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B. BLUM ET AL

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ESTIMATED TAP TEMPERATURE CALCULATOR FOR BASIC OXYGEN FURNACE

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FIG. 1

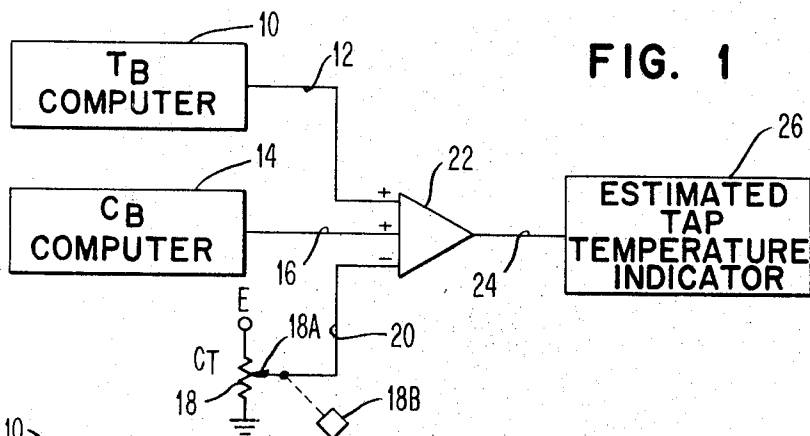


FIG. 2

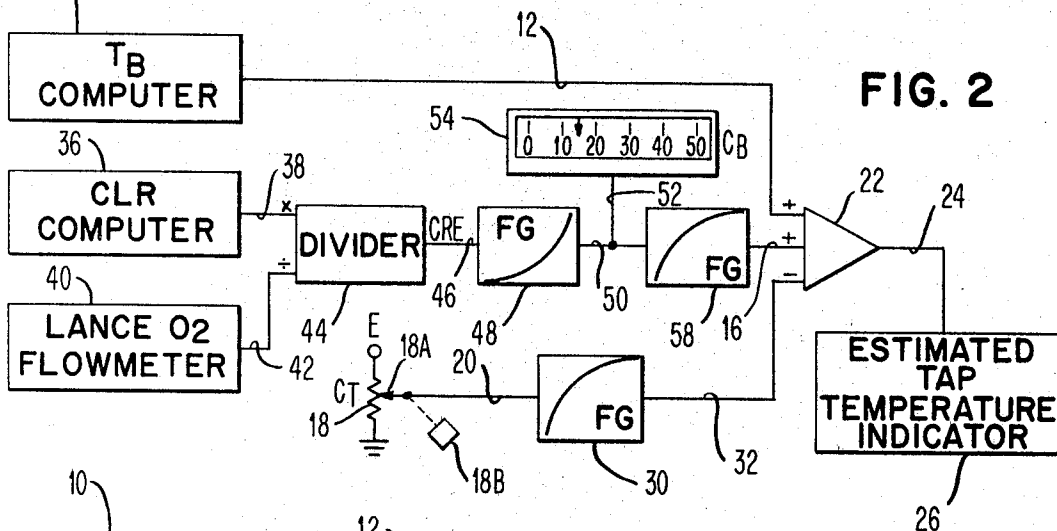
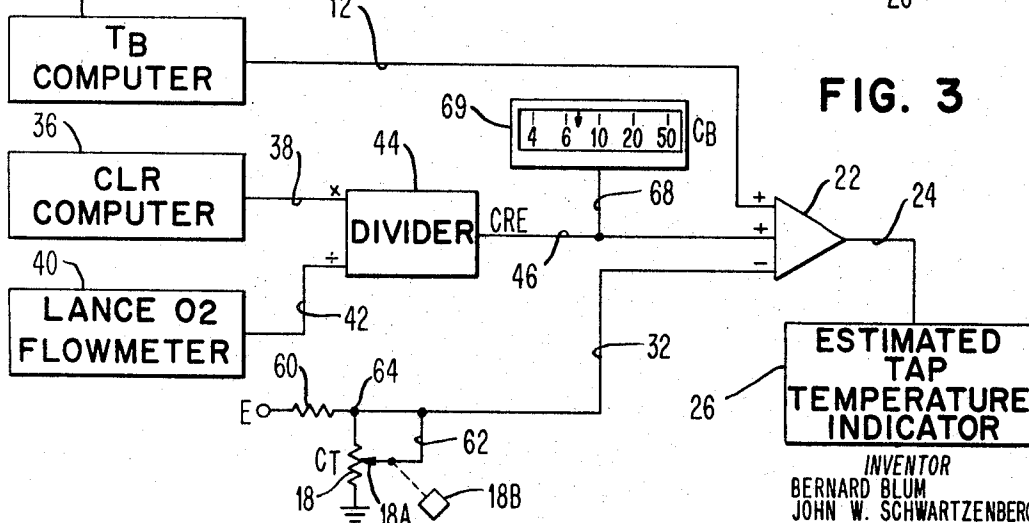


FIG. 3



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ESTIMATED TAP TEMPERATURE CALCULATOR FOR BASIC OXYGEN FURNACE

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12 Claims

This invention relates to a method and means for calculating that temperature of the bath in a basic oxygen furnace which is to be anticipated at the time when the heat is ready for tapping and more particularly, the means and methods for calculating the estimated tap temperature from existing values of process variables and the carbon content desired at tapping.

During the process of refining pig iron to produce steel in a basic oxygen furnace, a large amount of heat is produced by the refining process itself. This heat along with the heat content of the bath at the beginning of the refining process determines the final temperature of the bath. During certain portions of the refining process, the heat released is primarily due to the oxidation of carbon from the bath to form carbon monoxide and carbon dioxide while at other times during the process, a significant portion of the heat released is due to the FeO which is made in the slag cover of the bath.

It is usually desired that the operator should know as soon as possible during a heat the temperature which he can expect at the time when the carbon content of the bath is at the desired value for tapping. Therefore, a calculation of the estimated tap temperature during the process is capable of providing a very useful indication so that the operator may take any necessary steps to modify the temperature of the bath so as to produce a suitable tapping temperature at the time when the desired tap carbon has been reached.

It is therefore an object of this invention to provide a method and/or means for determining the estimated tap temperature continuously during the refining process in a basic oxygen furnace.

It is a further object of this invention to provide a means for computing the estimated tap temperature from continuously determined values for certain process variables.

In carrying out the above objects, the present invention, in one form, provides means for producing a bath temperature signal which is representative of the existing bath temperature. There is also produced a tap carbon signal representative of the temperature change which would be associated with the oxidation of the amount of carbon which is desired as the remaining carbon content of the bath after the refining process. The tap carbon signal is subtracted from a bath carbon signal which is produced to be representative of the temperature change which would be associated with the existing bath carbon content. The difference between the bath carbon and tap carbon signals is then added to the bath temperature signal to obtain the estimated tap temperature.

For a more detailed understanding of the invention and for an illustration of a preferred form thereof reference is made to the drawings in which:

FIG. 1 is a block diagram showing a circuit which is useful in obtaining the estimated tap temperature during high carbon heats.

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FIG. 2 is a modification of the circuit of FIG. 1 utilizing a different means for obtaining the signal representative of the temperature change associated with the bath carbon content.

FIG. 3 is still another variation of FIG. 1 showing an alternative but preferred means for producing the signal representative of the temperature change associated with the bath carbon content as well as a preferred form for obtaining the signal representative of the temperature change associated with the tap carbon content.

With reference to FIG. 1, it will be evident that the estimated tap temperature indication is obtained by combining several signals. The first of these signals is obtained from the bath temperature computer 10 which may be any one of a number of computer arrangements designed to continuously determine during the process the temperature (TB) of the bath. The computer 10 puts out a signal on line 12 which is indicative of the bath temperature.

The second signal which is utilized in calculating the estimated tap temperature is derived from the bath carbon (CB) computer 14 which is designed to continuously determine the carbon content of the bath in the basic oxygen furnace during the processing procedure. An output signal from the bath carbon computer is produced on line 16. This bath carbon signal is preferably representative of the temperature change which would be effected in the bath if the amount of carbon calculated to be contained in the bath by computer 14 were combined with the oxygen introduced into the bath by the lance.

The third signal which is necessary for the calculation of the estimated tap temperature is produced in FIG. 1 by the adjustment of adjustable contact 18A on potentiometer slidewire 18 by knob 18B so as to vary the potential on the output line 20 linearly with the movement of the knob 18B. As shown in FIG. 1, the potentiometer slidewire 18 has its upper terminal connected to a potential source E and its lower terminal connected to ground. There is thus produced on line 20 a tap carbon signal which is representative of the temperature change which would be effected by the combination of the amount of carbon which is desired as the remaining content in the steel at time of tapping with the oxygen supplied by the lance, or in other words, it is the temperature equivalent of the tap carbon for the bath in the basic oxygen furnace.

As shown in FIG. 1, the signals on lines 12, 16 and 20 are introduced as input signals into an amplifier 22, the signals on line 12 and 16 being added while the signal on line 20 subtracts from the sum thus obtained. There is thus produced an output from amplifier 22 on line 24 which is a composite signal supplied to the indicator 26 and representative of the estimated tap temperature.

The circuit diagram shown in block form in FIG. 1 is particularly useful in determining the estimated tap temperature for high carbon heats. Such heats do not usually involve the production of a large amount of slag FeO and therefore the signal on line 16 can be a linear function of the carbon content calculated for the bath and the signal on line 20 can be a linear function of the tap carbon value set by knob 18B. Both the bath carbon signal and the tap carbon signal as established by computer 14 and the potentiometer 18 respectively are in terms of points of carbon so that the signals provided on lines 16 and 20, respectively, are independent of the bath weight.

The bath temperature computer 10 may be any one of a number of computers designed to continuously compute the temperature of the bath. One example of such a computer is disclosed in our co-pending U.S. application Ser. No. 444,014. Also, in this co-pending application we have disclosed a means for computing the bath carbon, which means could be utilized as the bath carbon computer 14 of FIG. 1. Alternatively, the bath carbon could be computed in a manner disclosed in U.S. Patent 3,181,343 issued to J. D. Fillon on May 4, 1965.

When the heats to be produced by the basic oxygen furnace are what are commonly referred to as low carbon heats, a variation in the type of circuit utilized for obtaining the estimated tap temperature must be made and one such variation is illustrated in FIG. 2. In FIG. 2 the bath temperature computer 10 is similar to that described for FIG. 1 and it produces on its output line 12 a signal comparable to that produced in FIG. 1. Likewise, the tap carbon setting as established by the adjustment of knob 18B to adjust the variable contact 18A on potentiometer slidewire 18 is similar to that shown in FIG. 1 where the potentiometer slidewire 18 has its upper terminal connected to a potential source E and its lower terminal connected to ground. There is thus produced on output line 20 from the tap carbon potentiometer 18 a signal which provides an input to function generator (FG) 30. This input is indicative of the carbon content desired at the time of tapping.

The function generator 30 has a characteristic such as shown in the block 30 so as to produce on its output line 32 a tap carbon signal representative of the temperature change associated with the tap carbon content as established by the setting of knob 18B. The non-linearity introduced by the function generator 30 in establishing a signal on line 32 is necessary because of the non-linear relationship between the carbon content of the bath and the associated temperature change. This non-linearity is the result of the amount of heat which is released due to the production of FeO in the slag on the bath. Since a considerable amount of slag will be made during the production of the low carbon heat, this non-linearity is an important factor in relating the carbon content of the bath to an associated temperature change.

In FIG. 2, a different means is utilized for producing the bath carbon signal to amplifier 22. That signal is to be representative of the temperature change associated with the bath carbon content and in FIG. 2 this is produced from two signals indicative of different process conditions. The first of those two process condition signals is that produced by the carbon loss rate (CLR) computer 36 which is designed to produce on its output line 38 a signal indicative of the rate at which carbon is being lost from the bath of the basic oxygen furnace. The CLR computer 36 may be of the type disclosed in our co-pending application Ser. No. 444,014 filed on Mar. 30, 1965.

The other signal source which is necessary to determine the temperature equivalent of the bath carbon content is a measurement of the lance oxygen flow, which is shown as being obtained by a flowmeter indicated as block 40 in FIG. 2. The output of the flowmeter on line 42 is thus a signal representative of the oxygen flow in the lance of the furnace. To obtain the carbon removal efficiency for the process, the signal on line 38 is divided by the signal on line 42 in the dividing network shown as the block 44. The divider 44 then produces an output on line 46 representative of the carbon removal efficiency (CRE).

The carbon removal efficiency signal on line 46 provides an input to a function generator 48 having a characteristic similar to that illustrated in the block. The function generator in turn produces on its output line 50 a signal which is indicative of the bath carbon. That signal can be introduced through line 52 to an indicator 54 so as to indicate on a linear scale the bath carbon content. The linearity of the scale is possible on indicator 54 because of the non-linear function introduced by function

generator 48. Since normally the carbon removal efficiency signal, as introduced on line 46, has a non-linear relationship with the carbon content of the bath in the low carbon range, an accurate indication in that range can be obtained.

In order to establish a signal on line 16 representative of the temperature change associated with the bath carbon content, it is necessary to introduce a non-linearity by means of function generator 58 which uses as its input a signal from line 50 and produces an output on line 16 in accordance with the function illustrated in the block 58. Hence, the non-linearities introduced by the function generators 48 and 58 are substantially the inverse, one of the other. The net result of the two function generators is to produce a substantially linear functional relationship between the signal which is on line 16 and that which appears on line 46.

In FIG. 2, as in FIG. 1, the input signals to an amplifier 22 representative of the bath temperature and the temperature change associated with the bath carbon content are summed and from that value is subtracted a signal representative of the temperature change associated with the tap carbon content, namely that signal which appears on line 32. In a manner similar to that described for FIG. 1, the amplifier 22 produces on its output line 24 a composite signal which is introduced into the indicator 26, similar to that of FIG. 1 to introduce an indication of the estimated tap temperature.

Still another and a preferred embodiment of this invention, particularly for the production of an indication of the estimated tap temperature during the processing of a low carbon heat, is shown in FIG. 3. In FIG. 3, the bath temperature computer 10 produces a bath temperature signal on line 12 which is introduced into amplifier 22 much as described previously for FIG. 1 and FIG. 2. In FIG. 3 the tap carbon signal on line 32 which is also introduced in amplifier 22 is produced in a different fashion than that shown in FIG. 2. Instead of using a potentiometer arrangement which would give a linear relationship between the adjustment of the adjusting knob, such as knob 18B of FIG. 2, and the signal output from the potentiometer, there is provided a non-linear potentiometer arrangement which consists of a fixed resistor 60 having one terminal connected to a potential source E and its other terminal connected to one terminal of potentiometer resistor 18 whose variable tap 18A is adjusted by knob 18B. In FIG. 3, the variable tap 18A is connected by line 62 to line 32 which also connects to the point at which the resistor 60 and the potentiometer resistor 18 join, namely junction 64.

With the arrangement described above the tap carbon signal in the form of the potential which is provided on line 32 will have a non-linear relationship to the adjustment of the knob 18B so as to make unnecessary the inclusion of the function generator such as function generator 30 of FIG. 2, a non-linearity being introduced in the potentiometer arrangement itself, so that the signal provided on line 32 is representative of the temperature change associated with the tap carbon content.

In FIG. 3, there is also provided a variation in the manner in which the bath carbon signal representative of the temperature change associated with the bath carbon content is produced. In FIG. 3, the carbon loss rate computer 36 and the measurement of the lance oxygen flow by flowmeter 40 is similar to that described in FIG. 2. Each of these elements produces its associated output on lines 38 and 42 respectively to the dividing network 44 which is similar to that of FIG. 2. The dividing network 44 divides the signal produced on line 38 by that produced on line 42 so as to produce on its output line 46 a signal indicative of the carbon removal efficiency. This signal is likewise representative of the temperature change associated with the bath carbon content and is therefore introduced as one of the signals forming an input into amplifier 22. The carbon removal efficiency signal appearing on line 46 is also introduced by way of line 68

into inductor 69 for indicating the bath carbon content (CB). It will be noted that the scale on indicator 69 is in terms of points of carbon in the bath and is a non-linear scale. In fact, the scale is substantially logarithmic in character so that it provides easily read scale divisions in the lower carbon regions where it is most useful.

In FIG. 3, the amplifier 22 serves to sum the signals on lines 12 and 46 and to subtract from that sum the signal appearing on line 32 so as to produce an output signal on line 24 to the indicator 26 which then provides the indication of the estimated tap temperature much as described with regard to FIGS. 1 and 2.

It will be evident that the computations of bath temperature and bath carbon as well as carbon loss rate can be obtained from either analog or digital computers and it will also be evident that the signals representative of the temperature change associated with the tap carbon set by knob 18B may be derived from any one of a number of different type of signal generators so that the arrangement shown in FIGS. 1, 2 and 3 are merely representative of particular forms of invention. Other forms will be obvious to those skilled in the art.

What is claimed is:

1. Apparatus for computing an estimated tap temperature for the bath of a basic oxygen furnace comprising means for producing a bath temperature signal representative of the existing bath temperature, means for producing a tap carbon signal representative of the temperature change associated with the desired tap carbon content, means for producing a bath carbon signal representative of the temperature change associated with the existing bath carbon content, and means for producing from said bath temperature signal, said tap carbon signal, and said bath carbon signal a composite signal representative of the estimated tap temperature, said composite signal being equal to the sum of said bath temperature signal and said bath carbon signal minus said tap carbon signal.
2. Apparatus as set forth in claim 1 in which said means for producing said tap carbon signal includes
 - a linearly adjustable source for providing a signal representing the desired tap carbon content of the bath, and
 - a function generator in circuit with said source for modifying said last named signal so as to provide another signal representing the temperature change associated with said desired tap carbon content.
3. Apparatus as set forth in claim 1 in which said means for producing said bath carbon signal includes
 - means for producing a signal representative of the carbon loss rate from said furnace,
 - means for producing a signal representative of the oxygen flow to the lance of said furnace,
 - means for dividing said carbon loss rate signal by said oxygen flow signal to produce a signal representative of the carbon removal efficiency in the blowing of said furnace,
 - a first function generator means responsive to said carbon removal efficiency signal for producing a signal linearly related to the bath carbon content, and
 - a second function generator means responsive to the output of said first function generator means for producing a signal representative of the temperature change associated with said bath carbon content.
4. Apparatus as set forth in claim 3 in which said means for producing said tap carbon signal includes
 - a linearly adjustable source for providing a signal representing the desired tap carbon content of the bath, and
 - a function generator in circuit with said source for modifying said last named signal so as to provide another signal representing the temperature change associated with said desired tap carbon content.

5. Apparatus as set forth in claim 1 in which said means for producing said tap carbon signal includes an adjustable non-linear source for providing a signal representing the temperature change associated with said desired tap carbon content.

6. Apparatus as set forth in claim 1 in which said means for producing said bath carbon signal includes

- means for producing a signal representative of the carbon loss rate from said furnace,
- means for producing a signal representative of the oxygen flow in the lance of said furnace, and
- means for dividing said carbon loss rate signal by said oxygen flow signal to produce a signal representative of the temperature change associated with said bath carbon content.

7. Apparatus as set forth in claim 6 in which said means for producing said tap carbon signal includes an adjustable non-linear source for providing a signal representing the temperature change associated with said desired tap carbon.

8. Apparatus for computing an estimated tap temperature of the bath of a basic oxygen furnace comprising means for producing a bath temperature signal representative of the existing bath temperature, means for producing a tap carbon signal representative of the desired tap carbon content, means for producing a bath carbon signal representative of the existing bath carbon content, and means for summing said bath temperature signal and said bath carbon signal and subtracting from the sum said tap carbon signal to thereby produce a signal representative of an estimated tap temperature.

9. The method of calculating the estimated tap temperature of a basic oxygen furnace which comprises the steps of

- producing a bath temperature signal representative of the temperature of the bath of said furnace,
- producing a tap carbon signal representative of the temperature change associated with the desired tap carbon due to both bath carbon and the associated FeO effect,
- producing a bath carbon signal representative of the temperature change associated with the existing bath carbon content due to bath carbon and the associated FeO effect, and
- producing a composite signal representative of said estimated tap temperature, said composite signal being derived from the sum of said bath temperature signal and said bath carbon signal minus said tap carbon signal.

10. The method of claim 9 in which the production of said bath carbon signal includes

- producing a signal representative of the carbon loss rate from the furnace,
- producing a signal representing the flow of oxygen in the lance of said furnace, and
- dividing said carbon loss rate signal by said oxygen flow signal.

11. The method of claim 9 in which the production of said tap carbon signal includes

- adjusting the output of a non-linear signal producing means so that the signal produced has a non-linear relationship with the amount of adjustment made.

12. The method of claim 9 in which the production of said bath carbon signal includes,

- (a) producing a signal representative of the carbon loss rate from the furnace,
- (b) producing a signal representing the flow of oxygen in the lance of said furnace,
- (c) dividing said carbon loss rate signal by said oxygen flow signal,

and the production of said tap carbon signal includes,

- (a) adjusting the output of a non-linear signal producing means so that the signal produced has a non-

linear relationship with the amount of adjustment made.

References Cited

UNITED STATES PATENTS

3,100,699	8/1963	Von Bogdandy et al. ---	75—59
3,181,343	5/1965	Fillon -----	73—23
3,218,158	11/1965	Dumont-Fillon -----	75—60
3,329,495	7/1967	Ohta et al. -----	73—23 X

3,372,023	3/1968	Krainer et al. -----	75—60
3,377,158	4/1968	Meyer et al. -----	75—60

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