Aug. 26, 1969 P. VAYSSIERE ET AL 3,463,631

METHOD AND ARRANGEMENT FOR DETERMINING THE OXIDATION REACTIONS DURING REFINING OF METALS

Filed Nov. 30, 1964 3 Sheets-Sheet 1

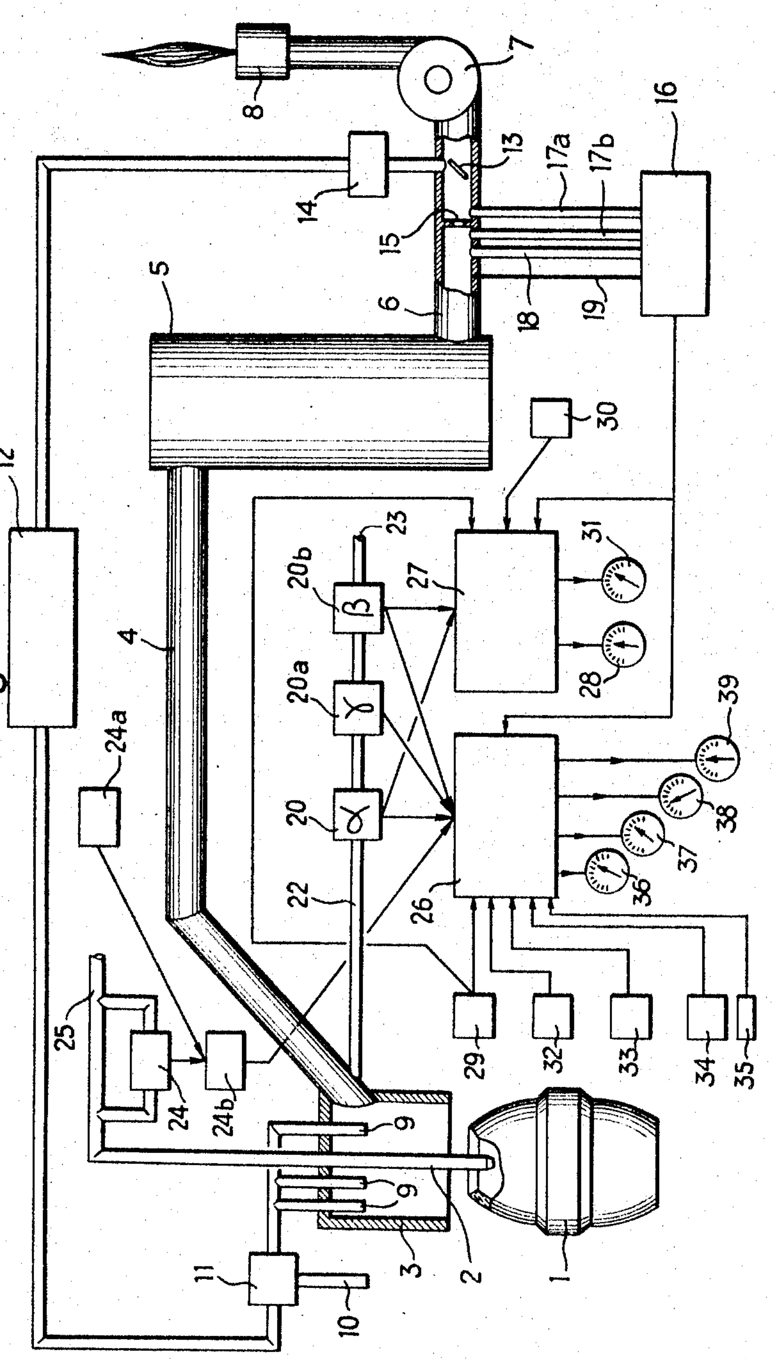

Fig. 1

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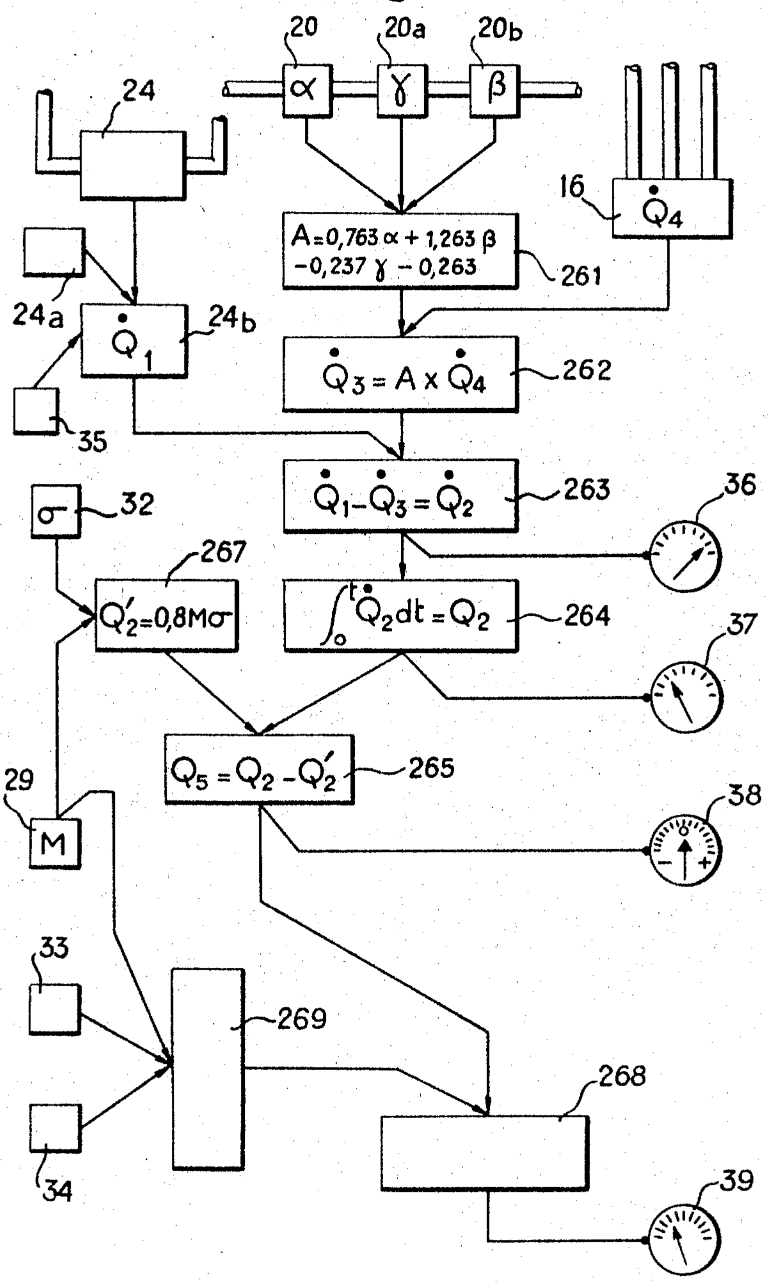
Fig. 2



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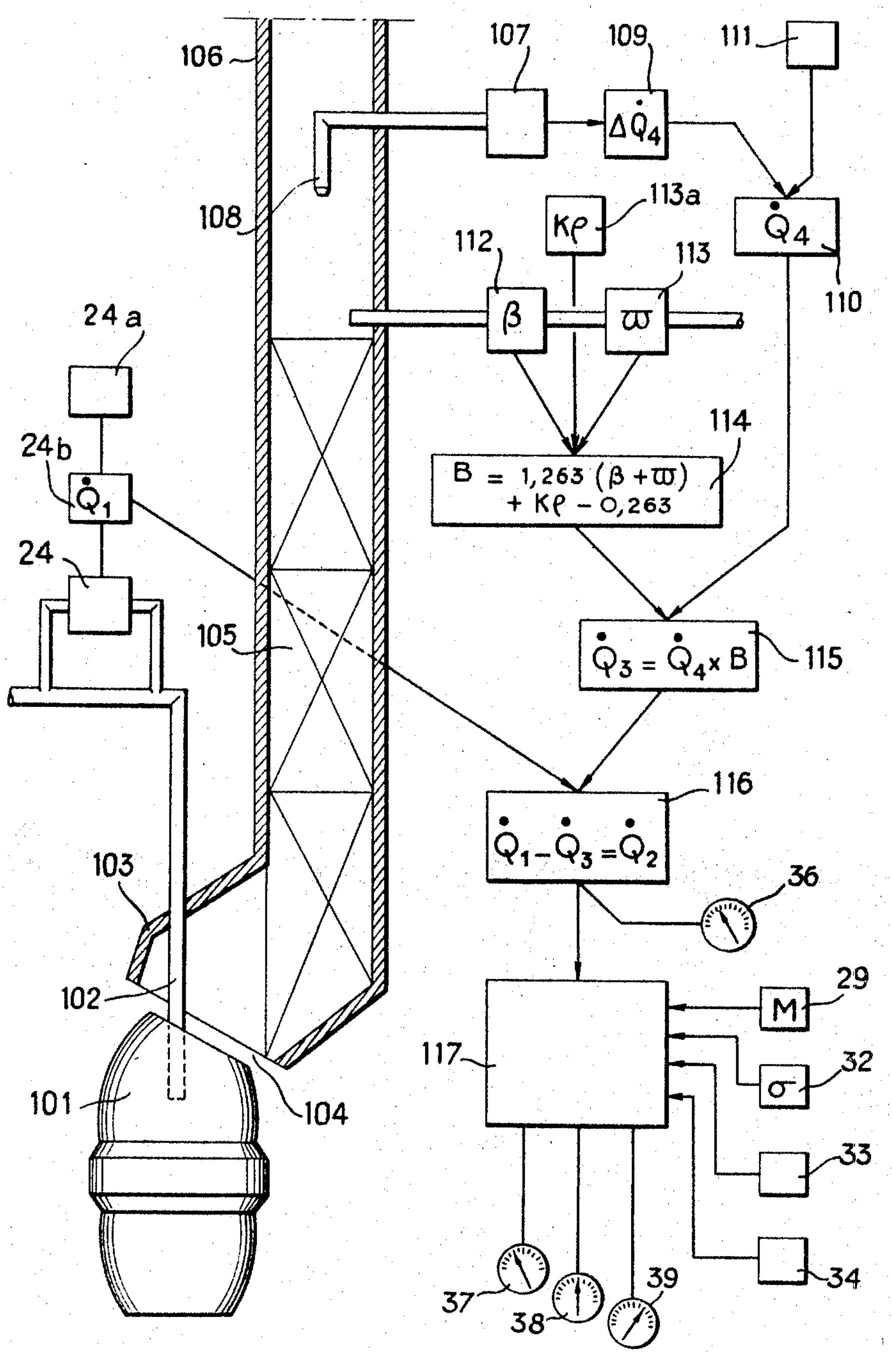

Fig.3

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United States Patent Office

3,463,631
Patented Aug. 26, 1969

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3,463,631

METHOD AND ARRANGEMENT FOR DETERMINING THE OXIDATION REACTIONS DURING REFINING OF METALS

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Filed Nov. 30, 1964, Ser. No. 414,809
Claims priority, application France, Dec. 3, 1963, 955,779
Int. Cl. C21c *1/00;* G01n *31/00*
U.S. Cl. 75—60 19 Claims

ABSTRACT OF THE DISCLOSURE

Pig iron is refined with continuous determining of the composition of the molten pig iron bath during oxygen blast refining in a converter in order to permit accurate adjustment of the rate of oxidation and for determination of the appropriate time for terminating the refining process, by introducing into an oxygen converter a charge of predetermined amount and composition including carbon, iron, silicon, manganese, phosphorus and oxygen, introducing an oxygen blast into the charged converter and continuously measuring the total quantity of oxygen introduced by said blast into the converter per unit of time, continuously measuring the quantity of oxygen which leaves the converter during such unit of time as free oxygen and combined with carbon, continuously measuring the quantity of oxygen bound by each of the elements of the bath other than carbon and silicon, continuously determining by integration from all of these measurements and the determination of the amount of oxygen required for oxidizing the silicon content of said charge the total quantity of oxygen bound by the iron, the phosphorus and the manganese of the bath, and ending refining of the pig iron when the total quantities of oxygen bound by the iron, phosphorus and manganese of the bath reach predetermined desired values.

The present invention relates to method and arrangement for determining the oxidation reactions during refining of metals and more particularly the continuous determination of the course of the oxidation in the refining of steel by means of the basic oxygen process.

It is known that in the refining by blowing of a bath of molten metal for the purpose of obtaining a steel, an oxidizing gas, for example pure oxygen, is blown into the bath in order to burn the carbon contained therein and to slag certain other elements such as silicon, manganese, and phosphorus as well as a certain quantity of iron which passes into the slag in the form of FeO.

It is a primary object of the present invention to provide improvements in the control of these oxidations during the course of oxidation by blowing into a molten bath for the production of steel.

It is another object of the present invention to provide for the continuous determination of the course of the oxidation reactions in the basic oxygen process whereby it is possible to better control the overall process.

It is yet another object of the present invention to provide a method of continuous determination by means of an in-line computer.

Other objects and advantages of the present invention will be apparent from a further reading of the specification and of the appended claims.

With the above and other objects in view, the present invention mainly comprises a process for following the course of the refining actions and the composition of a metallic bath during its refining by top blowing or the like, according to which continuous measurement and comparisons are made between the total quantity of oxygen introduced at each instant into the converter and the quantity of oxygen that escapes at each instant from the said converter in the form of gaseous carbon oxides as well as in the form of free gases, and also the quantity of oxygen that is bound by the different elements in the bath from which it is possible at each instant to determine by integration the total quantity of oxygen fixed by these elements and after slagging of the silicon the total quantity of oxygen bound by the iron, the phosphorus and the manganese, these calculations being made by means of knowledge of the initial composition introduced into the converter.

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The present invention provides for improvement in the control of the oxidation reactions during the course of refining by blowing of a metallic bath, and permits the determination of the distribution of oxygen in the different elements in the bath and even when it occurs the measurement of the quantity of iron oxide that passes into the slag.

According to a preferred embodiment of the present invention, the above described process is characterized by continuous measurement of the quantity of oxygen introduced at each instant into the converter, which comprises the oxygen carried by the charge, such as the minerals, scrap iron, etc., in measuring at each instant the quantities of oxygen which escape from the said converter in the form of one or more of the carbon oxide gases, i.e. CO, CO_2, and also in the form of free oxygen, and from this there is calculated with the aid of mathematical formulas which are set forth herein, the quantities of oxygen that are respectively fixed by the carbon of the bath, by the gaseous CO and by the elements Fe, Mn, Si and P of the bath which contribute to the formation of the slag. Then, by integration, the total quantity of oxygen bound at each instant by these different elements, and after slagging of the silicon, by difference, the total quantity of oxygen bound by the elements Fe, P and Mn, known in the initial compositoin of the metallic bath, are calculated.

The process of the present invention can equally comprises one or the other of the following characteristics, in combination with the characteristics mentioned above:

(a) In order to follow the evolution of the refining reactions and the composition of the bath during the refining by blowing into the refining converter there is provided an installation for capturing without combustion the refining gas, measuring the quantities of oxygen that escape from the said converter by measuring the total gas in the capturing or collecting installation, measuring its concentrations of CO, CO_2 and free oxygen, and deriving therefrom the corresponding discharge of oxygen.

(b) In order to follow the evolution of the refining reactions and the composition of the bath during the refining by blowing in a refining converter, there is provided an installation for capturing the refining gas with aspiration of air and complete combustion of CO, determining one time for all the nominal discharge of aspirated gas, there is detected and introduced as corrective terms the variations of the discharge, there is measured the concentration in the gas of CO_2 and O_2, and from this there is derived the corresponding discharge of oxygen.

It is a further object of the present invention to provide a measuring arrangement which permits the carrying out of the above described process, comprising measuring means for the total discharge of oxygen introduced into the converter in the form of a gas and also of chemical combinations with added materials and means for capturing the gas leaving the said converter and for measuring the amount thereof and its composition, characterized in that the device comprises in combination means for analyzing in sufficiently short times for measuring at each instant the composition of the captured gas and means for delivering the respective signals of the concentrations of at least one of the series of gases CO, CO_2, O_2 and H_2, and calculating means comprising at least one integrator operatively connected to the means for measuring the discharge and the means for analyzing the discharge for the purpose of elaborating the respective signals of the speed of the oxidation of the different elements of the bath and of the quantity of oxygen respectively fixed by these different elements of the bath.

This arrangement can comprise one or several of the following characteristics, possibly in combination with the preceding:

(a) Means for calculation and integration are constituted by an electronic calculator which has been programmed to solve the mathematical formulas which have been previously established for this purpose.

(b) Means for capturing the gas from the refiner which are arranged to effect the capture practically without combustion as the gas leaves the converter, the said analyzing means being arranged to deliver the respective signals as to the concentrations of CO, CO_2, O_2 and H_2.

(c) Means for capturing the gas from the converter being arranged to effect the capture with aspiration of air and partial combustion of CO, the said analyzing means being arranged to deliver the representative signals of the concentration of CO, CO_2, O_2, H_2 and by difference with 100% of N_2, for determining at each instant the portion of the air for combustion.

(d) Means for capturing the gas from the converter arranged for effecting the capture with aspiration with an excess of air and complete combustion of the CO, the said analyzing means being arranged to deliver the representative signals of the concentrations of CO_2, O_2, H_2 and by difference with 100%, of N_2, for determining at each instant the air for combustion which is delivered.

There is described in U.S. patent application Ser. No. 211,999 of Jacques Dumont-Fillon, now U.S. Patent No. 3,181,343, entitled "Method and Arrangement for Measuring Continuously the Change of the Carbon Content of a Bath of Molten Metal" and in the corresponding French Patent No. 1,309,212, a method for continuously measuring the concentration of carbon over metallic bath during refining, this method comprising continuously measuring the quantity of carbon which leaves the converter in the form of CO or of CO_2, and to derive at each instant, by integration, the concentration of carbon in the molten metal bath, by knowing the concentration of the initial carbon.

It is apparent that it is of considerable interest to be able to determine equally in the course of the refining the quantity of oxygen that is being bound and the quantity that has already been bound by the charge since this enables one to estimate at the time the instantaneous total production from the oxygen supply, and at the end of the operation, above all, to evaluate the total quantity of oxygen used in the formation of iron oxide, considering that it is possible to estimate under the best conditions the final quantities of Mn and P and consequently the quantities of oxygen bound thereby.

The present invention can be operated as well in refining installations where the gases leaving the converter are captured without burning the same as in installations where the capture of the gas is accompanied by the introduction of air which causes a more or less complete combustion.

There is indicated below the formulas useful for all cases, it being understood that in a case where the gas is captured with a quantity of air sufficient to burn all of the CO to CO_2 the concentration of CO in the gas need not be measured since it is always equal to zero.

The components that can be present in the gas captured above the converters are CO, CO_2, H_2, N_2 and O_2. Their concentrations, which are respectively designated herein by a, β, γ, δ, $\bar{\omega}$ are evidently such that their sum is always equal to unity, so that in the formulas for calculation which are given below the magnitude can be replaced by the difference between the unity and the sum of the concentrations of the other components. This will be further illustrated in the two examples for carrying out the invention which are described further below.

If the quantity of oxygen which is introduced into the converter in the unit of time is designated

$$\dot{Q}_1$$

the quantity during the unit of time which is bound by the total of all of the elements other than carbon in the bath is designated as

$$\dot{Q}_2$$

and the quantity of oxygen which leaves the converter during the unit of time is designated as

$$\dot{Q}_3$$

then:

$$\dot{Q}_2=\dot{Q}_1-\dot{Q}_3$$

Accordingly, according to one object of the present invention,

$$\dot{Q}_2$$

is measured by continuously determining

$$\dot{Q}_1 \text{ and } \dot{Q}_3$$

The value of

$$\dot{Q}_1$$

can be determined by means of a flow meter connected to the feed conduit for the refining lance. The value

$$\dot{Q}_3$$

is obtained as a result of the measurement of the rate of flow of the gas captured above the converter

$$(\dot{Q}_4)$$

and the measurement of the concentration

$$\alpha,\ \beta,\ \gamma,\ \delta \text{ and } \bar{\omega}$$

of its components, which permits the continuous elaboration of a representative signal for the value according to the equation:

$$\dot{Q}_3=\dot{Q}_4(0.5\alpha+\beta+\bar{\omega}-0.263\delta-0.5\gamma+kP)$$

in which k is the quantity of oxygen bound by each kilogram of dust and P the concentration of the dust (in kg. per $Nm.^3$ of captured gas).

Thus, as has been shown above, the measurement of the concentration δ of the nitrogen in the captured gas is not indispensable, provided that the determination of the values

$$\alpha,\ \beta,\ \gamma \text{ and } \bar{\omega}$$

be made with sufficient precision, and it is therefore possible in the above expression to replace δ by

$$1-(\alpha+\beta+\gamma+\bar{\omega})$$

which leads to the following:

$$\dot{Q}_3=\dot{Q}_4[0.763\alpha+1.26(\beta+\bar{\omega})-0.237\gamma+kP-0.263]$$

The present invention further provides for the measurement at each instant, of the total quantity of oxygen that is bound in the bath during the course of the refining, or at least from the start of a given phase of the refining, which is the quantity:

$$Q_2=\int_0^t \dot{Q}_2 dt$$

the knowledge of which permits appreciation of the state of advancement of the refining.

Moreover, since the initial quantity of silicon contained in the metal is known it is easy to determine a priori the quantity Q_2' of the oxygen in (Nm.^{3}) that is bound to the silicon. This quantity is expressed as:

$$Q_2'=0.8\ M_\sigma$$

In the above formula M is the mass of the metal in kg. and σ is the initial concentration of silicon.

It is therefore possible, in accordance with a further embodiment of the present invention, to determine towards the end of the refining the quantity $Q_5=Q_2-Q_2'$ which corresponds to the oxygen bound by the iron, the manganese and the phosphorus in the form of FeO, of MnO and of P_2O_5.

Finally, taking into consideration that in the final instance of the refining the concentrations of manganese and of phosphorus, μ_1 and φ_1 are in the neighborhood of the normal final values obtained in the refining installation, it is possible to determine the quantity Q_6 of oxygen bound by the iron, utilizing the equation:

$$Q_6=Q_5-M[0.204(\mu_0-\mu_1)+0{:}904(\varphi_0-\varphi_1)]$$

in which μ_0 and φ_0 are the initial concentrations of manganese and of phosphorus in the metal.

This quantity Q_6 represents, except for a coefficient of proportionality the quantity F of iron oxide in FeO, so that

$$F=4.99\ Q_6$$

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

FIG. 1 schematically illustrates an installation for capturing, without combustion, the gas leaving a basic oxygen converter, this installation being provided with an analyzer arrangement for making measurements in accordance with the present invention;

FIG. 2 schematically illustrates the function of the calculator arrangement of FIG. 1; and

FIG. 3 schematically illustrates a basic oxygen furnace equipped with an arrangement for capturing the gas comprising a boiler arrangement for recapturing of heat, this installation being provided with an analyzer arrangement for making measurements in accordance with the present invention.

Referring more particularly to the drawing, FIG. 1 shows a converter **1**, which is actually an experimental converter of 5 ton capacity, into which oxygen is blown by means of a refining lance **2**. The gas leaving the converter is captured in a hood **3** which is cooled by circulation of water. The captured gas is evacuated by a metallic conduit **4**, which is cooled by streaming water, towards a wet dust collector **5** of known type, from which it is aspirated towards a conduit **6** by means of a blower **7**. The CO is then burned as it leaves from an excess gas burning chimney **8** so that it is not passed into the atmosphere.

In order to achieve the capture of the gas without reentrance of air and without important loss of gas, the pressure in the hood **3** is always maintained at substantially the surrounding atmospheric pressure by means of a regulating system comprising: three pressure supply conduits **9** placed in the hood **3** at about ⅓ of its height, and connected in parallel, an atmospheric pressure supply conduit **10** placed at the exterior of the hood at the same height as the conduits **9**, a differential membrane manometer **11** which compares the pressure indicated by the conduits **9** and the atmospheric pressure, an electropneumatic regulator **12** of known construction which receives the indications of the differential manometer **11**, and a draft register **13** placed in the conduit **6** and actuated by a pneumatic jack **14** which receives its air at the command of the regulator **12**. The register **13** is positioned at each instant according to the indications of the differential manometer **11** in such manner that the pressure in the lower portion of the hood always remains equal to the exterior pressure.

The total amount of the captured gas is measured in the conduit **6**, after cooling and wet dust removal, by means of a flow meter corrected automatically for temperature, pressure, humidity and density, composed in actuality of a diaphragm **15** arranged in the said conduit **6**, and of a differential pressure meter **16** operatively connected to two pressure conduits **17*a***, **17*b***, a sampler humidity measurement device **18** and a sampling temperature measurement device **18**. The flow meter is automatically corrected and is per se known in the art.

The concentrations α, γ, and β of the gas in CO, H_2 and CO_2 are measured at the discharge of the hood by three infra-red gas absorption analyzers, **20**, **20*a*** and **20*b***, respectively, supplied with the gas by means of a small conduit **22**.

After passage through the analyzers, the slight current of gas necessary for the measurement is discharged into the atmosphere through conduit **23**.

The gaseous oxygen blast blown into the converter is measured by a flow meter **24** having two branches communicating with the conduit **25** which supplies the oxygen lance, while the amount of oxygen introduced into the converter in the form of pulverulent material is measured by flow meter **24*a***. The indications of flow meters **24** and **24*a*** are added at **24*b*** where a signal is given which is proportional to the total amount of oxygen $\dot{Q}_1$ which is introduced into the converter.

The indications of the different measurement apparatus are transmitted to an electronic calculator which is represented by two boxes **26** and **27**.

The element **27** continuously calculates the speed of decarburation, which is indicated by indicating device **28** of known type, and the concentration of carbon of the bath by integration of this value in relationship to the unity of the metal mass is then subtracted from the initial concentration of carbon. The mass of the metal and its initial concentration of carbon are provided at **29** and **30**, and the concentration of carbon at an instant *t* is indicated by the apparatus **31** of know type.

It is unnecessary to further describe the method and apparatus for determining the speed of decarburation and the concentration of carbon in the bath since the same was already fully described above and particularly described in said U.S. patent application Ser. No. 211,999 of the same assignee of the instant application, and in Patent No. 1,309,212.

The elements **29**, **32**, **33**, **34** are respectively potentiometers which indicate the mass of the metal, its initial concentration of silicon, and the predicted drop in the concentration of manganese ($\mu_0-\mu_1$) as well as the drop in the concentration of phosphorus ($\varphi_0-\varphi_1$). Element **35** is a potentiometer which indicates the amount of oxygen delivered by the additions of the mineral.

The values coming from the potentiometers above described and the indications coming from the flow meters **16** and **24** and from the analyzers **20** and **21** are transmitted to the calculator **26** which delivers to the indicators of known type **36**, **37**, **38**, **39** (which can moreover be recording devices) the representative indications of the following values: in **36**, the quantity of oxygen which, per unit of time, is bound to the elements of the bath other than carbon, in **37** the total quantity of oxygen which is bound to these elements from a chosen instant, in **38** the total quantity of oxygen which went into the formation of FeO, and in **39** the total loss of iron.

FIG. 2 schematically represents the functions of the calculating element **26**. There is shown in this figure the flow meters **24** and **16** and the analyzers **20**, **20**_a_ and **20**_b_.

The signals delivered by these analyzers, which are proportional to concentrations α, γ, and β of CO, H_2 and CO_2, are supplied to a scanner (adder) **261** in which there is formed a signal proportional to the quantity:

$$A=[0.763\alpha+1.263\beta-0.237\gamma-0.263]$$

This signal is introduced, as well as that which is provided by the flow meter **16**, into a multiplicator **262** which delivers a signal proportional to Q_3, which is the quantity of oxygen which, per unit of time, escapes from the converter. This signal, as well as that provided by the flow meter of the gaseous oxygen and of the posting device **35** of the amount of oxygen from the mineral addition is introduced into the subtractor **263** which delivers an indication proportional to Q_2, which is to say the quantity of oxygen which, per unit of time, is bound to the elements other than carbon and which remains in the converter. The signal representing Q_2 is transmitted on the one hand to the indicator **36** and on the other hand to an integrator **264** which continuously elaborates a value proportional to:

$$Q_2=\int_0^t Q_2dt$$

This is transmitted on the one hand to the indicating apparatus **37** and to a subtractor **265** which by subtracting a quantity equally proportional to:

$$Q_2'=M\times 0.8\sigma$$

representing the maximum quantity of oxygen that can be bound to the silicon of the bath, this quantity being elaborated from the given M, σ, posted at **29** and **32**, and introduced into a multiplicator **267**.

The signal proportional to $Q_5=Q_2-Q_2'$ formed in the subtractor **265** is supplied to the indicator **38** and to a subtractor **268** which subtracts a signal representing the quantity of oxygen that is bound by the phosphorus and the manganese of the bath. The signal representative of this difference is affected by a coefficient of proportionality equivalent to a multiplication by 4.49 and is introduced to the indicator **39** which indicates the quantity of iron slagged in the form of FeO

$$\frac{Fe0}{0}=\frac{71.84}{16}=4.49$$

The signal which is proportional to the quantity of oxygen that is bound by the phosphorus and the manganese of the bath is elaborated in a multiplicator **269** as a consequence of the given M, $(\mu_0-\mu_1)$, $(\varphi_0=\varphi_1)$ at **29**, **33** and **34**.

In the above description one can designate by the word "adder" the elements such as **261** which transform the signals A and B into signals proportional to:

$$\lambda_1A+\lambda_2B$$

λ_1 and λ_2 being the numerical coefficients determined one time for the entire calculation. This designation is explained by the fact that the application of these coefficients before the addition is only a simple question of regulating the attenuators of the entrance signals, which is well known in the art and is therefore not set forth in detail in FIG. 2 which is a simplified presentation.

During a first stage of the refining, the indications of the apparatus **38** corresponding to the negative values representing the quantity of oxygen which is not yet bound by the silicon, then, after being sent through a zero value, these indications representing the quantity of oxygen bound by the iron, by the phosphorus and by the manganese.

For the purpose of improving the precision in the determination of the concentration of carbon in the bath, it is possible to insert between the designating device **29** for the mass of the bath M and the calculating device **27**, a subtractor which receives the signal representing Φ and delivers a signal proportional to $(M-\Phi)$ which represents at the end of the refining a more precise value for the mass of the liquid metal.

FIG. 3 schematically represents an arrangement for carrying out the process of the present invention in a steel mill in which the capture of the gas is effected, according to known methods, with aspiration of an excess of air, burning the CO to CO_2, and recovering the heat in a boiler.

In FIG. 3 there is shown a converter **101** into which extends a blowing lance **102** fed with pure oxygen. Above the mouth of the converter is arranged an aspirating hood **103** provided with a large opening **104** through which a large excess of air is aspirated with the gas escaping from the converter.

This hood conducts the gas in a recuperating boiler of tubular sections **105**, represented schematically, and extended by conduit **106** for evacuation of the gas. A ventilator, which is not represented, aspirates the gas in the conduit **106** at a constant pressure.

Since all of the CO is burned to CO_2 in an excess of air, it is therefore necessary in order to evaluate the quantity of oxygen leaving the converter to measure the concentrations β and $\bar{\omega}$ of the gas in CO_2 and O_2 and to process the signals corresponding thereto so as to obtain a value proportional to:

$$Q_4=[1.263(\beta+\bar{\omega})-0.263]$$

The total quantity Q_4 of the gas which is given off per unit of time in the conduit **106** is extremely important in view of the supplementary aspirated air and varies little since the pressure in the ventilator is constant. This is why in the present realization there is measured variations $\Delta\dot{Q}_4$ of this value on the one hand and on the other hand the nominal value $\dot{Q}_4n$ which is added thereto to obtain $\dot{Q}_4$.

A membrane manometer **107** connected to a pitot tube **108** placed in the conduit **106** which permits measurement of $\Delta\dot{Q}_4$. The indications of the manometer **107** are transformed in **109** into electrical signals representative of $\Delta\dot{Q}_4$ and then, in an adder **110** are algebraically added to the nominal value $\dot{Q}_4n$ which is provided at **111**.

The concentrations β and $\bar{\omega}$ of the gas in CO_2 and O_2 are measured by the analyzers **112** and **113** of known type. A potentiometer indicator **113**_a_ delivers a proportional value to kP, which is the quantity of oxygen habitually carried off from the converter by the iron oxide dust transported by each $m.^3$ of captured gas. The signals delivered by the apparatus **112**, **113**, **113**_a_ are introduced into a calculating element **114** which elaborates a value proportional to the quantity:

$$B=1.263(\beta+\bar{\omega})+kP-0.263$$

which represents the quantity of oxygen in $Nm.^3$ per unit of time that escapes from the converter.

This quantity is multiplied by $\dot{Q}_4$ in a multiplier **115** which elaborates a signal proportional to $\dot{Q}_3=Bx\dot{Q}_4$, which value represents the quantity of oxygen which leaves the converter **101** per unit of time.

The total discharge $\dot{Q}_1$ of oxygen introduced into the converter in all forms is measured by an arrangement **24**, **24**_a_, **24**_b_, identical to that of the preceding example. These indications and those delivered by the element **115** are introduced into a subtractor **116** which elaborates a signal proportional to their difference, that is to say $\dot{Q}_2$ (quantity of oxygen which is bound, per second, to the elements other than carbon).

This quantity is indicated by a device **36** and is then treated, as in the preceding example, along with the given M, σ, $\mu_0-\mu_1$, $\varphi_0-\varphi_1$, fed in respectively at **29**, **32**, **33**, **34** by means of a calculator **117** which delivers to the indicators **37**, **38**, **39** the values representing:

Q_2—the total quantity of oxygen bound at an instant in the bath, and

Q'_2—the quantity of oxygen which is still necessary to be introduced in order to burn the Si, or, after its passage to zero, the quantity of oxygen bound by Mn, P and Fe, and finally the total quantity F of iron which is slagged.

It is clear from the above that the present invention is equally applicable to gas which is captured and burned as with gas which is captured without combustion, or with only partial combustion.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of methods and apparatus differing from the types described above.

While the invention has been illustrated and described as embodied in a method and apparatus for determining the course of oxidation in an iron converter, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. A method of refining pig iron wherein the course of the refining reactions and the composition of a molten pig iron bath are continuously ascertained during oxygen blast refining in a converter in order to permit accurate adjustment of the rate of oxidation and for determination of the appropriate time for terminating the refining process, which method comprises introducing into an oxygen converter a charge of predetermined amount and composition, said charge including carbon, iron, silicon, manganese, phosphorus and oxygen; introducing an oxygen blast into the charged converter and continuously measuring the total quantity of oxygen introduced by said blast into the converter per unit of time; continuously measuring the quantity of oxygen which leaves the converter per said unit of time as free oxygen and combined with carbon; continuously measuring the quantity of oxygen bound by each of the elements of the bath other than carbon and silicon; determining by integration from all of said measurements and the determination of the amount of oxygen required for oxidizing the silicon content of said charge the total quantity of oxygen bound by the iron, the phosphorus and the manganese of said bath; and ending refining of said pig iron when said total quantities of oxygen bound by the iron, phosphorus and manganese of said path reach predetermined desired values.

2. A method of refining pig iron wherein the course of the refining reactions and the composition of a molten pig iron bath are continuously ascertained during oxygen blast refining in a converter in order to permit accurate adjustment of the rate of oxidation and for determination of the appropriate time for terminating the refining process, which method comprises introducing into an oxygen converter a charge of predetermined amount and composition, said charge including carbon, iron, silicon, manganese, phosphorus and oxygen; determining the total quantity of oxygen introduced into the converter in the form of oxygen bound in said charge; introducing an oxygen blast into the charged converter and continuously measuring the total quantity of oxygen introduced by said blast into the converter per unit of time; continuously measuring the total quantity of oxygen which leaves the converter per said unit of time as free oxygen and combined with carbon; calculating by means of a computer the quantities of oxygen which are bound respectively by the carbon of the bath, by gaseous CO and by the elements Fe, Mn, Si and P of the bath which contribute to the formation of the slag, then calculating by integration the total quantity of oxygen bound at each instant by these different elements, and calculating by difference the total quantity of oxygen bound by the elements Fe, P and Mn of said bath; and ending refining of said pig iron when said total quantities of oxygen bound by the iron, phosphorus and manganese of said bath reach predetermined desired values.

3. A method of refining pig iron wherein the course of the refining reactions and the composition of a molten pig iron bath are continuously ascertained during oxygen blast refining in a converter in order to permit accurate adjustment of the rate of oxidation and for determination of the appropriate time for terminating the refining process, which method comprises introducing into an oxygen converter a charge of predetermined amount and composition, said charge including carbon, iron, silicon, manganese, phosphorus and oxygen; introducing an oxygen blast into the charged converter and continuously measuring the total quantity of oxygen introduced by said blast into the converter per unit of time; continuously capturing the gas leaving the converter without burning of said gas, continuously measuring the quantity of oxygen in said captured gas in the form of free oxygen and combined with carbon; continuously measuring the quantity of oxygen bound by each of the elements of the bath other than carbon and silicon; determining the amount of oxygen required for oxidation of the silicon of said charge; determining from all of said measurements and determinations by integration the total quantity of oxygen bound by the iron, the phosphorus and the manganese of said bath; and ending refining of said pig iron when said total quantities of oxygen bound by the iron, phosphorus and manganese of said bath reach predetermined desired values.

4. A method of refining pig iron wherein the course of the refining reactions and the composition of a molten pig iron bath are continuously ascertained during oxygen blast refining in a converter in order to permit accurate adjustment of the rate of oxidation and for determination of the appropriate time for terminating the refining process, which method comprises introducing into an oxygen converter a charge of predetermined amount and composition, said charge including carbon, iron, silicon, manganese, phosphorus and oxygen, and measuring the total quantity of oxygen introduced into the converter in the form of oxygen bound in said charge; introducing an oxygen blast into the charged converter and continuously measuring the total quantity of oxygen introduced by said blast into the converter per unit of time; continuously capturing the gas leaving the converter without burning of said gas; continuously measuring the quantity of oxygen in said captured gas in the form of free oxygen and combined with carbon; continuously measuring the quantity of oxygen bound by each of the elements of the bath other than carbon and silicon; determining the amount of oxygen required for oxidation of the silicon of said charge; calculating by means of a computer the quantities of oxygen which are bound respectively by the carbon of the bath, by gaseous CO and by the elements Fe, Mn and P of the bath which contribute to the formation of the slag, then calculating by integration the total quantity of oxygen bound at each instant by these different elements; calculating by difference after deducting the amount of oxygen bound by silicon the total quantity of oxygen bound by the elements Fe, P and Mn of said bath; and ending refining of said pig iron when said total quantities of oxygen bound by the iron, phosphorus and manganese of said bath reach predetermined desired values.

5. A method of refining pig iron wherein the course of the refining reactions and the composition of a molten pig iron bath are continuously ascertained during oxygen blast refining in a converter in order to permit accurate adjustment of the rate of oxidation and for determination of the appropriate time for terminating the refining process, which method comprises introducing into an oxygen converter a charge of predetermined amount and composition, said charge including carbon, iron, silicon, manganese, phosphorus and oxygen; introducing an oxygen blast into the charged converter and continuously measuring the total quantity of oxygen introduced by said blast into the converter while aspirating said gas with a measured quantity of oxygen sufficient to burn all of the CO to CO_2; continuously measuring the quantity of oxygen in said captured gas in the form of free oxygen and combined with carbon in the form of CO_2; continuously measuring the quantity of oxygen bound by each of the elements of the bath other than carbon and silicon; determining the amount of oxygen required for oxidation of the silicon of said charge; continuously determining by integration from all of said measurements and the determination of the amount of oxygen required for oxidizing the silicon content of said charge the total quantity of oxygen bound by the iron, phosphorus and manganese of said bath; and ending refining of said pig iron when said total quantities of oxygen bound by the iron, phosphorus and manganese of said bath reach predetermined desired values.

6. A method of refining pig iron wherein the course of the refining reactions and the composition of a molten pig iron bath are continuously ascertained during oxygen blast refining in a converter in order to permit accurate adjustment of the rate of oxidation and for determination of the appropriate time for terminating the refining process, which method comprises introducing into an oxygen converter a charge of predetermined amount and composition, said charge including carbon, iron, silicon, manganese, phosphorus and oxygen; determining the total quantity of oxygen introduced into the converter in the form of oxygen bound in said charge; introducing an oxygen blast into the charged converter and continuously measuring the total quantity of oxygen introduced by said blast blown into the converter per unit of time; continuously capturing the gas leaving the converter while aspirating said gas with a measured quantity of oxygen sufficient to burn all of the CO to CO_2; continuously measuring the quantity of oxygen in said captured gas in the form of free oxygen and combined with carbon in the form of CO_2; continuously measuring the quantity of oxygen bound by each of the elements of the bath other than carbon and silicon; calculating by means of a computer the quantities of oxygen which are bound respectively by the carbon of the bath, by gaseous CO and by the elements Fe, Mn and P of the bath which contribute to the formation of the slag, then calculating by integration the total quantity of oxygen bound at each instant by these different elements; deducting the amount of oxygen required for oxidizing the silicon, and calculating by difference the total quantity of oxygen bound by the elements Fe, P and Mn of said bath; and ending refining of said pig iron when said total quantities of oxygen bound by the iron, phosphorus and manganese of said bath reach predetermined desired values.

7. A method of refining pig iron wherein the course of the refining reactions and the composition of a molten pig iron bath are continuously ascertained during oxygen blast defining in a converter in order to permit accurate adjustment of the rate of oxidation and for determination of the appropriate time for terminating the refining process, which method comprises introducing into an oxygen converter a charge of predetermined amount and composition, said charge comprising iron, carbon and silicon; introducing an oxygen blast into the charged converter; measuring the total quantity of oxygen which leaves the converter per unit of time in the form of free oxygen and combined with carbon; measuring the quantity of oxygen bound by each element of the bath other than carbon and silicon; determining from the amount of oxygen required for oxidation of the silicon and all of said measurements per unit of time by integration the total quantity of oxygen bound by the iron of said charge; and ending refining of said pig iron when the total quantity of oxygen bound by the iron of said charge reaches a predetermined desired value.

8. Arrangement for determining the course of the refining reactions and the composition of the molten metal bath in an oxygen converter for iron into which is introduced a charge including carbon, iron, silicon, manganese, phosphorus and oxygen and into which oxygen is blown, said arrangement comprising, in combination, means for measuring the total amount of oxygen introduced in gaseous form into said converter; means for measuring the amount of combined oxygen of the charge introduced into said converter; means for capturing the gas leaving said converter and the amount thereof; measuring means for measuring in a given time period the composition of the captured gas and for producing electrical signals representing the concentrations in the captured gas of at least one of the gases CO, CO_2, O_2 and H_2; and calculating means operatively connected to said measuring means for receiving the electrical signals produced by said measuring means and for determining therefrom the speed of the oxidation of the different elements in the charge and the quantity of oxygen bound by the elements in the charge.

9. Arrangement for determining the course of the refining reactions and the composition of the molten metal bath in an oxygen converter for iron into which is introduced a charge including carbon, iron, silicon, manganese, phosphor and oxygen and into which oxygen is blown, said arrangement comprising, in combination, means for measuring the total amount of oxygen introduced in gaseous form into said converter; means for measuring the amount of combined oxygen of the charge introduced into said converter; means for capturing the gas leaving said converter and the amount thereof, measuring means for measuring in a given time period the composition of the captured gas and for producing electrical signals representing the concentration in the captured gas of at least one of the gases CO, CO_2, O_2 and H_2; and calculating means operatively connected to said measuring means for receiving the electrical signals produced by said measuring means and being programmed according to pre-established mathematical formulas to calculate therefrom the speed of the oxidation of the different elements in the charge and the quantity of oxygen bound by the elements in the charge.

10. Arrangement for determining the course of the refining reactions and the composition of the molten metal bath in an oxygen converter for iron into which is introduced a charge including carbon, iron, silicon, manganese, phosphorus and oxygen and into which oxygen is blown, said arrangement comprising, in combination, means for measuring the total amount of oxygen introduced in gaseous form into said converter; means for measuring the amount of combined oxygen of the charge introduced into said converter; means for capturing the gas leaving said converter and the amount thereof without burning of the captured gas; measuring means for measuring in a given time period the composition of the captured gas and for producing electrical signals representing the concentration in the captured gas of at least one of the gases CO, CO_2, O_2 and H_2; and calculating means operatively connected to said measuring means for receiving the electrical signals produced by said measuring means and for determining therefrom the speed of the oxidation of the different elements in the charge and the quantity of oxygen bound by the elements in the charge.

11. Arrangement for determining the course of the refining reactions and the composition of the molten metal bath in an oxygen converter for iron into which is introduced a charge including carbon, iron, silicon, manganese, phosphorus and oxygen and into which oxygen is blown, said arrangement comprising, in combination, means for measuring the total amount of oxygen introduced in gaseous form into said converter; means for measuring the amount of combined oxygen of the charge introduced into said converter; means for capturing the gas leaving said converter and the amount thereof without burning of the captured gas; measuring means for measuring in a given time period the composition of the captured gas and for producing electrical signals representing the concentration in the captured gas of at least one of the gases CO, CO_2, O_2 and H_2; and calculating means operatively connected to said measuring means for receiving the electrical signals produced by said measuring means and being programmed according to pre-established mathematical formulas to calculate therefrom the speed of the oxidation of the different elements in the charge and the quantity of oxygen bound by the elements in the charge.

12. Arrangement for determining the course of the refining reactions and the composition of the molten metal bath in an oxygen converter for iron into which is introduced a charge including carbon, iron, silicon, manganese, phosphorus and oxygen and into which oxygen is blown, said arrangement comprising, in combination, means for measuring the total amount of oxygen introduced in gaseous form into said converter; means for measuring the amount of combined oxygen of the charge introduced into said converter; means for capturing the gas leaving said converter and the amount thereof while aspirating the captured gas with a predetermined amount of oxygen sufficient to burn all of the CO to CO_2; measuring means for measuring in a given time period the composition of the captured gas and for producing electrical signals representing the concentration in the captured gas of at least one of the gases CO_2, O_2 and H_2; and calculating means operatively connected to said measuring means for receiving the electrical signals produced by said measuring means and for determining therefrom the speed of the oxidation of the different elements in the charge and the quantity of oxygen bound by the elements in the charge.

13. Arrangement for determining the course of the refining reactions and the composition of the molten metal bath in an oxygen converter for iron into which is introduced a charge including carbon, iron, silicon, manganese, phosphorus and oxygen and into which oxygen is blown, said arrangement comprising, in combination, means for measuring the total amount of oxygen introduced in gaseous form into said converter; means for measuring the amount of combined oxygen of the charge introduced into said converter; means for capturing the gas leaving said converter and the amount thereof while aspirating the captured gas with a predetermined amount of oxygen sufficient to burn all of the CO to CO_2; measuring means for measuring in a given time period the composition of the captured gas and for producing electrical signals representing the concentration in the captured gas of at least one of the gases CO_2, O_2 and H_2; and calculating means operatively connected to said measuring means for receiving the electrical signals produced by said measuring means and being programmed according to pre-established mathematical formulas to calculate therefrom the speed of the oxidation of the different elements in the charge and the quantity of oxygen bound by the elements in the charge.

14. Arrangement for determining the course of the refining reactions and the composition of the molten metal bath in an oxygen converter for iron into which is introduced a charge including carbon, iron, silicon, manganese, phosphorus and oxygen and into which oxygen is blown, said arrangement comprising, in combination, means for measuring the total amount of oxygen introduced in gaseous form into said converter; means for measuring the amount of combined oxygen of the charge introduced into said converter; means for capturing the gas leaving said converter and the amount thereof while aspirating the captured gas with a predetermined amount of oxygen sufficient to burn only a portion of the CO to CO_2; measuring means for measuring in a given time period the composition of the captured gas and for producing electrical signals representing the concentration in the captured gas of the gases CO, CO_2, O_2 and H_2 and by the difference therebetween and 100% the concentration of N_2; and calculating means operatively connected to said measuring means for receiving the electrical signals produced by said measuring means and for determining therefrom the speed of the oxidation of the different elements in the charge and the quantity of oxygen bound by the elements in the charge.

15. Arrangement for determining the course of the refining reactions and the composition of the molten metal bath in an oxygen converter for iron into which is introduced a charge including carbon, iron, silicon, manganese, phosphorus and oxygen and into which oxygen is blown, said arrangement comprising, in combination, means for measuring the total amount of oxygen introduced in gaseous form into said converter; means for measuring the amount of combined oxygen of the charge introduced into said converter; means for capturing the gas leaving said converter and the amount thereof while aspirating the captured gas with a predetermined amount of oxygen sufficient to burn only a portion of the CO to CO_2; measuring means for measuring in a given time period the composition of the captured gas and for producing electrical signals representing the concentration in the captured gas of the gases CO, CO_2, O_2 and H_2 and by the difference therebetween and 100% the concentration of N_2; and calculating means operatively connected to said measuring means for receiving the electrical signals produced by said measuring means and being programmed according to pre-established mathematical formulas to calculate therefrom the speed of the oxidation of the different elements in the charge and the quantity of oxygen bound by the elements in the charge.

16. Arrangement for determining the course of the refining reactions and the compositions of the molten metal bath in an oxygen converter for iron into which is introduced a charge including carbon, iron, silicon, manganese, phosphorus and oxygen and into which oxygen is blown, said arrangement comprising, in combination, means for measuring the total amount of oxygen introduced in gaseous form into said converter; means for measuring the amount of combined oxygen of the charge introduced into said converter; means for capturing the gas leaving said converter and the amount thereof while aspirating the captured gas with a predetermined amount of oxygen sufficient to burn all of the CO to CO_2; measuring means for measuring in a given time period of the composition of the captured gas and for producing electrical signals representing the concentration in the captured gas of the gases CO_2, O_2 and H_2 and by the difference therebetween and 100% the concentration of N_2; and calculating means operatively connected to said measuring means for receiving the electrical signals produced by said measuring means and for determining therefrom the speed of the oxidation of the different elements in the charge and the quantity of oxygen bound by the elements in the charge.

17. Arrangement for determining the course of the refining reactions and the composition of the molten metal bath in an oxygen converter for iron into which is introduced a charge including carbon, iron, silicon, manganese, phosphorus and oxygen and into which oxygen is blow, said arrangement comprising, in combination, means for measuring the total amount of oxygen introduced in gaseous form into said converter; means for measuring the amount of combined oxygen of the charge introduced into said converter; means for capturing the gas leaving said converter and the amount thereof while aspirating the captured gas with a predetermined amount of oxygen sufficient to burn all of the CO to CO_2; measuring means for measuring in a given time period the composition of the captured gas and for producing electrical signals representing the concentration in the captured gas of the gases CO_2, O_2 and H_2 and by the difference therebetween and 100% the concentration of N_2; and calculating means operatively connected to said measuring means for receiving the electrical signals produced by said measuring means and being programmed according to pre-established mathematical formulas to calculate therefrom the speed of the oxidation of the different elements in the charge and the quantity of oxygen bound by the elements in the charge.

18. Arrangement for continuously determining the course of the refining reactions and the composition of the molten metal bath in an oxygen converter for iron into which is introduced a charge including at least iron, carbon and silicon and into which oxygen is blown, said arrangement comprising in combination, means for measuring the total amount of oxygen introduced in gaseous form into said converter; means for measuring the amount of combined oxygen of the charge introduced into said converter; means for capturing the gas leaving said converter and the amount thereof; measuring means for measuring in a given time period the composition of the captured gas and for producing electrical signals representing the concentration in the captured gas of at least one of the gases of CO, CO_2, O_2 and H_2, and calculating means operatively connected to said measuring means for receiving the electrical signals produced by said measuring means and for determining therefrom the speed of the oxidation of the different elements in the charge and the quantity of oxygen bound by the elements in the charge.

19. Arrangement for continuously determining the course of the refining reactions and the composition of the molten metal bath in an oxygen converter for iron into which is introduced a charge including at least iron, carbon and silicon and into which oxygen is blown, said arrangement comprising in combination, means for measuring the total amount of oxygen introduced in gaseous form into said converter; means for measuring the amount of combined oxygen of the charge introduced into said converter; means for capturing the gas leaving said converter and the amount thereof; measuring means for measuring in a given time period the composition of the captured gas and for producing electrical signals representing the concentration in the captured gas of at least one of the gases CO, CO_2, O_2 and H_2; and calculating means operatively connected to said measuring means for receiving the electrical signals produced by said measuring means and being programmed according to pre-established mathematical formulas to calculate therefrom the speed of the oxidation of the different elements in the charge and the quantity of oxygen bound by the elements of the charge.

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U.S. Cl. X.R.

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