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ELECTROMETALLURGICAL PROCESS OF REDUCING METALLIC OXIDS.

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1,075,295. Patented Oct. 7, 1913.

Fig. 1

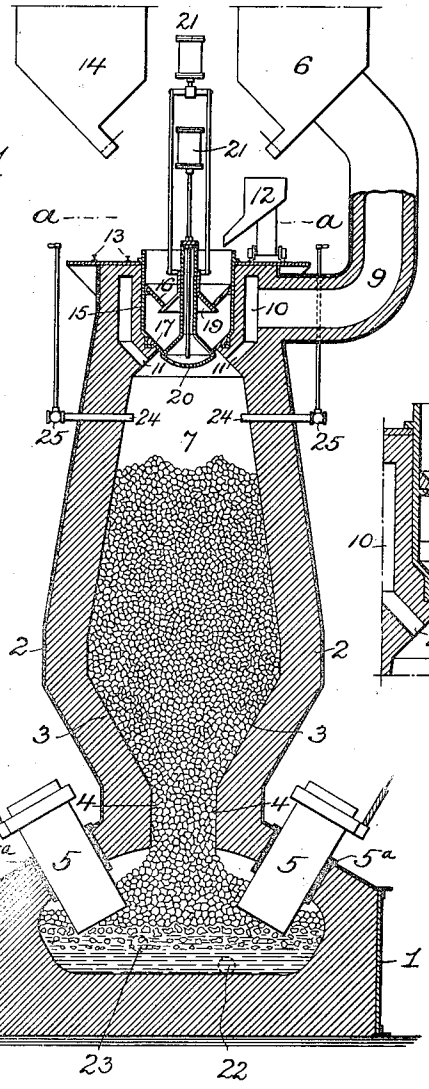


Fig. 2

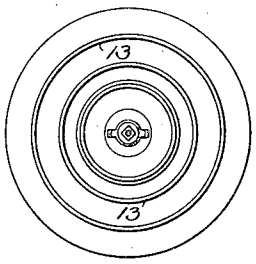


Fig. 3

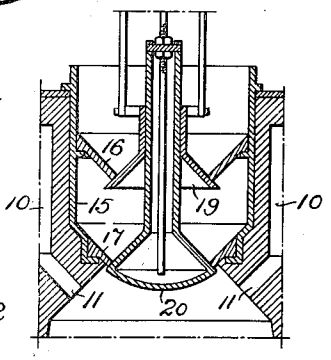
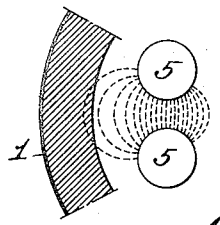


Fig. 4



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UNITED STATES PATENT OFFICE.

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ELECTROMETALLURGICAL PROCESS OF REDUCING METALLIC OXIDS.

1,075,295. Specification of Letters Patent. Patented Oct. 7, 1913.

Original application filed April 13, 1909, Serial No. 489,718. Divided and this application filed February 1, 1910. Serial No. 541,347.

To all whom it may concern:

Be it known that we, DORSEY A. LYON and EDWIN R. COX, Jr., citizens of the United States, and residents, respectively, of Palo Alto, county of Santa Clara, and State of California, and of Heroult, county of Shasta, and State of California, have invented certain Improvements in Electrometallurgical Processes of Reducing Metallic Oxids, of which the following is a specification.

The object of our invention is to provide an electrometallurgical process for reducing a metallic oxid, whereby the simplest and most economical form of apparatus or furnace may be used and the cost of operation may be reduced to a minimum, while a maximum yield of metal per kilowatt of electrical energy employed may be obtained, and particularly to provide such a process which shall be adapted for the production of iron or steel directly from the iron ore.

This application is a division of our application Serial Number 489,718, filed April 13, 1909, in the latter of which we disclose and claim a suitable form of apparatus for working our novel and improved process.

In the drawings we have illustrated a suitable and preferred form of apparatus for carrying out our improved process, in which—

Figure 1 is a vertical sectional view of an electrometallurgical furnace wherein our process may be practised; Fig. 2 is a sectional plan view on the line *a*—*a*, Fig. 1, but omitting the scale car shown in said figure; Fig. 3 is an enlarged vertical section of the charging mechanism at the top of the furnace; and Fig. 4 is a sectional plan view illustrating the position of the electrodes in respect to the outer wall of the crucible member of the furnace.

Our invention, while applicable in whole or in part to various furnaces, has been especially designed for the commercial production of iron or steel from ores with greater economy than has hitherto been attained with electric furnaces.

Our furnace in its entirety comprises the following members: 1st, an arched crucible of the electric resistance type; 2d, a stack superposed thereon and built substantially upon blast furnace lines; 3d, a contracted throat joining the crucible and the bosh of the stack; 4th, a combustion chamber at the top of the stack; 5th, charging mechanism, including devices for proportioning and distributing the charge and sealing the opening of the furnace against the admission of air and escape of gas; 6th, a preheater for ores and fluxing materials; 7th, a carbon bin or chute.

Referring now to the drawings, in which the same reference characters relate to the same or corresponding parts in all the views, 1 represents the crucible member at the base of the furnace, and 2 a superposed stack which resembles an ordinary blast furnace and has a bosh 3 communicating through a throat 4 with the working chamber of the crucible member. The roof of this chamber is arched from the side walls to the throat 4, any desired geometric form of arch being employed, such as a zone of a sphere, a frustum of a cone or pyramid, or any combination of or approximation of these figures, so long as it forms an angle with the horizontal which is substantially less than the angle of repose of the charge as it descends from the throat 4 to the bottom of the working chamber of the crucible, the object of this construction being to provide a space between the roof of said working chamber and the sloping sides of the charge, which space is filled with the gases of reduction, arising from that portion of the charge which is contained in the crucible.

The electrodes 5 pierce the roof of the crucible, pass through the gas space and enter the charge, the heat of the crucible being generated substantially by the current passing through the charge.

It is a well known fact that no refractory lining has yet been devised which does not become a fairly good conductor of electricity at the temperature of the electric crucible, and the heat-resisting properties of the usual refractory linings, such as firebrick, have about reached their limit in a blast furnace, consequently, if, to the heat which the walls receive by direct radiation and conduction from the melting zone, there is added heat generated by stray electric currents passing through the walls of the crucible the life of the lining is very short, the refractory material being rapidly melted down and passing away in the slag. By providing a gas space between the charge and the crucible roof this difficulty is obviated, for, as the gas has a much lower heat

conductivity than a charge consisting of largely reduced ore and metal, the insulation 5ª between the electrode and the refractory lining of the crucible roof is readily preserved and the lining is kept at a lower temperature than it could possibly be if it was in direct contact with the charge; furthermore, the length of the stray path of current is so much longer than the direct path through the charge, as indicated by the dotted lines in Fig. 4, that but a very small proportion of the current passes through the lining and this is not sufficient to materially affect the life of the latter.

In the operation of the furnace the ore, preferably mixed with its proper proportion of fluxing materials, is fed into a preheater 6, wherein it is dried and heated and the carbon dioxid is driven off from the limestone, in case the latter is used as a flux, the source of heat for the preheater being the products of combustion from the combustion chamber 7 at the top of the stack, which are let into the base of the preheater through a flue 9 communicating with an annular chamber 10 surrounding the top of the stack, connected with the combustion chamber 7 through openings or ducts 11.

A scale car 12 runs upon a circular track 13 around the top of the stack and alternately receives a charge of ore and flux from the preheater 6, and a weighed charge of carbon, preferably in the form of coke or charcoal, from the carbon hopper 14, these charges being delivered alternately, by the mechanism hereinafter described, into the body of the furnace.

The charging mechanism at the top of the stack comprises a tubular shell or hopper 15 having an upper inclined lip ring 16 and a lower inclined lip ring 17, both of which are provided with external shoulders resting upon suitable internal shoulders in the hopper, so that they can be readily removed therefrom without disturbing the hopper.

Coöperating with the upper lip ring 16 is an upper bell or cone 19 and coöperating with the lower lip ring 17 is a lower bell or cone 20, the latter being closed at the bottom and each bell being combined with suitable mechanism, preferably an air, steam or hydraulic cylinder 21, for raising and lowering it independently of the other. Since the lower bell also forms part of the combustion chamber roof it is preferably made in the form commonly called a "mushroom" valve and is water-cooled.

In the operation of the charging device for feeding a charge of ore and flux into the furnace, the charge is first dropped into the upper portion of the hopper, the bell 19 being closed, and after the charge is properly distributed about the hopper, the bell 19 is lowered so as to permit the charge to pass into the lower compartment of the hopper, the upper bell being then closed and the lower bell 20 opened, so as to permit said charge to pass into the stack. The charge of carbon is then fed into the lower compartment of the hopper in the same way and remains there until the next charging time arrives, the upper bell being then slightly lowered to permit the absorbed air and moisture in the carbon to escape as the latter is heated by the hot gases circulating about the hopper in the annular chamber 10. When the next time for charging arrives the upper bell is raised and the lower bell is lowered so as to permit the carbon charge to fall into the stack, and this is followed by a mixed charge of ore and flux which, however, is not permitted to remain in the lower compartment of the hopper but is fed immediately into the stack, the lower compartment of the hopper then receiving another carbon charge which is retained therein until the next charging interval, so that, if the latter interval is, for instance, ten minutes, and the charging operation requires two minutes, each charge of carbon will be heated and dried for eight minutes while being retained in the hopper and before being dropped into the stack.

It is the generally accepted theory of blast furnace reactions that, at the high temperature of the crucible or hearth, solid carbon is the most effective reducing agent, some claiming that the final stage of reduction can only be completed by solid carbon, while farther up in the stack, at a lower temperature, carbon monoxid is the more effective reducing agent. In our furnace, the reaction in the crucible would be

$$FeO+C=Fe+CO,$$

and farther up in the stack the reaction would be

$$FeO+CO=Fe+CO_2,$$

and

$$CO_2+C=2CO,$$

accordingly the volume of carbon monoxid is constantly doubling with each cycle of reduction as it rises in the stack. We find that in this way sufficient gas is generated to efficiently carry on the stack reduction without forcing carbon monoxid into the crucible, and the entire function of the gas space in the latter is to lengthen the life of the walls and electrode insulation.

The stack is built upon lines approximately those of blast furnace practice, as such lines have been demonstrated to be best suited for a proper settling of the charge while, at the same time, providing a sufficient volume for keeping the ascending gas and the descending charge in contact long enough for effective reduction.

By the time the charge has reached the contracted throat which connects the crucible with the bosh 3, the ore has been largely reduced and the function of the crucible is to finish the reduction and melt the resulting metal and slag, which are drawn off from the crucible through suitable tapping holes 22 and 23, the contracted throat serving the purpose of restricting the volume of the charge in the crucible so as to secure the concentration of heat necessary for the final stage of reduction and the melting of the metal and slag.

Any desired form of ore preheater may be employed, our preference being for the shelf kiln type such as has been generally used for roasting mercury ores, the hot gases from the flue 9 passing up through the preheater in intimate contact with the ore and heating it to a high temperature besides driving off any moisture contained therein, and also expelling the carbon dioxid contained in the limestone when the latter is used as a flux.

The carbon bin or hopper 14 should have sufficient storage capacity to prevent accidental interruption in the operation of the furnace, and this bin is provided with a valved spout for governing the discharge therefrom, as is also the ore preheater.

To effect the combustion of the carbon monoxid in the combustion chamber 7 of the furnace, we provide the latter with twyers or nozzles 24 for the supply of air from a conveniently arranged air pipe, the supply being regulated by means of valves 25.

The pre-heating of the ore before it enters the furnace serves not only to dry it and calcine the limestone but also to raise the ore and flux to such a high temperature as to permit of the reduction of the ore the moment it enters the stack, only enough gas being burned in the top of the stack to keep up the reduction temperature in the hot charge by maintaining the brickwork of the stack at such a temperature as to prevent it from absorbing heat from the charge when it first enters the stack. The gas burned in the top of the stack also serves to restore to the charge any heat which it may have lost during its transference from the preheater to the top of the stack.

If the charge is not preheated and the same has to be raised to the reduction temperature after it has entered the stack such raise in temperature is more difficult to effect and the efficiency of the process is materially impaired.

The operation of a process such as that forming the subject of our invention is attended with numerous advantages, all tending to the production of a commercially successful furnace, among which advantages we may enumerate, first, the moderate first cost of the requisite furnace, due to simplicity of general design, and low labor cost, due in particular to the convenience and efficiency of the charging mechanism, which can be readily operated by one man who also attends to the air regulation; secondly, the long life of parts, securing continuous operation and low cost of repairs, the general construction of the furnace, including the water cooling of the lower bell 20, tending to this result; but, thirdly, the important feature of advantage, in the practice of our process, is the preservation of the crucible line, this being generally recognized as the most troublesome and inconvenient part of an electric furnace; fourthly, the low consumption of carbon, which is secured by protecting the carbon from being consumed by the air admitted for the combustion of the carbon monoxid in the upper portion of the stack, and also by reducing the carbon dioxid resulting from combustion, the function of the carbon being thereby restricted to the reducing process and a large portion of the heat necessary to render the reducing process effective being supplied by the calorific value of the carbon monoxid resulting from such reduction; and, fifthly, the large yield per kilowatt of electrical energy which follows from the efficient utilization of the calorific value of the carbon monoxid, the heat generated by combustion of the latter largely replacing what would otherwise have to be generated electrically.

From the foregoing description of the operation of the process and the essential advantages thereof, it will be noted that the third specified important feature of advantage, namely, the preservation of the crucible line, is mainly due to the particular formation of the contour of the upper wall of the crucible coöperating with the contracted throat connecting the stack of the furnace with the crucible in such a way that the gases generated in the crucible are entrapped therein, that portion of the descending charge occupying the throat completely filling the same, so as to substantially seal the opening to the crucible. A body of gases which acts to an appreciable extent, as a non-conductor to the heat generated by counter-currents of electricity within the crucible is thus maintained in the closed space therein.

We claim as our invention:

1. The herein described improved process for reducing a metallic oxid by subjecting the same to the action of carbon and an electric current, comprising the following essential steps: first, preheating the ore by subjecting said ore to the action of a current of hot products of combustion derived from the subsequent heating of the ore; second, charging said ore, mixed with carbon in suitable proportions, into a suitable re-

ducing stack or furnace; third, subjecting said charge to the heat of a flame above the surface thereof, formed by feeding jets of air above said surface; fourth, reducing said metallic oxid by the action of the carbon charged therewith and the resultant gases generated in the ore body during its passage through the stack, and finally, subjecting the charge so treated to heat, generated by an electric current, sufficient to melt the resultant metal, substantially as described.

2. The herein described improved process for reducing a metallic oxid by subjecting the same to the combined action of carbon and an electric current, comprising the following essential steps: first, preheating the ore by subjecting said ore to the action of a current of hot products of combustion derived from the subsequent heating of the ore; second, charging said ore, mixed with carbon in suitable proportions, into a suitable reducing stack or furnace; third, subjecting said charge to the heat of a flame above the surface thereof, formed by injecting air above said surface in quantity only sufficient to combine with a portion of the carbon monoxid; fourth, reducing said metallic oxid by the action of the carbon charged therewith and the resultant gases generated in the ore body in its passage through the stack, and finally, subjecting the charge so treated to heat, generated by an electric current, sufficient to melt the resultant metal, substantially as described.

3. The herein described improved process for reducing a metallic oxid by subjecting the same to the combined action of carbon and an electric current, comprising the following essential steps; first, preheating the ore by subjecting said ore, admixed with suitable fluxing materials, to the action of a current of hot products of combustion derived from the subsequent heating of the ore; second, charging said ore, mixed with carbon in suitable proportions, into a suitable reducing stack or furnace; third, subjecting said charge to the heat of a flame above the surface thereof formed by injecting air above said surface; fourth, reducing said metallic oxid by the action of the carbon charged therewith and the resultant gases generated in the ore body during its passage through the stack, and finally, subjecting the charge so treated to heat, generated by an electric current, sufficient to melt the resultant metal and slag, substantially as described.

4. The herein described improved process for reducing a metallic oxid by subjecting the same to the action of carbon and an electric current, comprising the following essential steps: first, preheating the ore by subjecting said ore, admixed with suitable fluxing materials, to the action of a current of hot products of combustion derived from the subsequent heating of the ore; second, charging said ore, mixed with carbon in suitable proportions, into a suitable reducing stack or furnace; third, subjecting said charge to the heat of a flame above the surface thereof produced by feeding air above said surface in quantity sufficient to combine with a portion only of the carbon monoxid produced by reduction, the remainder of said carbon monoxid being utilized to partially reduce the ore as well as to preheat it; fourth, completely reducing said metallic oxid by the action of the carbon charged therewith and the resultant gases generated in the ore body during its passage through the stack, and finally, subjecting the charge so treated to heat, generated by an electric current, sufficient to melt the resultant metal and slag, substantially as described.

In testimony whereof, we have signed our names to this specification, in the presence of two subscribing witnesses.

DORSEY A. LYON.
EDWIN R. COX, JR.

Witnesses:
EARL M. BALDWIN,
W. B. HARPER.