A. G. JONES.

METALLIZING PROCESS.

APPLICATION FILED MAR. 26, 1914. RENEWED JAN. 20, 1916.

1,174,729.

Patented Mar. 7, 1916.

2 SHEETS—SHEET 1.

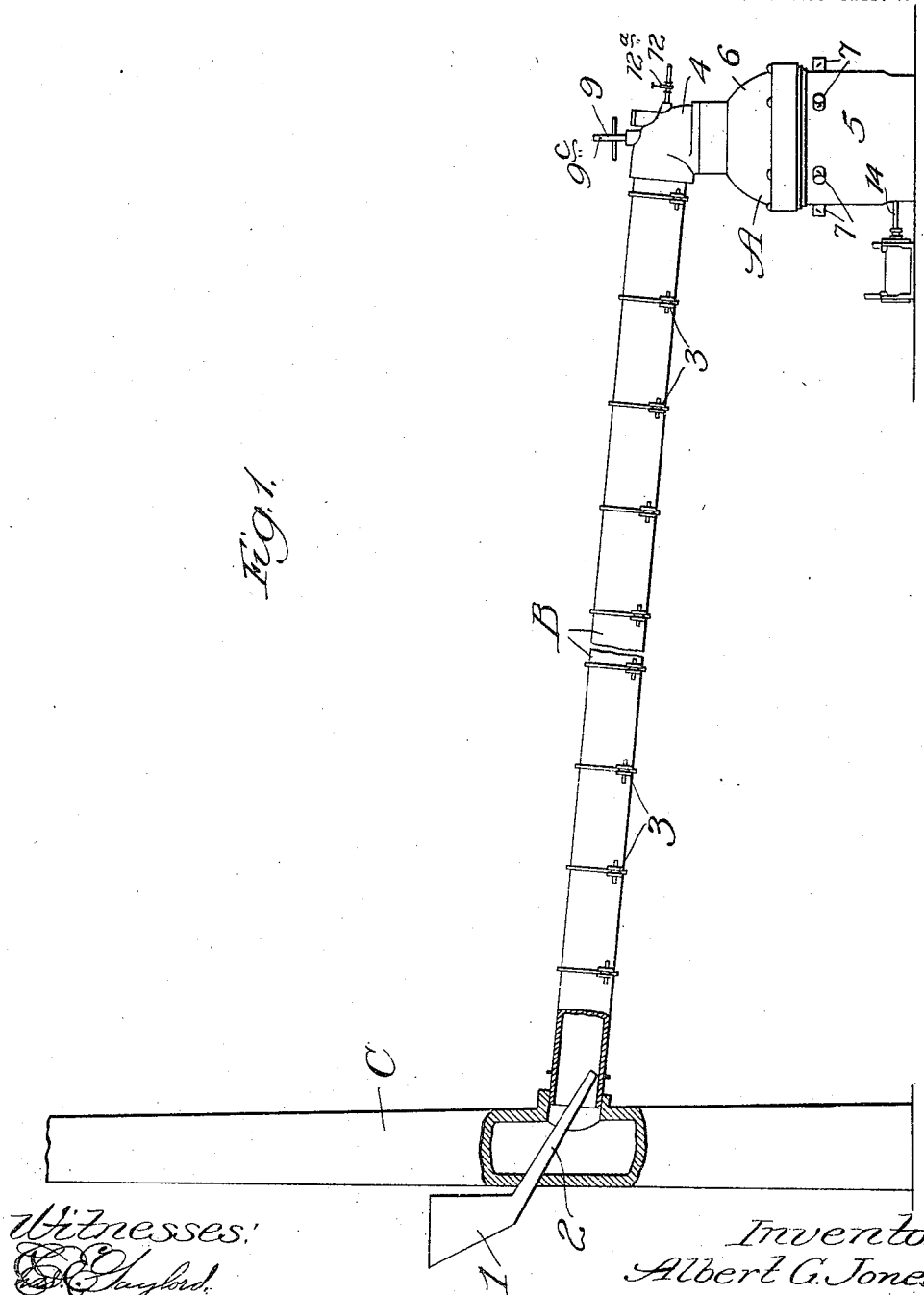


Fig. 1.

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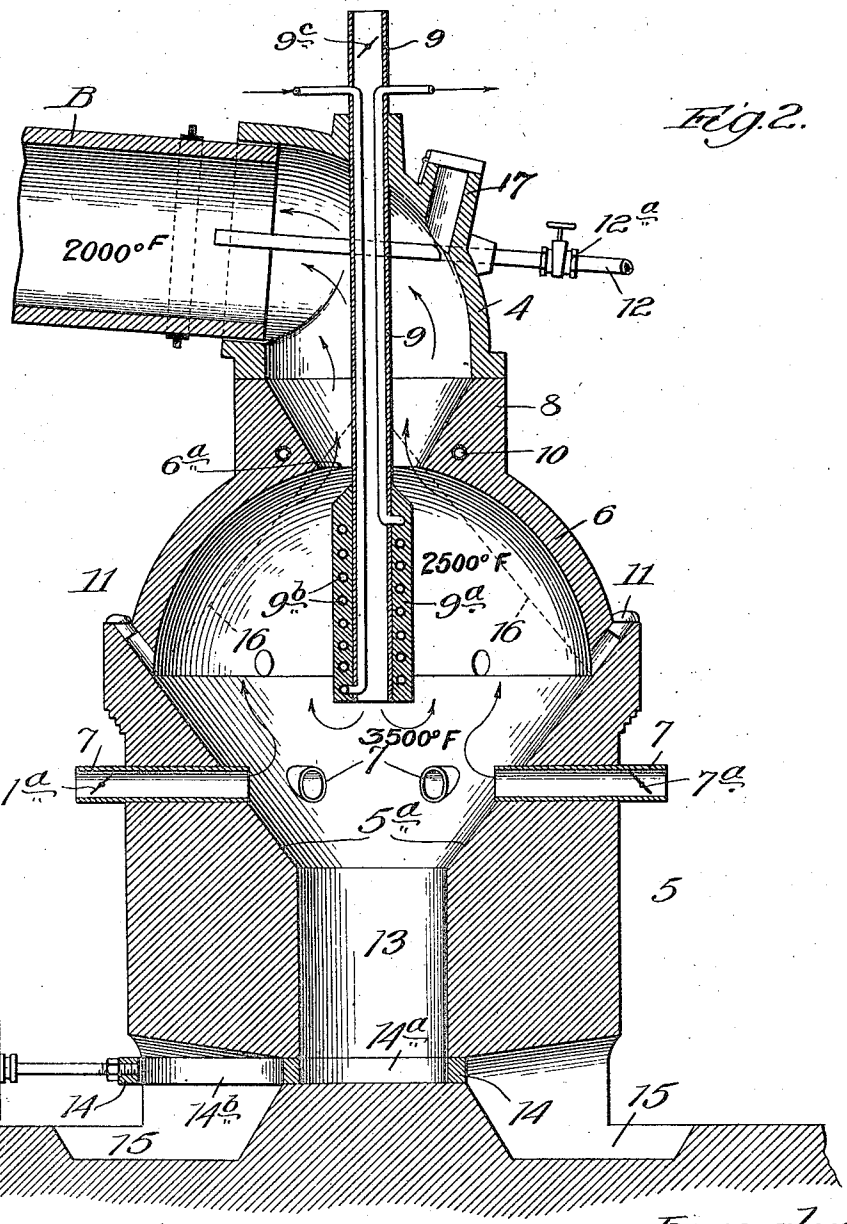


Fig. 2.

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UNITED STATES PATENT OFFICE.

ALBERT G. JONES, OF IRON MOUNTAIN, MICHIGAN, ASSIGNOR TO NEW METALS-PROCESS COMPANY, OF CHICAGO, ILLINOIS, A CORPORATION OF ILLINOIS.

METALLIZING PROCESS.

1,174,729. Specification of Letters Patent. Patented Mar. 7, 1916.

Application filed March 26, 1914, Serial No. 827,358. Renewed January 20, 1916. Serial No. 73,178.

To all whom it may concern:

Be it known that I, ALBERT G. JONES, a citizen of the United States, residing at Iron Mountain, in the county of Dickinson and State of Michigan, have invented a new and useful Improvement in Metallizing Processes, of which the following is a specification.

The present invention relates particularly to a direct process for metallizing metal oxids and carbonates, such as iron oxids, copper oxids, silver oxids, manganese oxid, lead oxid, zinc oxid, or carbonates of the various metals.

The primary object of the invention is to provide a thoroughly practical and highly economical process which will enable metals to be obtained in a highly pure state, di-directly from the oxid and carbonate ores, thus obviating the serious difficulties and expensive methods of modern practice.

By way of preliminary explanation, it may be stated, for illustration, that the standard practice of producing iron from ores containing iron oxids is to subject an ore and fuel column mixed with suitable fluxes, said column being ordinarily of a height of 80 feet or more, to the action of a hot-air blast, and thus fusing the entire mass to enable the fused metal to be separated from the molten slag. In this manner, pig-iron is produced at a comparatively high cost, the pig-iron being impregnated, as is well known, with impurities, such as a high percentage of silicon and carbon. In order to produce a wrought-iron, or steel, the pig-iron must be subjected to a refining process, such as the Bessemer process. Some such operation must be carried on in order to produce either wrought-iron or steel, the desired percentage of carbon being left in or introduced into the iron when steel is to be produced.

In producing pig-iron in accordance with standard methods, it is a well-known fact that perhaps less than 20% of the heat units of coal are effectively utilized. In accordance with the present method, it is possible, for instance to produce a practically pure wrought-iron in one operation, utilizing a very high percentage of the heat-units of the fuel. The improved process may be carried on continuously and is highly economical. Moreover, the improved process renders it feasible to produce iron at the mines, thus saving large transportation expenses. No flux is required to practice the improved process, whereas, in standard practice, the rule is that it requires one ton of lime to produce one ton of pig-iron.

I am aware that for many years efforts have been made to metallize ores by a single continuous operation and in such manner as to obviate the objections incident to the standard blast practice, but so far as I am informed, no commercially successful method has been devised to effect the desired result. I am able, by the process herein described, to metallize ores on a commercial scale, using natural draft in the operation and producing a highly pure metal, and effecting such economy that a practically pure wrought-iron can now be produced for approximately one-half the cost of producing wrought-iron by standard methods.

As an instance of one of the more recent efforts to accomplish the purpose which I have accomplished by the new process herein described, I may refer to U. S. Patent No. 981,280, granted January 10, 1911, to John T. Jones. Since the application for the patent referred to was filed, many thousands of dollars have been expended in an effort, participated in by me, to produce metal in furnaces of the construction shown in said patent. The results, however, were imperfect, and thus far the process described in said patent has not been put into practice. I have discovered that it is necessary, in order to produce metal in tangible form in accordance with the new process herein described, to employ a de-oxidizing temperature far in excess of that which has ordinarily been understood to be necessary. For instance, authorities state that de-oxidizing of metal oxids will occur at a temperature of between 1400° F. and 1500° F. I have discovered that in order to produce metals in tangible form it is necessary to employ such a high heat as will effect a vastly more rapid interchange of oxygen than has hitherto been supposed, and that such high heat will fuse the metals and globe them, so that they will "set" or "fix" and will not be subject to re-oxidation. The de-oxidizing and globing of the metals must be effected in such manner as to prevent the formation of a molten bath and to avoid any general fusing of the earthy or slag-making

constituents of the ore. It is essential, therefore, to the practice of the new process not only that a de-oxidizing and metal-globing temperature shall be used, but, also, that the ore shall be carried in lump-groups or ore-portions, practically enveloped or isolated by solid carbonaceous fuel, through the de-oxidizing and metal-globing zone. It is also desirable that the ore and solid fuel shall be preliminarily heated to a temperature approaching the de-oxidizing temperature before passing into the de-oxidizing and metal-globing zone.

The improved process herein described can best be set forth in detail by reference to the accompanying drawings, which show a furnace adapted to the practice of the process, said furnace being the subject-matter of a co-pending application of John T. and Albert G. Jones, No. 827,476, filed of even date herewith.

Referring to the accompanying drawings Figure 1 represents a broken, elevational view of an ore-reducing furnace adapted to the practice of the invention; and Fig. 2, an enlarged broken, vertical, sectional view of the de-oxidizing chamber and attendant parts.

In the construction illustrated, A represents a de-oxidizing chamber or furnace; B, a pre-heating-device, preferably a slowly-rotating, inclined tube; and C, a smoke-stack connected with the upper end of the tube B. The ore and solid fuel are introduced into the pre-heating tube through a hopper 1 which communicates therewith through an inclined chute 2 extending through the chimney C. The tube B should be provided with a refractory lining. A furnace having a capacity of approximately 100 tons per day, such as would be afforded by a de-oxidizing chamber having a diameter of 20 feet, the tube is preferably of approximately 8 feet in diameter and 120 feet in length. The diameter of the smoke-stack may be 8 feet. The tube B is supported on rollers 3 and slowly rotated by any suitable means (not shown).

The pre-heated ore and fuel are discharged from the lower end of the tube B through an elbow 4 into the upper end of the de-oxidizing chamber or furnace A. The chamber A is preferably of circular form, and may have the base-portion 5 provided with the frusto-conical downwardly-converging inner surface 5^a, the portion 5 being surmounted by the dome or hemispherical wall 6 which is provided at its upper end with the contracted opening 6^a, through which the ore and fuel enter from the elbow 4. The lower portion of the chamber A should not be contracted internally to such extent as to cause choking, however.

Through the walls of the base-portion 5 extend adjustable twyers 7 fitted with air-regulating devices 7^a. Depending through the elbow 4 and through the upper portion 8 of the deoxidizing-chamber is a central twyer 9 whose lower end is disposed somewhat above the plane of the twyers 7. The lower end of the twyer 9 is protected by refractory material 9^a containing a water-coil 9^b. The upper end of the twyer 9 is fitted with an air-regulating device 9^c. The neck at the upper portion of the chamber A may be provided with a water-coil 10. If desired, the upper wall 6 of the chamber A may be provided with poker-openings fitted with plugs 11. Through the elbow 4 extends a twyer 12 fitted with an air-regulating-device 12^a, the twyer 12 serving to supply air to the lower portion of the pre-heating-device B.

The twyers 7 and 9 should be of ample size to admit sufficient air to provide a high heat at the inner ends of the twyers. In reducing iron-oxid ore, it is preferred to maintain the temperature at approximately 3500° F. in the vicinity of the inner ends of said twyers, carbon dioxid being produced at these points. As the gases pass upwardly, they change to deoxidizing gases, and the temperature gradually decreases, somewhat as indicated in Fig. 2. The twyer 12 should be of ample size to provide sufficient air to burn such combustible gases as pass into the pre-heating tube, thus providing for complete combustion of the gases and preventing waste. It is desirable to maintain a neutral, as distinguished from either an oxidizing or a de-oxidizing flame in the preheating tube. That is to say, air should be admitted in sufficient quantity to effect complete combustion of the gases, but not to attack the solid fuel in the pre-heater, and, preferably, reduction of the ore in the pre-heater will be avoided to prevent destruction of the pre-heating cylinder. The temperature in the lower portion of the tube B is preferably maintained, in reducing iron-oxid, for illustration, at about 2000° F. The temperature decreases gradually as the upper end of the tube B is approached, and at the upper end of the tube the temperature need not exceed about 500° F.

Preferably, the chamber A surmounts a soaking-pit 13 which may be of cylindrical form and which is adapted to receive the highly-heated mixture of ore and fuel as the charge settles down, the deoxidizing action being continued in the soaking-pit. The temperature decreases as the lower end of the pit is approached. Provision is made for discharging the metallized ore and coke (or charcoal) from the lower end of the pit 13. In the illustration given, a hydraulic ram or slide 14 provided with recesses 14^a and 14^b is employed to discharge the materials into discharge-pits 15 or upon the ground, if desired. The pit 15 may contain

water, or water may be directed upon the discharged materials by means of a hose, if desired, to quench the burning fuel, after which the fuel may be separated from the ore and charged again into the pre-heater with a relatively small amount of ore.

In the furnace illustrated, the reducing-chamber at or near its median horizontal portion, has a diameter of 20 feet, and the height of the chamber above said median portion is approximately 10 feet. Below the median portion the inner surface of the chamber preferably slopes downwardly and inwardly, as indicated. Preferably a plurality of the twyers 7 are employed. Eight of such twyers, each having a diameter of 23 inches, should be ample to furnish an air-supply to the lower portion of the reducing-chamber. The central vertical twyer 9 may have a diameter of 2 feet or more.

In practising the improved process in the furnace described, the ore, if hard, is preferably fed in a crushed condition, say of a size of 1 inch or less, in dimensions, with a charge of coke (or charcoal), through the hopper 1 into the upper end of the pre-heater B. As the pre-heater slowly rotates, the materials gravitate to the lower end thereof and are discharged into the de-oxidizing chamber A. In this manner, the material may be practically continuously discharged into the de-oxidizing chamber so as to keep the de-oxidizing chamber full, or practically full, of a mixture of fuel and ore. In Fig. 2, the upper frusto-conical surface of the charge or burden, in the furnace is indicated by the dotted lines 16.

It is desirable to feed through the furnace distilled solid carbonaceous fuel (coke or charcoal) having many times the bulk or volume of the ore and preferably having about twice the weight, or more than twice the weight, of the ore. This is particularly true in dealing with high-grade ores. It is also desirable to feed directly into the chamber A, as through the charging device 17, a relatively small amount of fresh solid fuel from which carbo-hydrates may be distilled, such as bituminous coal or wood.

As an illustration, in dealing with a high-grade iron ore, the materials may be used in the proportion of 400 pounds of coke, 100 pounds of bituminous coal, and 250 pounds of ore, the fuel having approximately twice the weight of the ore and being approximately five times as large in volume as the ore. If wood and charcoal be used in place of coke and coal, the disparity in volume is much greater. For illustration, with 2240 pounds of ore, one may use 96 cubic feet of charcoal and 32 cubic feet of wood. In any case, it is preferred to use the fuel mainly in comparatively large lump or block form, although this is not indispensable. Cord or slab wood 16 inches long may be conveniently used, and where coal is used it is preferably used mainly in large lumps. As will be explained, the coke (or charcoal) is used over and over again, being gradually reduced in size, but being constantly replenished by freshly-formed coke (or charcoal) when the process is carried on in the preferred manner.

When passing through the pre-heater the ore and fuel are highly pre-heated and thus are in condition to enable a rapid interchange of oxygen to take place in the de-oxidizing chamber, where the temperature is maintained at a sufficiently high point to de-oxidize the metals and also fuse the metal particles and run them together in globes, or masses of globular lumps, the ore-groups or clusters being, in effect, isolated from each other and enveloped by pieces, lumps, or blocks of solid carbonaceous fuel while this action takes place, so that no molten bath is formed, and preferably any general fusing of the earthy materials or gangue of the ore is avoided. As the materials settle down into the soaking-pit the de-oxidizing action upon the metal oxids continues, but as the lower end of the soaking-pit is approached, the temperature gradually becomes lower. In the passage of the ore and fuel through the de-oxidizing chamber, myriads of minute metallized particles or globules may adhere to the coke or charcoal, and when the coke or charcoal is again fed through the furnace, these minute particles become fused and coalesce, forming globes, or globular masses, or masses of globes or globules, thus putting the metal in such tangible form or size as to enable it to be separated or concentrated by any suitable method. The sizes of the metal pieces may vary greatly, but eventually, whether of very fine mesh, or of meshes of very considerable size, say of sizes ranging up to 1 inch or larger, the metals are nevertheless produced in lumps of such tangible size as to enable them to be readily collected and with the metal in "set" or "fixed" condition, so that re-oxidizing will not occur. It will happen especially with rich iron or manganese ores that isolated pools of metal will form and congeal as the materials descend below the hottest zone; and it may happen, where the gangue contains a natural flux that small isolated fused portions or pools of gangue will form and sodidify as the charge slowly descends. In any case, the carbonaceous ore-spacing materials should be in such abundance and the air supply should be so regulated as to avoid destroying the spacing function of the fuel. That is, a preponderance of distilled solid fuel should be carried wholly through the de-oxidizing-chamber and bathing or general fusing of the charge is to be avoided.

It is noteworthy that the pre-heating tube

and smoke-stack are of comparatively large dimensions, so that the gases will pass freely therethrough, while the de-oxidizing chamber A is of relatively small height and large horizontal circumference or area, from which it follows that it is entirely practicable to carry on the metallizing operation by means of natural draft, thus avoiding the high expense incident to the operation of a blast furnace which is universally employed in modern practice for producing iron. In a furnace of small capacity, the height of the burden through which the air is drawn may be greater than the diameter of the chamber, but as compared with a blast furnace the height is preferably very low.

While the use of the air-blast is unnecessary, it is to be observed that, if desired, one could employ a blast in connection with the furnace shown, the twyers being suitably reduced; and such a blast could be operated at comparatively small expense, inasmuch as but slight pressure would be required. Moreover, inasmuch as a very high percentage of the heat units are utilized in this process and the carbo-hydrates produced from the fresh fuel directly in the deoxidizing chamber are utilized for de-oxidizing purposes, and general fusing is avoided, it will be understood that less air is used in the practice of the improved process than is necessary in the operation of the blast furnace. The furnace illustrated affords ample space in its upper portion for the inevitable swelling of the materials in the upper portion of the de-oxidizing chamber, and the de-oxidizing chamber is also of such form that the materials, and particularly the iron, are largely kept out of contact with the lining of the upper portion of the de-oxidizing chamber, so that the walls of the chamber will not be destroyed. By the practice of the improved process it is possible to produce practically pure iron, which, as is well known, possesses about twice the value of pig-iron on the market. Moreover, it is entirely feasible to obtain metals by direct process without use of fluxes, and operating with natural-draft. In producing iron, no lime need be added, whereas the usual rule in blast practice is that it requires 1 ton of lime to produce 1 ton of pig-iron. In ores containing natural flux, such as a mixture of lime or magnesium, or both, with the more refractory silica, the slag-making constituents will be fused at a lower temperature than in the case of silica alone or lime alone. In any case, the process should be so practised as to avoid general fusing of the earthy constituents or gangue, or the production of a bath, it being highly important to prevent the contamination of the metals which occurs when all of the materials are fused, as is the case in blast practice.

In treating iron-ore, it is entirely feasible, by the improved process, to produce comparatively large masses of coalesced or agglomerated globes or globules of iron, but without producing a bath, and without any general fusing of the gangue, the metal being in a highly pure state and capable of being removed from the furnace in solid form.

Manganese may be produced in comparatively large globular masses, as well as in smaller but still thoroughly tangible globules, by the same treatment as has been described for iron-ore. Copper may be produced in the same manner, and several metals, such as copper and iron, may be produced by one and the same treatment. In dealing simply with a copper ore, somewhat less fuel need be used, and copper may be produced at a somewhat lower temperature than is the case with iron.

Owing to the fact that zinc and lead volatilize at a temperature of approximately 2200° F., they must either be treated separately from the high fusing metals, such as iron, copper, manganese and silver, or some special provision must be made for collecting and condensing the vapors. If lead-ore, or zinc-ore, or both, be treated in accordance with the improved process, and it be desired to remove these elements in metallic form, great care must be exercised to recover the metals, and also to avoid their coming in contact with air while in a condition approaching the vaporization point. They should therefore be carefully treated and preferably cooled in a de-oxidizing zone.

One important advantage of the improved process will be understood when it is explained that in some regions are found vast deposits of high-grade iron ores, and near at hand are found large deposits of coal, or large supplies of wood, but with no flux, or lime, at hand. Such a condition is more apt to exist in rather inaccessible regions, from which it will be understood that the improved process will result in large economies, quite aside from the fact that the improved process results in the utilization of such a high percentage of the heat units developed in using the fuel. Again, in certain regions, there exist vast deposits of copper-oxids, zinc-oxids, lead-oxids, and carbonates, of these metals, which are not at the present time amenable, because of their low grade, to treatment, and therefore remain untouched. The present process renders it entirely feasible to metallize the copper-oxids, for illustration, thus producing metal globules or globes ranging in size from an intangible globule to the size of a pea. In such case, the ore, after subjection to the metallizing process, may be coarse crushed and subjected to a jigging operation to remove the large metal globules, after which the ore may be finely pulverized,

or ground, and subjected to a tabling or other concentrating operation; or any other preferred method of recovering the metal from the ore may be employed. It has been found, for illustration, that a copper-ore, after subjection to the improved metallizing process herein described, is amenable to treatment in accordance with the Lovett process described in U. S. Reissue Patent No. 13517; and that concentration with a high degree of saving can be effected, even where the metals are of exceedingly fine mesh.

The improved process may be practised, if desired, in a furnace employing a down-draft de-oxidizing-chamber of the type disclosed in the application of Albert G. Jones No. 827,357 filed of even date herewith. It may be added that, if desired, highly-refractory blocks or lumps, such as silica-boulders, may be passed with the coke or charcoal through the furnace. In such case, both the coke, or other lump-fuel, and the boulders, would serve as spacers adapted to practically isolate the ore-groups. In any case, however, it would be necessary to supply sufficient fuel to produce the necessary de-oxidizing-gas and such high temperature as would be sufficient to enable a rapid interchange of oxygen to occur and to effect fusing of the metals to enable the globing or coalescing effect to take place, care being taken, however, to avoid producing a bath of the slag-making constituents of the ore.

From the foregoing, it will be understood that preferably a limited supply of air is introduced into and burned at high temperature within a low stack of preheated distilled solid fuel and ore-portions substantially isolated therein, together with a relatively small amount of solid fuel containing hydro-carbons, the air supply being limited, however, to provide a de-oxidizing medium which nevertheless performs its mission largely at high temperature, or under metal-fixing conditions; and burning the combustible gases, after they have served their de-oxidizing function, in contact with the replenishing stream of ore and distilled solid fuel, under neutral conditions, thus pre-heating, without oxidizing the fuel or de-oxidizing the ore, the replenishing stream or mixture as it gravitates, while undergoing agitation, down the slowly revolving preheating tube.

The foregoing detailed description has been given for clearness of understanding, and no unnecessary limitation should be understood therefrom, but the appended claims should be construed as broadly as permissible in view of the prior art. It is my intention to claim all of my invention as it shall appear in view of the prior art, regardless of any variations which may be practised.

What I regard as new and desire to secure by Letters Patent is—

1. The process of recovering metal from ores of the class herein referred to, which consists in subjecting a slowly-settling charge of ore mixed with lump fuel of several times its volume sufficient to maintain the ore-groups in substantial isolation, to a de-oxidizing medium and a metal-fusing and globing temperature, without forming a bath, and without general fusing of the slag-making constituents of the ore.

2. The process of recovering metal from ore, which consists in slowly passing ore portions and solid fuel of several times the volume of the ore and serving to practically isolate said portions through a de-oxidizing-chamber and supplying and burning air therein sufficient to produce a de-oxidizing medium and metal-fusing-and-globing temperature, without effecting general fusing of the slag-making constituents, and removing the metals and earthy constituents in solid form with the unburned solid fuel.

3. The process of recovering metal from ore, which consists in slowly passing ore portions and solid fuel of several times the volume of the ore and serving to practically isolate said portions through a de-oxidizing-chamber and supplying and burning air therein sufficient to produce a de-oxidizing medium and a metal-fusing-and-globing temperature, without effecting general fusing of the slag-making constituents, removing the metals and earthy constituents in solid form and the unburned solid fuel, and repeatedly recharging the recovered solid fuel and adhering metal globules, with fresh ore and sufficient fresh solid fuel to maintain the proportions into the de-oxidizing-chamber.

4. The process of recovering metals, which volatilize, if at all, at high temperatures, which consists in subjecting, in a de-oxidizing-chamber, a low pile of ore mixed with several times its volume of coke or charcoal, which is mainly in large pieces and which serves practically to isolate the ore-portions, to a de-oxidizing gas and a metal-fusing temperature ranging upwardly from approximately 2000° F., but insufficient to effect general fusing of the earthy constituents of the ore or the formation of a bath, and removing the unused solid fuel and the metal and gangue as solids from the de-oxidizing-chamber.

5. The process of recovering metals, which volatilize, if at all, at high temperatures, which consists in subjecting, in a de-oxidizing-chamber, a low pile of ore mixed with several times its volume of coke or charcoal, which is mainly in large pieces and which serves practically to isolate the ore portions, to a de-oxidizing medium at metal-fusing temperature ranging upwardly from

approximately 2000° F., supplying air sufficient to produce such temperature but insufficient to effect general fusing of the earthy constituents of the ore or the formation of a bath, removing the unused solid fuel and metals and gangue in solid form, separating the coke and adhering metal globules, and feeding the same again through the de-oxidizing-chamber with a fresh ore-charge and with sufficient new fuel to maintain the proportions.

6. The process of recovering metals, which consists in subjecting, in a de-oxidizing-chamber, a low pile of pre-heated ore mixed with several times its volume of coke or charcoal, serving to practically isolate or envelop the ore portions, to a hot de-oxidizing and metal-fusing temperature, under natural-draft and without general fusing of the earthy constituents or the formation of a bath, and removing the unused solid fuel and the metal and gangue as solids.

7. The process of recovering metals, which volatilize, if at all, at high temperatures from ores of the class herein referred to, which consists in subjecting, in a deoxidizing-chamber, a low pile of ore mixed with several times its volume of coke or charcoal, which is mainly in large pieces and serves practically to isolate or envelop the ore portions, to a de-oxidizing medium and a metal-fusing temperature ranging upwardly from 2000° F., but without general fusing of the earthy constitutents or the formation of a bath, and removing the unused solid fuel and the metal and the gangue as solids.

8. The process of recovering metals, which volatilize, if at all, at high temperatures from ores of the class herein referred to, which consists in subjecting, in a de-oxidizing-chamber, a low pile of ore mixed with several times its volume of coke or charcoal, which is mainly in large pieces and serves practically to isolate or envelop the ore portions to a de-oxidizing and metal-fusing temperature ranging upwardly from 2000° F., under natural draft, with limited air-supply and without general fusing of the earthy constituents or the formation of a bath, and removing the unused solid fuel and the metal and the gangue as solids.

9. The process of recovering metals which volatilize, if at all, at high temperatures, which consists in pre-heating a mixture of ore and several times its volume of coke or charcoal, to a temperature of approximately 2000° F., and then passing the same through a de-oxidizing and metal-fusing zone ranging upwardly high above 2000° F., but without effecting general fusing of the slag-making constituents of the ore or forming a bath and removing the unburned coke and the metals and gangue as solids.

10. The process of recovering metals which volatilize, if at all, at temperatures much exceeding 2200° F., which consists in passing a mixture of ore and several times its volume of coke or charcoal through a pre-heating chamber and raising the temperature thereof to approximately 2000° F., and then feeding the materials in the form of a stack slowly through a de-oxidizing-chamber supplying sufficient air thereto to produce a temperature ranging upwardly above 2000° F., but without effecting general fusing of the earthy constituents of the ore or forming a bath, and removing the unconsumed coke and the metals and gangue as solids.

11. The process of recovering metals which volatilize, if at all, at temperatures above 2200° F., which consists in feeding a mixture of ore and several times its volume of coke or charcoal through a pre-heating device, then discharging said materials at a temperature approximately 2000° F. into a de-oxidizing-chamber adapted to maintain the materials in a low stack, charging a relatively small amount of solid fuel containing hydro-carbons into the de-oxidizing chamber, supplying to the de-oxidizing chamber sufficient air to produce a de-oxidizing and metal-fusing temperature, ranging in one zone far above 2000° F. and decreasing in temperature to form de-oxidizing gases, passing the de-oxidizing gases into the pre-heating-device and supplying air in limited quantity to the pre-heating-device to consume the gaseous fuel therein, the temperature in the de-oxidizing-chamber being such as to avoid forming a bath of the earthy constituents of the ore.

12. The process of recovering metals which volatilize, if at all, at high temperatures, which consists in passing a mixture of ore and several times its volume of coke or charcoal, through a large dimensioned pre-heating-device so disposed that gases may pass freely therethrough without undue obstruction by the ore and fuel, then passing the pre-heated materials into a de-oxidizing-chamber adapted to maintain the materials in a relatively-low stack, passing air into the stack of materials in the de-oxidizing-chamber at low pressure and in sufficient quantity to produce a temperature in one zone of said stack ranging far above 2000° F., decreasing the temperature as said zone is departed from to form a de-oxidizing gas, said operation being carried on without forming a bath of the slag-making constituents of the ore, passing the de-oxidizing-gas from the de-oxidizing-chamber into the pre-heating-device, and supplying air to the pre-heating device to burn the combustible gases therein.

13. The process of recovering metals, which consists in subjecting, in a de-oxidizing-chamber, a low pile of ore mixed with several times its volume of coke or charcoal, which is mainly in large pieces and serves to

isolate the ore-lumps, to a hot de-oxidizing and metal-fusing-and-globing medium, using air introduced into the ore-pile under natural-draft or low pressure, the operation being carried on without forming a bath of the earthy constituents of the ore, allowing the materials thus treated to settle down into a soaking-pit wherein de-oxidizing gases are maintained at a lower temperature, and finally removing the unconsumed coke and the metals and gangue in solid form from the soaking-pit.

14. The process of recovering metal from ores of the class herein referred to, which consists in supporting from below a stack comprising solid refractory spacing material and ore-portions mixed therewith, the spacing material having several times the volume of the ore and serving to substantially isolate the ore-portions, and passing air therethrough in sufficient quantity to maintain a temperature in excess of 2500° F. in one zone in the stack, sufficient fuel being present to provide the necessary temperature and provide deoxidizing gases in another zone in the stack, the operation being carried on without forming a bath of the gangue, the spacing material continuing in excess throughout the operation and being recovered in solid form at the bottom of the stack.

15. The process of recovering metal from ores of the class herein referred to, which consists in substantially isolating ore-portions in a supported stack of solid carbonaceous spacing materials of several times the volume of the ore, passing air through said stack in regulated quantity to produce in one zone in the stack a temperature exceeding 2500° F. and in another zone a reducing gas, so that metallization and fusing sufficient to "fix" the metals will occur, without forming a bath of the gangue; and removing the unconsumed carbonaceous spacing materials and gangue in solid form from the bottom of the stack.

16. The process of recovering metal from ores of the class herein referred to, which consists in passing through a supported burden of distilled solid fuel and ore-portions substantially isolated therein, undergoing combustion, air in regulated quantity to produce in one zone in said burden a temperature exceeding 2200° F. and in another zone a de-oxidizing gas, but without destroying the spacing function of the fuel and without forming a bath of the gangue.

17. The process of recovering metals which consists in passing through a supported burden of distilled solid fuel and a relatively small amount of solid fuel containing hydro-carbons and ore-portions substantially isolated in said fuel, said burden undergoing combustion, air sufficient to produce in one zone in said burden a temperature exceeding 2500° F., but limited to provide in another zone a de-oxidizing gas and to avoid destroying the spacing function of the fuel and to avoid forming a bath.

18. The bathless process of recovering metals which consists in passing through a supported stack of distilled solid fuel and a relatively small amount of solid fuel containing hydro-carbons, undergoing combustion, and ore-portions substantially isolated in said fuel, air regulated to produce in one zone in said stack a temperature exceeding 2500° F. and in another zone de-oxidizing gases, thereby effecting metallization and "fixing" of the metals, without producing a general bath, removing portions of the unconsumed fuel, metals and gangue from the bottom of the stack, and burning the de-oxidizing gases in the free conduit through which the ore and distilled solid fuel pass to replenish said stack.

19. The bathless process of recovering metals which consists in burning a limited supply of air at a high temperature in a stack of pre-heated distilled solid fuel and ore-portions substantially isolated therein, thus maintaining a metallizing and metal-fixing medium in said stack, removing solids from the bottom of the stack, and burning the combustible gases, after they have served the de-oxidizing function, and using them for pre-heating the distilled fuel and ore as it is supplied to the top of said stack.

20. The bathless process of recovering metals which consists in burning a limited supply of air at a high temperature in a stack of pre-heated distilled solid fuel and ore-portions substantially isolated therein, thus maintaining a metallizing and metal-fixing medium in said stack, removing solids from the bottom of the stack, and burning the combustible gases, after they have served the de-oxidizing function, and using them for pre-heating, without either oxidizing or de-oxidizing, the distilled fuel and ore supplied to the top of said stack.

21. The bathless process of recovering metals which consists in burning a limited supply of air at a high temperature in a stack of pre-heated distilled solid fuel and ore-portions substantially isolated therein, together with a relatively small amount of solid fuel containing hydro-carbons, mixed with the pre-heated distilled fuel and ore, the fuel being of several times the weight of the ore, thus maintaining a metallizing and metal-fixing medium in said stack, removing solids from the bottom of the stack, and burning the combustible gases, after they have served the de-oxidizing function, and using them for pre-heating the distilled fuel and ore as it is supplied to the top of said stack.

22. The bathless process of recovering

metals which consists in burning a limited supply of air at a high temperature in a stack of pre-heated distilled solid fuel and ore-portions substantially isolated therein, thus maintaining a metallizing and metal-fixing medium in said stack, removing solids from the bottom of the stack, and burning the combustible gases, after they have served the pre-heating function, in an unobstructed conduit, under neutral conditions, in contact with distilled fuel and fresh ore used to replenish the supply at the top of said stack.

23. The process of recovering metals, which consists in highly heating, in a de-oxidizing chamber, a stack composed of a mixture of ore and infusible spacing lumps of several times the volume of the ore and serving to practically isolate the ore-lump groups, said spacing-lumps including solid carbonaceous fuel, introducing a limited supply of air in said stack of materials and maintaining a temperature in a zone in said de-oxidizing-chamber sufficient to fuse the metals, but without forming a bath of the earthy constituents of the ore.

24. The process of recovering metals, which consists in highly heating, in a de-oxidizing chamber, a burden composed of a mixture of ore and infusible spacing-lumps of many times the volume of the ore and serving to practically isolate the ore-lump groups, maintaining in the chamber a de-oxidizing gas and a temperature in a zone thereof sufficient to fuse the metals, but without forming a general bath of the materials passing through said chamber.

ALBERT G. JONES.

In the presence of—
NELLIE B. DEARBORN,
OTTILIE C. AVISUS.