We, ARBED S.A. being the person identified below as the Applicant, request the grant of a patent to the person identified below as the Nominated Person, for an invention described in the accompanying standard complete specification.

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Invention Title: PROCESS FOR REGULATING THE HOT METAL REFINING OPERATION
Name(s) of actual Inventor(s): Robert Mousel and André Bock
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Basic Convention Application
Application Number Country Country Code Date of Application
87 857 Luxembourg LU 10 December 1990

Drawing number recommended to accompany the abstract 1.

DATED this 25th day of November, 1991.

ARBED S.A.
By its Patent Attorneys:

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To: The Commissioner of Patents.
NOTICE OF ENTITLEMENT

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state the following:-

The inventor(s) of the invention are as follows:

The person(s) nominated for the grant of the patent:

(i) is/are the actual inventor(s)
(ii) is/are the applicant(s) of the basic application

(i) has/have entitlement from the actual inventor(s) by virtue of

(iii) has/have entitlement from the applicant(s) of the basic

application(s) listed on the patent request form by virtue of

The person(s) nominated for the grant of the patent:

(i) is/are the applicant(s) of the application(s) listed in the

declaration under Article 8 of the PCT

(ii) has/have entitlement from the inventor(s) and/or the

applicant(s) of the application(s) listed in the declaration

under Article 8 of the PCT by virtue of

The basic application(s) listed:

(i) on the request form

(ii) in the declaration made under Article 8 of the PCT

is/are the first application(s) made in a Convention country in

respect of the invention.

ARBED S.A.

NEYEN René BECKER Fernand

October 16, 1991
The invention concerns a process for controlling the operation of the refining of hot metal in a steelmaking converter by blowing from above at least two supersonic primary oxygen jets of a given total flow rate against the surface of the bath to be refined. This process is characterized in that the aimed at ratio between the decarburization speed of the metal and the oxidation speed of the slag is achieved by the fact that each one of the jets coming out of a non rotating lance impinges within the same annular area of on the bath with a given energy. Depending on the physico-chemical condition of the bath, the impact energy of the jets is varied between upper and lower limits, whereas at the same time the height of the lance above the surface of the bath together with the total volume of the oxygen flow feeding the bath are both kept at a practically steady level.
THE FOLLOWING STATEMENT IS A FULL DESCRIPTION OF THIS INVENTION, INCLUDING THE BEST METHOD OF PERFORMING IT KNOWN TO ME:
Process for regulating the hot metal refining operation.

The present invention relates to a process which allows to regulate in an easier and more flexible way than hitherto the operation of the refining of hot metal, which has been obtained in a blast furnace by reducing iron ore with coke and with other auxiliary combustible materials.

In the steelplants the said refining operation of the hot metal is carried out mainly by injecting gaseous oxygen from top through a central vertical metallic lance into a converter containing the hot metal intended to be transformed into steel. By far the largest percentage of the world-wide annual tonnage of steel, obtained through the intermediary of liquid hot metal, is produced with the help of the oxygen refining processes known as LD-, LD-AC-, OLP-, BOF-processes. All these processes use industrially pure oxygen as the refining agent. This oxygen is injected in the gaseous condition, at a very high velocity and under the form of one or of more jets flowing through a central lance, into the bath contained within the converter. A very considerable volume of gaseous oxygen is of course required for refining the large mass of one converter batch or heat in a very short time period, which, as a rule, is not much longer than a quarter of an hour. The said heat can exceed 300 tons and it is made up of the charged hot metal and of possible additions of scrap and/or of other metallic or non metallic additions.

During the downward injection of the refining oxygen, in the form of at least one primary jet, it is above all important that the movement of the bath, which results in part from the impact...
energy of the primary oxygen jet or jets on the surface of the bath and in part from the release of bubbles of carbon monoxide (CO) attributable to the oxidation of the carbon accompanying the hot metal, remains sufficiently intensive. It is just as important that at its point of impact the injected oxygen is shared out in a judicious manner amongst the metal and the slag, so that during the entire course of the refining operations the desequilibrria between the metal and the gas and between the metal and the slag are kept upright and that they bring about the progression of the refining reactions. Indeed, conducting the refining reactions is synonymous with keeping at any moment upright a well defined relationship between the decarburization speed of the hot metal and the oxidation speed of the slag. To achieve this aim, the steelmaker can rely mainly on two well defined operating parameters, namely in the first place the modification of the height of the lance with respect to the level of the bath in the converter and in the second place the control of the flow rate of the oxygen conveyed through the lance, i.e. the volume of gaseous oxygen injected per unit of time. The steelmaker may act on one of those parameters or he may vary both parameters at the same time, depending on whether he wants to run the process with more or less hard and penetrating jets or to act with softer but stronger oxidizing jets mainly on the slag.

The equipment, which is located in the blowing stand and which is used for the controlled injection of oxygen into the bath, consists essentially of a vertically movable lance body. The latter is composed of a plurality of conduits and of concentric circuits, as well for the feeding of the gaseous oxygen as for the supply and the evacuation of the cooling water, all these operations being controlled by appropriate regulating instruments. The lower extremity of the lance is constituted by a special exchangeable copper lance head manufactured by way of casting or of machining. The lance head too is provided with circuits for the cooling water and with a given number of tuyeres
for leading or accelerating the gas. The number of tuyeres corresponds to the number of the primary oxygen jets, and sometimes also of the secondary oxygen jets which can be foreseen in some steelplants. As a rule multihole lances bear between 2 and 5 supersonic primary tuyeres having inclination angles of between 7° and 10° with respect to the axis of the lance body, the jets being the more harder as the number of the tuyeres becomes smaller. In addition to these primary tuyeres, secondary tuyeres may also be foreseen in view of dispensing gaseous oxygen at subsonic velocity under greater inclination angles and of allowing thus to operate a post-combustion of the carbon monoxide (CO) given off by the bath in the course of the decarburization.

The lance body is suspended to a carriage which is located outside above the converter and which is movable horizontally and vertically, so that in the first place the head of the lance can be introduced at the beginning of the refining operation through the mouth of the converter into its interior and that in the second place the distance between the head of the lance and the surface of the bath can be varied during the refining operation. So, in the course of the blowing of a heat, the lance head is brought closer to or removed further off the surface of the bath in a repetitive manner according to well defined diagrams.

In a similar way one modifies, also according to a well defined specific diagram, the instantaneous flow rate of the oxygen in order to take into account the evolution of the chemical and physical processes that are taking place in the converter. The response time for a modification of the oxygen flow rate resulting from a resetting of the opening degree of a valve is not appreciable. On another side the time required to move a lance into a new position is much more considerable.

For example, for a converter having a capacity of 200 tons the oxygen flow rates normally vary between 400 and 700 Nm³/min.
The farthest distances between the level of the bath in the converter and the tip of the lance head vary between 170 and 350 cm during the oxygen blowing period. Each one of these two parameters is changed at least six times during the course of the refining period of one single heat.

From what has been said herebefore it results that the steelmakers modulate, one with respect to the other, the position or height of the lance above the bath and the instantaneous flow rate of the gaseous refining oxygen. In doing this they follow well known preestablished blowing diagrams which allow to run the refining operation and to make the reactions progress in the desired direction. Of course the steelmakers do their best to avoid as far as possible any movement of the lance. Indeed, due to the important inertia of the translation car together with the body of the lance containing also the cooling water, the response time for this parameter is rather considerable. On the other hand it is known that when the lance is lowered too much - in order to get a hard jet - there exists a serious risk to damage the head of the lance due to the non molten scrap swimming on the surface of the bath, whereas, when the flow rate of the oxygen becomes too small - in order to get a soft jet - the self-protection of the lance head due to the gas screen becomes less efficacious and projected metal and scrap particles can again touch and damage the lance head.

Notwithstanding all the efforts undertaken to achieve this aim, it has not been possible up to now to renounce completely to a repetitive displacement of the lance in the course of the refining or merely to simplify to some extent the control of the refining process by cutting down to a really insignificant degree the frequency of this lance travelling.

So, the aim of the present invention is to foresee a simplified procedure for running the oxygen refining operation,
this operation procedure allowing, on the one hand, to keep a non rotating lance substantially motionless at a predetermined level and to reduce to a minimum the changing frequency of the total flow of the gas, without, on the other hand, rendering worse the distribution of the primary refining oxygen in the interior of the converter, whereas the mechanical mixing energy, which is transmitted to the bath in the converter by the impact of the injected gas thereon, is further increased.

To this end the refining process according to the present invention foresees to inject, from above, into the steelmaking converter containing the bath to be submitted to the refining, against the surface of this bath, at least two supersonic primary oxygen jets of a given total flow rate and this refining process is mainly characterized by the fact that each one of the jets coming out of a non rotating lance impinges within the same annular area on the bath with a given energy, which, depending on the physico-chemical state of the bath, varies between upper and lower limits, whereas at the same time the height of the lance above the surface of the bath, just as the total volume of the oxygen flow feeding the bath are both kept at practically unvarying levels.

For running the refining operation according to the present invention one consequently uses at least two individual separate supersonic jets of primary refining oxygen. The jets must diverge by a given angle from the lance axis in order to touch the bath surface within the predefined annular area. According to one execution embodiment the jets will freely rotate around the said axis of the lance at a variable and adjustable rotating velocity. The concept and the configuration of a refining lance capable to subdivide in its interior a main flow of primary oxygen into at least two distinct jets which leave the lance at a supersonic velocity and to which a free rotation of a required and variable velocity around the axis of the lance can be conferred, do not
constitute a part of the present application. Such a lance has been disclosed in the Luxembourg Patent 87855. According to another embodiment of the invention, the free passages of the stationary tuyeres, dividing the main gas stream into a plurality of obliquely deviated jets of primary oxygen, are alternately obturated partially by a revolving rotor of the lance in such a way that mainly the individual flow rates of the different jets are modulated according to a given periodical pattern. Due to the constantly varying impact energy of each one of those jets on the same of several spots of the annular area, the bath is stirred by a kind of pumping effect of a modulated frequency.

In all cases the average deflection angle of such primary oxygen jets, with respect to the vertical line of a given lance, is always selected according to the present invention by considering as well the geometry of the converter within which the lance will be used as the average distance at which one intends to keep the lance head above the bath surface during the refining operation. This deflection angle is determined in such a manner that the centre of the annular area within which each one of the individual jets will impinge on the bath is located on a radius at a point approximately half-way between the centre of the bath surface, which coincides with the vertical axis of the converter, and the inner wall of the converter lining. As a rule this angle has a value of between 10 and 30 degrees with respect to the vertical line. The axes of the tuyeres of the prior conventional multihole lance heads (2 to 5 primary openings per head) show also a deviation with respect to the central axis of the lance. However, as the distance between the classic multihole lances and the bath level is permanently modified and also due to the fact that the operator will try to cause only a minimum wear of the lining of the converter, the mean deflection angle is less pronounced and does not exceed 10 to 15 degrees as a rule. In this case too the yield of the injected oxygen is less good. Indeed, the optimum combination between the oxygen flow rate and
the height of the lance, with its inherent injection angle, is realized only during a fractional part of the total duration of the conventional refining operation.

As the lance, which is delivering jets of a controllable energy allowing the improved refining operation according the present invention, remains during the whole course of the refining operation substantially at the same distance from the bath surface, the lining of the converter wall is protected at best. Indeed, the said lining is not exaggeratedly exposed, nor to the direct interaction of the gas, nor to the contact with a strongly oxidized and corrosive slag produced in the immediate vicinity of the said lining. As compared to the prior situation, this improvement is attributable to the fact that in view of the control of the relationship between the decarburization speed of the hot metal and the oxidation speed of the slag, it is not any longer required to vary the position of the lance.

The outstanding advantage of the process according to the invention and the new effects resulting therefrom are due mainly to the fact that instead of the conventional couple of control parameters consisting in the height of the lance and in the oxygen flow rate, one now relies on one single and new parameter consisting in the energy with which the several individual jets touch the bath surface within an annular surface, the energy variations resulting either from modifications of the rotating speed of the freely revolving jets or from a modulation of the flow rates of the individual subdivided jets, the flow rate of the main stream remaining constant in both cases. Indeed, this new parameter allows to easily modify, - as a function of the progress of the refining operation or of others constraints, such as the foaming of the slag or the aimed at post-combustion degree -, as well the repartition of the oxygen over the bath surface, as the mechanical stirring energy transferred to the bath by varying the speed of the real or of the simulated rotation of the
jets. This means that one can now obtain, with the help of different means, the equivalent of what has been generally called up to now in the traditional LD refining operation 'soft oxygen jets' and 'hard oxygen jets'. It has already been tried to increase the scouring surface of a given lance by rotating the whole body of the lance. To achieve this a straight lance can be fastened eccentrically to a rotating mechanism, which latter will of course have to be able to support the centrifugal forces generated by the off-center lance body. With a central lance, whereof the lower extremity has been bent out of the direction of the central axis, the situation is not much easier due to the fact that the repulsive force acting on the free extremity of the rotating lance, - the body of which has a length of 20 meters or more -, has also to be somehow neutralized. Moreover, in any case the rotating velocity of a revolving lance will remain extremely low. When operating on the other hand according to the teaching of the present invention, it will be easy to generate extremely soft or hard jets by simply selecting another number of tours per time unit for the rotating mechanical elements of the lance. Indeed this rotating velocity can be varied at will within extremely large limits and one will dispose in reality of an extended regulation latitude with a nearly instantaneous response. Due to the fact that the regulation latitude is so wide, a variation of the total flow rate of the oxygen becomes superfluous. In the border-line case the invention allows to merely use a very simple valve allowing to completely open or shut the oxygen duct. Indeed, instead of varying the total flow rate of the gaseous oxygen, one merely changes the speed of the instantaneous repartition of the gas by exposing per time unit to the oxygen shower a greater or a smaller surface, or by varying the pumping effect of the impact energies of the jets by changing the modulation frequency, this being realized by modifying in a convenient manner the rotation velocity either of the free jets or of the tuyere obturating means. Due to this approach the operation of the hot metal refining is in reality reduced to a simple regulation of a velocity having an immediate effect on the
plurality of the jets acting on the bath at a given distance from the centre of the said bath. The said velocity may be very slow and limited to only a few tours per minute just as it can as well be very rapid and amount to a tenfold of the value of the slow velocity. The said rapid rotation can amount without any problem to 60 tours per minute or even more. In the daily practice the most generally used velocities will lie between 0 and 10 tours per minute for the freely rotating jets and for the obturator causing the cyclic energy variation of each of the jets. As the process can thus be run with a maximum oxygen flow rate, while nevertheless realizing at the same time a high gas utilization rate, the real blowing time is shortened in proportion. Blowing time shortenings in the range of one minute to one minute and a half of the overall oxygen blowing time are possible. Thus the said blowing abridgement can amount to more or less 10% of the oxygen blowing period which lasts normally about 15 minutes.

The new refining process relying on the real or on the simulated rotation of oxygen jets is suitable just as well for the refining of heats of hematite hot metal or of phosphorous containing hot metal as for the treatment of heats containing a high percentage of scrap. The flexibility of the operating possibilities allows without any noticeable difficulty to match specific conditions and variations of compositions of same or of successive heats. In the case of a very substantial increase of the scrap input mainly, it is of advantage to practise also the post-combustion technology while running the refining operation according to the teachings of the present invention. This is realized by injecting in a per se known manner into the vessel, at pressures and at flow rates which are smaller than those applicable to the primary oxygen injection, secondary oxygen which will be used to burn the carbon monoxyde generated by the decarburization of the bath and to confer to the bath a surplus of heat in order to smelt the scrap. Even without this post-combustion stratagem the scrap smelting capacity of the process according to the invention is better than that one of the
straight LD process. This is due to the fact that there exists not only a single main oxygen jet impinging on the bath, but a stirring of a large annular area of the bath surface with at least two individual jets which are deviated laterally and which follow each other at a distance of at most 180°, mostly four jets at a distance of 90°.

In the same manner it is possible to operate the new process in conjunction with any of the known mixed blowing processes, i.e. the processes by which the reactions due to the oxygen blown from above onto the bath are intensified and favoured by a bubbling of the bath achieved by an injection of a gas, the gas being blown from below into the bath through injectors which are incorporated in the bottom part of the converter lining.

The invention is illustrated in a more detailed manner with the help of two diagrams which are of the same nature as those already known and also used very commonly to quantify parameters of the oxygen refining of hot metal according to the LD process.

Figure 1, which is pertaining to the present invention, shows the general configuration of three curves, which concern:
- the first one, the variation of the real rotational velocity of the primary oxygen jets or of the rotor partially obturating the tuyeres generating the jets, quantified in 'number of revolutions per minute',
- the second diagram, the total flow rate of the main refining oxygen stream, expressed in 'Nm³ per minute', and
- the third diagram, the height of the lance in 'cm above the level of the bath'. All these parameters are shown as a function of the blowing time in 'minutes'.

Figure 2 shows, for a quite classic LD heat, the general trend of two curves, the first one being relative to the oxygen flow rate and the second one relative to the height of the lance. The scales and the units are the same as those used in figure 1.
In figure 2, which concerns a completely normal average LD heat, it can be seen that in the course of the initial phase a rather soft jet of oxygen is blown through the lance in a rather elevated position in order to first dissolve the lime and bring about the initiation of the reactions. Thereafter the flow rate is increased in view of the refining of the bath with a harder and more penetrating jet. The lance, which is kept higher at the beginning of the operation in order to accelerate the formation of the slag, is now lowered stepwise to the lowest level to perform the decarburization, before being raised again towards the end of the blowing period to confer to the slag a consistency which is favourable for the deslagging. The figures shown on the ordinates and on the abscissa of the figures are the figures which can occur for a heat of hematite hot metal treated in a normal way in an LD operated 100 ton converter.

In figure 1, which illustrates the changes occurring for the operation of the refining according to the present invention, it can be seen that the total oxygen flow rate is kept unvariably at the same value from the beginning to the end of the refining. However, in this case, the quantity of oxygen injected per minute during the first phase is higher than hitherto. This is possible due to the fact that the rotation or the modulation of the jets at adjustable velocities allows a much better control of the refining and the result thereof is a shorter refining time.

The height of the lance too is kept constant at the same level. Only if more important quantities of scrap are smelted and if the head of the lance is liable to be damaged by the scrap projecting beyond the level of the bath, one foresees an initial phase during which the height of the lance is more important, as has been illustrated by the part of the curve presented by the interrupted line. This precaution has absolutely no other effect on the process itself, as will be explained herebelow. According to the invention the higher position of the lance is not chosen to take influence in a specific and instantaneous manner for
example on the consistency or on the reactivity of the slag. This would result from such a variation of the lance position in the case of the LD operation.

On the upper diagram, illustrating mainly a heat run with freely rotating jets, it can be seen that at the beginning of the blowing phase a very slow rotation velocity of the jets has been set. This is due especially to the fact that the lance is kept higher than the standard position because of the presence of the scrap. Indeed, if the distance between the nose of the lance and the surface of the bath is important and if the rotation of the jets is slow, the impact of the jets on the surface of the bath is relatively harder and the ignition or start of the reactions is induced. This method of initiating the process can also be used when processing a heat which has the composition of a conventional LD heat, i.e. which contains much less scrap or even nearly no scrap at all. In this latter case however the values for the height of the lance and for the rotation velocity of the jets will be less extreme than in the mentioned example.

After the start of the reactions, the operating conditions will be those of a first phase of the blowing. During this phase the height of the lance and the flow rate of the refining oxygen will remain strictly constant, whereas the rotation velocity of the jets may remain constant in the case of an ideal heat. If however the heat shows a less ideal behaviour, it is possible to react either by increasing or by diminishing, depending on the situation, the rotation velocity. If the slag tends to become too foamy and to flow out of the converter, the rotation velocity of the jets is first slowed down and then increased again, as exemplified by the interrupted line in figure 1. During the second phase of the refining process, the jets are rendered harder again by reducing stepwise the velocity of the rotation of the jets, whereas the height of the lance is kept unvariably at the same standard level. At the very end of the operation cycle the blowing is rendered oxidizing in order to condition the
slag in view of the pouring out, this being again achieved by varying only the rotation velocity of the jets. The problems very often encountered with the oxygen top blowing operation, such as delayed ignition, bad slag formation, slopping tendency of the slag etc, are now controlled more easily and also more rapidly by intervening only on the sole rotation velocity. As already mentioned, the response to this intervention is instantaneous as the jets or the rotor can be accelerated or slowed down without any noticeable delay between the command signal and the response to this signal, the response consisting in the variation of the impact energy on the bath and of the corresponding stirring efficiency therefor. The new system is moreover also simpler than the conventional refining operation and it is in addition very well suited for a complete automation.
The claims defining the invention are as follows:

1. Process for regulating the operation of the refining of hot metal in a steelmaking converter by blowing from above at least two supersonic primary oxygen jets of a given total flow rate against the surface of the bath to be refined, characterized in that the aimed at ratio between the decarburization speed of the metal and the oxidation speed of the slag is achieved by the fact that each one of the several jets coming out of a non-rotating lance impinges within the same annular area on the bath with a given energy and in that this energy is varied, depending on the physico-chemical condition of the bath, between upper and lower limits, whereas at the same time the height of the lance above the surface of the bath, together with the total volume of the oxygen flow feeding the bath are both kept at practically steady levels.

2. Process according to claim 1, characterized in that individual free jets of the primary refining oxygen are continuously rotating around the central axis of the lance at a variable and adjustable velocity and in that, through the impact energy of the jets scouring the surface of the bath, the stirring intensity of this bath is regulated with the help of the said rotation velocity of the jets.

3. Process according to claim 1, characterized in that the flow rate of the several individual jets of primary refining oxygen leaving the lance is modulated for a given rotor speed according to a given periodical pattern and in that the overall stirring intensity of the bath, resulting from the cyclic variation of the impact energy of a given jet at the same impact points, is regulated instantaneously by varying the rotation speed.

4. Process according to claim 3, characterized in that the impact zone of each of the several jets is kept within half the inner wall of the lance.

5. Process according to claim 1, characterized in that a jet velocity varies, and in that the height of the lance above the surface of the bath is kept upright.

6. Process according to claim 1, characterized in that a jet velocity varies, and in that the height of the lance above the surface of the bath is kept upright.

7. Process according to claim 1, characterized in that the jet velocity varies, and in that the height of the lance above the surface of the bath is kept upright.

8. Process according to claim 1, characterized in that the jet velocity varies, and in that the height of the lance above the surface of the bath is kept upright.

9. Process according to claim 1, characterized in that the jet velocity varies, and in that the height of the lance above the surface of the bath is kept upright.
4. Process according to one of the claims 1 to 3, characterized in that the individual jets of primary refining oxygen diverge by an angle comprised between 10° and 30° from the central axis of the lance which is kept in the same position above the surface of the bath at such a distance therefrom that the centre of the impact zone of each single jet lies on a radius at approximately half the way between the vertical axis of the converter and the inner wall of the lining.

5. Process according to one of the claims 1 to 4, characterized in that during the operation of the process the rotation velocities of the jets or of the partially obturating rotor varies, according to physico-chemical needs of the refining reactions, between 1 and 60 revolutions per minute.

6. Process according to one of the claims 1 to 5, characterized in that at the beginning of the operation a given total flow rate is selected for the refining oxygen and in that this flow rate is kept upright and unvariable until the end of the blowing, the average flow rate being higher than the corresponding parameter of the conventional oxygen refining operation.

7. Process according to one of the claims 1 to 6, characterized in that the only deviation from the standard height of the lance will occur during the initial phase of the operation.

8. Process according to one of the claims 1 to 7, characterized in that apart from the jets of primary oxygen with controllable impact energy one injects also, laterally with respect to these primary jets, a plurality of jets of secondary post-combustion oxygen.

9. Process according to one of the claims 1 to 8, characterized in that the movement induced in the bath by the primary jets is intensified by at least one flow of bubbling gas injected through the refractory lining of the bottom part of the converter.
10. Process for regulating the operation of the refining of hot metal substantially as hereinbefore described with reference to the accompanying drawings.

DATED this 25th day of November, 1991.

ARBED S.A.

By its Patent Attorneys:

CALLINAN LAWRIE

[Signature]
Fig. 1

- Graph 1: t/min. vs. time (0-18 min.)
- Graph 2: Nm³/min. vs. time (0-18 min.)
- Graph 3: cm. vs. time (0-18 min.)