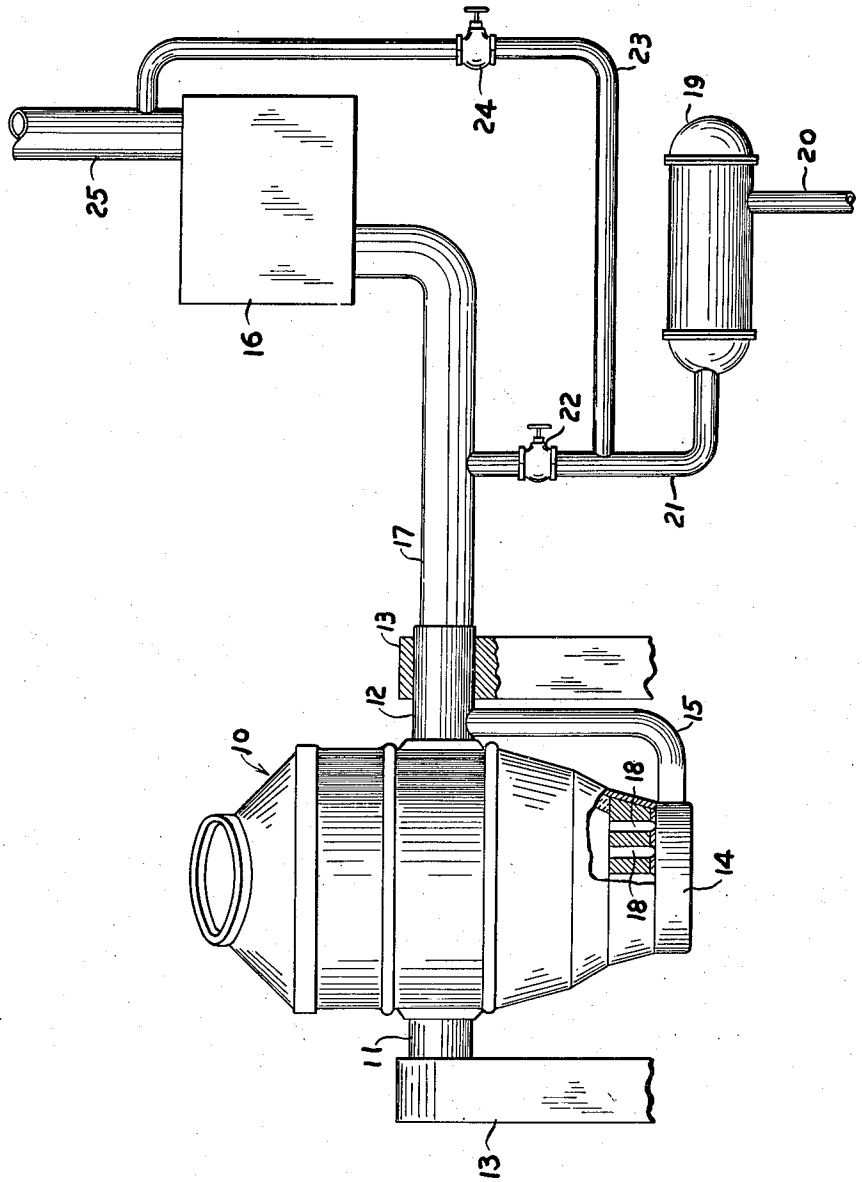
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METHOD OF BLOWING IRON

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METHOD OF BLOWING IRON

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This invention relates to improvements in blowing blast furnace iron in a converter and more particularly relates to improvements in the operation of such a converter for effecting improved separation of the slag from the molten metal to produce cleaner blown metal and for effecting other advantageous results.

This application is a continuation-in-part of my copending application Serial No. 785,218, filed November 12, 1947, entitled "Method of Blowing Iron," now abandoned.

In steel plants utilizing the Bessemer process, molten pig iron from the blast furnace is charged into an acid type converter and the charge is then blown with an air blast. The blowing operation reduces the silicon, manganese and carbon content of the molten metal through oxidation reactions and produces molten slag containing these constituents in addition to iron oxide. The blown metal, which is molten Bessemer metal, may be formed directly into Bessemer steel products or may be used in the usual duplex process to produce different types of steel. The metal in the converter at the end of the blow will contain 0.15% carbon, or less. In order to produce iron which can be successfully blown in the Bessemer converter, the materials charged to the blast furnace are so proportioned, and the blast furnace is so operated as to produce molten blast furnace metal containing up to about .5% to .7% manganese and containing about 1.25% to 1.8% silicon with the ratio of silicon to manganese not less than 2 and preferably about 2.5 or higher. Preferably, both the silicon and the ratio of silicon to manganese are maintained on the high side, and the manganese is maintained on the low side. The manganese, upon oxidation, forms a relatively fluid slag, and a high manganese content may produce a slag so fluid that slopping will occur during the blow and so fluid that the slag will not separate cleanly from the metal. Oxidation of the silicon during the blowing operation is an important source of heat so that, if the silicon is too low, a cold blow will result. Further, if the silicon is low, there is a tendency to form a corrosive slag because of the relatively higher iron oxide content of the slag. Accordingly, when blowing molten iron in the converter to produce Bessemer steel, it is necessary that the molten iron contain a relatively high ratio of silicon to manganese. At least at times, and despite the fact that the molten iron contains the proper ratio of silicon to manganese, the slag may not separate as cleanly as desired.

In those steel plants where all or a major portion of the blast furnace iron is charged directly to the basic open hearth furnace to produce open hearth steel, the blast furnace is operated to produce iron containing quite different amounts of manganese and silicon. In order to produce good iron for the open hearth, the charge to the blast furnace is so proportioned as to produce iron containing about 1.25% to 1.75% manganese with about 1.5% manganese being preferable. The silicon content of the iron is about .8% to 1.2% with about 1% being preferable. The silicon to manganese ratio is maintained relatively low and preferably is less than about 1. The relatively high per cent of manganese reduces the amount of ferromanganese which must be added to the open hearth steel in the ladle and increases the fluidity of the slag which reduces the time required to work the heat. A relatively long period is required to work a heat in an open hearth furnace, and it is particularly desirable that this period be reduced as much as possible. The amount of silicon is maintained relatively low to reduce the attack on the basic lining of the open hearth furnace and to reduce the amount of lime that must be charged into the furnace.

Some steel plants utilize the Weirton process described in Patent No. 2,390,346, which is an acid converter-basic open hearth process, to augment their production of open hearth steel. In such plants, some of the blast furnace iron is charged to the converter, but most of the iron is charged to the open hearth furnace. The molten pig iron usually is periodically withdrawn from the blast furnace and placed in a relatively large mixer to supply the pig iron for the converter as well as the pig iron for the open hearth. The blast furnace is operated to produce an iron that is, or is more nearly, satisfactory for the open hearth furnace than for the converter as the plant is primarily interested in producing open hearth steel, and the converter merely increases the output of steel per open hearth furnace. Quite often, only a relatively small percentage of iron is blown in the converter. Such an iron may contain, for example, about .9% to 1.3% manganese and from about .9% to 1.25% silicon, and the silicon to manganese ratio is preferably about one, or less. At times, the silicon to manganese ratio may be somewhat higher but is less than 1.5 and is less than the minimum usually considered desirable for good converter operation. This iron cannot be satisfactorily, completely blown in the converter to produce Bessemer steel. In the Weirton process, the iron is not blown all the way down, and the blow is stopped

before the carbon content is reduced to 1% and preferably the carbon content is reduced to between 2.5% to 1%. One serious difficulty encountered when blowing such an iron in the converter is that as a result of the relatively high manganese content and the relatively low ratio of silicon to manganese, the fluidity of the slag tends to be excessive so that slopping may occur and the slag does not separate cleanly from the blown molten metal. The presence of slag in the blown metal from the converter is highly undesirable, especially as the blown metal is charged to the open hearth furnace. One important difficulty caused by having slag in the metal charged to the open hearth is that as the slag is acid, the lining of the open hearth furnace is attacked and the amount of lime charged must be greatly increased. Another difficulty resulting from slag in the blown metal is that the steel from the open hearth furnace and the products produced therefrom tend to contain a relatively larger quantity of slag inclusions which are undesirable.

Accordingly, a primary object of this invention is to effect improved separation of the slag from the metal in the converter.

Another object of the present invention is to provide an improved process of operating a converter that will effect better separation of the slag from the metal.

Another object of the present invention is to provide an improved process of operating a converter that will effect better separation of the slag from the metal when the blast furnace metal charged to the converter contains silicon and manganese in a relatively low ratio of not more than 1½.

A further object of the present invention is to effect improved separation of the slag from the metal in the converter when the blast furnace metal charged to the converter contains silicon and manganese in such quantities that the blast furnace iron is suitable for charging into an open hearth furnace and contains from 0.9% to 1.3% manganese and from 0.9% to 1.25% silicon.

It is also an object of the present invention to effect improved separation of the slag from the metal in the converter when the blast furnace metal contains a relatively low ratio of silicon to manganese without causing excess fluidity of the slag which would result in slopping and incomplete separation of the slag from the blown metal.

Another object of the present invention is to provide an improved process of operating a converter that will increase the life of the converter lining, particularly the bottom.

It has been discovered that enriching the converter blast with oxygen during the final or finishing period of the blowing operation improves the "clean-up" or separation of the slag from the metal so that the blown metal poured from the converter is cleaner and is relatively free of undesirable slag inclusions. The improvement in "clean-up" of the metal is, of course, more pronounced when the charge of blast furnace iron contains silicon and manganese in a ratio of less than 1½, for normally it is difficult to have the slag separate cleanly from the metal under such conditions. In the Weirton process, the silicon to manganese ratio is about 1 and preferably less, and increasing the oxygen content of the blast during the finishing period is especially helpful as obtaining good slag separation is quite difficult and important. Although the present invention is more particularly useful in obtaining separation when the silicon to manganese ratio is less

than 1½ and especially so when this ratio is 1, or less, the present invention is not limited to such ratios and is useful for obtaining more complete slag separation when the silcon to manganese ratio is higher than 2 and the metal is not blown down to less than 0.25% carbon. At least, at times, it is difficult to obtain complete or satisfactory separation of the slag when the blast furnace metal is of the type usually considered satisfactory for producing Bessemer steel. It also has been found that the use of an oxygen enriched blast during the clean-up period to improve the slag separation does not cause excessive fluidity of the slag and slopping during the blowing operation. This is somewhat surprising for heretofore the primary reason for suggesting the use of an oxygen rich blast in the converter has been based on the fact that more heat would be available and excess heat may cause excessive fluidity which will cause incomplete separation of the slag and slopping during the blow.

An important advantage of the present invention is that cleaner blown metal is produced. Another important advantage is that the blast furnace can be operated to produce blast furnace iron that is suitable for charging to the open hearth furnace as is done in the Weirton process, and such a blast furnace iron can be charged to the converter and readily blown to produce clean blown metal without taking unusual precautions. Consequently, the blast furnace can be operated to produce good iron for the open hearth without altering the blast furnace process when some of the pig iron is to be charged to the converter and blown.

It is the oxygen content of the blast during the final or finishing period of the blowing operation that effects the separation of the slag. The length of the finishing period will depend in part upon the pressure of the blast, the quantity of the blast in cubic feet per minute and the percentage of oxygen in the blast. The finishing or "clean-up" period may constitute up to the last 1½ to 2 minutes of the blowing period preceding discharge of the blown metal. Normally, the finishing period will be at least ¼ minute, but this depends in part on the oxygen content of the blast and will be discussed more fully in connection with the oxygen content of the blast. Preferably, the finishing period is maintained as short as is consistent with good slag separation, so that preferably the finishing period is not longer than 1½ minutes. Good results can be obtained with a finishing period of from ¼ to ¾ minute.

If the percentage oxygen content of the blast during the finishing period is greater than that of air, improved slag separation results. Economic factors at the present time tend to limit the percentage oxygen content. In addition, it is desirable that the finishing period not proceed too rapidly so that normally the blast during the finishing period does not contain more than 30% by volume of oxygen and preferably does not contain more than 25% oxygen.

These and other objects and advantages will become more apparent when considering the following description, taken in connection with the accompanying drawing in which there is a diagrammatically shown apparatus including an acid type converter constructed and arranged for carrying out the present invention.

Referring to the drawing, an acid-type, refractory lined converter 10 is pivotally or tiltably mounted on a pair of trunnions 11 and 12 rotat-

ably supported in a pair of supports 13. At the bottom of the converter, there is a wind box 14 which is in communication with the outlet end of a pipe 15. The outlet side of a blower 16 is connected through pipe 17, hollow trunnion 12 and pipe 15 to the wind box 14. A plurality of tuyères 18 are in communication with wind box 14 so that when the blower 16 is in operation, a blast of air is blown through the tuyères 18 and the molten metal in the converter 10.

Means are provided for increasing the oxygen content of the blast. A tank 19 which may be a relatively large storage tank or which may be connected through a pipe 20 to a source of pure or impure oxygen is connected through pipe 21 to pipe 17. Pipe 21 contains a flow control valve 22 which may be opened to admit the desired amount of oxygen to pipe 17. When oxygen is added to pipe 17, the oxygen pressure must be higher than the blast pressure on the outlet side of blower 16 so that the oxygen will flow into the pipe 17 and mix with the air blast. Preferably, the oxygen is added to the inlet side of the blower. Pipe 23 containing valve 24 is connected to oxygen pipe 21 and to an inlet pipe 25 of blower 16. Inlet pipe 25 is connected to a suitable source of blast air which may be atmospheric air. With valve 24 open, oxygen flows through pipe 23, pipe 25 and the blower 16. When the oxygen is added to the blast on the inlet side of the blower, the pressure of the oxygen can be relatively low. The oxygen may be pure oxygen or impure oxygen if it is of sufficient purity so that it can be used to enrich the air blast.

In operation, the converter 10 is turned down to substantially the horizontal position and is charged with molten blast furnace iron. As soon as the converter is charged, the blower 16 is started and the blast is turned on and simultaneously the converter is turned to the erect position. The blast of air flows up through the molten iron and scrap, if any, to oxidize the carbon, silicon, and manganese. During the first part of the blowing operation, the silicon is relatively rapidly oxidized, and only a small amount of the carbon is oxidized. During the intermediate blowing step, both the silicon and carbon are oxidized in more nearly equal amounts. During the finishing or final period immediately preceding discharge of the blown metal, only a slight amount of silicon is oxidized while a relatively large amount of carbon is oxidized. The oxidized silicon and manganese, along with the oxidized iron, form a slag which floats on top of the molten metal. If conditions are such that the slag separates cleanly from the metal, only a slight amount of slag or no slag will be left in the molten metal.

As more fully described in my copending application, Serial No. 785,219, filed the same day as the parent application, Serial No. 785,218, now abandoned, the use of an oxygen rich blast during the first portion or melt-down period of the blowing operation increases the amount of scrap which can be charged and reduces the blowing period. If oxygen enriched blast is used during the melt-down period, the silicon content of the metal is reduced to a lower value than when the usual air blast is used. This increases, at least to a slight extent, the amount of slag, and if an oxygen enriched blast is used during the finishing period, this increased quantity of slag will separate cleanly from the blown metal.

A number of blows were made in which about

8,000 to 11,000 pounds of solid scrap steel and from about 45,000 to 47,000 pounds of molten blast furnace iron were charged into the converter for each blow. These charges were blown with a blast of atmospheric air containing the normal quantity of moisture present in the air and enriched with sufficient oxygen during the period set forth so as to contain the percentage of oxygen specified which is the total percentage of oxygen. The blast furnace iron contained from 4.0 to 4.40% carbon, from .90 to 1.30% manganese, and from .9 to 1.25% silicon. The blast pressure was about 25 pounds per square inch, and the blast volume was about 30,000 cubic feet per minute. A number of blows were made with the blast during the finishing period containing about 24% to 25% volume of oxygen. For a few blows, the blast contained about 22.5% oxygen. This finishing period was varied in length from ¾ to 2 minutes. For some of the blows and in addition to enriching the blast during the finishing period, the blast was enriched at the start of the blow for from 1 to 4½ minutes so that the blast contained about 25% by volume of oxygen. For those blows where an oxygen enriched blast was used during the first part or melt-down period of the blow, enrichment of the blast was discontinued when the scrap was melted or was discontinued before the scrap was melted and the silicon content of the blown metal was, on the average, less than for the other blows. The blast, except for the periods of enrichment, was atmospheric air. In all of these examples, the carbon was reduced to from 1.44 to 2.43%. Immediately after the finishing period, the converter was turned down, the blast discontinued and the blown metal and slag discharged from the converter. When the blown metal was poured, the slag separated cleanly from the metal and separated more cleanly than when similar blast furnace iron was blown with a straight air blast. The blown metal was relatively free of slag inclusions and was successfully charged and worked in the open hearth furnace.

In another series of blows with similar blast furnace iron, the blast pressure was about 26 pounds per square inch, and the blast volume was about 32,000 cubic feet per minute. The finishing period was maintained at about ½ minute and did not vary beyond the range of ¼ to ¾ minute. The blast was enriched during the finishing period by the addition of 800 cubic feet of oxygen per minute, so that the blast contained on the average about 22.65% total oxygen by volume. The blast preferably should not contain more than about 25% oxygen as there is a tendency for the finishing period to proceed so rapidly that it is difficult to control and preferably should contain at least about 21.5% oxygen by volume so as not to lengthen the finishing period unduly. For some of the blows, steam was added to the blast during various portions of the blowing operation, including the finishing period and the intermediate period between the melt-down and finishing periods. The slight variation in the blast resulting from the steam addition was ignored, and the same volume of oxygen—that is, 800 cubic feet per minute—was added to the blast. As used herein, the term "air blast" covers an air blast which may or may not contain added moisture but which contains no added oxygen, and the term "oxygen-enriched air blast" is directed to such air blast which contains added gaseous oxygen—either pure or im-

pure—so that the blast contains a higher percentage of oxygen than air.

While it is customary and correct to refer to the fact that during the first part of the blow silicon is oxidized or reduced and that during the last part of the blow the carbon is oxidized, each of these elements is oxidized to a limited extent during all portions of the blow so that enriching the blast does aid in oxidizing these elements. Enriching the blast during the clean-up period may shorten the blowing period, but this effect, if any, is very slight and is not sufficient to warrant the cost of the oxygen and has not been sufficient to be noticeable. The use of an oxygen-rich blast during the finishing period does have a marked effect on the slag separation. For example, in blows like those previously described, except that the blast was not enriched during the finishing period, the white hot blown metal when poured had a dirty appearance and black streaks of watery-appearing slag could be seen in the metal. The use of oxygen during the first part of the blow did not reduce the occurrence of these slag streaks. When the blast was enriched at the end of the blow, the white hot blown metal had a clean blue-white appearance without the streaks of slag. The additional oxygen seemed to dry up the slag so that it separated cleanly. Regardless of whether or not this is the correct explanation, the character of the slag was changed so that it separated cleanly, and this characteristic was retained when a number of blows were poured into a ladle, prior to pouring the metal into the open hearth. While the ladle contained some slag, the slag remained separate and did not re-enter the metal. In addition, there were strong indications that products made from the open hearth steel contained on the average fewer slag inclusions when the blast was enriched with oxygen during the finishing period.

Surprisingly, it has been found that enriching the blast with oxygen increases the life of the converter bottoms. Accordingly, it is preferable to also use an oxygen rich blast during at least part of the melting period in addition to the finishing period. It has been possible to increase the average number of blows per bottom by as much as fifty per cent, and in some instances a bottom has been used for more than twice the usual number of blows where the bottom was well constructed and oxygen was used both during the melt-down and finishing periods. The life of a converter bottom is influenced by other factors, and is particularly influenced by the skill used in making the bottom so that it is necessary to make a comparison over an extended period, and it is difficult, if not impossible, to express the increase in bottom life resulting from the use of oxygen enrichment in exact percentages. A long series of blows using oxygen enrichment has resulted in a great increase in the average life of the converter bottom, and this increase in average life has been about 50%.

Although the present invention has been described more particularly for use when the hot metal contains silicon and manganese in a ratio of less than 1½ and in a ratio of about one, or less—for it is under these conditions that it is very difficult to obtain complete separation of the slag from the blown metal—the present invention is not limited to such blast furnace metal and may be used with blast furnace iron containing silicon and manganese in a ratio greater than two. The problem of slag separation is more acute when the silicon to manganese ratio is less than 2, and especially so when such ratio is 1.5 or 1, or less. Furthermore, steam or water vapor may be added to the blast when the blast is or is not being enriched with oxygen. In addition, the blast may be enriched with oxygen in accordance with the present invention when the converter is either an acid or basic type converter.

Enrichment of the blast during the intermediate blowing period immediately preceding the finishing period produces no particular advantages and is undesirable. The use of an oxygen rich blast during this intermediate period changes the characteristics of the flame so that the operator cannot accurately control the blowing operations and also increases the temperature of the metal. If the temperature of metal is increased, the carbon may be oxidized and the siliconm not properly oxidized so that the blown metal will contain a relatively large amount of silicon which is undesirable, especially when the blown metal is charged to the open hearth furnace. Accordingly, an oxygen rich blast should not be used during the intermediate period between the first or melt-down period and the finishing or clean-up period as it does not produce any appreciable results and increases the cost.

The use of an oxygen rich blast during part of the blowing period, and especially during the finishing period at the end of the blowing period, has a further advantage. Heretofore, when blast furnace iron was blown in a Bessemer converter to produce Bessemer metal, it has been considered necessary to charge the blast furnace with Bessemer, low manganese types of ores. With the present invention, it is possible to utilize the basic, high manganese ores to replace, at least in part, the Bessemer ores and obtain blast furnace iron that contains a relatively higher amount of manganese and that can be blown to produce clean blown metal.

I claim:

1. In the method of blowing ferrous metal in a converter, the steps comprising charging molten blast furnace iron containing carbon, silicon and manganese into the converter, first blowing the charge and oxidizing constituents of the iron, blowing the charge with an air blast, and then finish blowing the charge with an oxygen-enriched air blast for a period of not longer than two minutes and at least oxidizing carbon, the blown metal at the end of the blow containing at least 0.25% carbon.

2. The method of blowing ferrous metal in the converter as claimed in claim 1 in which the oxygen-enriched air blast contains at least 21.5% oxygen by volume.

3. The method of blowing ferrous metal in the converter as claimed in claim 1 in which the finish blowing period is at least ¼ minute and not more than 1½ minutes.

4. The method of blowing ferrous metal in the converter as claimed in claim 1 in which the ratio of silicon to manganese in the molten blast furnace iron is not greater than 1½.

5. In the method of blowing ferrous metal in a converter, the steps comprising charging into the converter molten blast furnace iron containing carbon and containing silicon and manganese in a ratio not greater than 1½, first blowing the charge and oxidizing constituents of the iron, blowing the charge with an air blast, and then finish blowing the charge with an oxygen-enriched air blast containing at least 21.5% oxygen

by volume for a period of at least ¼ minute and not longer than 1½ minutes and oxidizing carbon, the blown metal at the end of the blow containing at least 0.25% carbon.

6. The method of blowing ferrous metal in the converter as claimed in claim 5 in which the finish blowing period is not longer than ¾ minute.

7. The method of blowing ferrous metal in the converter as claimed in claim 5 in which the oxygen-enriched air blast contains not more than 25% oxygen by volume.

8. The method of blowing ferrous metal in the converter as claimed in claim 5 in which the blown metal at the end of the blow contains at least 1% carbon.

9. The method of blowing ferrous metal in the converter as claimed in claim 8 in which the finish blowing period is not longer than ¾ minute.

10. The method of blowing ferrous metal in the converter as claimed in claim 8 in which the finish blowing period is about ½ minute.

11. The method of blowing ferrous metal in the converter as claimed in claim 8 in which the silicon to manganese ratio is about 1.

12. The method of blowing ferrous metal in the converter as claimed in claim 11 in which the finish blowing period is not longer than ¾ minute.

13. The method of blowing ferrous metal in the converter as claimed in claim 11 in which the finish blowing period is about ½ minute.

14. In the method of blowing ferrous metal in a converter, the steps comprising charging into the converter molten blast furnace iron containing carbon and containing silicon and manganese in a ratio of about 1, first blowing the charge and oxidizing constituents of the iron, blowing the charge with an air blast, and then finish blowing the charge with an oxygen-enriched air blast containing between 21.5 and 25% oxygen by volume for a period of from ¼ to ¾ minute and oxidizing carbon, the blown metal at the end of the blow containing at least 1% carbon.

15. The method of blowing ferrous metal in a converter as claimed in claim 14 in which the finish blowing period is about ½ minute.

16. In the method of blowing ferrous metal in a converter, the steps comprising charging solid ferrous metal and molten blast furnace iron into the converter, first blowing the charge with an oxygen-enriched air blast for a period not longer than required to melt the solid ferrous metal, blowing the charge with an air blast, and then finish blowing the charge with an oxygen-enriched air blast for a period of not longer than 2 minutes, the blown metal at the end of the blow containing at least 0.25% carbon.

17. In the method of blowing ferrous metal in a converter, the steps comprising charging solid ferrous metal and molten blast furnace iron into the converter, the molten blast furnace iron containing carbon and containing silicon and manganese in a ratio not greater than 1½, first blowing the charge with an oxygen-enriched air blast for a period not longer than required to melt the solid ferrous metal, blowing the charge with an air blast, and then finish blowing the charge with an oxygen-enriched air blast containing at least 21.5% oxygen by volume for a period of at least ¼ minute and not longer than 1½ minutes, the blown metal at the end of the blow containing at least 0.25% carbon.

18. The method of blowing ferrous metal in a converter as claimed in claim 17 in which the blown metal at the end of the blow contains at least 1% carbon.

19. In the method of blowing ferrous metal in a converter, the steps comprising charging solid ferrous metal and molten blast furnace iron into the converter, the molten blast furnace iron containing carbon and containing silicon and manganese in a ratio of about 1, first blowing the charge with an oxygen-enriched air blast for a period not longer than is required to melt solid ferrous metal scrap, blowing the charge with an air blast, and then finish blowing the charge with an oxygen-enriched air blast containing at least 21.5% oxygen for a period of at least ¼ minute and not longer than 1½ minutes and oxidizing carbon, the blown metal at the end of the blow containing at least 0.25% carbon.

20. In the method of blowing ferrous metal in a converter, the steps comprising charging solid ferrous metal and molten blast furnace iron into a converter, the molten blast furnace iron containing carbon and containing silicon and manganese in a ratio of about 1, first blowing the charge with an oxygen-enriched air blast for a period not longer than is required to melt the solid ferrous metal, blowing the charge with an air blast, and then finish blowing the charge with an oxygen-enriched air blast containing between 21.5% and 25% oxygen by volume for a period of at least ¼ minute and not longer than ¾ minute and oxidizing carbon, the blown metal at the end of the blow containing at least 1% carbon.

21. The method of blowing ferrous metal in a converter as claimed in claim 20 in which the finish blowing period is about ½ minute.

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