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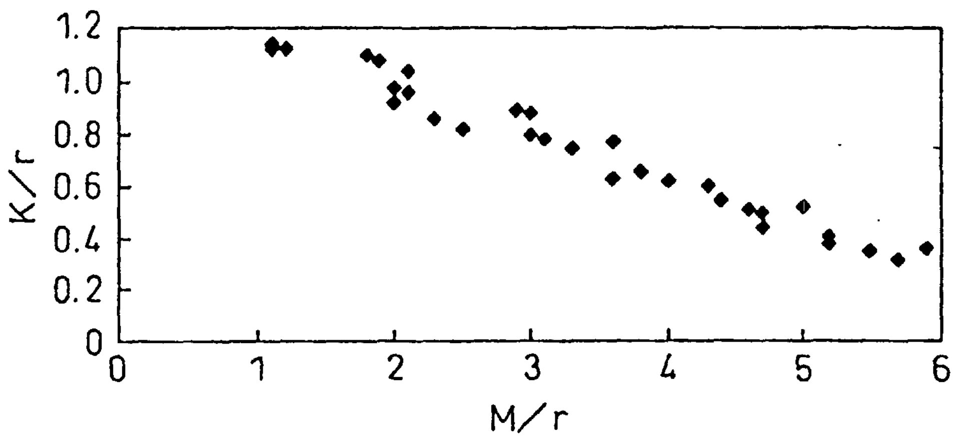
(54) **METHOD FOR OBSERVING INSIDE OF MOLTEN IRON REFINING FURNACE AND TUYERE FOR OBSERVING INSIDE OF FURNACE**

(57) It is possible to stably observe the temperature and/or composition of molten iron in a refining furnace by opening a tuyere for observation at all times according to the state of refining. There is provided a method of observing the inside of a molten metal refining furnace comprising the steps of: using a single tube tuyere for observing the temperature and/or composition of molten iron in the refining furnace via a tube penetrating refractories of a furnace wall and/or furnace bottom of the molten iron refining furnace by detecting electromagnetic waves radiated from molten metal at a forward end of the tuyere under a non-contact condition; and using an inert gas or an oxidizing gas, alone or mixed, according to the opening condition of the forward end of the tuyere.

Fig.1

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**Description**

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

**[0001]** The present invention relates to a method of stably observing the temperature and/or composition of molten iron, including molten steel, in a refining furnace by detecting electromagnetic waves, which are radiated from molten metal, at an end of a single tube under a non-contact state, via a tube penetrating refractories on a furnace wall and/or a furnace bottom of the molten iron refining furnace such as a converter, an AOD and an RH.

DESCRIPTION OF THE PRIOR ART

**[0002]** Conventionally, there is provided a method of observing the temperature and composition of molten iron in a refining furnace, which is represented by a converter, via a tube penetrating refractories on a furnace wall and/or a furnace bottom.

**[0003]** For example, the following methods are provided. Concerning the temperature of molten iron in a refining furnace, there is provided a method in which an image fiber is used as disclosed in Japanese Unexamined Patent Publication No. 11-142246. Concerning the composition of molten iron in a refining furnace, there is provided a method in which laser beams are used as disclosed in Japanese Unexamined Patent Publication No. 60-42644.

**[0004]** In the above techniques, it is necessary for a tuyere used for observation to be opened at all times. In general, in the case where gas is supplied from a tuyere to molten iron, a piece of solid iron, which is referred to as a mushroom, is created by coagulation at an end of the tuyere. Due to the creation of this mushroom, it becomes impossible to observe the temperature and composition of molten iron. In the case where the end of the tuyere is opened by an exothermic reaction which is caused by supplying oxygen gas, the front side of the tuyere is heated to a high temperature by the heat created in the process of oxidation. Therefore, it becomes impossible to measure the temperature. Further, it becomes impossible to measure the content of light elements, because they are absorbed by oxygen gas. The creation of the mushroom is greatly affected by not only the composition and flow rate of the gas supplied from a tube but also the temperature and the components of the molten steel. However, there is provided no knowledge to make the appropriate control condition clear. As described above, according to the prior art, no knowledge about now to keep open the tuyere used for observation at all times is known. Therefore, it is impossible to stably observe the inside of the furnace in the process of refining.

SUMMARY OF THE INVENTION

**[0005]** It is an object of the present invention to provide a method of stably observing the temperature and/or composition of molten iron, including molten steel, in a refining furnace by keeping a tuyere used for observation open at all times, according to the state of refining. It is another object of the present invention to provide a tuyere used for observation in the method. The invention will be described as follows.

(1) A method of observing the inside of a molten metal refining furnace comprising the steps of: using a single tube tuyere for observing the temperature and/or composition of molten iron in the refining furnace via a tube penetrating refractories of a furnace wall and/or furnace bottom of the molten iron refining furnace by detecting electromagnetic waves radiated from molten metal at a forward end of the tube under a non-contact state; and using an inert gas or an oxidizing gas alone, or mixed with each other, according to the opening condition of the forward end of the tube. In this case, the inert gas is Ar, nitrogen or CO, and the oxidizing gas is oxygen, air or $CO_2$.

(2) A method of observing the inside of a molten metal refining furnace according to item (1), wherein a mixed gas of an inert gas with an oxidizing gas or only an oxidizing gas is supplied (the opening period) in the case where the ratio (%) of opening of the tube is not higher than $\alpha$ which is calculated by the inner diameter r (mm) of the tuyere according to Equation (1), and only inert gas is supplied (the steady period) in the case where the ratio of opening is higher than $\alpha$.

$$\alpha = 765/r^2 \qquad (1)$$

In this case, the opening period is judged and completed when the temperature of molten iron at the forward end of the tube to be measured is not lower than 1800°C. Although the upper limit of the rate of opening is not particularly prescribed, it is preferable that the upper limit of the rate of opening is not more than 95% so as to prevent the fusion of the tuyere.

(3) A method of observing the inside of a molten metal refining furnace comprising the steps of: using a single tube tuyere for observing the temperature and/or composition of molten iron in the refining furnace via a tube penetrating refractories of a furnace wall and/or furnace bottom of the molten iron refining furnace, by detecting electromagnetic waves radiated from molten metal, at a forward end of the tube under a non-contact state; and controlling a flow rate of an inert gas according to the opening condition of the forward end of the tube. In this case, the inert gas is Ar, nitrogen or CO.

(4) A method of observing the inside of a molten metal refining furnace according to item (3), wherein the flow rate of an inert gas is controlled according to the temperature and composition of the molten iron so that the ratio (%) of opening of the single tube can be not less than $\alpha$, which is calculated by the inner diameter r (mm) of the tube according to Equation (1), and not more than 95%.

(5) A tuyere for observing the inside of a molten metal refining furnace having a single tube for observing the temperature and/or composition of molten iron in the refining furnace, via a tube penetrating refractories of a furnace wall and/or furnace bottom of the molten iron refining furnace, by detecting electromagnetic waves radiated from molten metal at a forward end of the tube under a non-contact state, the tuyere for observing the inside of a molten metal refining furnace comprising a control function by which an inert gas or an oxidizing gas can be used alone, or mixed with each other, according to the state of the opening of the forward end of the tube, the inner diameter of which is 2 to 6 mm.

(6) A method of observing the inside of a molten metal refining furnace in which the temperature and/or composition of the molten iron in the molten iron refining furnace is observed via a tube penetrating refractories of a furnace wall and/or furnace bottom of the molten metal refining furnace, in a non-contact state, by detecting electromagnetic waves radiated from molten iron at the forward end of the tube, the method of observing the inside of the molten metal refining furnace comprising the steps of: using a twin tube tuyere; detecting a ratio of opening of the forward end of the inner tube tuyere; and controlling a size of a mushroom at the forward end tuyere by changing gas flow rate and/or gas composition which is supplied through the inner and the outer tube according to a change in the ratio of opening so as to keep the ratio of opening necessary for observation.

(7) A method of observing the inside of a molten metal refining furnace according to item (6), further comprising the steps of: estimating the size of the mushroom at the forward end of tuyere according to the temperature and composition of molten iron; and controlling the size of the mushroom at the forward end of tuyere by changing the gas flow rate of and/or gas composition of LPG inert gas, inert gas and oxidizing gas which are supplied through the outer tube according to the result of the estimation so as to keep the ratio (%) of opening of the inner tube in a range from not less than $\alpha$ (%), which is calculated by Equation (5), to not more than 95%.

$$\alpha = 850/r^2 \tag{5}$$

where r is an inner diameter (mm) of the inner tube.

(8) A method of observing the inside of a molten metal refining furnace according to item (6), further comprising the steps of: supplying a mixed gas, in which an inert gas and an oxidizing gas are mixed with each other, or only an oxidizing gas from the inner tube, so as to increase the ratio of opening in a tube opening period in the case where the ratio of opening of the inner tube is lower than $\alpha$ (%) in Equation (5); and supplying only inert gas from the inner tube in a period except for the tube opening period.

(9) A method of observing the inside of a molten metal refining furnace according to one of items (6) to (8), further comprising the steps of: supplying an inert gas from the inner tube at all times; supplying a mixed gas, in which inert gas and oxidizing gas are mixed with each other, or only an oxidizing gas, from the outer tube so as to increase the ratio of opening of the inner tube in a tube opening period in the case where the ratio of opening of the inner tube is lower than $\alpha$ (%) in Equation (5); and supplying tuyere cooling gas, or inert gas alone, through the outer tube or supplying mixed gas, in which tuyere cooling gas and inert gas are mixed, from the outer tube in a period except for the tube opening period.

(10) A tuyere for observing the inside of a molten metal refining furnace, which is a double tube tuyere for observing the temperature and/or composition of molten iron in the refining furnace via a tube penetrating refractories of a furnace wall and/or a furnace bottom of the molten iron refining furnace by detecting electromagnetic waves radiated from molten metal at a forward end of the tube under a non-contact state, -the tuyere for observing the inside of a molten metal refining furnace comprising: a piping structure; and a control system capable of independently controlling a gas flow rate and/or gas composition which is supplied through each of the inner and the outer tube.

(11) A tuyere for observing the inside of a molten metal refining furnace according to claim 10, wherein inner

diameter r of the inner tube is 5 to 20 mm.

BRIEF DESCRIPTION OF THE DRAWINGS

**[0006]**

Fig. 1 is a view showing a relation between the diameter (K) of an opening section of a tuyere for observation, the diameter (M) of a mushroom created at a forward end of the tuyere, and inner diameter (r) of the inner tube.
Fig. 2 is a view showing a result of an experiment which shows a relation between parameter $\alpha$, inner diameter r of a tube and the accuracy of measurement of temperature by radiation.
Fig. 3 is a view showing a relation between a ratio of an opening and the accuracy of measurement of temperature by radiation in the case where a tube, the inner diameter of which is 10 mm, is used.
Fig. 4 is a view showing a model of a single tube for observation of the present invention.
Fig. 5 is a view showing a model of a twin tube for observing the inside of a furnace of the present invention.

DESCRIPTION OF THE MOST PREFERRED EMBODIMENT

**[0007]** The present invention has been accomplished according to the new knowledge that the opening area of a tuyere for observation and the size of a mushroom created at a forward end of the tube are correlated to each other and the opening area can be controlled when the mushroom size is controlled. Fig. 1 is a graph showing a detailed result of an experiment made by the present inventors in which a melting furnace, the capacity of which was 1 ton, was used. As shown in Fig. 1, M/r and K/r are strongly correlated to each other wherein r is an inner diameter of an inner tube of a tuyere, K is a diameter of an opening section of the tuyere for observation, and M is a diameter of a mushroom created at a forward end of the tube. That is, in order to control the ratio of opening of the tube to be a value necessary for observation, it is necessary to control the mushroom size by changing the gas flow rate and gas composition.

**[0008]** In this case, the electromagnetic wave is a generic name for emitted energy such as light used for radiant measurement and light used for laser beam emission analysis, the wave-length of which is peculiar to each component. The reason why the single tube is adopted in the present invention is that gas is supplied to the single tube from a single gas generation system, so that the equipment investment is small. The reason why the twin tube tuyere is adopted in the present invention is that the composition and gas flow rate can be independently controlled by the twin tube tuyere. Gas used for the inner and outer tube is a tuyere cooling gas, such as LPG inert gas, an inert gas and an oxidizing gas which are used alone or mixed. Concerning the tuyere cooling gas of the outer tube, by which the cooling effect can be positively provided when the gas is decomposed. Concerning the inert gas of the outer tube, Ar, nitrogen or carbon monoxide gas is used. Concerning the oxidizing gas of the outer tube, oxygen, air or carbon dioxide is used. Concerning the inert gas used for the inner tube, Ar, nitrogen or carbon monoxide gas is used. Concerning the oxidizing gas used for the inner tube, oxygen, air or carbon dioxide is used.

**[0009]** The first item of the present invention is a method of observing the inside of a molten metal refining furnace represented by a converter, an electric furnace or an AOD comprising the steps of: using a single tube for observing the temperature and/or composition of molten iron in the refining furnace via a tube penetrating refractories of a furnace wall and/or furnace bottom of the molten iron refining furnace by detecting electromagnetic waves radiated from molten metal at a forward end of the tube under a non-contact state; and using inert gas or oxidizing gas alone or mixed according to the opening condition of the forward end of the tube.

**[0010]** In the single tube, according to the state of opening at a forward end of the tube, inert gas and oxidizing gas are used alone or mixed. That is, observation is conducted by detecting an electromagnetic wave radiated from an interface formed between a molten iron face at the forward end of the tube and bubbles of gas blown out from the tuyere. The ratio of opening of the forward end of the tube is controlled according to the composition of gas so that an intensity of electromagnetic waves can be controlled to be a sufficiently high value prescribed according to the method of observation. In this case, the inert gas is Ar, nitrogen or CO. The oxidizing gas is oxygen, air or $CO_2$. In the case where the ratio of opening at the forward end of the tube is too low, the accuracy of observation is deteriorated. Therefore, oxidizing gas is mixed with inert gas, so that the mushroom created at the forward end of the tube is melted. On the contrary, in the case where the ratio of opening at the forward end of the tube is too high, the fusion of the tuyere is great, so that inert gas is used alone and the mushroom is created as long as the accuracy of observation is not deteriorated.

**[0011]** The second item of the present invention prescribes a specific control method in the first invention. In this case, the area of opening necessary for observation of temperature in which an intensity of electromagnetic waves is high is different from the area of opening necessary for observation in the case of laser emitted light for composition analysis in which an intensity of light is low. Further, the area of opening necessary for observation is different according to the inner diameter and length of the tuyere. In general, when consideration is given to the thickness of refractories of a large-scale converter, the length of the tuyere is approximately 1 to 2 m. In this case, the area of observation of 6 $mm^2$ is required, which is experimentally known. This knowledge is organized into Equation (1). Accordingly, the second item of the present invention provides a method of observing the inside of a molten metal refining furnace, wherein a mixed gas of an inert gas with an oxidizing gas, or only an oxidizing gas, is supplied (in the opening period) in the case where the ratio (%) of opening of the tube is not higher than $\alpha$ which is calculated by the inner diameter r of the tube according to Formula (1), and only inert gas is supplied (in the steady period) in the case where the ratio of opening is higher than $\alpha$.

$$\alpha = 765/r^2 \qquad (1)$$

**[0012]** In this case, the ratio of opening is defined as a value obtained when an area of the opening, at the forward end of the tube not covered with the mushroom, is divided by a cross-sectional area of the tube, wherein this ratio of opening is expressed by percent. In the case where a relation between the ratio of opening and the back pressure is previously measured, it is possible to detect the ratio of opening by a change in the back pressure of gas. Further, it is possible to directly detect the ratio of opening by the observation conducted by an image fiber arranged at the forward end of the tuyere on the shell side.

**[0013]** Fig. 2 is a graph showing an example in which the present invention is applied to the measurement of radiation in which an image fiber is used. The accuracy of the vertical axis corresponds to $2\sigma$ ($\sigma$ is a standard deviation) of the measured temperature. Due to the foregoing, it is understood that the temperature can be observed with accuracy when $\alpha \times r^2$ is not lower than 765. However, when $\alpha \times r^2$ is lower than 765, the visual field is decreased because of a block in the opening. Accordingly, the accuracy of observation is deteriorated.

**[0014]** Specifically, control is conducted as follows. In the case where the ratio of opening of the tube is lower than the critical value necessary for observation, the value of $\alpha \times r^2$ of which is 765, one of or two and more of the rate of flow of oxidizing gas of oxygen, air and $CO_2$ and the flow rate of inert gas of Ar, nitrogen and CO are adjusted according to the inner diameter of the tube, the temperature of the molten iron and the concentration of carbon in the molten iron, so that the rate of opening can be controlled.

**[0015]** The diameter of the mushroom formed at the forward end of the tube, which is an index of control, can be calculated according to the heat balance of each item described below. When a relation between the diameter of the mushroom and the rate of opening is experimentally found, it is possible to conduct control.

(1) Index (v1) of cooling by sensible heat of gas: function of specific heat of gas
(2) Index (v2) of cooling by latent heat of gas: function of reaction heat of gas
(3) Index (k) of receiving heat of the mushroom from molten iron

**[0016]** When the mushroom is assumed to be a hemisphere, the following heat balance is established.

$$k = M^2 \times (T - Ts) \times Q^n = a + b \times (v1 + v2) \qquad (2)$$

**[0017]** In the above Equation (2), a, b and n are constants, Q is a flow rate of total gas ($Nm^3/h/t$), T is a temperature (°C) of molten iron, and Ts is a solid line temperature (°C). In this case, v1 and v2 can be calculated when a ratio of contribution to the creation of the mushroom is determined by an experiment according to the physical property and reaction heat of the used gas. Ts can be found by the phase diagram. When these are put into Equation (2) and the constants are determined so that they can agree with the mushroom diameter obtained by an experiment, it is possible to obtain a formula of estimation of the mushroom diameter when an actual device is used. In this connection, concerning the ratio of contribution of reaction heat, the present inventors found the following by an experiment. In the case of oxygen (including a component of oxygen in air), the ratio of contribution is 70 to 80% of the latent heat of forming reaction of FeO calculated by the reaction of $2Fe + O_2 = FeO$. However, in the case of $CO_2$, the ratio of contribution is only 2 to 5% of the latent heat calculated by the reaction of $CO_2 + [C] = 2CO$. Further, according to the experiment made by the present inventors, diameter M (mm) of the mushroom, the inner diameter r (mm) of the tube and the diameter K (mm) of the opening section equivalent to a circle have a relation expressed by the following Equation (3).

$$(K/r) = \beta - 0.165 \times (M/r) \qquad (3)$$

**[0018]** In the above equation, $\beta$ is in a range from 1.0 to 1.3.

**[0019]** The third item of the present invention is a method of observing the inside of a molten metal refining furnace comprising the steps of: using a single tube for observing the temperature and/or composition of molten iron in the refining furnace via a tube penetrating refractories of a furnace wall and/or furnace bottom of the molten iron refining furnace by detecting electromagnetic waves radiated from molten metal at a forward end of the tube under a non-contact state; and controlling a flow rate of inert gas according to the opening condition of the forward end of the tube. According to the method, the mushroom size is controlled when the flow rate of inert gas is controlled. When the ratio of opening at the forward end of the tube is too low, the accuracy of observation is deteriorated. Therefore, when the flow rate of inert gas is decreased so as to decrease the cooling capacity given by the sensible heat of gas, the mushroom created at the forward end of the tube is melted. On the contrary, when the ratio of opening at the forward end of the tube is too high, the tube is greatly melted. Therefore, when the flow rate of inert gas is increased so as to increase the cooling capacity given by the sensible heat of gas, the mushroom is created as long as the accuracy of observation is not deteriorated.

**[0020]** This is necessary when the inside of the tube must be kept in an atmosphere of inert gas at all times so that the emitted light can be transmitted without causing attenuation in the case where light of a short wave-length, which has been emitted from carbon or phosphorus by laser beams, is observed. The present inventors found that the ratio of opening can be controlled even if the inside of the tube is kept in an atmosphere of inert gas at all times.

**[0021]** The fourth and the fifth item of the present invention prescribe a specific control method of the third invention. The fourth item of the present invention provides a method of observing the inside of a molten metal refining furnace, in which a flow rate of inert gas is controlled according to the temperature and composition of molten iron so that the ratio (%) of opening of the single tube can be not less than $\alpha$, which is calculated by the inner diameter r (mm) of the tube according to Equation (1), and not more than 95%. When the ratio of opening is higher than 95%, the size of the mushroom created at the forward end of the tube is too small. Therefore, it is impossible to protect the tube, and the life of the tube is short.

**[0022]** In the fifth item of the present invention, the carbon concentration can be estimated by a method in which the carbon concentration is calculated from the quantity of oxygen to be supplied and the decarbonizing efficiency, which is experimentally known, on the basis of the carbon concentration of molten iron to be charged. Further, the carbon concentration can be estimated by a method in which the carbon concentration is estimated from the exhaust gas analysis and the result of direct sampling of molten iron. Alternatively, the carbon concentration can be estimated by the combination of the above methods. The temperature can be estimated by a direct continuous measurement method or a semi-continuous measurement method. Further, the temperature can be estimated by a method in which the temperature is calculated from the temperature rising efficiency which is experimentally known. Alternatively, the temperature can be estimated by the combination of the above methods. The reason why the flow rate of inert gas is controlled according to the temperature and composition of molten iron is that the size of the mushroom is greatly affected by a difference between the temperature of molten iron and the temperature of the solid phase line of molten iron. Also, the reason why the flow rate of inert gas is controlled according to the temperature and composition of molten iron is that it is necessary to detect a difference between the temperature of molten iron and the temperature of the solid phase line which is determined by the molten iron composition (the carbon concentration) and also it is necessary to increase and decrease the flow rate according to the value of difference.

**[0023]** Also, in this case, the diameter of the mushroom at the forward end of the tube, which is an index of control, can be calculated by the heat balance of each item. It is possible to control when an experimental relation between the diameter of the mushroom and the ratio of opening is found.

(1) Index (v1) of cooling by sensible heat of gas: function of specific heat of gas
(2) Index (k) of receiving heat of the mushroom from molten iron

**[0024]** When the mushroom is assumed to be a hemisphere, the following heat balance is established.

$$k = M^2 \times (T - Ts) \times Q^n = a + b \text{ x } v1 \tag{4}$$

**[0025]** In the above Equation (4), a, b and n are constants, Q is a flow rate of total gas ($Nm^3/h/t$), T is a temperature (°C) of molten iron, and Ts is a solid line temperature (°C). In this case, v1 can be calculated according to the physical property of the used gas. Ts can be found according to the phase diagram. When these are put into Equation (4) the constants are determined so that they can agree with the mushroom diameter obtained by an experiment. In this way, it is possible to obtain a formula of estimation of the mushroom diameter when an actual device is used. The relation between diameter M of the mushroom and diameter K of the equivalent circle of the opening section can be calculated by Equation (3).

**[0026]** Concerning the tuyere, as shown by an embodiment in Fig. 4, the present invention provides a tuyere for observing the inside of a molten metal refining furnace which is a single tube for observing the temperature and/or composition of molten iron in the refining furnace via a tube penetrating refractories of a furnace wall and/or furnace bottom of the molten iron refining furnace by detecting electromagnetic waves radiated from molten metal at a forward end of the tube under a non-contact state, the tuyere for observing the inside of a molten metal refining furnace comprising a control function by which inert gas or oxidizing gas can be used alone or mixed according to a state of opening of the forward end of the tube.

**[0027]** In this case, concerning the inner diameter of the tube for observation, the inner diameter of the tube pipe is 2 to 6 mm. In the case where the inner diameter of the tube is smaller than 2 mm, it is impossible to create a mushroom when the opening area necessary for observation is ensured. Therefore, the life of the tuyere is short. In the case where the inner diameter of the tube is larger than 6 mm, the flow rate of gas is increased and the cost is raised, which is not economical.

**[0028]** Next, explanations will be made into a case in which the twin tube tuyere of the present invention is adopted.

**[0029]** According to the sixth item of the present invention, electromagnetic waves are detected which are emitted from an interface formed between the molten iron surface at the forward end of the tube and the bubbles of gas which has been blown into the tuyere. In this case, it is necessary to control the ratio of opening at the forward end of the inner tube by the composition and flow rate of gas in the inner and the outer tube so that an intensity of the electromagnetic waves emitted from the interface can be sufficiently high for the intensity required by the method of observation. Therefore, the ratio of opening is detected by the change in the back pressure of gas and the result of observation conducted by an image fiber. According to the thus detected ratio of opening, the flow rate and/or composition of gas in the inner and the outer tube is changed so as to change the size of the mushroom. In this way, the ratio of opening necessary for observation is kept.

**[0030]** The seventh item of the present invention is a specific control method of the above item 6 of the present invention. According to the seventh item of the present invention, when the cooling capacity of the outer tube is controlled according to the temperature and composition of molten iron, the ratio of opening of the tuyere is kept to be a value higher than the critical value necessary for observation at all times. When the gas flow rate and/or gas composition which are supplied through each of the tuyere, inert gas and oxidizing gas of the outer tube is changed according to the mushroom size which is estimated according to the temperature and composition of molten iron, the ratio (%) of opening of the tube is kept in a range not less than $\alpha$ (%) and not more than 95%.

$$\alpha = 850/r^2 \tag{5}$$

where r is an inner diameter (mm) of the inner tube. Since it is preferable that r is not less than 3 mm, $\alpha$ is set at a value lower than 95%. Further, it is preferable that inert gas is supplied into the inner tube at all times. In this case, the ratio of opening is defined as a value (%) which is obtained when an area of the opening region at the forward end of the tube not covered with the mushroom is divided by a cross-sectional area of the tuyere.

**[0031]** The critical value of the ratio of opening, in the case where the intensity of electromagnetic waves is high such as a case in which the temperature is observed, is different from the critical value of the ratio of opening, in the case where the intensity of electromagnetic waves is low such as a case of light emitted by a laser used for component analysis. Further, the critical value of the ratio of opening is different according to the inner diameter and the length of the tube. In general, when consideration is given to the thickness of refractories of a large-scale converter, the length of the tube is approximately 1 to 2 m. In this case, the area for observation not less than 6 mm$^2$ is required, which is experimentally known. This knowledge is organized into Equation (5). In the tube, the inner diameter of which is r (mm), in order to provide an area R mm$^2$ for observation at the forward end of the tube, the ratio of opening must be a value not less than $\alpha$ calculated by Equation (6).

$$\alpha = R/(\pi \times (r/2)^2) \times 100 = 127 \times R/r^2 \ (\%) \tag{6}$$

**[0032]** In this case, when a value not less than 6 mm$^2$ is substituted into R, Equation (5) can be obtained. In the case where the ratio of opening is lower than $\alpha$, the accuracy of observation is deteriorated because the area of the opening at the forward end of the tube is small. In the case where the ratio of opening is higher than 95%, since the size of the mushroom created at the forward end of the tube is too small, it is impossible to protect the tuyere. Therefore, the life of the tuyere is short. Fig. 3 is a view showing an example of the accuracy of measurement of temperature by radiation in which an image fiber, the inner diameter of which was 10 mm, was used. The accuracy of the vertical axis corresponds to 2σ (σ is a standard deviation) of the measured temperature. Due to the foregoing, it can be understood that the temperature can be accurately observed when the ratio of opening is not less than 8.5% (corresponding to α in Equation (5)). However, when the ratio of opening is lower than 8.5%, the visual field is decreased due to blocking by the tuyere. Therefore, the accuracy of observation is deteriorated. On the contrary, when the ratio of opening is higher than 95%, the ratio of opening is so high that the mushroom cannot be sufficiently created, and the tuyere is damaged by fusion.

**[0033]** The present invention has been accomplished according to the new knowledge that the size of the mushroom created at the forward end of the tube, which is closely related to the opening area of the tuyere for observation, is more affected by the outer tube gas than by the inner tube gas. Accordingly, in order to control the ratio of opening of the tube, the flow rate and/or composition of the outer tube is controlled. An example of the tuyere cooling gas of the outer tube is LPG. Examples of the inner gas are Ar, nitrogen and carbon monoxide gas. Examples of oxidizing gas are oxygen, air and carbon dioxide gas. Specifically, in order to make the ratio of opening to be higher than α, one of the following actions (1) to (4) is executed so as to raise the temperature of the forward end of the outer tube of the tuyere, so that the mushroom is melted. In this case, the inner tube is filled with inert gas at all times. Therefore, no problems are caused in the measurement of electromagnetic waves.

(1) The flow rate of inert gas is decreased.
(2) Oxidizing gas is mixed with inert gas.
(3) In the mixed gas in which inert gas and oxidizing gas are mixed with each other, while the total flow rate is being kept constant, the mixing ratio of oxidizing gas is increased, or while the flow rate of inert gas is being kept constant, the flow rate of oxidizing gas is increased.
(4) Only oxidizing gas is blown into the tuyere.

**[0034]** On the contrary, when the ratio of opening is made to be not more than 95%, at least one of the following actions (1) to (3) is executed so as to decrease the temperature at the forward end of the outer tube of the tuyere, so that the mushroom is created and the tuyere is protected. In this case, the inner tube is filled with inert gas at all times. Therefore, no problems are caused in the measurement of electromagnetic waves.

(1) The flow rate of inert gas is increased.
(2) Tuyere cooling gas is mixed with inert gas.
(3) In the mixed gas in which inert gas and tuyere cooling gas are mixed with each other, while the total flow rate is being kept constant, the mixing ratio of tuyere cooling gas is increased, or while the flow rate of inert gas is being kept constant, the flow rate of tuyere cooling gas is increased.

**[0035]** Since the behavior of creation of the mushroom is greatly affected by the composition and temperature of molten iron, it is necessary to control according to the composition and temperature of molten iron. It is most reasonable that the results of measurement of the composition and temperature of molten iron, which have been measured according to the electromagnetic waves obtained through the tuyere for observation, are used. However, it is possible to estimate the carbon concentration by the method in which the carbon concentration is calculated from the quantity of oxygen to be supplied and the decarbonizing oxygen efficiency, which is experimentally known, on the basis of the carbon concentration of charged molten iron. Also, it is possible to estimate the carbon concentration by the method in which the carbon concentration is estimated from the results of exhaust gas analysis or direct sampling of molten iron. The carbon concentration can be estimated by one of the above methods or the combination of the above methods. Further, the temperature can be estimated by the method in which the temperature is calculated from the temperature rising efficiency, which is experimentally known, on the basis of the temperature of the charged molten iron.

**[0036]** Specifically, according to the relation shown in Fig. 1, diameter M of the mushroom created at the forward end of the tube is controlled as M/r. Diameter M of the mushroom can be estimated in such a manner that diameter M of the mushroom is calculated by the heat balance of each of the following items (1) to (4).

(1) Cooling index (v1) by sensible heat of outer tube gas: function of specific heat of outer tube gas
(2) Cooling index (v2) by latent heat of outer tube gas: function of reaction heat of outer tube gas
(3) Cooling index (v3) by sensible heat of inner tube gas: function of specific heat of inner tube gas
(4) Heat receiving index (k) from molten iron of mushroom

**[0037]** When the mushroom is assumed to be a hemisphere, the following heat balance is established.

$$k = M^2 \times (T - Ts) \times Q^n = a + b \times (v1 + v2 + v3) \tag{7}$$

**[0038]** In the above Equation (7), a, b and n are constants, Q is a flow rate of total gas ($Nm^3/h/t$), T is a temperature (°C) of molten iron, and Ts is a solid line temperature (°C) determined by the composition of the molten iron. In this case, v1, v2 and v3 can be calculated when a ratio of contribution to the creation of the mushroom is determined by an experiment according to the physical property and reaction heat of the used gas. Ts can be found according to the phase diagram. When these are put into Equation (7) and the constants are determined so that they can agree with the mushroom diameter obtained by an experiment. In this way, it is possible to obtain a formula for estimating the mushroom diameter when an actual device is used.

**[0039]** The eighth item of the present invention provides a method of opening a tuyere by supplying oxidizing gas from the inner tube when the tuyere is blocked. That is, the present invention provides a method of observing the inside of a molten metal refining furnace, further comprising the steps of: supplying a mixed gas, in which an inert gas and an oxidizing gas are mixed, or containing only an oxidizing gas, from the inner tube so as to increase the ratio of opening in a tuyere opening period in the case where the ratio of opening of the tube is lower than $\alpha$ (%) in Equation (5); and supplying only inert gas from the inner tube in a period except for the tuyere opening period. In this case, the tuyere opening period is defined as a period from the point in time at which the ratio of opening becomes lower than $\alpha$ so that the action to open the opening is executed to the point in time at which the ratio of opening becomes a value not less than 95%. According to the knowledge of the inventors, in the case where the ratio of opening cannot be measured because the temperature of the forward end of the tube is high, it can be judged that the tuyere has been opened when the temperature of the forward end of the tube is raised to a temperature not lower than 1800°C, and the tuyere opening period can be ended. Concerning the action to open the opening, one of the following actions (1) and (2) or both of the following actions (1) and (2) may be executed, so that the temperature of the forward end of the tube is raised so as to melt the mushroom.

(1) The inner tube is filled with mixed gas in which inert gas and oxidizing gas are mixed with each other. While the total flow rate is being kept constant, the mixing ratio of oxidizing gas is increased. Alternatively, while the flow rate of the inert gas is being kept constant, the flow rate of oxidizing gas is increased.
(2) Only oxidizing gas is blown from the inner tube.

**[0040]** In this case, the reason why the action to open the opening is conducted in the inner tube is that it is possible to increase the flow rate of gas so that opening can be positively conducted in a short period of time. Specifically, as can be seen in Fig. 1, when M/r is not more than 2, K/r becomes not less than 1. The fact that K/r is 1 means that the opening diameter and the tuyere diameter coincide with each other. That is, the tuyere is completely open. Accordingly, in the case where the tuyere is blocked, the action is taken by which M/r becomes not more than 2, so that the tuyere can be opened since K/r is made to be not less than 1. Estimation of diameter M of the mushroom can be calculated by the heat balance described in each of the following items.

(1) Cooling index (v1') by sensible heat of outer tube gas: function of specific heat of outer tube gas
(2) Cooling index (v2') by latent heat of outer tube gas: function of reaction heat of outer tube gas
(3) Cooling index (v3') by sensible heat of inner tube gas: function of specific heat of inner tube gas
(4) Cooling index (v4') by latent heat of inner tube gas: function of reaction heat of inner tube gas
(5) Heat receiving index (k') from molten iron of mushroom

**[0041]** When the mushroom is assumed to be a hemisphere, the following heat balance is established.

$$k' = M^2 \times (T - Ts) \times Q^n = a' + b' \times (v1' + v2' + v3' + v4') \tag{8}$$

**[0042]** In the above Equation (8), a', b' and n are constants, Q is a flow rate of total gas ($Nm^3/h/t$), T is a temperature (°C) of molten iron, and Ts is a solid line temperature (°C) determined by the composition of molten iron. In this case, v1' v2', v3' and v4' can be calculated when a ratio of contribution to the creation of the mushroom is determined by an experiment according to the physical property and reaction heat of the used gas. Ts can be found according to the phase diagram. When these are put into Equation (8) and the constants are determined so that they can agree with the mushroom diameter obtained by an experiment. It is possible to obtain a equation of estimation of the mushroom diameter when an actual device is used. According to the investigation made by the present inventors, the following were found. The ratio of contribution of the heating value by inner tube oxygen to the diameter of the mushroom was only 3%, and the ratio of contribution of the sensible heat of inner tube gas to the diameter of the mushroom was only 30%.

**[0043]** The ninth item of the present invention shows another method of opening used when the tuyere is blocked. The method of observing the inside of a molten metal refining furnace comprises the steps of: supplying inert gas from the inner tube at all times; supplying a mixed gas, in which inert gas and oxidizing gas are mixed, or only supplying oxidizing gas, from the outer tube, so as to increase the ratio of opening in the tuyere opening period in the case where the ratio of opening of the tuyere is lower than $\alpha$ (%) shown in Equation (5); and supplying tuyere cooling gas or inert gas alone from the outer tube or supplying mixed gas, in which tuyere cooling gas and inert gas are mixed with each other, from the outer tube in a period except for the tuyere opening period. Concerning the action to open the tuyere, one of the following actions (1) to (3) is executed, so that the temperature at the forward end of the tuyere is raised and the mushroom is melted.

(1) Oxygen gas is mixed with inert gas in the outer tube.
(2) Tuyere cooling gas in the outer tube is changed over to oxidizing gas.
(3) Only oxidizing gas is supplied to the outer tube.

**[0044]** The reason why inert gas is supplied to the inner tube at all times and the opening is made by outer tube gas is described as follows. For example, when light of short wave-length, which is emitted by carbon or phosphorus by the action of the laser, is observed, the emitted light is greatly absorbed by oxygen in the tube. Therefore, in order to transmit the emitted light without being attenuated, it is necessary to fill the inner tube with an inert gas at all times. According to the investigation made by the present inventors, it was found that even when an inert gas is supplied from the inner tube at all times, the tuyere can be opened when the composition of gas supplied from the outer tube is controlled.

**[0045]** Specifically, in the same manner as that of the invention described in the above item (8), according to the relation shown in Fig. 1, diameter M of the mushroom created at the forward end of the tuyere is controlled as M/r, which is made to be not more than 2. Diameter M of the mushroom can be estimated in such a manner that diameter M of the mushroom is calculated by the heat balance of each of the following items (1) to (4).

(1) Cooling index (v1") by sensible heat of outer tube gas: function of specific heat of outer tube gas
(2) Cooling index (v2") by latent heat of outer tube gas: function of reaction heat of outer tube gas
(3) Cooling index (v3") by sensible heat of inner tube gas: function of specific heat of inner tube gas
(4) Heat receiving index (k") from molten iron of mushroom

**[0046]** When the mushroom is assumed to be a hemisphere, the following heat balance is established.

$$k'' = M^2 \times (T - Ts) \times Q^n = a'' + b'' \times (v1'' + v2'' + v3'') \tag{9}$$

**[0047]** In the above Equation (9), a", b" and n are constants, Q is a flow rate of total gas ($Nm^3/h/t$), T is a temperature (°C) of molten iron, and Ts is a solid line temperature (°C) determined by the composition of molten iron. In this case, v1", v2" and v3" can be calculated when a ratio of contribution to the creation of the mushroom is determined by an experiment according to the physical properties and the reaction heat of the gas used. Ts can be found according to the phase diagram. When these are put into Equation (9) and the constants are determined so that they can agree with the mushroom diameter obtained by an experiment, it is possible to obtain a formula of estimation of the mushroom diameter when an actual device is used. According to the investigation made by the present inventors, the following were found. The ratio of contribution of the heating value by outer tube oxygen to the diameter of the mushroom was 75%, and the ratio of contribution of the sensible heat of outer tube gas to the diameter of the mushroom was 100%.

**[0048]** The tenth item of the present invention provides a tuyere for executing a method of observing the inside of a molten metal refining furnace of the present invention. The reason why a double tube tuyere for observing the temperature is adopted is that the composition and flow rate of gas in the inner and the outer tube are independently controlled. In this double tube tuyere, the ratio of opening at the forward end of the inner tube tuyere is detected, and the flow rate and/or composition of gas in the inner and the outer tube is controlled according to the information obtained by the detection. In order to enable the above operation, the tuyere is composed as shown in Fig. 5. The tuyere is composed of a concentric double tube structure including an inner tube 1 and an outer tube 2 penetrating refractories of a refining furnace. In this structure, the inner tube 1 and the outer tube 2 are independent from each other.
The flow rate and/or composition of gas can be independently controlled via the inner tube gas supply pipe 9 and the outer tube gas supply pipe 10 which are independently connected with the control unit to control the composition and flow rate of gas. In this case, the inner diameter of the tuyere for observation is prescribed to be 5 to 20 mm. In the case where the inner diameter of the tuyere for observation is smaller than 5 mm, it is impossible to create a mushroom

when an opening area necessary for observation is ensured, and the life of the tuyere is shortened. In the case where the inner diameter of the tuyere for observation is larger than 20 mm, the flow rate of gas is increased, and the cost is raised, which is not economical.

EXAMPLE

**[0049]** In the example, a top-blow oxygen converter, the capacity of which was 3 ton, was used. A single tube tuyere, the diameter of which was 4 mm, which was arranged at the furnace bottom, was used as the tuyere for observation. (In this case, $\alpha$ in Formula (1) is 47.8.) Nitrogen was supplied alone from the tuyere. Alternatively, a mixed gas in which Ar and oxygen were mixed with each other was supplied. Molten iron of [C]: 4.2%, [Mn]: 0.16%, [Si]: 0.21% and [P]: 0.085% was charged into the furnace, and oxygen was supplied to the furnace for decarbonization. When the supply of oxygen was started, the temperature of molten iron was 1315°C. In this case, % means mass percent, which is the same in the following descriptions. The composition at the time of blowout was [C]: 0.04%, [Mn]: 0.07%, [Si]: 0.01% and [P]: 0.017%, and the temperature was 1657°C. The measurement of temperature with radiation was executed by an image fiber through the tuyere for observation. At the same time, laser beams were irradiated via the tuyere concerned, and light emitted from carbon was observed so as to measure the carbon concentration. The ratio of the opening was measured by an image obtained in the image fiber observation. According to a change in the ratio of opening, the composition and flow rate of gas were controlled.

EXAMPLE 1

**[0050]** Under the condition shown on Table 1, the flow rate of Ar was controlled for each carbon concentration and temperature. As a result, it was possible to make an accurate measurement of temperature and an analysis of carbon concentration all through the refining period.

Table 1

| Carbon (%) | Temperature (°C) | Inner tube: $Nm^3/s$ | | Ratio of opening % | Time of measurement $2\sigma$ |
|---|---|---|---|---|---|
| | | Ar | Oxygen | | |
| 4 - 2.5 | 1350 - 1425 | 0.0035 - 0.0050 | 0 | 68 - 76 | 2.5 - 3.1 |
| 2.5 - 1.0 | 1425 - 1525 | 0.0036 - 0.0050 | 0 | 75 - 88 | 2.2 - 3.3 |
| 1.0 - 0.5 | 1525 - 1600 | 0.0027 - 0.0036 | 0 | 79 - 90 | 1.9 - 2.9 |
| 0.5 - 0.05 | 1600 - 1650 | 0.0024 - 0.0027 | 0 | 60 - 72 | 2.1 - 3.1 |

EXAMPLE 2

**[0051]** The temperature rising rate was low at the beginning. Therefore, the tuyere was blocked at the point of time of [C] = about 0.05% and temperature = 1600°C (as shown by (1) on Table 2). Therefore, the composition and flow rate of gas were controlled under the condition shown by (2) on Table 2. As a result, the tuyere was opened again. After that, it was possible to make an accurate measurement of temperature and an analysis of carbon concentration all through the refining period.

Table 2

| | Carbon (%) | Temperature (°C) | Inner tube: $Nm^3/s$ | | Ratio of opening % | Time of measurement $2\sigma$ |
|---|---|---|---|---|---|---|
| | | | Ar | Oxygen | | |
| (1) Comparative Example | 0.05 | 1600 | 0.0024 | 0 | 42 -0 | Impossibility of measurement |
| (2) Present Invention | 0.05 | 1600 | 0.0024 | 0.00012 | 84 - 93 | 2.2 - 3.5 |

COMPARATIVE EXAMPLE 1

**[0052]** In Comparative Example 1, operation was performed under the condition shown on Table 3 while the flow rate of Ar was kept constant irrespective of the carbon concentration and temperature. As a result, the ratio of opening was decreased at the end of refining, and it became impossible to make observations.

Table 3

| Carbon (%) | Temperature (°C) | Inner tube: $Nm^3/s$ | | Ratio of opening % | Time of measurement 2σ |
|---|---|---|---|---|---|
| | | Ar | Oxygen | | |
| 4 - 2.5 | 1350 - 1425 | 0.0050 | 0 | 78 - 98 | 2.4 - 3.3 |
| 2.5 - 1.0 | 1425 - 1525 | 0.0050 | 0 | 68 - 82 | 2.9 - 3.6 |
| 1.0 - 0.5 | 1525 - 1600 | 0.0050 | 0 | 43 - 61 | 4.8 - 8.5 |
| 0.5 - 0.05 | 1600 - 1650 | 0.0050 | 0 | 39 - 0 | Impossibility of measurement |

EXAMPLE 3

**[0053]** In Example 3, a top-blow oxygen converter, the capacity of which was 3 ton, was used. A double tube tuyere, the inner diameter of the inner tube tuyere of which was 10 to 15 mm and the interval between the inner and the outer tube of which was 1 mm, which was arranged at the furnace bottom, was used as the tuyere for observation. Nitrogen and/or oxygen was supplied from the inner tube, and one of nitrogen, oxygen and LPG or not less than two of them were supplied from the outer tube. Molten iron of [C]: 4.2%, [Mn]: 0.16%, [Si]: 0.21% and [P]: 0.085% was charged into the furnace, and oxygen was supplied to the furnace for decarbonization. When the supply of oxygen was started, the temperature of molten iron was 1315°C. In this case, % means mass percent. The composition at the time of blowout was [C]: 0.04%, [Mn]: 0.07%, [Si]: 0.01% and [P]: 0.017%, and the temperature was 1657°C. The measurement of temperature with radiation was executed by an image fiber through the tuyere for observation. At the same time, laser beams were irradiated via the inner tube, and light emitted from carbon was observed so as to measure the carbon concentration. The ratio of opening was measured by an image obtained in the image fiber observation in the inner tube. According to a change in the ratio of opening, the composition and flow rate of gas in the inner and outer tube were changed so as to control the size of the mushroom at the forward end of the tuyere of the inner tube.

**[0054]** A double tube tuyere, the inner diameter of the inner tube tuyere of which was 15 mm, was used. Under the condition shown on Table 4, according to a change in the measured ratio of opening, while the mushroom size was being estimated for each carbon concentration and temperature, the flow rate of nitrogen in the outer tube was appropriately controlled. As a result, it was possible to make an accurate measurement of temperature (showing $2 \times \sigma$ on the table) and an analysis of carbon concentration all through the refining period. In-this connection, the flow rate of the inner tube was kept constant at a value 1.5 times as high as the critical flow rate. In this connection, $\alpha$ in Formula (5) is 3.8% because the inner diameter is 15 mm.

Table 4

| Carbon (%) | Temperature (°C) | Inner tube: $Nm^3/h/t$ Nitrogen | Inner tube: $Nm^3/h/t$ Oxygen | Outer tube: $Nm^3/h/t$ Nitrogen | Outer tube: $Nm^3/h/t$ Oxygen | Ratio of opening % | Time of measurement 2σ |
|---|---|---|---|---|---|---|---|
| 4 - 2.5 | 1350 - 1425 | 0.098 | 0 | 0.08 - 0.02 | 0 | 32 - 68 | 2.6 - 3.0 |
| 2.5 - 1.0 | 1425 - 1525 | 0.098 | 0 | 0.02 - 0.001 | 0 | 39 - 71 | 2.6 - 2.7 |
| 1.0 - 0.5 | 1525 - 1600 | 0.098 | 0 | 0.001 - 0.02 | 0 | 25 - 56 | 2.7 - 3.5 |
| 0.5 - 0.05 | 1600 - 1650 | 0.098 | 0 | 0.02 - 0.03 | 0 | 18 - 38 | 3.1 - 3.5 |

**[0055]** In this case, the critical flow rate (F: $Nm^3/h$) was calculated by the following formula.

$$F = 5.5 \times (\rho_g/\rho_1)^{-5/8} \times (1 + H/1.48)^{3/8} \times (r/1000)^{5/2} \quad (10)$$

**[0056]** In the above formula, $\rho_g$ is gas density (kg/m$^3$), $\rho_1$ is molten iron density (kg/m$^3$), and H is a bath depth (m).

EXAMPLE 4

**[0057]** In Example 4, the precondition was set to be the same as that of Example 3, and a double tube tuyere, the inner diameter of the inner tube tuyere of which was 10 mm, was used. Under the conditions shown on Table 5, according to the change of the ratio of opening that was measured, the composition and flow rate of outer tube gas were appropriately controlled while the mushroom size was being estimated for each carbon concentration and temperature. As a result, it was possible to make an accurate measurement of temperature and analysis of carbon concentration through all the refining period. In this connection, the inner tube flow rate was set at a constant value which was 1.5 times as high as the critical flow rate. In Formula (5), $\alpha$ was 8.5% because the inner diameter was 10 mm.

Table 5

| Carbon (%) | Temperature (°C) | Inner tube: $Nm^3/h/t$ | | Outer tube: $Nm^3/h/t$ | | | Ratio of opening % | Time of measurement 2σ |
|---|---|---|---|---|---|---|---|---|
| | | Nitrogen | Oxygen | Nitrogen | Oxygen | LPG | | |
| 4 - 2.5 | 1350 - 1425 | 0.036 | 0 | 0.01 | 0 - 0.0011 | 0 | 34 - 65 | 2.9 - 3.5 |
| 2.5 - 1.0 | 1425 - 1525 | 0.036 | 0 | 0.01 | 0.0011 - 0 | 0 - 0.0075 | 38 - 71 | 3.3 - 3.6 |
| 1.0 - 0.5 | 1525 - 1600 | 0.036 | 0 | 0.01 | 0 | 0.0075 - 0.015 | 35 - 68 | 2.8 - 3.6 |
| 0.5 - 0.05 | 1600 - 1650 | 0.036 | 0 | 0.01 | 0 | 0.015 - 0.02 | 28 - 51 | 3.3 - 3.9 |

EXAMPLE 5

**[0058]** In Example 5, the precondition was set to be the same as that of Example 3, and a double tube tuyere, the inner diameter of the inner tube tuyere of which was 10 mm, was used. However, the temperature rising rate was low at the beginning, and the tuyere was blocked at the point of time of [C] = about 2.4% and temperature = about 1400°C (shown by (1) on Table 6). Therefore, the composition and flow rate of outer tube gas were changed under the condition of (1) or (2) shown on Table 6, and the size of the mushroom at the forward end of the inner tube tuyere was controlled. As a result, the tuyere was opened again. As a result, it was possible to make an accurate measurement of temperature and an analysis of carbon concentration all through the refining period.

Table 6

| | Carbon (%) | Temperature (°C) | Inner tube: $Nm^3/h/t$ | | Outer tube: $Nm^3/h/t$ | | Ratio of opening % | Time of measurement $2\sigma$ |
|---|---|---|---|---|---|---|---|---|
| | | | Nitrogen | Oxygen | Nitrogen | Oxygen | | |
| (1) Comparative Example | 2.4 | 1400 | | 0 | 0.01 | 0 | 0 | Impossibility of measurement |
| (2) Present Invention | 2.4 | 1400 | 0.036 | 0 | 0.01 | 0.0018 | 82 - 93 | 2.6 - 3.4 |
| (3) Present Invention | 2.4 | 1400 | 0.036 | 0.6 | 0.01 | 0 | 84 - 91 | 2.8 - 3.3 |

COMPARATIVE EXAMPLE 2

**[0059]** In Comparative Example 2, a double tube tuyere, the inner diameter of the inner tube tuyere of which was 15 mm, was used, and operation was performed under the condition shown on Table 7 wherein the flow rate of nitrogen in the outer tube was kept constant irrespective of the carbon concentration and temperature. As a result, in the middle of refining, the ratio of opening was decreased, so that it became impossible to make observations. Further, at the end of refining, the mushroom was melted and the tuyere for observation was damaged by fusion.

Table 7

| Carbon (%) | Temperature (°C) | Inner tube: $Nm^3/h/t$ | | Outer tube: $Nm^3/h/t$ | | Ratio of opening % | Time of measurement $2\sigma$ |
|---|---|---|---|---|---|---|---|
| | | Nitrogen | Oxygen | Nitrogen | Oxygen | | |
| 4 - 2.5 | 1350 - 1425 | | 0 | 0.02 | 0 | 22 - 0 | 5.2 → Impossibility of measurement |
| 2.5 - 1.0 | 1425 - 1525 | 0.098 | 0 | 0.02 | 0 | 0 - 33 | Impossibility of measurement → 7.2 |
| 1.0 - 0.5 | 1525 - 1600 | 0.098 | 0 | 0.02 | 0 | 48 - 81 | 3.8 - 6.9 |
| 0.5 - 0.05 | 1600 - 1650 | 0.098 | 0 | 0.02 | 0 | 88 - 98 | Fusion of tuyere |

INDUSTRIAL POSSIBILITY

**[0060]** According to the present invention, it is possible to stably observe the temperature and/or composition of molten iron in a refining furnace by opening a tuyere for observation, at all times, according to the state of refining.

## Claims

1. A method of observing the inside of a molten metal refining furnace comprising the steps of: using a single tube tuyere for observing the temperature and/or composition of molten iron in the refining furnace via a tube penetrating refractories of a furnace wall and/or furnace bottom of the molten iron refining furnace by detecting electromagnetic waves radiated from molten metal at a forward end of the tube under a non-contact state; and using an inert gas or an oxidizing gas alone or mixed with each other according to the opening condition of the forward end of the tube.

2. A method of observing the inside of a molten metal refining furnace according to claim 1, wherein a mixed gas of an inert gas with an oxidizing gas or only an oxidizing gas is supplied in the case where the ratio (%) of opening of the tube is not higher than $\alpha$ which is calculated by the inner diameter r (mm) of the tube according to Equation (1), and only inert gas is supplied in the case where the ratio of opening is higher than $\alpha$.

$$\alpha = 765/r^2 \qquad (1)$$

3. A method of observing the inside of a molten metal refining furnace comprising the steps of: using a single tube tuyere for observing the temperature and/or composition of molten iron in the refining furnace via a tube penetrating refractories of a furnace wall and/or furnace bottom of the molten iron refining furnace by detecting electromagnetic waves radiated from molten metal at a forward end of the tube under a non-contact state; and controlling a flow rate of an inert gas according to the opening condition of the forward end of the tube.

4. A method of observing the inside of a molten metal refining furnace according to claim 3, wherein a flow rate of inert gas is controlled according to the temperature and composition of molten iron so that the ratio (%) of opening of the single tube can be not less than $\alpha$, which is calculated from the inner diameter r (mm) of the tube according to Equation (1), and not more than 95%.

5. A tuyere for observing the inside of a molten metal refining furnace having a single tube for observing the temperature and/or composition of molten iron in the refining furnace via a tube penetrating refractories of a furnace wall and/or furnace bottom of the molten iron refining furnace by detecting electromagnetic waves radiated from molten metal at a forward end of the tube under a non-contact state, the tuyere for observing the inside of a molten metal refining furnace comprising a control function by which an inert gas or an oxidizing gas can be used alone, or mixed with each other, according to a state of opening of the forward end of the tuyere tube, the inner diameter of which is 2 to 6 mm.

6. A method of observing the inside of a molten metal refining furnace in which the temperature and/or composition of molten iron in the molten iron refining furnace is observed via a tube penetrating refractories of a furnace wall and/or furnace bottom of the molten metal refining furnace in a non-contact state by detecting electromagnetic waves radiated from molten iron at the forward end of the tube, the method of observing the inside of the molten metal refining furnace comprising the steps of: using a twin tube tuyere; detecting a ratio of opening of the forward end of the inner tube tuyere; and controlling a size of a mushroom at the forward end of tuyere by changing gas flow rate and/or gas composition of which is supplied through the inner and the outer tube according to a change in the ratio of opening so as to keep the ratio of opening necessary for observation.

7. A method of observing the inside of a molten metal refining furnace according to claim 6, further comprising the steps of: estimating the size of the mushroom at the forward end of tuyere according to the temperature and composition of molten iron; and controlling the size of the mushroom at the forward end of tuyere by changing the gas flow rate of and/or gas composition of LPG inert gas, an inert gas and an oxidizing gas which are supplied through the outer tube according to the result of the estimation so as to keep the ratio (%) of opening of the inner tube in a range from not less than $\alpha$ (%), which is calculated by Equation (5), to not more than 95%.

$$\alpha = 850/r^2 \quad (5)$$

where r is an inner diameter (mm) of the inner tube.

**8.** A method of observing the inside of a molten metal refining furnace according to claim 6, further comprising the steps of: supplying mixed gas, in which an inert gas and an oxidizing gas are mixed, or only an oxidizing gas, from the inner tube so as to increase the ratio of opening in a tube opening period in the case where the ratio of opening of the inner tube is lower than $\alpha$ (%) in Equation (5); and supplying only an inert gas from the inner tube in a period except for the tube opening period.

**9.** A method of observing the inside of a molten metal refining furnace according to one of claims 6 to 8, further comprising the steps of: supplying an inert gas from the inner tube at all times; supplying a mixed gas, in which an inert gas and an oxidizing gas are mixed with each other, or only an oxidizing gas from the outer tube so as to increase the ratio of opening of the inner tube in a tube opening period in the case where the ratio of opening of the inner tube is lower than $\alpha$ (%) in Equation (5); and supplying tuyere cooling gas or an inert gas alone through the outer tube or supplying a mixed gas, in which tuyere cooling gas and an inert gas are mixed, from the outer tube in a period except for the tube opening period.

**10.** A tuyere for observing the inside of a molten metal refining furnace which is double tube tuyere for observing the temperature and/or composition of molten iron in the refining furnace via a tube penetrating refractories of a furnace wall and/or furnace bottom of the molten iron refining furnace by detecting electromagnetic waves radiated from molten metal at a forward end of the tube under a non-contact state, the tuyere for observing the inside of a molten metal refining furnace comprising: a piping structure; and a control system capable of independently controlling a gas flow rate and/or gas composition which is supplied through each of the inner and the outer tube.

**11.** A tuyere for observing the inside of a molten metal refining furnace according to claim 10, wherein inner diameter r of the inner tube is 5 to 20 mm.

Fig.1

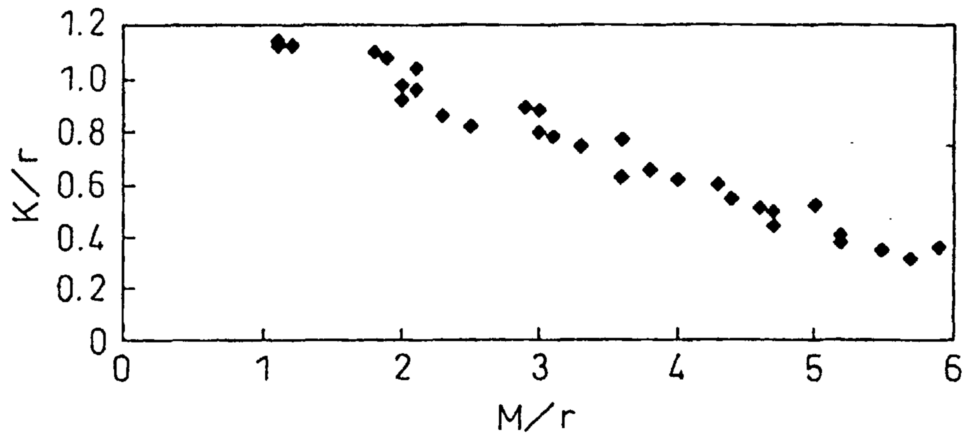

K/r
1.2
1.0
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
M/r

Fig.2

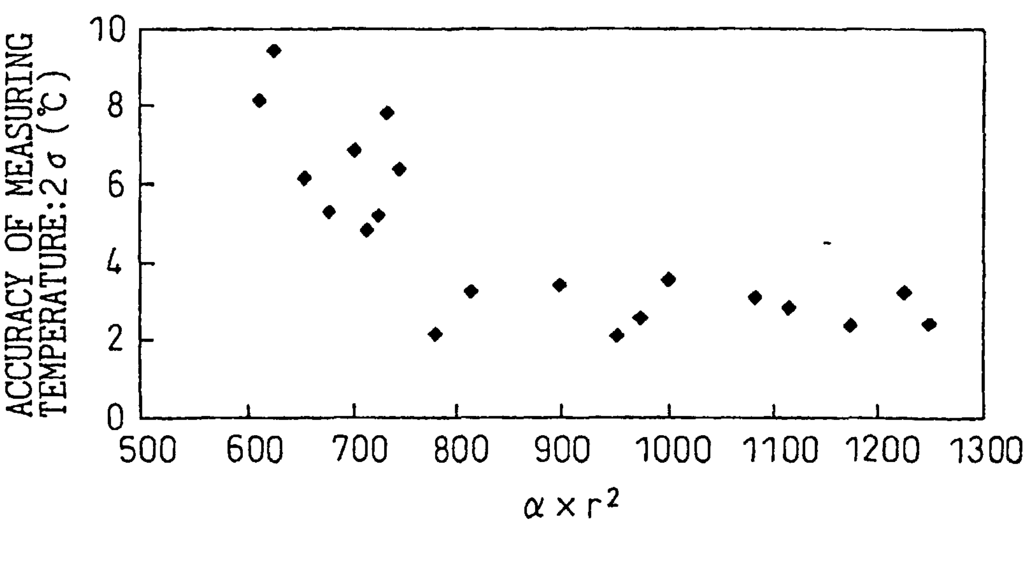

ACCURACY OF MEASURING TEMPERATURE:2σ (℃)
10
8
6
4
2
0
500
600
700
800
900
1000
1100
1200
1300
α × r²

Fig.3

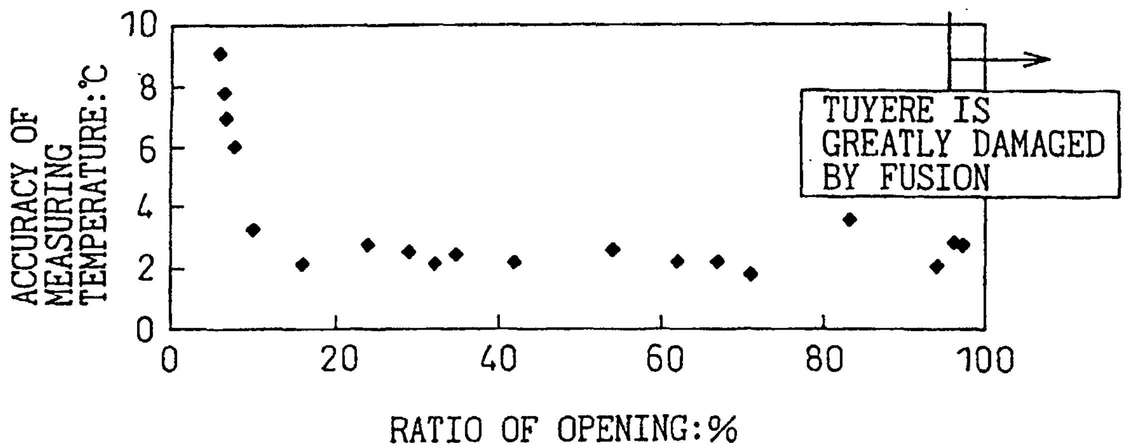

10
8
6
4
2
0
ACCURACY OF MEASURING TEMPERATURE:°C
0
20
40
60
80
100
RATIO OF OPENING:%
TUYERE IS GREATLY DAMAGED BY FUSION

Fig. 4

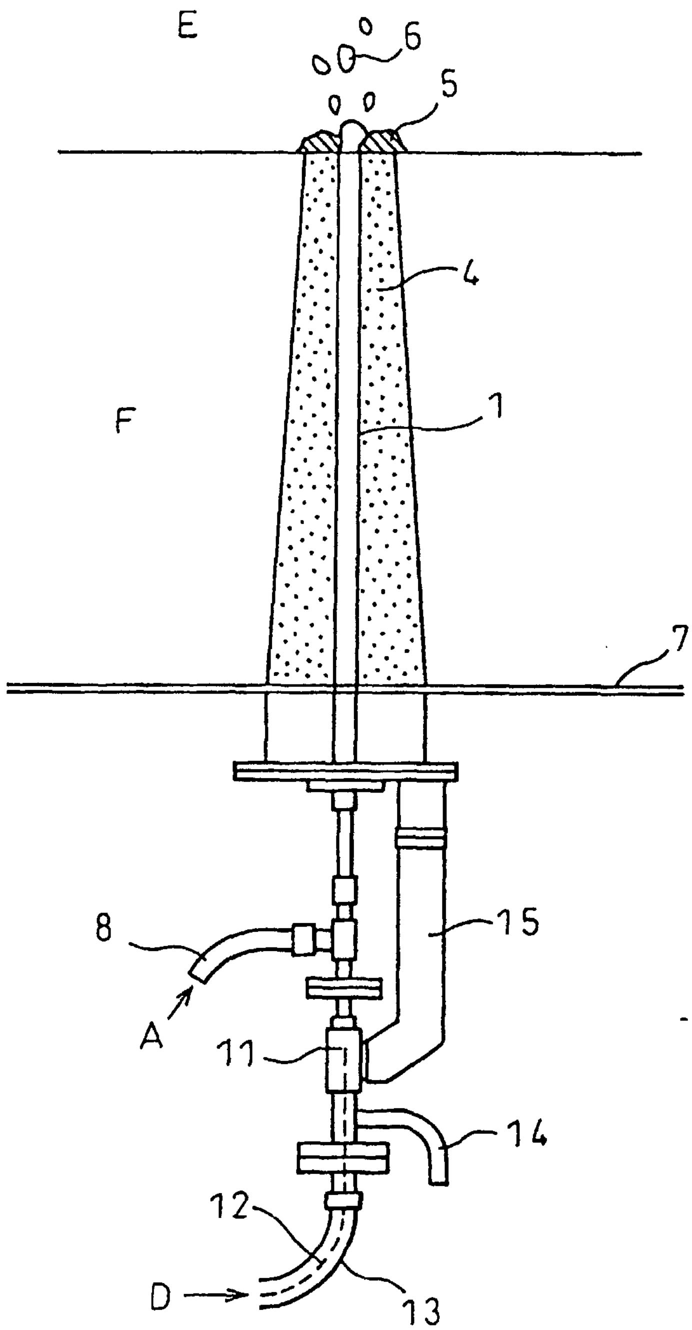
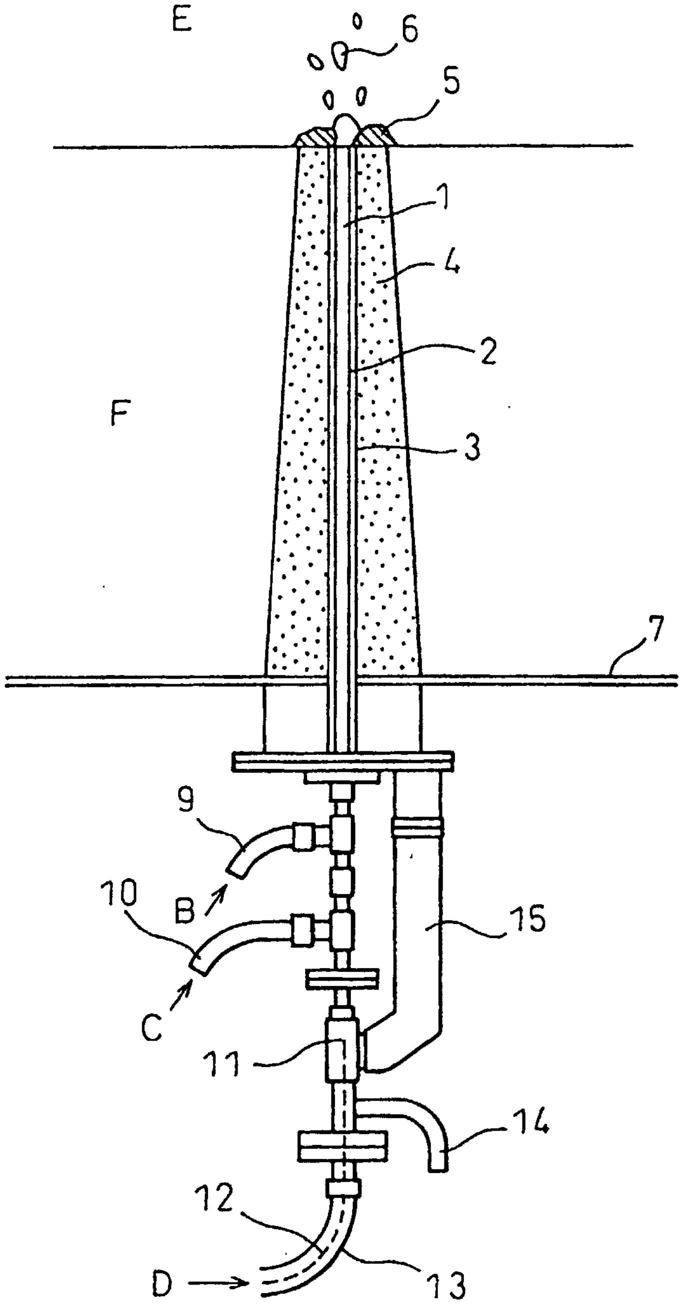


Fig.5



## DESCRIPTION OF THE REFERENCE NUMERALS

1 ... Single tube tuyere (Single tube)
2 ... Inner tube of twin (double) tube tuyere
3 ... Outer tube of twin (double) tube tuyere
4 ... Tuyere refractory
5 ... Mushroom
6 ... Babbles of gas
7 ... Furnace wall
8 ... Gas supply pipe (Single pipe)
9 ... Inner tube gas supply pipe
10 ... Outer tube gas supply pipe
11 ... Front end of image fiber
12 ... Image fiber
13 ... Flexible hose
14 ... Pipe end of cooling gas for image fiber
15 ... Jig
A ... Gas (Single pipe)
B ... Inner tube gas
C ... Outer tube gas
D ... Cooling gas for image fiber
E ... Molter iron
F ... Refining furnace refractory

## INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP01/04975

**A. CLASSIFICATION OF SUBJECT MATTER**
Int.Cl[7] C21C 5/48

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)
Int.Cl[7] C21C 5/48

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

| | | | |
|---|---|---|---|
| Jitsuyo Shinan Koho | 1926-1996 | Jitsuyo Shinan Toroku Koho | 1996-2001 |
| Kokai Jitsuyo Shinan Koho | 1971-2001 | Toroku Jitsuyo Shinan Koho | 1994-2001 |

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. |
|---|---|---|
| X | JP 8-165506 A (NKK Corporation), 25 June, 1996 (25.06.96), working example (Family: none) | 1-11 |
| X | JP 60-129628 A (Sumitomo Metal Industries, Ltd.), 10 July, 1985 (10.07.85), working example (Family: none) | 1-11 |

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| | |
|---|---|
| Date of the actual completion of the international search<br>27 August, 2001 (27.08.01) | Date of mailing of the international search report<br>11 September, 2001 (11.09.01) |
| Name and mailing address of the ISA/<br>Japanese Patent Office | Authorized officer |
| Facsimile No. | Telephone No. |

Form PCT/ISA/210 (second sheet) (July 1992)