No. 608,779.

Patented Aug. 9, 1898.

A. KARYSCHEFF.

METHOD OF AND APPARATUS FOR REDUCING OXID OF IRON.

(Application filed May 11, 1896.)

(No Model.)

5 Sheets—Sheet 1.

Fig. 2.

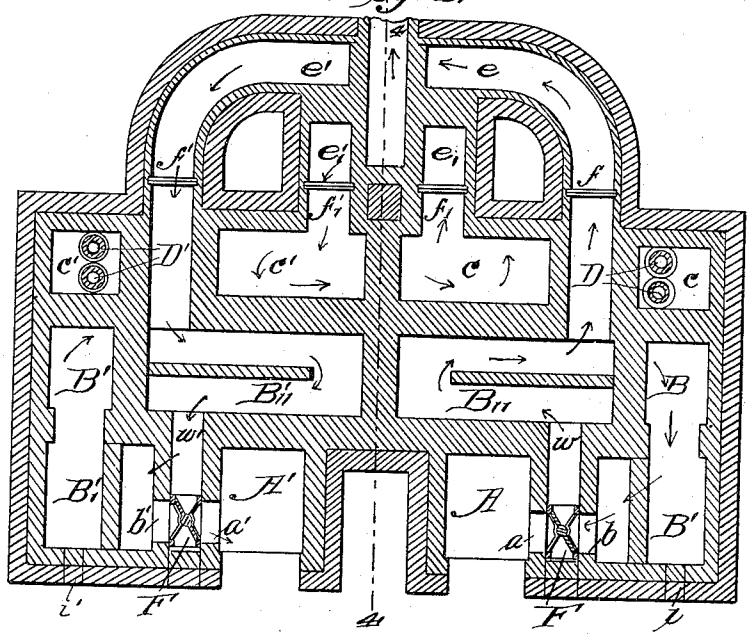
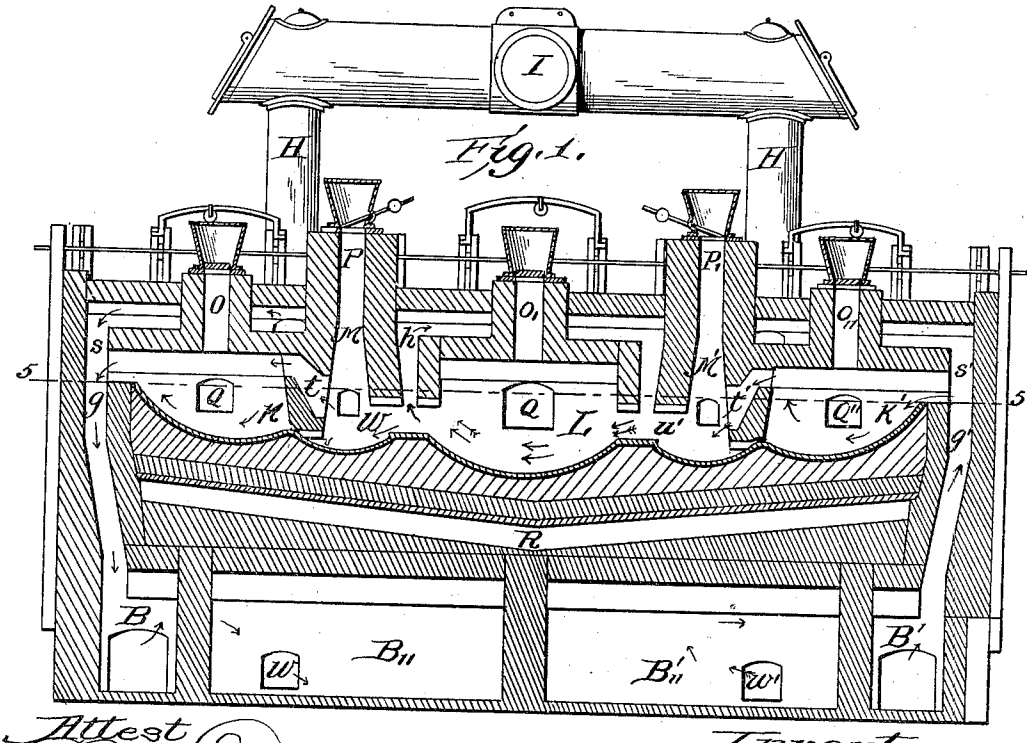


Fig. 1.



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Fig. 3.

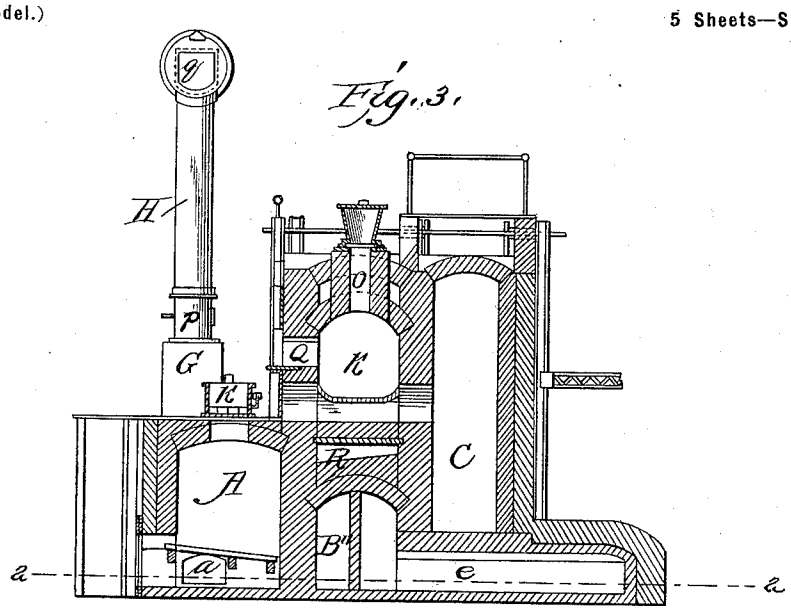
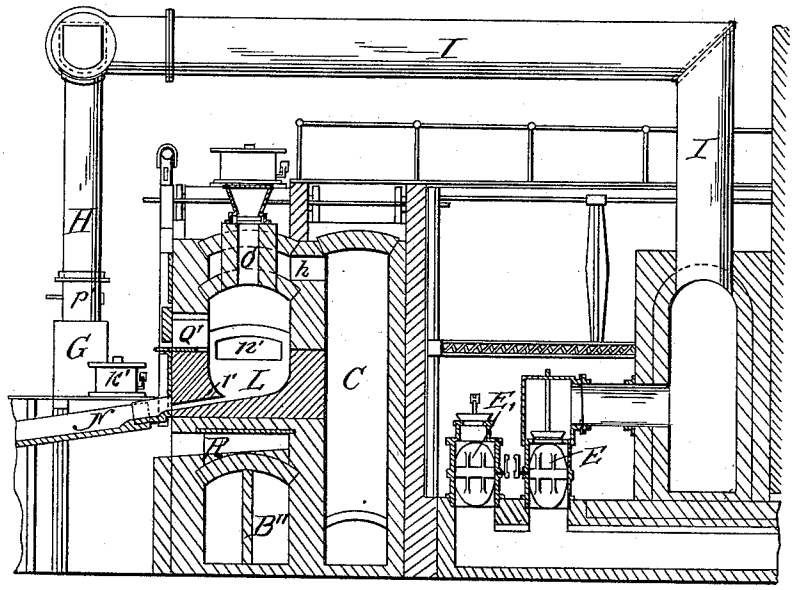


Fig. 4.



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Fig. 5.

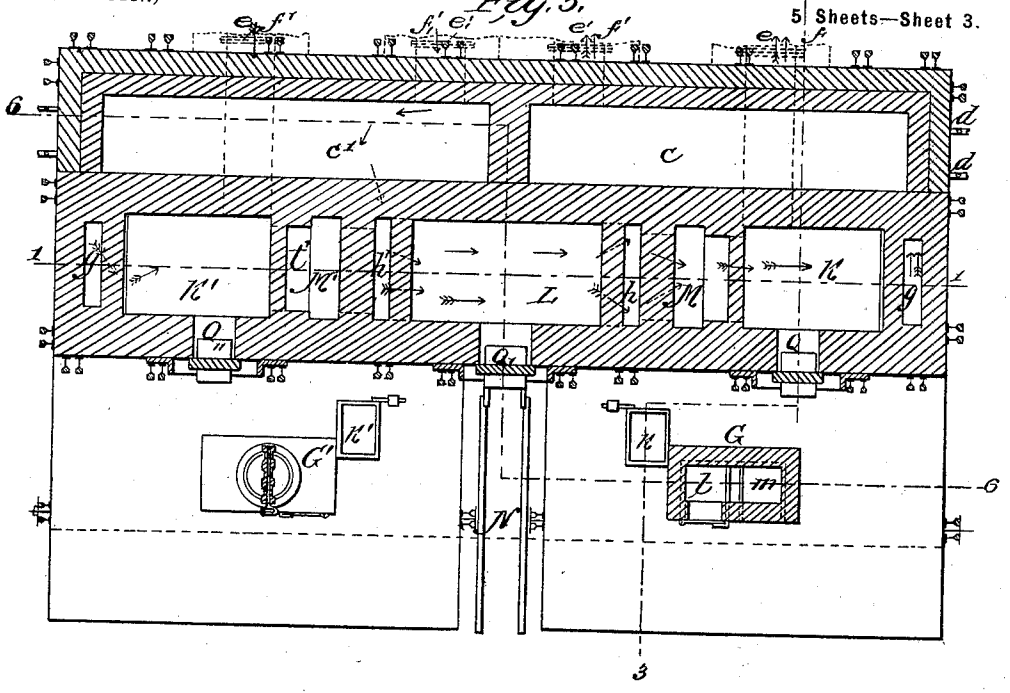
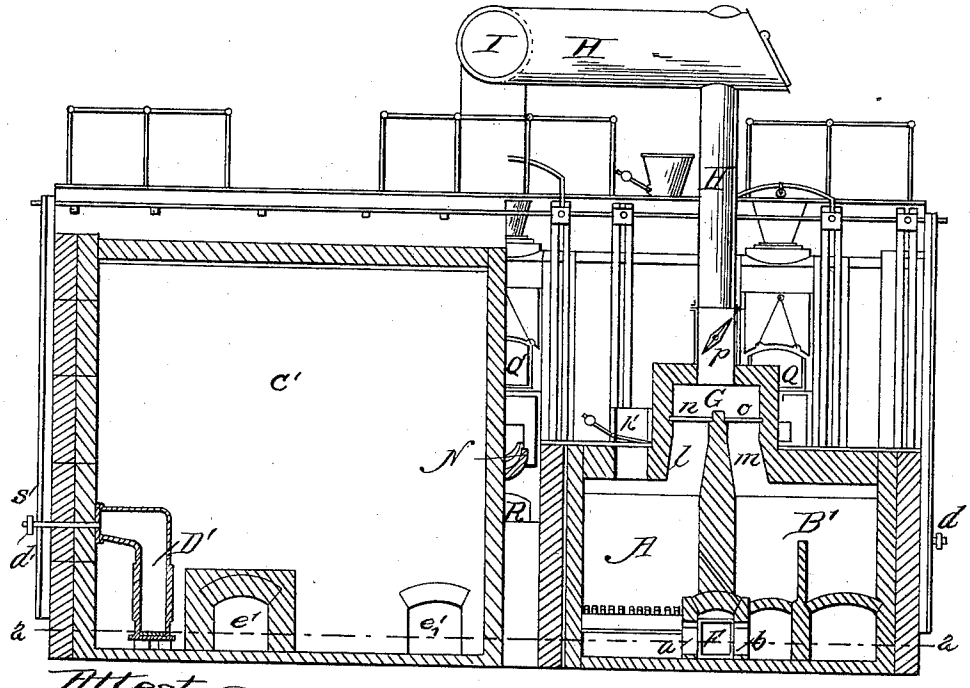


Fig. 6.



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5 Sheets—Sheet 4.

Fig. 7.

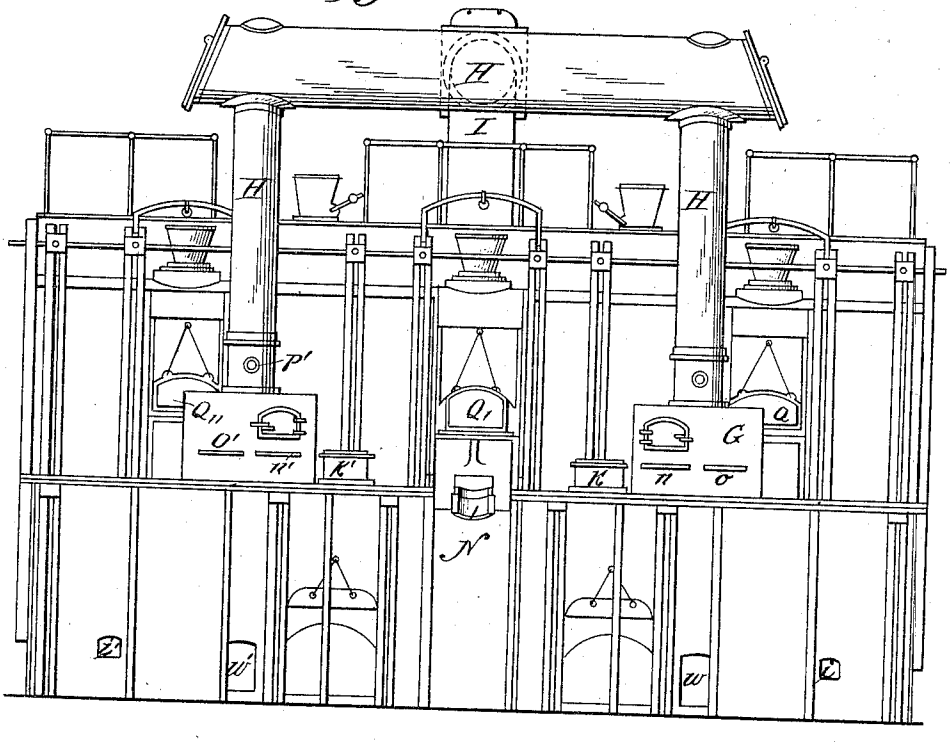
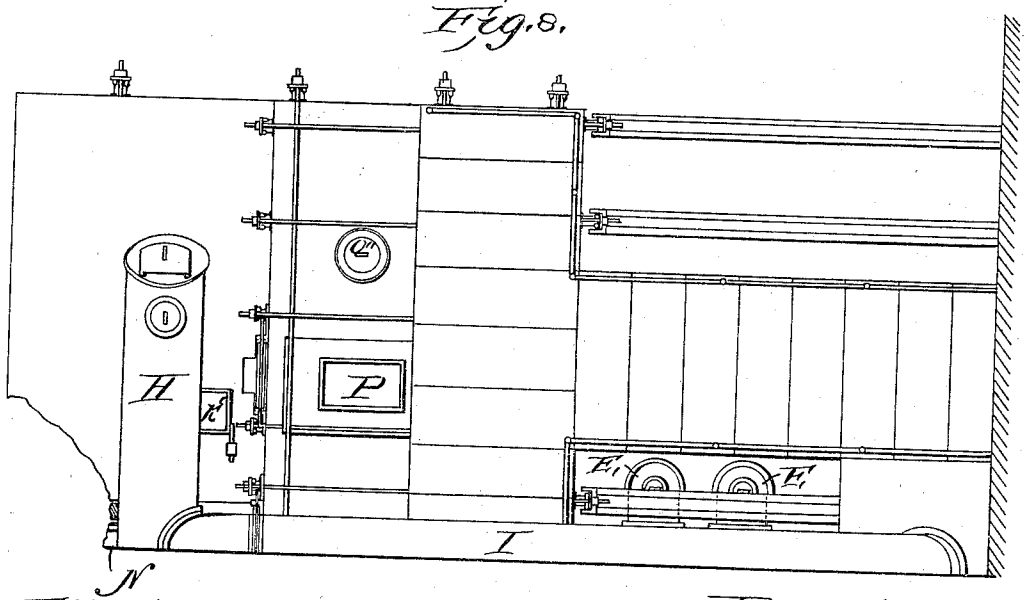


Fig. 8.



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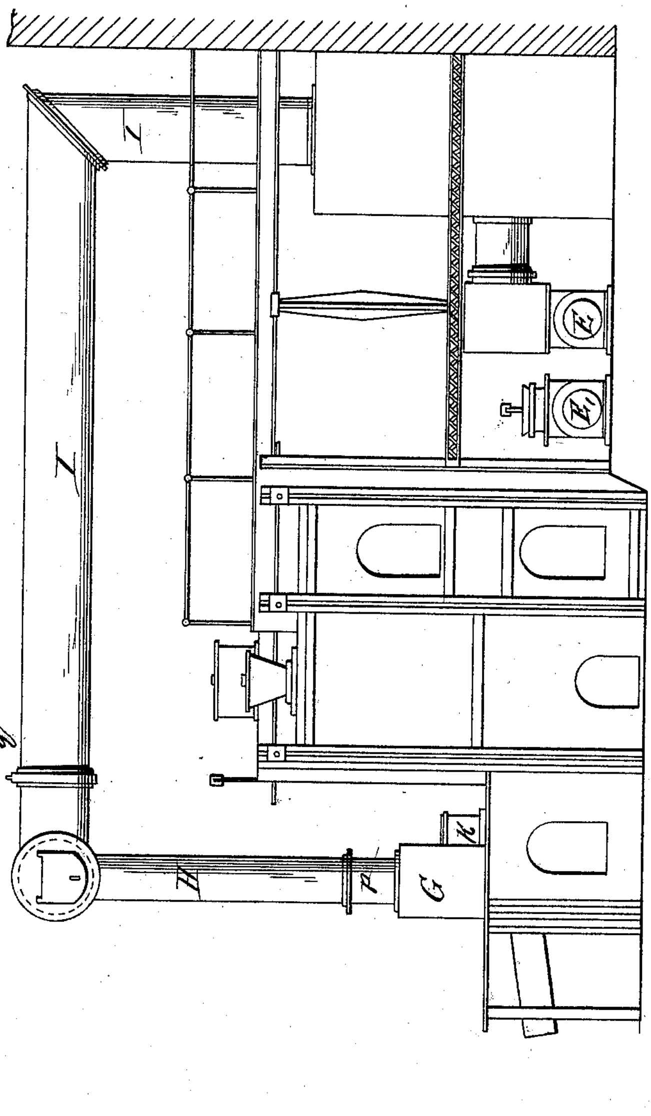


Fig. 9.

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UNITED STATES PATENT OFFICE.

ALEXANDER KARYSCHEFF, OF ST. PETERSBURG, RUSSIA.

METHOD OF AND APPARATUS FOR REDUCING OXID OF IRON.

SPECIFICATION forming part of Letters Patent No. 608,779, dated August 9, 1898.

Application filed May 11, 1896. Serial No. 591,099. (No model.)

To all whom it may concern:

Be it known that I, ALEXANDER KARYSCHEFF, a subject of the Emperor of Russia, residing at St. Petersburg, Russia, have invented certain new and useful Improvements in Methods of and Apparatus for Reducing Oxid of Iron, of which the following is a specification.

My said invention relates to a process or method of and apparatus for reducing oxid of iron; and the object of the invention is to effect the reduction of the oxid of iron in such a manner as to produce iron directly in a molten state.

The said process consists, essentially, in dissolving the oxid of iron in a suitable molten slag and bringing this solution into contact with a reducing agent consisting of carbon dissolved in a molten metal.

In carrying out the process the various metallic ores, together with their fluxes and with the addition of a small quantity of carbon, (in form of charcoal, &c.,) are made up in the following proportions: According to the furnace temperature, the charge requires an addition of carbon to the extent of from one-fifth to one-tenth the quantity required for the conversion of the oxygen contained in the metallic oxids into carbon dioxid. The higher the furnace temperature is the smaller is the necessary proportion of added carbon, as if it were possible to attain the dissociation temperature then, as above explained, no addition of carbon would be necessary. In addition there must always remain from the previous operation on the furnace-bed a small quantity of metals saturated with carbon. The atmosphere of that section of the furnace in which the reagent is prepared must be of a reducing nature. Under these conditions the production of the reagent takes place rapidly and energetically. The dissolved metallic compounds act at the high temperature employed energetically upon the dissolved carbon of the alloy containing carbon on the bed of the furnace. They become reduced and are saturated with carbon on coming in contact therewith, thus acquiring the property of acting in a reducing manner upon the next following portions of the ore. In proportion as the quantity of metal saturated with carbon increases the reaction becomes more and more energetic. The reduced metals collect on the bottom of the bed, and the slags, perfectly free from metal, float on the top thereof. The reaction continues uninterruptedly if the metals saturated with carbon flow off continuously toward the middle part of the furnace, the excess of slag being uninterruptedly discharged from the furnace and new quantities of the charge being fed forward.

My reagent consists, therefore, of nothing else than the metals to be worked themselves or others, but which are reduced, saturated with carbon, and melted—that is to say, which contain carbon in dissolved form. It would be wrong to imagine that this reagent was cast-iron. It is an alloy of iron and other metals, which serves the purpose of dissolving a maximum quantity of carbon, the metals of the reagent being regarded as useful additions to the article of manufacture. Thus, for instance, for iron the reagent can contain considerable quantities of manganese, chromium, or wolfram, which increase the good properties of the iron and also favor the formation of alloys rich in carbon. The obtaining of the definite product is effected with the assistance of this reagent in a very effective and rapid manner, as the metallic compounds contained in the solution in a dissolved condition act energetically upon the carbon, also in dissolved condition, of the reagent, being themselves subject to the reduction process, and freeing the reagent from its carbon. With this reaction the temperature rises considerably, and the overheated metal being very liquid can be readily cast in molds. The quality of the metal can be easily regulated, as this results from the reciprocal reaction of two liquids of known composition.

The improved furnace or apparatus for carrying out the said process is illustrated in the accompanying drawings, in which—

Figure 1 shows a vertical section of the furnace on line 1 1, Fig. 5. Fig. 2 is a horizontal section on line 2 2, Figs. 3 and 6. Fig. 3 is a vertical section on line 3 3, Fig. 5. Fig. 4 is a vertical section on line 4 4, Figs. 2 and 5. Fig. 5 is a horizontal section on line 5 5, Fig. 1. Fig. 6 is a vertical section on line 6 6 6, Fig. 5. Fig. 7 is a front view of the furnace; Fig. 8, a plan of one-half thereof; Fig. 9, a side view of the furnace.

The same parts are indicated by the same letters of reference in all the figures. The direction of the gases is indicated by the feathered arrows and the direction of the air by the non-feathered arrows.

The furnace is constructed on the regenerative system. It consists of five chambers—namely, three large ones K L K′, which are separated from each other at their upper parts by two smaller ones M M′, which are always quite full of carbonaceous material, but the beds of the three large chambers all communicate with each other.

A A′ are gas-producers worked with wood, coal, or coke, the gas obtained from coke being ordinary water-gas produced by the action of steam on the coke.

B B_1 B_{11} and B′ B'_1 B'_{11} are gas-regenerators; C C′, air-regenerators.

The regenerators C C′ contain retorts D D D′ D′, of cast-iron or refractory material, which have a grating-like bottom and are closed at top by a cover, with pipes d_1 d' passing through the wall of the regenerators. The retorts are filled with compounds generating oxygen, to be presently described.

E E_1 are reversing-valves, the first one for gas and the second for air. By reversing the positions of these valves the direction of the gaseous currents can be reversed.

e e' are flues for the gases, and e_1 e'_1 flues for the air. These four flues establish, by means of the valves E E_1, a communication between the regenerators and the chimney.

The dampers f f' f_1 f'_1 serve for regulating the draft through the air and gas regenerators.

From the regenerators the gas passes through the flues g g' alternately into the two large lateral chambers K K′. The air enters through openings h h' between the double arches of the middle large chamber L.

F F′ are cast-iron valves which enable the gas-regenerators B_{11} B'_{11} to be put in communication at will either with the producers A A′ or with the regenerators B_1 B'_1 by means of the channels a a' or b b'.

The gas-producers A A′ are supplied with fuel through the feed-hopper k k'. The gas enters through the channels l l' from the producers into the brick uptakes G G′, from which it passes through the channels m m' into the regenerators B_1 B'_1. The uptakes G G′ communicate with each other by means of the iron pipes H, which, on the other hand, are connected by the pipe T with the gas-valve E. The channels l l' and m m' can be hermetically closed by the dampers n n' and o o'. In the communicating pipes H for the gas are provided valves p p', by means of which the gas-producers can be separated from each other, and a slide q also enables the communication between the producers and the valves E to be cut off. In the middle chamber L the definite product is prepared, which flows off from the furnace through the top hole r and chute N. In the two lateral large chambers K K′ are produced the reagents.

The introduction of the charges into the three large chambers K L K′ is effected through the openings O O_1 O_{11} in the roofs thereof. The charging of the chambers M M′ with carbon is effected through the openings P P′. The doors Q Q_1 Q_{11} allow of access to the furnace when the bed requires to be relined, as also generally for repairs, &c. The air-spaces between the superposed arches of the lateral chambers K K′ do not communicate with the air-regenerators, but directly with the atmosphere, and, through the openings s s', also with the chambers K K′. Within the furnace the gases flow from one compartment into the other through the channels t t' and u u', while the reagents from the lateral chambers K K′ pass into the middle one L through the openings v v'. The space R below the furnace-bed serves to receive any metal that may escape through the bed and to protect the regenerators. The reversing-valves E E_1 are so arranged that the gases are made to flow in the direction of the arrows. The regulating-valves of the apparatus remain open.

First heating combination.—The producers communicate with each other and are closed to the gas-valve E, (the slide q being closed.) Air enters through the two reversing-valves. From the valves E_1 the air passes through the regenerators C′ into the furnace, into which it enters from the opening h' in the roof. From the valves E the air, after having passed through the regenerator B'_{11} and become heated, passes into the closed ash-pit of the gas-producers A A′ from the apparatus F′. The ash-pits are connected together by means of pipe. (Not shown on the drawings.) In this way the producers work with a heated air-supply, in consequence of which, as is known, the quantity of carbon dioxid in the producer-gas is reduced. From the producers the gas flows into the regenerator B'_1 (the slide o' is open, the slide o is closed, the slides n n' remain always open) and from thence into the furnace. The combustion of the gas will only begin to take place in the middle chamber L, where the gas comes into contact with the air entering through the opening h'. The products of combustion will partly pass from the furnace through the opening h, regenerator C, apparatus E_1, and chimney and partly through the carbon contained in chamber M, where they are converted into carbon monoxid in order after passing through chamber K to enter into combustion with heated air entering through the openings. After passing through flue g and regenerators B, B_1, and B_{11} the combustion products escape through the apparatus E to the chimney. For changing the direction of the gases the valves of the apparatus E E_1 F F′ and the slides o o' must be reversed, which is effected by means of the motion of a single lever, the mechanism of which may be of any known arrangement and is therefore not shown.

Second heating combination.—Through the reversing apparatus E steam is let in instead

of air. The ash-pits of the producers do not communicate with each other. The circulation of the gases remains as above described, but the character of the furnace is changed. The combustible gas now consists of a mixture of water-gas and ordinary producer-gas. The steam superheated in the regenerator B'_{11} passes into the closed ash-pit of A' and forms water-gas therein. In consequence thereof the producer becomes cooled, while the other producer, which is supplied with air, becomes hotter. On reversing the direction of the gases the first generator A', which was cooled, is now supplied with air, while the second A is supplied with superheated steam. In this way both producers alternately supply water-gas and ordinary producer-gas, while a mixture of both passes continuously into the furnace.

Third heating combination.—Should it be desired only to supply water-gas to the furnace, it is sufficient to close the communication between the two producers by means of the valves *p p'* and to open all slides. The gas circulation will then only differ from the foregoing in that the gas passing from the producer, which for the time being works with air, does not pass into the general gas-supply pipe, but into the contiguous gas-regenerator, which for the time being communicates with the chimney. By this means the reheating by the admission of air of the producer, which has been cooled by the entrance of steam, is utilized for heating the gas-regenerators and for superheating the steam, the furnace itself being then worked with water-gas alone. In this case, as also in the foregoing one, the reheating of the gas-producers by means of air is indispensable, as the cooling thereof in forming water-gas is very considerable under all circumstances. However, this cooling is less than in the water-gas producers of other systems, because the producers are also heated from the outside by the escaping furnace heat.

Fourth heating combination.—If both valves F F' receive the position shown for F on the drawings and the slides *o o'* be closed (whereby the producers are separated from the regenerators) and if the communication between the gas-pipe H and the apparatus E be established, then the furnace will work in the same way as ordinary regenerative gas-furnaces.

Fifth heating combination.—Instead of using atmospheric air for effecting the combustion in the furnace oxygen is used. For this purpose the retorts D D D' D' are introduced into the air-regenerators. The mixture from which oxygen is obtained consists of the haloid compounds of those metals the production of which from their ores forms the subject of the present invention. I employ these metallic compounds in a condition corresponding to the ultimate application thereof in the presence of caustic alkalies. If a current of atmospheric air be passed through this mass, the substances contained therein form some higher oxygen compounds, which in their turn, on treatment with superheated steam, give free oxygen, which is then led into the furnace. The retorts containing the said mixture are for this purpose heated by the combustion-gases from the furnace to the necessary temperature of about 350° centigrade. Air entering through the pipes *d d* passes simultaneously through the retorts, which air gives up its oxygen to the mixture therein, while the nitrogen escapes with the products of combustion to the chimney. Superheated steam is then made to enter the retorts D D, the charges of which are saturated with oxygen, so that such oxygen passes off therefrom and enters the furnace through the regenerator C'. The air can be admitted through the valve E_1 or can be entirely cut off, according as a supply of oxygen alone or of air rich in oxygen is desired. In consequence of the continuous alternation of taking up and giving off oxygen the above-mentioned mixture will remain effective for a considerable length of time. The degree to which the retorts are heated is observed through sight-holes *c* in the wall of the regenerator. The regulation of such heating is effected by regulating the quantity of air supplied thereto and also by increasing and decreasing the chimney-draft by means of the slides $f f'_1$.

Sixth heating combination.—In place of the ordinary producer-gases acetylene can be generated in the producers from calcium carbid in the following manner: I close the openings *b b'*, and the valves of the apparatus F F' receive the position shown for F' on the drawings. The combustion products after passing through the regenerators B B_1 are made to enter the producer A through the channels *l* and *m* and to pass from the ash-pit thereof into the regenerator B_{11} and thence to the chimney. The producer is not filled with ordinary fuel, but with small blocks formed of a compressed mixture of lime and carbon powder. When heated by the combustion-gases passing through, this mixture will produce calcium carbid. At the same time the calcium carbid generated in the other producer in the same manner is decomposed by means of superheated steam, which after passing through the regenerator B'_{11} and the apparatus F' into the ash-pit of the producer enters through the apparatus E. By the decomposition of the calcium carbid acetylene is obtained, which enters the furnace through the regenerators B'_1 and B'. The caustic lime produced by this reaction will trickle through the grate-openings of the producers and serves again for the manufacture of the before-mentioned small blocks serving for the production of the calcium carbid. Consequently the lime is not used up, but serves solely for producing acetylene directly from carbon and steam. With regard to this heating combination the following must be observed: First, for the produc-

tion of calcium carbid a very high temperature is required, (about 3,500° centigrade;) but the temperature of the gases escaping from my furnace in the sixth heating combination and in using air having a large percentage of oxygen mixed with it will be more than sufficient for producing such a degree of heat, and consequently the production of acetylene will be effectually carried out, of course under the assumption that the producers are placed in the neighborhood of the point where the combustion-gases issue; second, at the temperature of the gases issuing from the furnace the calcium carbid is not only formed, but also melted, and in dropping down upon the still-unmelted carbon and lime blocks it offers a large surface to the following reaction of the steam, whereby the production of the acetylene is considerably facilitated.

The degree of heat produced by the combustion of acetylene is so great that in order to utilize it it is very advantageous to introduce into the furnace also a portion of the hot combustion-gases containing carbon dioxid. The latter will then be decomposed, and the carbon monoxid produced will form a supplemental heating medium, while the liberated oxygen will assist in the combustion of the acetylene.

Seventh heating combination.—It is very easy to lead half of the combustion-gases from the furnace under the grates of the gas-producers in order to again convert them into producer-gases at the expense of the fuel and of the heat contained in them.

If the channels *u u'* are closed and a communication be established between the ash-pits of the producers and a steam-jet exhauster of refractory material be arranged in the openings *b* b'_1, the combustion products can be drawn from the regenerator B'_1 and forced into the producers, the gases evolved in the producers being delivered through the channels *e e'* into the common gas-main, and from there they pass through the channel *m* into the regenerators B' B and thence into the furnace, channel *m'* being closed. The other half of the combustion products pass away to the chimney through the air-regenerators in the usual manner.

Eighth heating combination.—Each of the openings *i i'* serves to receive a pipe which supplies naphtha from a reservoir or from an injector. If naphtha be injected without air-supply into the regenerator through which at the time the producer-gas is passing to the furnace, as above described, the naphtha will not only be readily volatilized, but it is also converted into naphtha-gas at the cost of some of the large quantity of heat stored in the regenerator. It is evident that such a heating process affords the possibility of regulating the working of the furnace within the widest limits and, if necessary, to produce an extraordinarily high temperature in the furnace (which could not possibly be produced in ordinary furnaces) by the exclusive use of oxygen and a mixture of water-gas and acetylene or naphtha gas. In addition, as will be seen from the above description, the utilization of the heat of the furnace is much more perfect than in ordinary furnaces, as all the heat which is ordinarily lost is utilized for heating air and gas for the furnace and air or steam for the producers, as also for the production of oxygen and acetylene and the decomposition of naphtha.

From the above description of the circulation of the gases it will be seen that the lateral furnace-chambers K K' are always filled with reducing-gases, the one chamber being alternately always filled with the gases that pass from the producer into the middle chamber L, while the other one will be filled with the combustion-gases from the chamber L, which in passing through the carbon of the intermediate chamber M or M' will have become decomposed. The central chamber L, in which combustion takes place and in which the highest temperature is reached, has an oxidizing atmosphere. The temperature of the side furnace-chambers K K', which depends on the degree to which the gases in the regenerators are heated, may also be highly increased or intensified without any difficulty, according to requirement, by means of the partial combustion of the gas traversing the same, said combustion being effected by means of the air, which is to be introduced, as desired, through the openings *s s'* in the roof. In the side chambers the ores are reduced at the expense of the reducing-gases of these furnaces and of the carbon that has been added to the charge in the presence, also, of the molten carbonaceous mixtures, as has already been explained hereinbefore. The reduced and carbureted or carburized (saturated with carbon) alloys (reagents) produced in the side furnace-chambers flow in same measure as they are formed through the openings *v v'* into the cavity of the chambers M M', said cavity being still filled with carbon. Here in the said cavity and in direct contact with the incandescent carbon the said alloys combine with said incandescent carbon up to the point of saturation (if this point has not been previously completely reached or if said alloys have already again lost a part of their carbon) and flow continuously through the window-openings *u u'* into the central chamber.

On account of its small specific gravity the slag formed in the side chambers K K' cannot pass into the central chamber. It accumulates up to a certain level, and when this level is reached the slag is tapped or removed through special openings provided in the wall of the furnace for this purpose.

The charge introduced into the central chamber L melts, and the metallic compounds that are contained in a dissolved state in the slag act upon the carbon of the reagent which is flowing from out of the side

chambers, with the result that the former are reduced and the latter are decarburized.

As the temperature of all the chambers can be easily regulated, no difficulty whatever will be experienced in effecting the reduction and the other reactions under the most favorable conditions for this purpose. As already hereinbefore stated, the floors and walls of the furnaces may be basic or acid, according to requirement. It is, however, preferable to employ a neutral material for these, such as graphite, which when it is protected from direct contact with air behaves entirely neutral. A hearth composed of graphite mass is extremely durable.

As my side chambers K K' are constantly filled up to a certain level with charge and slag—that is to say, are constantly protected from contact with or the entrance of air—I construct these furnaces with their internal surfaces lined or coated with slabs or plates of graphite up to the said level.

The central chamber L is lined with dolomite, which is supported on a foundation of chromo-iron rock or ore.

Generally any fire-resisting material can be employed in the construction of my furnace; but it must be of a very good quality in view of the very high temperatures which it will have to withstand.

With respect to the arrangement and working of the furnace I think it well to add the following:

First. The drawings show merely the general type or idea of my furnace, which differs by its construction and arrangement very essentially from other metallurgical furnaces. The details of the construction of the same may be modified in many ways without departing from the spirit of my invention. The charging-hoppers in the roof might be arranged to operate automatically, and so on. Unimportant modifications of details might be effected without end; but the general type or idea of the whole apparatus and its essential parts will remain unaltered. Thus it is for that reason that I have illustrated the essential features of the apparatus in the drawings and have not thought it necessary to show in the same the less important modifications of details that I have had in mind and intend to make.

Second. With respect to an essential part of my furnace—namely, of the side chambers K K', whose atmosphere acts with a reducing effect—I think that it is absolutely necessary to add the following: These chambers are shown in the drawings as of small height, although in some cases, dependent on the local conditions, the properties of the ores and metals to be treated, the force of the draft or of the suction, &c., the height of the chambers may be increased until they become actual shaft-furnaces. This modification would be a very important one, although it would not, nevertheless, be a departure from the principle of my furnace, for which reason I have not annexed hereto any drawings on this point, as I am of opinion that what has been said here is sufficient.

Third. It would be easy to combine two of my furnaces longitudinally, so as to form one common furnace with two parallel rows of chambers K L K' and each having a tap-hole on each side. A modification of this kind of my construction would be very suitable in many cases, because with greater compactness the apparatus is less costly and the efficiency is increased.

Having fully described my invention, what I claim, and desire to secure by Letters Patent, is—

1. The method of reducing oxid of iron which consists in dissolving it in a suitable molten slag and bringing this solution into contact with a reducing agent consisting of carbon dissolved in a molten metal, thereby directly producing iron in a molten state, substantially as described.

2. In combination the central chamber, the side chambers, the carbon-chambers interposed between said central and side chambers, all of said chambers having continuous or communicating bottoms, the flues for the combustion-gases communicating with the two side chambers with means for reversing the flow of gases, vaulted roofs over said central and side chambers and air-spaces over said roofs, substantially as described.

3. In combination the central and side chambers, the interposed carbon-chambers, gas-generators, the air-and-gas regenerators, flues connecting said parts, the reversing-valves in said flues and the oxygen-generating retorts located within the air-regenerators, substantially as described.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

ALEXANDER KARYSCHEFF.

Witnesses:
N. TSCHEKALOFF,
T. BLAN.