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DECARBURIZATION, DEOXIDATION, AND ALLOY ADDITION

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This invention relates to a method of decarburization, deoxidation and alloy addition in molten iron-base melts promoted by the addition of an inert gas to said molten iron-base melt.

The present processes for making steel generally proceed in four phases; namely, (1) meltdown (2) decarburization with air or pure oxygen whereby a substantial portion of slag is formed containing alloying element oxidation products from the iron-base melt, (3) reduction of alloying elements from the slag by the addition of metallic reducing agents, and (4) finishing or deoxidation of the final product.

The process of steel-making is directed to controlling or circumventing the undesirable effects dictated by a number of complex equilibrium relationships. The most important of these relationships being the equilibrium between carbon and oxygen in molten metallic melts. The relationship may be generally stated as follows.

$$C+MO \rightleftarrows M+CO$$

where C is carbon, M is a metal in the melt and O is oxygen in the melt.

The tendency of this reaction to proceed to the right is governed by the effective pressure of carbon oxide in the melt and to some extent by the temperature of the melt. In general an increase in temperature renders the metal more stable than carbon in the presence of oxygen although there are exceptions for particular metals and temperatures.

Since steels require a low carbon content, the present processes find it desirable to add sufficient oxygen to the melt to force the reaction to the right by greatly increasing the iron oxide content of the melt. This causes a substantial portion of the alloying elements in the steel to oxidize and pass to the slag. The metal oxides are subsequently reduced by addition of reducing agents such as silicon, manganese or chromium but the addition of reducing agents also cause further introduction of carbon; therefore, the previously adjusted carbon content is upset. Expensive high grade reductants (low carbon reductants) can be utilized only if economic considerations permit.

Another method of driving the above reaction to the right would be to utilize vacuum decarburization methods. These methods have been utilized but they are expensive and complicated. Furthermore the low pressures required to effectively reduce the pressure of carbon oxides in the bath result in vaporization of the melt constituents causing a change in bath composition. Moreover, the use of a vacuum to remove carbon monoxide, or any other gas for that matter, in the presence of a slag is hampered by the fact that any slag will reduce the effective surface area of the melt available for decarburization and hence, will decrease the reaction rate. In addition, for such an application, the slag must have such physical characteristics with respect to permeability and viscosity as to avoid the sealing off of the molten metal charge from the effects of the vacuum or near-vacuum atmosphere within the furnace. This seriously limits the possible slag compositions that can be employed and, furthermore, increases the possibility of operating difficulties occasioned by changes in slag properties or characteristics, namely, the slag becoming the spreading, glassy type.

While blowing an inert gas over the surface of the melt appears to avoid some of the aforementioned difficulties, this process is highly impractical for commercial steel production. Such a method relies on disturbing the equilibrium between the melt surface and the adjacent furnace atmosphere for the removal of the dissolved gases. In view of the relatively small surface area available for this purpose in comparison with the amount of the metal charge to be processed and the need to rely on diffusion for the migration of the dissolved gases to the surface of the melt, considerable amounts of the valuable processing time are required, usually of the order of hours, to effect some, if any, removal of dissolved gas. The diffusion rate could possibly be augmented by severe agitation of the molten metal charge; however, this calls for additional costly equipment installation. Moreover, the presence of slag on the surface of the melt further reduces the effectiveneses of the above-described gas-removal principle by reducing the effective surface area available. Also, the inert-gas consumption for the above process is very high, possibly reaching the degree where the cost of the inert gas becomes economically prohibitive.

It is an object of the present invention to provide a process for the deoxidation of molten iron-base melts without the use of metallic deoxidizers.

It is another object to provide an improved process for deoxidizing and decarburizing molten iron-base melts.

It is a further object to provide a process for the addition of alloying elements to molten iron-base melts by reduction of the oxidic alloying elements from the slag without the use of reducing agents.

It is still another object to provide an improved process for adding alloying elements to a molten iron-base melt in an oxidic form while simultaneously decarburizing and deoxidizing the melt.

It is another object to provide an improved process for finishing steel, in particular stainless steel, by decarburization without loss of alloying elements and/or deoxidation and decarburization without loss of alloying elements and in some cases with addition of alloying elements from the slag itself without the use of reducing agents.

Other objects will be apparent from the remaining disclosure and the appended claims.

An exemplary process accomplishing the above-mentioned objects comprises as a step in the production of steel from a molten iron base melt introducing at least one inert gas selected from the group consisting of argon, krypton, xenon, helium and neon into said molten iron-base melt to decrease the effective pressure of carbon oxide in the melt and thereby permit greater extent of reaction betwen carbon and oxygen in the melt.

For the purpose of the present invention "inert gas" is defined as a gas which in addition to being chemically inert will not alloy with iron-base melts in appreciable portions when the oxygen content in the melt is low.

It has been found that the proper introduction of an inert gas into the steel melt at the right time can accomplish rapid and thorough decarburization and deoxidation reactions. The inert gas should be injected in the form of small single bubbles or a dispersion of small bubbles at least several inches below the melt level. In the preferred embodiment of this invention, the bubbles should not exceed about 3 to 5 millimeters in diameter. This gives minimum inert gas consumption. Larger bubble sizes can also be used if inert gas consumption is not of major importance. Small bubbles provide an extremely large metal surface area per unit amount of gas introduced into the melt. For example, one standard cubic foot of inert gas will be exposed to about 4000 square feet of molten metal surface if the bubble size is about 3 mm. The effective surface area can be chosen essentially at will or as required for a particular metal treatment by

choosing the proper bubble size. The smaller the average bubble size, the larger the effective metal surface area for the process of this invention. The effective surface area in the prior art processes is essentially limited by the furnace or ladle employed. This is not the case with the present invention.

Moreover, the mass transfer rate is dependent on the relative partial pressures of the components to be transferred and also on the equilibrium partial pressures of a given component for the dissolved and gaseous state. The essentially pure inert gas, as employed in the practice of this invention, has an initial partial pressure of carbon monoxide equal to about zero, and, in this manner, provides a large driving force for the rapid removal of the dissolved carbon monoxide. During normal practice of this invention, the residence time of a bubble in the melt is of the order of about 1 second per foot of melt depth, hence the inert gas bubbles essentially get saturated with carbon monoxide during the bubbling process and are rapidly removed from the melt. However, every bubble gets the benefit of being introduced at essentially zero carbon monoxide partial pressure within the bubble, and therefore deoxidation of the melt can proceed to a much greater extent.

The proper use of inert gases for the most effective results in the practice of this invention is not suggested by their apparent function in reducing the effective pressure of carbon monoxide in a gas mixture. In fact, any gas, inert or reactive, will fulfill such function; hence, for the purpose of this invention, an "inert gas" is not defined simply by the partial pressure laws. As used herein, the term "inert gas" is defined to mean a gas selected from the group consisting of helium, krypton, neon, argon, and xenon. We have found that the rate at which nitrogen is dissolved by molten iron and its alloys is influenced markedly by the oxygen content of the metal. The lower the oxygen content, the more rapidly nitrogen will be dissolved. If carbon removal was attempted in accordance with the present invention by bubbling with nitrogen gas, the oxygen content, of course, would be also reduced but nitrogen will be adsorbed at the same time. The important point is that at an oxygen level in the steel bath of about 0.01% the rate of nitrogen inclusion will be rapid enough to raise significantly the nitrogen content of the finished steel. Excessive nitrogen content in the steel is undesirable, since it promotes blow holes, metal rising, and also nitride formation. The latter is a cause of embrittlement in the finished product. Therefore nitrogen is not considered to be an inert gas within the connotation reserved for that term throughout this application and claims.

Deoxidation as accomplished by the present process entails reduction of the effective pressure of carbon oxides in the melt itself at the sites where the carbon-oxygen reaction is proceeding. The effective pressure of carbon oxide is that pressure which dictates the extent to which the carbon-oxide reaction will proceed and is essentially equal to the pressure surrounding the molten melt when an inert gas is not utilized. When an inert gas is utilized as taught in the present process, the effective pressure of carbon oxides is reduced thereby allowing the carbon-oxygen reaction to proceed further.

The extent of deoxidation is limited only by the presence of carbon in the melt. If there is sufficient carbon in the melt to react with all the oxygen in the melt then the introduction of inert gas and transfer of inert gas to the reaction sites in the melt will result in virtually complete elimination of oxygen from the melt as a carbon oxide.

By the same token substantially stoichiometric amounts of carbon and oxygen in the melt will lead to virtually complete and simultaneous decarburization and deoxidation of the melt.

When there is a deficiency of carbon or oxygen reactants in the melt, several alternative steps can be taken to provide the portions required to enable deoxidation and/or decarburization to be completed.

A deficiency of carbon can be corrected by adding a carbonaceous reducing agent to the melt from some external source. For example, a fluidized stream of carbonaceous reducing agent may be added in the inert gas stream itself.

A deficiency of oxygen can be supplemented by several different methods of adding oxygen. For example an oxidic metal compound may be added to the melt either fluidized in the inert gas stream or otherwise. Iron oxide is an example of an oxidic metal addition, also, oxidic compounds of chromium, silicon, manganese, and nickel may be added to supply sufficient oxygen to the melt to supplement the original oxygen content and enable adjustment of the oxygen content to a level required to completely decarburize the melt. The latter alternative presents another facet of the present invention, namely, alloy addition accomplished simultaneously with deoxidation and decarburization to very low levels or in fact to any desired level.

This three-fold function of the present process can also be applied to accomplish the last three steps in steel making processes without the need or at least greatly reducing the need for adding metallic reducing agents to recover alloying elements from the slag. An equilibrium exists between the metals of the melt and the corresponding oxides of these metals in the slag over the melt. The introduction of an inert gas into the molten bath effectively reduces the pressure of carbon oxides in the melt causing a greater extent of reaction between carbon and oxygen in the melt. As the oxygen is consumed in this reaction, the equilibrium between metal and oxygen in the melt and the corresponding metal oxides in the slag is upset and to reach equilibrium conditions the metal oxide from the slag phase must pass to the melt where it supplies oxygen for further reaction with carbon. This results in metal addition from the slag to the molten metal without the use of reducing agents.

As shown above carbon may be required from a external source to sustain such a reaction. The distinct advantage of such a process over the prior art steps in steelmaking as shown above is that a steelmaker can deoxidize, decarburize and recover alloying elements and iron from the slag without addition of metallic reducing agents which will upset the carbon adjustment in the finished steel.

Another distinct advantage of the present deoxidation and decarburization process is the ability to reduce carbon content to virtually nothing in a virtually completely deoxidized melt without the loss of valuable alloying elements such as chromium, manganese and nickel for example. As is well known in the art, a definite relationship exists between carbon, chromium and temperature. Attempts to remove carbon to a low level results in chromium loss by oxidation unless the temperature of the melt is maintained at very high levels during introduction of oxygen. The present process permits a steelmaker to reduce carbon contents to lower than four parts per ten thousand with virtually no loss of chromium, for example.

Molten steel cannot be deoxidized to an extremely low oxygen content of, say, about 0.003% while it is being held in a container constructed from or lined with refractory oxide materials. At certain low oxygen levels, these levels being determined by the particular refractory oxide employed, this refractory oxide will begin to dissolve into the metal. This may result in both severe refractory damage and oxide inclusions in the metal. Consequently, it is preferred to deoxidize, at least during the last stages of the process, in the presence of a slag which will dissociate into oxygen and metal before the refractory lining is attacked. Such slag serves the double purpose of protecting the furnace or ladle refractory lining from attack and also of providing a means for the addition of useful alloys such as chromium and silicon to the molten metal.

The inert gas decarburization and deoxidation process of this invention is particularly applicable for the manufacture of silicon-iron alloys. Such alloys are employed in electrical apparatus and machinery because of their desirable magnetic properties. Typical applications of silicon-iron alloys are the manufacture of transformer cores, electric motor armatures, and the like. The ideal alloy for such application, in order to minimize hysteresis and eddy current losses, is a pure silicon-iron alloy containing essentially no carbon, sulfur, manganese, oxide inclusions or internal stresses.

The usual processes for the manufacture of silicon-iron alloys meeting such specifications comprise treating a low-carbon charge in either an electric or an open hearth furnace. The main object of the furnace-refining step is to make a very low carbon (about 0.02%) ingot iron. This iron is the basic material for the manufacture of the silicon-iron alloys. The silicon content of these alloys usually does not exceed about 4 to 4½ percent.

Silicon additions are usually made in the ladle or pouring stream after tapping from the open hearth or electric furnace. A portion of the silicon is oxidized in lowering the oxygen content from that in equilibrium with the carbon to that in equilibrium with the final silicon content of the iron. This leaves carbon in the melt appreciably in excess of the value which would be in equilibrium with the oxygen content of the iron.

Inert gas decarburization can be beneficially applied at this point. The final carbon content is then reduced to a low level, the exact value depending on the effective pressure of carbon monoxide in the inert gas bubbles leaving the melt, and also the oxygen content of the melt. In such a manner oxygen can be removed to levels as low as 0.004 percent.

The nozzle for the injection of the inert gas, with or without fluidized solids contained therein, may be constructed from any suitable, relatively non-consumable, material. Non-consumability is desired, since in this manner the introduction of undesirable elements into the molten metal is effectively avoided. Nozzles with internal diameters of up to 0.5 inch may be employed.

The following examples illustrate embodiments of the present process.

EXAMPLE I

Argon gas was bubbled through a 5-lb. molten steel charge in a crucible. A chrome oxide slag was employed but was not melted and did not react with the metal. The nozzle used for injecting the gas stream comprised a magnesia tube with a 3/32-inch orifice. The experiment was performed in a closed furnace filled with circulating argon gas to prevent metal oxidation by air. Argon bubbling was continued for 15 minutes at an argon flow rate of about ¼ s.c.f./hour. The average bubble size was about 3 mm. in diameter, and the average bubble residence time within the melt was about 1 second/foot of melt depth. Table I is a compilation of the experimental results.

Table I

	In the steel	
	Carbon, Percent	Chromium, Percent
Before argon bubbling	0.14	10.6
After argon bubbling	0.04	10.6

EXAMPLE II

In this experiment, argon was bubbled from the bottom of a 50-lb. crucible containing molten steel covered with fused chrome oxide-containing slag. The nozzle used for injecting the gas stream comprised the partially porous bottom of the crucible, through which gas was forced under pressure. Argon bubbling was continued for 70 minutes, at an argon flow rate of about 4 standard cubic feet/hour. The average bubble size was about 4 mm. in diameter, and the average bubble residence time within the melt was about 1 second/foot of melt depth. The experimental results are compiled in Table II.

Table II

	In the steel		
	Carbon, Percent	Chromium, Percent	Nitrogen, Percent
Before argon bubbling	0.13	0.17	0.009
After argon bubbling	0.037	0.23	0.007

This experiment shows that argon bubbling was instrumental in lowering the carbon and nitrogen contents of the melt and also in the introduction of chromium from the slag.

The following embodiment is presented to illustrate the use of the present process in conjunction with oxygen injection decarburization to further decarburize stainless steel without loss of alloying elements as contrasted with a standard finishing process requiring substantial use of reducing agents, deoxidants and alloy addition agents.

It is desired to produce a 12% Ni, 12% Cr stainless steel. The following time sequence of operations show a standard oxygen injection process.

Time, p.m.:

1:15 Power on. 1 cwt. limestone charged
2:48 All melted, temperature 1550° C., steel sample 1, slag sample A
2:55 Electrodes raised
2:56 Oxygen injection started at 150 lb./sq. in. pressure
3:06 Oxygen injection stopped
3:07 Steel sample 2, slag sample B, temperature 1720° C.
3:20 Second oxygen injection 150 lb./sq. in.
3:24 Oxygen injection stopped
3:26 Steel sample 3; slag sample C; temperature 1740° C.
3:28 1 lb. Al added; 5 lb. spar
3:30 1 cwt. crushed FeSi (75 percent) added to slag
3:38 1 cwt. crushed FeSi added to slag
3:48 Slag sample D
3:50 20 lb. low-C FeMn
26 lb. low-C FeCr
20 lb. lump FeSi
3:55 28 lb. crushed FeSi added to slag
4:04 Steel sample 4; slag sample E; temperature 1560° C.
4:06 28 lb. FeSi added to slag
4:12 Slag sample F
4:16 Tapped

Oxygen consumption, 370 cu. ft./ton

Steel samples	Laboratory analyses				
	C	Mn	Si	Ni	Cr
1 (melted)	0.16	0.26	0.42	12.96	11.25
2 (after 1st injection)	0.11	0.17	0.19	13.24	10.02
3 (after 2d injection)	0.09	0.14	0.14	13.42	9.71
4 (12 minutes before tapping)	0.07	0.25	0.61	12.25	11.92
Pit sample	0.08	0.37	1.10	12.20	13.20

Slag samples	Cr_2O_3, percentages
A	9.9
B	35.3
C	38.7
D	39.6
E	12.6
F	9.3

The following time sequence of operations may be utilized when employing the present process to treat a starting material of the same composition as shown above. Note that steel sample 4 shows the composition of the melt which is attainable after argon treatment in accordance with the present process.

Time, p.m.	Operation
1:15	Power on. 1 cwt. limestone charged.
2:48	All melted, temperature 1550° C., steel sample 1.
2:55	Electrodes raised.
2:56	Oxygen injection started at 150 lb./sq. in. pressure.
3:06	Oxygen injection stopped.
3:07	Steel Sample 2, temperature 1720° C.
3:20	Second oxygen injection at 150 lb./sq. in. pressure.
3:24	Oxygen injection stopped.
3:26	Steel sample 3, temperature 1740° C. Argon injection started at a rate of about 200 s.c.f./ton.

Steel samples	Laboratory analyses				
	C	Mn	Si	Ni	Cr
1 (melted)	0.16	0.26	0.42	12.96	11.25
2 (after 1st injection)	0.11	0.17	0.19	13.24	10.02
3 (after 2nd injection)	0.09	0.14	0.14	13.42	9.71
4 (after argon blow)	0.04	0.14	0.14	13.42	9.71+

Several important advantages are acquired by employment of the present process. Note that a much lower carbon content can be achieved with virtually no loss of manganese, nickel, silicon or chromium. Note that some chromium must be supplied by alloy addition and/or the use of reducing agents to raise the chromium content to specifications but the loss of chromium which causes the need for the use of alloy addition was the oxygen injection sequence. Argon injection actually prevents further loss of chromium. Some deoxidation will be required here after the introduction of argon but this situation prevails only because there was insufficient carbon in the melt at the beginning of the argon flow to react with the large amount of oxygen remaining after pure oxygen injection. This situation could be remedied by supplying sufficient carbon to the bath to react stoichiometrically with the oxygen in the bath during argon injection.

EXAMPLE III

This experiment was performed by introducing a fine spray of argon bubbles at the bottom of a 50-lb. crucible. The molten metal charge was covered with a high-silica slag. The nozzle used for injecting the gas stream comprised the partially porous bottom of the crucible, through which gas was forced under pressure. Argon bubbling was continued for 82 minutes at an argon flow rate of about 4 s.c.f./hour. The average bubble size was about 4 millimeters in diameter, and the average bubble residence time within the melt was about 1 second/foot of melt depth. The experimental results are compiled in Table III.

Table III

	In the metal		
	Carbon, percent	Silicon, percent	Nitrogen, percent
Before argon bubbling	0.38	0.47	0.015
After argon bubbling	0.32	0.57	0.006

The above results indicate that reduction of alloying elements from the slag is not limited to chromium but that silicon or any other alloying element having a high thermodynamic activity in the slag can also be reduced by inert gas bubbling. The reduction in nitrogen content to less than ½ of the initial value shows that the fine dispersion of bubbles rising through the metal is effective in promoting the transfer of soluble gases such as nitrogen from the molten steel to the gas bubbles in conjunction with deoxidation and decarburization.

EXAMPLE IV

A 5-lb. molten iron charge containing 0.04% oxygen was placed in a crucible. No slag was employed. To this charge 1.4 grams of carbon were added. After the carbon addition, argon was bubbled through the molten charge for 1 minute at a rate of about 15 s.c.f./hour. The bubbling was done by means of a 3/32-inch orifice in a magnesia tube. The final analysis of the melt showed 0.01% oxygen.

This experiment illustrates effective deoxidation of a molten iron charge by the addition of carbon to the melt and subsequent bubbling with an inert gas.

EXAMPLE V

A 2000-lb. molten iron charge in a furnace contains 0.20% carbon by analysis. A fluidized stream of Cr_2O_3 in argon is introduced into the molten iron charge through a bottom nozzle having a 0.5-inch inside diameter. About 6.33 lb. of Cr_2O_3 are introduced into the melt in this manner. About 225 standard cubic feet of argon are used. About 25.6 cubic feet of carbon monoxide are produced and the carbon content of the steel is reduced to about 0.10%. The chromium content of the melt is increased by about 0.216 weight percent.

In this same manner, additional carbon as carbon particles or a carbonaceous gas may also be introduced into the melt for the purpose of removing the dissolved oxygen. Only enough carbon is introduced in the inert gas stream to react with the oxygen present. The carbon content of the molten metal charge remains essentially unaltered during this operation.

Moreover, both carbon and an alloying element or an alloying element oxide may be introduced into the melt via the inert gas stream. By suitably adjusting the amounts and proportions of the carbon and the alloying elements of the gas stream, control of the severity of both the decarburization and deoxidation reactions may be achieved.

As shown in the above examples denitriding can be accomplished in conjunction with decarburization, deoxidation and alloy addition. Though denitriding has been accomplished to a limited extent in the prior art by flushing molten melts with inert gases, denitriding has not been accomplished in the prior art during decarburization, deoxidation and/or alloy addition by introducing inert gases into molten iron-base melts. In the present process, the above four adjustments can be made in a single step. Also denitriding can be carried out alone by the introduction of inert gases into molten irons as shown below.

Inert gas injection according to this invention can also be combined with a vacuum deoxidizing process for very effective nitrogen removal. In a vacuum deoxidizing process, the relatively high surface area required is produced by the gases released from the melt. However, as oxygen and carbon concentration in the melt become low, the available surface area is drastically reduced and degassing practically ceases before nitrogen removal is substantially completed. The process cannot then be accelerated significantly either by producing a higher vacuum or by prolonging the time of treatment.

The poor nitrogen removal by such a process is a direct consequence of the reduction of the available surface area, since nitrogen removal is most effective at oxygen concentrations in the melt below about 0.01% or equivalent low oxygen activity. These disadvantages of a vacuum degassing process can be effectively eliminated by the process of this invention whereby the gas-liquid surface area may be regulated systematically as an independent process variable by varying the bubble size of the introduced inert gas.

Accordingly, the vacuum degassing may be carried out until an oxygen concentration in the melt of about 0.01%

is reached or the carbon boil has stopped, whichever is observed first. Inert gas injection is then carried out until the desired nitrogen level in the melt is attained. Simultaneous additional deoxidation is also achieved in this manner. As an alternate mode of operation, inert gas injection may be carried out simultaneously with the vacuum degassing step.

This particular embodiment of the present invention is further illustrated by the following examples:

EXAMPLE VI

Molten field-grade transformer iron having an approximate composition of about 0.3% Si, 0.02% C, 0.01% O_2, and 0.006% N_2 is degassed at a pressure of about 1 mm. of mercury in a vacuum vessel until the carbon boil stops. At this time, the nitrogen content of the melt is still essentially the same as the initial nitrogen content. About 300 s.c.f. argon/ton of melt are then injected into the melt by means of a ceramic injection device. After the inert gas injection, the final nitrogen content is less than about 0.001%.

EXAMPLE VII

A melt of non-aging mild steel having an approximate composition of about 0.10% C, 0.03% O_2, and 0.006% N_2 is degassed in a vacuum vessel at a pressure of about 1 mm. of mercury. The degassing by vacuum is continued until the melt contains about 0.01% oxygen. The vacuum is interrupted and argon is then injected into the melt near the bottom of the molten metal container in the form of small bubbles at a rate of about 300 s.c.f./ton of steel by means of a suitable ceramic injection device. The final nitrogen content of the melt is less than about 0.001%.

EXAMPLE VIII

Two Armco iron melts were separately saturated with nitrogen gas at 1 atmosphere pressure in a controlled atmosphere furnace. Melt (1) contained 0.076 weight percent oxygen and melt (2) contained 0.010 weight percent oxygen.

Melt deoxidation was achieved by the addition of stoichiometric amounts of carbon to each melt. The carbon content of each melt after deoxidation was about 0.02 weight percent. After carbon addition argon was introduced into each of melts (1) and (2) for various periods of time. Melt (1) showed a nitrogen content of 0.012 weight percent at the end of about 108 minutes of argon introduction and melt (2) showed a nitrogen content of about 0.004 at the end of about 40 minutes of argon introduction.

What I claim is:

1. A process for treating a molten iron-base melt and reducing alloy constituents from a molten slag in contact with a molten iron-base melt to cause an increase in the alloy constituents in said molten iron-base melt comprising providing a molten iron-base melt and a molten slag covering said iron-base melt said slag containing at least one oxidic alloying compound containing an element capable of alloying with said molten iron-base melt and introducing at least one inert gas selected from the group consisting of argon, xenon, krypton, neon, and helium into said iron-base melt and introducing a carbonaceous reducing agent into said melt; substantially decreasing the effective pressure of carbon oxide in the melt thereby causing a greater extent of reaction between said carbon and oxygen in said molten iron-base melt to cause reduction of said oxidic form of said alloying element from said slag and increasing the content of said alloy element in said molten iron-base melt.

2. A process in accordance with claim 1 wherein sufficient carbon is introduced into said molten iron-base melt as a fluidized stream of carbonaceous reducing agent in said selected inert gas to react with the oxygen in said melt.

3. A process for treating a molten high-carbon iron-base melt comprising introducing at least one inert gas selected from the group consisting of argon, xenon, krypton, neon and helium into said melt, said selected gas containing fluidized oxidic alloying compounds; substantially decreasing the effective pressure of carbon oxide in said molten iron-base melt thereby causing a greater extent of reaction between said carbon in said molten iron-base melt and said oxygen in said iron-base melt; and reducing alloying elements from said introduced oxidic alloying compounds to increase the alloy element content in said iron-base melt.

4. A process in accordance with claim 3 for deoxidizing and decarburizing a molten iron-base melt and reducing alloy constituents added to said molten melt wherein a sufficient amount of carbon is added to said melt to react with substantially all the oxygen in said melt.

5. A process for concurrent deoxidation, denitriding, decarburization, and alloy addition in molten iron-base melts comprising introducing at least one inert gas selected from the group consisting of argon, xenon, krypton, neon, and helium into said molten iron-base melt and introducing oxidic alloying compounds into said molten iron-base melt and introducing sufficient carbon into said molten iron-base melt to react with substantially all the oxygen present in said molten iron-base melt, reducing the effective pressure of carbon oxide in said melt to cause an increased extent of reaction between carbon and oxygen in said melt.

6. A process in accordance with claim 5 wherein said introduction of said selected inert gas is accomplished under vacuum conditions.

7. A non-vacuum process for treating a molten iron-base melt and reducing alloy constituents from a molten slag in contact with a molten iron-base melt to cause an increase in the alloy constituents in said molten iron-base melt comprising, providing a molten iron-base melt and a molten slag covering said iron-base melt, said slag comprising at least one oxidic alloying compound containing an element capable of alloying with said molten iron-base melt; introducing a flow of at least one inert gas selected from the group consisting of argon, xenon, krypton, neon, and helium into said iron-base melt, said melt being in a non-vacuum environment; and introducing a carbonaceous reducing agent into said melt; maintaining said flow at a rate which substantially decreases the effective pressure of carbon oxide in the melt thereby causing a greater extent of reaction between said carbon and oxygen in said molten iron-base melt to cause reduction of said oxidic form of said alloying element from said slag and increasing the content of said alloy element in said molten iron-base melt.

8. A process in accordance with claim 7 wherein sufficient carbon is introduced into said molten iron-base melt as a fluidized stream of carbonaceous reducing agent in said selected inert gas to react with the oxygen in said melt.

9. A non-vacuum process for treating a molten high-carbon iron-base melt comprising; introducing a flow of at least one inert gas selected from the group consisting of argon, xenon, krypton, neon and helium into said melt, said selected gas containing fluidized oxidic alloying compounds; maintaining said flow at a rate which substantially decreases the effective pressure of carbon oxide in said molten iron-base melt thereby causing a greater extent of reaction between said carbon in said molten iron-base melt and said oxygen in said iron-base melt; and reducing alloying elements from said introduced oxidic alloying compounds to increase the alloy element content in said iron-base melt.

10. A process in accordance with claim 9 for deoxidizing and decarburizing a molten iron-base melt and reducing alloy constituents added to said molten melt wherein

a sufficient amount of carbon is added to said melt to react with substantially all the oxygen in said melt.

11. A non-vacuum process for concurrent deoxidation, denitriding, recarburization, and alloy addition in molten iron-base melts comprising; introducing a flow of at least one inert gas selected from the group consisting of argon, xenon, krypton, neon, and helium into said molten iron-base melt, said melt being in a non-vacuum environment; and introducing oxidic alloying compounds into said molten iron-base melt and introducing sufficient carbon into said molten iron-base melt to react with substantially all the oxygen present in said molten iron-base melt; maintaining said flow at a rate which reduces the effective pressure of carbon oxide in said melt to cause an increased extent of reaction between carbon and oxygen in said melt.

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338,409	Great Britain	Nov. 20, 1930