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2,733,141

PNEUMATIC PROCESS FOR THE REFINING OF BASIC PIG IRON

Filed Oct. 6, 1950

2 Sheets-Sheet 1

FIG. 1.

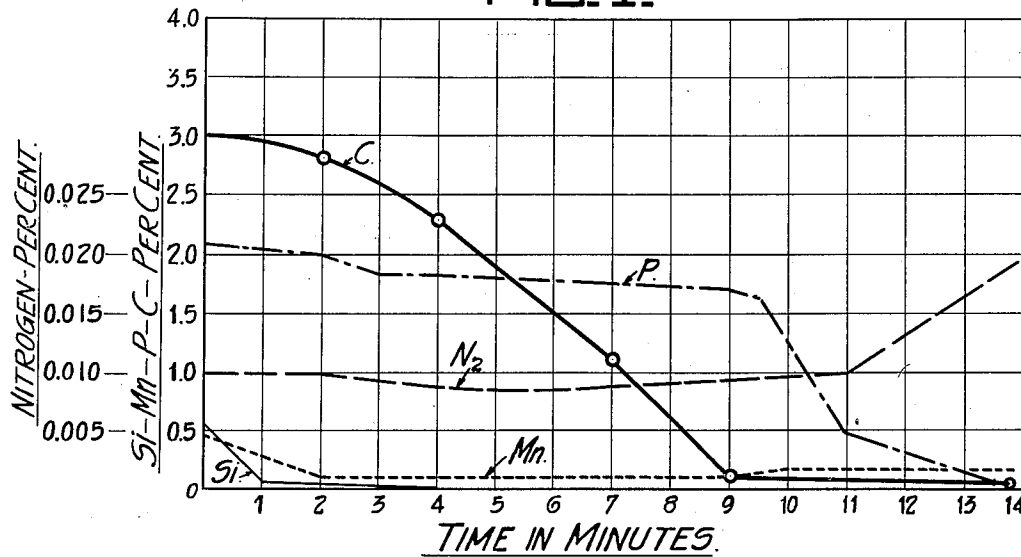


FIG. 3.

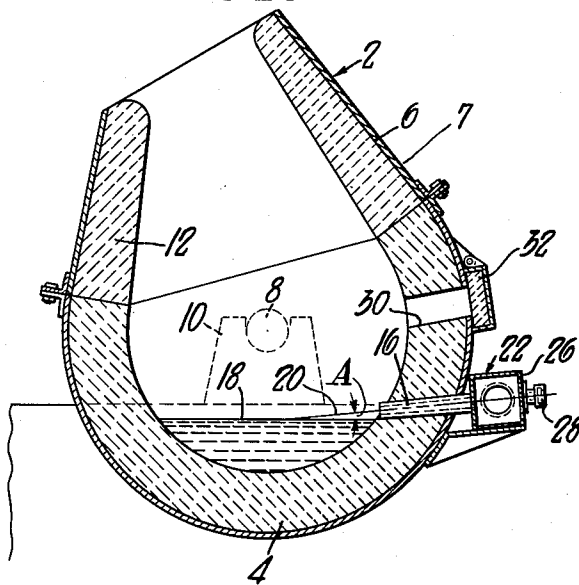
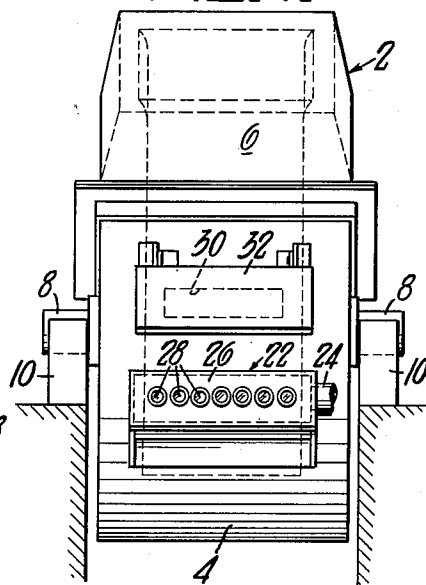


FIG. 4.



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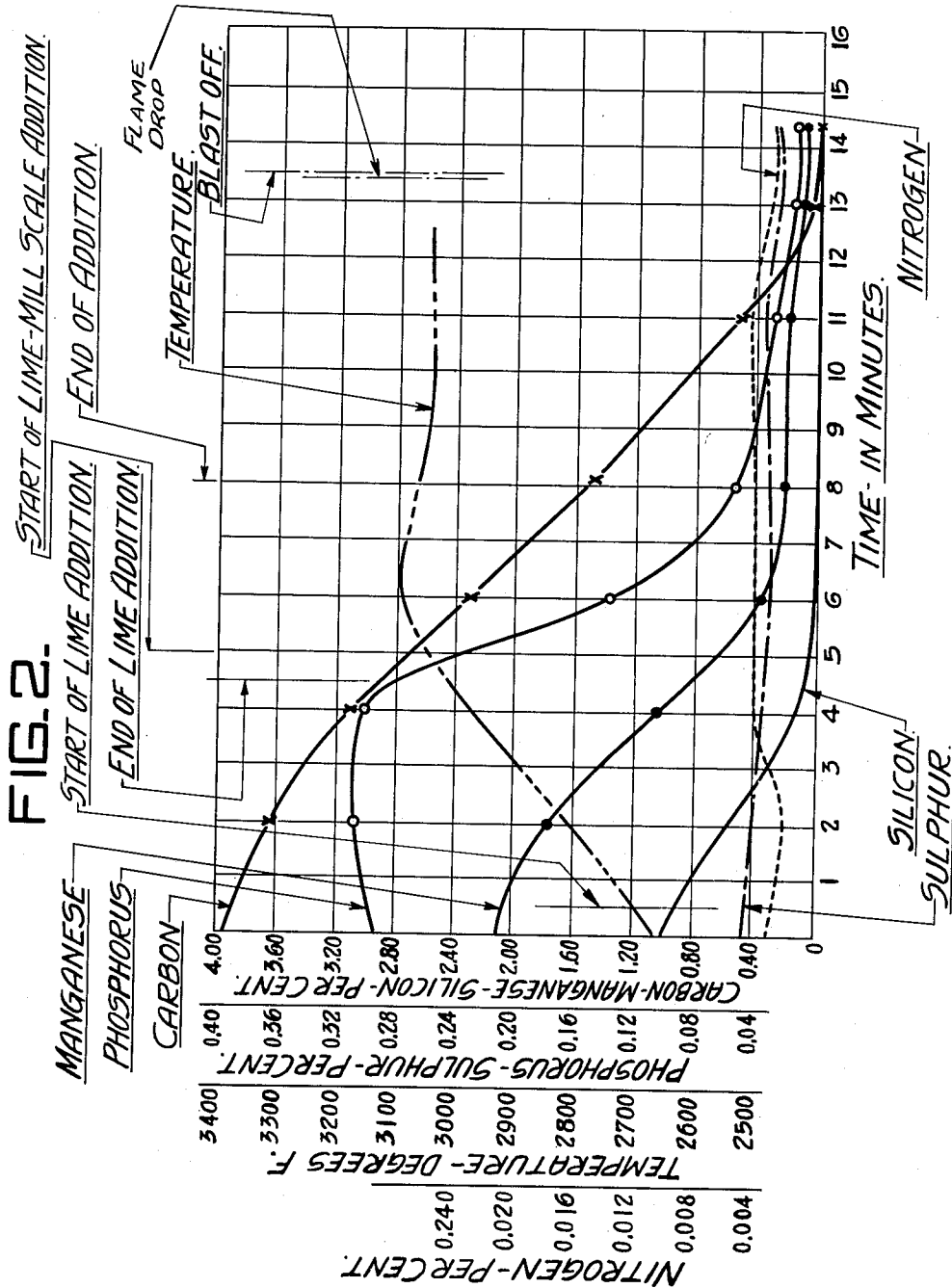
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2 Sheets-Sheet 2



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PNEUMATIC PROCESS FOR THE REFINING OF BASIC PIG IRON

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10 Claims. (Cl. 75—52)

This invention relates to a method of making steel and in particular to a pneumatic method of making low carbon steel.

The pneumatic processes known heretofore are applicable only to the refining of certain grades of pig iron, e. g., the acid Bessemer process require an iron high in silicon (1% minimum) to provide the necessary heat and low in phosphorus (0.10% maximum) since this element cannot be eliminated; the basic Bessemer (Thomas) process is restricted to the refining of iron having a relatively low silicon content to minimize the amount of cold slagging materials which must be added and high phosphorus (1.8% minimum) in order to provide the necessary heat. Because of these restrictions as to iron analysis, the processes cannot be used in the refining of American basic pig iron which averages about 0.3% phosphorus. Pig iron of this type represents about 75% of the iron refined in the United States.

In addition to the aforementioned limitations, the pneumatic processes known heretofore cannot be used to produce certain grades of low carbon steel since the carbon cannot be lowered to the low values required in these grades without the absorption of excessive quantities of nitrogen. The latter renders the resulting steel unsuitable for many uses, particularly for deep drawing and similar purposes. About 25% of the steel produced is used for such purposes. These steels are characterized by a carbon content of 0.10 maximum (generally about 0.06 C); phosphorus 0.045 maximum; sulphur 0.045 maximum; nitrogen 0.005 maximum. At present they must be produced in the basic open hearth although the refining time in this method is 8 to 15 hours compared to the 15 to 22 minutes required in the pneumatic processes.

Accordingly it is an object of the present invention to provide a pneumatic process for refining American basic pig iron.

Another object is to provide a basic pneumatic process capable of producing low-carbon steel, low in nitrogen, suitable for deep drawing and like purposes.

These and other objects will be made apparent in the following specification when read in conjunction with the attached drawings in which:

Figure 1 is a graph showing the silicon, manganese, carbon, phosphorus and nitrogen content of a typical basic Bessemer (Thomas process) heat during the refining thereof;

Figure 2 is a graph logging a heat made in accordance with the principles of the present invention;

Figure 3 is a schematic cross-section of equipment suitable for carrying out the process of the present invention; and

Figure 4 is a side elevation of the apparatus of Figure 3, looking toward the "operating" side thereof.

It is well known that in the Thomas process the carbon oxidation is essentially complete before the phosphorus oxidation proceeds. This progressive elimination of carbon and phosphorus is characteristic of the Thomas method and is clearly shown in Figure 1. The phosphorus oxidation period is known as the "after-blow" and it will be noted that it is during this period that the nitrogen content of the bath increases. As previously mentioned this nitrogen absorption is detrimental. I have discovered that the carbon and phosphorus oxidations can be made to proceed simultaneously by directing the air blast across the surface of the bath rather than through the bath as has been the practice heretofore. Thus the necessity for an "after-blow" is eliminated and nitrogen pick-up is avoided. Further I have found that this practice, when conducted in the manner which will subsequently be described permits the refining of iron containing considerably higher silicon and considerably lower phosphorus than is possible in the Thomas process. Typical results of the new practices are shown in the graph of Figure 2 and the differences in results over those of the prior practices are clearly evident upon comparison of the carbon, phosphorus and nitrogen curves of Figures 1 and 2.

With particular reference to Figures 3 and 4, the reference numeral 2 indicates a modified converter-like vessel adapted to the practice of the present invention. The vessel is shown in the upright or blowing position and is comprised of a lower or hearth section 4 and a detachable upper or nose section 6. Section 4 is in the shape of a horizontally disposed cylinder with a segment removed where nose section 6 attaches. The latter is in the form of a truncated pyramid having a top shape such that the gases and flame are directed away from side wall 7 which is the operating side of the vessel. The vessel is rotatably supported on trunnions 8 and trunnion stands 10. It is charged and poured in the usual manner by tilting the vessel, in this instance counterclockwise, and conventional mechanism, not shown, is provided for this purpose. The vessel is provided with a basic refractory lining 12 of magnesite or the like. Air is introduced along the side wall 7 through a series of parallelly disposed jet pipes 16. The latter are located so that when the vessel is in the blowing position, a longitudinal center line 20 through any of the pipes will make an angle A of about 5° with the horizontal, i. e., with the surface of the bath and the bottom edges of the inner ends of the pipes will terminate approximately at the maximum bath level 18. This value of angle A represents the minimum angle of incidence of the blast with the bath surface which can be attained without submerging the ends of the pipes. The angle may be increased by rotating the vessel on trunnions 8. Since regulation of the angle of incidence is an important feature of the present method it is advantageous to provide a protractor gauge, not shown, on one of the trunnions so that the blast angle may be read directly. Jet pipes 16 are supplied from wind box 22 which is connected through a suitable conduit 24 to control valves and a blowing engine, not shown. The latter should be of sufficient capacity to provide air at up to about six pounds pressure in a volume of about 2000 C. F. M. for each ton of iron capacity of the vessel. Jets 16 should be proportioned to deliver this volume at a velocity of about 350 F. P. S. Wind box 22 is provided with the removable backing plate 26 which carries a row of heat resistant glass windows 28 arranged so that the operator can sight down any of the jet pipes to observe furnace conditions. This feature is essential to the operation of the process as will become apparent as the description proceeds. The windows 28 are preferably mounted in screw caps or the like so as to be quickly removable. This facilitates the clearing of any of the pipes which might become clogged during the blowing operation. If desired, an opening 30, closed by a refractory lined door 32, can be provided in operating side wall 7 above the wind box 22 for the addition of slagging materials and the like. Such additions, however,

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can be made through the nose section without interfering with the blowing operation.

The present method contemplates refining molten American basic pig iron containing:

	Percent
Carbon -----	3.80-4.50
Manganese -----	2.60 and under
Silicon -----	2.00-0.50
Phosphorus -----	0.50-0.15
Nitrogen -----	0.008 and under

to low carbon, low phosphorus steel having a nitrogen content less than 0.005% by blowing the iron while it is in intimate contact with a basic slag under such conditions as to cause the simultaneous oxidation of carbon and phosphorus.

Certain critical practices must be observed to achieve these conditions. The oxidizing blast must be introduced above the surface of the bath and as close to the surface as possible. It is essential to direct the blast toward the surface at a slight angle. Any angle of incidence between 9 and 18° may be used. Outside this range the contact of the blast with the slag-metal surface becomes inadequate to effect efficient absorption of oxygen. Angles greater than 18° must also be avoided since they result in the blast penetrating the surface of the metal. It is preferable to provide a jet velocity of about 350 F. P. S. Velocities below 300 F. P. S. are insufficient to maintain the jets clear of splashes of slag and metal. Jet velocities above 500 F. P. S. must be avoided as these are likely to cause local boring of the blast into the metal, and in addition result in excessive ejection of slag and metal.

It is essential to the purposes of the present invention to maintain a highly oxidizing slag in a rolling state of agitation with the metal surface. The controlling factor in this regard is the rate of oxygen or air input, particularly during the carbon oxidation period. This is not susceptible to numerical definition of any practical significance since it depends upon factors such as temperature and composition of the iron and slag which vary from heat to heat and during the course of refining, and must be controlled as dictated by visual observation of conditions in the refining vessel through jet pipe observation windows 28.

A satisfactory rate of air input is characterized by uniform boiling action over the surface of the bath. Increasing the rate of air input beyond that necessary to achieve uniform boiling increases the rate of refining and is not detrimental to the process, except that the loss of iron by oxidation and ejection increases.

An insufficient rate of air input is indicated by erratic local boiling which is often accompanied by explosive eruption of gas which expels large slag cakes from the vessel. Too low a rate of air input precludes the desired simultaneous oxidation of carbon and phosphorus. This may be explained as follows: The aforementioned boiling action is caused by gas evolution resulting from the carbon oxidation. A ragged, non-uniform boil is associated with a low rate of carbon oxidation and derives from a slag which is deficient in oxygen, or more specifically in iron oxide. Phosphorus elimination requires a basic slag high in iron oxide. Insufficient air input, therefore, results in slag conditions which are unfavorable to phosphorus oxidation.

It should be mentioned that the effects of insufficient air input are cumulative, i. e., the initial decrease in the rate of carbon oxidation decreases bath temperature and bath agitation which in turn impedes the replenishment of iron oxide to the slag further decreasing the oxygen supply. It is advisable, therefore, to observe conditions within the vessel at frequent intervals and regulate air volume and pressure to maintain the rate of air input as high as possible, i. e., just short of that which causes excessive ejection of slag and metal. Experience indicates

that this corresponds to a rate of carbon oxidation of about 0.5% per minute.

Much higher temperatures are attainable in the present method than in basic Thomas practices. This is occasioned by the burning of carbon monoxide to carbon dioxide in the space immediately above the bath. To insure satisfactory phosphorus elimination it is necessary to prevent the temperature from rising over 3100° F. Since air input must be regulated to provide a high rate of carbon oxidation in order to maintain the conditions necessary for the simultaneous oxidation of phosphorus and carbon, temperature of the bath in the present method must be controlled by the addition of suitable quantities of a cold diluent such as scrap or iron oxide as indicated by temperature measurements. Either of these expedients increase the steel yield; the scrap adding directly to the volume of steel in the vessel; iron oxide being reduced in the carbon-phosphorus oxidation reactions.

Slagging additions of burnt lime should be started immediately after starting the blow in order to protect the magnesite lining against attack by silicon and manganese oxides. The lime addition is preferably made in the form of small pebbles scattered over the surface of the bath to promote uniform rapid fusion. The total addition should be made in small increments over the silicon-manganese oxidation period which occupies about the first third of the blow. This practice affords optimum conditions from the standpoint of slag fusion and its effect on bath temperature. Comparison of the silicon and manganese curves of Figures 1 and 2 show that the practices of the present method result in a lower rate of oxidation of these elements. This feature contributes to the practicability of the present method in that sufficient time is available to provide a slag of adequate basicity to protect the vessel lining against erosion. Between 120 and 180 pounds of burnt lime are required per ton of American basic pig iron, the amount varying with the silicon, manganese and phosphorus contents of the iron, the total quantity of lime being such as to produce a slag having:

	Percent
CaO+MgO -----	30-40
FeO+Fe ₂ O ₃ -----	30-40
MnO -----	7- 9
SiO ₂ -----	8-10

Limey slags are preferred at all times as this minimizes slopping. Any lime additions necessary in the later half of the blow to regulate slag conditions should be mixed with iron oxide or made in the form of calcium ferrite in order to effect rapid fusion and blending. Fluorspar or the like may be added to promote slag fluidity. Double slagging practices can be resorted to if desired to reduce lime requirements. Limestone can be substituted for all or part of the burnt lime.

The end of the refining period is marked by an abrupt drop in the flame at the mouth of the vessel which occurs when the carbon content reaches about 0.05%. The change in flame is exceptionally sharp and clear since fumes and sparking are greatly reduced by the practices described. The blast is turned down and the metal poured as soon as possible following the flame drop.

Continuing the blow for a moderate period will not result in serious nitrogen pick-up, however iron continues to oxidize decreasing the steel yield and phosphorus reversion occurs as the temperature increases.

As a specific example of the practice of the present method a suitable quantity of molten pig iron at a temperature between 2400 and 2700° F. is charged into the vessel 2 which has been pre-heated to a temperature of about 2800° F. The vessel is then rotated and its position regulated while sighting through the observation windows 28 to bring the ends of jet pipes 16 to a point just above the metal surface, i. e., to make an angle of incidence A of about 14° with the bath surface. The

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blast is turned on and regulated to provide a nominal blast rate of about 1500 C. F. M. per ton of metal charge. As soon as a "light" is obtained slag forming operations are commenced by scattering burnt lime in the form of one-fourth inch pebbles over the surface of the bath. Slag conditions are observed through windows 28 and the lime addition is made in small quantities to maintain a limey slag free of large lumps of semi-fused lime. As the slag is built up and the level of the metal bath lowered by the oxidation of iron, it may be necessary to adjust the blowing angle A to obtain optimum distribution of the blast. Care must be taken to avoid boring of the blast into the metal. The blowing rate is also adjusted to maintain the slag at a maximum state of agitation just short of slopping. Under the foregoing practices the temperature of the bath increases rapidly due at first to the oxidation of silicon, manganese and iron and later, as the iron oxide content of the slag builds up, to the increased rate of oxidation of carbon and phosphorus. As the temperature approaches 3000° F., iron oxide in the form of ore, mill scale or the like is added along with the pebbled lime so as to limit the temperature rise to 3100° F. Cold scrap may be substituted for this purpose but the use of iron oxide is preferred, if the addition is required before or just following the start of the carbon boil. Blowing is continued, the rate being adjusted as observation indicates in accordance with principles previously described, until the drop in flame occurs at the mouth of the vessel. At this time the blast is turned off and the heat poured. The order and rates of the refining reactions are indicated in the graph of Figure 2 which is based on temperature readings and analyses of samples taken during the blowing of a 1000 pound experimental heat. Analyses of the hot metal is shown along the left hand ordinate and is typical of a good grade of American basic pig iron. The amounts and materials of the slag additions are indicated at the top of the graph.

The present method is distinctive from all prior pneumatic processes in that no special compositions of hot metal are required and it is adapted to the refining of American basic pig iron. Further it produces low-carbon steel of a quality equal in all respects to that produced by the best basic open hearth practices. Carbons as low as 0.03%, manganese below 0.1% and silicon below 0.01% are produced. About 97% of the phosphorus is eliminated making phosphorus specifications of below 0.04% easily attainable. Nitrogen contents as low as 0.003% are commonly produced. Up to 50% of the sulphur content of the charge is also eliminated.

While I have shown and described certain specific embodiments of my invention, I do not wish to be limited exactly thereto except as defined in the scope of the appended claims.

I claim:

1. The pneumatic method of refining American basic pig iron to low carbon steel containing not more than 0.045 phosphorus and not more than 0.005 nitrogen, comprising charging a quantity of molten American basic pig iron at a temperature of between 2400-2700° F. onto a basic hearth, adding materials for forming a basic slag, applying a blast of air to the surface only of said molten bath at a rate of about 1500 cubic feet per minute per ton of molten metal charged, said blast being applied at an angle of incidence with said surface of between 9 and 18° and at a blast velocity of between 300 and 500 feet per second to maintain said slag in a state of rolling agitation without boring of the blast into said molten metal, adding cold material from the group consisting of ferrous scrap and iron oxide when the temperature of said molten iron approaches about 3000° F. to maintain the temperature below 3100° F., and discontinuing said blast at the carbon end point.

2. The process of refining American basic pig iron to

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low carbon steel containing not more than 0.045 phosphorus and not more than 0.005 nitrogen, comprising charging a quantity of molten American basic pig iron at a temperature of between 2400 and 2700° F. onto a basic hearth, charging materials for forming a basic slag, applying a blast of air to the surface only of said molten iron at a rate of about 1500 cubic feet per minute per ton of molten metal charged, said blast being applied at an angle of incidence with said surface of between 9 and 18° and at a velocity of between 300 and 500 feet per second to maintain said slag in a state of rolling agitation without boring of the blast into said molten metal, and discontinuing said blast at the carbon end point.

3. The pneumatic method for producing low carbon steel of open hearth quality comprising charging molten American basic pig iron onto a basic hearth, adding basic slag forming agents, applying a continuous blast of air to the surface only of said molten iron, at an angle of incidence therewith of between 9 and 18° and at a velocity of between 300 and 500 feet per second adding cold material from the group consisting of ferrous scrap and iron oxide when the temperature of said molten iron approaches about 3000° F. to maintain the temperature below 3100° F. and discontinuing said blast at the carbon end point, said blast being supplied under the aforementioned conditions at a rate producing a continuous carbon boil but eliminating not more than 0.5% carbon per minute whereby the phosphorus in said charge is substantially eliminated when said carbon end point is reached.

4. The process of producing low carbon steel of open hearth quality comprising charging molten American basic pig iron onto a basic hearth, charging basic slag forming agents, applying a blast of air to the surface only of said molten iron at an angle of incidence therewith of between 9 and 18° and at a velocity of between 300 and 500 feet per second, and discontinuing said blast at the carbon end point, said blast being supplied under the aforementioned conditions at a rate producing a continuous carbon boil but eliminating not more than 0.5% carbon per minute whereby the phosphorus in said charge is substantially eliminated when said carbon end point is reached.

5. The pneumatic method for producing low carbon steel of open hearth quality comprising charging molten American basic pig iron onto a basic hearth, adding basic slag forming agents, applying a continuous blast of air to the surface only of said molten iron at an angle of incidence therewith of between 9 and 18° and at a velocity of between 300 and 500 feet per second, adding cold material from the group consisting of ferrous scrap and iron oxide when the temperature of said molten iron approaches about 3000° F. to maintain the temperature below 3100° F. and discontinuing said blast at the carbon end point, said blast being supplied under the aforementioned conditions at a rate substantially eliminating phosphorus when such carbon end point is reached.

6. The pneumatic method for producing low carbon steel of open hearth quality comprising charging molten American basic pig iron onto a basic hearth, adding basic slag forming agents, applying a continuous blast of air to the surface only of said molten iron at an angle of incidence therewith of between 9 and 18° and at a velocity of between 300 and 500 feet per second, and discontinuing said blast at the carbon end point, said blast being supplied under the aforementioned conditions at a rate substantially eliminating phosphorus when such carbon end point is reached.

7. The pneumatic method of producing low carbon steel of open hearth quality comprising charging molten American basic pig iron onto a basic hearth, charging basic slag forming agents, applying a continuous blast of air to the surface only of said molten iron at a slight angle of incidence therewith at a rate providing a continuous carbon boil but eliminating not more than 0.5% carbon per minute and at a velocity regulated to violently

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agitate the slag without substantially penetrating the metal bath and maintain the slag in a highly oxidizing condition, adding cold material from the group consisting of ferrous scrap and iron oxide when the temperature of said molten iron approaches about 3000° F. to maintain the temperature below 3100° F., and discontinuing said blast at the carbon end point whereby the phosphorus in said charge is substantially eliminated when said carbon end point is reached.

8. The pneumatic method of producing low carbon steel of open hearth quality comprising charging molten American basic pig iron onto a basic hearth, charging basic slag forming agents, applying a continuous blast of air to the surface only of said molten iron at a slight angle of incidence therewith at a rate providing a continuous carbon boil but eliminating not more than 0.5% carbon per minute and at a velocity regulated to violently agitate the slag without substantially penetrating the metal bath and maintain the slag in a highly oxidizing condition, and discontinuing said blast at the carbon end point whereby the phosphorus in said charge is substantially eliminated when said carbon end point is reached.

9. The pneumatic method of producing low carbon steel of open hearth quality comprising charging molten American basic pig iron onto a basic hearth, charging basic slag forming ingredients, applying a continuous blast of air to the surface only of said molten iron at a slight angle of incidence therewith at a rate providing a continuous carbon boil but eliminating not more than 0.5% carbon per minute and at a velocity of between 300 and

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500 feet per second to violently agitate the slag and maintain it in a highly oxidizing condition and discontinuing said blast at the carbon end point whereby the phosphorus in said charge is substantially eliminated when said carbon end point is reached.

10. The pneumatic method for producing low carbon steel of open hearth quality comprising charging American basic pig iron onto a basic hearth, adding basic slag forming elements, applying a continuous blast of air to the surface only of said molten iron at a slight angle of incidence therewith at a velocity of between 300 and 500 feet per second to violently agitate the slag and maintain it in a highly oxidizing condition and discontinuing said blast at the carbon end point, said blast being supplied under the aforementioned conditions at a rate substantially eliminating phosphorus when such carbon end point is reached.

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