

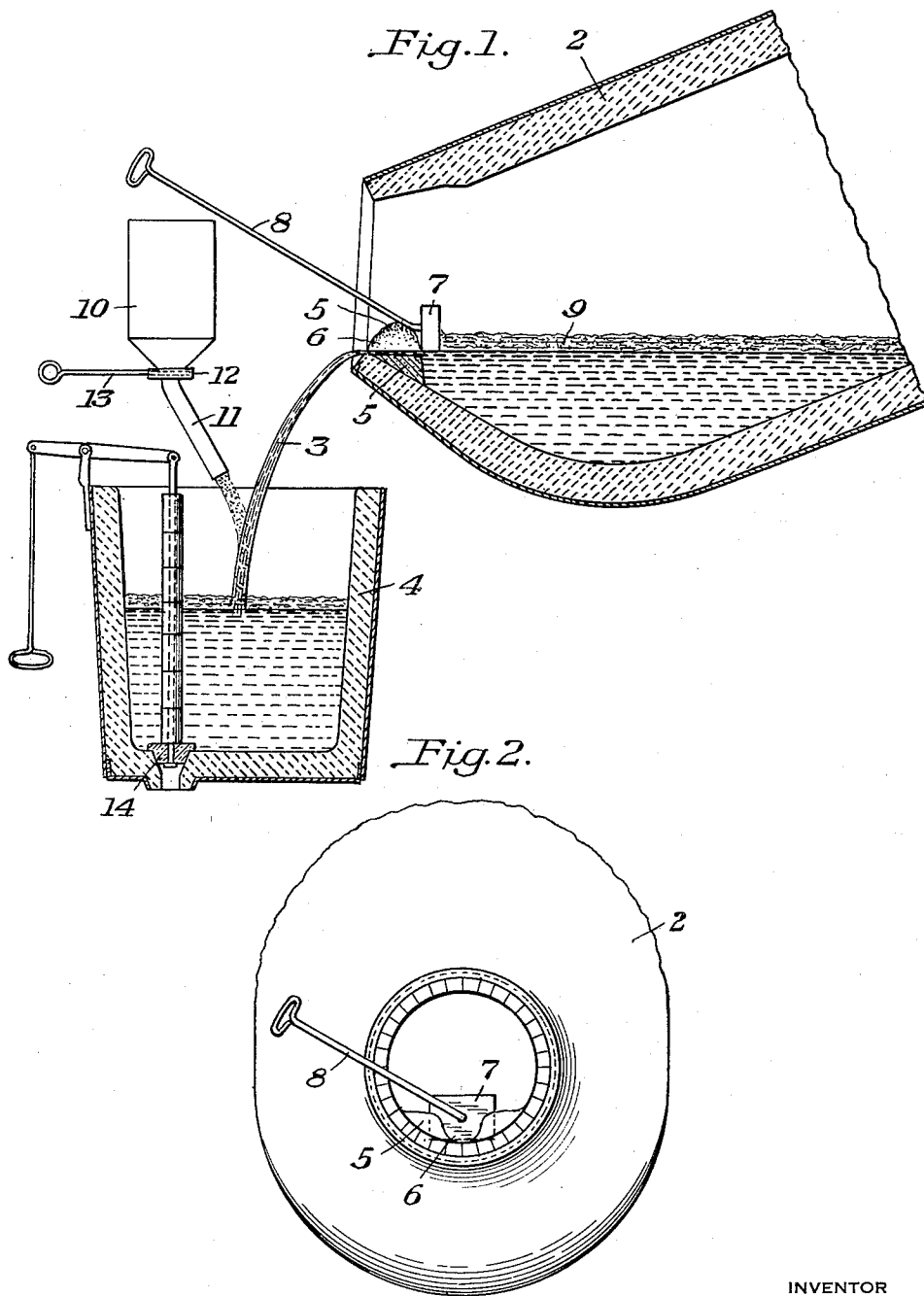
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MANUFACTURE OF ACID BESSEMER STEEL

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MANUFACTURE OF ACID BESSEMER STEEL

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7 Claims. (Cl. 75-46)

This invention relates generally to the manufacture of steel and more particularly to the manufacture of acid Bessemer steel in which the steel from an acid converter is treated with a dephosphorizing mixture in order to lower its phosphorus content.

This application is a continuation-in-part of my copending application, Serial No. 271,442, filed May 3, 1939.

In the accompanying drawing, which illustrates in a diagrammatic manner the preferred method of carrying out my invention:

Fig. 1 is a vertical section of a portion of a Bessemer converter and a ladle illustrating the addition of a dephosphorizing mixture to the blown metal as it is poured from the converter into the ladle; and

Fig. 2 is a front elevation of the converter when in the turned down position illustrated in Fig. 1, showing one method of retaining the acid slag in the converter while the blown metal is being poured.

The present invention provides a simple, efficient and economical process for reducing the phosphorus content of acid Bessemer steel. It avoids the necessity for employing any additional receptacles for the blown metal beyond the single pouring ladle required for producing ordinary acid Bessemer steel by the usual process in which the phosphorus content is not reduced.

In carrying out the preferred method, molten iron, with or without the addition of scrap, is introduced into an acid lined Bessemer converter and the metal is blown to reduce the silicon, manganese and carbon. The blow is stopped short of a full blow as will be described more in detail hereinafter, and there is thus produced a thick, viscous, lumpy slag which can be more readily retained in the converter when it is turned down and the blown metal is poured. The blown metal is then poured into a dephosphorizing ladle, care being taken to retain the acid slag in the converter. In order to accomplish this, the pouring lip of the converter nose is built up with mud or other refractory material, so as to form a smaller pouring opening and a block of wood secured to the end of a long rod is placed behind the built up nose in order to prevent the slag from running out of the converter with the metal. While the blown metal is being poured into the ladle, a dephosphorizing mixture, which preferably consists of lime, iron oxide and fluorspar, is added to the molten stream. The dephosphorizing mixture is thoroughly mixed with the blown metal in the ladle

by proper manipulation of both the flowing stream of metal and the mixture. The mixture then melts in the hot blown metal and a chemical reaction ensues, the result of which is a very fluid slag which removes the phosphorus and rises to the top of the metal. The dephosphorized metal is then separated from the slag, preferably by pouring it directly into molds.

Referring now more in detail to the process and to the accompanying drawing, it is important for the success of my process that the correct correlation of certain factors be employed. There is a correlation between the initial temperature of the raw iron, the silicon content of the raw iron, the manganese content of the raw iron and the length of blow in the converter. The raw iron as charged into the converter may vary considerably in temperature, say from 2300° to 2800° F. The blown metal when discharged from the converter must be at a temperature sufficient to melt the dephosphorizing mixture and at the same time retain a normal pouring temperature of the metal in the ladle. The temperature of the blown metal is dependent upon the initial temperature of the iron charged into the converter and upon the amount of silicon contained in the charge. The reaction of the air with the silicon of the charge during the blow is strongly exothermic and thereby provides considerable heat in addition to the temperature of the metal as charged. When the initial temperature of the charge is low, it is necessary to employ relatively high silicon and when the initial temperature of the charge is high, a lower percentage of silicon may be used. Thus if the initial temperature of the charge is, say, 2300° F., it is necessary that the silicon content be about 2.0 to 2.5%. On the other hand, however, if the initial temperature is about 2800° F., then I may use a charge having a silicon content as low as about .90%.

The consistency of the slag in the converter at the end of the blow is important in enabling it to be readily separated from the blown metal. If the slag is too thin at the end of the blow, it renders it difficult, if not impossible, to separate cleanly the slag from the blown metal as it is poured from the converter into the dephosphorizing ladle. Too thin a slag also is objectionable, in that it rapidly attacks the lining of the converter. On the other hand, if the slag is too thick, it gums up the converter, sticking to the lining after the blown metal is poured and rendering the subsequent operations inefficient.

The consistency of the slag is dependent upon

the silicon and manganese contents of the charge and the length of blow. In addition to silicon, both manganese and iron oxidize during the blow forming manganese and iron oxides which flux the silicious slag and thin it. I have found that in order to have a slag of proper consistency, so that it may be readily separated from the blown metal, it is necessary that the silicon and manganese be within certain ranges and that the ratio between the silicon and manganese be within certain limits. The preferred range of silicon in the charge before blowing in order to obtain slag of the best consistency is between about 1.25% and 1.75%. The manganese is preferably between about .50% and .80%. I have used and have efficiently dephosphorized metal blown from raw iron containing silicon as low as .90% and as high as 2.50% and manganese as low as .30% and as high as 1.00%. The silicon to manganese ratio should be between 2:1 and 3:1, preferably about 2½:1. In using the wider ranges of silicon and manganese referred to more complicated and more expensive methods must be employed for separating the slag from the blown metal.

Preferably the charge is blown for a somewhat shorter period of time than would ordinarily be used in the usual acid Bessemer process. This results, when operating on a charge having the proper silicon to manganese ratio, in a slag which is thick and lumpy and can be readily separated from the blow metal in the converter. The period of time for the blow will vary, of course, with the composition of the charge, the amount of charge and other factors. The physical characteristics of the preferred slag may be best described by stating that it is quite similar in appearance and consistency to a mix of gravel and asphalt commonly used in forming the top coating of roads. The physical characteristics are determined by the chemical composition of the slag, particularly its silica content, as is pointed out more in detail hereinafter. During the first part of the blow, the silicon is oxidized along with some manganese. During this period, very little flame issues from the converter, this period usually occupying about two minutes where the total blowing period is approximately 8 minutes. The next period is that in which the carbon is rapidly oxidized and this period is characterized by a bright, long flame issuing from the converter. This carbon reduction period may continue for perhaps five or six minutes and then there occurs a change in the appearance of the flame referred to as the "first change," which indicates that the carbon has been reduced to a low amount, say .03 to .05%. At the time of the first change, the length and brightness of the flame decreases materially. Within a few seconds, say four to six seconds, after the first change there occurs a change which is referred to as the "second change." This second change is characterized by a dark or reddish flame, due probably to the more rapid oxidation of the iron. In ordinary acid Bessemer practice, the heat is blown for a period of a few seconds, say five seconds, after the second change occurs before the converter is turned down for pouring and the air blast is shut off. This usual practice produces a fluid slag, due to the further oxidation of the iron. In contrast with this usual practice, I turn down the converter, thereby terminating the blow, immediately after the second change appears and then pour the blown metal directly into the dephosphorizing ladle. By this procedure the slag is maintained in a thick, lumpy form which can be

readily retained in the converter while the blown metal is poured into the dephosphorizing ladle.

The control of the iron analysis, that is the analysis of the charge introduced into the converter, within the limits and ratios of silicon to manganese as described and the length of blow in turn control the chemical analysis of the slag formed in the converter within certain fairly narrow limits which determine the physical condition of the slag.

Semi-fluid or fluid slags can not be sufficiently or completely held back in the converter for separation from the blown metal, and such slags are a common occurrence in the practice of the prior arts.

As previously mentioned, silicon is oxidized during the blow and in addition manganese and iron are also oxidized. The oxides of manganese and iron act as a flux on the silicious slag formed in the converter, making it more fluid. As the time of blow in the converter is increased, greater quantities of manganese oxide and iron oxides are formed in the slag and the percentage of silica in the slag decreases. Thus, as a general statement, it may be said that as the length of blow increases the silica content of the slag decreases and the fluidity of the slag increases. According to the present invention, the blow is stopped earlier than in the usual practice and while the slag is still in a thick lumpy condition, so that it may be readily separated from the blown metal. If the slag in the converter contains 50 to 55% or less of silica, the slag is so fluid that it is impossible to hold back a major portion of the slag in the converter when the blown metal is poured. A large proportion of the acid slag in the converter flows into the ladle with the blown metal and neutralizes the basic dephosphorizing addition, so that the dephosphorizing step is relatively ineffective. An example of a slag which is unsuited to the present process is:

EXAMPLE I

SiO ₂	Al ₂ O ₃	Iron oxides	MnO
50 to 55% or less.	2 to 3% or more.	21 to 23% or more.	16 to 18% or more.

The minimum requirement of silica which must be present in the slag in order that the slag be sufficiently thick, so that the major portion of the slag can be held back in the converter is about 57%. Accordingly in carrying out the present process the blow in the converter is stopped while the slag is still in a thick lumpy condition and contains at least 57% silica. An example of such slag which is suitable according to the present invention is:

EXAMPLE II

SiO ₂	Al ₂ O ₃	Iron oxides	MnO
Per cent 57	Per cent 3	Per cent 22	Per cent 16

The slag of Example II was fluid enough so that about 15 to 20% of it flowed with the blown metal into the ladle, thus neutralizing a portion of the dephosphorizing addition, so that the dephosphorization was partial, rather than being complete.

It is preferred that the slag contain from 60 to 70% silica. This enables practically complete separation of the slag from the blown metal. An

example of a preferred range of compositions for the slag is:

EXAMPLE III

SiO ₂	Al ₂ O ₃	Iron oxides	MnO
Percent 60 to 70	Percent 2 to 3	Percent 13 to 20	Percent 12 to 16

Slags of ideal physical condition so that they may be completely separated from the blown metal contain about 65% silica and are within 1 or 2% of the following analysis:

EXAMPLE IV

SiO ₂	Al ₂ O ₃	Iron oxides	MnO
Percent 65	Percent 2.5	Percent 16.5	Percent 14

Silica contents above 70% are not objectionable from a slag separation standpoint, but are of no value practically because they cannot be used continuously. They are very dry and extremely silicious and tend to stick fast to the converter lining in layer upon layer, heat after heat, and eventually (in about one week) reduce the capacity of the vessel to such an extent that only smaller heats can be accommodated in the reduced area. It is, therefore, best practice to limit the silica content of the slag to about 70%.

The reasons for the control of the silica content in the slag to about 60 to 70% are due to the fluxing effect of the manganese oxide and iron oxides. By controlling the ratio of silicon to manganese in the Bessemer converter charge at about 2½:1, and at the same time stopping the blowing period short of a full blow, a slag of proper chemical composition and proper physical characteristics results. In order to show the effect on the composition of the slag resulting from blowing a controlled iron for different periods of time, Table 1 is given. The converter charge contained 1.50% silicon, .60% manganese and .09% phosphorus.

TABLE 1
Slag analyses

	Young blown heat	Medium blown heat	Medium full- blown heat	Full- blown heat
	Per cent	Per cent	Per cent	Per cent
SiO ₂	65.93	64.82	61.90	60.20
Al ₂ O ₃	2.57	2.66	2.88	3.0
Iron oxides.....	15.66	16.27	18.80	21.20
MnO.....	13.76	13.40	13.56	13.60
Slag condition.....	(1)	(2)	(3)	(4)

¹ Very thick.

² Thick.

³ Medium thick.

⁴ Semi-fluid.

It is to be noted from Table 1 that the manganese oxide content remained about the same but that as the degree of blowing was extended from a "young" to a "full" blow the iron oxides content increased from 15.66 to 21.20% and caused the silica content to be reduced from 65.93% to 60.20%.

The effect of a lowered silica content of the slag upon the subsequent dephosphorizing operation is clearly shown in the steel analysis of the final metal of the heats blown as above.

TABLE 2
Steel analyses

	Young blown heat	Medium blown heat	Medium full blown heat	Full blown heat
Carbon.....	.07	.07	.07	.07
Manganese.....	.29	.28	.30	.27
Sulphur.....	.040	.035	.034	.043
Phosphorus.....	.023	.023	.034	.065

It is to be noted that as the degree of the blowing was extended from "young" to "full" the removal of phosphorus was decreased. The explanation of this is found in the physical condition of the slag. In the case of the "medium full" or "full" blows the iron oxides concentration was high enough to cause small quantities of somewhat fluid slag to form around the edges of the lumps of slag and when the converter was tilted for pouring metal, the fluid portions of the slag became disengaged from the lumps and flowed with the metal into the ladle, thereby allowing the silicious material in the slag to neutralize the basic dephosphorizing addition sufficiently to reduce its effectiveness in reducing phosphorus. This is clearly shown in the analyses of the final ladle slags of the above four heats. The final ladle slags are the slags formed in the ladle after the addition of the basic dephosphorizing mixture to the blown metal.

TABLE 3
Ladle slag analyses

	Young blown heat	Medium blown heat	Medium full blown heat	Full blown heat
	Per cent	Per cent	Per cent	Per cent
SiO ₂	17.80	18.23	21.37	22.54
Al ₂ O ₃	5.99	6.07	6.42	7.02
FeO.....	10.20	12.52	6.94	7.40
Fe ₂ O ₃	3.73	3.66	1.93	1.85
MnO.....	7.71	6.08	5.07	4.50
CaO.....	51.52	49.42	48.10	46.20
Phosphorus.....	1.67	1.90	1.59	1.07
Sulphur.....	.147	.165	.093	.087

About 15% of the SiO₂ present in the above slags is due to erosion of the silicious ladle lining by the basic dephosphorizing slag. It will be noted that with a full blown heat the phosphorus in the ladle slag amounted to only 1.07%, whereas with a young blown heat it amounted to 1.67%.

In Figs. 1 and 2, the converter 2 is shown in its turned down position and the stream of blown metal 3 is being poured into a dephosphorizing ladle 4. In order to retain the acid slag in the converter, the pouring lip of the converter is built up with mud or other refractory material before the converter is charged. The built up portion of the lip is indicated by the reference numeral 5 and forms a smaller pouring opening 6. A wooden block 7 secured to the end of a long rod 8 is placed behind the built up lip of the converter and retains the acid slag 9 in the converter as the blown metal is being poured. In this manner, the stream 3 is maintained substantially entirely free from slag.

The dephosphorizing mixture is added to the stream of blown metal as it flows into the ladle 4. The dephosphorizing mixture is placed in a container 10 having a delivery spout 11 and a valve 12 controlled by a handle 13. The dephosphorizing mixture and stream of molten blown

metal are intimately mixed as they flow into the ladle and a thin fluid slag is formed which rapidly removes phosphorus from the steel. The pouring time for a seven ton heat is usually about 1½ minutes. Ordinarily, about 150 to 500 pounds of the dephosphorizing mix is used for this size heat, depending upon the amount of phosphorus which it is desired to remove. After the heat is poured into the ladle, the ladle is moved over ingot molds and the steel is cast into ingots by raising the stopper 14 in the usual manner.

The preferred dephosphorizing mixture consists of about 50% lime, 30% iron oxide in the form of roll scale and 20% of fluorspar. These proportions may be varied considerably but produce less satisfactory results. I have used lime as low as 30% and as high as 65% of the mixture, iron oxide from 10-50% and fluorspar from 0-40%. However, I usually employ at least 10% of fluorspar. As indicated, the fluorspar or other flux may be eliminated entirely in some instances, provided that the iron oxide content is increased. For example, I may use a dephosphorizing mixture containing about 50% of lime and 50% of iron oxide. However, in this case the high percentage of iron oxide has a tendency to oxidize the steel and it then becomes necessary, where it is desired to obtain deoxidized steel, to add aluminum or some other deoxidizer to the steel after the dephosphorizing operation. Ordinarily, my process will reduce the phosphorus from, say .100 or .090% to .03 or .04% and in some cases to .015 or .012%. I have reduced the phosphorus by my process from .20% to .077%. The carbon in the blown metal is ordinarily about .03 or .05%.

Although I prefer to use fluorspar as the flux for the lime in the dephosphorizing mixture because of its efficiency and low cost, I may use any neutral, acid or basic flux, for example soda ash, borax or bauxite. It is preferred to use roll scale as the source of the iron oxide but I may use finely ground high grade iron ore, such as hematite or magnetite, provided that their phosphorus and silica contents are low. I have found that lime is much more efficient than limestone, although appreciable phosphorus reduction may be obtained by the use of the latter. Lime, however, is much preferred, since less of it is required and it abstracts less heat from the metal in forming the dephosphorizing slag.

In the preferred procedure, ferromanganese is added to the blown metal at the same time as the dephosphorizing mixture. The ferromanganese acts as a deoxidizer and also raises the manganese content of the steel to the desired point. It is unnecessary in my process to transfer the steel from the dephosphorizing ladle to another ladle before pouring it into ingots.

I have found that the amount of ferromanganese used in my process to produce a given content of manganese in the steel is from 25 to 35% less than the amount which is usually required according to ordinary acid Bessemer practice. It is believed that this saving in ferromanganese results from two causes. First because the charge is not blown so far in the converter as in ordinary practice and, therefore, less manganese is oxidized during the blow. Second, in ordinary practice the acid slag is not retained in the converter but flows into the ladle with the blown metal. Some of the ferromanganese added to the ladle reacts with the acid slag and is lost. The saving in cost due to the decreased amount

of ferromanganese which I use practically compensates for the increased cost of the dephosphorizing operation.

In carrying out my process, I preferably blow the metal hotter than in ordinary practice. This is done by using a lesser amount of scrap than would ordinarily be employed for cooling the metal down to a proper pouring temperature. For example, in blowing a six ton heat, I use approximately 1,000 pounds less scrap or its equivalent in other cooling means such as steam in my process than if the ordinary acid Bessemer process was being followed.

My preferred process involves a combination of steps which leads to efficient removal of phosphorus in a simple, economical manner. The relatively short blow given to the metal in the converter, together with the proper ratio of silicon and manganese in the converter charge, results in a thick, lumpy slag which can be readily separated from the blown metal as the latter is poured from the converter. The acid slag formed in the converter is then retained therein by the wooden block or other equivalent mechanical restraining means, so that substantially no slag flows into the dephosphorizing ladle. The blown metal, substantially free from slag, is poured directly into a ladle where a dephosphorizing mixture is added. This mixture contains the ingredients in loose form. It is unused and the proportions of ingredients may be varied to suit particular conditions. The dephosphorized steel is poured directly from the dephosphorizing ladle into the ingot molds, so that only one ladle is employed. The use of a ladle for separating the acid slag from the metal and a separate ladle for a dephosphorizing operation is avoided. This substantially reduces the heat losses entailed when reladling is employed.

Although I have illustrated and described the present preferred embodiment of my invention, it is to be understood that the invention is not so limited but may be otherwise embodied or practiced within the scope of the following claims.

I claim:

1. The process of making low phosphorus steel, which comprises blowing molten iron in an acid Bessemer converter, stopping the blow immediately after the second change point which is characterized by the appearance of a dark or reddish flame and while the acid slag formed in the converter is still in a thick lumpy condition and contains about 60 to 70% silica, pouring the blown metal from the converter into a dephosphorizing ladle while restraining the acid slag in the converter from flowing into the ladle, introducing lime, iron oxide and flux into the ladle during pouring to form a basic slag which lowers the phosphorus, and pouring the dephosphorized steel.

2. The process of making low phosphorus steel, which comprises blowing molten iron in an acid Bessemer converter, stopping the blow immediately after the second change point which is characterized by the appearance of a dark or reddish flame and while the acid slag formed in the converter is still in a thick lumpy condition and contains about 60 to 70% silica, pouring the blown metal from the converter into a dephosphorizing ladle while restraining the acid slag in the converter from flowing into the ladle, introducing lime, iron oxide and fluorspar into the ladle during pouring to form a basic slag

which lowers the phosphorus, and pouring the dephosphorized steel.

3. The process of making low phosphorus steel, which comprises blowing molten iron in an acid Bessemer converter, stopping the blow immediately after the second change point which is characterized by the appearance of a dark or reddish flame and while the acid slag formed in the converter is still in a thick lumpy condition and contains about 60 to 70% silica, pouring the blown metal from the converter into a dephosphorizing ladle while restraining the acid slag in the converter from flowing into the ladle, during pouring introducing into the ladle a loose mechanical dephosphorizing mixture containing about 30 to 65% lime, about 10 to 50% iron oxide and about 10 to 40% fluorspar, and pouring the dephosphorized steel.

4. The process of making low phosphorus steel, which comprises introducing into an acid Bessemer converter a charge of molten iron containing silicon between about .90% and 2.50% and also containing manganese, the ratio of silicon to manganese being between about 2:1 and 3:1, blowing the charge and stopping the blow immediately after the second change point which is characterized by the appearance of a dark or reddish flame and while the acid slag formed in the converter is still in a thick lumpy condition and contains about 60 to 70% of silica, pouring the blown metal from the converter into a dephosphorizing ladle while restraining the acid slag in the converter from flowing into the ladle, introducing lime, iron oxide and flux into the ladle during pouring to form a basic slag which lowers the phosphorus, and pouring the dephosphorized steel.

5. The process of making low phosphorus steel, which comprises introducing into an acid Bessemer converter a charge of molten iron containing silicon between about 1.25% and 1.75% and manganese between about .50% and .80%, the ratio of silicon to manganese being between about 2:1 and 3:1, blowing the charge and stopping the blow immediately after the second change point which is characterized by the appearance of a dark or reddish flame and while the acid slag formed in the converter is still in a thick lumpy condition and contains about 60

to 70% silica, pouring the blown metal from the converter into a dephosphorizing ladle while restraining the acid slag in the converter from flowing into the ladle, during pouring introducing into the ladle a loose mechanical dephosphorizing mixture containing about 30 to 65% lime, about 10 to 50% iron oxide and about 10 to 40% fluorspar, and pouring the dephosphorized steel.

6. The process of making low phosphorus steel, which comprises blowing molten iron in an acid Bessemer converter, stopping the blow after the desired amounts of silicon, carbon and manganese have been removed but not later than immediately after the second change point, which is characterized by the appearance of a dark or reddish flame and while the acid slag formed in the converter is still in a thick lumpy condition and contains about 60 to 70% silica, pouring the blown metal from the converter into a dephosphorizing ladle while restraining the acid slag in the converter from flowing into the ladle, introducing lime and iron oxide into the ladle during pouring to form a basic slag which lowers the phosphorus, and pouring the dephosphorized steel.

7. The process of making low phosphorus steel, which comprises introducing into an acid Bessemer converter a charge of molten iron containing silicon between about .90% and 2.50% and also containing manganese, the ratio of silicon to manganese being between about 2:1 and 3:1, blowing the charge and stopping the blow after the desired amounts of silicon, carbon and manganese have been removed but not later than immediately after the second change point, which is characterized by the appearance of a dark or reddish flame and while the acid slag formed in the converter is still in a thick lumpy condition and contains about 60 to 70% silica, pouring the blown metal from the converter into a dephosphorizing ladle while restraining the acid slag in the converter from flowing into the ladle, introducing lime and iron oxide into the ladle during pouring to form a basic slag which lowers the phosphorus, and pouring the dephosphorized steel.

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