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PROCESS FOR REDUCING IRON OXIDE FUME FORMATION DURING REFINING OF STEEL

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ABSTRACT OF THE DISCLOSURE

A process for the fumeless refining of steel in which a particulate metal oxide is suspended in a carrier gas, such as air, containing less than about 30% oxygen and at a ratio of less than about 3 cubic feet of gas per pound of oxide and injected into a molten ferrous bath at a rate sufficient to produce a rapid carbon boil in the bath.

This application is a continuation-in-part of our application Ser. No. 792,800, filed Jan. 21, 1969, and now abandoned.

This invention relates to the refining of steels, including all grades of plain carbon steels, low and high alloy steels, heat-resisting steels, and stainless steels. More particularly, this invention relates to a new and improved process for the fumeless refining of steels.

An essential step of refining in all steel-making processes (e.g., convertor vessels, open-hearth furnaces, and electric furnaces) is the removal of carbon by oxidation, together with other oxidisable elements, notably silicon, manganese, and phosphorus. Hydrogen and nitrogen are also removed by the flushing of the "carbon boil." The amount of carbon to be removed and the rate of its removal governs the speed of the process, and also the final hydrogen and nitrogen contents, and accordingly it is usual to arrange for at least 0.20% of carbon to be removed from ferritic grades of steel, and 0.1% to 0.25% from austenitic stainless steels. This necessitates an adequately high carbon content in the bath, whatever the nature of the charge: steel scrap, hot metal, or cold pig iron, or various proportions of any of these. In the case of charging with 100% steel scrap, the high carbon content required for the refining usually necessitates the addition of carbon, e.g., in the form of crushed electrodes, anthracite or coke.

Usually, the extent of refining is such as to leave the steel with the required carbon content, but it is also known to refine a charge initially having a carbon content equal to or less than that required in the refined steel, when the steel after refining inevitably has less than the required amount of carbon. In this case, it is normal to recarburize the refined steel to give it its required carbon content.

The rate of carbon removal varies according to the oxidation practice adopted. In the case of ore boiling, i.e., the manual addition of iron ore or millscale to the bath, which is essentially a slag-metal reaction, the reaction proceeds according to the equation:

$$C+FeO \rightarrow Fe+CO$$

and similarly with other oxides of iron, Fe_2O_3, Fe_3O_4, and with the oxidation of silicon and other elements referred to above. Although the process avoids pollution of the surrounding atmosphere, or at any rate produces only an amount of "fume" that can be easily disposed of by fume-cleaning equipment, it has several fundamental disadvantages:

(i) the reaction is slow; and
(ii) in consequence of (i), the removal of hydrogen and nitrogen due to the flushing action of the "boil" is not assured.

In addition, the technique is generally inapplicable to stainless-steel charges.

Thus, the process which results in a carbon boil that is very slow and relatively uneconomic has been considered unsatisfactory by steel-makers, and their insistence for ever-increasing rates of carbon removal has led to the development of processes to replace the ore-boiling technique.

Of the processes that were developed, only one had provided the desired rapidity of carbon removal, and prior to the present invention was regarded by all as the only way of achieving the high rates of carbon removal required by most steel-makers. This is the so-called oxygen-lancing technique, in which gaseous oxygen is injected into a molten bath. The result of such injection is that oxygen is rapidly dispersed throughout a melt, and this leads to rapid oxidation of carbon, i.e., a rapid carbon boil ensues with its beneficial flushing effect on nitrogen and hydrogen.

Thus, in oxygen-lancing:

(i) the reaction is fast; and
(ii) in consequence of (i) the removal of hydrogen and nitrogen due to the flushing action of the boil is not assured.

This technique as opposed to ore-boiling is suitable for stainless steel charges.

Oxygen-lancing, therefore, meets all the requirements of the steel-makers, but it has one serious disadvantage; the inevitable result of oxygen-lancing is that large volumes of dense, brown iron-oxide fumes are emitted when the reaction is proceeding and expensive fume-cleaning equipment must be provided to prevent pollution of the surrounding atmosphere.

The cost of a fume-cleaning plant, however, has lead some steel-makers to sacrifice the rate of carbon removal achieved in oxygen-lancing by accepting one of the other processes that were developed, such as the oxy-fuel burner (oil or gas). Such process can be controlled so that little or no iron oxide fume is emitted, but the carbon-removal rate is generally slower than with oxygen-lancing. Thus, the cost is increased, particularly by the consumption of fuel and the increased consumption of oxygen, as well as the cost of providing cooling water for the burners. Moreover, the technique is limited to carbon steels and low alloy steels.

A principal object of the present invention, therefore, is to provide an economic and efficient process for the rapid removal of carbon and other oxidisable elements from a molten ferrous bath without the undue emission of the dense, brown iron oxide fumes commonly associated with oxygen-lancing. A further object is to provide such a process in which the required reduction in hydrogen and nitrogen contents will be assured.

According to the present invention, a process for refining a steel comprises injecting into a molten ferrous bath a particulate oxide of a metal desired in the finished steel by means of a carrier gas containing free or bound oxygen in such quantities and at a rate sufficient to react with carbon to effect a rapid carbon boil, with evolution of carbon monoxide which flushes hydrogen and nitrogen from the bath, the volume of evolved carbon monoxide in relation to the volume of oxygen available in the carrier gas under conditions prevailing in the bath being such as to give rise to a protective gaseous atmosphere above the bath which is non-oxidising for elemental iron, whereby production of brown iron oxide fume resulting from oxidation of elemental iron is substantially inhibited.

Preferably, the carrier gas is one having an oxidising potential not greater than oxygen-enriched air containing about 30% to about 35% O_2 by volume, and it is further preferable that the carrier gas be utilised at a ratio of less than about 3 cubic feet of gas per pound of metal oxide injected, so that the volume of carbon monoxide produced exceeds the volume of oxygen injected to substantially inhibit the oxidation of elemental iron by the gas and the production of brown iron oxide fumes. Thus, the ratio of carrier gas to oxide injected may be about 1 cubic foot of air per pound of oxide.

It is to be understood that the foregoing general description and the following detailed description are exemplary and explanatory but are not restrictive of the invention.

Thus, the present invention has unexpectedly found that when the volume of carrier gas is kept near the minimum required to inject the oxide that a satisfactory carbon boil and a sufficient flushing of hydrogen and nitrogen is achieved without any or little production of obnoxious, brown iron oxide fumes.

The injection of the oxide by the use of a carrier gas, in accordance with the present invention, promotes a sufficiently high rate of carbon removal for the removal of hydrogen and nitrogen from the bath to be assured during the carbon boil. At the same time, this method of carbon removal has the most important advantage that the process can be conducted with the total elimination or minimisation of brown iron oxide fume.

Thus, the invention recognises for the first time that the volume of carbon monoxide resulting from the oxidation of carbon can be utilised to bring about the substantial inhibition of the production of dense iron oxide fume in a refining process that has a rate of carbon elimination comparable with that of oxygen-lancing.

During a rapid carbon boil, irrespective of how it is brought about, the boil results in there being thrown from the surface of the melt a fine spray or vapour of almost pure iron, it being the oxidation of this fine spray or vapour that leads to the production of dense iron oxide fume. The fine spray or vapour only exists immediately above the bath because beyond that, there is coagulation into large particles which, if then oxidised, would only be given an external coating and would, in all probability, drop back into the slag. Therefore, when the carrier gas contains less than about 30% to 35% by volume of oxygen and the volume of the carrier gas such as air, and is preferably substantially no more than that required conveniently to bring about injection of the particulate metal oxide, e.g., less than about 3 cubic feet per pound of oxide, the volume of carbon monoxide produced by the reaction exceeds the volume of oxygen injected and forms a blanket across the surface of the melt, the non-oxidising nature of which is not disturbed by the relatively small volume of gaseous oxygen from the carrier gas which also escapes from the melt. Thus, in the area of the furnace atmosphere where the fine spray or vapour of iron is to be found, non-oxidising conditions prevail, with the result that the process proceeds in the almost complete absence of dense brown iron oxide fume.

As stated above, the volume of carrier gas should preferably at most be no more than about 3 cubic feet of gas per pound of metal oxide. When conditions permit, however, even smaller volumes such as 2 cubic feet and preferably one cubic foot of gas per pound of particulate oxide can be employed.

The carrier gas employed for the purpose of this invention is one which functions essentially as a carrier for the added metal oxide, the oxide being the principal agent for converting carbon in the bath into carbon monoxide. The carrier gas, however, may participate to a small extent in the oxidising process without departing from the process of the present invention and, therefore, may be active as far as oxidation reactions are concerned by introducing some oxygen into the molten bath. Accordingly, carbon dioxide, air, or even oxygen-enriched air may be used as the carrier gas provided the oxygen content of the gas is maintained below about 30% by volume and the volume of gas to oxide is maintained within the limits described above. Gases containing higher amounts of oxygen even at minimum ratios of gas to oxide produce objectionable iron oxide fume.

Additional advantages, particularly when using air as the carrier gas are:

(i) the process is relatively cheap;
(ii) the boil can be initiated and continued at a relatively low bath temperature or the boil enriched and continued at any desired temperature by the maintained application of an external heat source to the furnace;
(iii) in consequence of (ii), conditions can be created that are especially favourable to the oxidation and removal of any desired elements;
(iv) any desirable rate of carbon removal can be re-produced in successive operations;
(v) part of the oxide can be injected into the slag above the bath to build up slag iron which not only aids carbon removal from the bath but also increases the metal yield, and
(vi) the injection does not give rise to the severe wear of the refractory of the furnace frequently occasioned by O_2 lancing or by oxy-fuel burners, neither does it require the consumption of water involved for the cooling of such burners.

The equipment for dispensing and injecting the oxide is cheap to install and operate. Thus, it may simply be a hopper having an outlet communicating with the line for the carrier gas with means in the outlet for controlling the flow of powder to the line communicating with a lance for injecting the powder into the bath. Preferably, the powder is controlled by providing means capable of pulse-feeding the powder into the line for the carrier gas, the pulse-feeding may be carried out by providing a valve in the form of a paddle wheel in the bottom of a hopper, the compartments formed between two vanes of the paddle wheel effectively metering the supply of particulate oxide to the gas line. Preferably, two hoppers are provided, secured to a central spindle, one of which is connected to the carrier gas line. When that hopper is empty, the hopper is simply disconnected from the line, the assembly rotated about the spindle to bring the other, full hopper to the position in which it can be connected to the carrier gas line, and while that hopper is emptying, the other hopper is filled.

The process admits of variation in the initial carbon content of the bath. Thus, if the carbon content of the charge from which the bath is formed is in excess of that required in the refined steel, the injection is continued until carbon has been removed by oxidation to leave an amount equal to that required in the final steel, by which time hydrogen and nitrogen have been appreciably reduced and other undesirable elements such as silicon, manganese, and phosphorus have all been oxidised to the desired level. Again, if there is a lower carbon content of the charge from which the bath is formed than is sufficient for the final content to be that required in the refined steel, the injection is continued until carbon has been removed by an amount sufficient to assure removal of hydrogen and nitrogen and oxidation of any other undesirable elements, and the refined steel is then recarburised in known manner, to give it its required carbon content.

The technique is applicable to all the grades of steel mentioned above. Depending on the particular steel to be produced, suitable oxides are those of iron, nickel, chromium, molybdenum, copper, cobalt and tungsten. For example, for carbon steels, iron oxide is used, e.g., in the form of millscale, iron ore, or iron oxide dust from fume-cleaning plants; and for stainless steel, oxides of nickel, chromium, molybdenum, copper, cobalt or tungsten, or any combination of these, possibly with an iron oxide also both to promote the oxidation reactions and to provide a cheaper source for at least part of the metal constituents of the steels.

"Particle" as used in the specification and claims, is intended to embrace all useful grades from relatively coarse, granular grades (say 5.75 mm. grain size) down to very fine grades. Of course, the metal oxide cannot be so coarse as to be incapable of being blown through the lance nor can it be so very fine that it would remain entrained in the gas and simply be blown into the furnace atmosphere. The following has proved to be an adequate range of gradings:

100% less than 6.35 mm.;
not more than approximately 30% less than 0.0104 mm.

To facilitate and accelerate slag/metal reactions forming part of the refining process, slag-forming materials such as powdered lime, limestone, or fluorspar may be injected with the powdered metal oxide or oxides, either continuously therewith or during one or more selected periods during the process.

To illustrate the invention more specifically, reference is made to the following examples. These examples illustrate the fumeless refining of steel by the process of this invention.

The examples are merely illustrative and are not to be understood as limiting the scope and underlying principles of the invention in any way.

Example 1.—Carbon steel

A 4-ton electric arc furnace was charged with steel scrap and heated to a temperature of 1550° C., a slag being formed on the bath in known manner. The bath was then ready to be oxidised, and powdered millscale with the following grading:

3.17–2.41	6.1
2.41–1.685	13.4
1.685–1.395	3.5
1.395–1.193	6.1
1.193–0.99	6.1
0.99–0.863	4.5
0.863–0.687	6.1
0.687–0.508	11.8
0.508–0.356	11.8
Less than 0.356	30.6

was injected into the bath for two (2) minutes at 50 lbs./minute by a lance immersed in the bath, using compressed air as the carrier gas. The total volume of air used was 100 cubic feet, when converted to standard temperature and pressure (S.T.P.).

The bath was sampled immediately before and immediately after the oxide injection and was found to contain (percent by weight):

	C	Mn	Si	S	P	Ni	Cr	N_2	H_2, p.p.m.
1	0.39	0.32	0.02	0.033	0.015	0.15	0.09	0.012	5.3
2	0.24	0.25	0.00	0.032	0.13	0.15	0.09	0.008	2.4

NOTE.—1=Before injection; 2=After injection.

This steel was required to have 0.24% CA and accordingly required no recarburisation. The bath was then slagged off, de-oxidised, a reducing slag made up, in known manner and finally tapped.

The rate of carbon removal was such that nitrogen and hydrogen were appreciably reduced as can be seen from the above table and the oxidation proceeded with no visible brown fume from the bath.

Example 2.—Carbon steel

The procedure as outlined in Example 1 was followed and the bath again oxidised by injecting millscale powdered to —5 BSS with compresssed air as the carrier gas, but in this case, 100 lbs./minute of powder was injected for 3½ minutes, utilising a total of 375 cubic feet of air at S.T.P. The oxidation proceeded with no visible brown fume from the bath.

Sampling of the bath immediately before and after the injection showed the bath to contain (percent by weight):

	C	Mn	S	P	N_2	H_2, p.p.m.
1	0.40	0.29	0.034	0.004	0.011	3.0
2	0.24	0.23	0.025	0.002	0.010	2.7

NOTE.—1=Before injection; 2=After injection.

In this case, the steel was required to have 0.30% C and accordingly, the steel was recarburised by adding 280 lbs. of pig iron known to contain 4% C.

Example 3.— Austenitic stainless steel

The same procedure as outlined in Example 1 was followed, on ½-ton charge in an electric arc furnace, and the bath again oxidised by injecting millscale powdered to —5 BSS (as in Example 1) with compressed air as the carrier gas. The powder was injected at a rate of 20 lbs./minute for 3½ minutes, utilising a total of 105 cubic feet of air at S.T.P. The oxidation proceeded with no visible brown fume from the bath.

Sampling of the bath immediately before and after oxidation showed the bath to contain (percent by weight):

	C	Si	S	P	Ni	Cr	N
1	1.1	0.52	0.022	0.041	8.66	16.1	0.053
2	0.05	0.42	0.019	0.030	7.48	9.1	0.020

NOTE.—1=Before injection; 2=After injection.

The table shows clearly the reduction by oxidation of the oxidisable elements. The Cr content of the steel has been reduced to a level too low for the required final analysis of the steel, and accordingly, additions of reducing agents, such as ferro-silicon are made to the slag whereby Cr is released from the slag back to the bath. After sampling, the Cr content was found to have increased to 14%.

The bath was then slagged off and a reducing slag made up and finally tapped. If it had been the case that the other alloying elements needed to be increased, suitable additions of such elements could be made after the reducing slag had been made up.

Example 4.—Austenitic stainless steel

The same procedure as outlined in Example 1 was followed but in this case powdered nickel oxide, graded in similar manner to the milliscale of Example 1, was used in the oxidation stage, with compressed air as the carrier gas, the powder being injected at 10 lbs./minute for two (2) minutes, utilising a total of 30 cubic feet of air at S.T.P. The oxidation proceeded with no visible brown fume from the bath.

Sampling of the bath before and after oxidation showed the bath to contain:

	C	Si	S	P	Mn	Cr	Ni	Mo
1	0.26	0.28	0.005	0.034	0.76	10.8	5.49	0.73
2	0.20	0.10	0.001	0.037	0.38	8.16	9.06	0.77

NOTE.—1=Before injection; 2=After injection.

During the oxidation stage, the increase in nickel content showed that 95% of the nickel of the nickel oxide had been recovered. The chromium (and other alloying elements) were modified to suit the requirement of the final steel as explained in Example 3.

Example 5.—5% chrome alloy steel

The same procedure as outlined in Example 1 was followed, using a mixture of 50% chromite sand (crushed chrome ore) and 50% millscale, both graded in similar manner to the millscale of Example 1. The oxidation proceeded with no visible brown fume given off from the bath.

Immediately before oxidation the bath was sampled and found to contain 0.75% carbon and 6.18% chromium. After oxidation, the bath contained 0.65% carbon and 5.80% chromium, well within the 5% to 6% chromium required in the final steel. The chromite sand has, therefore, provided a cheap source of chromium for the bath, and has effectively offset the reduction by oxidation of the chromium, making unnecessary the addition of expensive chromium at the reducing stage.

Example 6.—Carbon steel

An electric arc furnace was charged with 37.95 tons of scrap and heated to a temperature of 1,500° C.; a slag being formed in a known manner. The bath was then ready to be oxidised and fines from an iron ore sinter plant which had passed through ¼" (6.35 mm.) sieve were injected into the bath for 3 minutes at a rate of 373 lbs./minute by a lance immersed in the bath. 450 cubic feet at S.T.P. of compressed air were used as a carrier gas at a pressure of 50 p.s.i. The oxidation proceeded with no visible brown fume from the bath.

The bath was sampled immediately before and immediately after injection and was found to contain (percent by weight):

C	Mn	Si	S	P	Cr	N_2
0.415	0.33	0.03	0.047	0.021	0.21	0.015
0.265	0.20	0.02	0.045	0.015	0.18	0.007

The bath was then slagged off, de-oxidised, a reducing slag made up in known manner and finally tapped.

Example 7

A 240-ton open-hearth furnace was charged with 145 tons of scrap and 95 tons of hot metal from a blast furnace. At melt-out the metal contained 0.70% carbon which dropped to 0.45% 48 minutes after melt-out. At this point 3,136 lbs. of iron oxide powder were injected with 1,400 cubic feet at S.T.P. of air at a pressure of 50 lbs./square inch by a lance immersed in the metal.

The iron oxide had the following grading:

Particle size (mm.):	Percent by wt.
3.390–1.590	0.7
1.590–0.060	15.0
0.060–0.025	24.5
0.025–0.018	3.8
0.018–0.015	11.6
0.015–0.0105	10.5
0.0105–0.0075	24.7

Samples taken from the bath at various times during the refining period gave the following results:

Sample	Percent C	Percent C drop/hr.
At melt-out	0.70	.31
18 mins. after melt-out	0.45	
51½ mins. after melt-out	Start injection	.60
57½ mins. after melt-out	Finish injection	
60 mins. after melt-out	0.25	.17
117 mins. after melt-out	0.08	

The steel was then tapped in the usual manner and cast into ingots.

The oxidation proceeded with no visible brown fume from the bath.

Examples 8 and 9

Examples 8 and 9 are carried out to illustrate the limit required on the amount of oxygen that should be in the carrier gas to prevent the production of brown fume.

In each example, powdered millscale is injected into a 450 lb. resistor rod furnace using compressed air as the carrier gas. The air is then enriched with oxygen up to the point when brown oxide fume is first observed and the percentage of oxygen in the carrier gas at that point is recorded in the following table:

Example	Millscale flow rate, lb./min.	Air flow rate, ft.³/min.	Oxygen flow rate at pt. of of fuming, ft.³/min.	Total gas flow rate, ft.³/min.	Volume of oxygen in air, ft.³/min.	Total volume of oxygen at pt. of fuming ft./min.	Percent oxygen in carrier gas at pt. of fuming	Ft.³ of carrier gas/lb. of millscale
8	10	13	2.0	15.0	2.6	4.6	30.5	1.50
	15	13	1.3	14.3	2.6	3.9	27.7	.95
	20	13	2.3	15.3	2.6	4.9	31.8	.77
9	10	13	1.5	14.5	2.6	4.1	28.0	1.45
	15	10.6	1.8	12.4	2.1	3.9	31.5	.82
	20	14.3	3.0	17.3	2.9	5.9	35.0	.86

From the foregoing table it can be seen that at various flow rates from 10 to 20 lbs./minute of millscale and at gas/oxide ratios of about 1:1, that fuming began to occur when the oxygen content of the gas approached about 30% by volume.

Example 10.—Carbon steel

A 450 lb. resistor rod furnace was charged with steel scrap and heated to a temperature of 1540° C., a slag being formed on the bath in known manner. The bath was then ready to be oxidised and powdered millscale, generally of the grading referred to in previous examples, was injected into the bath for 1 (one) minute at 10 lbs./minute by a lance immersed in the bath, using carbon dioxide as the carrier gas. The total volume of carbon dioxide was 50 cubic feet when converted to S.T.P.

The bath was sampled immediately before and immediately after the oxide injection and was found to contain (percent by weight).

	C	Mn	Si	S	P
1	1.03	.65	.01	0.024	.035
2	.85	.23	.01	.036	.024

NOTE.—1=Before injection; 2=After injection.

The steel was brought to its carbon content by the reaction and, accordingly, required no recarburisation. The bath was then slagged off, de-oxidised, a reducing slag made up in known manner and finally tapped.

The rate of carbon removal was such that nitrogen and hydrogen were appreciably reduced, and the oxidation proceeded with no visible brown fume from the bath.

The invention in its broader aspects is not limited to the specific details shown and described and departures may be made from such details without departing from the principles of the invention and without sacrificing its chief advantages.

What we claim is:

1. A process for the refining of steel in which the production of brown iron oxide fume during decarburization is substantially reduced comprising injecting into a molten ferrous bath containing carbon, a particulate oxide of a metal desired in the finished steel, said oxide being injected by means of a carrier gas and at a rate sufficient to oxidize the carbon in the bath and effect a rapid carbon boil with the evolution of carbon monoxide and the flushing of hydrogen and nitrogen from the bath, said carrier gas being used in an amount sufficient to inject the desired rate of oxide but having an oxidizing potential not greater than oxygen-enriched air containing about 35% oxygen by volume so that the carrier gas will not substantially influence the rate of oxidation of carbon from the bath and so that the particulate metal oxide will be the principal oxdizing agent for the carbon, whereby

the evolving carbon monoxide will create a non-iron oxidizing atmosphere above the bath and substantially reduce the production of the brown iron oxide fumes during the decarburizing process.

2. The process of claim **1**, wherein the carrier gas is selected from the group consisting of air, oxygen-enriched air containing up to 35% oxygen by volume, carbon dioxide, or mixtures thereof.

3. The process of claim **1**, wherein said carrier gas is used at a ratio of less than about three (3) cubic feet of gas per pound of metal oxide injected.

4. The process as in claim **3**, wherein said carrier gas is used at a ratio of about one (1) cubic foot of gas per pound of metal oxide injected.

5. The process of claim **1**, wherein the bath has a carbon content in excess of that required in the final steel and the injection is continued until carbon has been reduced down to an amount equal to that required in the final steel.

6. The process of claim **1**, wherein the bath has a carbon content lower than is sufficient for the final content to be that required in the final steel and the injection is continued until carbon has been reduced by an amount sufficient to assure removal by oxidation of other oxidizable elements in the bath, the refined steel then being recarburized to give it its required carbon content.

7. The process of claim **1**, wherein particulate iron oxide is injected into the molten bath.

8. The process of claim **7**, wherein the iron oxide is in the form of millscale, iron ore, or iron oxide dust.

9. The process of claim **7**, wherein part of the iron oxide is injected into the slag above the bath.

10. The process of claim **1**, wherein the steel is a stainless steel.

11. A process for the refining of carbon steel in which the production of brown iron oxide fume during decarburization is substantially reduced comprising injecting into a molten ferrous bath containing carbon, particulate iron oxide suspended in air as a carrier gas for the oxide, said oxide being injected at a rate sufficient to oxidize the carbon in the bath and effect a rapid carbon boil with the evolution of carbon monoxide and the flushing of hydrogen and nitrogen from the bath, and said carrier air being used at a ratio of less than about three (3) cubic feet of air per pound of iron oxide injected, so that the air will not substantially influence the rate of oxidation of carbon from the bath and so that the iron oxide will be the principal oxidizing agent for the carbon, whereby the evolving carbon monoxide will create a non-iron oxidizing atmosphere above the bath and substantially reduce the production of brown iron oxide fumes during the decarburizing.

12. The process of claim **11**, wherein said carrier air is used at a ratio of about one (1) cubic foot of air per pound of iron oxide injected.

13. The process of claim **11**, wherein the iron oxide is in the form of millscale, iron ore, or iron oxide dust.

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