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REFINING ALLOYS

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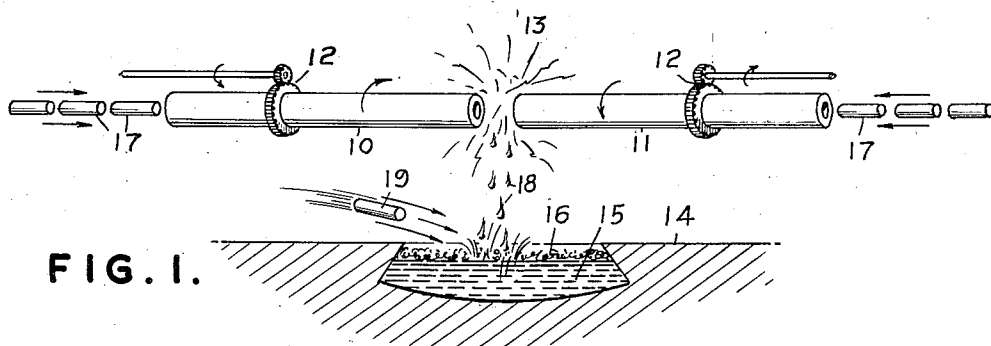


FIG. 1.

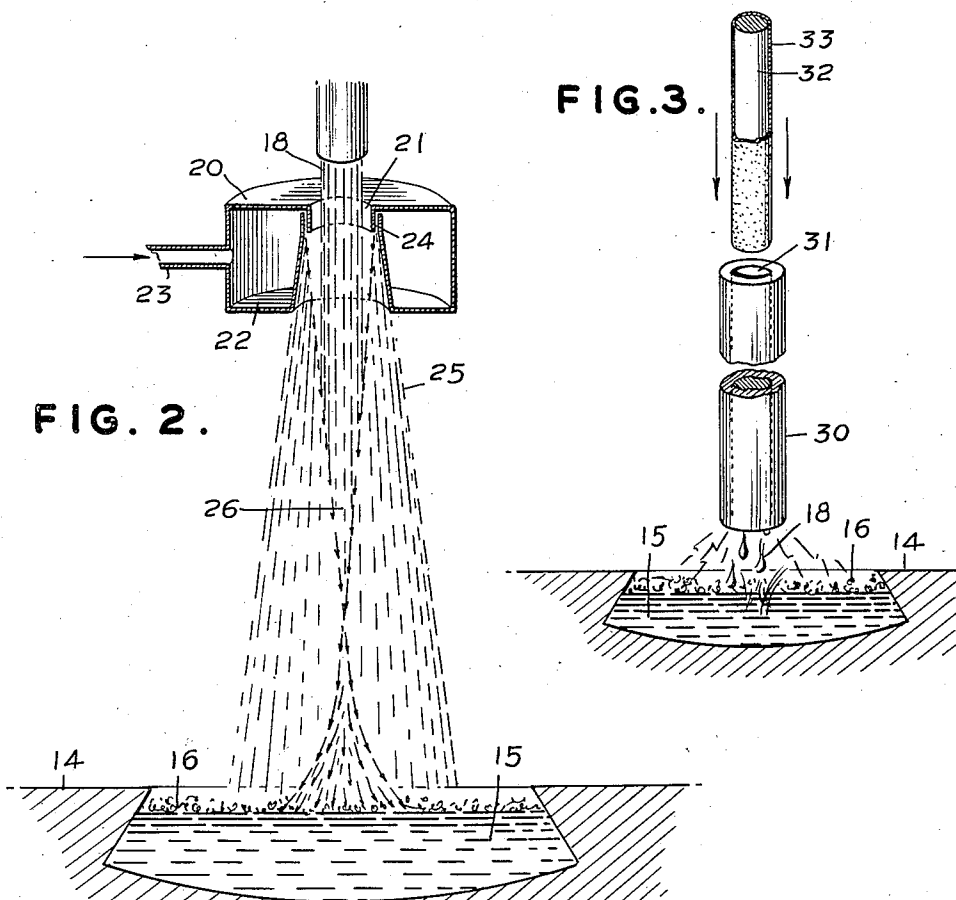


FIG. 3.

FIG. 2.

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2,084,978

REFINING ALLOYS

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Application September 9, 1936, Serial No. 99,906

18 Claims. (Cl. 75-10)

This invention relates to electric furnace practice in the making of metal alloys, and more particularly chromium steels.

I have proposed heretofore, to reduce the oxidizable impurities in chromium steel while increasing its chromium or other desirable metal content by heating a mass of chrome steel to be refined, in an electric furnace having a carbon monoxide atmosphere, to a temperature at which it is molten and wherein its oxidizable impurities, such as carbon, manganese and silicon, are in solution, while maintaining on the molten mass, an oxidizing slag. To this molten mass or bath, there is added continually a refining and oxidizing metallic material formed in a hollow electrode of the same or another furnace. This material or agent comprises a metal having in solution therein a desirable metal oxide, such as chromic oxide (Cr_2O_3). The refining agent solution and the molten metal bath are miscible. When the agent and the bath become mixed, the oxygen of the metal-oxide in the agent oxidizes the undesirable constituents of the bath, such as carbon, manganese and silicon, to convert them into oxides (in the case of carbon to CO) whereupon increments of the reduced desirable metal, such as chromium, are added to the bath. The resulting refined metal is then recovered. (See my patent applications Serial Nos. 59,690, 59,691 and 59,692, all filed January 18, 1936.)

In practicing this process of metal refining, a metal material or agent is supplied in finely divided condition onto the slag on the molten bath, whereupon the slag must be penetrated and passed by the agent before the agent can attain certain desired characteristics and then enter the molten bath of metal to be refined. The passage of the metal agent through the slag and its treatment in such transit offers an interesting problem, the solution of which constitutes an object of this invention, while the control and facilitating of helpful phenomena in this zone are important immediate factors of this invention. More specifically, an object of this invention is to expose an increased surface of a metal to slag action at a temperature higher than usual, in order to prepare in the mass on the furnace hearth, a reagent comprising a metal oxide dispersed in a metal, so that an oxidizing reaction between the oxidizable impurities in the bath and the metal oxide in the reagent takes place easily and rapidly.

In metallurgy when reactions take place between a metal and a slag superimposed upon it, a long time is required before the reaction

comes to completion or progresses far enough so that the desired metallurgical effect is obtained. This is due to the fact that the metal and the slag are immiscible and, therefore, any migration of oxides from the slag to the metal or the metal to the slag are relatively slow. The rate of migration may be increased by exposing larger surfaces between the slag and the metal for migration. This may be stated as increasing the surface contact between the slag and the metal. The metal supplied to the slag is insoluble therein, although the slag may be a solvent for certain impurities in the metal, and the metal may be a solvent for some of the oxides in the slag. Consequently, another object of this invention is to speed up the attainment of this equilibrium between the slag and the metal by increasing the surface of contact between the metal agent and the slag. A further feature of the invention is that after the metal agent passes through the slag under these conditions of equilibrium, it has become in transit a refining reagent with enhanced oxidizing and refining characteristics. And still further, it is another feature of the invention to cause the metal agent to be impinged onto or into the slag to hasten its penetration through the slag where its oxidizing attributes are acquired and into the metal bath thereunder where the desired oxidizing and refining reactions take place. Another and paramount aspect of the invention is to apply the teaching of the law of mass action to this general process of metal refining. That law states that the rate at which a substance reacts is proportionate to the active mass of the substance, and further, that when chemical equilibrium is established, this is due to opposing reaction velocities neutralizing one another. This law can be deduced from a kinetic molecular standpoint as well as from the standpoint of thermo-dynamics. Although it has been mathematically deduced, there can be no doubt as to the application of this law to chemical reactions, because there is no known chemical reaction which does not obey the law of mass action. Therefore a feature of this invention is the disruption or vaporizing of a metal agent into a very finely divided condition so that it effects the greatest possible surface contact with the slag, whereby the advantages of the law of partition between a solute and two immiscible solvents may be applied, and the time required for equilibrium to take place has been decreased in accordance with, and directly proportionable to, the surface exposed between the immiscible solvents.

Another feature of this invention is the treat-

ment of the metal bath to reduce the content therein of other oxidizable impurities, such as manganese and silicon, prior to the addition of the oxidizing reagent to the molten bath of metal to be refined, so that when it contacts therewith, the oxidizing effect can be used principally on the carbon present in the bath instead of having it oxidize, variously or jointly, manganese, silicon and carbon.

- 10 And a still further feature of this invention is the making practical use of my discovery that the amount of residual carbon in low carbon steels during refining is a function of the percentage of silica in the slag, of the reducible
15 metallic oxides in the slag, and of the silicon as well as of the manganese in the metal.

- Since the more specific application of this invention is to chromium steels in which Cr_2O_3 is substantially the only oxide that exists therein,
20 let us assume for the following discussion that the metal agent contains Cr_2O_3 dissolved in a chromium alloy; that the molten chromium alloy bearing bath has carbon as the oxidizable impurity dissolved therein; and that the slag on
25 the bath receives the Cr_2O_3 agent in continual additions thereto. Then the concentration of Cr_2O_3 in the metal and the concentration of Cr_2O_3 in the slag are controlled by the coefficient of partition of this oxide in the two immiscible
30 solvents. The coefficient of partition is a function of the solubility of Cr_2O_3 in the slag to the solubility of the Cr_2O_3 in the metal.

- Cr_2O_3 is soluble in the metal, and at every set temperature there is a definite limit to the
35 amount of Cr_2O_3 which is soluble. With the slags, however, this is not exactly true because the Cr_2O_3 is miscible in all proportions with the slag, although there is a change of slag mobility as the Cr_2O_3 increases. Stated in other words,
40 the Cr_2O_3 in a slag is possibly a molten solution, while the Cr_2O_3 in the metal is in true solution. Therefore, it is considered to be true that Cr_2O_3 is miscible with the slag but not in solution in the slag. Because of this fact the concentration
45 of Cr_2O_3 in a properly mobile slag controls the concentration of Cr_2O_3 in the metal.

- When the distribution of Cr_2O_3 in solution in the metal and in molten solution in the slag, which are immiscible solvents, has reached a
50 static condition, equilibrium has been attained. That is, there is no longer any tendency for Cr_2O_3 to migrate in either direction between the slag and the metal because the coefficient of distribution has been satisfied. In connection
55 with this definition, no consideration is given to any metal which is held in the slag or any slag which is held in the metal as affecting the final product.

- It is known from my slag samples and from
60 metallurgical practice, that fine globules of metal are found suspended in slag, so when I use the term "dispersed in the slag", I refer to the small particles of metal suspended as metal in the
65 slag, offering surface contact between the slag and the metal for whatever migrations of oxide can take place.

- When it is stated that equilibrium exists between the slag and these globules of metal which
70 are dispersed in the slag, the equilibrium refers to Cr_2O_3 or some other metallic oxide which is present both in the slag and in the metal. The time for reaching equilibrium between the metal globules and the slag in which they are suspended
75 is a function of the size of the globules, or the

surface exposed. The function of the dispersed metal in the slag is that of an oxide carrier.

When the oxide migrates from the slag to the metal, with no dispersed metal in the slag, the only surface through which this migration can
5 take place is the contact surface between the bath proper and the slag. However, the rate of reaction between the slag and the metal can be increased through agitation whereby a greater surface contact between the slag globules and
10 the bath proper can be attained. In normal practice in a one-ton furnace, there is a maximum of 20 square feet contact surface between metal and slag. In a ten-ton furnace there is
15 but 120 square feet of maximum surface contact, or 12 square feet per ton of metal. This invention increases the surface contact between metal
20 and slag by dispersing new metal continuously in the slag and allowing it to come to a rapid equilibrium and to carry oxide to the metal bath
25 proper. The time is decreased by two factors, one being the physical factor caused by the terrific turbulence when the Cr_2O_3 of my oxidizing agent reacts with the carbon in the metal, and
30 the second (which causes the first) is the equilibrium set up between the highly dispersed metal as it passes through the slag and carries
35 Cr_2O_3 into the metal in a solvent which is miscible with the metal bath. During the time required for the highly dispersed metal to come into equilibrium with the slag in respect to Cr_2O_3 , there is also a violent evolution of CO in the slag proper which adds to the turbulence of the entire system and tends to shorten the time required for equilibrium between the slag proper and the
40 metallic bath.

In order to increase the rate of migration of Cr_2O_3 from a properly constituted slag into the metal of the bath, I bring about the impinging
45 of comminuted metal or metal vapor on the upper surface of the slag so that a maximum metal surface is exposed to slag action at a maximum temperature in order to oxidize any oxidizable material, such as manganese, silicon, or carbon, from the dispersed metal, each particle of
50 which is surrounded by slag, and to bring this dispersed metal into equilibrium with the slag as quickly as possible.

The dispersed metal in the slag will either stay in suspension or separate from the slag in accordance with Stoke's law which states that the
55 rate of movement of a metal globule through a slag is equal to $\frac{1}{8}$ the fall of gravity multiplied by the square of the radius of the particle of metal multiplied by the difference between the specific gravities of the metal and the slag divided by the coefficient of viscosity (that is, the
60 frictional resistance to flow between the metal surface and the slag surface).

These slags for a period will accumulate the
65 dispersed metal until a point is reached where the metal particles get close enough to each other to agglomerate, or the slag becomes so saturated that metal separation takes place. The metal leaving the slag after its passage therethrough
70 will have become an oxidizing reagent containing Cr_2O_3 either dispersed in the metal or in solution in the metal whereupon it enters the metal bath to oxidize oxidizable impurities therein.

This is true in the simple system which is now
75 being considered. This system consists of Cr_2O_3 , chromium carbide, and two immiscible solvents. Unfortunately the concentration of Cr_2O_3 in the metal is affected by other impurities in the metal which are capable of reducing the Cr_2O_3 to

chromium metal. The worst offenders are manganese and silicon. They are considered the worst offenders because they react with the Cr_2O_3 (which is supposed to remove the carbon) just as carbon reacts with Cr_2O_3 .

For this reason it is preferable in making chromium steels, to remove as much of the manganese and silicon from the system as is possible by deslagging at the right temperature and under the proper slag conditions and then using a slag which contains the amount of silica which will give sufficient mobility for the carbon removal reactions to take place. Sufficient mobility of the slag is a relative term which depends upon the temperature and constitution of the slag. A slag that does not hold metallic shot of an appreciable size usually has the proper mobility for operation. Appreciable size can be measured as easily discernible by the naked eye. If the manganese and silicon are held at a minimum in the metal, then the full concentration of Cr_2O_3 in the metal is available for the removal of carbon from the metal.

Inasmuch as manganese and silicon are oxidized by Cr_2O_3 dissolved in the metal, the rate at which each one is removed depends upon its concentration and the concentration of the Cr_2O_3 in solution. There is a definite concentration of manganese in the metal, a definite concentration of silicon in the metal, and a definite concentration of carbon in the metal at which the rate of reaction with Cr_2O_3 and the rate of solution in the metal is equal for all three. If any one of these oxidizable materials is present in a concentration at which its rate of oxidation is greater than the rate of oxidation of the other two, it is oxidized preferentially until all the oxidizable impurities attain the same rate of oxidation under the prevailing conditions. Inasmuch as the concentration of silica (SiO_2) in the slag determines the concentration of silicon (Si) in the metal, it is essential that the slag proper contain the minimum amount of silica compatible with the proper slag mobility for furnace operation.

It is necessary to control the constitution of the slag and the temperature of the bath so that the reaction which is desired to take place, takes place without too much interference by other reactions. A high concentration of Cr_2O_3 in the metal with a relatively cold bath (slightly above the melting point) covered with a slag rich in Cr_2O_3 , but as low in silica as is consistent with good furnace operation, are ideal for the removal of both silicon and manganese from stainless steel.

A study of the above features has brought me evidence that in the reduction of carbon in low carbon alloys such as stainless steel, there is a definite relationship between the percentage of silica in the slag and the silicon and carbon in the steel. This conception recognizes that there is an equilibrium between the silica in the slag and the silicon in the metal and that the rate of carbon and silicon removal from the metal by a definite content in the slag of reducible metallic oxides, depends upon certain concentrations of silicon and carbon in the metal. As an example—with .15% carbon in the metal and .60% silicon in the metal, the silicon under set conditions will be reduced to .15% before the carbon can be reduced. In other words, at .15% silicon and .15% carbon, the conditions under which both silicon and carbon are reduced are approximately identical. At that point the percentage of silicon and carbon will be reduced at the same time until

another point is reached, at which either the silicon or the carbon may be reduced, depending upon the slag-metal reactions.

A similar relationship appears to exist between manganese and carbon. In order to get the lowest possible carbon in the metal it is essential that the slag contains the minimum amount of manganese oxide. Thus it seems to be a fact that the amount of residual carbon in low carbon steels is a function of the percentage of silica in the slag, of the reducible metallic oxides in the slag, and of the silicon in the metal, as well as of the manganese in the metal.

However, with further reference to the effect of the silica (SiO_2) content of the slag on the metal of the bath, it has been found where there is at least 5% of the weight of the bath metal present as slag, a very definite relationship exists between the silica in the slag and the silicon (Si) in the metal after the slag and metal have come into equilibrium. This relationship is constant under the same constant conditions of temperature and pressure. The relationship between the silica and silicon is such that when the weight of the slag is one-twentieth or more of the weight of the bath metal, there is always sufficient silica in the slag to furnish metal for effecting the conditions of equilibrium. In discussing slag in reference to its silica content, it must be borne in mind that the fact that an analysis shows a certain SiO_2 content does not mean that all the silicon found to be present is present as an oxide. In simple silicates, the silicon in the slag is present in combination with oxygen, but there exist fluid compounds containing silicon products that are not necessarily combined with oxide. These compounds as a rule are not easily decomposed by electrolytic reduction or by carbon reduction into silicon and these complex or fixed silicates do not affect the equilibrium between the oxygen of the silica in the slag and the silicon in the metal. Such a complex or fixed silicate is exemplified in calcium fluo-silicate and magnesium fluo-silicate.

Means usable in carrying out this invention are shown diagrammatically in the accompanying drawing in which:

Figure 1 illustrates in essence an arrangement of hollow electrode and a bath of metal to be refined having slag thereon, such as is shown and described in more detail in my patent applications Serial Nos. 22,963 and 69,450, herein further referred to;

Fig. 2 illustrates in essence an arrangement for comminuting or finely dividing the metallic material and impinging it onto and into the slag on the molten metal bath, described in more detail in my Patent No. 1,807,178, patented May 26, 1931 herein further referred to; and

Fig. 3 illustrates in essence a modified arrangement of hollow electrode.

This invention may be carried out advantageously in a hollow electrode furnace of the type shown in my patent applications Serial Nos. 22,963 and 69,450, filed respectively on May 23, 1935 and March 18, 1936. Such a furnace comprises, as shown diagrammatically in Fig. 1 of the drawing, two substantially hollow electrodes 10 and 11 possibly with means such as gears 12 for rotating them. The electrodes are adapted to support an arc 13 between their abutting ends. On the furnace hearth 14 is maintained a molten bath 15 of metal to be refined having slag 16 thereon. Cores 17 of starting materials are forced into and along the bores of the electrodes. These

materials in practicing the present invention comprise essentially substances which, when molten, contain a desirable metal with or without its oxide and preferably without carbon, although under certain circumstances with it. As the cores pass into the heated zone of the hollow electrode, they attain a temperature above the melting point of the material of the cores, whereupon the fluid mass automatically releases itself and drops continually from the electrode in drops 18 onto the slag on the molten metal bath on the hearth. The metal material will be caught by the slag as by a sponge and condensed due to the lower temperature of the slag. The condensate will accumulate as a suspension until the slag is saturated therewith, whereupon the resulting material will descend or migrate from the slag into the metal bath below. Thereafter, the oxidizing of the carbon, or other oxidizable impurity of the bath will take place, with resulting great turbulence, as above described. A batch or core of corrective 19 for controlling or modifying the viscosity or permeability of the slag may be added directly to the slag. After the metal leaves the electrode it impinges upon the slag and reacts with the slag. If the metal leaving the electrode should contain carbon, the reaction yields first a metal without carbon, without silicon, and without manganese, these elements being transferred either to the atmosphere as CO or to the slag as SiO_2 or MnO . The metal, free of oxidizable impurities then takes a portion of the Cr_2O_3 in the slag into solution in itself, until the oxide in solution in the metal is in equilibrium with the oxide in solution in the slag under the prevailing conditions. The metal dispersed in the slag has now become a solvent for metallic oxide and is the reagent which leaves the slag and enters the metal to oxidize any of the oxidizable impurities in the metal. All the dispersed metal which enters the slag follows through this system and thereby carries the oxidizing agent from the slag into the metal bath. There is a great difference between the metal which impinges upon the slag and the metal which leaves the slag to enter the metallic bath, the difference being in the amount of oxidizing agent dissolved in the dispersed metal and the absence of oxidizable impurities in the dispersed metal.

However, in the practice of this invention, a distinction must be made from the mechanism of reaction used in the hollow electrode furnace in accordance with my said patent applications Serial Nos. 59,690; 59,691; and 59,692. In those disclosures, an oxidizing reagent for the bath of metal to be refined on the furnace hearth is prepared in the hollow electrode by reacting therein at elevated or superheated temperatures, a mixture of a metal oxide with an insufficient quantity of reducing agent, such as carbon, for complete reduction of all of the oxide, under conditions whereby a metal refining reagent drops from the arc end of the electrode comprising essentially a metal having dispersed therein a metal oxide. The starting mixture is forced into the bore of the electrode in the form of briquettes or cores.

In those disclosures the oxidizing reagent is arranged to be prepared in the electrode. On the contrary, in the present invention, the oxidizing reagent is prepared during transit of certain materials caused to traverse or travel through the oxidizing slag that is upon the metal to be refined. So when it is desired to use a hollow electrode in which to prepare a metal material to

be supplied to the slag, in which slag it will become an oxidizing reagent, the cores forced into the bore of the hollow electrode instead of containing, as in those cases, a deficiency of reducing agent such as carbon, may contain an excess of carbon by which substantially all of the reducible oxides in the cores are reduced to metal, and the metal leaving the electrodes may even contain carbon in solution since it will react with the oxides in the slag, thereby increasing the total amount of metal dispersed in the slag as a base for the reagent which consists of the oxide dissolved in the metal.

Nevertheless, it has been found that the more finely divided or comminuted is the metallic material 18 supplied from the electrodes to the slag and the more force is used to inject that material to cause penetration thereof into the slag, the more effective is the process because the law of partition between immiscible solvents is thus brought into more effective operation. This I may do in an arrangement shown diagrammatically in Fig. 2 illustrating by outline the apparatus of my Patent No. 1,807,178. It consists of an annular hollow fitting 20 having a bore 21 having its interior space 22 connected by a pipe 23 with a source of gas under pressure such as steam. In the bore 21 is an annular nozzle arrangement 24 through which the gas under pressure in the space 22 is emitted in tubular form 25 surrounding a stream 26 of molten material 18 (which has been composed previously elsewhere). The action of the tube 25 of high pressure gas causes a disruption and disintegration of the stream 26 of metal material 18 into an extremely fine state of subdivision. The force of the gas stream will also act to drive the metal material into the slag.

Under certain conditions, it may be desirable to vaporize the metal material as an aid to its entrance into the slag. In the apparatus indicated in Fig. 1 it is possible to vaporize the metal material 18 since all of it must pass through the arc 19, the only precaution being to have the arc zone attain a temperature at or above the vaporization point of the metal material. It may be difficult to determine whether or not the metal material has been actually vaporized, but there is contemplated a disruption of the metal into fine particles which approach in their physical condition of subdivision, the vapor state or phase as a limit.

The arrangement of Fig. 1 contemplates one embodiment of hollow electrode furnace for supplying the molten metal to the bath on the furnace hearth while another arrangement of hollow electrode that may be used is shown in Fig. 3. Here the same reference numerals are used for hearth, bath and slag. But a hollow electrode 30 is used which may be disposed vertically, or inclined, as well as horizontally. It has a bore 31 into which is forced a metallic rod or wire 32 of any suitable metal bearing composition, either bare or clad with materials 33 which may be active or inert as occasion may demand. Inert materials may be used to protect the metal rod or wire from contact with the vessel or equipment in which the metallic rod or wire is being vaporized. The covering of the wire or rod may be in the form of materials required for the slag on the bath or for correcting the slag on the bath. When metallic wire or rod is used in a horizontal or a vertical hollow electrode, the metallic wire or rod is a source of dispersed metal which is suspended in the slag and becomes the reagent for

oxidizing the oxidizable impurities of the metal bath.

There may, of course, be a change in atmosphere in the furnace when there is no source of carbon monoxide except the removal of carbon from the metallic bath.

The cores in the hollow electrodes of the furnace used in practicing this invention, are a source of large amounts of carbon monoxide which causes an atmosphere of approximately 100% of carbon monoxide in the furnace above the slag. If this reaction were carried out in a Heroult furnace, which is not properly sealed and which has a stack effect due to the openings above the vertical electrode through the roof, there is a considerable circulation due to inward and outward leakage which causes an atmosphere of either air or a mixture of CO_2 and nitrogen mixed with other gases. The infiltration of air or the inward leakage of air may be sufficient to oxidize all the CO, which is formed from the removal of carbon from the metallic bath, to CO_2 .

Another manner of supplying the metal in finely divided condition to the molten bath on the furnace hearth with its slag is to comminute the metal outside of the furnace and then force it into the slag by mechanical means. Indeed it may be possible to use an intermittent supply of pulverized metal on the properly constituted slag by some simple method such as shoveling a definite portion into the furnace at set intervals.

Not only may comminuted metal be thus supplied to the slag either through a hollow electrode or directly, but so also may be supplied thereto comminuted reducing materials such as carbon, silicon and silicides.

Since the function of the carbon is to reduce a small portion of the reducible oxides in the slag to metal, which will become dispersed in the slag, this metal reduced by the finely divided carbon will come into equilibrium with the slag as to Cr_2O_3 content. The metal which has been reduced by the finely divided carbon becomes the solvent for the reagent Cr_2O_3 which, upon leaving the slag and entering the metal, oxidizes the oxidizable impurities in the metal bath.

The principal functions of the comminuted material which impinges on the slag thus are to enter the oxidizing slag in a very fine state of subdivision so that (1) it readily gives up its oxidizable impurities to the slag or atmosphere (2) it next attains, at a rapid rate, equilibrium with the slag in regard to Cr_2O_3 , which it takes into solution, and (3) to enter the metal bath, still in a fine state of subdivision carrying the dissolved Cr_2O_3 , which being in solution in a miscible solvent, rapidly reacts with the carbon (or other oxidizable impurities) in the metal bath, forming metallic Cr, thereby increasing the content of this desirable element in the metal bath and CO (or other oxides which enter the slag or the atmosphere), thereby reducing the content of this undesirable element in the metal bath.

Inasmuch as the term "solution" is very loosely used in the scientific literature, I wish to define this term so as to differentiate between "solution", "miscibility" and that phenomenon which occurs when metals react with reagents such as acids and form salts which in turn dissolve in aqueous solutions of the reagent. A solution has a definite limit known as the saturation point at each temperature and pressure; an example of which is a solution of sodium chloride in water. Miscibility is that property by which two materials form a homogeneous mixture in all propor-

tions of one material to the other; such as alcohol and water; water and glycerine, etc. The third type of so-called "solutions" is typified by the reaction of iron with hydrochloric acid forming ferrous chloride and hydrogen, the ferrous chloride dissolving in the dilute hydrochloric acid. I therefore, define "solution" as used in this application as that phenomenon by which one material mixes homogeneously with a liquid within definite limits under set conditions whereby the resulting product is a liquid which can be separated physically into the original starting materials.

I claim:

1. In the process of metal refining which comprises forming a molten bath of metal to be refined, having therein an oxidizable impurity and thereon an oxidizing slag, supplying a metal therein to the slag in finely divided condition to permit the finely divided metal to dissolve an oxidizing reagent from the slag to an extent that addition of the metal to the slag causes migration of an oxidizing agent into the dispersed molten metal in the slag, causing the dispersed metal to enter the molten bath from the slag whereby an effect is realized by which a quantity of oxidizing reagent is transferred from the slag to the metal bath whereby the oxidizable impurity of the bath is oxidized and departs therefrom into the slag or atmosphere, and finally recovering the refined metal.

2. The process according to claim 1 in which the removal of undesirable impurities in the dispersed metal is brought about by a rapid slag reaction with the dispersed metal impurities.

3. The process according to claim 1 in which the steps are carried out in an atmosphere essentially of carbon monoxide.

4. The process according to claim 1 with the added step of preparing in the heated zone of a hollow electrode the metal to be dispersed in the slag.

5. The process according to claim 1 with the added step of preparing in the heated zone of a hollow electrode the metal, and dispersing the metal in the slag by the action of the arc of the electrode.

6. The process according to claim 1 with the added step of preparing in the heated zone of a hollow electrode the metal, and dispersing the metal in the slag by volatilization by the arc.

7. The process according to claim 1 with the added step of preparing the metal in the heated zone of a hollow rotating electrode.

8. The process according to claim 1 with the added step of preparing the metal to be dispersed in the slag in the heated zone of a hollow electrode, and adding the finely divided molten metal to the slag while at a temperature above that of the slag.

9. The process according to claim 1 with the added step of forcibly impinging the finely divided metal onto the slag.

10. The process according to claim 1 with the added step of causing the fine division of the metal material by gas under pressure.

11. The process according to claim 1 with the added step of causing the fine division of the metal by vaporization thereof.

12. The process according to claim 1 with the added step of preparing in a hollow electrode the metal to be supplied, by feeding into the heated zone of the bore of the electrode a length of shaped metal such as a rod.

13. The process of claim 1 with the added step of regulating the silica content of the slag.
14. The process of claim 1 with the added step of regulating the content of undesirable reducible metal oxides such as silica and manganese oxide in the slag.
15. The process of claim 1 with the added step of regulating the content of desirable reducible metal oxide such as Cr_2O_3 and FeO in the slag.
16. The process according to claim 1 with the added step of removing from the zone of slag reaction, the manganese and the silicon which has been oxidized by removing the slag from the metal and from the furnace.
17. The process according to claim 1 with the added step of reducing the manganese oxide and silica content of the metal slag mixture by removing the slag from the furnace, and then adding a mixture to form a slag on the molten bath in which the percentage of silica and manganese oxide as undesirable elements are controlled and in which the percentage of desirable oxides such as chromic oxide and iron oxide are regulated.
18. The process according to claim 1 with the added step of supplying a reducing reagent such as carbon to the slag to reduce a quantity of reducible oxides in the slag to dispersed metal in the slag.

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