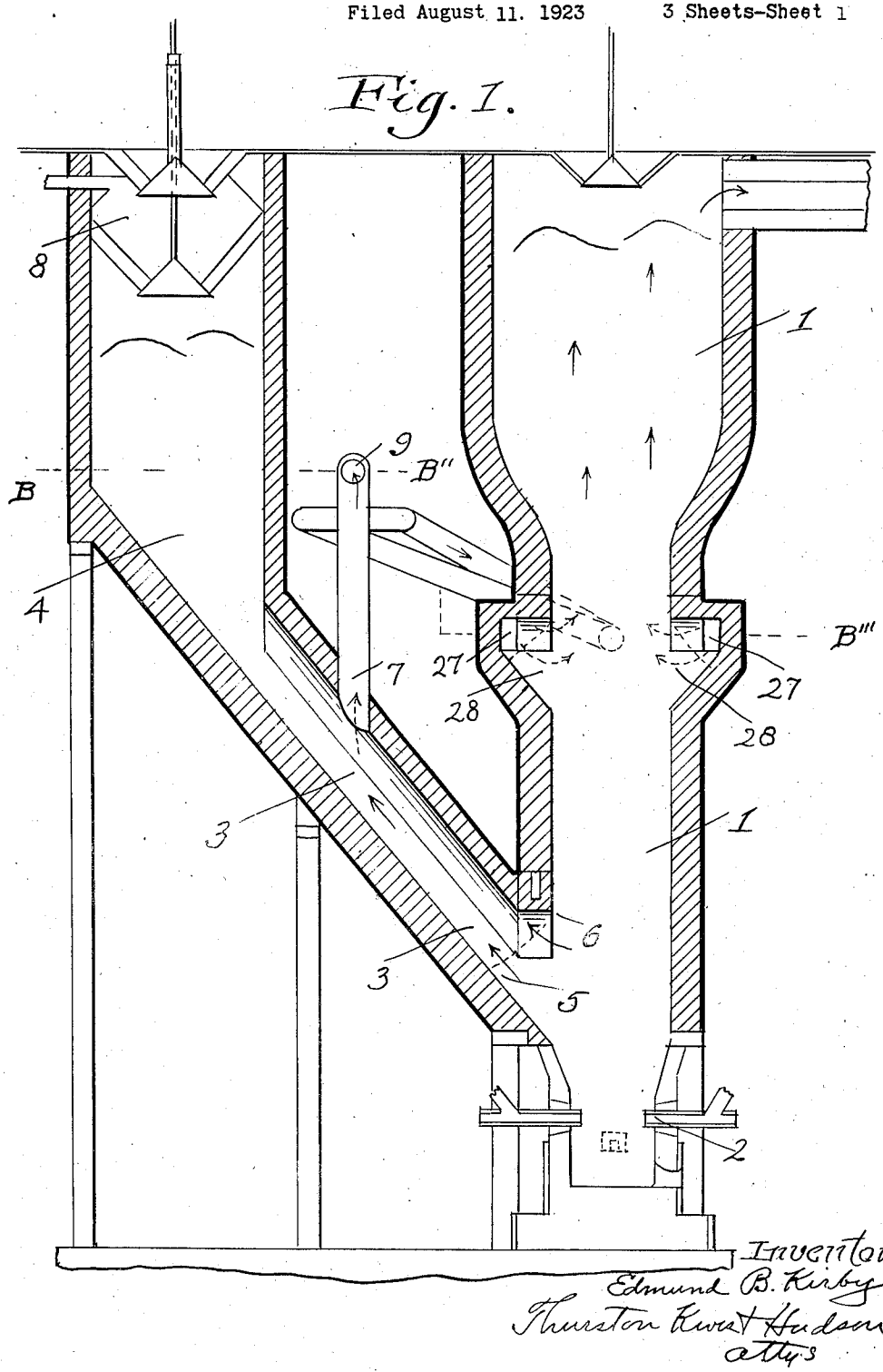
May 11, 1926. 1,583,933

E. B. KIRBY

METHOD OF SEPARATING METAL FROM THE MATERIAL CONTAINING IT

Filed August 11. 1923 3 Sheets-Sheet 1

Fig. 1.



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May 11, 1926. 1,583,933

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METHOD OF SEPARATING METAL FROM THE MATERIAL CONTAINING IT

Filed August 11, 1923 3 Sheets-Sheet 2

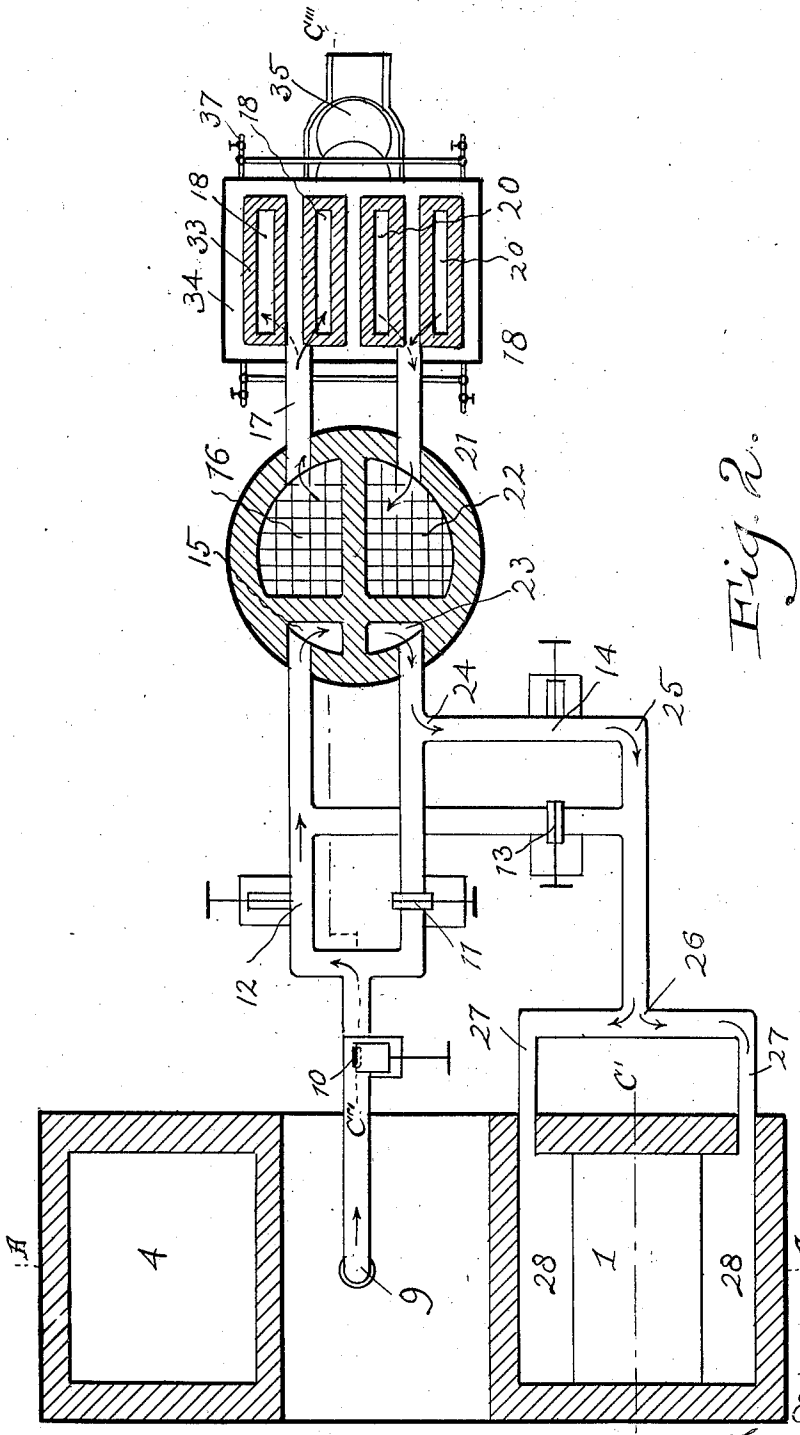


Fig. 2.

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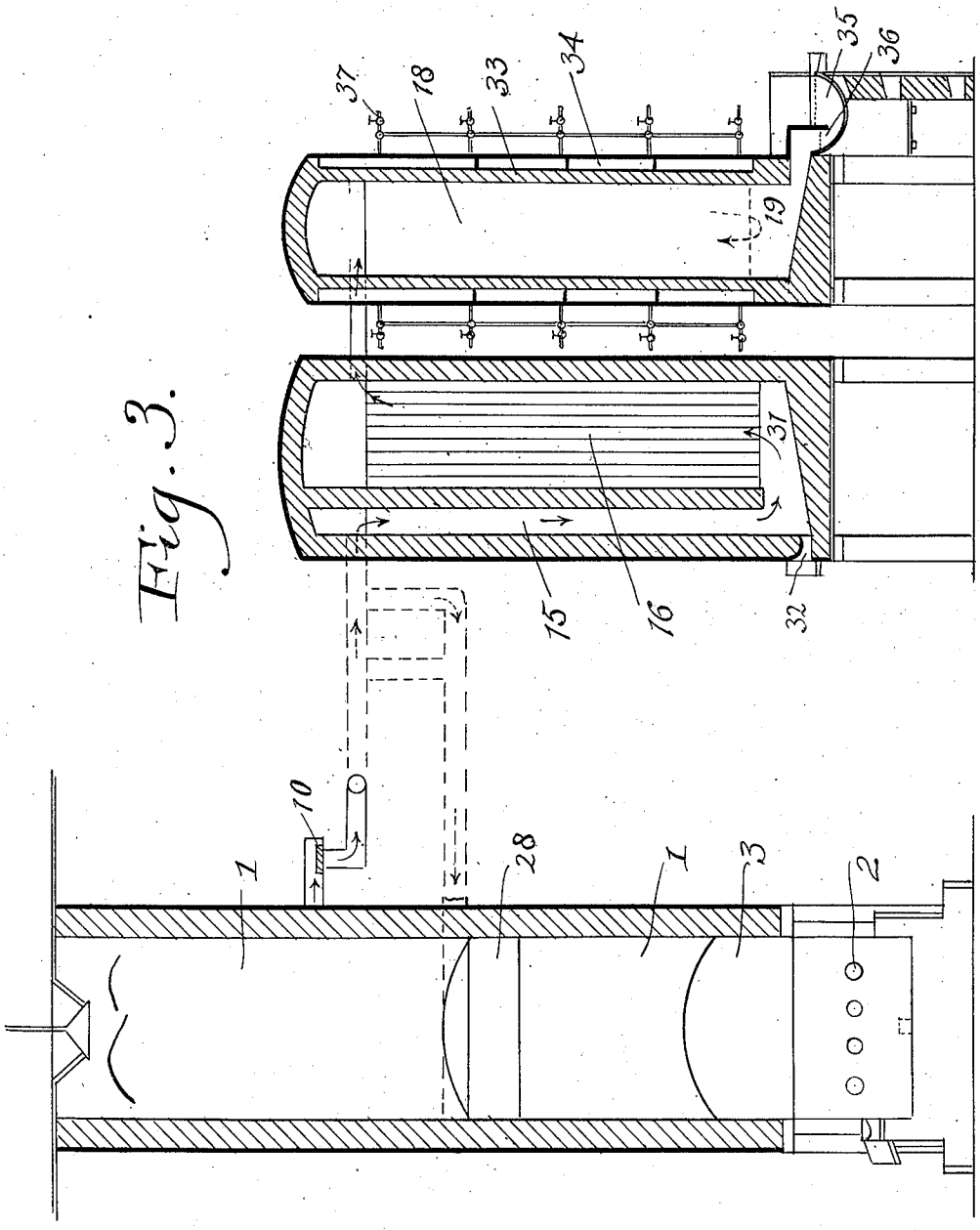
May 11, 1926. **1,583,933**

E. B. KIRBY

METHOD OF SEPARATING METAL FROM THE MATERIAL CONTAINING IT

Filed August 11. 1923 3 Sheets-Sheet 3

Fig. 3.



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Patented May 11, 1926. 1,583,933

UNITED STATES PATENT OFFICE.

EDMUND B. KIRBY, OF NEW YORK, N. Y.

METHOD OF SEPARATING METAL FROM THE MATERIAL CONTAINING IT.

Application filed August 11, 1923. Serial No. 656,798.

I have invented a new and useful improvement in the art of extracting metals from ores or other materials containing them.

My improvement relates to the operation of blast furnace smelting in which the material, after such preparation as it may require in the way of selection, roasting, sintering, mixing and proportioning with fluxes; all according to the well known practice of the art, is smelted in order to separate the metals or some concentrated furnace product containing them, from the waste or rocky constituents of the charge.

In present practice the charge of material is fed into the top of the blast furnace column accompanied by coke or other suitable fuel; a blast of air is injected through tuyères near the base of the column, sometimes accompanied by injectable fuel; the furnace products such as metal, matte and slag, are drawn from the bottom of the furnace; while by-products such as flue dust and fume are recovered from the gases which issue from the top.

My process consists of adapting the blast furnace operation, which is one of the most efficient methods of smelting, to the distillation of a metal; the latter operation being at present performed in other and less efficient types of furnaces and at comparatively great expense.

In general the operation consists of so operating the blast furnace as to vaporize the desired metal or metals, of drawing off the gases containing the metal vapor (which gases would usually flow up to the top of the furnace through the interstices of the blast furnace column with diminishing pressure and temperature,) and of by-passing this diverted current of gases around the middle part of the column; subjecting them while thus temporarily separated from the column to the operation of condensation. I thus separate a comparatively volatile component of the charge not only from the slag constituents but also from the less volatile components.

It is obvious that after condensation the gases need not be returned to the column and may be rejected but I prefer to return them for the reasons hereafter explained.

My process is specially suitable for such metals as zinc, magnesium, lead, aluminum, but I do not restrict myself to these and the process may be applied to any metal or any chemical compound which is capable of being vaporized in the blast furnace by the means described hereafter.

It may in certain cases be found desirable to vaporize several metals at the same time such as zinc and lead, and in such cases a more or less effective separation of them may be made during their condensation by having the condensing apparatus operated in successive units each of which is maintained at the temperature required to condense one of the group.

For simplicity however, I shall describe the process as if only one metal was being vaporized.

The accompanying drawings show a furnace and condensing apparatus in which my process may be operated. Since blast furnace construction and operation is well understood, I shall only indicate in the specification and drawings those features which are essential to an understanding of my improvements.

Fig. 1 is a vertical cross-section of the furnace and coke filter taken through the plane (A. A.) indicated in Fig. 2; Fig. 2 is a horizontal cross-section of the furnace and condensing apparatus through the broken plane (B‴—B—B″) indicated in Fig. 1; Fig. 3 is a vertical cross-section of the furnace and condensing apparatus through the broken plane (C.—C.—C″—C‴) indicated in Fig. 2. For clearness conduits, valves, etc., are merely indicated without the construction details which are necessary for handling highly heated gases.

In operating my process I vaporize the metal by so arranging the charge and the operation of the furnace that the metal in question will be reduced to the metallic form before fusion and will be then subjected to a temperature which will vaporize it and that there will be a quantity of heat sufficient to convert it to vapor. I adjust and control the temperature, reducing action, and heat quantity, by the following means.

The maximum temperature attained by the material in the column is fixed by the free running temperature of the slag produced in the zone of fusion because the higher temperature of the flame in the zone of combustion is instantly lowered by the absorption of its heat in the fusion of the material.

Hence, by suitably proportioning the mixture of ores and fluxes I make a slag whose

free running temperature is above the temperature required to vaporize the metal in question and is, moreover, high enough to give the carbon and carbon monoxide a final intensity of reducing action just before and during fusion which will complete the reduction and prevent any important residue of the metal from combining with silica as oxide and entering the slag.

In the case of very rich material, such as scrap refuse or bar metal to be re-distilled for purification, there is but little slag and the temperature attained is fixed by the boiling point of the metal.

The total extent of reducing action to which the material is subjected is governed not only by the maximum temperature created at the zone of fusion, but also by the relations between size and permeability of the lumps of material and the length of time occupied by their descent, the latter being controlled mainly by the speed of the furnace and the height, cross-section and shape of the column.

In the usual operation of a blast furnace, the quantity of heat liberated by combustion is that required to fuse the metal, slag and other products, to perform the chemical reactions upon the material and to make up the various losses.

In my process I supply not only the above normal requirements but also a large additional quantity of heat equal to the latent heat of vaporization plus the extra losses incurred in the condensation circuit. I do this by using an adequate excess of fuel and blast above the proportions required by the material for ordinary blast furnace reduction and fusion.

By the various means thus indicated I so proportion the blast furnace and so adjust its operation that the metal I wish to vaporize will practically all be converted to vapor.

In ordinary blast furnace operation the gaseous products of combustion rise throughout the interstices of the column to the top where they leave the furnace. During their ascent their pressure and temperature gradually decrease and their composition is modified by various reactions with the components of the column.

If the smelting is so conducted as to vaporize the desired metal and the furnace gases are drawn out of this column for the purpose of condensing the metallic vapor contents the latter operation will be hindered by the excessive volume of the gases.

The metal vapor constitutes such a small proportion of the total volume that its low partial pressure lowers the condensation point to an extent which destroys the conditions required for condensation to liquid metal. Cooling below a certain limit yields a product which is in solid particles; mixed with more or less oxide in case certain gases are present to react with it: the blue powder produced in the condensation of zinc being a familiar instance.

The first requirement therefore is to obtain a gas which is rich enough for condensation. I do this by using a blast composed of pure oxygen or of air sufficiently enriched with oxygen. This reduces the volume of the gases by eliminating the nitrogen wholly or nearly so and by saving the fuel consumed to heat this nitrogen. The reduction of volume of the gases proportionally raises the percentage of their metallic vapor content.

It is also necessary to provide for the reduced percentage of vapor towards the end of the condensing operation for this, if not separated in some form (such as blue powder for zinc) will be carried to waste by the large volume of gases. I do it by returning the current to the blast furnace column in the cooler portions of which this residue of vapor will be precipitated as metal or oxide or otherwise and this precipitate will be carried down by the column back to the zone of fusion.

Any precipitated fume too impalpable to be retained by the column will pass out of the furnace top with the gases and may be caught in baghouses or other well known means for collecting such fumes from blast furnace gases. I therefore operate the condenser at temperatures which are above the limit at which solid precipitate begins to form, but which are low enough to condense liquid metal.

I also raise the percentage of metal vapor by another expedient which may be employed either with or without the use of oxygen in the blast.

This is to pass through the condensing apparatus only a portion of the total gases formed; the remainder being allowed to rise through the interstices of the column. As the cooler regions are reached the metal vapor is precipitated as metal or in other forms while the gases escape from the top of the furnace.

The precipitate is carried back by the descending column to the zone of fusion where it is re-vaporized in company with fresh metal from the charge and another fraction is withdrawn. The amount of accumulated metal thus traveling in a closed circuit, may be made as great as the interstices of the column will permit and will raise the percentage of metal vapor at the point from which the fraction for condensation is drawn.

It is obvious that equivalent methods of forming the closed circuit will be to draw the entire volume of gases from the column and to then divide the current into one portion which is returned without con-

densation and another portion which is condensed.

Another method will be to pass all the gases through the condensing apparatus and to so operate this apparatus as to leave a sufficient residue of uncondensed vapor in the current which re-enters the column.

Such equivalent methods may be preferable in order to meet special conditions such as a clogging of the interstices of the middle part of the column, and I do not restrict myself as to their choice.

In treating the current of gases drawn from the furnace column I do not restrict myself to any particular apparatus or method for performing the condensation of the metallic vapor. The current may be rejected after condensation or it may be returned to the column at a higher level in order to return its residual metal vapor contents and its heat contents to the column.

Nevertheless, the capacity of blast furnace operation so greatly exceeds that of any present furnaces used for distillation processes that the condensation required will be on a scale never before attempted. Present apparatus and methods are not suitable for the work and I have therefore invented improvements in condensation which will meet the new conditions which are briefly outlined as follows.

The daily tonnage of metal to be condensed is so great that the quantity of latent heat to be absorbed from the condenser requires definite and accurately controlled cooling apparatus and methods instead of those now employed.

Moreover, the gases drawn from the furnace at the point of maximum vapor content, which will be near the zone of fusion, have a high temperature (1100° to 1300° C. in the case of zinc) and unless much of this visible heat is returned to the furnace in some way more fuel will be required to do the furnace work and this aside from its cost will increase the volume of furnace gases.

Again blast furnace gases, unlike those of distillation furnaces, contain much carbon dioxide, steam and free oxygen at the point where they are drawn off, and they will also carry dust and fume which would soon clog the condensing apparatus. The carbon dioxide steam and oxygen oxidize the metal during condensation and must therefore be reduced to safe limits.

In order to meet these requirements I first pass the current through the interstices of a large mass of lumps of coke or other carbon fuel, maintained at a temperature as near as possible to the furnace maximum. This hot carbon filter eliminates the carbon dioxide, steam and free oxygen; reduces and vaporizes any oxide fume and catches the dust.

I then remove the visible heat until the current has the most effective temperature for condensing the metal in question which in the case of zinc will usually be the range between 600 and 800° C. I prefer to return the heat removed back to the furnace column by means of a pair of regenerators.

Having thus reached the proper temperature for liquid condensation, the current enters the condenser proper where the latent heat is removed by an artificial cooling of the walls through the flow of a cooling medium which is under positive and accurate regulation.

Referring to the accompanying drawing in which is shown apparatus suitable for carrying out my process: the blast furnace column, with the charge and the fuel usually in alternate layers, is indicated at (1—1) and the blast tuyères at (2). The tapping arrangements for metal and slag are merely indicated. A column (3—3—4) of coke or other form of carbon fuel is arranged in any convenient way so as to join the main column at (5) just above the zone of fusion. The lower part (3—3) of this coke column constitutes the hot carbon filter, the upper or cold portion (4) constituting merely a gas tight bin to supply the filter.

The contact (5—6) between the columns is an inclined surface owing to the fact that the charge is heavier than the coke. This fluctuating surface, dragging away some of the coke, maintains a large open passageway whereby the gases may escape from the furnace column into the more open and free interstices of the coke column. They leave the carbon filter at (7) to pass to the condensing apparatus.

The slagged dust accumulations and coke ash flows down the sloping conduit into the main column. The coke is consumed slowly and fresh coke is supplied by gravity from the cold upper part of the column which is replenished occasionally by any suitable gas tight feeding apparatus such as is indicated at (8).

The current passing through conduit (7—9) enters the condensing apparatus through a regulated damper or throttle indicated at (10) which is constructed of any suitable refractory material. This admits to the condensing apparatus such a fraction of the total furnace gases as is desired.

The condensing apparatus consists of two parallel and similar sets, which for convenience are built together, each composed of a regenerator (16) followed by a condenser (18). The sets are joined at the extreme lower ends (19) of their condensers so as to constitute a continuous open conduit.

Disregarding losses, the current enters the vertical regenerator conduit (15) at the full temperature of the furnace (1100°—1300° C. when smelting zinc). As it descends

through the conduit (15) and rises through the passages of regenerator (16) it deposits enough heat in them to be reduced to the temperature at which condensation can begin (800° C. for zinc). It then flows down the parallel passages (18—18) of the condenser where latent heat is removed through the cooled walls (33) and liquid metal is condensed.

Since the percentage of metal vapor becomes less as the operation proceeds the temperature must be lowered to correspond so that the extremity of the condenser at (19) is kept cooler than the top where fresh gas is entering.

At (19) the cool end of the condenser, the current, with what remains of uncondensed residual vapor, is down to the minimum temperature allowed (say about 600° C. in the case of zinc). Before returning to the furnace column its visible heat is restored by passing it backwards through the other condenser (20—20), regenerator (22) and regenerator conduit (23) which are full of heat stored during the previous reversal of current. The current therefore emerges from the regenerator conduit (23) restored to its original temperature (losses disregarded) and passes to the furnace column by conduits (24—25—26—27) and the furnace wall enlargements (28—28). The latter are provided in order to give the gases free access to a large open inclined surface of the column so that they may freely enter its interstices.

Reversing valves indicated at (11—12—13—14) periodically reverse the current through the duplicate regenerator and condenser sets (16—18) and (22—20). The regenerators may be of any of the forms known in metallurgical practice. They are chambers filled with fixed brick work or tile or with loose stone or bricks or other suitable material capable of absorbing and storing heat. The form I prefer has the open down conduit (15) and the tile filled vertical chamber (16) which receives the current from its lower end (31). There is a sump and tap hole (32) at the bottom for collecting and removing slag drip.

The condensers may be of any design, for like regenerators, many forms are known in the art. I prefer a group of vertical narrow condensing conduits (two shown in drawing) set in parallel and illustrated by (18—18). Each conduit has a large amount of wall surface which is cooled by a regulated current of water or air or other suitable medium flowing on the other side of the wall. Those shown have a lining of refractory material (33) of thickness suitable for transmitting the required flow of latent heat and this is absorbed by a metal jacket (34) with regulating means for the flow of water or air, etc. through it at a sufficient rate to absorb the latent heat. There is a system of pipes, valves and temperature indicators to control and adjust the cooling flow separately in different parts of the condenser and thus the rate of heat transmission but it is not necessary to show the details of this beyond the indication at (37).

The interior of the condensing conduits may be filled with lumps of coke, rock, tile or other material to diffuse the current and absorb heat. A receptacle (35) and an inverted siphon tap (36) serve to collect and remove the condensed metal.

When a plurality of metals is vaporized, for instance zinc and lead, the condenser of each set and preferably both regenerator and condenser will be made in two units following each other.

In the first unit the condenser would be maintained below 1525° C. the condensing point for pure lead vapor and above 930° C. the condensing point for pure zinc vapor (effect of blast pressure disregarded). The current after the condensation of its lead vapor would pass to the second unit where at the lower temperature required the zinc would be condensed.

Many forms of reversing valves for high temperature gases, arranged and operated in many ways, are known in the art in connection with regenerative work and I do not restrict myself to any particular design or method for use in my process. I have therefore merely indicated at (11—12—13—14) the valves required to reverse the current.

It is an important and novel feature of my system that I operate my condenser hot enough to condense liquid metal only and then precipitate all the uncondensed residual vapor in the interstices of the blast furnace column. I thus return to the furnace promptly and efficiently all metal which escapes the condenser.

The force moving the current through the apparatus is the difference in pressure between the gases at the point (5) where they are drawn off and that at the higher point (28) where they re-enter the column, because the coke filter and condensing apparatus offer little resistance compared to the interstices of the column. This difference in pressure may be made anything desired for the problem in hand by raising or lowering the point 28 of re-entry.

I do not restrict myself to this method of moving the current which may obviously be moved by other means such as a fan or blower placed at the coolest end of the condenser.

In employing a blast of pure oxygen or one enriched in oxygen, I protect the tuyère nozzles, not only by the usual water cooling, but by injecting a little steam in such a way as to act upon the incandescent coke which adjoins or radiates upon them, and

at the same time to keep the oxygen from such contact with the heated outer surface of the tuyère nozzles as to set the metal on fire.

The de-composition of the steam into carbon monoxide and hydrogen by the incandescent coke absorbs so much heat that a very little steam will chill the adjacent coke which is doing the radiating and will thus protect the tuyère.

The furnace is so proportioned that the column above the point where the gases re-enter it, will have a cross section large enough to properly slow up and cool the current and thus to precipitate its residual vapor contents.

The vaporization of the metal in question does not interfere with the fusion and separation of the liquid metals, matte, slag, etc. in the usual way, nor with the usual collection of flue dust and fume from the waste gases leaving the furnace.

Having described my invention, I claim:—

1. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace with such excess of fuel as will supply latent heat of vaporization to the metal, in making a slag whose free running temperature exceeds the boiling point of the metal, in subjecting the material to reducing agents for a time sufficient to reduce the metal before fusion, in drawing off the gases and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, in enriching the gases by causing an accumulated portion of the metal to traverse a closed circuit which includes part of the column, and in maintaining the condenser temperature above the point at which solid precipitate is formed and precipitating the residual vapor within the interstices of the column.

2. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace with such excess of fuel as will supply latent heat of vaporization to the metal, in making a slag whose free running temperature exceeds the boiling point of the metal, in subjecting the material to reducing agents for a time sufficient to reduce the metal before fusion, in drawing off the gases and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, in enriching the gases by causing an accumulated portion of the metal to traverse a closed circuit which includes part of the column, and in withdrawing the latent heat of condensation through the condenser walls to a cooling medium of accurately regulated flow.

3. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace with such excess of fuel as will supply latent heat of vaporization to the metal, in making a slag whose free running temperature exceeds the boiling point of the metal, in subjecting the material to reducing agents for a time sufficient to reduce the metal before fusion, in drawing off the gases and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, in enriching the gases by causing an acumulated portion of the metal to traverse a closed circuit which includes part of the column, and in returning visible heat from the gases to the column by reversing flow through regenerators.

4. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace with such excess of fuel as will supply latent heat of vaporization to the metal, in making a slag whose free running temperature exceeds the boiling point of the metal, in subjecting the material to reducing agents for a time sufficient to reduce the metal before fusion, in drawing off the gases and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, in enriching the gases by causing an accumulated portion of the metal to traverse a closed circuit which includes part of the column, and in passing the gases through a highly heated carbon filter.

5. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace with such excess of fuel as will supply latent heat of vaporization to the metal, in making a slag whose free running temperature exceeds the boiling point of the metal, in subjecting the material to reducing agents for a time sufficient to reduce the metal before fusion, in using a blast whose oxygen content exceeds that of air, in drawing off the gases and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, and in maintaining the condenser temperature above the point at which solid precipitate is formed and precipitating the residual vapor within the interstices of the column.

6. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace with such excess of fuel as will supply latent heat of vaporization to the metal, in making a slag whose free running temperature exceeds the boiling point of the metal, in subjecting the material to reducing agents for a time sufficient to reduce the metal before fusion, in using a blast whose oxygen content exceeds that of air, in drawing off the gases

and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, and in withdrawing the latent heat of condensation through the condenser walls to a cooling medium of accurately regulated flow.

7. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace with such excess of fuel as will supply latent heat of vaporization to the metal, in making a slag whose free running temperature exceeds the boiling point of the metal, in subjecting the material to reducing agents for a time sufficient to reduce the metal before fusion, in using a blast whose oxygen content exceeds that of air, in drawing off the gases and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, and in passing the gases through a highly heated carbon filter.

8. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace with such excess of fuel as will supply latent heat of vaporization to the metal, in making a slag whose free running temperature exceeds the boiling point of the metal, in subjecting the material to reducing agents for a time sufficient to reduce the metal before fusion, in using a blast whose oxygen content exceeds that of air, in drawing off the gases and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, and in enriching the gases by causing an accumulated portion of the metal to traverse a closed circuit which includes part of the column.

9. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace with such excess of fuel as will supply latent heat of vaporization to the metal, in making a slag whose free running temperature exceeds the boiling point of the metal, in subjecting the material to reducing agents for a time sufficient to reduce the metal before fusion, in using a blast whose oxygen content exceeds that of air, in drawing off the gases and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, and in returning visible heat from the gases to the column by reversing flow through regenerators.

10. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace with such excess of fuel as will supply latent heat of vaporization to the metal, in making a slag whose free running temperature exceeds the boiling point of the metal, in subjecting the material to reducing agents for a time sufficient to reduce the metal before fusion, in using a blast whose oxygen content exceeds that of air, in drawing off the gases and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, in enriching the gases by causing an accumulated portion of the metal to traverse a closed circuit which includes part of the column, in passing the gases through a highly heated carbon filter, in withdrawing the latent heat of condensation through the condenser walls to a cooling medium of accurately regulated flow, and in maintaining the condenser temperature above the point at which solid precipitate is formed and precipitating the residual vapor within the interstices of the column.

11. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace with such excess of fuel as will supply latent heat of vaporization to the metal, in making a slag whose free running temperature exceeds the boiling point of the metal, in subjecting the material to reducing agents for a time sufficient to reduce the metal before fusion, in using a blast whose oxygen content exceeds that of air, and in drawing off the gases and condensing the metal vapor.

12. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace with such excess of fuel as will supply latent heat of vaporization to the metal, in making a slag whose free running temperature exceeds the boiling point of the metal, in subjecting the material to reducing agents for a time sufficient to reduce the metal before fusion, in using a blast whose oxygen content exceeds that of air, in drawing off the gases and condensing the metal vapor, and in enriching the gases by causing an accumulated portion of the metal to traverse a closed circuit within the column.

13. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace and creating conditions which vaporize the metal, in drawing off the gases and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, and in passing the gases through a highly heated carbon filter.

14. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace and creating conditions which vaporize the metal, in drawing off the gases and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, and in passing the gases through a highly heated

carbon filter which drains into the furnace column and is self replenishing.

15. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace and creating conditions which vaporize the metal, in drawing off the gases from the point of maximum richness and condensing the metal vapor, and in returning the gases to the furnace column at an elevation higher than that at which they are drawn off.

16. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace, and creating conditions which vaporize the metal, in drawing off the gases and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, and in maintaining the condenser temperature above the point at which solid precipitate is formed and precipitating the residual vapor within the interstices of the column.

17. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace and creating conditions which vaporize the metal, in using a blast whose oxygen content exceeds that of air, in drawing off the gases and condensing the metal vapor, and in returning the gases to the furnace column at an elevation higher than that at which they are drawn off.

18. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace and creating conditions which vaporize the metal, in drawing off the gases and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, and in enriching the gases by causing an accumulated portion of the metal to traverse a closed circuit which includes part of the column.

19. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace and creating conditions which vaporize the metal, in drawing off the gases and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, and in withdrawing the latent heat of condensation through the condenser walls to a cooling medium of accurately regulated flow.

20. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace and creating conditions which vaporize the metal, in drawing off the gases and condensing the metal vapor, in returning the gases to the furnace column at an elevation higher than that at which they are drawn off, and in returning visible heat from the gases to the column by passing them through regenerators.

21. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace and creating conditions which vaporize the metal, with a blast whose oxygen content exceeds that of air, in so injecting steam as to react with the adjacent fuel and protect the tuyère nozzles, and in drawing off the gases and condensing the metal vapor.

22. The method of separating a metal from the material containing it which consists in smelting the material in a blast furnace and creating conditions which vaporize the metal, with a blast whose oxygen content exceeds that of air, in so injecting steam as to react with the adjacent fuel and protect the tuyère nozzles, in drawing off the gases and condensing the metal vapor, and in returning the gases to the furnace column at an elevation higher than that at which they are drawn off.

23. The method of separating metal from the material containing it which consists in vaporizing the metal in a furnace in a current of other gases, in drawing off the gases from the point of maximum richness and condensing the metal vapor, and in returning the gases to the furnace for the recovery of their residual vapor contents and heat.

24. The method of separating a metal from the material containing it which consists in vaporizing the metal in a furnace in a current of other gases, in drawing off the gases from the point of maximum richness and condensing the metal vapor, in returning the gases to the furnace for the recovery of their residual vapor contents and heat, and in enriching the gases by causing an accumulated portion of the metal to traverse a closed circuit.

25. The method of separating a metal from the material containing it which consists in vaporizing the metal in a furnace in a current of other gases, in drawing off the gases from the point of maximum richness and condensing the metal vapor, in returning the gases to the furnace for the recovery of their residual vapor contents and heat, in passing the gases through a highly heated carbon filter, and in returning visible heat from the gases to the column by passing them through regenerators.

26. The method of separating a plurality of metals from the material containing them which consists in vaporizing the metals in a current of other gases, in drawing off the current and condensing the metals, by passing it through a condenser of several sections each maintained at the temperature of condensation for one of said metals, and in returning the gases to the furnace for the recovery of their residual vapor contents.

27. The method of separating a metal from the material containing it which consists in vaporizing the metal in a furnace in a current of other gases, in drawing off the gases and condensing the metal vapor, and in passing the current successively through a regenerator and a condenser then backwards through another condenser and regenerator and into the furnace, the current being reversed periodically between the two sets of regenerators and condensers.

28. The method of separating a metal from the material containing it which consists in vaporizing the metal in a furnace in a current of other gases, in drawing off the gases and condensing the metal vapor, by passing the current through a highly heated carbon filter, then with periodic reversals through two sets of regenerators and condensers, which sets are connected at the coolest ends of their respective condensers, and then back to the furnace.

In testimony whereof, I hereunto affix my signature.

EDMUND B. KIRBY.