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(54) REFINING MOLTEN METAL

FEINEN VON SCHMELZFLÜSSIGEM METALL

RAFFINAGE DE METAL EN FUSION

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US-A- 4 396 182	**US-B1- 6 432 163**

- **PATENT ABSTRACTS OF JAPAN vol. 013, no. 536 (C-660), 29 November 1989 (1989-11-29) -& JP 01 219116 A (SUMITOMO METAL IND LTD), 1 September 1989 (1989-09-01)**
- **PATENT ABSTRACTS OF JAPAN vol. 1997, no. 01, 31 January 1997 (1997-01-31) -& JP 08 246017 A (NIPPON STEEL CORP), 24 September 1996 (1996-09-24)**

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Description

[0001] This invention relates to a method of refining molten metal.

[0002] It is well known to refine molten metal by introducing one or more jets of oxygen into it. For example, steel is made from iron in this way. In some processes the jets of oxygen are introduced into a bath of the molten metal from tuyeres whose tips are situated below the surface of the molten metal. The use of tuyeres is considered to be less than ideal, being associated as a cause of damage to the refractory lining of the vessel in which the metal refining operation is carried out. It is therefore common practice to introduce some or all the jets of oxygen into the molten metal from above. The commercially important Basic Oxygen Steelmaking (BOS) process is one that uses oxygen jets "blown" into the molten metal from above. The oxygen reacts with carbon that is found in dissolved form in the molten metal to form carbon monoxide. In addition the oxygen reacts with impurities or minor components of the molten metal (for example, silicon) so as to form a slag on the surface of the molten metal.

[0003] In general, the reaction between oxygen and, say, carbon in the molten metal is not rate limited. It is therefore desirable to maximise the rate at which the oxygen is introduced into the molten metal. Practical issues do, however, limit this rate. One of these issues is the degree of turbulence caused by the introduction of the oxygen into the molten metal. If there is excessive splashing of molten metal, it is believed that wear of the lance through which the oxygen is blown may become excessive resulting in a need to replace the head of the lance so frequently that the economical manufacture of the metal is prejudiced. Excessive splashing of the molten metal may also cause it to be ejected from the vessel giving rise to loss of yield and an increased need for maintenance of downstream equipment. On the other hand, in order to facilitate reaction between oxygen and carbon it is desirable that there is a certain amount of turbulence in the molten metal particularly during the latter stages, typically the last 20% of the blow, when mass transfer limitations can be encountered.

[0004] It is disclosed in patents applications such as EP-A-866 138 and EP-A-866 139 that a jet of oxygen as it travels through a stationary atmosphere tends to entrain the stationary atmosphere into it. This entrainment has the effect of reducing the velocity and the thrust of the oxygen jet. It is postulated that as a result of the entrainment the lance head has to be positioned closer to the surface of the molten metal than is ideal, therefore making it more vulnerable to damage by the splashing molten metal. EP-A-866 138 and EP-A-866 139 propose that the lance head is in effect converted into a burner. There is still a primary jet of oxygen, which is ejected from the lance at supersonic velocity, but now the primary jet of oxygen is surrounded by a secondary flame envelope. The secondary flame envelope is formed by ejecting a fuel gas (or liquid fuel) and secondary oxygen from the lance head. The fuel gas and secondary oxygen mix to form a flame. The flame envelope is stated to prevent entrainment of stationary atmosphere into the oxygen jet. Therefore, so it is explained, the oxygen jet does not diverge or lose velocity in the way it would were there to be no flame envelope. Accordingly, the oxygen jet is able to penetrate well beneath the surface of the molten metal, thereby facilitating its reaction with carbon dissolved in the molten metal. Further, the lance head can be readily positioned sufficiently above the molten metal that its rate of wear can be kept to acceptable levels.

[0005] Although this is a beguiling theory, we believe it overestimates the disadvantages of conventional practice. Further, the formation of the flame envelope has one substantial disadvantage, namely the fuel gas or liquid fuel has to be supplied to the overhead lance. The degree of disadvantage may vary from metal melting or refining process to metal melting or refining process. In, for example, the BOS process the disadvantage is quite substantial because the teachings of EP-A-866 138 and EP-A-866 139 require an overhead fuel supply to be laid on specially for the creation of the flame envelope. The engineering difficulties of doing this are considerable, particularly as the lance normally has to be manipulated between upper and lower positions. In addition, the likelihood of hydrogen pick-up by the molten metal is significantly increased and for many grades of steel is unacceptable.

[0006] US4 396 182 discloses a lance for blowing an oxidising gas onto a bath of molten metal, in which the lance has a set of primary oxygen ports 3 and a set of secondary oxygen ports 6. It is not agreed, however, that entrainment of this secondary jet into the primary jet is disclosed. The main idea on which the invention is based is to create of the outlet of lance a continuous sheet of oxygen [from the secondary jets] which expands in the form of an "umbrella" around the principle jets while being directed toward the bath.

[0007] JP-A-08-246017 discloses a lance head having an axial oxygen port 1 surrounded by a series of secondary oxygen ports 4. The general arrangement appears to be similar to those of US 4 396 182, in particular, and there is no disclosure of entraining oxygen from the port 3 into oxygen from the ports 4, or vice versa.

[0008] US6 432 163 B1 relates to an improvement or modification of the apparatus disclosed in EP-A-866 138. D5 discloses a lance with central primary oxygen nozzles 5. There is a first ring 8 of secondary nozzles surrounding the primary nozzles 5 and a third ring 9 of tertiary oxygen nozzles outside the ring 8 of secondary nozzles. In one mode of operation fuel may be passed through the secondary nozzles. This fuel mixes with the tertiary oxygen and forms a flame shroud or envelope which surrounds the primary oxygen jets. The flame shroud or envelope serves the same purpose as that in EP-A-866138, namely to prevent entrainment of surrounding atmosphere into the primary jets.

[0009] We believe the ability to improve oxygen blowing techniques in metal refining is contingent upon increasing the rate at which oxidant is made available for reaction without causing concomitant problems of unduly enhanced rates of lance wear.

[0010] According to the present invention there is provided a method of refining molten metal in a vessel by the reaction of oxygen with impurities in the molten metal, according to claim 1.

[0011] It is believed that the method according to the invention can be operated so as to decrease the time taken to reduce the carbon content of a given volume of molten metal. It is further believed that this result can be achieved without increasing the initial pressure, velocity and flow of the primary oxygen, thereby keeping down the risk of increasing the rate of erosion or damage to the lance head, in comparison with that usually experienced in conventional methods. Increased pressure, velocity and flow of the primary oxygen can also cause ejection of some molten metal and slag from the vessel with attendant loss of yield and maintenance issues. The method and lance head according to the invention also offer the advantage that no fuel is supplied to the lance head, thereby avoiding the need for an overhead fuel supply, such an overhead fuel supply being required for the formation of the shrouded gas jets described in EP-A-866 138 and EP-A-866 139.

[0012] The method and lance head according to the invention are particularly intended for use in the Basic Oxygen Steelmaking (BOS) process, but are also applicable to some other steelmaking processes and some processes for refining non-ferrous metals.

[0013] The said primary jet of oxygen is desirably ejected from the lance in both step (a) and step (b) of the method according to the invention at an axial velocity that is supersonic. In both these steps, a supersonic velocity in the range of Mach 1.5 to Mach 3 may be used.

[0014] In order to achieve entrainment of each secondary oxygen jet at a suitable intermediate location of its associated primary jet, the longitudinal axis of each secondary jet diverges from the longitudinal axis of its associated primary jet in the direction of travel at an angle of 5° to 25°.

[0015] The angle of divergence of each secondary oxygen jet from its associated primary oxygen jet is in the range of 5° to 25° depending on the absolute velocity of the second oxygen jet and its velocity relative to the first oxygen jet. Preferred angles of divergence are in the range of 10° to 20°.

[0016] Typically, from two to eight secondary oxygen jets are used, with from two to six being preferred. The exact number of secondary ports may be selected in accordance with the desired ratio of primary oxygen to secondary oxygen flow. For example, the secondary oxygen flow may be up to 50% of the primary oxygen flow and up to twelve secondary ports may be used. Normally the secondary oxygen flow is from 5 to 50% of the primary oxygen flow.

[0017] The linear separation of each secondary oxygen port from its associated primary oxygen port is typically less than twice the diameter of the primary oxygen port.

[0018] Each secondary oxygen jet is preferably thinner than the primary oxygen jet.

[0019] The individual secondary oxygen jets preferably travel separately from one another to their entrainment in the primary jet of oxygen.

[0020] In, for example, Basic Oxygen Steelmaking, the head of the lance is typically immersed in the slag layer during the said step (b). In this example of Basic Oxygen Steelmaking and in other examples, there is a plurality of primary oxygen jets, each being associated with one or more secondary oxygen jets.

[0021] The relationship between each primary oxygen jet and its associated secondary oxygen jets may be such that any or all of the typical or preferred features described above may be employed.

[0022] A plurality of primary oxygen jets is employed. They typically issue from primary oxygen ports that are arranged generally circumferentially (or on the perimeter of another closed geometric figure). The secondary oxygen ports are typically arranged outside the primary oxygen ports.

[0023] Each primary oxygen port has a group of secondary oxygen ports associated with it and each group of secondary oxygen ports is arranged on the arc of a circle that is concentric with the primary oxygen port with which said group is associated. The angle subtended by the arc is normally less than 180°.

[0024] In a preferred lance head according to the invention each primary oxygen port is in the form of a convergent-divergent nozzle and each oxygen jet is emitted from the tip of the lance head.

[0025] Lance heads according to the invention generally have passages for the flow of a coolant, for example, water.

[0026] In some preferred embodiments of the lance head according to the invention all the primary and secondary oxygen ports communicate with a common chamber in the lance head. Such embodiments offer the advantage of mechanical simplicity. In other preferred embodiments of the lance head according to the invention, the or each primary oxygen port communicates with a chamber in the lance head that does not communicate with the secondary oxygen ports. These embodiments offer the advantage of making possible control of the velocity and flow rate of the secondary oxygen independently of the primary oxygen.

[0027] On many occasions it is preferred to perform in a method according to the invention the addition step of

> e) mixing with at least one stirring gas upstream of ejection the oxygen from which the primary jet and/or secondary jet is formed.

[0028] In conventional practice with a conventional lance commercially pure oxygen is simply blown at supersonic velocity into the molten metal. The rate and velocity are chosen so as to complete a refining operation in a minimum time without creating excessive turbulence and splashing. Including a stirring gas in the primary jet in accordance with the invention tends to facilitate metallurgical reaction between dissolved carbon in the molten metal and the gaseous oxygen that penetrates the surface of the molten metal. Further, the use of the secondary jet provides additional oxygen and the rates of supply of primary oxygen, secondary oxygen and stirring gas may be chosen so as to maximise the total rate of oxygen input whilst ensuring that the force imparted by the primary jet is not increased to the point where unacceptable splashing would occur.

[0029] If a stirring gas is used, the primary jet is preferably formed by premixing the stirring gas with the oxygen.

[0030] The stirring gas is preferably a noble gas, particularly argon. For some grades of steel, however, nitrogen may be tolerated as the stirring gas provided it does not have a deleterious effect on the steel.

[0031] If a stirring gas is used, the said primary jet of oxygen may have the same composition throughout a heat. Alternatively its composition can be varied, being increased at one or more instants during a heat. Indeed, there may be during an initial period no deliberate addition of stirring gas. (Some argon will always be present as an impurity in the oxygen.) The need for stirring is usually greatest towards the end of a heat and therefore the mole fraction of stirring gas in the primary jet is preferably greater in the last part (typically the last fifth) of the heat than in the first half of the heat. Indeed, it is possible to continue the supply of stirring gas after the supply of oxygen has been discontinued.

[0032] The method according to the invention and lance heads according to embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a schema of a BOS vessel adapted to operate the method according to the invention;

Figure 2 is an end view of a first lance head according to the invention;

Figure 3 is a section through the line N-N of Figure 2;

Figure 4 is a side elevation of the lance head shown in Figure 2;

Figure 5 is an end view of a second lance head according to the invention; and

Figure 6 is a section through the line M-M of Figure 5.

[0033] Referring to Figure 1 of the drawings, there is shown a Basic Oxygen Steelmaking (BOS) vessel 102. The vessel 102 has a refractory lining (not shown). In operation, the vessel is charged with a batch of molten iron. This volume of molten iron is shown by the reference numeral 106 in Figure 1. The molten iron is refined by reaction with oxygen. The oxygen is supplied through a vertical lance 110 having a head 112. The lance 110 is typically made of stainless steel and has a plurality of primary ports 114 in its head 112 for the discharge of oxygen. The ports 114 communicate with an oxygen passage 115 through the lance 110. The lance 110 and head 112 are also provided with passages 116 for the flow of a coolant (typically, water) to protect it against catastrophic damage in the hot environment of the BOS vessel 102. The lance 110 is also associated with a lance manipulator (not shown) which is able to raise and lower the lance 110. In typical practice, the lance 110 is operated in two positions. One is a so-called "soft blowing" position, in which the lance 110 is operated with its tip relatively distant from the surface of the molten metal, and the other is a so-called "hard blowing" position, in which the lance 110 is operated with its tip relatively close to the surface of the molten metal and typically with the lance head 112 immersed in a volume 118 of molten slag that is formed on the surface of the volume 106 of molten metal during the refining of the molten metal. It is one of the advantages of the method according to the present invention that it does not necessarily involve any change to the soft and hard blowing lance head positions that are sometimes conventionally used.

[0034] The method according to the invention may equally be used with a lance whose position is controlled dynamically in response to decarburisation rate and other factors. Such dynamic control is well known in the art.

[0035] The refining of the molten iron commences with the supply of oxygen from the lance head 112 in a soft blowing position. The oxygen is ejected from the head 112 at a supersonic velocity, typically in the range of Mach 1.5 to 3. The oxygen is typically supplied to the lance head at a temperature in the range of 0°C to 50°C. There is no need to preheat the oxygen, but a small amount of incidental preheating may take place as the ambient environmental of a BOS vessel is usually at a substantially higher temperature than normal room temperature. The oxygen is also typically supplied at a pressure in the range of 5 bar to 20 bar so as to enable it to be ejected from the lance head at a supersonic velocity. The primary oxygen penetrates the surface of the molten metal 106 and reacts with carbon and other impurities such as silicon and phosphorus therein. The chemistry of steelmaking is well known and need not be described in detail herein. Suffice it to say that the dissolved carbon in the bath of molten metal has a high affinity for oxygen and reacts rapidly with it to form carbon monoxide, while other impurities react with the oxygen to form a molten slag which, being lighter than the molten ferrous metal, rises to the surface to form a molten slag layer. The velocity of the primary oxygen is such as to cause agitation of the molten metal and there is typically a degree of turbulence at its surface. The slag layer 118 will also be turbulent and will contain a considerable volume of carbon monoxide bubbles as a result of the reaction between the carbon dissolved in the molten ferrous metal and the oxygen.

[0036] After the formation of the slag layer it is desirable to increase the rate of decarburisation of the molten metal. The lance 110 is thus lowered into its hard blowing position with the head 112 immersed in the molten slag 118. (It is this position which is illustrated in Figure 1.) The primary oxygen is supplied at a supersonic ejection velocity during the hard blowing stage. In addition, in accordance with the invention, secondary oxygen is also supplied. If desired, or as an inevitable consequence of the configuration of the lance head, the secondary oxygen may be supplied during the soft blowing phase and may then help to form the slag. There are a number of different options. For example, the primary oxygen flow rate and velocity may be increased from the soft blowing phase to the hard blowing phase.

[0037] A plurality of primary oxygen jets is employed and each is associated with a plurality of secondary oxygen jets. One such primary oxygen jet 120 is illustrated schematically in Figure 1. The primary oxygen jets 120 diverge in the direction of flow of oxygen. Two secondary oxygen jets 122 are shown in Figure 1. The secondary oxygen jets 122 travel separately from one another. They diverge from the primary oxygen jets 120. The angle of divergence depends on the absolute and relative velocities of the primary and secondary oxygen jets. In general, the lower the absolute and relative velocity of the secondary oxygen jets, the wider can be the angle of divergence. The purpose of the angle of divergence is to ensure that most of the secondary jets are entrained back into the primary jets upstream of the surface of the molten metal. However, it is preferred to avoid this entrainment from taking place too near the tip of the lance head itself. This may happen if the angle of divergence is too small. On the other hand, if the angle of divergence is too large the secondary oxygen jets may simply continue to diverge and peter out without being entrained into the primary jets and without penetrating the molten metal. An angle of divergence in the range of 5° to 25°, preferably 10° to 20° is employed.

[0038] As the secondary oxygen jets 122 travel through the slag layer 118 so they encounter bubbles of carbon monoxide therein. Such is the temperature in the slag layer that we predict that there will probably be reaction between carbon monoxide and oxygen to form carbon dioxide. Indeed, this reaction may quite possibly be sufficiently intense to form each secondary oxygen jet into a flame. The formation of carbon dioxide in this way is not intrinsically disadvantageous as carbon dioxide can act as a decarburising agent. The entrainment of secondary oxidant into the primary oxygen jets brings more oxidant into contact with the molten metal. As a result the rate of oxidation of carbon and other impurities is enhanced and it therefore is possible to reduce the time taken to reduce the concentration of dissolved carbon to a chosen level. It matters little whether the secondary oxidant enters as the primary oxygen jets as secondary oxygen, secondary carbon dioxide, or a secondary mixture of the two gases. Thus, any formation of carbon dioxide is incidental to the invention.

[0039] It is believed that the time taken to reduce the carbon level in the molten metal to a given value is dependent upon the rate at which oxidant molecules are brought into contact with dissolved carbon molecules. Enhancing the rate at which oxidant molecules come into intimate contact with the dissolved carbon reduces the refining time. Accordingly, there are advantages to be had in employing a sizeable quantity of secondary oxidant. In general terms, the rate of flow of secondary oxidant can be up to 50% of the rate of flow of primary oxidant.

[0040] If the primary oxygen and the secondary oxygen flow via the same chamber in the lance head, there is no freedom in setting the secondary oxygen jet velocity independently of the primary jet velocity; it tends to be a little less than the primary oxygen jet velocity, there being greater "frictional losses" associated with the secondary jets because they are normally generated from thinner passages than the primary jets. In such an example, the secondary jets would typically exit the secondary passages at sonic velocities but in an underexpanded condition, leading to an immediate strong shock to supersonic flow conditions and a series of shock waves dissipating the kinetic energy of the jets. On the other hand, if the secondary oxygen comes from a separate source than the primary oxygen there is a much greater freedom to vary the secondary oxygen velocity. In general, a secondary oxygen velocity substantially less than the primary oxygen velocity facilitates entrainment of the secondary jets into the primary oxygen.

[0041] During or throughout the hard blowing stage argon or other stirring gas may be added to the primary oxygen upstream of the lance 110. Typically the stirring gas is added at a rate up to or equal to that at which secondary oxygen is used. The total flow of gas to the primary jets preferably remains unaltered throughout the hard blowing phase of a heat. The stirring gas may be supplied at constant rate throughout a heat, or may be supplied towards the end of a heat when the level of dissolved carbon is approaching what is desired. Stirring gas may be substituted for some of the primary oxygen and supplied to the primary jets.

[0042] When the carbon level in the ferrous metal has been reduced to a desired value, the supply of oxygen (both primary and secondary) and stirring gas may be stopped and the lance 110 withdrawn from the steelmaking vessel 102. The molten metal may then be tapped off from the vessel 102 in a conventional manner.

[0043] The ability to select when and how much stirring gas to supply helps the steelmaker to optimise the steelmaking process. During an initial period of the hard blow phase of a heat, the carbon levels are relatively high and the substitution of stirring gas for oxygen may simply retard the refining. Towards the end of the heat, when carbon levels are lower, the addition of a stirring gas is believed to be beneficial.

[0044] The configuration of a first lance head 200 for use in the method according to the invention is illustrated in Figures 2 to 4. With reference to Figures 2 to 4, the lance head 200 has a nose 202 at its forward end or tip 204. The nose 202 is surrounded by a sloping annular face 206 which has its inner circumferential edge more forward than its outer circumferential edge. As shown in Figure 2, four primary oxygen ports 208 are formed in the annular face 206. Each of the primary oxygen ports 208 has its axis normal to the face. Thus, each of the primary oxygen ports 208 has an axis that diverges in the direction of oxygen flow from the longitudinal axis of the lance head 200 itself. The angle of divergence is typically in the order of 5 to 15°. The oxygen ports 208 are arranged circumferentially being equally spaced form one another. As a result of this arrangement the primary oxygen jets penetrate the surface of the molten metal at four different regions, thereby facilitating a good dispersal of the oxygen. If desired, fewer or more primary oxygen ports 208 than the four illustrated may be employed.

[0045] Each primary oxygen port 208 forms the termination of a convergent-divergent nozzle 210 formed through the lance head 200. The nozzle 210 has an upstream convergent portion 212, an intermediate portion 214 of constant diameter and a divergent potion 216. The convergent portion 212 communicates with an oxygen chamber 218 which is formed as an extension of the head 200. The convergent-divergent nozzles 210 (sometimes referred to as Laval nozzles) are able to eject at supersonic velocity oxygen supplied at elevated pressure to the chamber 218. The design of the convergent-divergent nozzles 210 is preferably such that the oxygen is perfectly expanded on exit from the primary oxygen ports 208.

[0046] Each primary oxygen port is associated with a plurality of secondary oxygen ports 220. As shown in Figure 2, each primary oxygen port 208 is associated with two secondary oxygen ports 220. Each port 220 is formed in the annular face 206. The secondary ports 220 are all positioned intermediate the primary oxygen ports 208 and the outer circumferential edge of the annular face 206. Each secondary port 220 is of a considerably smaller diameter than the primary oxygen ports 208. Each secondary port 220 has an axis which in the direction of oxygen flow diverges from the corresponding axis of the primary oxygen port 208 with which it is associated. The angle of divergence may be up to 45° provided that the criteria discussed above with reference to Figure 1 are fulfilled. Typically, however, the angle of divergence is in the range of 5 to 25°, more typically in the range of 10 to 20°.

[0047] Each secondary oxygen port 220 is at the termination of a secondary oxygen passage 222. The secondary oxygen passages 222 are each formed with an upstream leg 224 and a downstream leg 226. The downstream leg 226 is preferably at an angle to the upstream leg 224. Each upstream leg 224 communicates with the chamber 218. As shown in Figure 3, the downstream legs 226 are of smaller diameter than the upstream legs 224. If desired, however, the opposite arrangement can be employed with the upstream legs 224 being of smaller diameter than the downstream legs 226. Such an arrangement may be used if lower secondary oxygen jet velocities are desired. The passages 222 are typically all formed as bore and counterbore.

[0048] For ease of illustration, each primary oxygen port 208 is shown as associated with only two secondary oxygen ports 220. Typically, however, each primary oxygen port 208 is associated with a greater number than two of secondary oxygen ports 220. Thus, typically, each primary oxygen port 208 is associated with from two to eight secondary oxygen ports 220. Each group of secondary oxygen ports 220 is preferably arranged on the circumference of a circle that is concentric with the axis of the associated primary oxygen port 208. The spacing of the secondary oxygen ports 220 is such that, in operation, the jets of oxygen that issue therefrom do not merge with one another. Each group of secondary oxygen ports 220 is typically arranged so that the ports 220 do not extend around the entire circumference but instead subtend an arc that is less than 360° and normally less than 180°.

[0049] The head 200 is formed with an inner integral sleeve 228 and an outer integral sleeve 230 surrounding the oxygen chamber 218. The sleeves 228 and 230 define passages for the flow of a coolant, normally water, through the lance head in its normal operation. These passages extend into the nose 202 of the lance 200.

[0050] The lance head 200 may simply be welded or otherwise fixed fluid tight to a lance (not shown in Figures 2 to 4) which has three concentric passages, an inner one being for oxygen and the two others for coolant. After use to refine a large number of batches of molten metal, it becomes necessary to replace the lance head 200. This may simply be done by cutting off the used head from the lance and welding on a new lance head.

[0051] The operation of the lance head shown in Figures 2 to 4 is essentially as described herein with reference to Figure 1. The secondary oxygen jets are entrained in each primary oxygen jet and, as discussed above, enhance the flow of decarburising agent that comes into intimate contact with the molten metal being refined. As a result, it is believed that the time taken to refine a given volume of molten metal of given composition may be reduced in comparison with conventional practice in which only primary jets of oxygen are used. Any combustion of the secondary oxygen that might take place as a result of entrainment of carbon monoxide into the secondary oxygen jets is incidental to the invention.

[0052] Because the secondary oxygen ports 220 communicate with the oxygen chamber 218, the secondary oxygen jets typically issue at sonic velocity and expand rapidly to supersonic velocity owing to the pressure of differential between their underexpanded exit condition and the ambient vessel pressure. This supersonic velocity may be less than that at which the primary oxygen jets are ejected as a result of "frictional" interaction between the flowing oxygen and the walls defining the secondary oxygen passages 222.

[0053] An alternative embodiment of the lance head is shown in Figures 5 and 6. Parts in Figures 5 and 6 that correspond to ones in Figures 2 to 4 are indicated by the same reference numerals as in Figures 2 to 4. In general, the configuration and operation of the lance head shown in Figures 5 and 6 are very similar to the configuration and operation of that shown in Figures 2 to 4. The main difference between the two embodiments is that in the lance head shown in Figures 5 and 6 the secondary oxygen passages 222 communicate with an annular secondary oxygen chamber 300 that surrounds the chamber 218 and is coaxial therewith. As a result, the secondary oxygen may be ejected at a velocity independent of that at which the primary oxygen issues from the lance head. Accordingly, if desired, the secondary oxygen may be ejected at a supersonic velocity greater than the primary oxygen velocity, a supersonic velocity less than the primary oxygen velocity, sonic velocity, or a subsonic velocity. One advantage of a subsonic secondary oxygen velocity is that it facilitates entrainment of the secondary oxygen jets into the primary oxygen.

[0054] Various changes and modifications to the lance heads may be made. For example, if desired, the lance head can have at its proximal end apertures formed in the wall of an oxygen chamber so as to allow some of the oxygen to be ejected for the purpose of post-combustion of carbon monoxide at a region of the BOS vessel remote from the surface of the molten metal. Other embodiments of the invention will be readily apparent to a person skilled in the art. The scope of the invention is defined in the following claims.

Claims

1. A method of refining molten metal in a vessel by the reaction of oxygen with impurities in the molten metal, wherein the vessel contains a volume of the molten metal, comprising the steps of :

    a) ejecting at least one primary jet of oxygen from a lance positioned above the molten metal into the molten metal to react with impurities therein and to form a layer of molten slag;
    b) continuing to eject the primary jet of oxygen from the lance and thereby causing the primary jet of oxygen to pass through the slag layer into the molten metal;
    c) ejecting a plurality of secondary jets of oxygen from the lance, the secondary jet of oxygen travelling for a distance separately from the primary jet of oxygen; and
    d) entraining the secondary jets of oxygen into the primary jet of oxygen upstream of the entry of the primary jet of oxygen into the volume of the molten metal

    wherein the lance has a head having at least one primary oxygen port and a plurality of secondary oxygen ports, each secondary oxygen port being associated with the primary oxygen port or one of the primary oxygen ports and having an axis diverging in the direction of flow from its associated primary oxygen port at an angle of 5 to 25°, the angle of divergence assuring that most of the secondary jets are entrained back into the primary jets upstream the surface of the molten metal, wherein there is a plurality of primary oxygen ports and a group of two to eight secondary oxygen ports associated with each primary oxygen port, and
    wherein each group of secondary oxygen ports are arranged on an arc of a circle that is concentric with the primary oxygen port with which said group is associated.

2. A method according to claim 1, wherein In step (b) the said primary jet of oxygen is ejected at a supersonic axial velocity is in the range of Mach 1.5 to Mach 3.

3. A method according to claim 1 or claim 2, wherein the longitudinal axis of each secondary jet diverges from the longitudinal axis of its associated primary jet in the direction of travel at an angle of 10 to 20°.

4. A method according to any one of the preceding claims, in which the secondary oxygen flow is from 5-50% of the primary oxygen flow.

5. A method according to any one of the preceding claims, additionally including the step of mixing with at least one stirring gas upstream of ejection the oxygen from which the primary jet and/or secondary jet is formed.

Patentansprüche

1. Verfahren zum Frischen von geschmolzenem Metall in einem Behälter durch die Reaktion von Sauerstoff mit Verunreinigungen in dem geschmolzenen Metall, wobei der Behälter ein Volumen des geschmolzenen Metalls enthält, umfassend die folgenden Schritte:

    a) Ausstoßen von mindestens einem primären Sauerstoffstrahl aus einer oberhalb des geschmolzenen Metalls positionierten Blaslanze in das geschmolzene Metall zur Umsetzung mit

Verunreinigungen darin und zur Bildung einer Schicht aus geschmolzener Schlacke;

b) weiter Ausstoßen des primären Sauerstoffstrahls aus der Blaslanze und **dadurch** Bewirken, dass der primäre Sauerstoffstrahl durch die Schlackeschicht hindurch in das geschmolzene Metall gelangt;

c) Ausstoßen einer Vielzahl an sekundären Sauerstoffstrahlen aus der Blaslanze, wobei der sekundäre Sauerstoffstrahl eine Strecke getrennt von dem primären Sauerstoffstrahl zurücklegt; und

d) Mitführen der sekundären Sauerstoffstrahlen in den primären Sauerstoffstrahl stromaufwärts vom Einlass des primären Sauerstoffstrahls in das Volumen des geschmolzenen Metalls, wobei die Blaslanze ein Kopfteil mit mindestens einer primären Sauerstofföffnung bzw. Öffnung für primären Sauerstoff und einer Vielzahl von sekundären Sauerstofföffnungen aufweist, wobei jede sekundäre Sauerstofföffnung mit der primären Sauerstofföffnung oder einer der primären Sauerstofföffnungen assoziiert bzw. verbunden ist und eine Achse aufweist, die in Strömungsrichtung von der damit verbundenen primären Sauerstofföffnung in einem Winkel von 5 bis 25° divergiert, wobei der Divergenzwinkel sicherstellt, dass die meisten sekundären Strahlen in die primären Strahlen stromaufwärts von der Oberfläche des geschmolzenen Metalls zurückgeführt werden, wobei es eine Vielzahl von primären Sauerstofföffnungen und eine Gruppe von zwei bis acht sekundären Sauerstofföffnungen, die mit jeder primären Sauerstofföffnung verbunden sind, gibt, und wobei jede Gruppe von sekundären Sauerstofföffnungen auf einem Kreisbogen eines Kreises angeordnet ist, welcher mit der primären Sauerstofföffnung, mit welcher die Gruppe verbunden ist, konzentrisch ist.

2. Verfahren gemäß Anspruch 1, wobei im Schritt (b) der besagte primäre Sauerstoffstrahl mit einer axialen Überschallgeschwindigkeit im Bereich von Mach 1,5 bis Mach 3 ausgestoßen wird.

3. Verfahren gemäß Anspruch 1 oder Anspruch 2, wobei die Längsachse jedes sekundären Strahls von der Längsachse des damit verbundenen primären Strahls in der Bewegungsrichtung in einem Winkel von 10 bis 20° divergiert.

4. Verfahren gemäß einem Beliebigen der vorhergehenden Ansprüche, in welchem der sekundäre Sauerstoffstrom 5 - 50 % des primären Sauerstoffstroms ausmacht.

5. Verfahren gemäß einem Beliebigen der vorhergehenden Ansprüche, welches weiterhin den Schritt des Mischens mit mindestens einem Rührgas stromaufwärts des Sauerstoffausstoßes, aus welchem der primäre Strahl und/oder sekundäre Strahl gebildet wird, einschließt.

Revendications

1. Procédé de raffinage de métal en fusion dans une cuve par la réaction d'oxygène avec des impuretés dans le métal en fusion, dans lequel la cuve contient un volume du métal en fusion, comprenant les étapes suivantes:

a) éjecter au moins un jet primaire d'oxygène à partir d'une lance qui est positionnée au-dessus du métal en fusion dans le métal en fusion pour la réaction avec des impuretés dans celui-ci et la formation d'une couche de laitier en fusion;

b) continuer à éjecter le jet primaire d'oxygène à partir de la lance et entraîner ainsi le jet primaire d'oxygène à passer à travers la couche de laitier dans le métal en fusion;

c) éjecter une pluralité de jets secondaires d'oxygène à partir de la lance, le jet secondaire d'oxygène parcourant une distance séparément du jet primaire d'oxygène; et

d) entraîner les jets secondaires d'oxygène dans le jet primaire d'oxygène en amont de l'entrée du jet primaire d'oxygène dans le volume de métal en fusion,

dans lequel la lance comprend une tête qui présente au moins une sortie d'oxygène primaire et une pluralité de sorties d'oxygène secondaires, chaque sortie d'oxygène secondaire étant associée à la sortie d'oxygène primaire ou à l'une des sorties d'oxygène primaires et présentant un axe qui diverge dans la direction d'écoulement de sa sortie d'oxygène primaire associée d'un angle de 5° à 25°, l'angle de divergence assurant que la plupart des jets secondaires sont entraînés à revenir dans les jets primaires en amont de la surface du métal en fusion, dans lequel il y a une pluralité de sorties d'oxygène primaires et un groupe de deux à huit sorties d'oxygène secondaires associées à chaque sortie d'oxygène primaire, et

dans lequel chaque groupe de sorties d'oxygène secondaires est agencé sur un arc d'un cercle qui est concentrique à la sortie d'oxygène primaire à laquelle ledit groupe est associé.

2. Procédé selon la revendication 1, dans lequel, à l'étape (b), ledit jet primaire d'oxygène est éjecté à une vitesse axiale supersonique qui est comprise dans la gamme de Mach 1,5 à Mach 3.

3. Procédé selon la revendication 1 ou la revendication 2, dans lequel l'axe longitudinal de chaque jet secondaire diverge de l'axe longitudinal de son jet primaire associé dans la direction de déplacement d'un angle de 10° à 20°.

4. Procédé selon l'une quelconque des revendications précédentes, dans lequel le flux secondaire d'oxygène équivaut à 5 % à 50 % du flux primaire d'oxygène.

5. Procédé selon l'une quelconque des revendications précédentes, comprenant en outre l'étape consistant à mélanger avec au moins un gaz d'agitation en amont de l'éjection l'oxygène à partir duquel le jet primaire et/ou le jet secondaire sont formés.

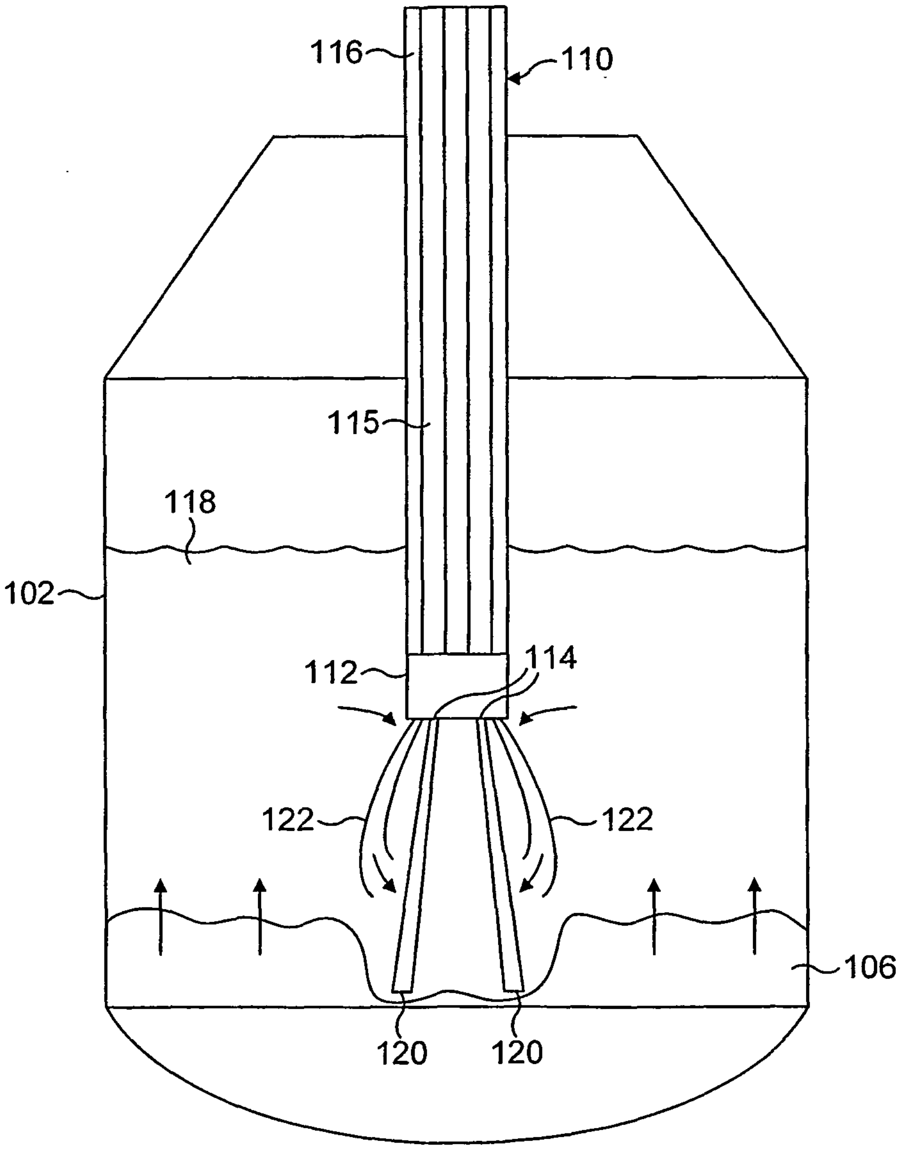

FIG. 1

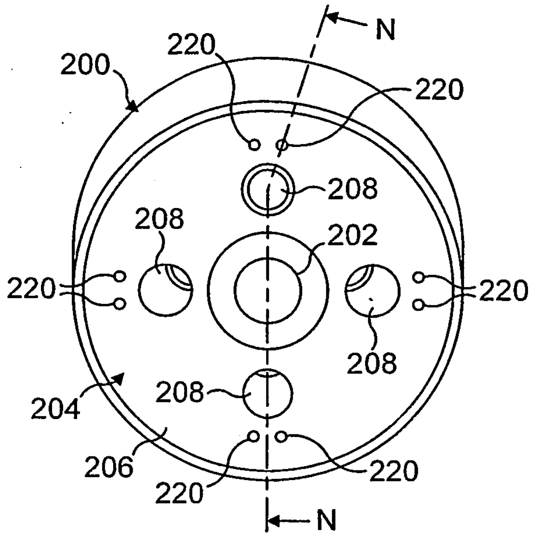

FIG. 2

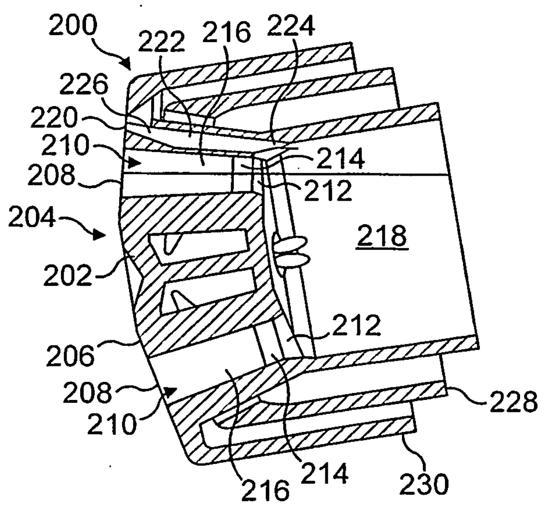

FIG. 3

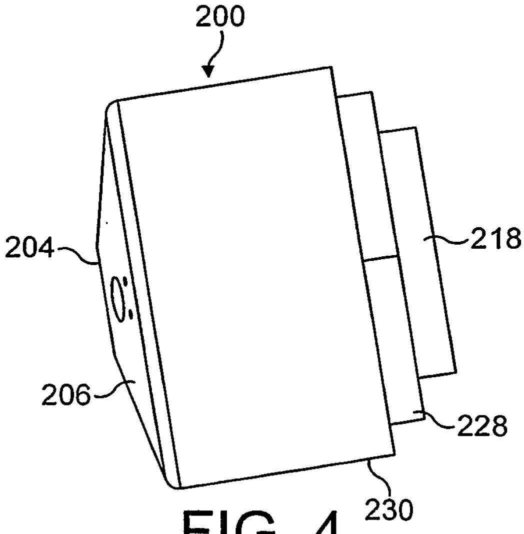

FIG. 4

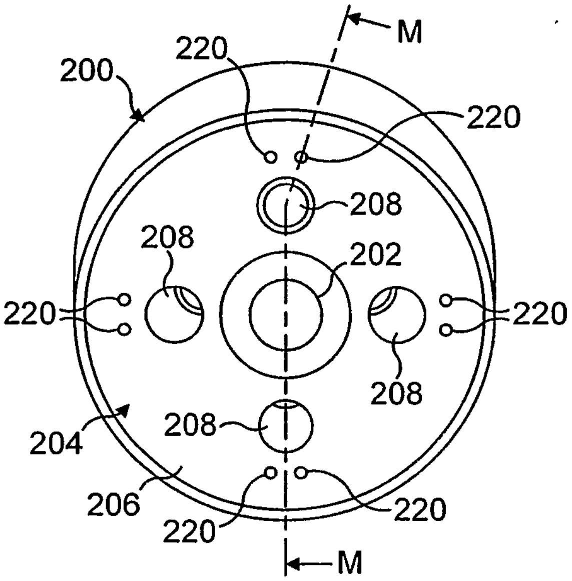
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FIG. 5

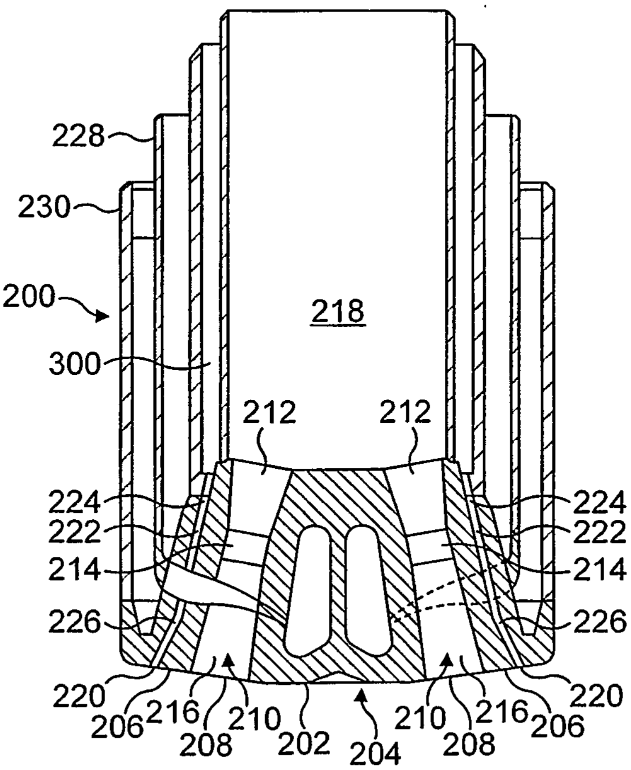
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FIG. 6

REFERENCES CITED IN THE DESCRIPTION

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