March 3, 1936. A. E. GREENE 2,033,029

ELECTRIC REDUCTION FURNACE

Filed April 2, 1931 4 Sheets-Sheet 1

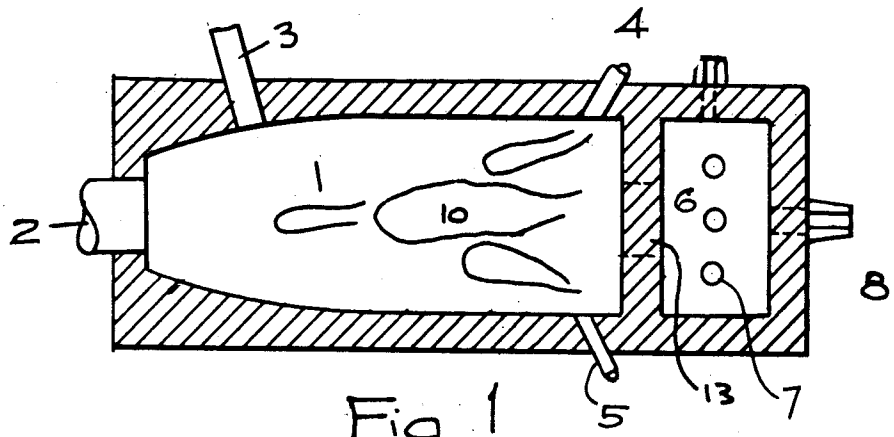


Fig 1

Gas

Slag

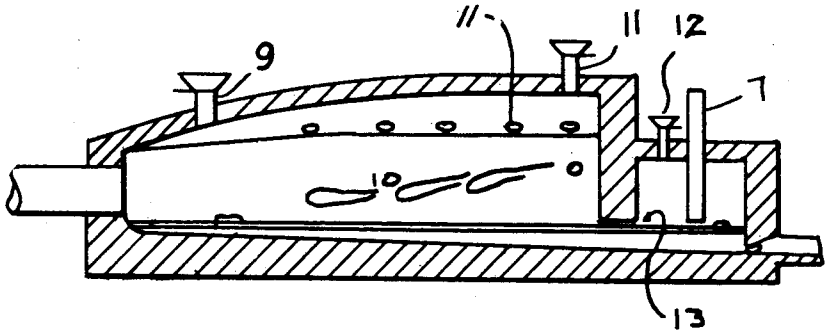


Fig. 2

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ELECTRIC REDUCTION FURNACE

Filed April 2, 1931 4 Sheets-Sheet 2

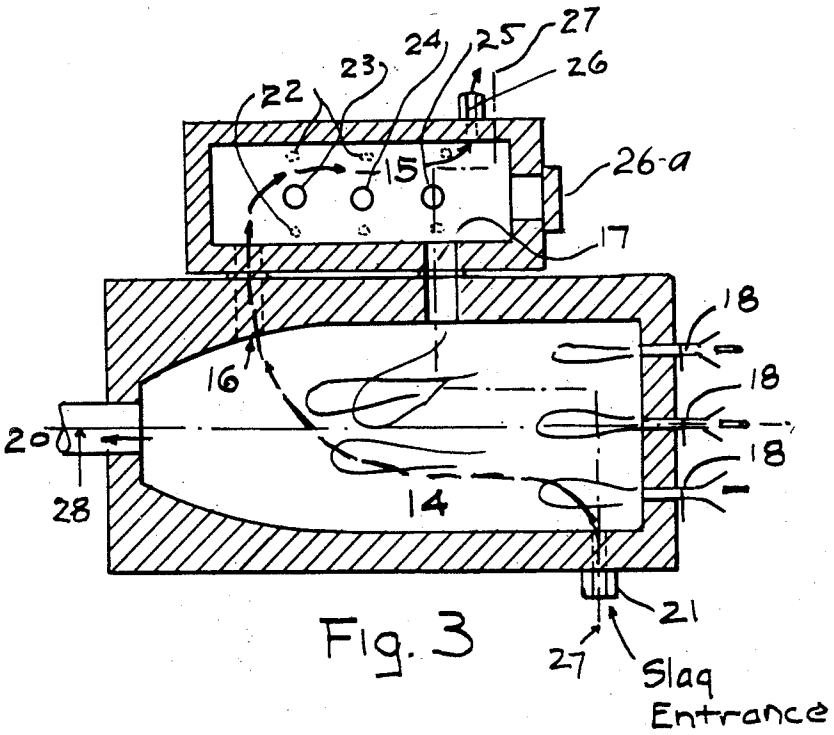
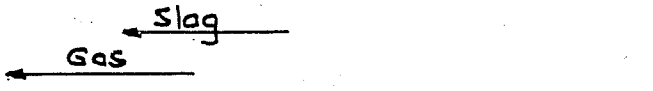


Fig. 3



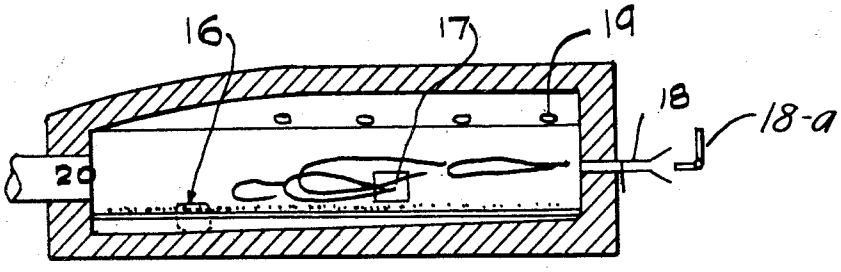


Fig. 4

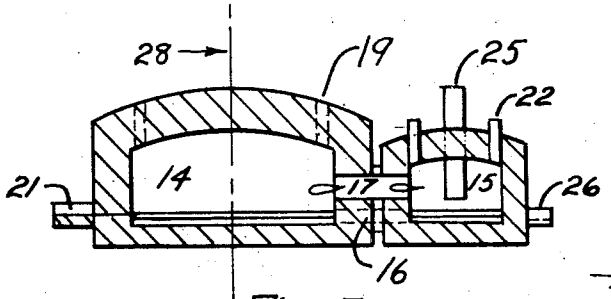


Fig. 5

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March 3, 1936. A. E. GREENE 2,033,029

ELECTRIC REDUCTION FURNACE

Filed April 2, 1931 4 Sheets-Sheet 3

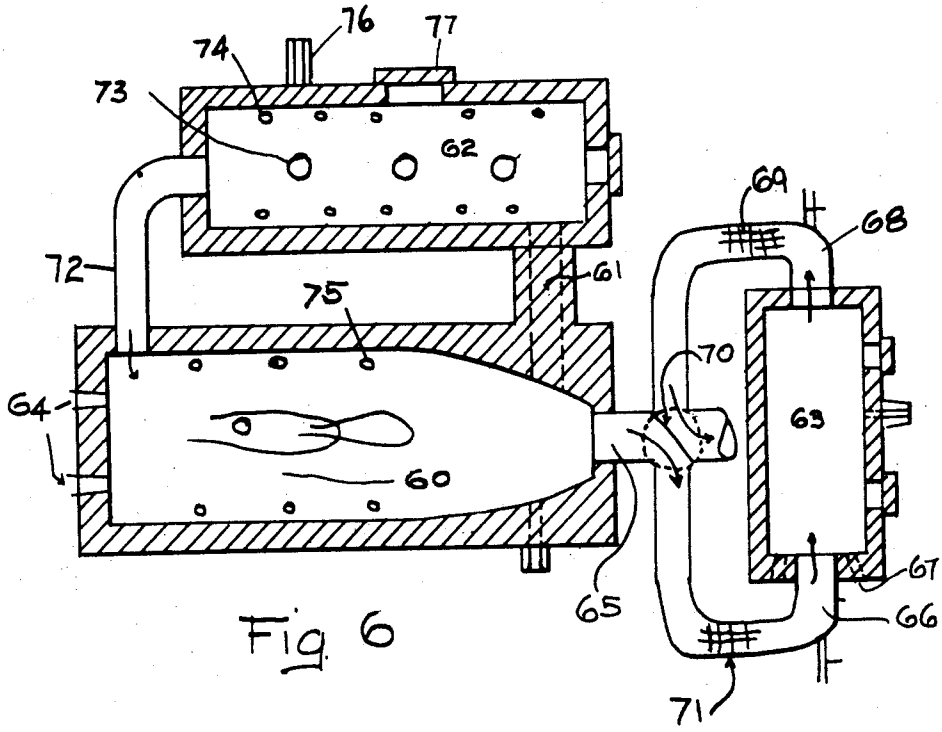


Fig. 6

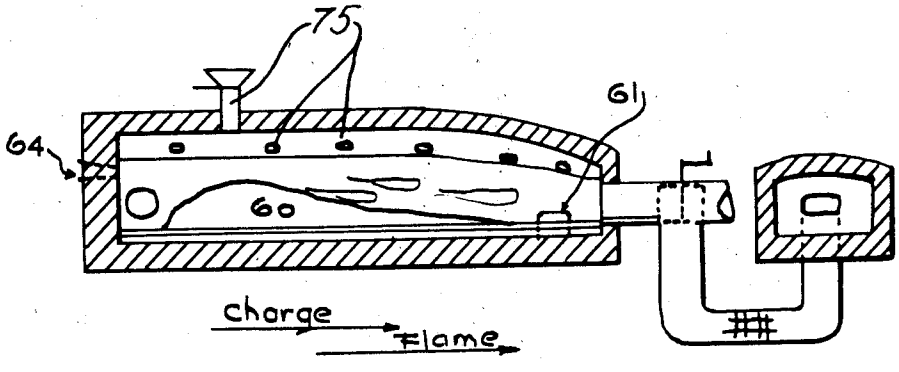


Fig. 7

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March 3, 1936. A. E. GREENE 2,033,029

ELECTRIC REDUCTION FURNACE

Filed April 2, 1931 4 Sheets-Sheet 4

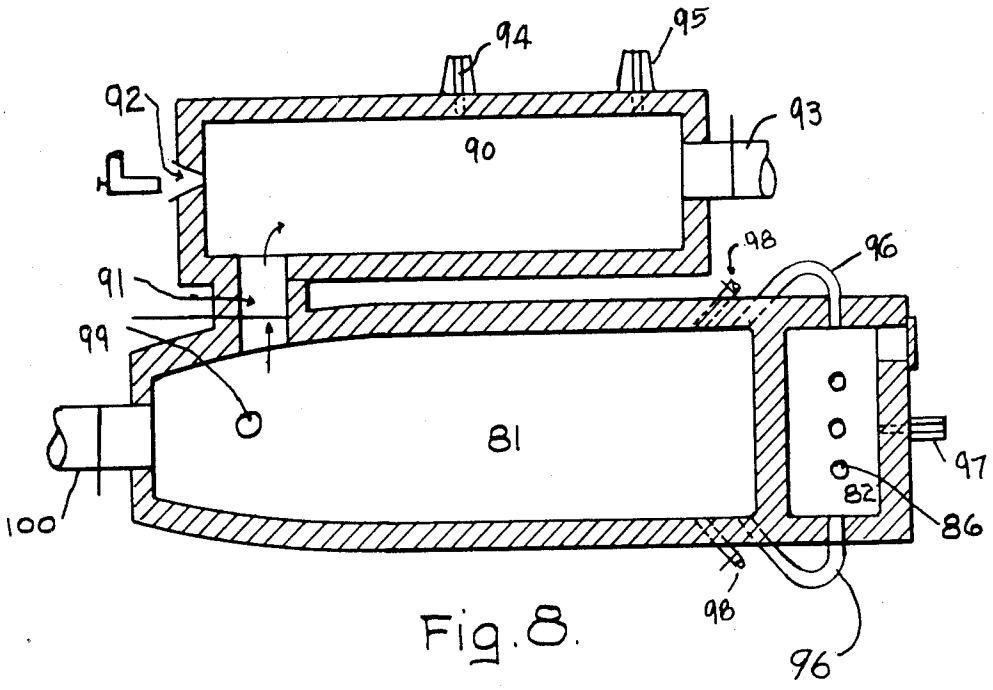


Fig. 8.

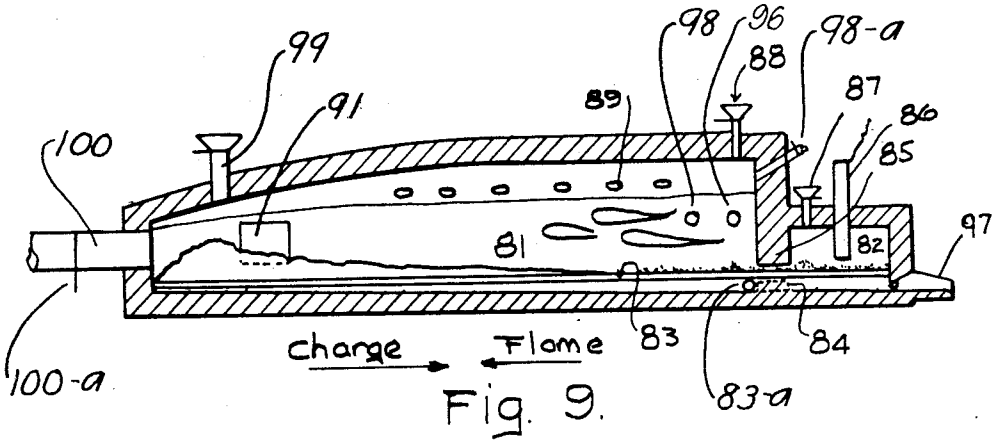


Fig. 9.

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Patented Mar. 3, 1936 2,033,029

UNITED STATES PATENT OFFICE

2,033,029

ELECTRIC REDUCTION FURNACE

Albert E. Greene, Medina, Wash.

Application April 2, 1931, Serial No. 527,101

3 Claims. (Cl. 13—2)

My present invention relates to metallurgical smelting and reduction furnaces particularly for the reduction of metal oxides. My invention relates to such apparatus especially for reduction of metal contained in either solid or molten oxide, and my invention has for its object broadly the reduction of oxide, whether introduced into the furnace in solid or in molten condition. My present application is a continuation in part of my applications for patent, Serial No. 726,541 filed July 17, 1924 and Serial No. 34,041 filed June 1, 1925, which have been issued as Patents 1,819,238 and 1,819,239, respectively, dated August 18, 1931.

One object of my invention is an apparatus and method of reduction for the reduction of metal oxide contained in or on a molten slag covered bath. In the reduction of oxide ore or oxide slags by the processes of my above mentioned applications for patent, I found it desirable to use electrically generated heat in one part of an enlarged chamber in order to more fully reduce the oxide left in the slag, after preliminary reduction prior to the entrance of the remaining unreduced oxide into the higher temperature zone of the electric arcs. Thus my process involves preliminary reduction of the fine solid oxide by means of some reducing agent such as carbon and then the completion of the reduction process by subjecting the oxide to stronger reducing conditions in the vicinity of arcs to the slag. In carrying out this process I found that the area of the bath affects the rate of reduction and that I was able to reduce larger quantities of ore charge by using a large area of hearth, and that the use of the electric heat generated in arcs to the slag bath from adjustable electrodes above the bath could be separated in one part of the furnace. I found then that the electric heating could be carried on in a chamber separated above the bath from an adjoining reverberatory chamber whose hearth is common to both so that the electric heat could be developed largely in a separate chamber above the bath but utilized also in the adjoining reverberatory chamber. The apparatus for such treatment forms one modification of my present invention,—namely a furnace comprising a heating chamber having a hearth which is common to another chamber separate from the first above the bath, and having electrode heating in this separated portion.

My invention relates to smelting furnaces or reducing furnaces having two or more chambers, one of which is provided with electrodes in which the partly reduced charge may be further reduced. In one modification of the apparatus of my invention, I provide a hearth furnace having the portion above the bath separated so that electric heat can be developed in one part separately from the other part and so that stronger reducing conditions can be maintained in the electric chamber and so that the gases from the electric chamber can pass into and thru the adjoining chamber having common hearth.

A further modification of my invention relates to the development of heat by combustion in the chamber separated above the hearth from the electrode containing chamber. The combustion taking place may be controlled by the admission of a regulated supply of air or oxygen and this control may be such as to merely burn a part of the carbonaceous material present whereby the reducing conditions are maintained thruout this portion of the furnace.

In apparatus where reducing conditions are desired both in the electrically heated portion and in the adjoining portion of the furnace having a hearth common to both these portions, the exit gas, that is the gas which leaves the furnace may have a relatively large amount of reducing gas such as CO gas in it and also a large amount of heat. In order to further take advantage of this gas, I provide a second separate furnace in which the reducing gases from the combined or double chamber furnace with common hearth may be used by burning them. Of course these gases may be burned in any suitable apparatus where heat is desired, but I have found that in the apparatus and method of my present invention it is desirable to provide a chamber in which limited reducing conditions are maintained above a molten bath, and that when I do this, there is available from this chamber in which limited reduction takes place, a considerable quantity of reducing gas which must be removed from that chamber, and one modification of my apparatus is designed to take advantage of this hot reducing gas by burning it in a furnace such as an open-hearth furnace.

My invention has for its object the treatment of oxide ores to reduce them and it also has for its object the treatment of molten slags containing metallic oxides to reduce these oxides and obtain the metal. Thus, this apparatus may be used for the reduction of fine oxide ores mixed with carbonaceous material, for example iron or manganese ore or chrome ore, and this apparatus may be used for the reduction of molten slags, either such as the slag from the preliminary ore reduction where solid ore is treated, or the treatment of molten slags containing valuable metallic ox-

ides, such as zinc or lead oxides. Slags from lead blast furnaces or from reverberatory furnaces which slags contain oxides of lead and zinc may thus be treated by the apparatus and process of my present invention.

I have found that oxide slags can be reduced in the apparatus of my present invention by maintaining the slags molten and maintaining solid carbonaceous reducing agents or material on top of these slags and I have found that reduction of the oxides contained can be aided by proper control of the slag composition. I have also found that partial combustion may be maintained in the chamber having a common hearth with an electrically heated portion above the bath, and the apparatus of my invention, at least in certain modifications comprises means for admission of air and for exit of the gases and for control of combustion in the reverberatory chamber adjoining the electrically heated chamber, the two of which are joined and have a common hearth and bath. I have found that I am able to secure selective reduction when desired by the combined control of slag composition as to basic and acid oxide components, together with temperature control and control of the reducing action. For example it is possible in this way to reduce zinc oxide without reducing some other oxide like oxide of iron which can be held in the slag in combination with an acid oxide such as silica with ample fluidity.

I have discovered that in the furnace of my present invention having a common hearth and separate compartments above the bath, one of which is electrically heated, I am able to maintain strong reducing conditions thruout the reverberatory chamber and a sufficient amount of solid carbon present in or on the charge and slag to cause an effective reduction in the reverberatory chamber before the material reaches the electrically heated chamber where stronger reducing conditions can be maintained; and I have found that the gases from the electric chamber can be utilized to maintain the temperature in the reverberatory portion with or without the admission of air to partly burn the carbonaceous material in the reverberatory portion. Thus I am able to expose a large amount of slag bath to the action of solid carbon and yet separate the electric heat development into a chamber largely out of the influence of oxygen which would oxidize the electrodes. In the apparatus of my present invention I provide for the admission of solid carbonaceous reducing agent into both chambers of the common hearth furnace, and I also provide for combustion in the reverberatory portion by means of controlled air inlet means and in addition, in certain modifications, the admission of combustible material, gaseous or fluid or liquid, into the reverberatory chamber part of the combination furnace.

The apparatus and process of my invention will be more fully understood by reference to the annexed drawings which show several combinations of the apparatus and steps embodying and constituting my invention.

Fig. 1 is a sectional plan view of a combination furnace having a reverberatory and an electric chamber and a common hearth, embodying my invention;

Fig. 2 is a sectional elevation view of the furnace of Fig. 1;

Fig. 3 is a plan view in section of another embodiment of my invention; and Fig. 4 is a sectional elevation view of the reverberatory chamber of Fig. 3. Fig. 5 is a sectional elevation view thru the reverberatory and thru the electric chamber of Fig. 3.

Fig. 6 is a sectional plan view of a combination reverberatory and electric chamber furnace embodying my invention with common hearth and a separate open-hearth furnace.

Fig. 7 is a sectional elevation view thru the reverberatory furnace chamber of Fig. 6.

Fig. 8 is a sectional plan view of another embodiment of my invention for the treatment of oxide in either solid or molten form or both.

Fig. 9 is a sectional elevation view of the reverberatory and electric chambers of the furnace of Fig. 8.

I will now describe certain operations which may be carried out for the reduction of oxide in the apparatus and process of my present invention, and I will also describe the apparatus in further detail.

Referring to Figs. 1 and 2, the furnace here shown comprises a reverberatory chamber 1 having a flue 2 and an opening 3 for entrance of molten slag near the flue end. Air inlets are indicated at 4 and 5 located near the electric chamber portion. These are preferably fitted with control means not shown, so that the amount of air may be controlled and so that combustion may be regulated in the reverberatory chamber. I have used the term reverberatory to include merely the reflection of heat in this chamber from the walls and roof, regardless of whether combustion takes place or not. I have indicated a flame at 10 but it is understood that this also may merely indicate the general direction of the flow of gases thru this chamber whether combustion takes place or not. A charge opening for material such as carbonaceous material is indicated at 11 and other similar openings may be provided along the sides of the chamber as at the location marked 11—A. Another charge opening 12 is shown into the electric chamber for the charging of carbon or other material there. The hearth of the two chambers is the same hearth; that is the hearth extends into and between both chambers. I have shown a layer of molten slag on top of the metal and I have indicated solid carbon on top of the slag.

This apparatus may be used for carrying out the processes of my co-pending applications for patent, or for the reduction of solid oxide charged into the reverberatory chamber or for the reduction of molten slag charged thereinto, for example, thru the slag charge opening 3. Altho the detailed steps of operation constitute in certain cases the subject matter of my other applications for patent, the description of certain ways of operating this apparatus will serve to make my invention more easily understood. One application of this apparatus is for the reduction of oxide of iron or other similar oxide such as manganese or chromium. Another application is to the treatment of molten slag containing iron oxide and also zinc and lead oxide; and a modification is the treatment in which only the zinc and lead are reduced and the iron oxide left unreduced. This constitutes an application of my selective reduction process of my co-pending applications already mentioned. This apparatus may also be used for the reduction of solid oxides charged into the reverberatory chamber on a molten bath, such as the reduction of chromium or manganese into a bath of iron or steel. Furthermore, the selective reduction referred to may be applied to the reduction of iron without re-

duction of phosphorus, or to the reduction of manganese without reduction of silica to silicon, as well as to the reduction of zinc without reduction of iron oxide.

It should be noted that the apparatus of my invention provides means for limited reducing action under lower temperatures and subsequently it provides means for stronger reducing conditions to be maintained in an electric arc chamber whose hearth is common with that of the reverberatory but whose upper chamber is largely separated from that above the bath in the reverberatory part. This combination provides means for limited reducing action in the reverberatory chamber of oxides in the slag and on top of it, and then provides means for the completion of the reduction of the oxides remaining in the slag when it reaches the electric chamber. This apparatus provides means for subjecting the slag to reducing action at relatively lower temperatures in the reverberatory chamber, and subsequently to higher temperatures in the electric chamber. Thus the temperature of charge on the molten bath in the reverberatory may be maintained above sintering temperatures without stopping the action and movement of the charge. Thus, I am able to maintain reducing conditions so as to reduce an oxide such as manganese oxide by treating a mixture of material containing it and carbon to reduce it on the bath in the reverberatory chamber and thus reduce the oxide at relatively low temperature with a lower vaporization loss, and I am able to further reduce the resulting slag by means of electric heat and the application of a reducing agent such as solid carbonaceous material to the slag in the electric chamber. My apparatus provides for admission of solid charge including oxide, reducing agent and fluxes or slag making materials and also for admission of combustible material, either fluid or gaseous or solid, and with or without the admission of air for combustion. The completion of the slag reduction preferably takes place under control of slag composition to facilitate reduction, as well as by means of the combined action of electric heat and reducing agent. Gas formed in the electric chamber passes into the reverberatory chamber, and in the furnace of Figs. 1 and 2, the space **13** serves this purpose,—namely for gas to get from the electric chamber into the reverberatory chamber.

It should be understood that the reverberatory chamber may be operated largely or entirely as a reducing chamber; or it may be operated with partial combustion taking place by admission of air into this chamber, but without preventing continuous reducing action on the oxide and carbon mixture on the slag; or it may be operated under more intensive oxidizing conditions such as by admission of sufficient air or oxygen to burn the gas in this chamber. In this last mentioned example, the zinc vapor may thus be burned to zinc oxide and carried out of this reverberatory chamber for collection or treatment outside this chamber.

The apparatus of my present invention may be combined in different ways. The movement of materials may be carried on in different combinations, as for example, in Fig. 2 the movement of gas is from the electric end of the reverberatory toward the flue end and the movement of material to be reduced is against the current of gas. In Figs. 3 and 4, the movement of material in the reverberatory chamber may be with the current of gas. In Figs. 6 and 7 the movement of charge is shown as the same as that of the gas in the reverberatory, and in both the furnaces of Fig. 3 and Fig. 6 the material is subjected to further treatment in the electric chamber having common hearths, or having means for movement of the molten material from the reverberatory into the electric chamber. In Figs. 8 and 9, the movement of charge thru the reverberatory chamber **81** is counter to that of the gas current, but the gas in this furnace is further utilized in an adjoining smelting furnace or open-hearth furnace chamber **90**, in somewhat the same manner as the reducing gas from the furnace chamber **60** of Fig. 6 is further utilized in the open-hearth chamber **63**.

The apparatus of Figs. 3, 4 and 5 may be used for molten slag reduction. The operations taking place in the reverberatory chamber **14** include the treatment of the molten bath with slag covering, as for example by means of solid carbon applied thereon. This chamber **14** has entrance openings for charging solid material at **19** and the other similar openings. These are shown diagrammatically but it is understood that they are provided with covers or equivalent means of controlling entrance and exit of material. They are shown along the sides of this chamber **14** but may also be placed at any other convenient locations. This chamber **14** is shown with a slag or molten material exit at **16** by which the hearth of this chamber **14** connects with that of the adjoining electric chamber **15**. Another opening **17** between these two chambers provides for movement of gas from the electric chamber into the reverberatory chamber. Still another opening **20** is provided in the flue end of the reverberatory for the exit of gas from this chamber. In addition, I have shown tubes with control valves shown diagrammatically at the end of this reverberatory chamber opposite the flue and these are marked **18**. I have indicated them as including means for entrance of both air and combustible material such as oil or powdered coal indicated at **18**—*a*.

The electric chamber **15** is provided with electrodes **23**, **24** and **25**, and with material-charging openings **22**, and a slag and metal tap spout **26** and a charge door **26**—*a*. Fig. 5 shows a sectional elevation thru the gas opening from the electric into the reverberatory. It also shows the slag charge spout **21** for admission of slag into the reverberatory. The heavy line with arrows indicates the general direction of movement of slag thru the two chambers.

The apparatus of Fig. 6 and Fig. 7 shows a combination reverberatory and electric furnace together with an open-hearth chamber provided with checker work similar to the well known open hearth steel furnace. This combination of furnace chambers might be used, for example, for the treatment of high phosphorus iron ore, to reduce the iron together with phosphorus in the two combined chambers **60** and **62** and then to subsequently treat the phosphorus bearing molten iron in the open hearth chamber to dephosphorize it under oxidizing conditions in that chamber. The apparatus of these figures includes the reverberatory chamber **60** with material charging openings **75**, burner openings **64**, gas entrance duct **72** from the electric chamber, a hearth connection with the electric chamber at **61** and a flue opening **65**. The flue **65** leads by way of a valve **70** thru the open hearth chamber **63** and thence to the flue by way of the same

valve. Checker work is indicated diagrammatically at 69 and 71. The electric furnace chamber 62 is provided with electrodes as at 73 and with charge openings as at 74 and tapping spout 76 and door 77. The gas flues into the open hearth chamber are shown fitted with air entrance pipes at 66 and 68 for admission of air to burn the gas from the reverberatory chamber 60.

The combination of chambers illustrated in Figs. 8 and 9 differs somewhat from the combination in Figs. 6 and 7, in that I have shown the direction of movement of charge in Fig. 9 as counter to the current of gas from the electric and in Fig. 7 the direction of movement thru the reverberatory is the same for both gas and charge.

The description of the apparatus shown in Figs. 8 and 9 is as follows. The main reverberatory chamber 81 is fitted with material charge means indicated diagrammatically at 89 and 88 and 99, and gas or air entrance pipes, 96 and 98, the pipes 96 serving as flues for gas from the electric chamber 82. A flue 91 connects with an open-hearth chamber 90. This chamber could be located directly in line with the reverberatory, as for example connecting with the flue pipe 100 shown closed by a gate 100—*a*. The open hearth chamber 90 is provided with controlled air inlet at 92, a flue 93 and metal and slag tap spouts 94 and 95, for operation in a manner similar to that described for the open hearth furnace illustrated in Fig. 6 except that I have not shown any checker work. The reverberatory connects with an electric chamber 82 which is provided with electrodes 86, charge opening 87 a door and a tap spout 97, and the electric chamber is separated from the reverberatory by the wall 85 above the molten bath, and a provision may be included for preventing the metal from freely moving into the electric chamber by means of a bottom section indicated at 84. The slag, indicated at 83, is free to flow into the electric chamber and to carry solid carbon on top of it and gas may come from the electric chamber either under the partition 85 or thru the pipes 96. I have shown an additional entrance pipe 96—*a* for admission of controlled amounts of air or oxygen or other materials into the reverberatory chamber.

In Fig. 9 I have illustrated one operation which might be carried out in this apparatus. This example is the treatment of iron ore containing phosphorus. It may be carried out as follows. A mixture of finely ground iron ore and carbon, such as coal, likewise fine, is preferably preheated and then charged on top of a molten bath of iron and slag in the reverberatory chamber 81 thru the entrance 99. For such treatment as this, the reverberatory is preferably lined with neutral or basic refractories in the hearth. The slag is not maintained especially basic because in this example it is intended to reduce the phosphorus into the iron, and the lining might therefore be even made of silicious material. The operation will take place at relatively low temperatures and therefore an essentially neutral hearth material may be used. The ore charge will be made up to contain in addition to the ore, an amount of lime and silica such as will provide when melted and reduced a fluid slag on the molten metal beneath, and the amounts of lime and silica are determined from the content of these materials in the ore. The slag would be neutral or slightly basic. The proportion of solid carbonaceous material is governed by the amount of this which is to be used up in this chamber and an excess may be provided which will appear on the slag at the end where it enters the electric furnace and pass into the latter. The lower partition 84 need not be used in this example. In the reverberatory chamber reduction of the iron oxide takes place at relatively low temperatures and only a limited amount of air is admitted, not enough to completely burn the carbon reducing agent material. The amount of combustion is governed by the temperature requirements and by the amount of gas from the electric chamber. Admission of coal into the electric chamber results in considerable amounts of gas formation there and this gas passes into the reverberatory and may be partly burned there by admission of air. However, the purpose desired is to provide a large hearth area on which ore charge may be fed and there reduced to metal and slag. The reduction takes place in the manner described in my co-pending applications for patent already referred to. In view of the requirements of this operation a large amount of hot reducing gas passes out the flue end of this furnace. This gas is utilized directly in the adjoining open hearth chamber to treat and heat the molten material or other material therein, by combustion from admission of air into that chamber. The result of the reduction which takes place in chamber 81 is the formation of reduced iron containing phosphorus and also slag. The slag is more completely reduced when it reaches the arc section in chamber 82. The products are tapped from this chamber 82, as molten iron containing phosphorus and as molten slag largely reduced and containing basic and acid oxides such as lime, alumina and silica. The molten high phosphorus iron may be tapped and transferred into the open hearth furnace which is preferably basic lined. The metal is there treated with iron oxide and lime in a slag which serves to take up the phosphorus from the iron and thus separate it from the metal. This operation may be carried on by means of the combustion of the gas from the chamber 81. This reduction process may be worked without using the gas in the open-hearth, but the advantage of such a combination lies in the fact that hot reducing gas is available from the reverberatory chamber, and it contains more heat than can ordinarily be utilized in a preheating furnace in which molten temperatures are not maintained.

This process including the open hearth step might be carried out in the apparatus illustrated in Figs. 6 and 7.

The operation of my apparatus of this invention for the treatment of molten slag may now be described, with reference particularly to Figs. 3, 4 and 5. To simplify consideration of this operation I will first describe the treatment of slag containing oxide of iron in considerable quantity, for example one containing 40% or more of metallic iron. This slag may be charged molten thru the opening 21 or it may be charged cold thru other openings and melted, but I will first describe the treatment of slag charged molten into the chamber 14 of Fig. 3. The composition of this entering slag should be known so that addition of slag materials to form a fluid slag after reduction of the iron oxide from the slag may be calculated. Thus, if the entering slag consists largely of FeO and SiO_2, I provide for admission of sufficient lime or other basic oxide to form a suitable slag with the silica content of the iron oxide slag. Then on top of the

slag I charge solid carbonaceous material such as carbon in some form, and in amount such that it sinks into the slag to increase contact therewith. As the carbon is consumed I add more carbon to maintain reducing conditions in the slag. It is necessary to limit the amount of combustion in this chamber so as not to overheat the upper part of the chamber and so as not to burn the carbon from the slag to an extent which will limit the operation of slag reduction. The molten slag moves into the electric chamber as the slag in that chamber is tapped out. In the electric chamber the reducing conditions are more intense and they are maintained sufficient to reduce the slag to the desired extent. The reduced iron collects in the bath beneath in both these chambers and is tapped out of the electric chamber at necessary intervals. I have shown means for admission of air or combustible material into the reverberatory but in the operation described I limit the admission of air as already described. The result is that a considerable amount of hot reducing gas is available from this chamber.

I may carry out a modified slag reduction process by treating slags which contain oxides of zinc and lead or either of these along with other oxides in order to reduce the zinc oxide and separate the zinc. This separation may be accomplished either as zinc vapor or as zinc oxide. The control of conditions in the reverberatory chamber will be determined by which object is desired, that is, whether the zinc is reduced and taken out of the chamber as zinc vapor or whether the zinc oxide is reduced and then reoxidized above the bath. The raw material may be either molten or solid slag or other materials containing the oxide such as zinc to be reduced. If a selective reduction is to be carried out such as the reduction of zinc while iron is to be retained in the slag, then the slag composition is controlled so as to use the iron oxide as the essential base and hold it against reduction by means of silica preferably. That is I do not add a basic oxide to replace the iron and I limit the reducing conditions in that way so as to avoid reduction of iron, or to largely avoid it. However, I maintain a considerable amount of solid carbon present and thus reduce the zinc oxide. Then I supply sufficient air to burn the zinc vapor thus formed and reoxidize it to zinc oxide fume. This operation would be carried out in the reverberatory chamber of Fig. 4 and the fume carried out the flue end of this chamber. Completion of the reduction of the slag takes place in the electric chamber and the zinc vapor formed passes into the reverberatory chamber where it is oxidized, and carried out, and the heat of oxidation utilized in the reverberatory chamber. The slag then tapped from the electric furnace will contain most of the iron as oxide. Some iron may be reduced and collected in this electric chamber and likewise lead may be reduced and tapped from this electric chamber.

The apparatus of my present invention may be used for the reduction of manganese ore or chrome ore, or for the reduction of these ores or oxides of these metals to produce alloys thereof with iron. Thus I may charge into a furnace such as that shown in Fig. 2 a mixture of finely divided oxide of manganese and carbon, for example manganese ore and coke, on a bath of steel covered with a slag, for example a lime silica slag containing 20 to 30 percent of silica and over 50% lime, the balance consisting of magnesia and some alumina, and then this incoming charge is subjected to heat in the reverberatory chamber so that the manganese oxide is reduced by the carbon and collects beneath. Thus it is possible to reduce the oxide at relatively low temperature until the manganese is materially reduced. The slag thus partly reduced next passes into the electric arc chamber and here the slag is further reduced by the heat of the arcs and by carbonaceous material added on the slag. By the combined control of slag composition, which for this case should be basic, and reducing conditions, and depth of the slag, it is possible to further reduce the manganese oxide out of the slag with a relatively small vaporization loss. The advantage of my apparatus in this instance is the reduction at relatively low temperatures which minimize vaporization of manganese.

In the case of chromium, I may use this apparatus to reduce chromium from its oxide in the manner above described and in the manner further described in my copending applications for patent. But in the case of chromium, the relative proportions of reverberatory and electric chambers may be quite different from that illustrated in the drawings herewith, for the reason that reduction of chromium, altho taking place at temperatures which are below those in an arc furnace, yet requires higher temperatures especially where very low carbon alloy metal is produced. It is understood that the relative proportions of the two upper chambers may be varied without getting away from the advantages of my invention.

I do not limit myself to any particular method of preheating the charge of fine oxide ore and carbonaceous reducing agent, and might use, in fact preferably do use, in one modification the method of preheating the mixture of ore, for example iron ore and coal, in a closed furnace, so as to remove the byproducts of the coal and save them, and subsequently further heat the mixture remaining on a molten bath in a furnace such as one of those described in my present application for patent.

One of the special advantages of the present invention is the saving of electrodes by using them in a separate compartment above the molten bath. Another advantage is the means thus provided for heating coal in the electric chamber whereby the volatile matter is thus driven off and serves to carry heat into the reverberatory chamber. Another advantage in the apparatus of my present invention is the means for preliminary reduction of oxides and slag at lower temperatures followed by more intensive reduction in an adjoining electric chamber. Still another advantage in my invention is the means for reducing oxides without allowing the carbon reducing agent to come in contact with the molten bath below. Another advantage is the combination of apparatus which presents a large bath area for use in reducing at lower temperatures and then an electric chamber for further reduction of the slag.

I do not limit myself to the use of carbonaceous material but may use any suitable reducing agent, for example in reducing chrome ore I may use silicon or ferrosilicon mixed with the chrome oxide to accomplish reduction in the manner illustrated herein.

What I claim is:—

1. A combination combustion and electric melting furnace comprising an elongated rever-

beratory chamber above a portion of an elongated hearth for holding molten material, a flue for exit of gas at one end of said reverberatory chamber, means for maintaining combustion in said reverberatory chamber from the direction of the opposite end toward the flue end, an electrode chamber above the remainder of the hearth adjoining the said opposite end of said reverberatory chamber, said hearth sloping from the flue end to the electrode chamber so that molten material from the reverberatory chamber will move into the electrode chamber, vertically adjustable electrodes extending through the roof of the electrode chamber for heating the molten bath in the electrode chamber by current from the electrodes which arcs to the charge therein, means for introducing charge materials into the reverberatory chamber of said furnace, means for limiting the entrance of oxidizing gas from the reverberatory chamber into the electrode chamber, means for introducing carbonaceous matter into the electrode chamber from which it may move on the charge into the reverberatory chamber, and means for tapping the molten material from the furnace.

2. A combination combustion and electric smelting furnace comprising an elongated hearth for holding molten material, two chambers above said hearth, one for combustion and the other for arc heating of the charge, vertically adjustable electrodes entering said electrode chamber for arcing to the charge, means for introducing carbonaceous material into said electrode chamber and from which this material or part thereof may float on the charge into the adjacent combustion chamber, means for introducing oxidizing gas to burn the carbonaceous material in the combustion chamber, a flue for exit of gas from said combustion chamber at the end opposite the electrode chamber, means for introducing charge materials into the combustion chamber in such manner as to cause movement of molten material into the electrode chamber, means for limiting flow of gas from the combustion chamber into the electrode chamber, and means for tapping the molten material.

3. A reverberatory-electric smelting furnace comprising an elongated hearth for holding a bath of molten material, a reverberatory combustion chamber above part of said hearth and means for maintaining combustion therein toward a flue exit at one end of this chamber, an electrode chamber above the rest of the hearth adjoining the opposite end of the combustion chamber and having vertically adjustable electrodes for arcing to and heating the molten bath at that end of the hearth, said electrode chamber being smaller and having more restricted space above the bath than the combustion chamber, means for introducing charge materials into the reverberatory combustion chamber above the bath therein so as to gradually cause movement of molten material into the electrode chamber, a restriction between the two chambers to limit movement of gas from the combustion zone into the vicinity of the electrodes, means for charging carbonaceous material into the electrode chamber to cause movement of gas therefrom into the combustion zone, and means for tapping molten material from the electrode chamber of the furnace.

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