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METHOD OF PRODUCING CAST IRON IN A CUPOLA FURNACE UTILIZING AN OXYGEN ENRICHED AIR BLAST

Eugene E. Langner, Jr., and Wilburn S. Clay, Birmingham, Ala., assignors to Union Carbide Corporation, a corporation of New York

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This invention relates to a method of producing cast iron in a shaft-type furnace wherein the air blast may be continuously enriched with pure oxygen to effect greater economies in operation without the occurrence of excessive refractory attack.

A particularly valuable phase of the invention deals with improvements to the conventional cupola process for making cast iron wherein alternate charges, called splits, of coke and metal are charged into the top of the cupola. The coke bed near the bottom of the cupola, after being heated to ignition temperature, reacts with a blast of air supplied through tuyeres to provide sufficient heat to melt the charge materials which move down through the layers of coke into the cupola well. The melted metal tapped from the well will have picked up the necessary carbon from the charged coke in order for it to have the required carbon content needed for the particular product to be cast. A fluxing material is usually added to the charge along with the metal and coke in order to reduce sulfur and other impurities to an acceptable level.

Heretofore continuous oxygen enrichment of the cupola operation has not been widely used.

As will be explained hereinafter, prior attempts to use oxygen enrichment on a continuous basis were predicated on intended savings in coke. It was found however, that after prolonged operation with reduced percentages of coke in the charge that there was a resulting loss in cupola control, i.e. it became exceedingly difficult to maintain a consistent chemical composition in the final product.

Another reason why enrichment of the cupola air blast with oxygen has never been accepted as part of commercial practice is that excessive refractory attack was always associated with its use. This in turn limited the use of oxygen enrichment to intermittent periods of operation to control temperature or to rapidly bring the cupola up to operating temperature after start-up or after a shutdown period. In other words, the main use of oxygen was for corrective purposes.

It is the primary object of this invention to provide a method for operating a cupola furnace using continuous oxygen enrichment whereby substantial economies and flexible cupola control are realized.

It is also an object of this invention to provide a method for achieving economies in the production of cast iron through oxygen enrichment of the blast without danger of excessive refractory attack or cupola damage.

Other aims and advantages of this invention will be apparent from the following description and the appended claims.

According to this invention a method is provided for producing cast iron in a shaft-type furnace wherein iron-containing materials, coke and fluxing materials are charged and an air blast is introduced into the shaft for combustion of the coke, the improvement comprising enriching the air blast with oxygen to increase the temperature of reaction with the coke and thereby increase the iron temperature whereby a higher rate of carbon pickup by the iron occurs, while increasing the rate of coke charged into the shaft to compensate for the increased rate of combustion of coke with the oxygen en-

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riched blast and thereby substantially maintain a normal bed height of coke in the shaft.

One embodiment of the invention provides an improvement for increasing the production rate of a cupola over its normal capacity with a given charge, while simultaneously effecting improved economy of operation thereof. The improvement comprises increasing the proportion of steel scrap or other less expensive scrap in the charge while reducing the proportion of more expensive iron materials therein, continuously enriching the air blast with oxygen to increase the rate of reaction with the coke and thereby increase the melting rate of the charged steel scrap and iron materials. In addition, these materials will be increased in temperature whereby a higher rate of carbon pickup will occur. The percentage of coke charged into the cupola is increased to compensate for the increased rate of coke combustion with the oxygen enriched air blast in order to substantially maintain a normal bed height of coke in the cupola.

Another embodiment contemplates maintaining the production rate substantially constant while substituting some additional steel scrap for a portion of the normally charged iron material, such that the increased heat made available by the oxygen and coke will be absorbed thereby. In still another embodiment, sufficient oxygen and coke is supplied such that the normal production rate is maintained when the normally charged iron materials in the charge are completely replaced by steel scrap.

Preferably, the oxygen is continuously introduced into the air blast to provide constant enrichment. It has been previously thought that the higher temperature heat made available by oxygen enrichment would allow a reduction in the charged coke percentage whereby economies would result. Applicants have found, however, that such a practice is not productive of economies and, in fact, actually leads to excessive refractory attack or cupola damage which does not justify the savings in coke. Applicants have found that with the use of continuous oxygen enrichment the faster rate of coke consumption will lower the coke bed height and concentrate the high temperature coke-oxidant reaction such that the adjacent shaft wall areas will be overheated and subjected to more oxidizing conditions, causing more severe attack. Reducing the percentage of coke in the charge acts to accelerate this undesirable condition. In the process of this invention, however, the coke rate is not decreased, but instead is actually increased such that the normal bed height is substantially maintained. As a result, excessive refractory damage is avoided and the beneficial effects of continuous oxygen enrichment are achieved.

A number of benefits are possible when practicing the present invention.

Depending upon foundry requirements, the cupola operator is able to either effect a substantial increase in production or maximum economies in operation. For example, by charging a large proportion of higher cost pig iron or iron scrap with little steel scrap, the operator by utilizing the method of this invention is able to achieve substantially increased production rates over normal practice. Alternatively when the foundry does not require maximum increased production, substantial economies in operation can be effected by substituting a large proportion of low cost steel and iron scrap for the higher cost pig iron. The required foundry production rate can be maintained when using a metallic charge composed of 100 percent steel scrap and thereby realize a substantial savings in the cost of the product.

While the use of continuous oxygen enrichment of the air blast in accordance with the over-all method of our invention may be carried out by injecting the oxygen thereinto through the tuyeres in separate streams, as well

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as by enriching the over-all air blast upstream of the tuyeres, the latter injection method is preferred because it distributes the oxygen more evenly over the coke charge.

Although substantial benefits may be achieved over a wide range of oxygen enrichment levels, it has been found that an air blast having an oxygen concentration of between 22 and 27 percent and preferably 24-25 percent by volume at S.T.P. will yield excellent results.

The addition of an oxygen enriched blast causes the ignited coke bed to burn more intensely and at a higher temperature. This in turn increases the temperature of the iron, whereupon it will pick up carbon faster from the coke bed in accordance with the known iron-carbon-temperature equilibrium relationship. Because of the more rapid carbon pickup by the higher temperature iron, it had been heretofore suggested that less coke could be charged in order to produce a final iron product of given carbon content, i.e., the efficiency of carbon pickup from the coke to the iron is increased as a direct function of the iron temperature.

We have found, however, that the coke charge cannot be reduced and, in fact, it must be increased over the normal amount used without oxygen enrichment, in order to substantially maintain the optimum coke bed height in the cupola. The rate of coke charged should, according to this invention, be increased preferably about 2 to 25 percent above the normal coke charge without oxygen enrichment. This method then follows a coke charging practice which is directly opposed to the prior art practices in which continuous oxygen enrichment was proposed.

According to this invention the increased amount of coke charged not only prevents excessive refractory attack but is used in addition to melt a greater quantity of charge materials to provide an increased production rate. Alternatively, a greater proportion of steel scrap may be substituted for iron in order to utilize the additional heat available from the increased coke charge.

The invention will be further described and illustrated by the following examples:

Example I

To establish a datum, a standard acid refractory lined, 48-inch diameter cupola was operated with 475° F. air blast but without oxygen enrichment to produce a typical grey iron having the following analysis: 3.15-3.45% C, 0.40-0.60% Mn, 1.90-2.40% Si, 0.30-0.50% P and 0.12% S max. The composition of the individual charges were as follows:

	Lbs.
Steel bundles	300
Pig iron (2.90% Si)	1500
Cast iron turnings	700
Limestone	90
Ferromanganese (75% Mn)	4
Ferrosilicon (46% Si)	5
Coke	280

The starting bed height for the coke was about 50 inches above the tuyeres. Production from the cupola was at the rate of 13 tons per hour over a duration of 10 to 15 hour campaigns.

Example II

The cupola described in Example I was operated in accordance with the present invention with a charge as follows:

	Lbs.
Steel bundles	300
Pig iron (2.90% Si)	1500
Cast iron turnings	700
Limestone	90
Ferromanganese (75% Mn)	4
Ferrosilicon (46% Si)	5
Coke	300

The 475° F. air blast had a continuous oxygen concen-

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tration of 25 percent by volume at S.T.P. The increase in coke over the amount used in Example I, made it possible to increase the production rate to 17.5 tons per hour, a 35 percent increase, over the Example I production rate. The final product produced had the same composition as the produce specified in Example I.

Example III

The cupola described in Example I was operated in accordance with the present invention with a metallic charge of the quantity used in Example I to produce a product having the same analysis as the Example I product. The 475° F. air blast had a continuous oxygen concentration of 25 percent by volume at S.T.P. In order to maintain the coke bed at the normal optimum height, it was necessary to charge 330 lbs. of coke. This represented an increase of about 18 percent over the coke charged in Example I. Under these conditions refractory consumption was not excessive. The production rate was 17 tons per hour, a 31 percent increase over the Example I production rate. Additionally, the proportion of steel scrap in the metallic charge of Example I was changed from 300 lbs. to 600 lbs., while the amount of pig iron was reduced from 1500 lbs. to 1200 lbs. This practice made it possible to maintain the Example I analysis while increasing the Example I production rate and producing the product at a substantially reduced cost per ton because of the greater proportion of low cost steel scrap substituted for a portion of the pig iron.

Example IV

The cupola described in Example I was operated in accordance with the present invention to produce a product having the same composition as the Example I product. The 475° F. air blast had a continuous oxygen concentration of 25 percent by volume at S.T.P. The Example I production rate of 13.0 tons per hour was maintained; however, the proportions of pig iron, steel scrap and iron scrap making up the total 2500-lb. metallic charge split of Example I were changed. The composition of the charge was as follows:

	Lbs.
Steel bundles	2000
Pig iron (2.90% Si)	500
Cast iron turnings	0
Limestone	30
Ferromanganese (75% Mn)	8
Ferrosilicon (46% Si)	75
Coke	340

The example illustrates how the present invention can be employed to effect substantial cost savings while maintaining the normal production rate of the foundry. It should be noted that in this example it was necessary to increase the coke by approximately 22 percent in order to maintain these cost savings on a continuous basis without causing excessive refractory attack.

The following table shows typical operating conditions of the Example I cupola when producing grey iron according to this invention with varying oxygen concentrations in the 475° F. air blast:

Percent O ₂ in Blast	Prod. Rate, tons/hr.	Metal to Coke Ratio	2,500-lb. Metallic Charge		
			Percent Steel	Percent Pig	Percent Iron Scrap
20.9	13.0	9-6:1	12	60	28
22.0	14.0	9-25:1	14	58	23
23.0	15.0	8-9:1	16	56	23
24.0	16.0	8-3:1	20	52	23
25.0	17.0	7-8:1	24	48	23
25.5	17.5	7-6:1	26	46	23
26.0	18.0	7-35:1	28	44	23
27.0	19.0	6-95:1	32	40	23

¹ Air.

Example V

To establish a datum, a standard basic refractory lined, 36-inch diameter cupola was operated with an ambient

temperature air blast without oxygen enrichment to produce a typical grey iron having substantially the same composition specified in Example I. The composition of the individual charges were as follows:

Steel bundles -----	Lbs. 5	600
Pig iron (3.15% Si) -----		400
Limestone -----		10
Ferromanganese (75% Mn) -----		6
Ferrosilicon (46% Si) -----	10	36
Coke -----		180

The optimum starting bed height for the coke was about 50 inches above the tuyeres. Production from the cupola was at the rate of 5 tons per hour.

Example VI

The cupola described in Example V was operated in accordance with the present invention to produce a grey iron product having the analysis specified in Example I. The ambient temperature air blast had a continuous oxygen concentration of 25 percent by volume at S.T.P. The Example V production rate of 5 tons per hour was held constant, while low cost steel scrap was substituted for the pig iron in order to effect maximum over-all economy of cupola operation. The composition of the charge was as follows:

Steel bundles -----	Lbs.	1000
Pig iron -----		0
Limestone -----		10
Ferromanganese -----		6
Ferrosilicon (46% Si) -----		64
Coke -----	30	200

It will be observed that an 11 percent increase in coke over the Example V case was required to substantially maintain the normal operating bed height.

The following table shows typical operating conditions of the Example V cupola when producing grey iron according to this invention with varying oxygen concentrations in the ambient temperature air blast:

Percent O ₂ in Blast	Prod. Rate, tons/hour	Metal to Coke Ratio	1,000-lb. Metallic Charge	
			Percent Steel	Percent Pig
120.9	5.0	5.55:1	60	40
22.0	5.5	5.40:1	70	30
23.0	6.0	5.30:1	70	30
24.0	6.5	5.30:1	80	20
25.0	7.0	5.0:1	90	10
25.5	7.5	5.0:1	90	10
26.0	8.0	4.76:1	100	0

¹ Air.

What is claimed is:

1. In the method of producing cast iron in a cupola furnace wherein iron materials, coke and fluxing materials are charged and an air blast is introduced into the shaft for combustion of coke, the improvement comprising enriching the air blast with oxygen to increase the temperature of reaction with the coke and thereby increase the iron temperature whereby a higher rate of carbon pickup by said iron occurs, and substantially maintaining a normal bed height of coke in said shaft by increasing the rate of coke charged into said shaft to compensate for the increased rate of combustion of coke with the oxygen enriched blast.

2. In the method of producing cast iron in a cupola furnace wherein iron materials, coke and fluxing materials are charged and an air blast is introduced thereinto for the combustion of coke, the improvement for substantially increasing the production rate of said cupola which comprises continuously enriching the air blast with oxygen to increase the rate of reaction with the coke and

thereby increase the melting rate of the charged iron materials and substantially maintaining a normal bed height of coke in said shaft by increasing the rate of coke charged into said cupola to compensate for the increased rate of combustion of coke with the oxygen enriched blast.

3. In the method of producing cast iron in a cupola furnace wherein iron materials, steel scrap, coke and fluxing materials are charged and an air blast is introduced thereinto for the combustion of coke, the improvement for increasing the production rate of said cupola while simultaneously effecting improved economy of operation thereof which comprises increasing the proportion of steel scrap in said charge while reducing the proportion of iron materials therein, continuously enriching the air blast with oxygen to increase the rate of reaction with the coke and thereby increase the melting rate of the charged steel scrap and iron materials in addition to increasing the temperature thereof whereby a higher rate of carbon pickup thereby occurs, and substantially maintaining a normal bed height of coke in said shaft by increasing the rate of coke charged into said cupola to compensate for the increased rate of combustion of coke with the oxygen enriched blast.

4. In the method of producing cast iron in a cupola furnace having a certain production rate when a specific charge of steel scrap, iron materials, coke and fluxing materials are charged thereinto and an air blast is introduced for the combustion of the coke, the improvement for effecting a substantial economy of operation while substantially maintaining said production rate, which comprises continuously enriching the air blast with oxygen to increase the temperature of reaction with the coke and thereby increase the iron temperature whereby a higher rate of carbon pickup by said iron will occur and substantially maintaining a normal bed height of coke in said shaft by increasing the percentage of coke charged to compensate for the increased rate of combustion of coke with the oxygen enriched blast, and substituting sufficient steel scrap for a portion of said iron materials such that the increased heat made available by said oxygen and coke will be absorbed thereby in order to substantially maintain said production rate.

5. In a method as claimed in claim 4 the improvement which comprises supplying sufficient oxygen and coke to maintain said production rate when said iron materials are completely replaced by steel scrap.

6. In a method as claimed in claim 3 the improvement which comprises supplying sufficient oxygen such that the oxygen concentration in said blast is maintained between 24 and 25 percent.

7. In a method as claimed in claim 3, the improvement which comprises increasing the coke charge about 2 to 25 percent above the normal coke charge.

8. In a method as claimed in claim 3, wherein the oxygen is injected into the air blast upstream of the tuyeres.

9. In a method as claimed in claim 3 wherein the oxygen is injected into the air blast through the tuyeres.

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DAVID L. RECK, *Primary Examiner*.

HYLAND BIZOT, *Examiner*.

H. W. TARRING, *Assisant Examiner*.