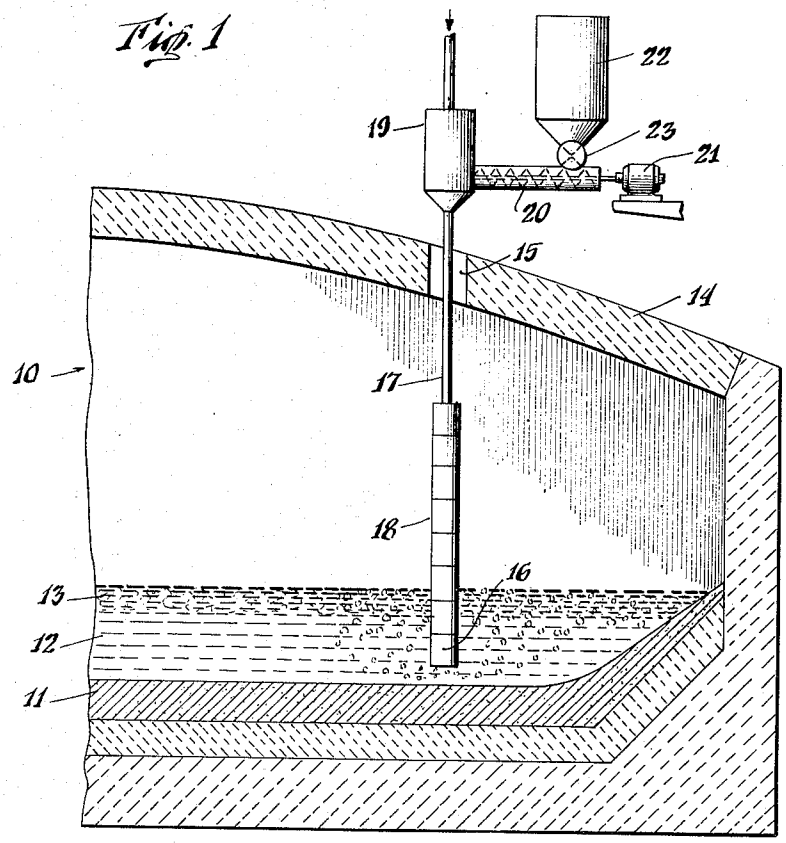
April 22, 1952 J. B. WAGSTAFF 2,593,505

METAL REFINING PROCESS

Filed April 10, 1948

Fig. 1



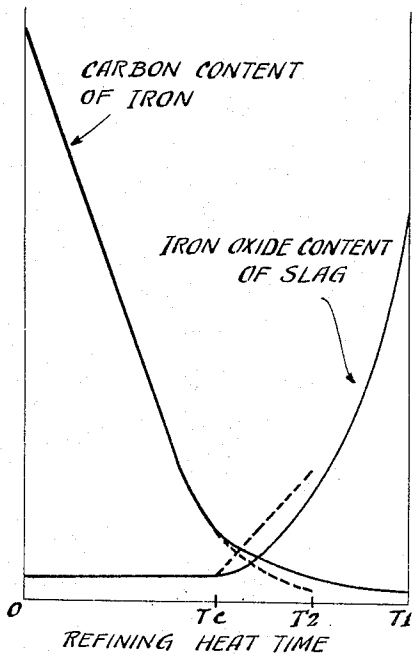


Fig. 2

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METAL REFINING PROCESS

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2 Claims. (Cl. 75—51)

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This invention relates to the refining of metal compositions. More particularly, it pertains to a process wherein oxygen is introduced into a bath of molten crude iron to effect decarburization.

Oxygen is advantageously used in the elimination of carbon from molten iron preparatory to the manufacture of steel. A stream of the gas may be introduced at a substantially constant rate into a bath of the metal including, for example, pig and scrap irons in an open hearth furnace and the process continued until the carbon content of the metal bath is decreased to a predetermined amount as dictated by the type of steel which is to be produced.

It has been found in practice that when the carbon content of the molten iron is decreased by this process to below a certain figure, which, incidentally, is substantially above the desired ultimate content, increasingly greater amounts of oxygen are required to be introduced into the metal bath to avoid a substantial diminution in the rate of carbon elimination. This figure appears to vary with several factors including the compositions of the metal bath and the slag layer. Stated in another way, after the carbon content of the iron bath has been decreased to that certain figure (hereinafter for convenience called the critical carbon content), a constant rate of oxygen introduction into the molten metal yields a decreasingly smaller rate of decarburization or carbon elimination. In most cases, the critical carbon content is of the order of 0.6% by weight. When the carbon content approaches this value, an equilibrium condition is apparently created involving the iron oxide in the slag layer and the residual carbon in the molten metal. This equilibrium indicates that, as the oxygen input continues after the critical carbon content has been reached, some of the oxygen is consumed in the formation of iron oxide and thus is not available for further decreasing the carbon content of the molten iron.

After the carbon content has been brought down to the critical value by the introduction of oxygen into the molten iron, further decrease in the carbon content of the molten iron can be effected by continuing the introduction of oxygen at substantially the same rate over a relatively long period or by increasing the rate of oxygen introduction and thus decreasing the carbon content of the molten iron to the ultimate desired value in a shorter period. In either case, it is clear that a greater volume of oxygen is consumed per unit weight of carbon eliminated from the molten iron after the critical carbon content has been passed than was consumed before this value was

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reached. Furthermore, some of the iron reacts with the oxygen to form iron oxide after the carbon content of the molten bath has been decreased to below the critical value. Thus, a portion of the iron, which would otherwise be recovered as a useful and valuable product, is undesirably converted to iron oxide as a by-product of the refining operation.

A primary object of the present invention is to increase the efficiency in the refining of crude iron by contact with oxygen in concentrated form.

Another important object is to accelerate the decarburization of molten crude iron after its carbon content has been decreased to the critical value.

Other objects and advantages of the invention will become apparent from the following description considered in connection with the drawings illustrative of the applications of the invention.

In accordance with the present invention, it has been found that the aforesaid disadvantages are substantially minimized by adding continuously or periodically, iron oxide to the metal bath after the carbon content thereof has been lowered to the critical value by blowing oxygen in concentrated form through the molten iron. The added iron oxide appears to block or at least materially diminish the reaction between the oxygen and the molten iron so that as the introduction of oxygen is continued when the carbon content of the metal is below the critical value a smaller proportion of the oxygen is wasted in the undesirable side reaction than is the case when iron oxide is not added to the bath.

The iron oxide is preferably and conveniently introduced below the surface of the molten metal bath by suspension in the oxygen stream injected thereinto. Any desired iron oxide such as ferrous oxide, magnetite, hematite, mill scale or the like may be used for the purposes of this invention but it is preferred to select the more highly oxidized forms of iron like hematite. The iron oxide is added to the bath in finely comminuted or powdered form and is rapidly dispersed under the agitation caused by the oxygen injected into the molten bath. The added oxide tends to collect in the slag layer.

The entrainment of the iron oxide in the oxygen stream is thought advisable since in this way the iron oxide is in the immediate presence of the oxygen introduced into the metal bath. Also, a somewhat improved distribution of the iron oxide is accomplished by introducing this agent directly into the molten bath along with the oxygen.

Referring to the diagrammatic drawing of Fig-

ure 1, I have shown for illustrative purposes, my invention as applied to the refining of crude iron in an open hearth furnace. The numeral 10 indicates an open hearth furnace of well-known type having a refractory base 11 on which the bath of molten metal 12 rests, this bath as usual having an upper slag layer 13. The top 14 of this furnace is formed with an opening 15 through which extends the leading end of a metal conduit 17, the lower portion of which is provided with refractory sheath elements 18 for protection of the metal pipe from the deteriorating effect of the molten metal. This lance comprising pipe 17 and refractory elements 18 is fully described and claimed in my copending application, Serial No. 3,726, filed January 22, 1948. The lower portion 16 of the conduit 17 dips into the metal bath well below the slag layer 13. The oxygen is introduced into a mixing chamber 19 where it becomes intimately mixed with powdered or comminuted iron oxide introduced into the mixing chamber by a screw conveyor 20 driven by a motor 21. The iron oxide is passed to the screw conveyor from a hopper 22 through a valve 23 and thence into the mixing chamber 19. Thus, the comminuted iron oxide is suspended in the oxygen stream flowing through chamber 19 and carried thereby through the lance into the molten metal bath.

Figure 2 is a graphic representation of a typical heat. The carbon content of the molten iron and the iron oxide content of the slag layer are both plotted against the time of the refining heat. As shown, the crude iron has a high carbon content at the start of the heat, usually in the range of about 2 to 4% by weight. Oxygen, say about 95% pure, is injected through the lance into the molten bath and its carbon content decreases because of the reaction with oxygen. The rate at which the carbon is eliminated from the iron is fairly constant until the carbon content of the metal falls below 1% by weight. Depending on the composition of the iron bath under treatment, the rate of carbon elimination becomes appreciably smaller in many instances when the carbon content has dropped down to about 0.6% and more generally when the carbon content has fallen to about 0.4% and lower. The carbon content at which an appreciably lower rate of carbon elimination is noted has been referred to hereinbefore as the critical carbon content. If the injection of oxygen is continued at a uniform rate, the carbon content of the iron is slowly brought down to the desired value, say 0.06% by weight, in time T_1. Thus, under normal circumstances, the length of the heat period is time T_1. During this heat, it is noticed that the iron oxide content of the slag layer over the molten iron is fairly constant until the carbon content of the iron has fallen below about 1% by weight; in the vicinity of the critical carbon content of the iron, the slag shows an increasing content of iron oxide and this oxide content appears to keep rising rapidly to the end of the heat. I believe that the increase of iron oxide in the slag layer is attributable to a competitive reaction between the molten iron and its carbon content for the oxygen blown into the bath and that this competition for oxygen seriously affects the rate of carbon elimination only after the carbon content of the molten metal has been decreased to a relatively low value, say 0.6% by weight. References herein to the critical carbon content of the molten iron are more readily understood in the light of this theory.

In accordance with my invention, when the critical carbon content of the iron has been

reached, say at time T_c, iron oxide is introduced into the molten bath as well as the oxygen stream. Assuming a substantially uniform rate of addition of iron oxide from time T_c to time T_2, the slag layer shows an increasing content of iron oxide which content is made higher (see dotted line) than that normally noted in the absence of added iron oxide. The added oxide, however, promotes more rapid elimination of carbon (see dotted line) so that by the end of time T_2 the carbon content of the iron is down to the value attained in the absence of added oxide in the longer time T_1. Stated in another way, the added oxide appears to accelerate the rate of carbon elimination so that if the introduction of iron oxide and oxygen were continued to time T_1, the carbon content of the iron would then be well below the desired ultimate content.

As graphically represented in Figure 2, my invention of adding an iron oxide to iron undergoing refining by oxygen after the carbon content has been lowered to the point (critical carbon content) where the rate of carbon elimination is appreciably curtailed results in a shortening of the heat period by an amount equal to the difference between times T_1 and T_2. If the operation of my invention is carried on to time T_1, the carbon content of the finished iron is lower than it would otherwise be. In any instance, it is evident that the addition of iron oxide to the bath after the critical carbon content has been reached results in an economy of valuable oxygen. The added iron oxide also minimizes the amount of iron converted to oxide during the refining treatment.

For further clarification of the invention, a specific example is now presented. An open hearth furnace contains a molten bath comprising 160 tons of pig iron and 40 tons of scrap iron. The carbon content of the molten iron is 3.6% by weight at the start of the refining heat. The furnace is maintained at a temperature of about 2900° F. Oxygen (96% by volume purity) is injected into the molten iron at a uniform rate of about 250 cu. ft. (standard conditions) per ton of iron per hour. The injected oxygen not only eliminates carbon from the molten iron but also oxidizes other impurities such as silicon, phosphorus and manganese. When the carbon content of the molten iron has been decreased to a value of about 0.4% by weight, comminuted mill scale is added to the bath at the uniform rate of 7 tons per hour while the injection of oxygen is continued at the aforesaid rate. The charging of the mill scale into the molten bath is preferably accomplished with apparatus of the type shown in Figure 1 wherein the mill scale is fed from hopper 22 into the mixing chamber 19 and thence conveyed by the oxygen stream through lance 17 into the molten bath. The desired ultimate carbon content of the iron is 0.05% by weight and this carbon content is reached in about 1 hour from the time when the addition of mill scale is started. At this point the refining heat is terminated and the refined iron withdrawn from the furnace.

In contrast to the results obtained when the refining process is conducted in accordance with the principles of this invention, the desired ultimate carbon content of 0.05% by weight can be reached without the addition of the mill scale used in the example or any other iron oxide if the refining period is lengthened by about 1 hour. It is obvious that the additional hour required to reach the desired ultimate carbon content without the addition of iron oxide will

consume an additional 50,000 cu. ft. (standard conditions) of oxygen for the specified refining heat.

In refining crude iron by injecting concentrated oxygen into a molten bath of the iron, I find it advisable to use oxygen of at least 80% by volume purity and preferably of at least 90% by volume purity. Recent developments in the field of oxygen production have eventuated in processes which yield oxygen of about 95% by volume purity at costs permitting the large-scale use of such oxygen in processes of the type contemplated by this invention.

Various modifications of the invention will occur to those skilled in the art upon consideration of the foregoing disclosure without departing from the spirit and scope thereof. Accordingly, only such limitations should be imposed as are indicated by the appended claims.

I claim:

1. The process of refining crude iron having a carbon content of abcut 2 to 4% by weight to yield a refined iron having a carbon content of the order of not more than 0.95% by weight, which comprises decreasing the carbon content of said crude iron to a carbon content of about 0.4 to 1% by weight solely by injecting concentrated oxygen of at least 80% by volume purity into a molten bath of said crude iron, and thereafter further decreasing the carbon content of the iron in said molten bath to a carbon content of the order of not more than 0.05% by weight by simultaneously injecting concentrated oxygen of at least 80% by volume purity and iron oxide into said molten bath.

2. The process of refining crude iron having a carbon content of about 2 to 4% by weight to yield a refined iron having a carbon content of the order of not more than 0.05% by weight, which comprises decreasing the carbon content of said crude iron to a carbon content of about 0.4 to 0.6% by weight solely by injecting concentrated oxygen of at least 80% by volume purity into a molten bath of said crude iron, and

thereafter further decreasing the carbon content of the iron in said molten bath to a carbon content of the order of not more than 0.05% by weight by simultaneously injecting concentrated oxygen of at least 80% by volume purity and iron oxide into said molten bath.

JAMES B. WAGSTAFF.

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