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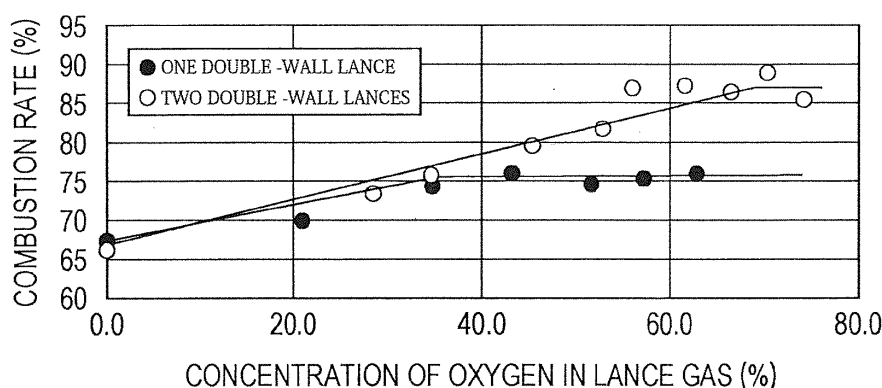
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(54) **BLAST FURNACE OPERATION METHOD**

(57) Each lance 4 for injecting a fuel through a tuyere 3 is a double tube. Pulverized coal is injected through an inner tube of each of two double wall lances 4. Oxygen is injected through an outer tube of each of the two double wall lances 4. The concentration of oxygen in a gas composed of a carrier gas for the pulverized coal and a gas injected through the outer tubes 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 CO₂ emissions can be reduced. At a pulverized coal ratio of 170 kg/t or more, the oxygen concentration is less than 70% by volume. The concentration of pulverized coal flows injected through the two double wall lances 4 can be prevented by placing the double wall lances 4 such that the pulverized coal flows do not overlap each other. This ensures high combustion efficiency.

FIG. 10



Description**[Citation List]****[Technical Field]****[Patent Literature]**

[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 CO₂ emissions.

[Background Art]

[0002] Considering recent global warming due to increased carbon dioxide emissions, it is also important for the iron industry to reduce CO₂ 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 CO₂ 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 the combustibility of pulverized coal is improved by placing two double wall lances for injecting the pulverized coal through an inner tube thereof and oxygen through an outer tube thereof opposite each other, wherein extension lines of the central axes of the two double wall lances do not cross each other and do not cross the center of a blow pipe. Oxygen is brought closer to the main streamline of the pulverized coal by setting the injecting angle of oxygen injected through the outer tube at 30 degrees or more with respect to the center of the lance. The angle between the lance and the blow pipe (the injecting angle of the lance to the blast direction) is greater than 45 degrees.

[0005] Patent Literature 4 discloses that two double wall lances for injecting pulverized coal through an inner tube thereof and oxygen through an outer tube thereof are disposed opposite each other, and the front end of each of the lances is disposed further inside the furnace than a small-diameter portion of a tapered portion of a tuyere.

5 **[0006]**

[PTL 1] Japanese Patent No. 4074467

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

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[PTL 3] Japanese Unexamined Patent Application Publication No. 10-251715

[PTL 4] Japanese Unexamined Patent Application Publication No. 2000-192119

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[Summary of Invention]**[Technical Problem]**

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[0007] 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 CO₂ 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-pig iron 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.

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[0008] 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.

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[0009] In the case that the angle between a lance and a blow pipe (the injecting angle of the lance to the blast direction) is greater than 45 degrees as described in Patent Literature 3, hot air flowing along the lance causes turbulence at a front end of the lance and excessively disperses pulverized coal. Thus, a tuyere or blow pipe may be damaged by deposition or collision of the pulverized coal. Furthermore, it is difficult to process the front end of the lance such that the injecting angle of oxygen injected through the outer tube is 30 degrees or more with respect to the center of the lance. In addition, because of a melting loss of the lance resulting from deposition of or clogging with pulverized coal, the technique described in Patent Literature 3 is not practical.

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[0010] When a front end of a lance is disposed further

inside a furnace than a small-diameter portion of a tapered portion of a tuyere as described in Patent Literature 4, turbulence of hot air blown through the tapered portion causes excessive dispersion of pulverized coal and causes damage to the tuyere or a blow pipe.

[0011] 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 CO₂ emissions without causing damage to a tuyere or a blow pipe.

[Solution to Problem]

[0012] 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 two double wall lances for injecting the pulverized coal and a combustion-supporting gas through a tuyere, each of the two double wall lances having an inner tube and an outer tube;

blowing hot air through the tuyere;

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

injecting the combustion-supporting gas through the outer tube of each of the two double wall lances, 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 pulverized coal is injected such that the pulverized coal flows injected through the two double wall lances do not overlap each other.

(3) The blast furnace operation method according to (2),

wherein axes of front ends of the two double wall lances do not cross each other.

(4) The blast furnace operation method according to (1), wherein the double wall lances are inserted in a blow pipe at an angle of 45 degrees or less.

(5) 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 each of the double wall lances.

(6) 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.

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

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

(9) 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.

(10) The blast furnace operation method according to (9),

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.

(11) The blast furnace operation method according to (10), 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.

(12) The blast furnace operation method according to (8), wherein the pulverized coal ratio is 170 kg/t-pig iron or more and 300 kg/t-pig iron or less.

(13) The blast furnace operation method according to (9), wherein the pulverized coal ratio is 170 kg/t-pig iron or more and 300 kg/t-pig iron or less.

(14) 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.

(15) The blast furnace operation method according to (14), 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.

(16) The blast furnace operation method according to (15), 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.

(17) 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.

(18) 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.

(19) 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.

(20) The blast furnace operation method according to any one of (1) to (19), 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.

(21) The blast furnace operation method according to (20), 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]

[0013] In a blast furnace operation method according to the present invention in which each 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 each of two double wall lances and injecting a combustion-supporting gas through an outer tube of each of the two double wall lances, wherein the concentration of oxygen in a gas composed of the carrier gas and the combustion-supporting gas in the double wall lances 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 CO₂ 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 lances to less than 70% by volume.

[0014] The concentration of pulverized coal flows injected through the inner tubes of the two double wall lances can be prevented by injecting pulverized coal such that the pulverized coal flows do not overlap each other. This ensures high combustion efficiency.

[0015] The axes of the front ends of the two double wall lances do not cross each other, thereby ensuring that the pulverized coal flows injected through the inner tubes of the two double wall lances do not overlap each other.

[0016] Turbulence in the blast injected through the front ends of the double wall lances can be reduced by inserting the double wall lances into the blow pipe at an angle of 45 degrees or less.

[0017] Injecting part of oxygen for enrichment into a blast as a combustion-supporting gas through the outer tube of each of the double wall lances can prevent excess oxygen supply without disturbing the gas balance in the blast furnace.

[Brief Description of Drawings]

[0018]

[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] Fig. 7 is a detail view of a injecting front end of the lance illustrated in Fig. 1.

[Fig. 8] Fig. 8 is an explanatory view 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 or more and less than 170 kg/t.

[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 or more.

[Fig. 11] Figs. 11(a) and 11(b) are explanatory views of the insertion angle of a lance to a blow pipe.

[Fig. 12] Fig. 12 is a graphic explanatory view of the distance between a front end of a lance and an inner surface of a front end of a tuyere in the radial direction.

[Fig. 13] Fig. 13 is an explanatory view of the relationship between the flow velocity at a lance outlet and the lance surface temperature.

[Description of Embodiments]

[0019] A blast furnace operation method according to an embodiment of the present invention will be described below with reference to the accompanying drawings.

[0020] 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.

[0021] 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.

[0022] 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.

[0023] 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.

[0024] 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.

[0025] 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 Nm³/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/Nm³ 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/Nm³ 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 injected into the furnace. The combustion-supporting gas may also be an oxygen-enriched air.

[0026] 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. Thus, in the present invention, two double wall lances are used, and a reduced amount of pulverized coal is injected through the inner tube of each of the double wall lances. Even if two double wall lances are used, when the pulverized coal ratio is 170 kg/t or more, the combustion temperature levels off at an oxygen concentration of approximately 70% by volume. 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.

[0027] 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 con-

stant 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 injected is increased to promote contact with oxygen, when the amount of oxygen injected 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.

[0028] In the present embodiment, therefore, two double wall lances 4 are used, as illustrated in Fig. 7. Pulverized coal is injected through an inner tube of each of the double wall lances 4, and a combustion-supporting gas oxygen is injected through an outer tube of each of the double wall lances 4. It is important that pulverized coal flows from the two double wall lances 4 should not overlap each other. In other words, the double wall lances 4 are placed such that the two pulverized coal flows do not overlap each other. More specifically, as illustrated in Fig. 7, the two double wall lances 4 may be decentered such that the axes of the two double wall lances 4, particularly the axes at front ends of the two double wall lances 4 do not cross each other.

[0029] For example, when two pulverized coal flows overlap each other as illustrated in Fig. 8, the pulverized coal flows are concentrated in the overlap region. This hinders the contact with oxygen, and consequently the combustion temperature may level off or may be decreased. In the case that two pulverized coal flows from the two double wall lances 4 do not overlap each other, the amount of pulverized coal in the pulverized coal flow injected through each of the double wall lances 4 is half the amount of pulverized coal injected through a single lance. Thus, the combustion temperature rarely levels off and can be increased. This allows the pulverized coal ratio to be increased and can reduce CO₂ emissions.

[0030] However, as described later, even if two double wall lances 4 are used, when the pulverized coal ratio is 170 kg/t or more, it is difficult to prevent the concentration of a pulverized coal flow and, in particular, the combustion temperature levels off at an oxygen concentration of 70% by volume or more.

[0031] Fig. 9 shows the combustion temperature represented by the combustion rate under the conditions

that the pulverized coal ratio is 150 kg/t or more and less than 170 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 number of double wall lances 4 is one or two (decentered). In both cases, pulverized coal is injected through the inner tube of the double wall lance(s) 4, and a combustion-supporting gas oxygen is injected through the outer tube of the double wall lance(s) 4. As is clear from the figure, in the case of a single double wall lance 4, 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 a single double wall lance 4, the combustion temperature is not increased at an oxygen concentration of 35% by volume or more. In contrast, in the case of two decentered double wall lances 4, the combustion temperature increases even when the concentration of oxygen in the 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 each of the double wall lances 4 is not concentrated at a pulverized coal ratio of 150 kg/t or more and less than 170 kg/t.

[0032] Even in the case of two double wall lances 4, 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 the gas composed of the carrier gas and the combustion-supporting gas in the lances 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 lances 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 two double wall lances 4, the concentration of oxygen in the gas composed of the carrier gas and the combustion-supporting gas in the lances is 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 170 kg/t or more. The upper limit of the pulverized coal ratio is 300 kg/t or less, preferably 250 kg/t or less.

[0033] The present inventors examined the angle between a lance and a blow pipe, that is, the insertion angle of the lance with respect to the blast direction while changing the distance between a front end of the lance and an inner surface of a front end of a tuyere in the radial direction. The double wall lance is a coaxial double tube, preferably a straight tube. In a straight tube, depending on the insertion angle of the lance to the blow pipe, that is, the insertion angle of the lance with respect to the blast direction, the blast from a front end of the lance causes turbulence. Thus, it is necessary to regulate the insertion angle of the lance to the blow pipe. For example,

when the insertion angle θ of the lance 4 to the blow pipe 2 (the insertion angle of the lance 4 with respect to the blast direction) is small, as illustrated in Fig. 11(a), the hot air flow along the lance 4 changes gently. Thus, the hot air flow along the lance 4 causes low turbulence at a front end of the lance, and the pulverized coal flow has a small dispersion width. In contrast, when the insertion angle θ of the lance 4 to the blow pipe 2 (the insertion angle of the lance 4 with respect to the blast direction) is large, as illustrated in Fig. 11(b), the hot air flow along the lance 4 changes steeply. Thus, the hot air flow along the lance 4 causes high turbulence at the front end of the lance, and the pulverized coal flow has a large dispersion width. The combustion of pulverized coal before the diffusion of the pulverized coal can increase the combustion temperature, whereas the diffusion of pulverized coal before the combustion of the pulverized coal results in a low combustion temperature and low combustion efficiency.

[0034] Fig. 12 is a graph illustrating the distance between a front end of a lance and an inner surface of a front end of a tuyere in the radial direction as a matrix. The distance between the front end of the lance and the inner surface of the front end of the tuyere in the radial direction is denoted by "-" (minus) in the case that the front end of the lance is disposed outside the inner surface of the front end of the tuyere in the radial direction and is denoted by "+" (plus) in the case that the front end of the lance is disposed within the inner surface of the front end of the tuyere in the radial direction. In the matrix of the distance between the front end of the lance and the inner surface of the front end of the tuyere in the radial direction and the insertion angle θ of the lance 4 to the blow pipe 2 (the insertion angle of the lance 4 with respect to the blast direction), pulverized coal having high combustibility is represented by a circle "○", and pulverized coal having low combustibility is represented by a cross "×". Pulverized coal has good combustibility in the case that the insertion angle θ of the lance 4 to the blow pipe 2 (the insertion angle of the lance 4 with respect to the blast direction) is 45 degrees or less, and the front end of the lance is disposed within the inner surface of the front end of the tuyere in the radial direction. However, in the case that the insertion angle θ of the lance 4 to the blow pipe 2 (the insertion angle of the lance 4 with respect to the blast direction) is more than 45 degrees, the combustibility reduces even if the front end of the lance is disposed within the inner surface of the front end of the tuyere in the radial direction. Thus, the insertion angle θ of the lance 4 to the blow pipe 2 (the insertion angle of the lance 4 with respect to the blast direction) is preferably 45 degrees or less. When the front end of the lance is disposed below the center of the inner surface of the front end of the tuyere ("-" (minus) position), the pulverized coal flow from the lance hits the tuyere inner surface. Thus, the pulverized coal is represented by a cross "×".

[0035] The front end may be bent along the blast direction so as to reduce turbulence in the blast injected

through the front end of the lance. A short bent front end tends to result in turbulence of the pulverized coal flow injected through the inner tube and oxygen injected through the outer tube. Thus, the bent front end has a length of at least 200 mm or more, preferably 300 mm or more.

[0036] 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.

[0037] 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. 13 shows the measurement results.

[0038] 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.

[0039] 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.

[0040] 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.

[0041] 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.

[0042] 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. In use, 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 pul-

verized 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.

[0043] 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.

[0044] In a blast furnace operation method according to the present embodiment in which each lance 4 for injecting a fuel through a tuyere 3 is a double tube, the method includes injecting pulverized coal through an inner tube of each of two double wall lances 4 and injecting oxygen (a combustion-supporting gas) through an outer tube of each of the two double wall lances 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 CO₂ 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.

[0045] The concentration of pulverized coal flows injected through the inner tubes of the two double wall lances 4 can be prevented by injecting pulverized coal such that the pulverized coal flows do not overlap each other. This ensures high combustion efficiency.

[0046] The axes of the front ends of the two double wall lances 4 can be decentered so as not to overlap each other, thereby ensuring that the pulverized coal flows injected through the inner tubes of the two double wall lances 4 do not overlap each other.

[0047] Turbulence in the blast injected through the front ends of the double wall lances can be reduced by inserting the double wall lances 4 into the blow pipe 2 at an angle of 45 degrees or less.

[0048] Injecting part of oxygen for enrichment into a blast (as a combustion-supporting gas) through the outer tube of each of the double wall lances 4 can prevent

excess oxygen supply without disturbing the gas balance in the blast furnace and reduce the specific oxygen consumption.

[Reference Signs List]

[0049]

- 1 blast furnace
- 2 blow pipe
- 3 tuyere
- 4 lance
- 5 raceway
- 6 pulverized coal
- 7 coke
- 8 char
- 9 oxygen

Claims

1. A blast furnace operation method, comprising:

preparing pulverized coal having a volatile matter content of 25 mass% or less;
 preparing two double wall lances for injecting the pulverized coal and a combustion-supporting gas through a tuyere, each of the two double wall lances having an inner tube and an outer tube;
 blowing hot air through the tuyere;
 injecting the pulverized coal together with a carrier gas through the inner tube of each of the two double wall lances at a pulverized coal ratio of 150 kg/t-pig iron or more; and
 injecting the combustion-supporting gas through the outer tube of each of the two double wall lances,
 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 Claim 1, wherein the pulverized coal is injected such that the pulverized coal flows injected through the two double wall lances do not overlap each other.
3. The blast furnace operation method according to Claim 2, wherein axes of front ends of the two double wall lances do not cross each other.
4. The blast furnace operation method according to Claim 1, wherein the double wall lances are inserted in a blow pipe at an angle of 45 degrees or less.
5. The blast furnace operation method according to Claim 1, wherein the combustion-supporting gas is oxygen, and part of oxygen for enrichment is injected

into a blast through the outer tube of each of the double wall lances.

6. The blast furnace operation method according to Claim 1, wherein the pulverized coal has a volatile matter content of 3 mass% or more and 25 mass% or less.
7. The blast furnace operation method according to Claim 1, wherein the combustion-supporting gas injected through the outer tube of each of the double wall lances has an outlet flow velocity in the range of 20 to 120 m/sec.
8. The blast furnace operation method according to Claim 1, wherein the pulverized coal ratio is 170 kg/t-pig iron or more.
9. The blast furnace operation method according to Claim 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.
10. The blast furnace operation method according to Claim 9, 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.
11. The blast furnace operation method according to Claim 10, 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.
12. The blast furnace operation method according to Claim 8, wherein the pulverized coal ratio is 170 kg/t-pig iron or more and 300 kg/t-pig iron or less.
13. The blast furnace operation method according to Claim 9, wherein the pulverized coal ratio is 170 kg/t-pig iron or more and 300 kg/t-pig iron or less.
14. The blast furnace operation method according to Claim 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.
15. The blast furnace operation method according to Claim 14, 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.

16. The blast furnace operation method according to Claim 15, 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. 5
17. The blast furnace operation method according to Claim 1, wherein the pulverized coal ratio is 150 kg/t-pig iron or more and 300 kg/t-pig iron or less. 10
18. The blast furnace operation method according to Claim 1, wherein the pulverized coal ratio is 150 kg/t-pig iron or more and less than 170 kg/t-pig iron.
19. The blast furnace operation method according to Claim 1, wherein 15
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 20
is 35% by volume or more and less than 70% by
volume.
20. The blast furnace operation method according to any one of Claims 1 to 19, wherein at least one selected 25
from the group consisting of waste plastics, refuse-derived fuels, organic resources, scrap woods, and CDQ coke dust is added to the pulverized coal.
21. The blast furnace operation method according to Claim 20, wherein the pulverized coal accounts for 80 mass% or more, and at least one of the waste 30
plastics, refuse-derived fuels, organic resources,
scrap woods, and CDQ coke dust is used. 35

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FIG. 1

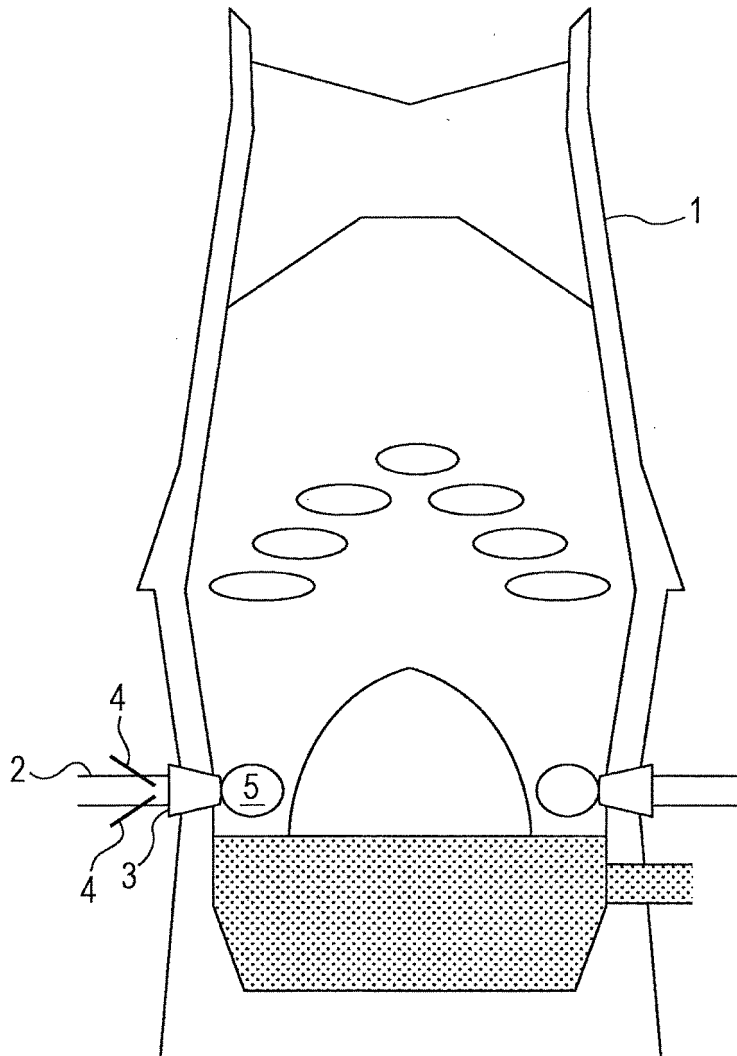


FIG. 2

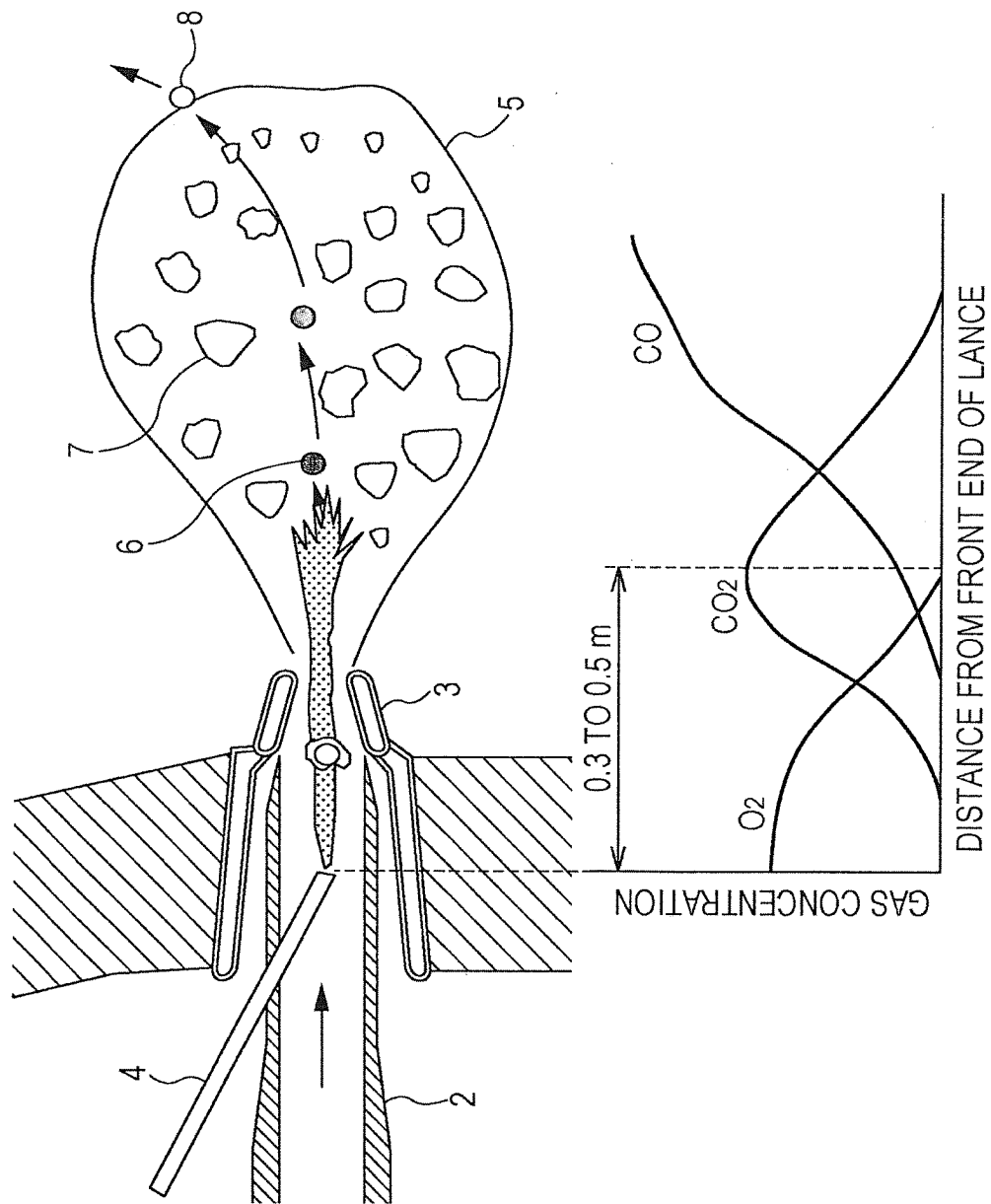


FIG. 3

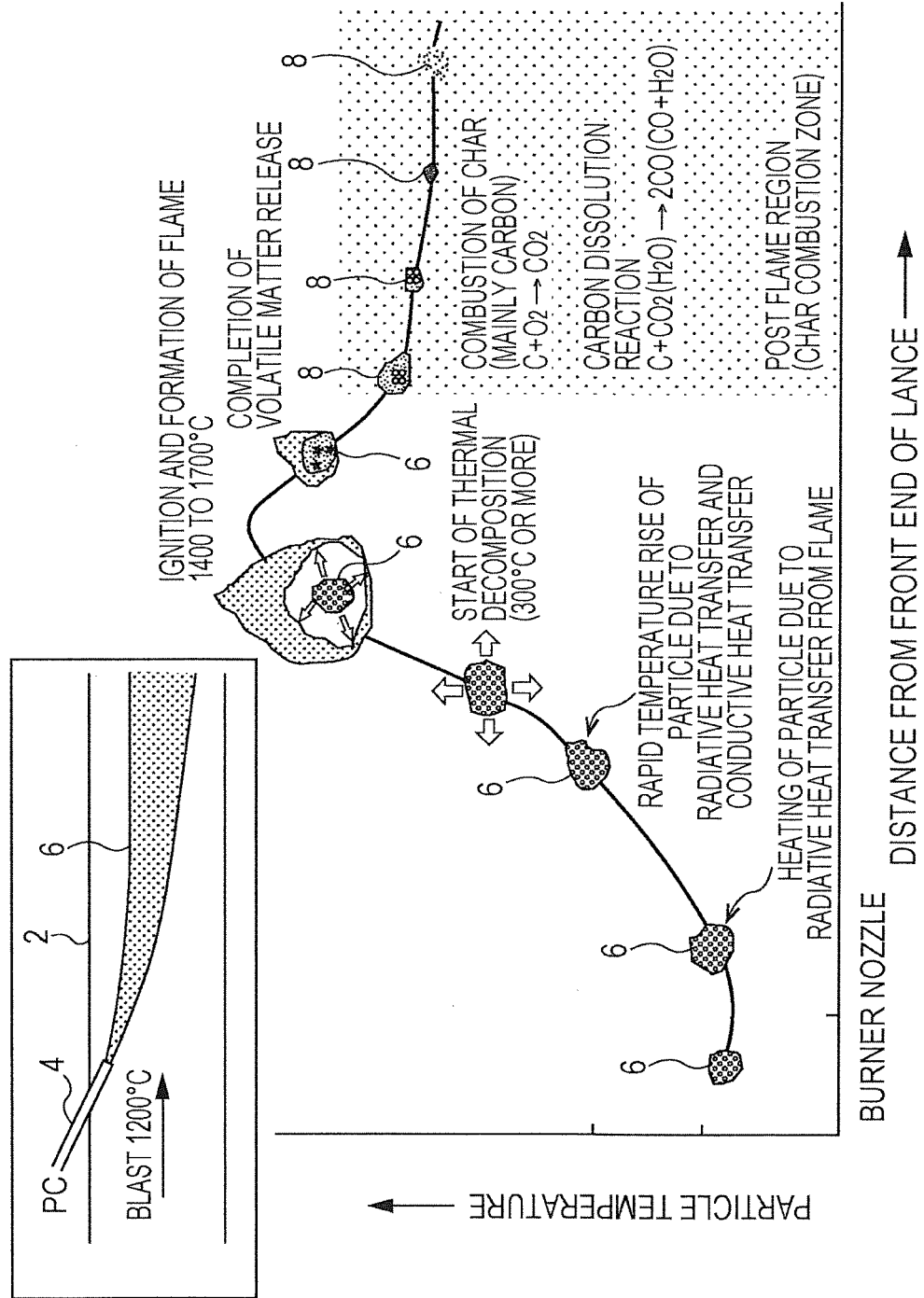
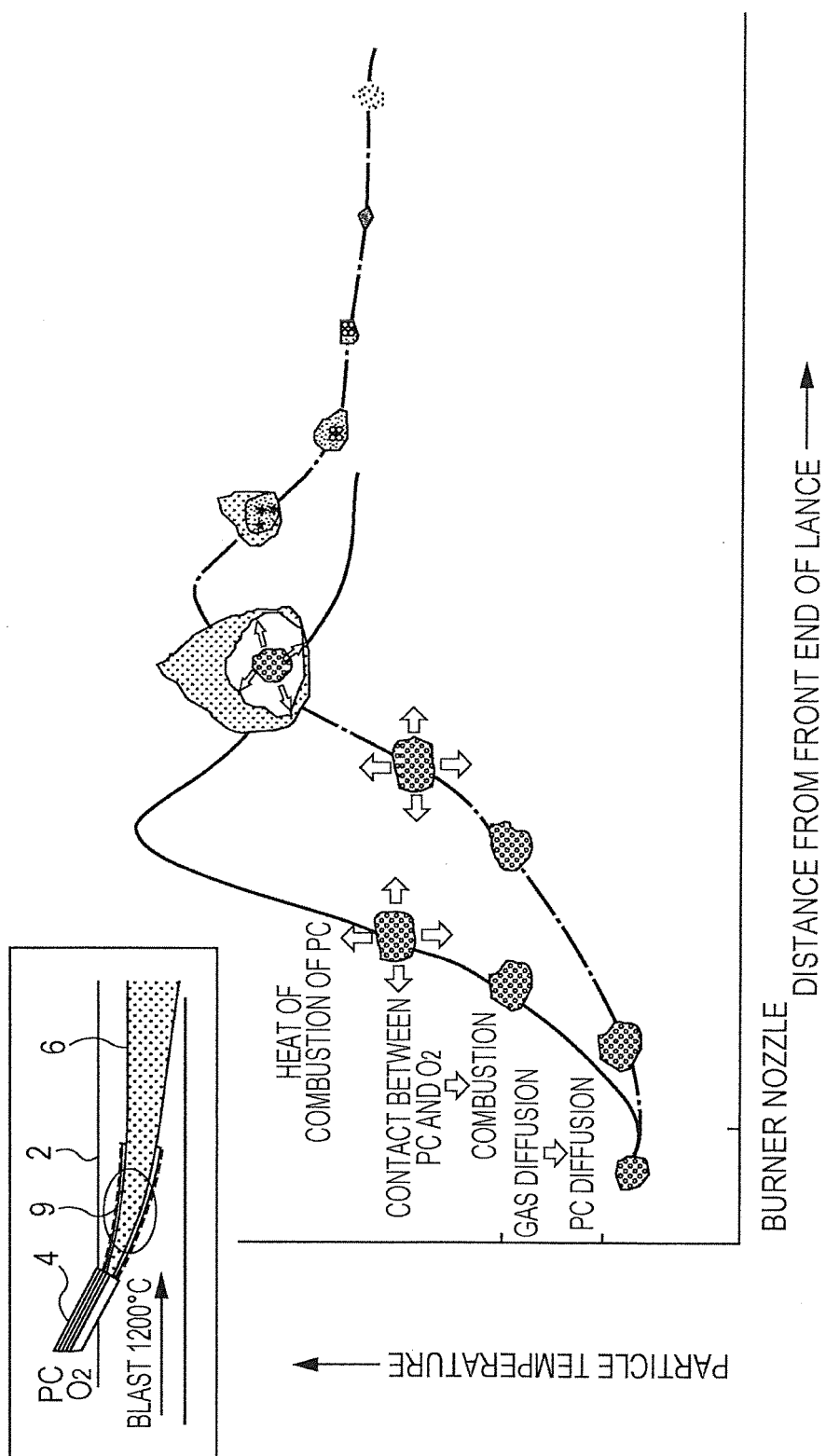


FIG. 4



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G.
F

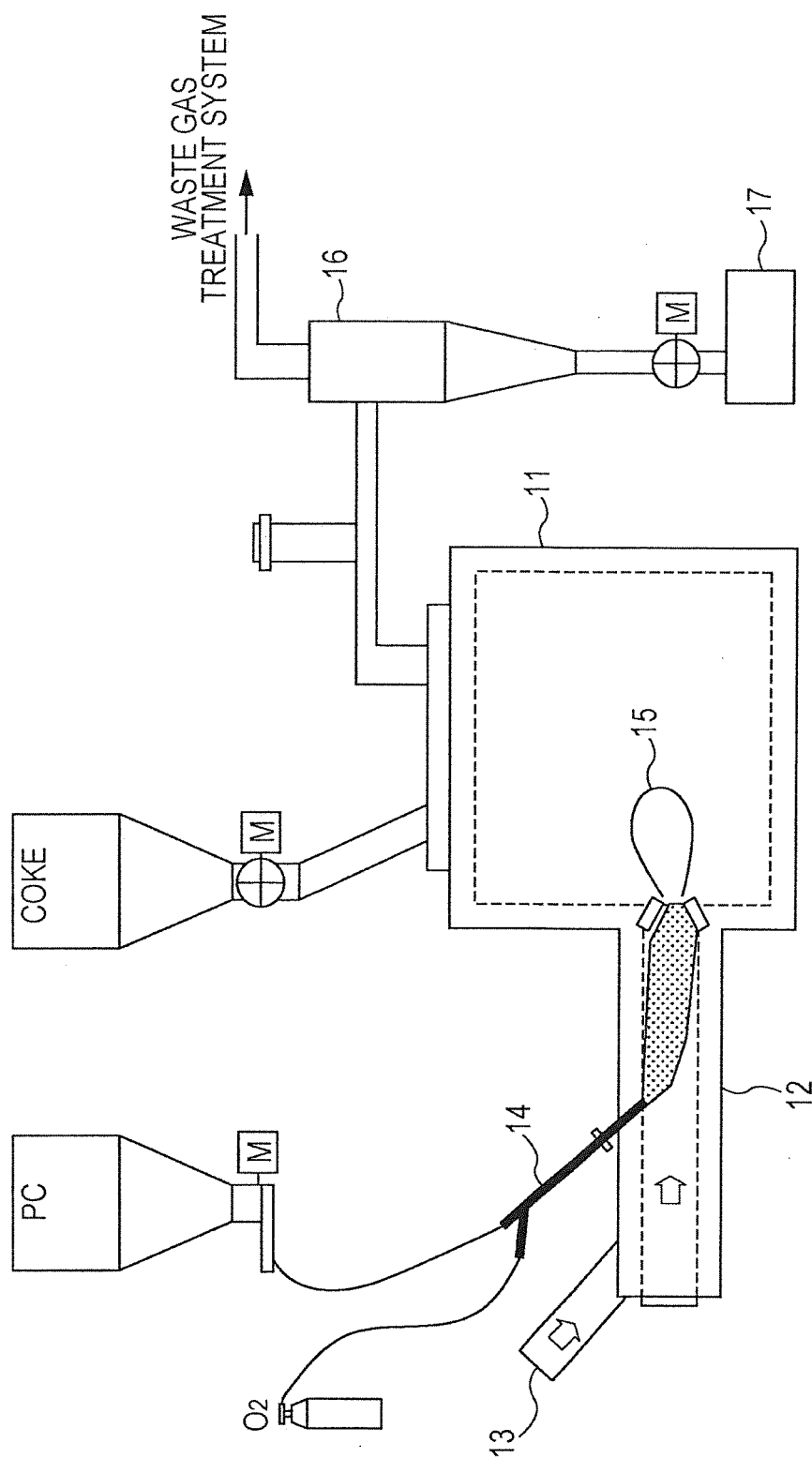


FIG. 6

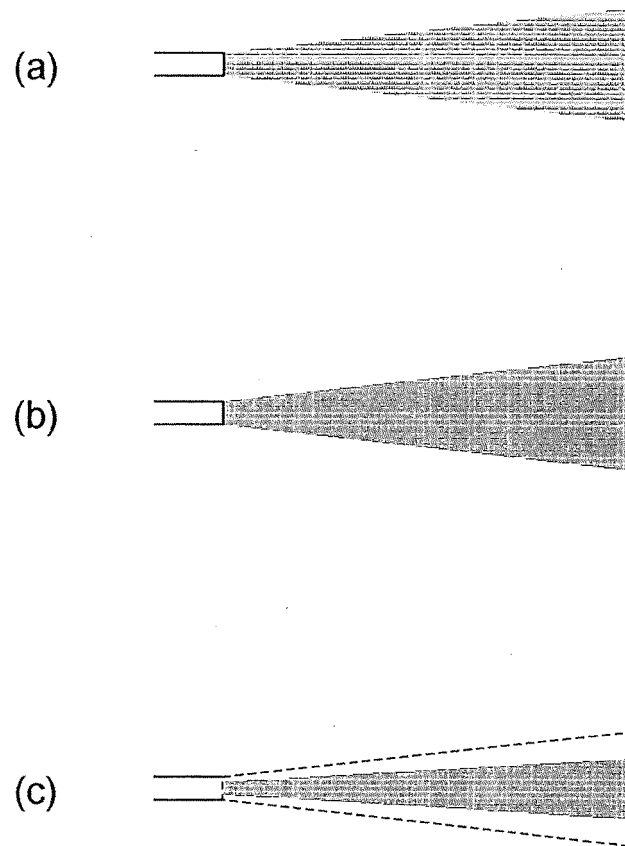


FIG. 7

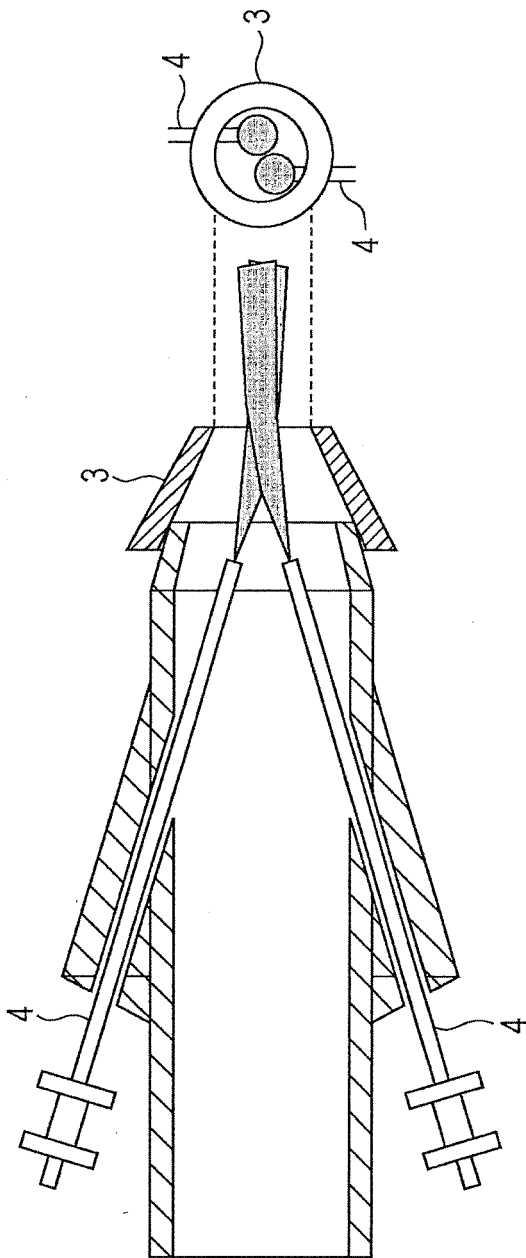


FIG. 8

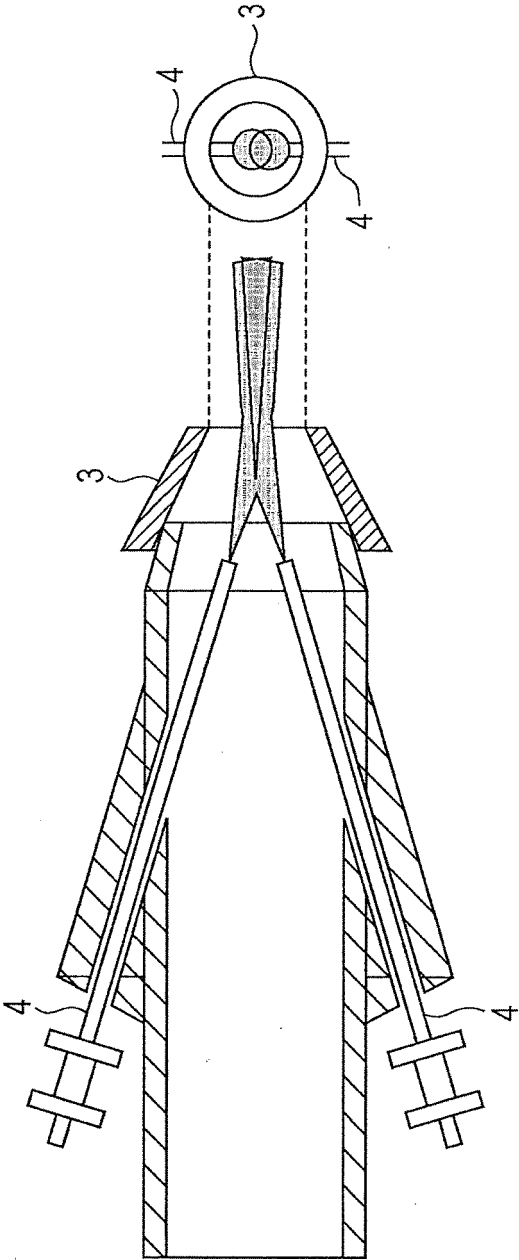


FIG. 9

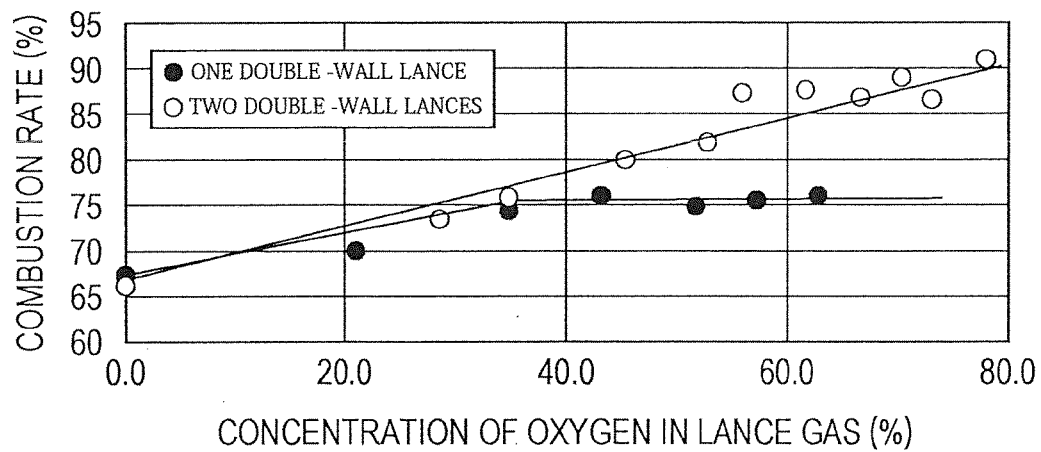


FIG. 10

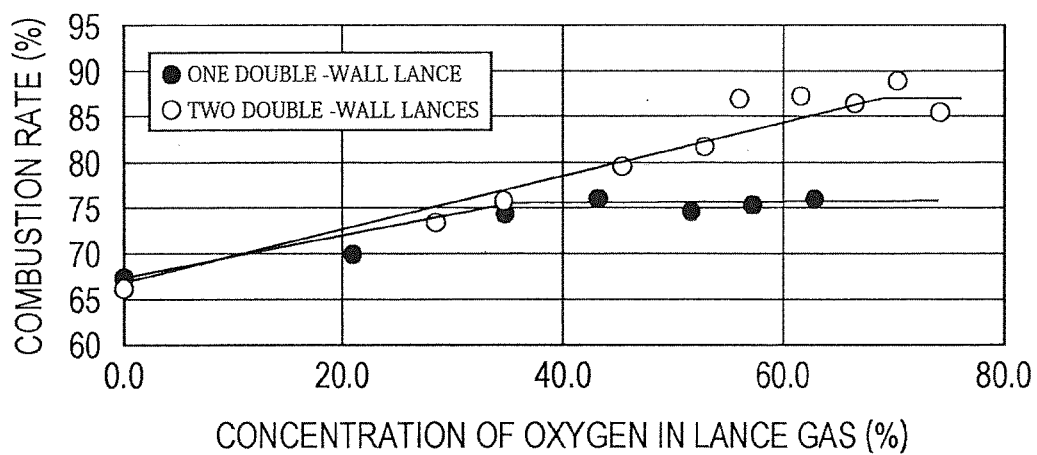


FIG. 11

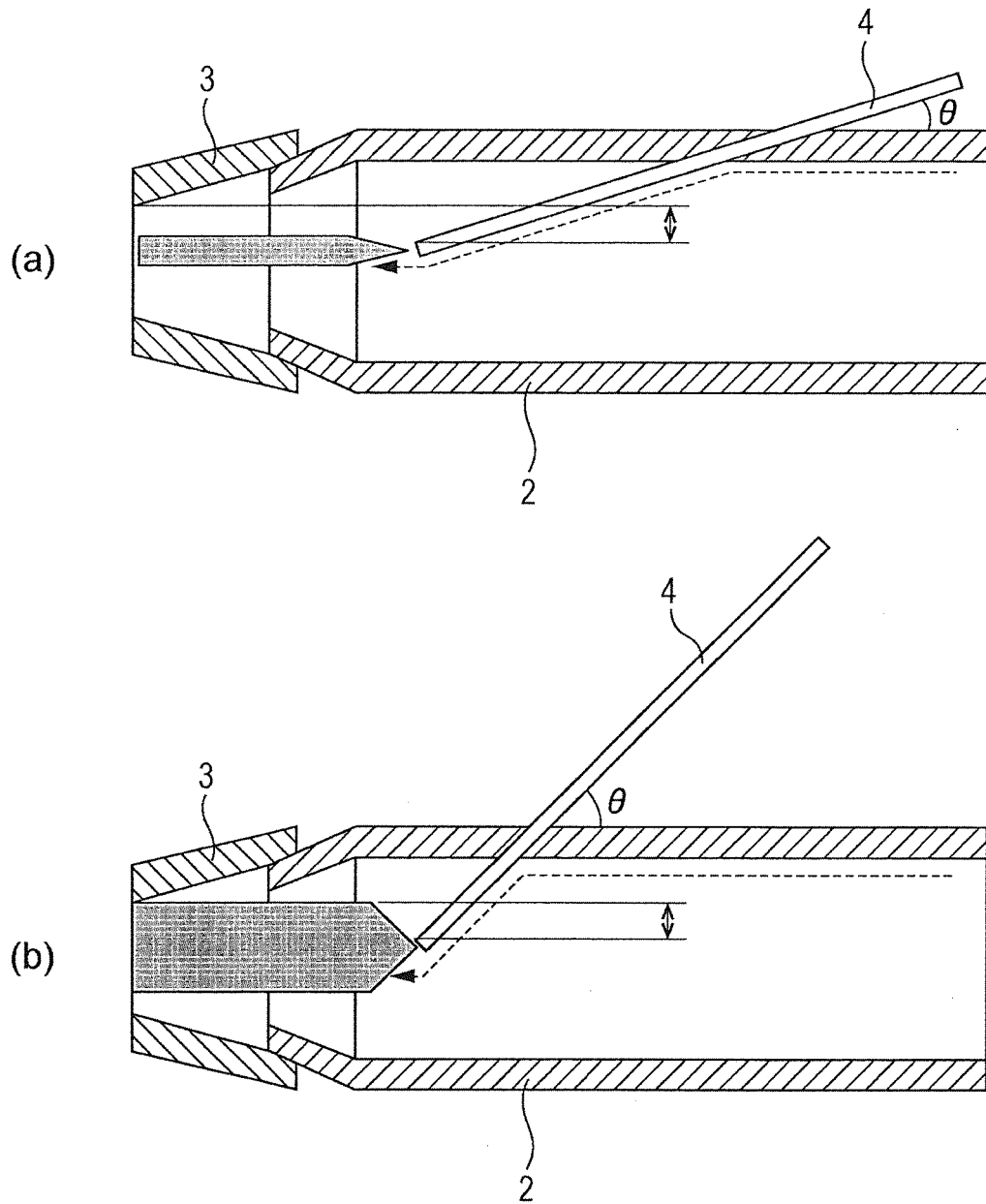


FIG. 12

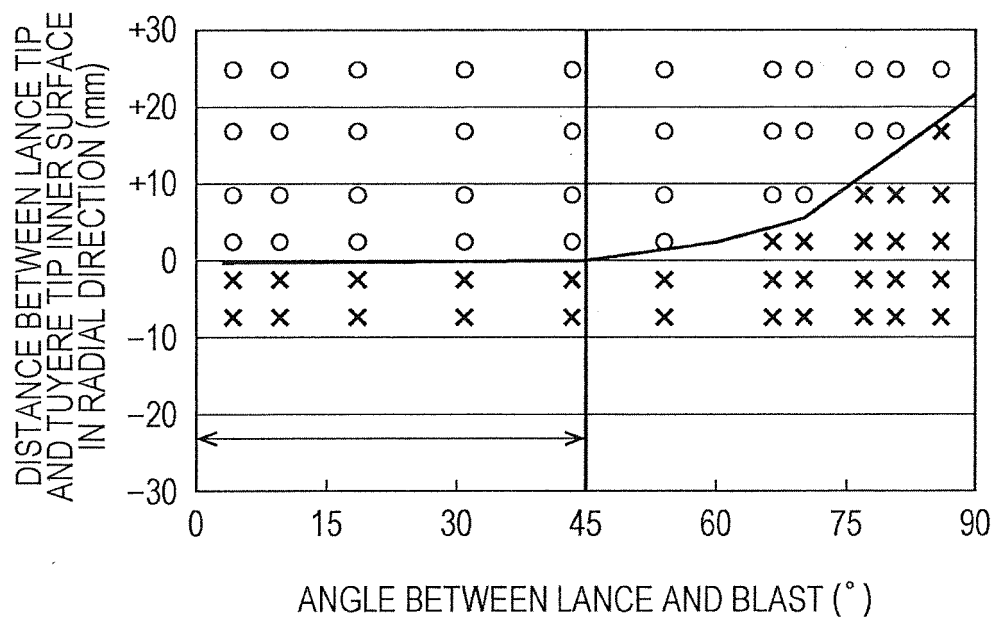
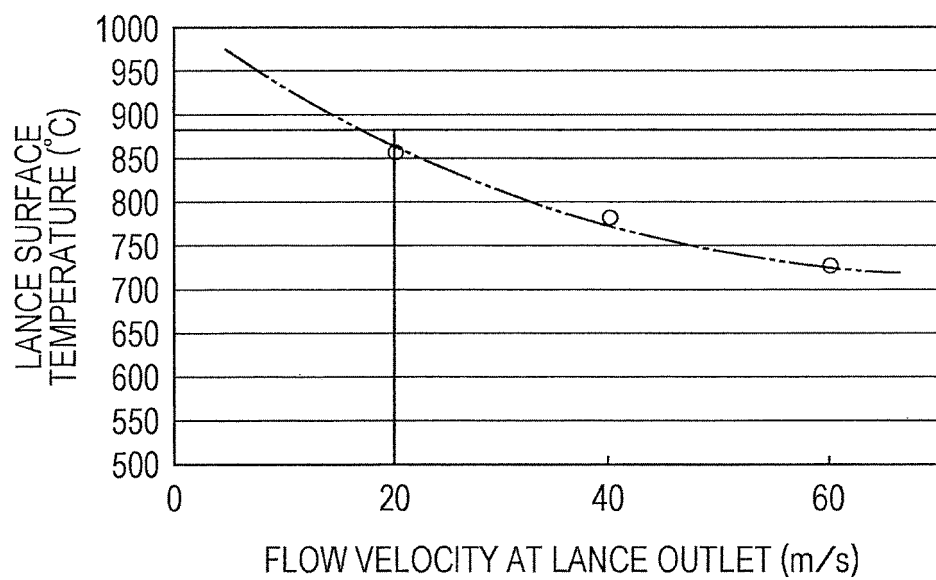


FIG. 13



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/055886

A. CLASSIFICATION OF SUBJECT MATTER

C21B5/00(2006.01) i, C21B7/00(2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C21B5/00, C21B7/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2012

Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2003-286511 A (Nippon Steel Corp.), 10 October 2003 (10.10.2003), claims 1, 3; paragraphs [0002] to [0004], [0009] to [0023], [0027]; table 1 (Family: none)	1-8, 14-21 9-13
Y A	JP 6-2020 A (Kawasaki Steel Corp.), 11 January 1994 (11.01.1994), claim 1; paragraphs [0003], [0008] to [0013] (Family: none)	1-8, 14-21 9-13
A	JP 4-346610 A (Kawasaki Steel Corp.), 02 December 1992 (02.12.1992), paragraphs [0003] to [0011]; fig. 1 (Family: none)	1-21

☒ Further documents are listed in the continuation of Box C.
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Date of the actual completion of the international search
04 June, 2012 (04.06.12)Date of mailing of the international search report
12 June, 2012 (12.06.12)Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/055886

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 6-330113 A (NKK Corp.), 29 November 1994 (29.11.1994), paragraphs [0013] to [0019]; fig. 1, 2 (Family: none)	1-8, 14-21
Y	JP 2001-323307 A (NKK Corp.), 22 November 2001 (22.11.2001), paragraph [0029]; fig. 5 (Family: none)	1-8, 14-21

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REFERENCES CITED IN THE DESCRIPTION

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