No. 812,247. PATENTED FEB. 13, 1906.

G. M. WESTMAN.

PROCESS OF REDUCING IRON ORE.

APPLICATION FILED JUNE 24, 1903.

2 SHEETS—SHEET 1.

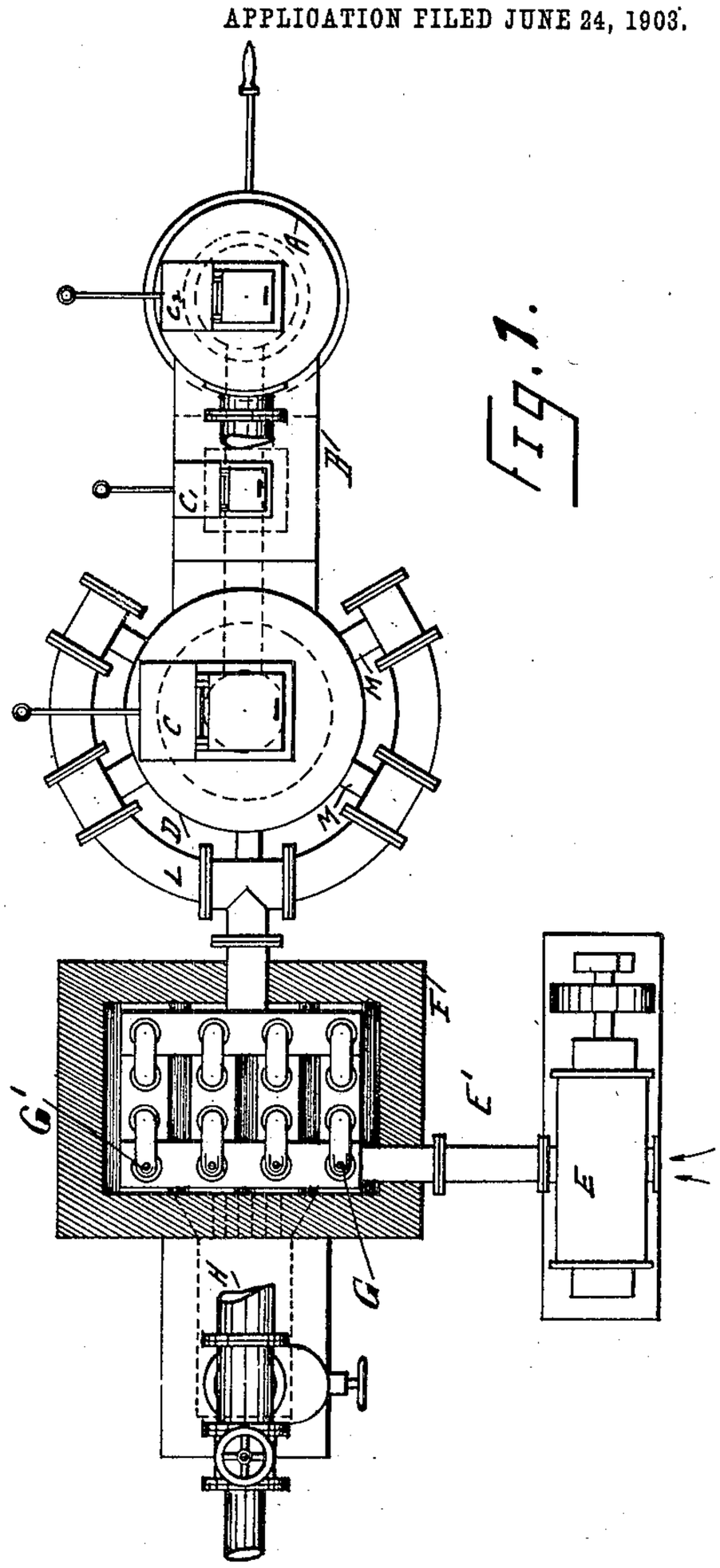

FIG. 1.

WITNESSES
A. White.
James Galiani.

INVENTOR
Gustaf M. Westman
by Philipp. Sawyer. Rice & Kennedy
Atty's.

No. 812,247. PATENTED FEB. 13, 1906.

G. M. WESTMAN.

PROCESS OF REDUCING IRON ORE.

APPLICATION FILED JUNE 24, 1903.

2 SHEETS—SHEET 2.

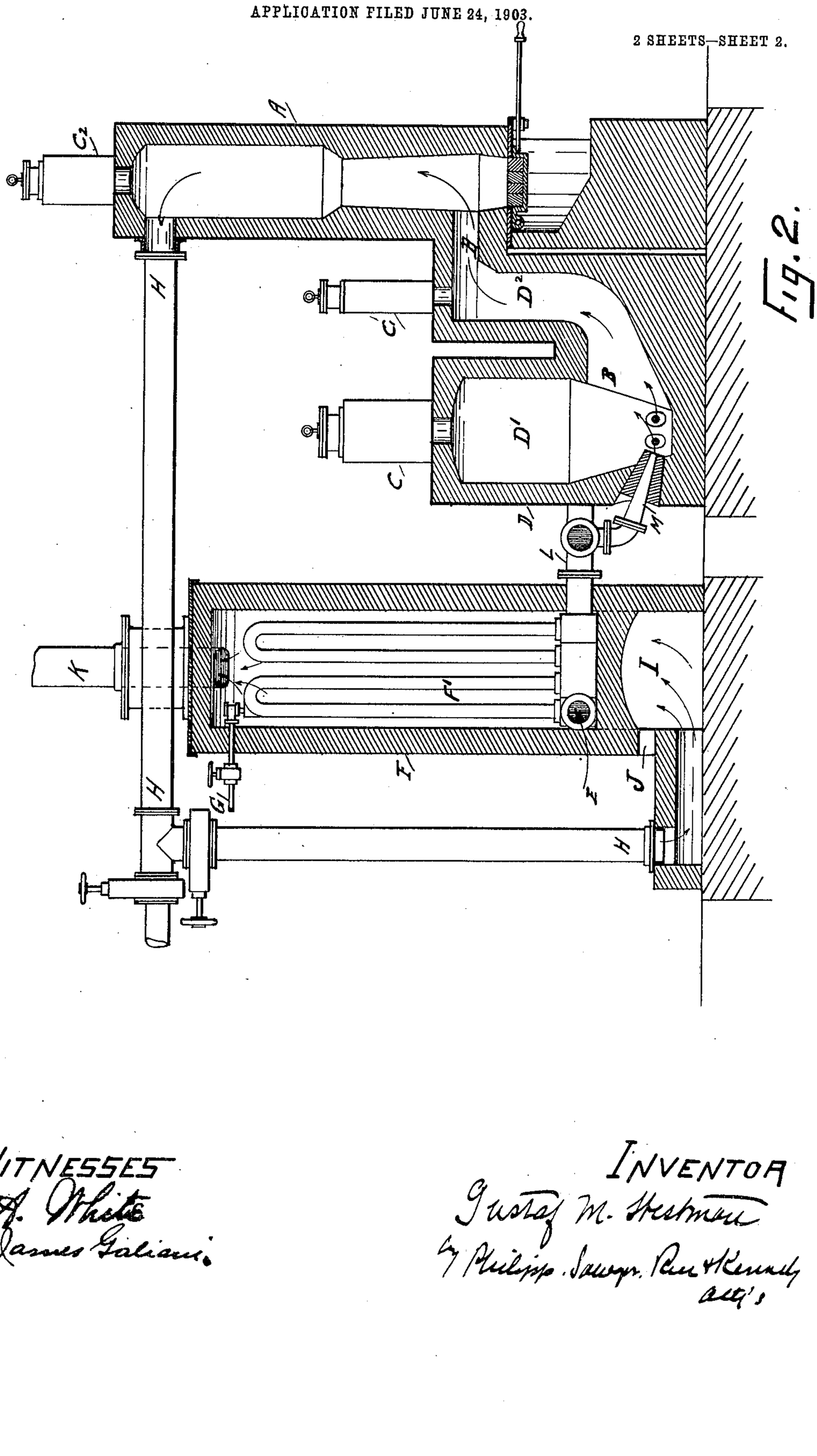

Fig. 2.

WITNESSES
A. White
James Galiani.

INVENTOR
Gustaf M. Westman
by Philipp, Sawyer, Rue & Kennedy
att'ys

UNITED STATES PATENT OFFICE.

GUSTAF M. WESTMAN, OF NEW YORK, N. Y.

PROCESS OF REDUCING IRON ORE.

No. 812,247. Specification of Letters Patent. Patented Feb. 13, 1906.

Application filed June 24, 1903. Serial No. 162,876.

To all whom it may concern:

Be it known that I, GUSTAF M. WESTMAN, a subject of the King of Sweden and Norway, residing at New York, county of New York, and State of New York, have invented certain new and useful Improvements in Processes of Reducing Iron Ore, fully described and represented in the following specification and the accompanying drawings, forming a part of the same.

It has been proposed heretofore to reduce iron ore by subjecting it to the action of highly-heated water-gas—that is, a gas consisting principally of carbon monoxid and hydrogen. This gas, however, contains oxidizing material—such, for instance, as carbonic acid—which prevents the complete reduction of the ore. Furthermore, in the processes heretofore proposed in which the use of water-gas was suggested the temperature at which it was proposed to use the gas was not sufficiently high for the complete reduction of the ore. Furthermore, these processes contemplated the reduction of the ore without the addition of carbon.

The object of this invention is to provide a new and improved process for reducing iron ore by the production of gases containing carbon monoxid and hydrogen at temperatures sufficiently high to reduce the ores when brought into contact therewith, this temperature being in the case of iron ores about 1,100° centigrade.

With this and other objects in view the invention consists in the process which is hereinafter described and then more specifically set forth in the claims hereunto appended.

In order that the process may be fully understood, the same will be described in connection with an apparatus which is capacitated for carrying it out. It is to be understood, however, that the process is in no way dependent upon the particular form of apparatus which is herein shown and described.

In the accompanying drawings, Figure 1 is a plan view, partly in section, of a form of furnace suitable for carrying out the process which forms the invention. Fig. 2 is a longitudinal section of the same.

In order to successfully reduce iron ore, the gas employed in the reduction should be free from oxidizing material and should be employed at a temperature of about 1,100° centigrade. According to the present invention the gas which is to be employed in reducing the ore is obtained by a proper treatment of air mixed with water or steam. The preferred mode of obtaining this mixture is to spray water into a current of air, which is afterward raised to a temperature which must at least be high enough to convert the water into steam. In practically carrying out the invention, however, the temperature to which the mixture of air and steam is subjected will be as high as possible. It may be here remarked that it is desirable to introduce into the air as large a proportion of water as possible in order to form as much hydrogen as possible; but the proportion of air must be high enough to maintain the gases at a proper reducing temperature. In other words, the proportion of air to water or steam must be so regulated that the resulting gases will be delivered to the furnace at a proper reducing temperature, which with iron ores is about 1,100° centigrade. After raising the temperature of the mixture of air and water or steam in the manner described the air and steam is then brought into contact with carbon in order to form carbon monoxid and hydrogen. This can best be accomplished by bringing the air and steam in its heated condition into contact with a mass of glowing coke. The contact of the heated steam and air with the glowing coke produces the gases described—that is to say, hydrogen and carbon monoxid; but it also produces a small percentage of carbonic acid, which is objectionable for the reason that the carbonic acid prevents the complete reduction of the ore. In order to change this carbonic acid into monoxid, the gas is kept in contact with a mass of glowing coke until the carbonic acid has taken up carbon enough to form carbon monoxid. This not only frees the gas from the objectionable carbonic acid, but by changing it into carbon monoxid further increases the reductive capacity of the gas, so that its efficiency is increased. In order to enable this gas, which, as before indicated, contains hydrogen and carbon monoxid, to reduce the iron ore, it is desirable to use in reducing the ore a small percentage of carbon, inasmuch as this carbon influences the reductive capacity of the carbon monoxid. The desired small percentage of carbon may be obtained and utilized in various ways. Preferably, however, the gas after being freed from the carbonic acid in the manner described is brought into contact with the ore, which has mixed therewith a small quantity of solid carbon—say about

three per cent. This solid carbon may be mixed with the ore in any desired manner; but preferably the ore and carbon will be formed into briquets. The use of this small percentage of carbon in reducing the ore is to practically remove all traces of oxygen from the ore. The effect thus produced by using this small percentage of carbon in reducing the ore is to be carefully distinguished from the well-known blast-furnace process in which a comparatively large percentage of carbon is mixed with the ore. The mixing of a large percentage of carbon with the ore carburizes the ore and converts it into pig-iron, whereas the object of the present process is to produce wrought-iron, which object would be defeated if a large percentage of carbon were mixed with ore prior to reduction. It may happen that the gases resulting from the action of the glowing coke on the air and steam will contain an objectionable percentage of sulfur, due to the presence of sulfur in the coke, and when this is the case it is desirable to purify the gases by removing the sulfur. While this may be effected in various ways, it can best be accomplished by mixing limestone with the coke in the chambers of the gas-producer. This will preferably be done by mixing the proper percentage—say about ten per cent.— of limestone with the coke in the gas-producer and with the coke in the charging receptacles or hoppers, so that as the coke is renewed in the gas-producer the proper percentage of limestone will be fed in with it. The lime in the limestone combines with the sulfur in the coke, thus forming calcium sulfid, and at the same time the small percentage of carbonic acid present in the lime will unite with the carbon in the glowing coke to form carbon monoxid. The mixing of lime with the glowing coke has the further beneficial effect of making slag of the silicate in the coke.

In the apparatus illustrated in the drawings there is shown a reducing-furnace A, which is connected by a channel B with a gas-producer D, said producer consisting of a chamber D′. The hopper through which the coke or coke and limestone when limestone is mixed with the coke are introduced in the chamber D′ is marked C, this hopper being mounted above the chamber so as to discharge directly thereinto. A chamber F is provided which contains sets of iron pipes F′, into which air is forced by means of a blower E, the conduit leading from the blower to the pipes F′ being marked E′.

G indicates a water-pipe, which is provided at its ends with a suitable spray through which water may be sprayed into the pipes F′. A series of these pipes G may be employed, the point of connection at which the sprays enter the pipes being marked G′. The pipes F′ in the apparatus shown are heated by means of the resulting gases from the furnace A. The gases are burned in a combustion-chamber I by contact with air, which is led into the chamber through an opening indicated at J. The products are led out from the chamber F through the pipe or stack K′.

In practically carrying out the invention as high a temperature as possible is maintained in the chamber F, because the higher the temperature in this chamber the more water can be introduced into the current of air which passes therethrough. It is desirable that the temperature maintained in this chamber F should not be less than 400° centigrade. The air and steam is led from the pipes F′ by means of a pipe L, from which it is forced through twyers M into the chamber of the gas-producer D. This gas-producer contains incandescent coke. When the mixed air and steam strikes this incandescent coke, a gas is formed containing nitrogen, hydrogen, carbon monoxid, and a small amount of carbonic acid. In order to free the gas from the carbonic acid, it is led through the channel B, which also contains incandescent coke, said channel being supplied with coke from a hopper C′. This channel is given an upward bend, as shown, so that the gas will pass more readily therethrough, and is sufficiently long so that the carbonic-acid gas will remain a sufficient length of time in contact with the incandescent coke to take up the molecule of carbon necessary to convert it into carbon monoxid. When, as before indicated, there is limestone mixed with the coke, the lime will unite with the sulfur in the coke, forming calcium sulfid, whereby pure gases are generated, and the limestone will also act to slag the silicate in the coke. The gas passes from the channel B into the furnace A and is there brought into contact with ore, which, as before pointed out, preferably has mixed with it from two to three per cent. of solid carbon. After the gas has passed through the ore it will be led back, as before described, into the combustion-chamber, so that the reducing process is a continuous one. The temperature in the lower part of the gas-producer D may be roughly estimated at about 1,600° centigrade. The temperature at which the gas is utilized in the furnace A, however, need not be above 1,100° centigrade. The temperature in the gas-producer D will of course be lowered by an amount corresponding to the amount of steam which is introduced into it with the air. This amount of steam is, however, controlled by the amount of water introduced into the air by the spray G. In carrying out the invention, therefore, the spray G should be so controlled that the temperature of the gas at the end of the channel B will not be lowered

below or raised above about 1,100° centigrade, which can be readily effected by watching the temperature of the gases at the mouth of the channel B and regulating the spray in accordance therewith. Under ordinary conditions the amount of water introduced will be from four per cent. to six per cent.

The process above described can be carried on at a low cost and is of high efficiency. Furthermore, ore which cannot be reduced in ordinary blast-furnaces because it contains titanic acid can be reduced by this process. This process can also be advantageously used in reducing ores containing phosphoric acid. In blast-furnaces on account of the high temperature the phosphoric acid is converted into phosphorus, which enters the iron. At the comparatively low temperatures employed in this process, however, the phosphoric acid is only slightly reduced, so that the resulting iron contains but little phosphorus.

What is claimed is—

1. The process of reducing iron ore which consists in subjecting air mixed with steam in a continuous heated current to the action of glowing coke to form carbon monoxid and hydrogen and so regulating the proportion of air to the steam that the resulting gases will have a temperature of about 1,100° centigrade and finally passing the gases at said temperature through the ores to be reduced, substantially as described.

2. The process of reducing iron ore which consists in subjecting air mixed with steam in a continuous heated current to the action of glowing coke having limestone mixed therewith, whereby carbon monoxid and hydrogen free from sulfur are formed and so regulating the proportion of air to the steam that the resulting gases will have a temperature of about 1,100° centigrade, and finally passing the gases at said temperature through the ores to be reduced, substantially as described.

3. The process of reducing iron ore which consists in introducing water into a continuous current of air, heating the mixed air and water to form steam, passing the air and steam through glowing coke to form carbon monoxid and hydrogen, regulating the proportion of air to the steam so that the resulting gases will have a temperature of about 1,100° centigrade and passing the gases at said temperature through the ores to be reduced, substantially as described.

4. The process of reducing iron ore which consists in introducing water into a continuous current of air, heating the mixed air and water to form steam, passing the air and steam through glowing coke mixed with limestone to form carbon monoxid and hydrogen free from sulfur, regulating the proportion of air to the steam so that the resulting gases will have a temperature of about 1,100° centigrade and passing gases at said temperature through the ores to be reduced, substantially as described.

5. The process of reducing iron ore which consists in subjecting air mixed with steam in a continuous heated current to the action of glowing coke to form carbon monoxid and hydrogen and so regulating the proportion of air to the steam that the resulting gases will have a temperature of about 1,100° centigrade and finally causing the gases at said temperature to act upon the ores to be reduced in the presence of a small percentage of carbon, substantially as described.

6. The process of reducing iron ore which consists in subjecting air mixed with steam in a continuous heated current to the action of glowing coke mixed with limestone to form carbon monoxid and hydrogen free from sulfur and so regulating the proportion of air to the steam that the resulting gases will have a temperature of about 1,100° centigrade and finally causing the gases at said temperature to act upon the ores to be reduced in the presence of a small percentage of carbon, substantially as described.

7. The process of reducing iron ore which consists in introducing water into a continuous current of air, heating the mixed air and water to form steam, passing the air and steam through glowing coke to form carbon monoxid and hydrogen, regulating the proportion of air to the steam so that the resulting gases will have a temperature of about 1,100° centigrade and finally causing the gases at said temperature to act upon the ores to be reduced in the presence of a small percentage of carbon, substantially as described.

8. The process of reducing iron ore which consists in introducing water into a continuous current of air, heating the mixed air and water to form steam, passing the air and steam through glowing coke mixed with limestone to form carbon monoxid and hydrogen free from sulfur, regulating the proportion of air to the steam so that the resulting gases will have a temperature of about 1,100° centigrade and finally causing the gases at said temperature to act upon the ores to be reduced in the presence of a small percentage of carbon, substantially as described.

9. The process of reducing iron ore which consists in spraying water into a current of air, raising the temperature of the mixed air and water to form air and steam, passing the air and steam through incandescent carbon to form carbon monoxid and hydrogen, and subjecting the gases thus formed to the action of the incandescent carbon, regulating the proportion of air to steam so that the resulting gases will have a temperature of about 1,100° centigrade, and then causing the gases at said temperature to act upon the ores to be reduced in the presence of a small percentage of carbon, substantially as described.

10. The process of reducing iron ore which consists in spraying water into a current of air, raising the temperature of the mixed air and water to form air and steam, passing the air and steam through incandescent carbon mixed with lime to form carbon monoxid and hydrogen, and subjecting the gases thus formed to the action of the incandescent carbon and lime whereby pure gases are generated, regulating the proportions of the air and steam so that the resulting gases will have a temperature of about 1,100° centigrade, and then causing the gases at said temperature to act upon the ores to be reduced in the presence of a small percentage of carbon, substantially as described.

In testimony whereof I have hereunto set my hand in the presence of two subscribing witnesses.

GUSTAF M. WESTMAN.

Witnesses:
JAMES Q. RICE,
W H. KENNEDY