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[54] **APPARATUS FOR MAKING STEEL**
4 Claims, 1 Drawing Fig.

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[50] **Field of Search** 266/35, 34.1, 34.2; 75/60; 235/151.3, 151.35; 239/71, 75; 73/355

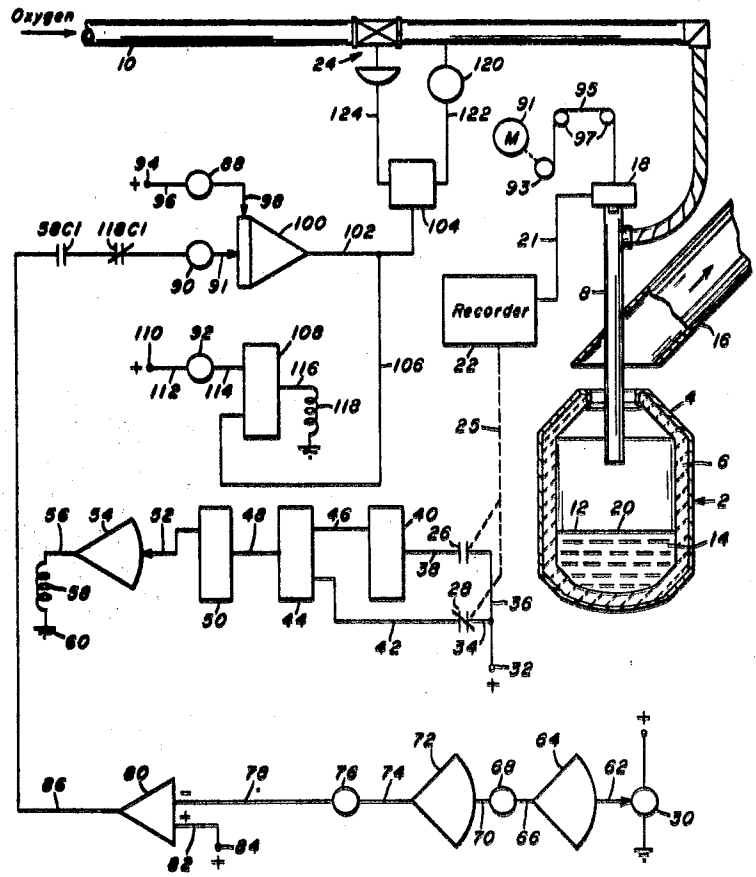
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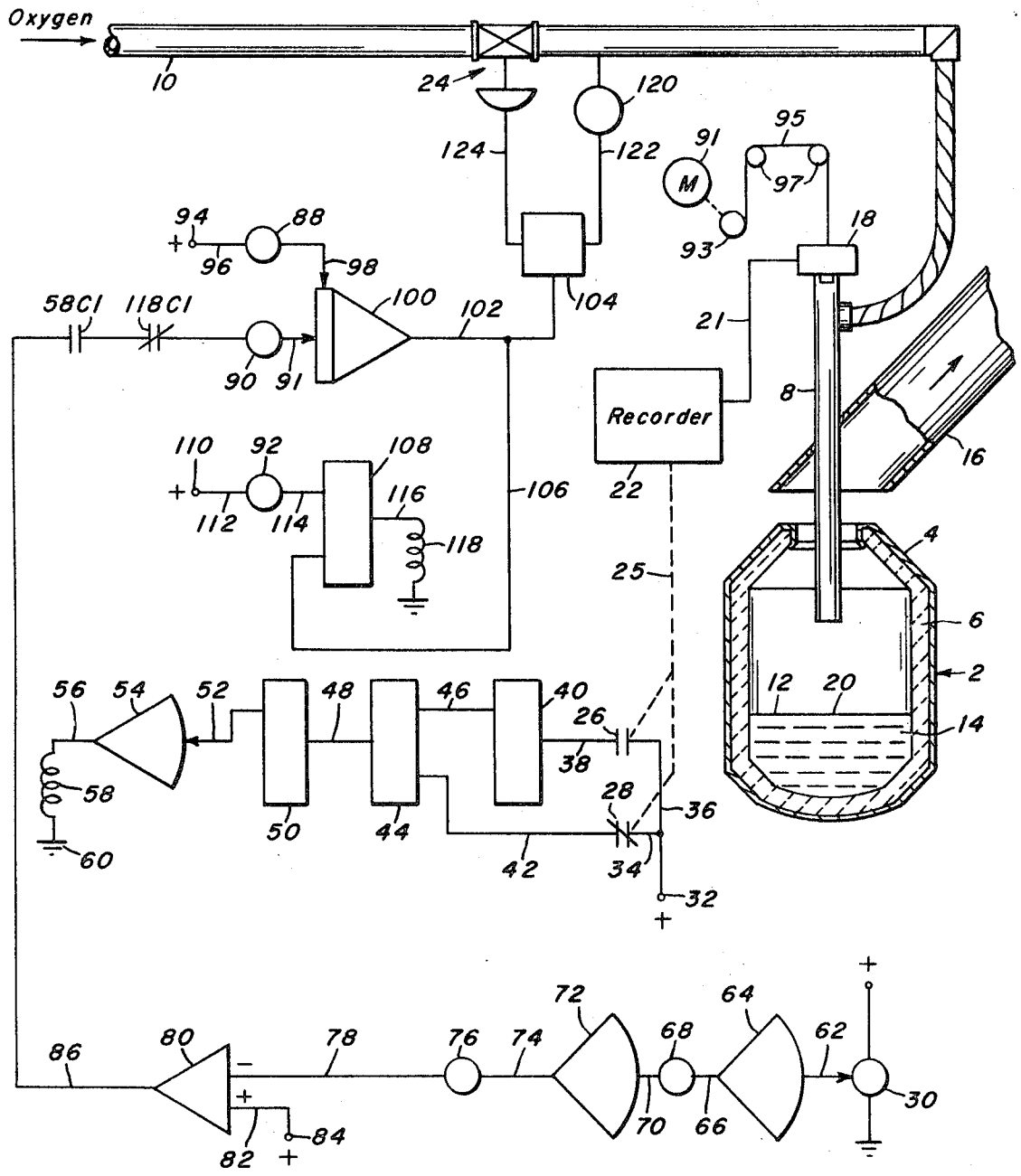
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ABSTRACT: This invention relates to a method and apparatus for making steel in a converter top-blown with oxygen. In particular, the invention relates to operating a converter top-blown with oxygen by monitoring the temperature on the area of the bath surface contacted by the oxygen jet, which is the reaction zone, determining the reaction-zone temperature decrease indicating the end of desiliconization of the bath, and thereupon increasing the amount of oxygen and preferably also decreasing the height of the oxygen lance above the bath surface during the carbon-removal portion of oxygen blowing. The increased oxygen flow rate and decreased lance height is maintained for the remainder of the Steelmaking operation.





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APPARATUS FOR MAKING STEEL

One known practice for making steel in a top-blown oxygen converter is to use a fixed lance height and fixed oxygen flow rates substantially throughout each heat. This practice is inefficient and does not take into the account that the oxygen first reacts principally with the silicon present in the molten metal, and then later principally with the carbon. During the later part of a heat, when the removal of carbon is the principal reaction, greater oxygen flow rates can be tolerated than during and immediately after the desiliconization period. With an oxygen rate too high and/or a lance height too low during the desiliconization period, a viscous, low-basicity slag is formed and as decarburization develops, much of the slag and metal "slops-out" of the converter vessel, necessitating a drastic decrease in the oxygen flow rate. This is wasteful of iron units, decreases production rate, and is hazardous to equipment and personnel. The usual way to avoid this has been to start with and to maintain a low and steady oxygen flow rate until well past the silicon end point, accepting the resulting inefficiency. This has been done, in large part, because of the absence of satisfactory means for determining rapidly and accurately the end of the desiliconization period.

Another practice used in connection with such method involves continuously analyzing for carbon the waste gases emitted by the converter. Carbon removal rate increases after the desiliconization period is over, and by determining the carbon content of the off-gas and its volume, it is possible to calculate the carbon-removal rate and use this as an indication that the desiliconization period is over and the oxygen flow rate may now be increased. This practice has two drawbacks, however. First, it is not capable of giving a very rapid indication of the end of desiliconization; the off-gas must be collected, and analyzed, so that, the output of the analyzer is about 15 seconds to a minute behind the actual state of the process in the vessel, depending on where the waste gas is sampled. Second, this practice becomes undependable when the initial silicon content of the iron is high, e.g., over 1.5 percent, because when the iron contains that much silicon, the slag volumes are necessarily larger and the bath becomes hotter, with the result that the decarburization rate is appreciable even while desiliconization proceeds, all of this also promoting slopping. As a consequence, with high-silicon iron, this practice does not provide a distinct indication of the end of the desiliconization period. In addition, high-silicon baths tend to slop more readily, so that it is even more important with them than with the low-silicon baths to obtain a sufficiently rapid indication of the changes that are taking place in the bath reactions in order to obtain adequate and effective control.

It is accordingly the primary object of the present invention to provide for the effective determination of the end of desiliconization during the operation of top-blown, oxygen converter. This result is achieved by monitoring the chemical reaction whereby silicon is removed from the bath by monitoring the temperature at the reaction zone of the bath. An abrupt temperature decrease at the reaction zone signals the end of desiliconization.

These and other objects of the invention as well as a complete understanding thereof may be obtained from the following description and drawings, in which the single FIGURE is a schematic diagram of one embodiment of equipment useful for the practice of a preferred embodiment of the invention.

Broadly, the invention involves following the bath chemical reactions by monitoring the temperature in the reaction zone, which is in the vicinity at which the oxygen impinges upon the molten iron to be refined, and using before the silicon end point a suitable low oxygen flow rate and high lance height, and after the silicon end point, a suitable higher oxygen flow rate and lower lance height. There are provided apparatus for following the bath chemical reactions by monitoring the temperature in the reaction zone, and control means responsive to

the above-mentioned temperature-following means for suitably increasing the oxygen flow rate when the temperature in the reaction zone decreases as a result of the end of desiliconization. In accordance with the preferred aspect of the invention, the means for following the reaction temperature comprises a radiation pyrometer sighting down the lance. Moreover, automatic means are provided responsive to signals emitted by the radiation-pyrometer means for gradually increasing the oxygen flow rate from an initial relatively low value used during the desiliconization period to a second relatively higher value used after the silicon end point. It should be noted that the invention is in no way concerned with measuring the temperature of the molten metal bath, either at the reaction zone thereof or otherwise. In addition, it is the temperature change at the reaction zone rather than the bath temperature which is the prime control function of the invention.

With reference to the drawing, the apparatus of the present invention comprises a conventional open-top converter 2 having an exterior steel shell 4 and an interior lining 6 of refractory material, the converter being arranged to rotate about trunnions (not shown) to permit charging and subsequently discharge of molten steel upon the completion of the refining operation. There is also provided a lance 8, by means of which oxygen from a source 10 is blown upon surface 12 of a bath 14 of molten iron contained in converter 2. Hood 16 provides means by which fume-laden gases produced during the refining operation are removed for cleaning and disposal. There is further provided a device 18, such as a radiation pyrometer, that is used to sense the temperature in the region 20, which is the reaction zone, of the bath 14. The output of the radiation-sensitive device 18 is a suitable electrical signal conveyed by line 21 to a strip-chart recorder 22. Flow of oxygen from the source 10 to the lance 8 is controlled by means of a valve 24.

It will now be described how the remaining equipment operates in response to indications of the strip-chart recorder 22 to control valve 24 in such a manner that a low constant rate of oxygen flow through the lance is obtained prior to the silicon end point and a higher constant rate of oxygen flow through the lance is obtained after the silicon end point, a smooth transition being made from one steady state to the other.

The recorder 22 may be of the known strip-chart type containing a null-balance potentiometer and servomotor by means of which voltages incoming on line 21 are translated into a pen position indicative of the value of such voltage. The recorder 22 is mechanically connected as at 25 with an upper limit switch 26 and a lower limit switch 28, and the recorder 22 also contains or drives a potentiometer 30, for a purpose which will hereinafter be more fully explained. One side of each of the limit switches 26 and 28 is connected to a suitable source of current 32 by means of lines 34 and 36. The other side of the upper limit switch 26 is connected by line 38 to a bistable multivibrator 40. The other side of lower limit switch 28 is connected by line 42 to an "AND" gate 44, to which the output of multivibrator 40 is connected by means of the line 46. The output of "AND" gate 44 is connected by line 48 to a second bistable multivibrator 50, the output of which is connected by a line 52 to relay-driving means 54, which is connected by line 56 to coil 58 of a relay having normally open contacts 58C1 and thence to ground at 60.

The output of the recorder-driven potentiometer 30 is passed by line 62 to a differentiation circuit 64 and thence by line 66 to a potentiometer 68. The output of potentiometer 68 is transmitted by line 70 to a dead-band function generator 72, the output of which is passed by a line 74 to a potentiometer 76. The output of potentiometer 76 is passed by line 78 to a summing amplifier 80, to which there is fed through a line 82 from a source 84 a constant potential opposite in polarity to that on the line 78. The output of the summing amplifier 80 appears on the line 86.

The apparatus of the invention further comprises potentiometers 88, 90, and 92, upon which are set respectively, the initial oxygen flow rate, the rate of change of flow rate during

the transition period (transition between predominately silicon blow to predominately carbon blow), and the desired final oxygen flow rate.

There are also provided means for raising and lowering the lance with respect to the bath, comprising a motor 91, takeup reel 93 and cable 95 passing over sheaves 97.

Potentiometer 88 is connected to a source of current 94 through the line 96, and its output is connected by a line 98 with an integrating device 100, the output of which is fed by a line 102 to a flow control 104 and by a line 106 to a comparator device 108. The other signal fed to the comparator device 108 is the desired final flow set on the potentiometer 92, which is powered from a source 110 through the line 112, the output of potentiometer 92 being conveyed to the comparator device 108 by line 114. The comparator device 108 operates, whenever the signal on the line 106 is as great as that on line 114, to energize coil 118 via line 116. Coil 118 is the coil of a relay having normally closed contacts 118C1. It is located in line 86.

The flow controller 104 receives indications of actual oxygen flow from flow transmitter 120, via line 122, and emits, via line 124, a suitable command signal to the flow-control valve 24.

The apparatus described above may be operated in the following manner. After a suitable hot-metal charge 14 is placed in the converter vessel 2, appropriate values are set on the potentiometers 88, 90 and 92 and the circuit is actuated. At the outset, considering that contacts 58C1 are open, as shown in the Figure, the signal on line 102 corresponds to the initial flow rate set on potentiometer 88, which may be calibrated in standard cubic feet per minute. When the reaction temperature sensed by device 18 rises above the setting of lower limit switch 28, that switch, which is normally closed, will open. When the temperature sensed by the device 18 rises still further, so that the setting of upper limit switch 28 is exceeded, that switch will close, causing a change in the state of the multivibrator 40. Thus, for the first time, the "AND" gate 44 is enabled, such that if it should detect a signal on the line 42, it will pass a signal across the line 48 and thus, operating through the multivibrator 50 and the relay driver 54, energize relay 58 to connect with the integrating device 100 the signal on line 86 and thus initiate a change in the oxygen flow rate.

The temperature detected by the device 18 falls rapidly at the end of the silicon blow. As it drops below the setting of upper limit switch 26, that switch will open again, but of course multivibrator 40 will not change state. As the detected temperature drops below the setting of lower limit switch 28, switch 28 will again close to produce a signal across line 42 and the "AND" gate 44 will thus operate to change the state of multivibrator 50, with the results described above.

When the contact 58C1 closes, the reference voltage 84 is connected by line 86 with the potentiometer 90, which may be calibrated in standard cubic feet per minute. The output of integrating device 100 will now increase at a preselected rate, which is determined by the setting of potentiometer 90, thereby changing the command signal to the flow controller 104 and at the same time the setting of flow control valve 24 and consequently the rate at which oxygen is delivered to the converter 2 through the lance 8.

At this time, the operator also operates motor 91, which then acts through takeup reel 93 and cable 95 to lower the lance 8 a suitable and substantial selected distance toward the bath. For example, the lance-bath distance may be reduced from 150 inches before the silicon end point to 90 inches after the silicon end point, but these numbers are strictly illustrative, the optimal practice depending upon such factors as the oxygen flow rates used, the size and shape of the furnace vessel, and the weight and composition of the charge.

Comparator 108 is a bistable device that will energize and latch the relay 118 when the input of line 106 is equal to or greater than the input through the line 114. The switching point is determined by the setting of the potentiometer 92, which is calibrated in terms of standard cubic feet per minute. Thus, when the final desired flow rate indicated on potentiometer 92 is reached, the comparator 108 opens the input to the potentiometer 90, so that the signal on line 102 does not change further.

It will be seen that the above description of operation is strictly open-loop, no use being made of differentiation circuit 64 and dead-band function generator 72.

In accordance with an alternative mode of operating the equipment disclosed in the attached FIGURE, the potentiometer 76 is set at a value other than zero. Let us assume, for example, that the setting on potentiometer 76 is such that it can pass on the line 78 a signal capable of cancelling that on the line 82. This would mean that, when contact 58C1 is closed, there might result, with an appropriate signal on the line 74, no input to the integrator 100 through the potentiometer 90, and no change in the output of the integrating device 100.

In closed-loop operation, the differentiation circuit 64 senses the rate of change, with respect to time, of the temperature detected by the device 18, a value corresponding to this detected rate of change appearing on line 66. The signal on line 66 is modified by potentiometer 68, and said modified signal appears on line 70. The operation of the dead-band function generator 72 is such that it produces a signal on line 74 when the magnitude of the signal on line 70 exceeds the "dead-band" set on the function generator. If the signal on line 70 is within the dead-band, then the signal on line 74 will be constant as will be the signal from the summing amplifier 80 on the line 86. In the operation of the circuit, when the relay 58 is closed, a signal on line 74 other than constant will affect the oxygen flow rate. There will be a signal on the line 74, as explained above, if there is a signal on the line 70 of such magnitude that it lies outside the dead-band generated by the dead-band function generator 72. This will happen only if the differentiation circuit 64 detects, at that time, that there is, for example, a substantial decrease in the rate of change of the temperature sensed by the device 18. It will, incidentally, ordinarily be the case that such a decrease in observed temperature will be in progress at the time that the relay 58 is energized. As a result, there is produced on line 74 a negative signal, which is then passed by the potentiometer 76 to the line 78, with the result that the summing amplifier 80 reverses the effect of that substantial negative signal and adds it to the reference voltage 84, thereby changing the signal on line 91 to integrator 100 to increase the oxygen flow rate by providing a signal to controller 104 via line 102. This will have the result that the observed drop in temperature will tend to be reversed. After a short time, assuming that the signal on line 102 has not risen to such a value that by operation of the comparator device 108 the relay 118 has become energized, the temperature change exceeding the dead-band as detected by circuit 64, will no longer occur, with the result that the signal on line 74 will return to its normal constant value and the equipment will continue to operate in the manner described above with reference to open-loop operation until the desired final flow rate is reached.

If it should happen that during a subsequent operation of the device during the time between the closing of contacts 58C1 and the time of the opening of contact 118C1 that the temperature detected by the device 18 should begin to increase outside the dead-band, the result would be that a substantial positive signal will be produced on the line 70 and on the line 74, which will cause a decrease in the signal on line 86 that will in turn decrease the signal on the line 102 from the integrator 100. Hence, the rate of change of the oxygen flow will be decreased. This will tend to decrease the rate of reaction-temperature increase, as sensed by the temperature-sensing device 18.

It will be apparent to those skilled in the art that the computing functions described above could be performed by any of various electrical, mechanical, or pneumatic methods, including the use of a digital computer.

While I have shown and described herein certain embodiments of my invention, I intend to cover as well any change or modification therein which may be made without departing from the spirit and scope of the invention.

I claim:

1. In apparatus for refining iron to make steel, the combination with a converter vessel and a lance for directing a jet of oxygen-containing gas onto said iron whereby there is formed a reaction zone in the vicinity of the area of impingement of said jet on said iron, of a radiation detector for monitoring temperature in said reaction zone and positioned within and sighted down said lance and producing a signal proportionate to the temperature in said reaction zone, and control means comprising a circuit for detecting change in said signal and said control means further including actuating means for increasing the rate of flow of oxygen-containing gas in said jet in response to a detected change in said signal when the temperature in said reaction zone decreases as a result of the end of desiliconization.

2. A combination as defined in claim 1, characterized in that said control means for increasing the rate of flow of oxygen-containing gas in said jet comprises a first device upon which a setting corresponding to an initial oxygen flow rate is made, a second device upon which a setting corresponding to the final oxygen flow rate is made, a third device upon which a setting is made corresponding to the rate of increase of oxygen flow rate to be observed between the end of the time of using the initial oxygen flow rate and the start of the time of using the final oxygen flow rate, and means responsive to said first, second, and third devices and to said means for following the temperature in said reaction zOne for varying the rate of flow of oxygen-containing gas in said jet.

3. A combination as defined in claim 2 further characterized in that means are provided for determining reaction-zone temperature-rate changes outside selected temperature-rate change limits and for affecting said control means for increasing the rate of flow of oxygen-containing gas to correct said rate of flow to bring said reaction-zone temperature change within said selected temperature-rate change limits.

4. A combination as defined in claim 3, characterized in that means are provided for lowering said lance toward said iron.