, the double wall lance has no deformation or bending. An outlet flow velocity of more than 120 m/sec in the outer tube of the double wall lance is not practical in terms of the operating cost of the equipment. Thus, 120 m/sec is the upper limit of the outlet flow velocity in the outer tube of the double wall lance. In the case of single-tube lances, which have a lower heat load than double wall lances, the outlet flow velocity may be 20 m/sec or more, if necessary.

[0037] In the embodiment described above, the pulverized coal may have an average particle size in the range of 10 to 100 μm. Considering combustibility as well as supply from the lance and supply to the lance, the pulverized coal preferably has an average particle size in the range of 20 to 50 μm. Although pulverized coal having an average particle size of less than 20 μm has high combustibility, the lance is often clogged during transport of the pulverized coal (pneumatic transport). Pulverized coal having an average particle size of more than 50 μm may have low combustibility.

[0038] Pulverized coal injected through the inner tube of the double wall lance may be coal having a volatile matter content of 25 mass% or less or anthracite coal, which can be used as a solid reducing material. Anthracite coal has a volatile matter content in the range of 3 to 5 mass%. Thus, pulverized coal used in the present invention is referred to as pulverized coal having a volatile matter content of 3 mass% or more and 25 mass% or less, including anthracite coal.

[0039] A solid reducing material to be injected mainly contains pulverized coal and may also contain a waste plastic, refuse-derived fuel (RDF), organic resource (biomass), scrap wood, and/or CDQ coke dust. CDQ coke dust is coke breeze collected by a coke dry quenching (CDQ) apparatus. When used, the ratio of pulverized coal to all the solid reducing material is preferably 80 mass% or more. The heat of reaction of pulverized coal is different from the heat of reaction of a waste plastic, refuse-derived fuel (RDF), organic resource (biomass), scrap wood, or CDQ coke dust. Thus, when the amount of pulverized coal approaches the amount of auxiliary material, this tends to result in uneven combustion and unstable operation. Furthermore, the calorific value of a combustion reaction of a waste plastic, refuse-derived fuel (RDF), organic resource (biomass), or scrap wood is lower than the calorific value of a combustion reaction of pulverized coal. Thus, injecting a large amount of the auxiliary material results in low substitution efficiency for the solid reducing material charged through the top of the furnace. Although CDQ coke dust has a high calorific value, CDQ coke dust contains no volatile matter, is difficult to ignite, and has low substitution efficiency. Thus, pulverized coal preferably accounts for 80 mass% or more.

[0040] A waste plastic, refuse-derived fuel (RDF), organic resource (biomass), or scrap wood may be used in the form of small grains having a size of 6 mm or less, preferably 3 mm or less, in combination with pulverized coal. CDQ coke dust may be directly used. The auxiliary material may be mixed with pulverized coal carried by a carrier gas. The auxiliary material may be mixed with pulverized coal in advance.

[0041] In a blast furnace operation method according to the present embodiment in which a lance 4 for injecting a fuel through a tuyere 3 is a double tube, the method includes injecting pulverized coal through an inner tube 21 of the double wall lance 4, injecting oxygen (a combustion-supporting gas) through an outer tube 22 of the double wall lance 4, and forming notches 23 in a injecting front end of the inner tube 21 of the double wall lance 4, wherein the concentration of oxygen in a gas composed of a carrier gas for carrying the pulverized coal and the combustion-supporting gas is 35% by volume or more. Even in an operation using pulverized coal having a volatile matter content of 25 mass% or less at a high pulverized coal ratio of 150 kg/t or more, the combustion temperature can be increased, and consequently CO_2 emissions can be reduced. At a pulverized coal ratio of 170 kg/t or more, the specific oxygen consumption can be reduced by decreasing the concentration of oxygen in the gas composed of the carrier gas for carrying pulverized coal and the combustion-supporting gas to less than 70% by volume.

[0042] The notches 23 circumferentially evenly spaced in the front end of the inner tube 21 of the double wall lance 4 improve the diffusion of pulverized coal and the combustion-supporting gas and further improve combustion efficiency.

[0043] Injecting part of oxygen for enrichment into a blast (as a combustion-supporting gas) through the outer tube 22 of the double wall lance 4 can prevent excess oxygen supply without disturbing the gas balance in the blast furnace and reduce the specific oxygen consumption.

[Reference Signs List]

[0044]

1	blast furnace
2	blow pipe
3	tuyere
4	lance
5	raceway
6	pulverized coal
7	coke
8	char
9	oxygen
21	inner tube
22	outer tube
23	notch

[0045] The following numbered paragraphs set out particular combinations of features which are considered relevant to particular embodiments of the present disclosure.

[Paragraph 1] A blast furnace operation method, comprising:

preparing pulverized coal having a volatile matter content of 25 mass% or less;

preparing a double wall lance for injecting the pulverized coal and a combustion-supporting gas through a tuyere, the double wall lance having an inner tube and an outer tube;

blowing hot air through the tuyere;

circumferentially forming a plurality of notches in a injecting front end of the inner tube of the double wall lance, the notches being cut in the axial direction;

injecting the pulverized coal together with a carrier gas through the inner tube at a pulverized coal ratio of 150 kg/t-pig iron or more; and

injecting the combustion-supporting gas through the outer tube of the double wall lance,

wherein the concentration of oxygen in a gas composed of the carrier gas and the combustion-supporting gas is 35% by volume or more.

[Paragraph 2] The blast furnace operation method according to Paragraph 1, wherein the notches are circumferentially evenly spaced in the front end of the inner tube of the double wall lance.

[Paragraph 3] The blast furnace operation method according to Paragraph 2, wherein the ratio of the total width of the notches to the internal circumference of the inner tube of the double wall lance is more than 0 and 0.5 or less.

[Paragraph 4] The blast furnace operation method according to Paragraph 3, wherein the ratio of the total width of the notches to the internal circumference of the inner tube of the double wall lance is 0.05 or more and 0.3 or less.

[Paragraph 5] The blast furnace operation method according to Paragraph 4, wherein the ratio of the total width of the notches to the internal circumference of the inner tube of the double wall lance is 0.1 or more and 0.2 or less.

[Paragraph 6] The blast furnace operation method according to Paragraph 2, wherein each of the notches has a depth of more than 0 mm and 12 mm or less.

[Paragraph 7] The blast furnace operation method according to Paragraph 6, wherein each of the notches has a depth of 2 mm or more and 10 mm or less.

[Paragraph 8] The blast furnace operation method according to Paragraph 7, wherein each of the notches has a depth of 3 mm or more and 7 mm or less.

[Paragraph 9] The blast furnace operation method according to Paragraph 2, wherein the ratio of the number of the notches to the maximum number of notches is more than 0 and 0.8 or less, wherein the maximum number of notches is an integer part of a quotient obtained by dividing the internal circumference of the inner tube of the double wall lance by the width of one of the notches.

[Paragraph 10] The blast furnace operation method according to Paragraph 9, wherein the ratio of the number of the notches to the maximum number of notches is 0.1 or more and 0.6 or less.

[Paragraph 11] The blast furnace operation method according to Paragraph 10, wherein the ratio of the number of the notches to the maximum number of notches is 0.2 or more and 0.5 or less.

[Paragraph 12] The blast furnace operation method according to Paragraph 1, wherein the combustion-supporting gas is oxygen, and part of oxygen for enrichment is injected into a blast through the outer tube of the double wall lance.

[Paragraph 13] The blast furnace operation method according to Paragraph 1, wherein the pulverized coal has a volatile matter content of 3 mass% or more and 25 mass% or less.

[Paragraph 14] The blast furnace operation method according to Paragraph 1, wherein the combustion-supporting gas injected through the outer tube of the double wall lance has an outlet flow velocity in the range of 20 to 120 m/sec.

[Paragraph 15] The blast furnace operation method according to Paragraph 1, wherein the pulverized coal ratio is 170 kg/t-pig iron or more.

[Paragraph 16] The blast furnace operation method according to Paragraph 1, wherein

the pulverized coal ratio is 170 kg/t-pig iron or more, and

the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas is 35% by volume or more and less than 70% by volume.

[Paragraph 17] The blast furnace operation method according to Paragraph 16, wherein the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas is 40% by volume or more and 65% by volume or less.

[Paragraph 18] The blast furnace operation method according to Paragraph 17, wherein the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas is 45% by volume or more and 60% by volume or less.

[Paragraph 19] The blast furnace operation method according to Paragraph 15, wherein the pulverized coal ratio is 170 kg/t-pig iron or more and 300 kg/t-pig iron or less.

[Paragraph 20] The blast furnace operation method according to Paragraph 16, wherein the pulverized coal ratio is 170 kg/t-pig iron or more and 300 kg/t-pig iron or less.

[Paragraph 21] The blast furnace operation method according to Paragraph 1, wherein the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas is 35% by volume or more and less than 70% by volume.

[Paragraph 22] The blast furnace operation method according to Paragraph 21, wherein the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas is 40% by volume or more and 65% by volume or less.

[Paragraph 23] The blast furnace operation method according to Paragraph 22, wherein the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas is 45% by volume or more and 60% by volume or less.

[Paragraph 24] The blast furnace operation method according to Paragraph 1, wherein the pulverized coal ratio is 150 kg/t-pig iron or more and 300 kg/t-pig iron or less.

[Paragraph 25] The blast furnace operation method according to Paragraph 1, wherein the pulverized coal ratio is 150 kg/t-pig iron or more and less than 170 kg/t-pig iron.

[Paragraph 26] The blast furnace operation method according to Paragraph 1, wherein
the pulverized coal ratio is 150 kg/t-pig iron or more and less than 170 kg/t-pig iron, and
the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas is 35% by volume or more and less than 70% by volume.

[Paragraph 27] The blast furnace operation method according to any one of Paragraphs 1 to 26, wherein at least one selected from the group consisting of waste plastics, refuse-derived fuels, organic resources, scrap woods, and CDQ coke dust is added to the pulverized coal.

[Paragraph 28] The blast furnace operation method according to Paragraph 27, wherein the pulverized coal accounts for 80 mass% or more, and at least one of the waste plastics, refuse-derived fuels, organic resources, scrap woods, and CDQ coke dust is used.

Claims

1. Double wall lance (4) comprising:

   an inner tube (21);
   an outer tube (22);
   a plurality of notches (23) formed circumferentially in an injection front end of the inner tube (21).

2. Double wall lance (4) according to claim 1, wherein the notches (23) are circumferentially evenly spaced in the front end of the inner tube (21).

3. Double wall lance (4) according to claim 1 or 2, wherein
   the ratio of the total width of the notches (23) to the internal circumference of the inner tube (21) is more than 0 and 0.5 or less, preferably 0.05 or more and 0.3 or less and more preferably 0.1 or more and 0.2 or less.

4. Double wall lance (4) according to any one of the preceding claims, wherein
   each of the notches (23) has a depth of more than 0 mm and 12 mm or less, preferably 2 mm or more and 10 mm or less and more preferably 3 mm or more and 7 mm or less.

5. Double wall lance (4) according to any one of the preceding claims, wherein
   the ratio of the number of the notches (23) to the maximum number of notches (23) is more than 0 and 0.8 or less, preferably 0.1 or more and 0.6 or less and further preferably 0.2 or more and 0.5 or less;
   wherein the maximum number of notches (23) is an integer part of a quotient obtained by dividing the internal circumference of the inner tube (21) of the double wall lance (4) by the width of one of the notches (23).

6. Double wall lance (4) according to any one of the preceding claims, wherein
   the shape of the notches (23) in the inner tube (21) viewed in the radial direction is tetragonal or triangular or U-shaped.

7. Double wall lance (4) according to any one of the preceding claims, wherein
   an angle θ made by a center of the front end and a center of the lower end of each of the notches (23), preferably the angle O of a line segment between the center of the opening and the center of the bottom of each of the notches (23) with respect to a chord of the opening preferably ranges from 30 to 90 degrees.

8. Double wall lance (4) according to any one of the preceding claims, wherein
   the notches (23) are configured so as to penetrate an injection front end wall of the inner tube (21), preferably such that matter flowing through the inner tube (21) and outer tube (22) can diffuse through the notches (23) and can come in contact with each other.

9. Double wall lance (4) according to any one of the preceding claims, wherein
   the double wall lance (4) is formed of a straight tube, preferably made of stainless steel.

10. Blast furnace (1), comprising:

    a blow pipe (2);
    a tuyere (3) coupled to the blow pipe (2); and
    a double wall lance (4) according to any one of the preceding claims inserted into the blow pipe (2).

11. Use of a double wall lance (4) according to any one of claims 1 to 9 for operating a blast furnace.

FIG. 1

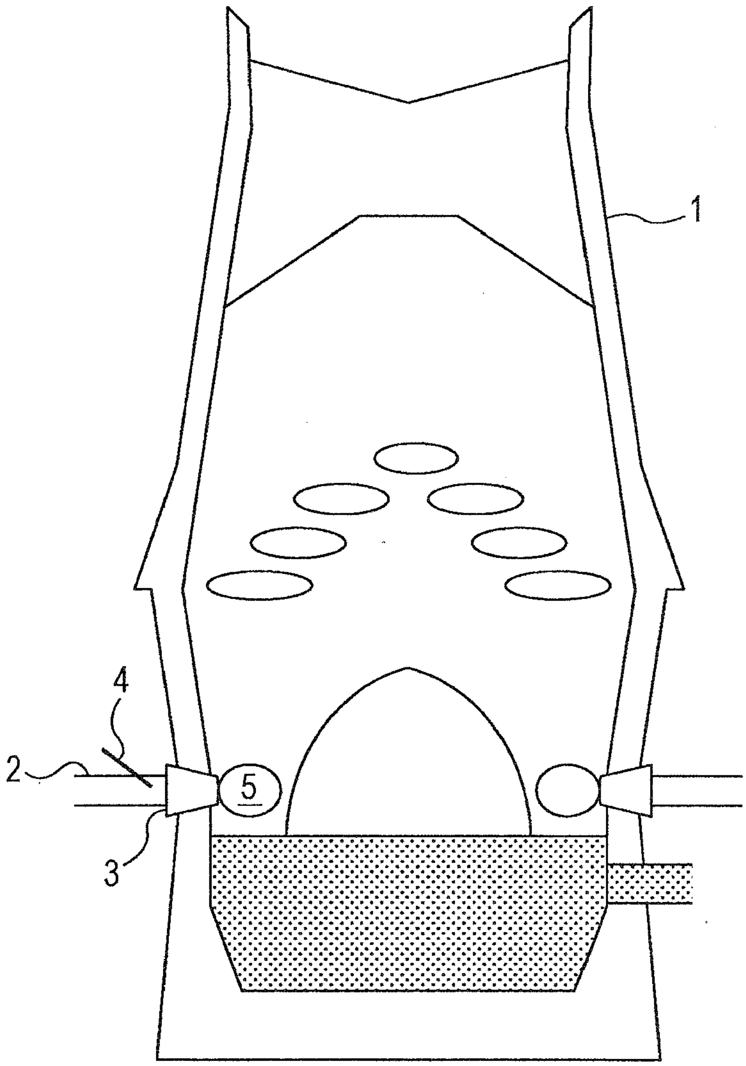


FIG. 2

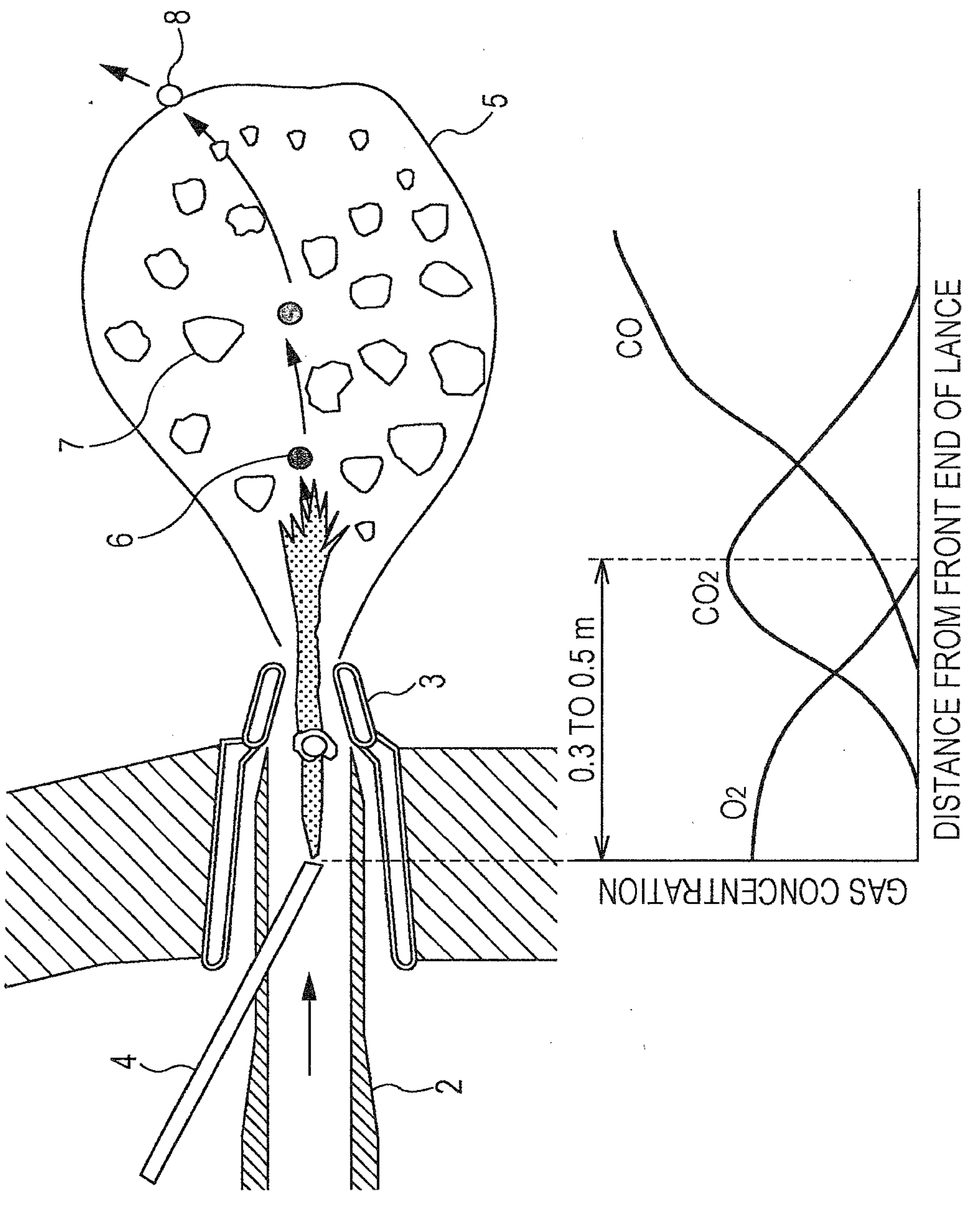

8
5
7
6
3
4
2
CO
CO_2
O_2
0.3 TO 0.5 m
GAS CONCENTRATION
DISTANCE FROM FRONT END OF LANCE

FIG. 3

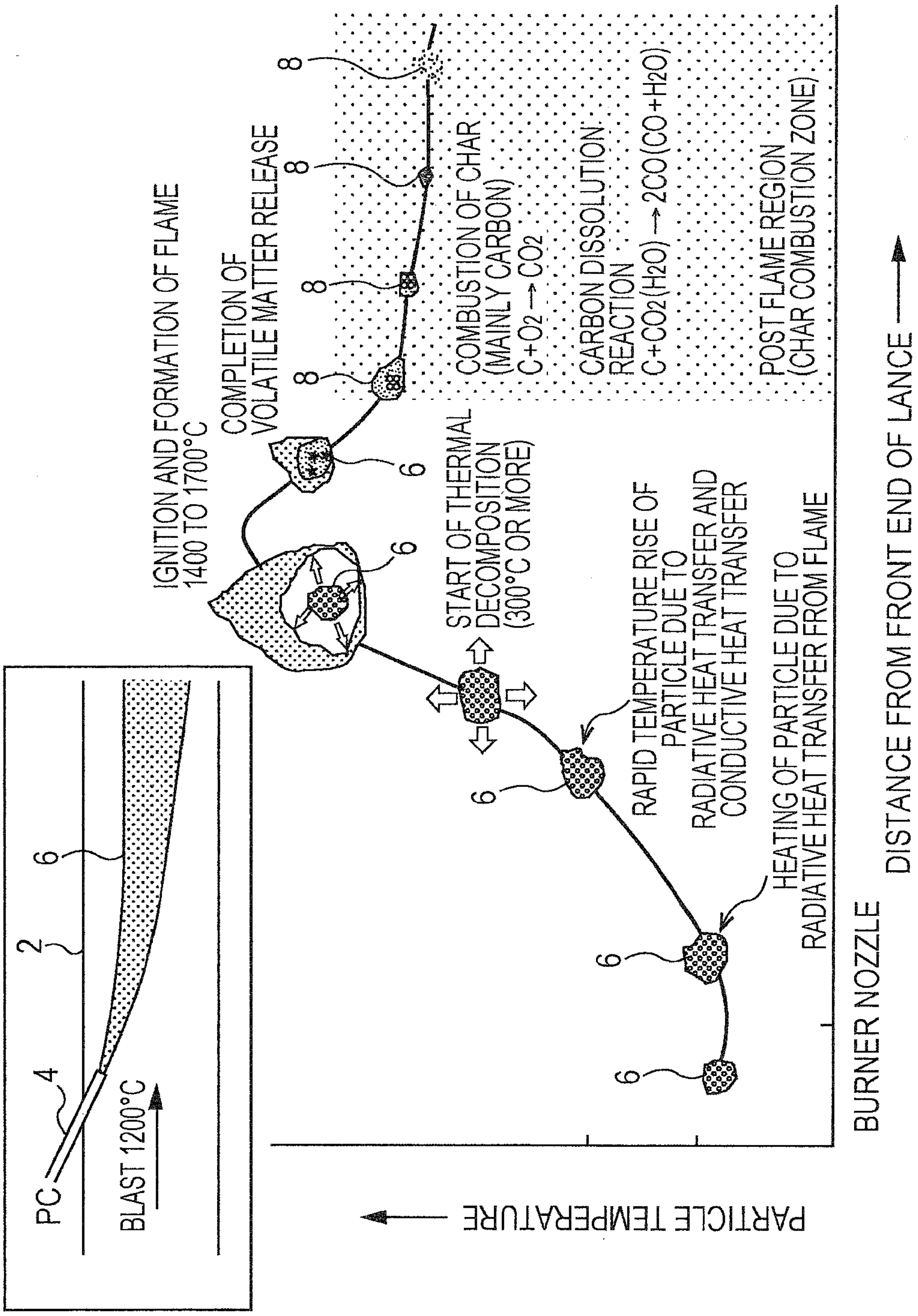

PC
4
2
6
BLAST 1200°C
PARTICLE TEMPERATURE
BURNER NOZZLE
DISTANCE FROM FRONT END OF LANCE
HEATING OF PARTICLE DUE TO RADIATIVE HEAT TRANSFER FROM FLAME
RAPID TEMPERATURE RISE OF PARTICLE DUE TO RADIATIVE HEAT TRANSFER AND CONDUCTIVE HEAT TRANSFER
START OF THERMAL DECOMPOSITION (300°C OR MORE)
IGNITION AND FORMATION OF FLAME 1400 TO 1700°C
COMPLETION OF VOLATILE MATTER RELEASE
COMBUSTION OF CHAR (MAINLY CARBON)
$C+O_2 \rightarrow CO_2$
CARBON DISSOLUTION REACTION
$C+CO_2(H_2O) \rightarrow 2CO(CO+H_2O)$
POST FLAME REGION (CHAR COMBUSTION ZONE)
8

FIG. 4

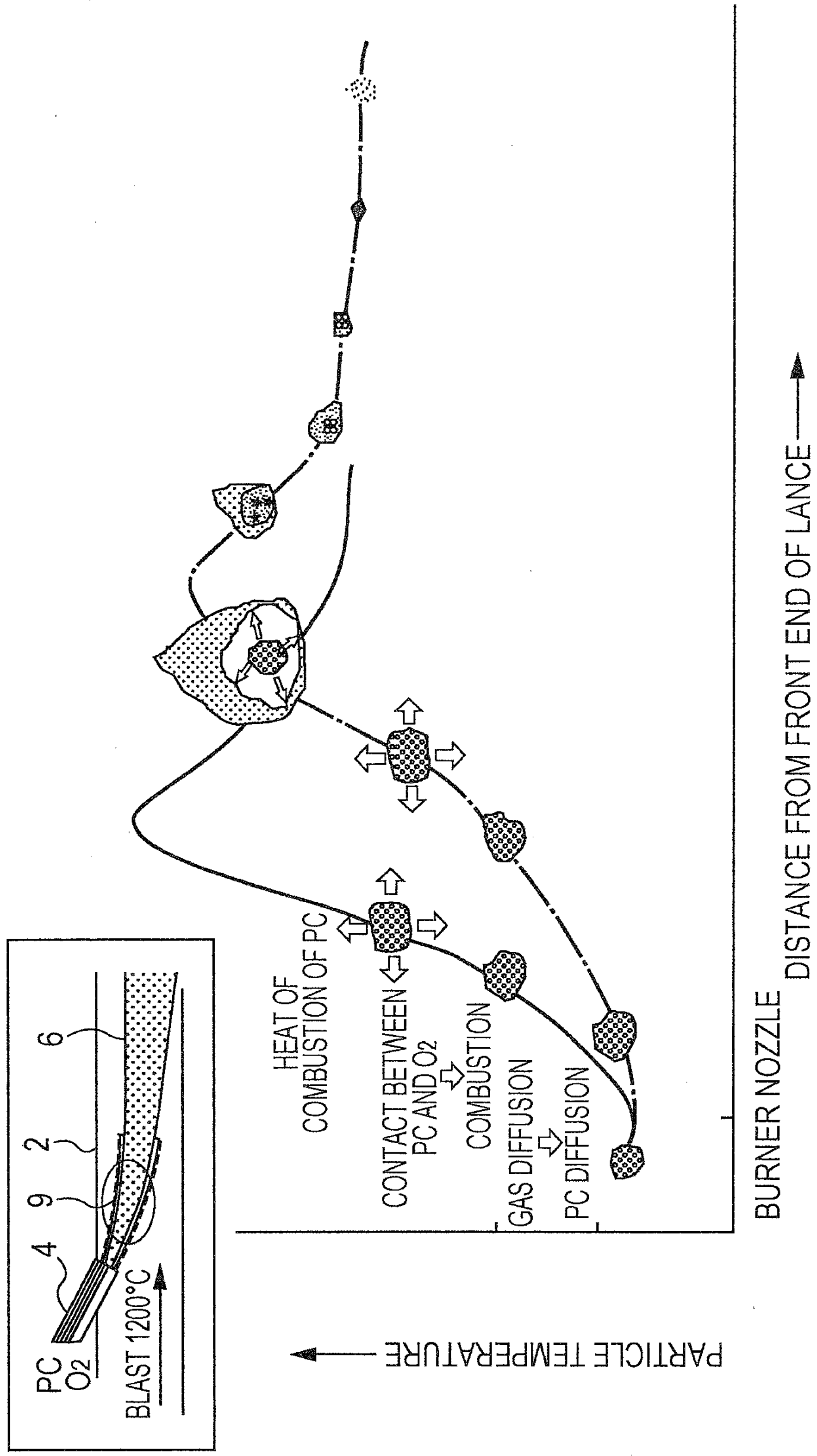

PC
O_2
4
9
2
6
BLAST 1200°C
HEAT OF COMBUSTION OF PC
CONTACT BETWEEN PC AND O_2
COMBUSTION
GAS DIFFUSION
PC DIFFUSION
BURNER NOZZLE
DISTANCE FROM FRONT END OF LANCE
PARTICLE TEMPERATURE

FIG. 5

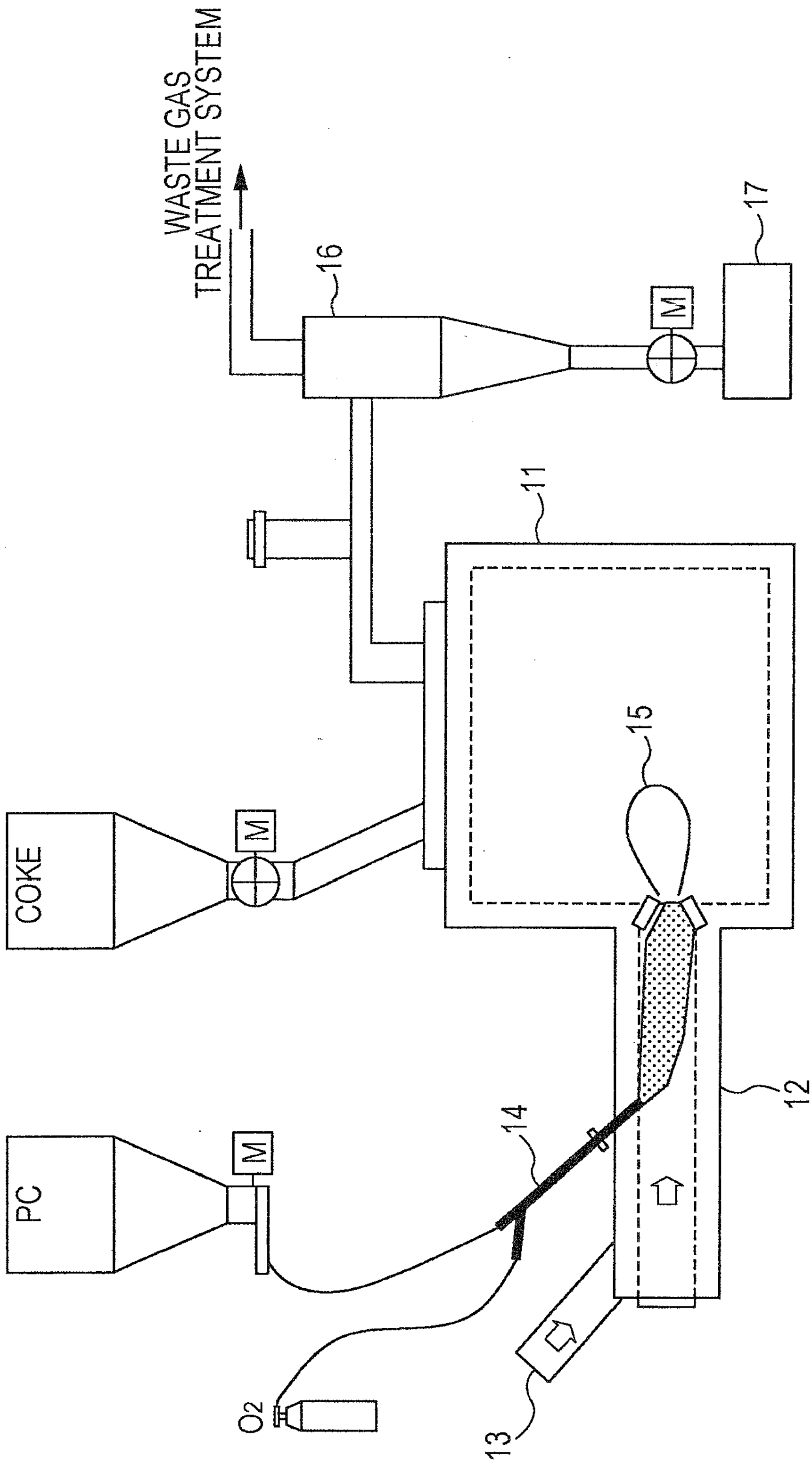


FIG. 6

(a)

(b)

(c)

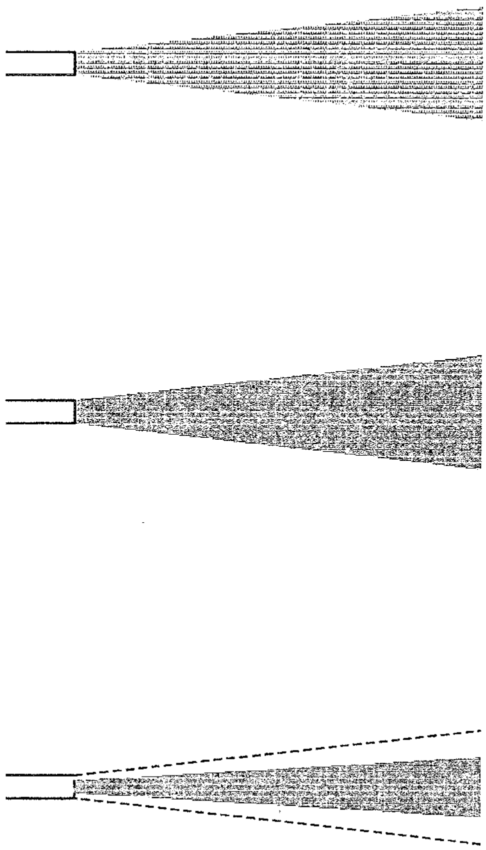


FIG. 7

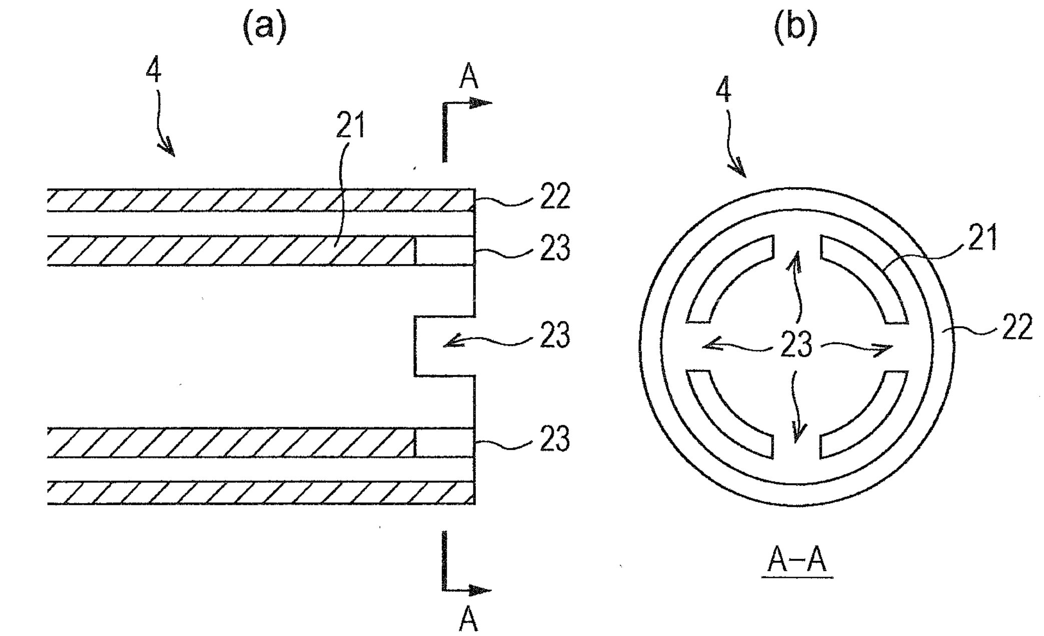


FIG. 8

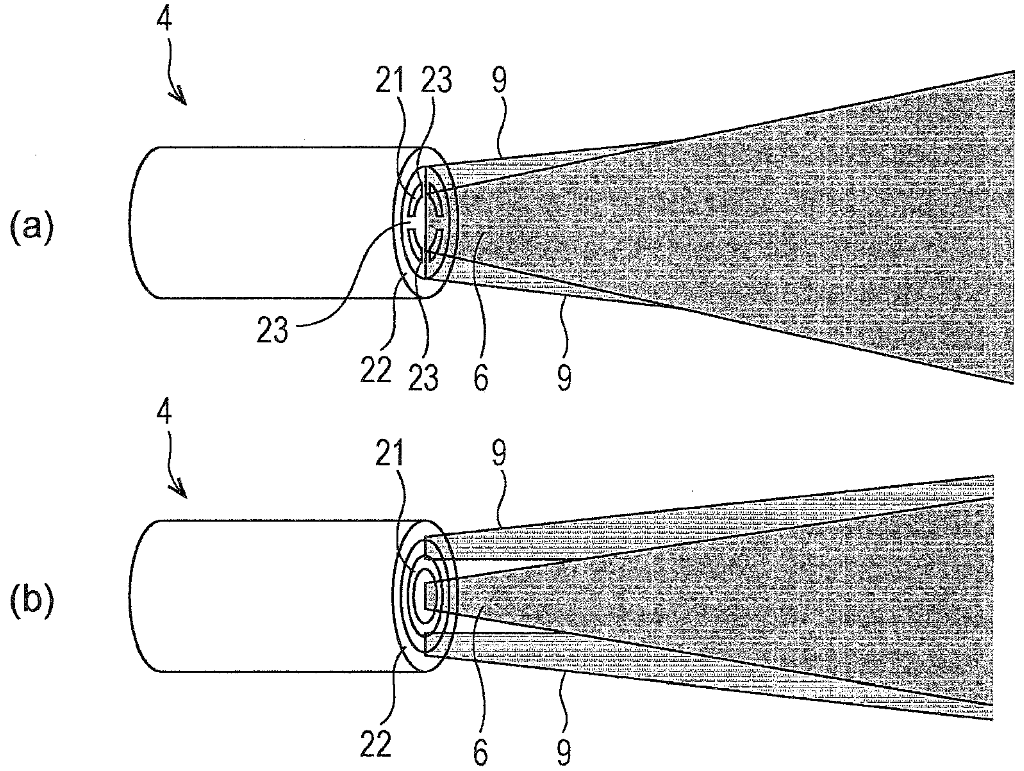
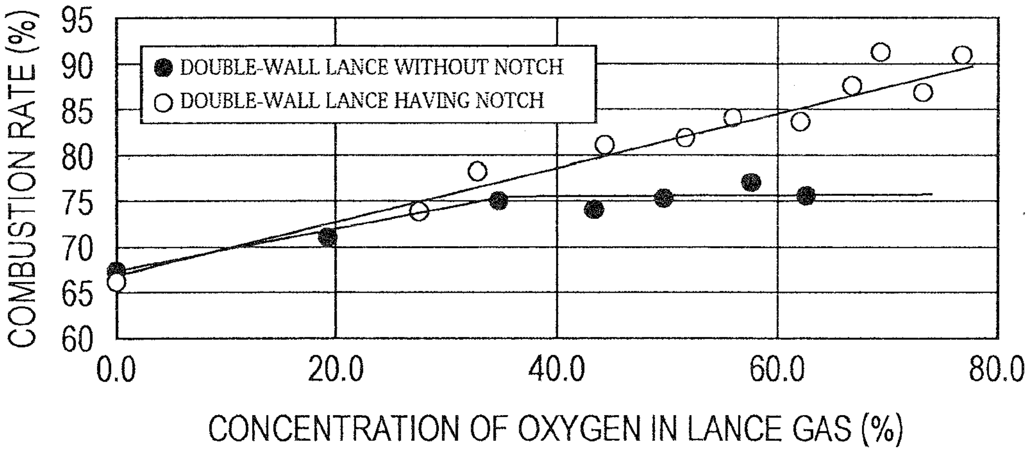
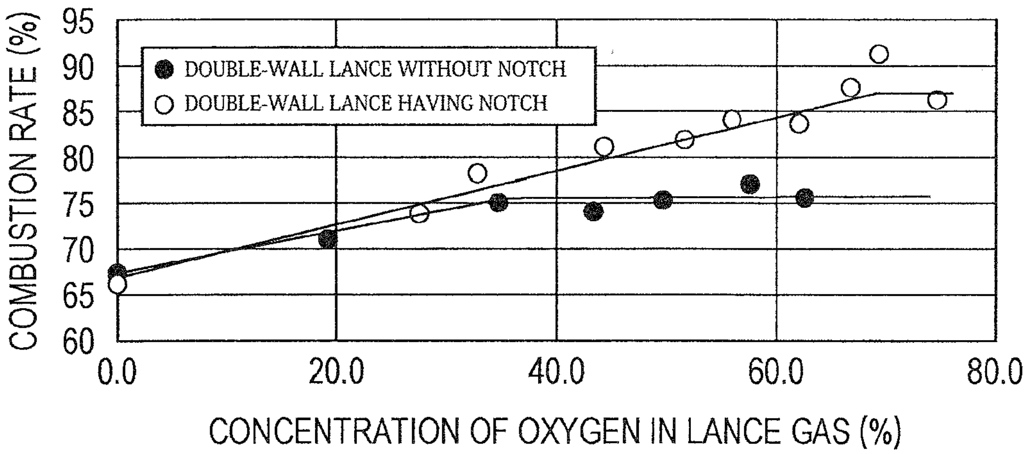


FIG. 9



95
90
85
80
75
70
65
60
COMBUSTION RATE (%)
DOUBLE-WALL LANCE WITHOUT NOTCH
DOUBLE-WALL LANCE HAVING NOTCH
0.0
20.0
40.0
60.0
80.0
CONCENTRATION OF OXYGEN IN LANCE GAS (%)

FIG. 10



95
90
85
80
75
70
65
60
COMBUSTION RATE (%)
DOUBLE-WALL LANCE WITHOUT NOTCH
DOUBLE-WALL LANCE HAVING NOTCH
0.0
20.0
40.0
60.0
80.0
CONCENTRATION OF OXYGEN IN LANCE GAS (%)

FIG. 11

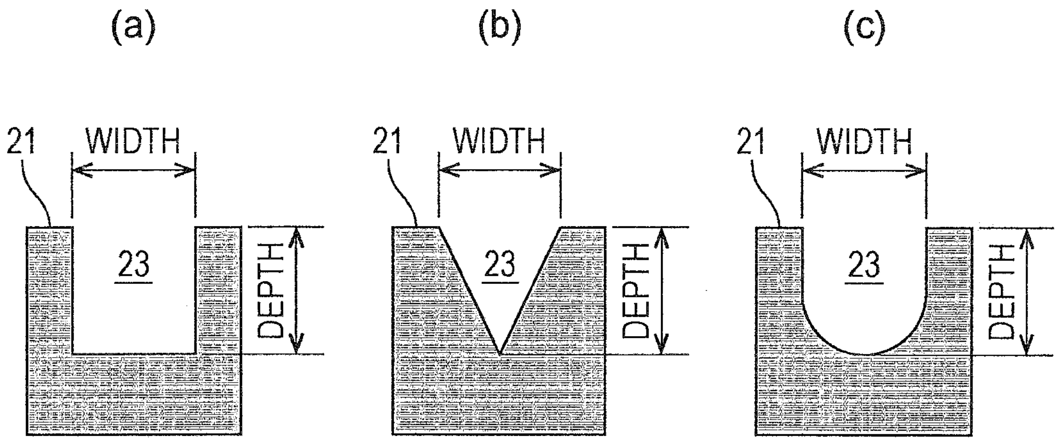

(a)
(b)
(c)
21
WIDTH
23
DEPTH
21
WIDTH
23
DEPTH
21
WIDTH
23
DEPTH

FIG. 12

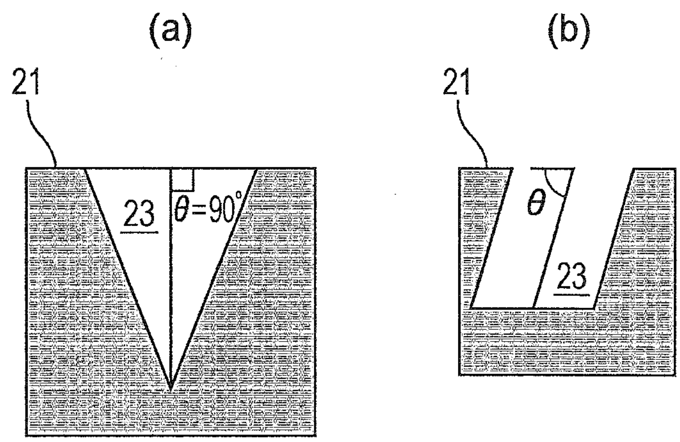

(a)
(b)
21
23
θ=90°
21
θ
23

FIG. 13

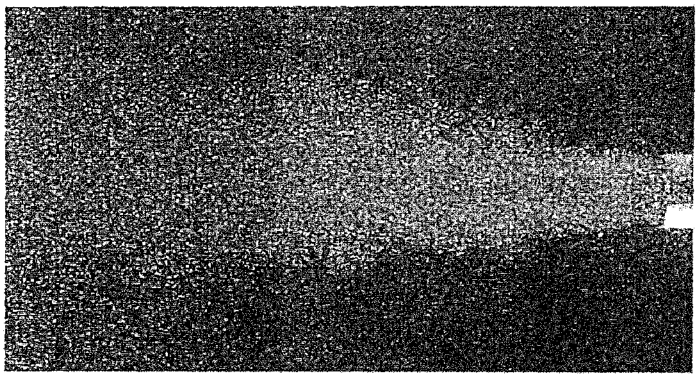


FIG. 14

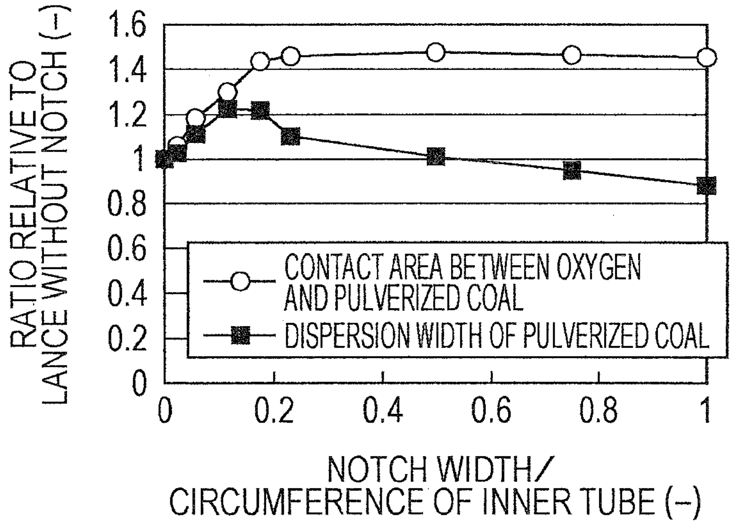

RATIO RELATIVE TO LANCE WITHOUT NOTCH (–)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
CONTACT AREA BETWEEN OXYGEN AND PULVERIZED COAL
DISPERSION WIDTH OF PULVERIZED COAL
0
0.2
0.4
0.6
0.8
1
NOTCH WIDTH/ CIRCUMFERENCE OF INNER TUBE (–)

FIG. 15

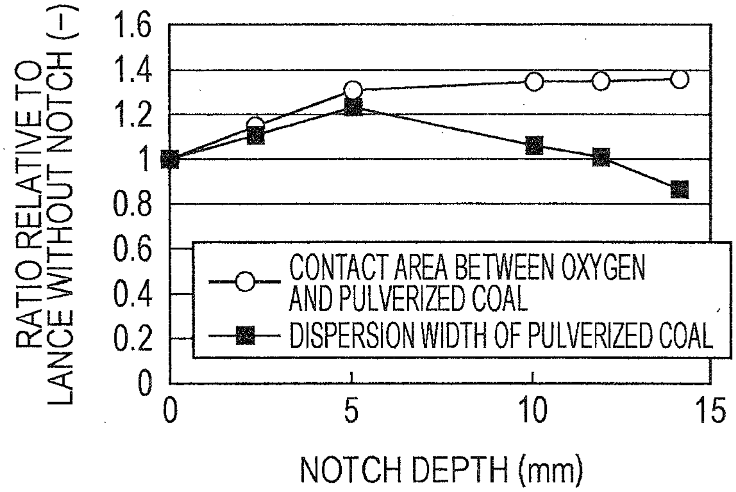

RATIO RELATIVE TO LANCE WITHOUT NOTCH (–)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
CONTACT AREA BETWEEN OXYGEN AND PULVERIZED COAL
DISPERSION WIDTH OF PULVERIZED COAL
0
5
10
15
NOTCH DEPTH (mm)

FIG. 16

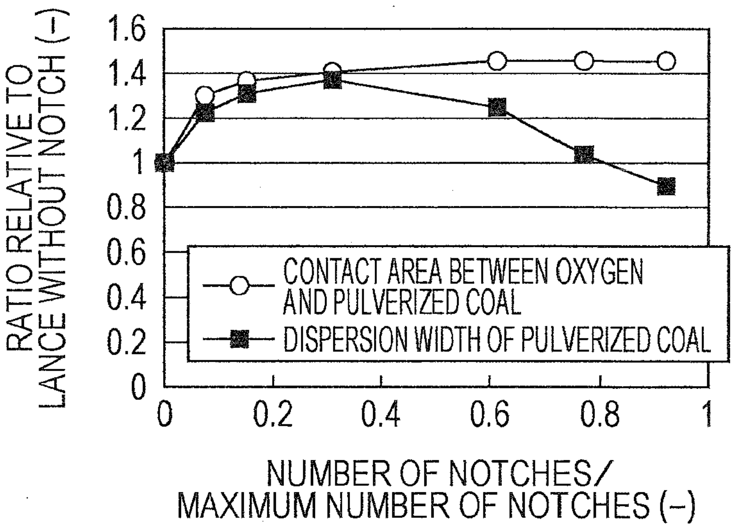

RATIO RELATIVE TO
LANCE WITHOUT NOTCH (-)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
CONTACT AREA BETWEEN OXYGEN
AND PULVERIZED COAL
DISPERSION WIDTH OF PULVERIZED COAL
NUMBER OF NOTCHES/
MAXIMUM NUMBER OF NOTCHES (-)

FIG. 17

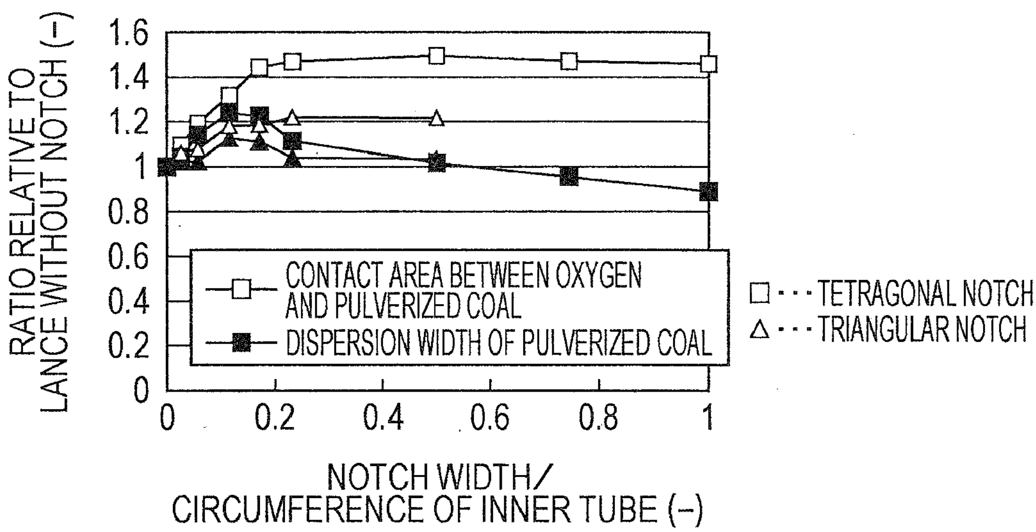
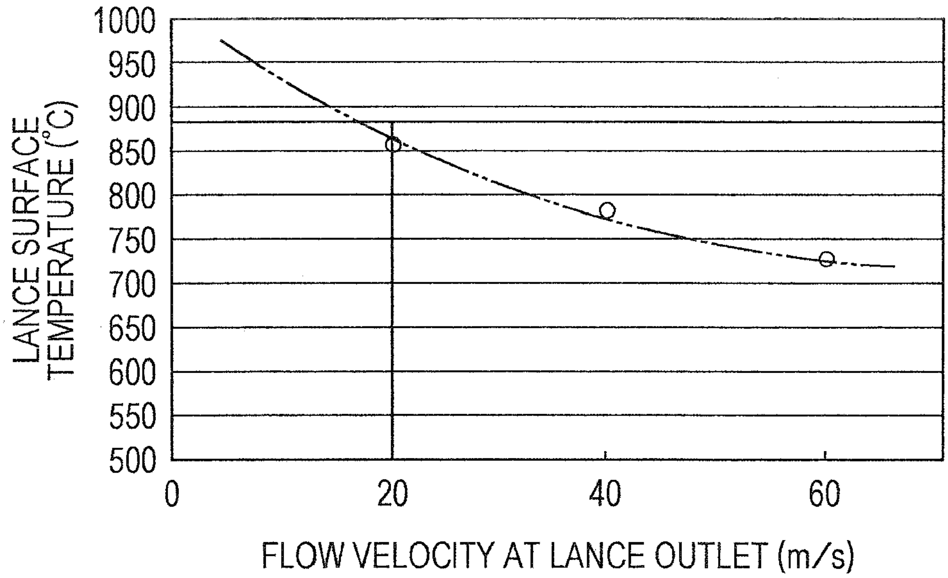

RATIO RELATIVE TO
LANCE WITHOUT NOTCH (-)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
CONTACT AREA BETWEEN OXYGEN
AND PULVERIZED COAL
DISPERSION WIDTH OF PULVERIZED COAL
□ · · · TETRAGONAL NOTCH
△ · · · TRIANGULAR NOTCH
NOTCH WIDTH/
CIRCUMFERENCE OF INNER TUBE (-)

FIG. 18


1000
950
900
850
800
750
700
650
600
550
500
LANCE SURFACE TEMPERATURE (°C)
0
20
40
60
FLOW VELOCITY AT LANCE OUTLET (m/s)

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EUROPEAN SEARCH REPORT

Application Number
EP 18 18 1898

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	WO 2008/006764 A1 (WURTH PAUL SA [LU]; KROEMMER YVAN [LU]; GOEDERT PAUL [LU]; STAMATAKIS) 17 January 2008 (2008-01-17) * abstract * * figure 3 *	1-11	INV. C21B5/00 C21B7/00 C21B7/16 F27D3/16
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TECHNICAL FIELDS SEARCHED (IPC)

C21B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	11 September 2018	Gimeno-Fabra, Lluis

CATEGORY OF CITED DOCUMENTS

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11-09-2018

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