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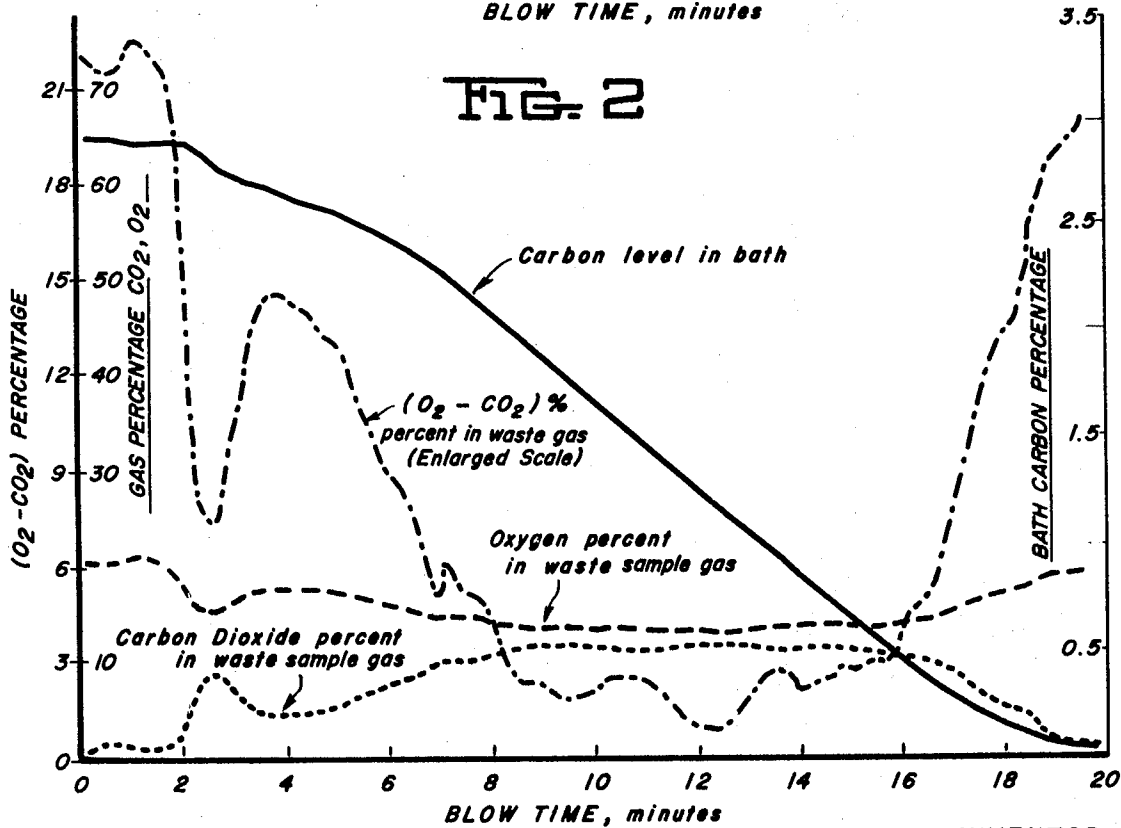
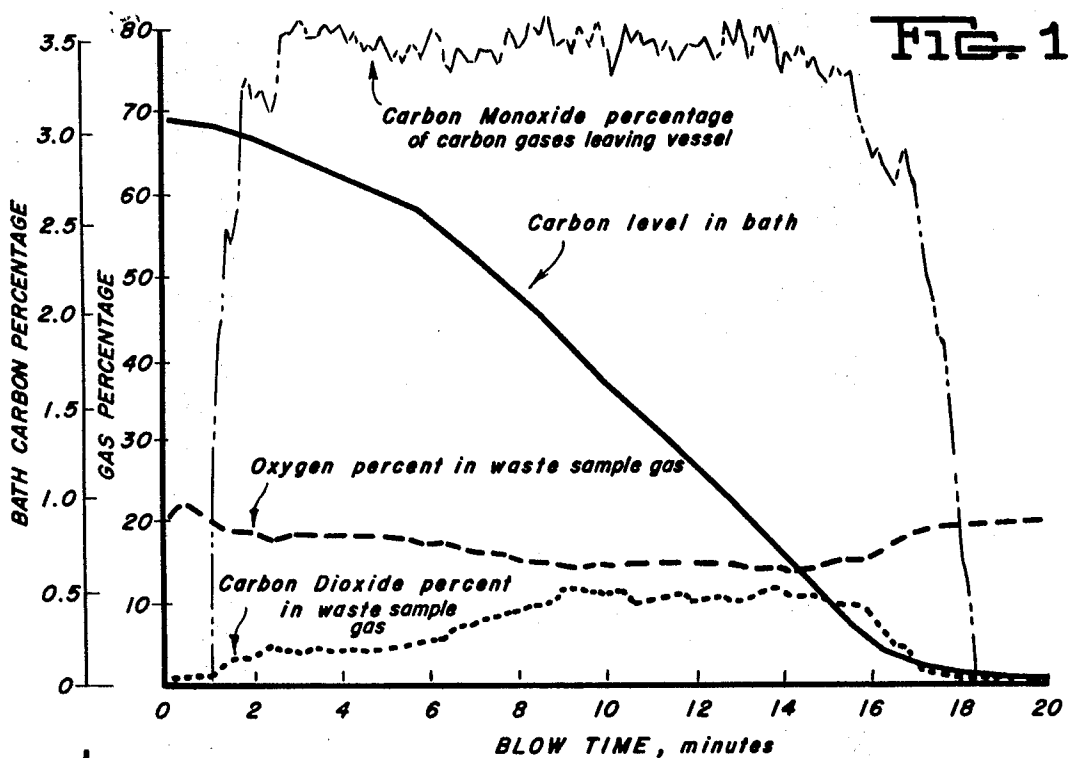
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[50]	Field of Search.....	75/60; 23/230

3,181,343	5/1965	Fillon	73/23
3,236,630	2/1966	Stephan.....	75/60
3,329,495	7/1967	Ohta et al.....	75/60
3,377,158	4/1968	Meyer et al.....	75/60
3,432,288	3/1969	Ardito et al.....	75/60
3,463,631	8/1969	Vayssiere et al.....	75/60
3,485,619	12/1969	Maatsch et al.....	75/60
3,489,518	1/1970	Revell et al.....	75/60 X
3,520,657	7/1970	Frumerman.....	23/230
3,528,800	9/1970	Blum et al.....	75/60

The graph plots five variables against blow time in minutes (0 to 20). The left y-axis represents Bath Carbon Percentage (0 to 3.5) and Gas Percentage (0 to 80). The right y-axis represents Gas Percentage (0 to 80). The variables are:

- Carbon Monoxide percentage of carbon gases leaving vessel:** A jagged line starting at ~70%, peaking at ~75% around 4 minutes, and then fluctuating between 70% and 80%.
- Carbon level in bath:** A solid line starting at ~3.0%, decreasing steadily to ~1.0% at 16 minutes, and then dropping sharply to 0% by 18 minutes.
- Oxygen percent in waste sample gas:** A dashed line starting at ~18%, decreasing slightly to ~15% at 10 minutes, and then rising to ~18% by 20 minutes.
- Carbon Dioxide percent in waste sample gas:** A dotted line starting at 0%, rising to ~10% at 10 minutes, and then dropping to 0% by 18 minutes.

Blow Time (minutes)	Carbon Monoxide (%)	Carbon level in bath (%)	Oxygen percent (%)	Carbon Dioxide percent (%)
0	70	3.0	18	0
2	75	2.8	17	2
4	75	2.5	17	5
6	75	2.2	16	8
8	75	1.8	15	10
10	75	1.4	15	10
12	75	1.1	15	8
14	75	0.8	15	5
16	75	1.0	15	2
18	75	0	15	0
20	75	0	18	0



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PROCESS FOR CONTROLLING THE CARBON CONTENT OF A MOLTEN METAL BATH

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a process for controlling the carbon content of a molten-metal bath and more particularly to a process for controlling the carbon content of a molten-metal bath in a top blown oxygen converter by determining the carbon content of the molten-metal bath when a phase change occurs in the carbon reaction process and thereafter determining the carbon evolved as a gas from the converter.

2. Description of the Prior Art

In a top blown oxygen converter oxygen is introduced into a molten-metal bath to oxidize the impurities and carbon. A controlled amount of carbon is removed from the molten-metal bath in gaseous form to produce steel containing a predetermined percentage of carbon. The control and measurement of the carbon content of the molten-metal bath by the prior techniques used in open hearth type furnaces is not possible with the top blown oxygen converter because of the rapidity at which the conversion takes place. The extraction of samples of the molten metal during the conversion process for carbon determination by chemical analysis has also proved impractical.

Several proposals have been made in the past to continuously determine the carbon content of a molten-metal bath in a top blown oxygen converter. U.S. Pat. No. 3,181,343 determines the carbon content of the molten-metal bath at turn-down by a continuous subtracting of the summated carbon present in the waste gas from the total carbon in the material initially fed to the converter. This process has one major inherent source of error. The total initial carbon content of the materials is determined by calculating the saturation carbon level in the hot metal and the carbon in the other constituents of the charge. Errors occur in sample analysis and the temperature of the hot metal which result in errors in the carbon content of the hot metal. It is also difficult to assess the carbon content of varying grades of scrap, pig iron and the like. The magnitude and deviation of the summated errors, although possibly small in comparison with the initial carbon level, are of the same magnitude and deviation to the final carbon level, thus making this process impractical for reliable low carbon steel conversion processes.

Others have attempted to avoid the induced errors of the above process by eliminating the determination of the total carbon content of the material supplied to the converter. In U.S. Pat. No. 3,329,495 the amount of waste gas given off during the conversion process is continuously measured and the amount of carbon dioxide and carbon monoxide present in the waste gas is also continuously measured. These measurements are correlated to determine the decarburizing velocity during the conversion process and the decarburization velocity is differentiated to obtain the decarburizing acceleration. The times at which changes occur in the decarburizing acceleration are noted and the carbon content of the molten metal bath is determined. The above process is dependent on the rate of carbon decarburization and the relatively small changes in both the velocity and acceleration must be carefully and accurately measured, which is difficult, especially during the initial stages of the conversion process.

In U.S. Pat. No. 3,377,158 the carbon oxidation rate is determined by measuring the carbon dioxide and oxygen in the waste gas and the amount of oxygen blown during the same period of time. From these measurements the carbon oxidation rate is calculated and a curve is established correlating the carbon oxidation rate with the carbon content of the molten-metal bath. The curve is extrapolated for the carbon oxidation rate to zero carbon and curves from previous blows are used to determine the approximate quantity of carbon remaining in the molten-metal bath and thereafter a fixed quantity of oxygen is supplied to the bath to obtain molten metal with a desired carbon content.

In U.S. Pat. No. 3,326,630 the oxygen content of the waste gases is measured and the conversion process is terminated when the oxygen content reaches a given value. It is stated the carbon content of the molten-metal bath is directly related to the oxygen content of the waste gas.

It will be apparent that the above processes require accurate and continuous measurement of both the volume and the composition of the waste gases to determine the carbon content at any given period during the conversion process. It is difficult to obtain the above measurements with the degree of accuracy required for low carbon steels.

SUMMARY OF THE INVENTION

According to the present invention continuous, accurate volumetric measurement and accurate composition of the waste gas is not required to determine the carbon content of the molten-metal bath when a phase change occurs in the carbon reaction process. This phase change is determined by measuring both the amount of carbon dioxide in the waste gas and the amount of unreacted oxygen present in the waste gas. The phase change in the carbon reaction process takes place. When there is a simultaneous rapid decrease in the amount of carbon dioxide and a rapid increase in the amount of unreacted oxygen present in the waste gas, the carbon content of the molten-metal bath at the time of this phase change is substantially the same for a majority of the heats and is not dependent on the total carbon in the initial charge nor dependent on the rate of decarburization. With the known carbon content of the molten-metal bath determined at the time of the phase change, the amount of carbon removed thereafter is determined by summing the carbon in the gaseous carbon compounds evolved as a gas and subtracting the summated value from the known amount of carbon in the bath.

Accordingly, the primary object of this invention is to determine the carbon content of a molten-metal bath without first determining the total carbon in the charge fed to the converter.

Another object of this invention is to control the carbon content of a molten-metal bath without continually and accurately measuring the volume and composition of the waste gas.

A still further object of this invention is to provide a method of accurately determining the carbon content of a molten-metal bath at a preselected time during the reduction process.

These and other objects and advantages of this invention will be more completely disclosed and described in the following specification, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graphical representation of the change in the oxygen and carbon dioxide composition of the waste gas during the reduction process and illustrating the rapid change in the amounts of unreacted oxygen and carbon dioxide at the time when the phase change occurs in the conversion process.

FIG. 2 is a graphical representation similar to FIG. 1 for a different heat illustrating the change in the composition of the waste gas at the time of the phase change and includes a graphical representation of difference between the amount of unreacted oxygen and the amount of carbon dioxide in the waste gas and the rapid increase in this value at the time of the phase change.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In accordance with the present invention a gas analyzer is adapted to receive and analyze the waste gases given off by the converter during the conversion process. Suitable apparatus for analyzing the waste gases is disclosed and described in U.S. Pat. No. 3,489,518, entitled "Carbon Determination and Apparatus." It should be understood, however, other apparatus may be used that is suitable to determine the volume and composition of the waste gas. The percent carbon dioxide present in the waste gas is periodically measured and plotted.

Similarly, the percent unreacted oxygen in the waste gas is periodically determined and plotted on the same graph as the percent carbon dioxide in the waste gas.

In order to determine the constant for the particular converter, the time at which the percent carbon dioxide in the waste gas rapidly decreases and the percent oxygen in the waste gas rapidly increases is noted. Subsequent to the time when the phase change occurs, the carbon content of the waste gas is continually measured and converted to a bath level until the termination of the conversion process. The steel is carefully analyzed for carbon and the total carbon remaining in the steel is determined. By back calculation according to the following equation, the carbon content at the time of the phase change is determined:

$$(I) \quad CF + CWG = CPC$$

Where CF is the carbon content of the end product and CWG is a summation of the carbon evolved after the phase change was observed converted to the equivalent bath carbon loss, CPC is a constant indicating the carbon content of substantially all molten-metal baths in a particular converter at the time the phase change occurs. Values of CPC for several heats are measured to obtain a statistically accurate average constant for subsequent heats.

Thereafter the CPC for the particular converter is employed as the starting point for controlling the carbon content of the particular molten-metal bath. Since the phase change in the carbon reaction process does not occur until the latter part of the conversion process, the measurement of the waste gases for the early part of the blow is not necessary. For example, the gas analyzer can be activated in a conventional B.O.F. process after the conversion process determined from the start of the oxygen blow has continued for about 12 to 14 minutes. Thereafter the gas analyzer periodically measures both the percent of oxygen in the waste gas and the percent carbon dioxide in the waste gas. When the curves for oxygen and carbon dioxide simultaneously and rapidly continue to diverge, as illustrated in FIG. 1, the carbon content of the molten metal bath is known. Thereafter the carbon content of the waste gases is carefully measured, summated and subtracted from the known carbon content and the conversion process is terminated when the desired level of carbon is present in the molten-metal bath. The carbon content at the termination of the conversion process CF is determined according to the following equation:

$$(II) \quad CF = CPC - \frac{\sum_{TPC}^{TF} CWG}{TPC}$$

where $\sum CWG$ is the summation of the carbon evolved in the waste gases calculated for the actual bath carbon reduction between the time the phase change occurs TPC and the time the conversion process is terminated TF.

As illustrated in FIG. 2, the difference between the percent oxygen in the waste gas and the percent carbon dioxide in the waste gas may also be used to determine the phase change of the carbon conversion process. The curve for the difference between the oxygen and carbon dioxide in the waste gas rapidly increases when the phase change occurs, as is illustrated in FIG. 2. It is desirable, however, due to the gas fluctuations, not to measure the difference in the percent oxygen and carbon dioxide in the waste gas until the conversion process has progressed for a predetermined period of time, for example in FIG. 2 after the conversion process has progressed for about 14 minutes, after which the measurement of the difference between the oxygen and carbon dioxide in the waste gas is continually measured and plotted against the total elapsed time of the conversion process. The carbon content of the molten metal at the termination of the conversion process may be determined in substantially the same manner as described above.

The information from the gas analyzer may be transmitted to a computer which, in turn, will translate the information and provide a continuous plot of the percent oxygen and percent carbon dioxide in the waste gas and quickly indicate when the phase change occurs in the conversion process. The computer can also be utilized to summate the carbon evolved in the waste gas after the phase change has occurred and continually equate and subtract the summated carbon evolved to periodically determine the remaining carbon in the molten-metal bath so that the conversion process may be terminated when the carbon content of the molten-metal bath reaches a desired preselected level. Also, the computer can determine the volume of oxygen required after the phase change occurs to react with the carbon in the molten-metal bath and remove sufficient additional carbon to provide a desired carbon level at the termination of the conversion process. After the predetermined volume of oxygen is supplied through the lance, the conversion process is terminated.

The following example illustrates the manner of controlling the carbon content of a molten-metal bath.

EXAMPLE I

A charge comprising the following constituents was fed to a converter:

hot metal	240,800 lbs.
scrap metal	108,600 lbs.
fluxes	37,710 lbs.

By prior determination it was noted that the carbon phase change in the molten metal occurred when the molten metal contained 0.330 percent carbon.

An oxygen lance was lowered into the converter and oxygen was delivered through the lance at a constant rate. After approximately 14 minutes the gas analyzer was actuated to periodically measure at 5-second intervals the total volume of the waste gas in the stack, the volume of carbon dioxide in the waste gas and the volume of the unreacted oxygen in the waste gas in the stack. Other measurements were taken but were not pertinent to the instant invention. The following table illustrates the periodic measurements. The time was measured from the start of the conversion and the volume of the gases at standard temperature and pressure were determined and summated at 5-second intervals.

TABLE I

Time	VTOTWG	VCO2WG	VO2WG
14.00	18982.6	2156.9	2634.1
14.50	18356.0	1967.2	2616.8
15.00	18739.6	1968.6	2694.1
15.50	19187.9	1827.7	2851.5
15.58	19500.8	1862.9	2893.1
15.75	19755.1	1891.2	2939.1
15.91	19702.5	1857.1	2942.0
16.00	19913.0	1862.2	2994.6
16.25	19633.7	1553.0	3123.4
16.50	20244.4	1260.6	3381.8

The above information was transmitted to a computer and the computer converted the above information into volume percent and plotted the converted values against the lapsed time of the conversion process to provide a graphical representation, as illustrated in FIG. 1. It is apparent at approximately 15.58 a phase change occurred in the carbon reduction process and the molten-metal bath at that time contained 0.330 percent carbon.

It was also desired to provide an end product having 0.036 percent carbon and the volume of oxygen to remove an additional 0.294 percent (0.330%—0.036%) carbon from the bath was determined by the computer and the time required to

supply this volume of oxygen at a predetermined flow rate determined to be 4 minutes from the time of the phase change. The conversion process was continued for approximately 4 minutes to provide a lapsed time of 20.00 minutes at which time the desired carbon level of 0.036 percent had been reached and the conversion process was terminated.

After the phase change had occurred, i.e. 15.58 minutes had elapsed in the conversion process from start of the oxygen blow, the volume of the carbon dioxide and the volume of the carbon monoxide in the stack waste gases were carefully recorded by the analyzer and transmitted to the computer and the carbon content of the gases leaving the converter were continually summated, equated and subtracted from the known carbon level at the time of the phase change and the computer indicated when the molten-metal bath had reached a carbon level of 0.036 percent. On turndown, the product was chemically analyzed for carbon. The accuracy of the above process has proven well within ± 0.05 percent carbon.

Also, as illustrated in FIG. 1, the percent of carbon monoxide leaving the converter, as distinguished from the waste gases in the stack, in concurrence with equilibrium calculations decreases sharply after the phase conversion has taken place.

EXAMPLE II

A similar conversion process was carried out where the difference between the percent oxygen and the percent carbon dioxide in the waste gases was plotted after the conversion process had been in progress about 14 minutes. At about 16 minutes the value for the above difference between the oxygen and carbon monoxide gases increased sharply and continuously indicating that the phase change had occurred and 0.330 percent carbon was then present in the molten metal.

According to the provisions of the patent statutes, I have explained the principle, preferred construction, and mode of operation of my invention and have illustrated and described what I now consider to represent its best embodiment.

I claim:

1. A method for determining when a molten-metal bath in a particular top blown oxygen converter contains a predetermined amount of carbon comprising,

- a. feeding oxygen to a converter containing a molten-metal bath at a predetermined rate,
- b. periodically measuring the amount of unreacted oxygen in the waste gas,
- c. periodically measuring the amount of carbon dioxide in the waste gas,
- d. noting the time when there is a simultaneous and continuous increase in the amount of unreacted oxygen and a continuous decrease in the amount of carbon dioxide in the waste gas,
- e. thereafter measuring the total amount of carbon removed from the molten-metal bath until the conversion process is terminated,
- f. determining the total carbon content of the molten-metal bath after the conversion process is terminated, and
- g. determining from the values obtained by steps (e) and (f) the carbon content of the molten-metal bath at the time during the conversion process when there is a simultaneous and continuous increase in the amount of unreacted oxygen and decrease in the amount of carbon dioxide in the waste gas.

2. A method of determining when a molten-metal bath in a particular top blown oxygen converter contains a predetermined amount of carbon as set forth in claim 1 in which the carbon content of the molten-metal bath at the time there is a simultaneous and continuous increase in the amount of unreacted oxygen and decrease in the amount of carbon dioxide expressed as CPC is determined from the relationship

$$CPC=CF+CWG$$

where CF is the total carbon content of the molten-metal bath after the conversion process is terminated and CWG is the summation of the carbon removed from the molten-metal bath after the simultaneous and continuous increase in the amount of unreacted oxygen and decrease in the amount of carbon dioxide in the waste gas has occurred.

3. A method for controlling the carbon content of a molten-metal bath in a top blown oxygen converter comprising,

- a. feeding oxygen to a converter containing a molten-metal bath at a preselected rate,
- b. measuring the amount of unreacted oxygen in the waste gas,
- c. measuring the amount of carbon dioxide in the waste gas,
- d. determining the time the phase change occurs in the carbon oxygen reaction by noting the time when a simultaneous and continuous increase in the amount of unreacted oxygen and a continuous decrease in the amount of carbon dioxide in the waste gas occurs,

e. determining the carbon content of the molten-metal bath at the time the phase change occurs in the carbon reaction from the previous metal conversions in the same converter by measuring in the previous metal conversions the total amount of carbon removed from the molten-metal bath from the time the phase change occurs until the conversion process is terminated, determining the total carbon content of the molten-metal bath in the same previous metal conversions after the conversion process is terminated and determining from the carbon content values the carbon content of the molten-metal bath at the time during the conversion process that the phase change occurred,

f. feeding oxygen to the converter to remove additional carbon from the molten-metal bath,

g. continuously summating from the waste gases the amount of carbon removed from the molten-metal bath after the phase change occurs,

h. continuously reducing the amount of carbon present in the molten-metal bath at the time the phase change occurred by the summated amount of carbon removed from the molten-metal bath after the phase change occurred, and

i. terminating the conversion process when the carbon content of the molten-metal bath reaches a preselected value.

4. A method for controlling the carbon content of a molten-metal bath in a top blown oxygen converter as set forth in claim 3 which includes,

determining the volume of oxygen required to react with the carbon in the molten metal after the phase change occurs to remove a predetermined amount of carbon from the molten-metal bath and reduce the carbon content to a preselected value,

feeding said predetermined volume of oxygen to the converter to remove said predetermined amount of carbon, and

terminating the conversion process after said volume of oxygen has been delivered to said converter.

5. A method for controlling the carbon content of a molten-metal bath as set forth in claim 3 which includes,

a. measuring the amount of unreacted oxygen in the waste gas,

b. measuring the amount of carbon dioxide in the waste gas, and

c. determining the time the phase change occurs in the carbon-oxygen reaction by noting the time the difference between the amount of unreacted oxygen and the amount of carbon dioxide in the waste gas increases substantially and continuously.

6. A method for controlling the carbon content of a molten-metal bath as set forth in claim 3 which includes,

measuring the amount of carbon removed from the molten-metal bath after the phase change occurs.

7. A method for controlling the carbon content of a molten-metal bath in a top blown oxygen converter as set forth in claim 3 which includes, initiating the measurement of the amount of unreacted oxygen and the amount of carbon dioxide in the waste gas after the conversion process has progressed a preselected period of time.

8. A method for controlling the carbon content of a molten-metal bath in a top blown oxygen converter as set forth in claim 3 which includes, terminating the conversion process when the molten metal bath contains below 0.30 percent carbon.

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