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METHOD OF AUTOMATIC CONTROL AND ADJUSTMENT OF OXYGEN
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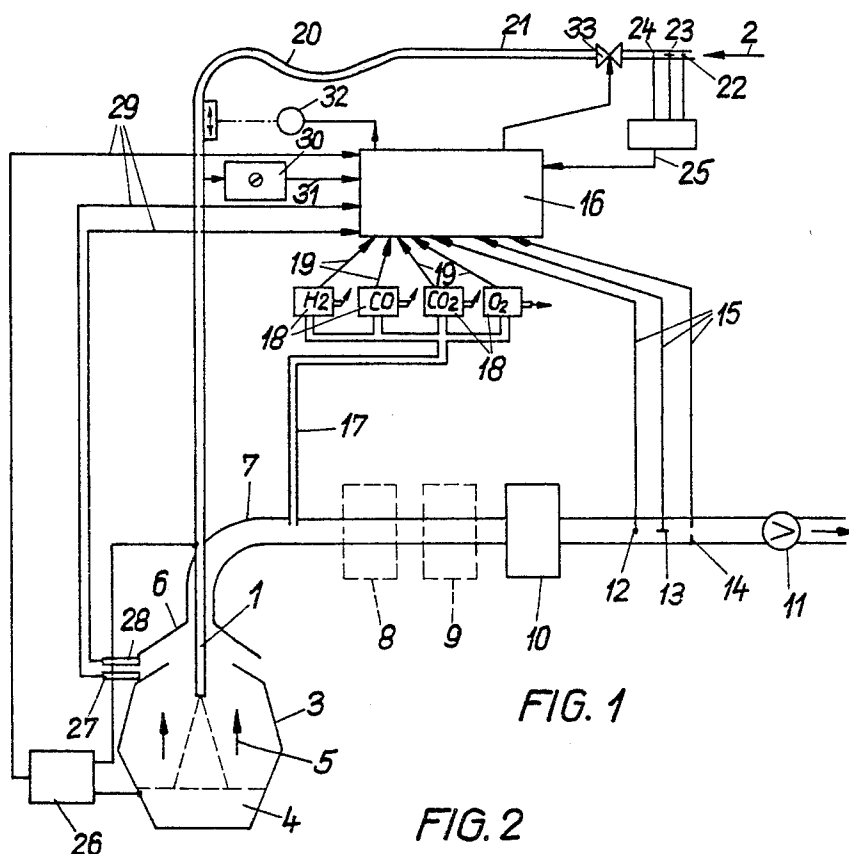
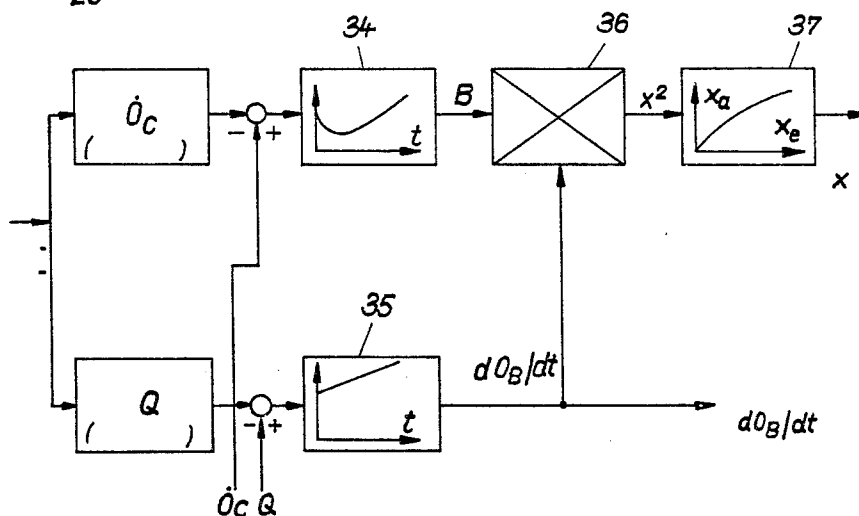


FIG. 1

FIG. 2



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METHOD OF AUTOMATIC CONTROL AND ADJUSTMENT OF OXYGEN BLOWING PROCESSES

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ABSTRACT OF THE DISCLOSURE

A method of automatically controlling and regulating the oxygen-blowing process by means of a blowing nozzle during the production of steel from pig iron by blowing of oxygen onto a metal-slag bath comprising the steps of feeding during the oxygen-blowing process two given values independent upon each other to an electronic computer, the first of the values representing a measure of the metallurgical course of the process, and the second of the values representing a measure of the flow of the pressurized oxygen or a measure of the amount or effect, of waste gas formed in a converter, and setting automatically the distance of the blowing nozzle from the surface of the bath and the flow of pressurized oxygen by the electronic computer.

The present invention relates to an oxygen blowing process for refining of liquid carbon-containing metal.

In the oxygen blowing process, the distance of the blowing nozzle from the bath and the flow of oxygen under pressure, the quantity of oxygen blown onto the metal bath in a time limit, are the most important control values for the metallurgical course of the process. The blower spacing and the stream of oxygen under pressure determine essentially the temperature and the composition of the gas upon impinging upon the surface of the bath and the depth of penetration of the blast jet into the surface of the bath and thus the metallurgical action of the blast jet. If, for instance, in case of a high blast pressure and short spacing of the blower nozzle from the bath, the blast jet penetrates through the slag into the metal, then the decarbonization of the bath and possibly even reduction of the slag is enhanced. If the blast jet cannot penetrate through the slag or can penetrate only slightly through it, then the oxygen of the jet is released predominantly to the slag and is combined there.

In the known methods, the spacing of the blower nozzle from the surface of the bath and the flow of oxygen under pressure are adjusted on the basis of empirical values and corrected manually in accordance with subjective impressions, of for instance the blast foreman or else in accordance with measured values, respectively, such as the intensity of certain frequencies of the converter noise and the like. This type of operation of the melt requires a high degree of experience and attention on the part of the operating personnel and amounts to a substantial uncertainty, since it is only recognized relatively later whether, for instance, the change of the spacing of the blast nozzle from the surface of the bath is too small, correct or too large. In addition, there is the aggravating circumstance that the effect of a change in the spacing of the blast nozzle from the surface of the bath and of the flow of oxygen under pressure also depends on the prevailing condition at the time of the metal-slag bath, such as the temperature, the amounts of slag-present, and the composition of the metal-slag bath.

Upon a simultaneous change in the flow of oxygen under pressure and the spacing of the blast nozzle from the surface of the bath, the conditions become so complicated, that they can no longer be controlled by the operators. In addition to this, furthermore, is the difficulty in determining with any degree of precision the spacing of the blast nozzle from the surface of the bath, since, on the one hand the quantity of pig iron filled in varies from melt to melt and, on the other hand, the variation of the condition of the wall of the refining vessels cause different heights of the surface of the bath for the same amounts of iron.

A method has, therefore also been proposed already (U.S. Patent No. 3,372,023), which method, however, is not yet part of the prior art, in which by means of the values of the flow of oxygen under pressure and of the flow of waste gas, the quantity of the waste gas removed in a time unit, as well as the chemical composition of the waste gas with respect to carbon monoxide, carbon dioxide, oxygen and hydrogen, which values are continuously measured and fed to an electronic computer, a characteristic index for the distribution of the oxygen upon the reactions taking place in the reaction vessel is calculated and used for the supervising and automatic control of the course of the reaction.

In this method an empirically determined function for the distribution of the oxygen, which function can be affected by additional measured values, is used to supervise and control the course of the reaction. By this method it is, however, not possible to control the distribution of the oxygen and the quantities of waste gas to be formed in the refining vessel or their effect independently of each other.

In another known method, the position of the lance is controlled as a function of the rate of decarbonization. In this case it is not possible, for instance, to establish in advance in addition to the decarbonization rate, also for instance the distribution of the oxygen.

It is one object of the present invention to provide a method of automatically controlling and regulating the oxygen blowing process, in which the oxygen top-blow process is automated and the position of the lance and the flow of oxygen is controlled and regulated such that the blowing process takes place under optimum conditions. By optimum conditions, it is understood in this connection, for instance, a short blowing time, a slag which corresponds with the metallurgical course of the process at each moment thereof, as well as to the quantity, temperature and composition, the avoidance of spattering and foaming-over, the obtaining of the desired composition and temperature of the metal and slag upon an intermediate removal of slag and, first of all, at the end of the process. From the dust removal system, in addition a possibly most constant quantity of waste gas over the entire course of the blasting procedure can be desired.

It is another object of the present invention to provide a method of automatic control and adjustment of oxygen blowing processes, wherein given values independent from each other are preset.

It is another object of the present invention to provide a method for automatically controlling and regulating the oxygen blowing processes which includes an adjustment of the spacing of the blast nozzle from the surface of the bath and of the flow of oxygen under pressure during the working of metals, particularly during the manufacturing of steel from pig iron, by blowing of oxygen onto the metal-slag bath in accordance with the oxygen blowing process in stationary and/or rotating refining vessels.

It is still another object of the present invention to provide a method of automatically controlling and regulating the oxygen blowing process, wherein during the

blowing process by the establishing in advance of two independent given values, one of which represents a measure for the metallurgical course of the process and the other of which represents the value of the flow of the compressed oxygen itself or a measure of the quantity of waste gas to be formed in the refining vessel, the distance of the blast nozzle from the surface of the bath and the stream of pressurized oxygen are controlled automatically by means of an electronic computer and/or a controller.

In order to carry out the blowing process in an optimum manner, there is used, in accordance with another feature of the present invention, as given value, representing a measure of the metallurgical course of the process, the distribution of oxygen over the metal-slag bath and the waste gas, while as given value, which represents a measure of the amount of waste gas to be formed in the refining vessel, there is used the rate of carbon combustion in the bath and/or the temperature of the waste gas and/or the CO₂ content and/or the O₂ content and/or the CO content in the waste gas and/or the vapor pressure and/or the amount of vapor produced per time unit in the waste gas condenser and/or the heat flow in the waste gas.

A more favorable adjustment simultaneously directed to the different effects of the oxygen distribution and the formation of the amount of waste gas and is obtained such, that the spacing x of the blowing nozzle from the surface of the bath and the flow of the pressurized oxygen dO_B/dt to a blowing number B is connected together, for instance by an electronic computer, in the equation:

$$B = K \frac{dO_B/dt}{(x+a)^2}$$

In order to be able to adjust in equal manner, independently of the prevailing spacing of the blast nozzle from the surface of the bath and the prevailing flow of pressurized oxygen, disturbances, such as changes in the metal bath and the slag in temperature, composition, physical nature and quantity, the non-linear behavior of the oxygen blowing process is advantageously compensated for completely or approximately by a control system adapted to this process for the entire range of the position of the blowing nozzle and of the flow of pressurized oxygen.

It has, furthermore, been found, that it is favorable to influence the oxygen distribution, preferably by the spacing of the blowing nozzle from the surface of the bath and to influence the other mentioned values, preferably by means of the flow of the pressurized oxygen. In order to control the spacing of the blast nozzle from the surface of the bath upon a change in the flow of the pressurized oxygen such, that the metallurgical action of the oxygen blast jet is retained, the flow of pressurized oxygen and the oxygen distribution are, in accordance with a further feature of the present invention, separated from each other in accordance with the blow-number relationship. In this way it is possible to change the flow of pressurized oxygen, without requiring that the change in the blowing action caused thereby must be adjusted at first by means of the blowing process and the control system by an additional control process.

On the basis of empirical values, established by experience, there is advantageously used as a given value for the oxygen distribution a value which varies with the time and/or the quantity of blown oxygen and/or the bath temperature and/or the progress of the carbon combustion.

Since particularly during employment of pig iron having a high phosphorus content, the formation of a foam slag is desirable, but too high a level of the slag and overfoaming are undesired, the given value for the oxygen distribution is advantageously changed by the measured value of the conductivity between blow lances and the bath and/or by the measured value of an acoustic meas-

urement, both of which represent a measure for the level of a foam slag.

As further advantageous possibility of keeping the oxygen blowing time optimally short without, for instance, to overload the waste gas purification plant, which generally represents a limiting factor for the size of the pressurized oxygen flow and the waste gas flow dependent thereon, respectively, the given values are maintained constant during the blowing period, for the values, which represent a measure of the quantity of waste gas to be formed in the refining vessel or varied with the time and/or the quantity of blow oxygen and/or the bath temperature and/or the progress of the carbon combustion. Thus, for the speed of the carbon combustion and by constant withdrawal flow with full combustion of the waste gas, a specific value to be maintained can be pre-established also for the CO₂ content.

In order to prevent splattering of the slag, particularly during formation of a voluminous foam slag, it has proven favorable, upon underpassing the given value by the actual value of the oxygen distribution for a predetermined value dependent upon the process, to prevent by the automatic system an increase in the flow of pressurized oxygen.

The ignition processes which often occur explosive-like upon repeated igniting are avoided, if at the start of the oxygen blowing, oxygen is blown with a low flow of pressurized oxygen, for instance $\leq 2 \text{ Nm}^3(\text{STP})/\text{min. t.}$ and with a small spacing of the blow nozzle from the surface of the bath and by increasing the electrical conductivity between the blow lance and the bath and/or the brightness in front of the mouth of the refining vessel and/or the analysis of the waste gas and values calculated therefrom, the ignition is indicated and after a short time of, for instance, 20 seconds after the ignition, the automatic system is switched on for controlling and regulating the blow lance and the pressurized oxygen flow. In this way, an extinguishing of the blow jet can also be indicated during the blowing process, the automatic system being automatically shut off and the ignition newly introduced upon the extinguishing of the blow jet during the blowing process.

Above all, during the start of a new plant, it is advisable and constitutes a considerable advance over the methods previously employed, to control the blowing process semi-automatically by hand by pre-establishing given values for the oxygen distribution and the pressurized oxygen.

With these and other objects in view which will become apparent in the following detailed description, the present invention will be clearly understood in connection with the accompanying drawing, in which:

FIGURE 1 is a schematic elevation of a plant for producing steel in accordance with the oxygen blowing process with means employed for controlling and regulating the distance of the blowing nozzle from the surface of the bath and the flow of pressurized oxygen; and

FIG. 2 is a block diagram for controlling the oxygen distribution and the flow of heat by the position of the blow lance and the pressure oxygen flow.

Referring now to the drawing, the pressure oxygen which is indicated by an arrow 2 is blown by means of the oxygen blowing lance 1 onto the top of the metal-slag bath 4 contained in the converter 3 and reacts there predominantly with the accompanying elements contained in the pig iron such as carbon, phosphorus, silicon, etc. The converter waste gases produced by the reaction of the oxygen with carbon, which gases are indicated by arrows 5, are collected in a gas-collecting hood 6 and pass through cooled gas discharge pipes 7, for instance into a waste heat boiler 8. In further gas-cooling units 9, the burned-off waste gases are cooled and dust removed in a dust-precipitator 10. The cooled purified waste gases are discharged by means of a waste-gas blower 11.

The determining of the dry stream of waste gas $\dot{V}$ is

effected in the gas conduit pipe 7 by a pressure measuring point 12 disposed behind the dust precipitator 10, a temperature measuring point 13 and a differential pressure-measuring point 14. The values of the stream of waste gas measured there are transmitted electrically, as indicated by arrows 15, to the electronic computer 16.

The waste gas analysis required for the calculation of the oxygen distribution over waste gas and bath in the converter 3 takes place, since sampling in the converter 3 itself requires considerable expense, by a sampling of the waste gas from the gas conduit pipe 7 in front of the waste heat boiler 8 by a sampling tube 17. After the removal of the dust and drying of the sample of waste gas, it is analyzed for carbon monoxide, carbon dioxide, oxygen and possibly hydrogen in the analyzers 18, from which the values ascertained are electrically transmitted, as indicated by arrows 19, also to the electric computer 16.

The determination of the flow of pressurized oxygen takes place in the pressure oxygen conduit 21, which is connected by a movable connecting member 20 with the oxygen blow lance 1 by means of a pressure measurement at the point 22, a temperature measurement at the point 23, and a differential-pressure measurement at the point 24. The obtained measured values are transmitted electrically, as indicated by the arrow 25, to the electronic computer 16.

The values of the conductivity between the oxygen blow lance 1 suspended in an electrically insulated manner and the metal-slag bath 4, the intensity of the converter noise and the intensity of the flame radiation at the mouth of the converter 3, which are also used for controlling and observing the process, are measured by means of a conductivity measuring device 26, a microphone probe 27 and a pyrometer 28 and, as indicated by arrows 29, fed into the computer 16.

The distance of the blow nozzle from the surface of the bath and the position of the blow lance 1, respectively, is also measured at 30 and, as indicated by the arrow 31, fed into the computer 16.

From the flow and the analysis of the waste gas, as well as the flow of the pressurized oxygen, the oxygen distribution, the waste gas heat flow and further values are calculated in the computer 16, which then controls the motor 32 to adjust the distance of the blast nozzle from the surface of the bath, and controls the valve 33 for a specific flow of pressurized oxygen.

In the calculator 16, as can be noted from the example shown in FIG. 2, the actual values of the oxygen distribution $\dot{O}_C$ and the heat flow Q are calculated from the measured values of the waste gas and the pressurized oxygen. For the oxygen distribution there applies in this connection the equation:

$$\dot{O}_C = \frac{1}{100} \cdot \frac{\dot{V}}{dO_B/dt} [0,766 \cdot CO + 1,266(CO_2 + O_2) - 0,234H_2 - 26,582]$$

under the condition that CO , CO_2 , O_2 and H_2 are present in the form of measured values.

In this equation for the oxygen distribution dO_B/dt stands for the amount of oxygen blown onto the top of the metal bath per unit of time, namely the pressure oxygen flow, $\dot{V}$ is the dry waste gas flow converted to standard conditions, for instance $0^\circ C$. and one atmosphere, and CO , CO_2 , O_2 and H_2 are the percentages by volume of carbon monoxide, carbon dioxide, oxygen and hydrogen in the dry waste gas in the gas discharge system of the reaction vessel. $\dot{O}_C$ is defined in such a manner that for $\dot{O}_C=1$ all pressurized oxygen reacts with carbon and is discharged in the waste gas. $\dot{O}_C<1$ means that a part of the pressurized oxygen is combined in the slag and $\dot{O}_C>1$ means, that there is reduced out of the slag beyond the pressurized oxygen flow oxygen, which was either stored in the slag or was fed as ore-oxygen and the

like. For the formation of a slag, there is therefore established a given value $\dot{O}_C<1$, while for the maintenance of the quantity of the slag there is established a value of $\dot{O}_C=1$ and for the reduction of a slag, for instance before the removal of the slag, a value of $\dot{O}_C>1$ is set. For the establishing, or instance, of a foam slag desired in the processing of pig iron of high phosphorus content, at first there is adjusted the value $\dot{O}_C/-1$, for instance $\dot{O}_C=0.6$. Since the foam slag has the phosphorus removed well only, if it is so high, that the blast nozzle is emerged therein, while too high a level of the slag and a foaming over are not desired, the given value is set for $\dot{O}_C>1$, when the foam slag has reached the blow lance.

For the heat flow Q there applies the equation:

$$Q = \dot{O}_C \cdot \frac{dO_B}{dt} [(a+b)CO_{red} + c \cdot CO_{2red}]$$

in which CO_{red} and CO_{2red} are the contents of the gas formed in the refining vessel, which contents are calculated from the measured values of the gas in the waste gas discharge pipe; a and c are values for the average sensitive heat of the waste gas components and b contains the reaction heat for the reaction $CO + \frac{1}{2}O_2 = CO_2$.

The oxygen blowing process has a non-linear behavior with respect to the position of the blow lance and the pressurized oxygen flow, which is characterized by the equation:

$$B = K \frac{dO_B/dt}{(x+a)^2}$$

for a blow number B , whereby K and a are constants, which depend upon the used blast nozzle, for instance a single-hole nozzle, a multi-hole nozzle, a cylindrical nozzle and the like and upon the selected dimension of B .

Since a is frequently very small, as compared with x , many cases it is sufficient to represent the blow number B in the simplified form:

$$B = K \frac{dO_B/dt}{x^2}$$

The blow number B and the metallurgical blowing action, expressed by it, is in this connection approximately proportional to the oxygen distribution $\dot{O}_C$, in which connection disturbing factors such as bath temperature, amount of slag and the like can also influence this relationship. Thus, in this way there is created a relationship between the measured variable $\dot{O}_C$ and the manipulated variables, i.e., the position of the blow lance and the pressure oxygen flow.

In the proportional plus reset plus rate-action controller 34 there is formed from the calculated actual value and the preliminary given value for the oxygen distribution $\dot{O}_C$ the deviation and from the latter the output signal for the blow number B is formed. In corresponding manner, the proportional plus reset controller 35 forms the deviation from the calculated actual value and the preliminary given value for the heat flow Q , and from this the pressurized oxygen flow. At the same time the value dO_B/dt calculated for the pressurized oxygen flow is fed into the divider 36. From the proportional plus reset plus rate action controller 34, the blow number B is fed into the divider 36 and the square of the distance of the blow nozzle from the surface of the bath is calculated. In the following root-extractor 37 the set point x for the distance of the blow nozzle from the bath surface is thereupon calculated.

By the combining of the blow number B and the pressurized oxygen flow dO_B/dt in the divider 36, there is obtained a decoupling between the oxygen distribution $\dot{O}_C$ and the heat flow Q , whereby it is possible to vary the pressure oxygen flow without the change in the blow action caused thereby having to be first of all compensated for by the process and the control system by means of an additional control process.

The values calculated for the distance x between the blow nozzle and the surface of the bath and for the pressurized oxygen flow dO_B/dt produce signals by which the position of the blow lance 1 by means of the motor 32 and the valve 33 for the pressure oxygen flow are regulated.

The method for the automatic control and regulation of the adjustment of the distance of the blow nozzle from the surface of the bath and of the pressurized oxygen flow in the oxygen blowing process according to the present invention, makes it possible, at any time during the blowing process, to obtain an optimum adjustment of the position of the blow lance and of the pressurized oxygen flow with respect to the metallurgical requirements and simultaneously with respect to the quantity of waste gas formed in the refining vessel or the effects thereof, whereby it is not necessary to know the actual distance of the blow nozzle from the surface of the bath. By means of this method, it is furthermore possible, to carry out the process in such a manner, that with given dust-precipitation means the oxygen blowing time or in case of the provision of subsequent boilers for the production of steam, the greatest possible production of steam can be obtained without impairing a favorable metallurgical course. At every time during the process, there is obtained in this connection a suitable slag composition even in case of a relatively small amount of slag and thus, for instance, a high removal of phosphorus and sulfur. Splattering and over-foaming of metal and slag from the refining vessel can be substantially avoided. Furthermore, before the removal of the slag, the latter can be extensively reduced as a result of which, with a low consumption of oxygen and a high output of liquid metal an optimum utilization of the process heat is made possible. In addition to this, the control adapts itself to all disturbances, for instance accidental and systematic changes in the temperature, composition of the metal and of the fluxes and the changes of the refining vessel and to a certain extent also of the blow nozzles.

This method can be carried out both in a stationary as well as in a rotating refining vessel. It can be used in addition to working of phosphorus-poor and phosphorus-rich pig iron, also advantageously for working of other metals by the oxygen blowing method, such as for instance, the refining of ferrous chromium carbide alloys.

While we have disclosed several embodiments of the present invention, it is to be understood that these embodiments are given by example only and not in a limiting sense, the scope of the present invention being determined by the objects and the claims.

We claim:

1. A method of automatically controlling and regulating the oxygen-blowing process, comprising the steps of blowing oxygen at the start of the oxygen blowing with a flow of low pressure oxygen and at close distance of the blowing nozzle from the bath surface, indicating the ignition by the increase of the electric conductivity between the blowing lance and the bath, the brightness in front of the mouth of the refining vessel, the analysis of the waste gas and values calculated therefrom, and switching on a short time period after the ignition the automatic system for controlling and regulating said oxygen blowing process, feeding during said oxygen blowing process two given values independent upon each other to an electronic computer, the first of said values representing a measure of the metallurgical course of said process, and the second of said values representing a measure of the flow of pressurized oxygen or a measure of the amount or effect of waste-gas occurring in said process, determining during the oxygen blowing continuously the given values corresponding to the desired values

and comparing the latter with the given values, and setting automatically the distance of the blowing nozzle from the surface of the bath and the flow of pressurized oxygen in case of deviations of the given values from the desired values by adjusting the former to the latter by said electronic computer.

2. The method, as set forth in claim 1, wherein said given value representing a measure for the metallurgical course is the oxygen distribution to the metal-slag bath and the waste-gas, and

said given value representing a measure for the amount of waste-gas to be formed in a refining vessel indicates the carbon combustion speed in the bath, the temperature of said waste-gas, the CO_2 content, the O_2 content, the CO content in the waste gas, and the heat flow in the waste-gas, respectively.

3. The method, as set forth in claim 2, wherein the distance x of the blowing nozzle from the surface of the bath and the flow of pressurized oxygen dO_B/dt are combined with a blow-number B by the equation

$$B = K \frac{dO_B/dt}{(x+a)^2}$$

where K and a are constants.

4. The method, as set forth in claim 2, wherein the oxygen blowing stream is varied by the distance of the blowing nozzle from the surface of the bath and said second of said given values.

5. The method, as set forth in claim 3, which includes the step of

separating said flow of pressurized oxygen and said oxygen distribution by means of the blow-number relationship B.

6. The method, as set forth in claim 4, wherein said given value for the oxygen distribution is a value variable with time, the amount of blown oxygen, the bath temperature, and the progress of the carbon carburization, respectively.

7. The method, as set forth in claim 4 which includes the steps of

feeding the given value to a computer, varying the given value for the oxygen blowing stream by monitoring the control factors depending upon the measuring value of the conductivity between the blowing lance and the bath and the measuring value of intensity of predetermined frequencies of the converter noises, respectively, which measuring values represent a measure for the position of a foam slag.

8. The method, as set forth in claim 1, which includes the step of

compensating at least approximately for the non-linear course of the oxygen-blowing process by a regulating system adapted to said non-linear course for the total range of positions of said blowing nozzle and of the flow of the pressurized oxygen.

9. The method, as set forth in claim 1, which includes the steps of

maintaining constant during the blowing period the given value for the values which represent a measure for the amount of waste-gas to be formed in a refining vessel, and varying said values with the time, the amount of oxygen blown, the bath temperature, and the progress of the carbon combustion, respectively.

10. The method, as set forth in claim 1, which includes the step of

preventing the increase of the flow of pressurized oxygen by the automatic system, upon underpassing the given value by the actual value of the oxygen-distribution for a predetermined value dependent upon the process.

11. The method, as set forth in claim 1, wherein

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said oxygen blowing step with a flow of low pressure oxygen is performed at about 2 Nm.³/min. t.

12. The method, as set forth in claim 1, wherein said step of switching on said automatic system after the ignition takes place in about 20 seconds.

13. The method, as set forth in claim 1, which includes the steps of

extinguishing automatically the blow stream during the blow process, and starting again the ignition.

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