

T. S. BLAIR.

Improvement in Process and Apparatus for Reducing the Ores of Iron.

No. 126,922.

Patented May 21, 1872.

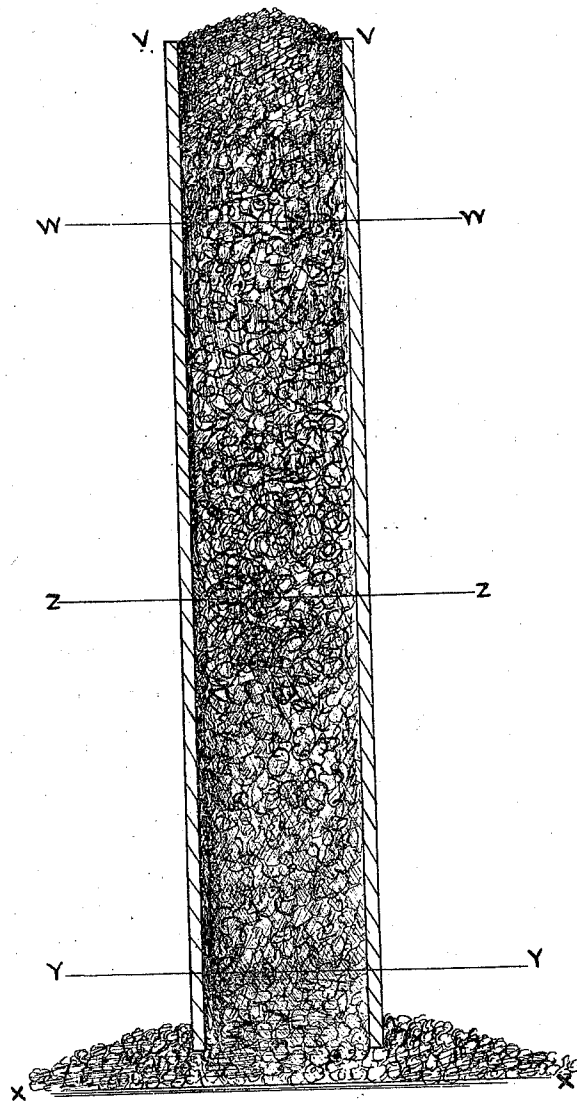


FIG. 1.

Witnesses:

W. Baxwell
J. J. Miller

Inventor:

Thos. S. Blair

T. S. BLAIR

Improvement in Process and Apparatus for Reducing the Ores of Iron.

Patented May 21, 1872.

No. 126,922

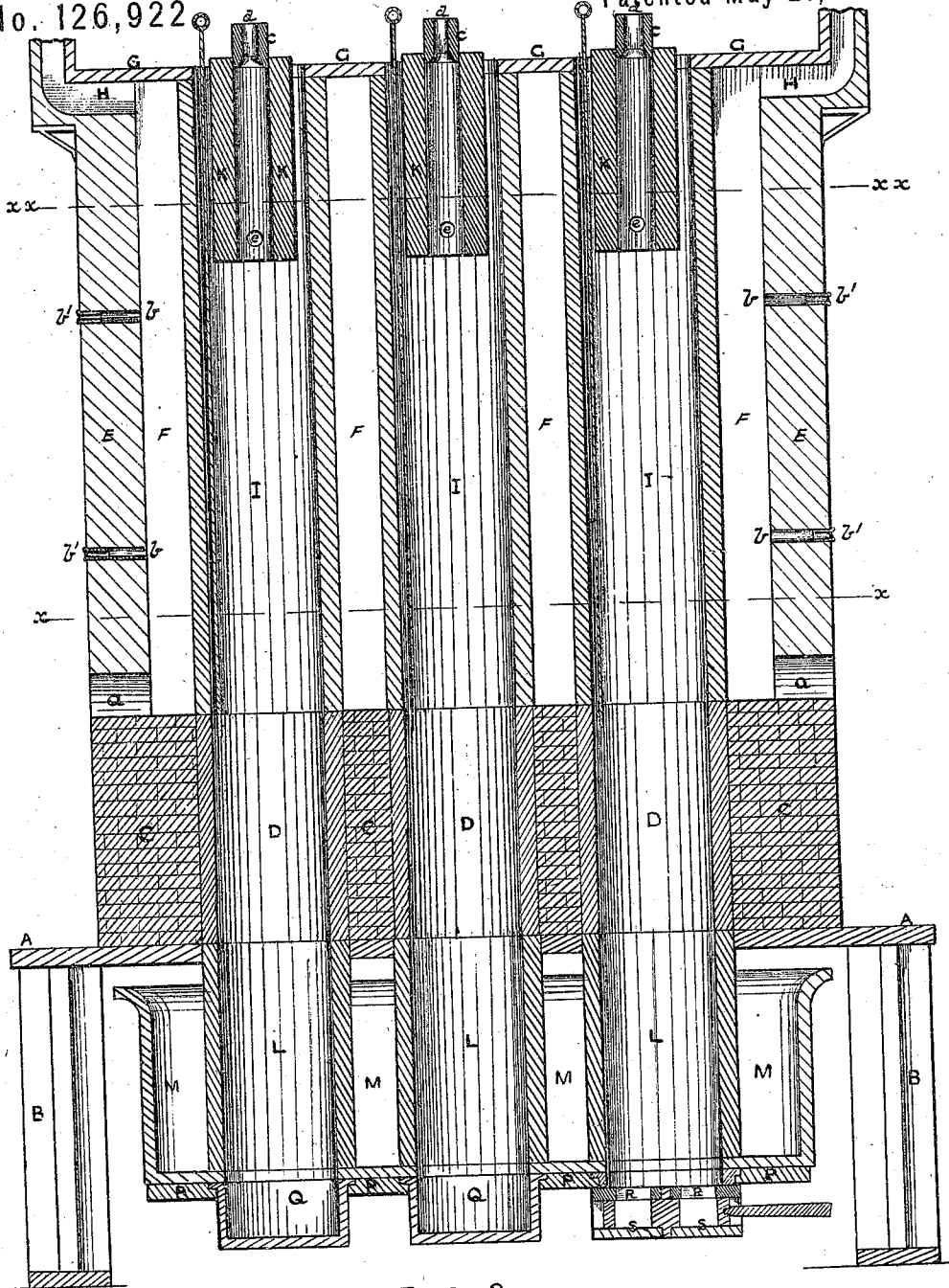


FIG 2.

Witnesses:

N. B. Bakewell

J. M. Miller

Inventor:

Thos. S. Blair

T. S. BLAIR.

Improvement in Process and Apparatus for Reducing the Ores of Iron.

No. 126,922.

Patented May 21, 1872.

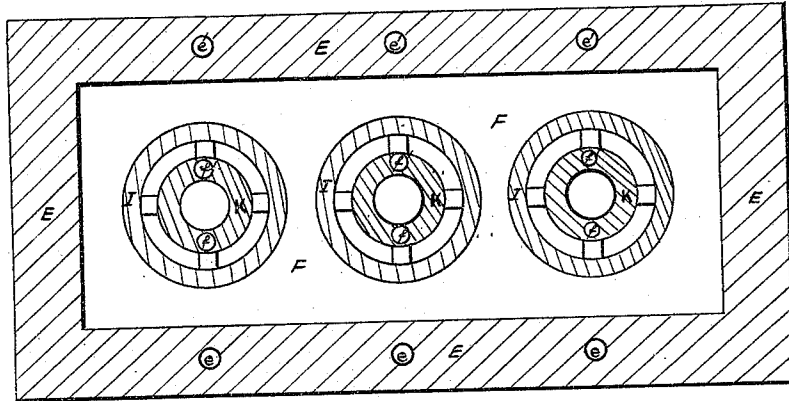


FIG 4.

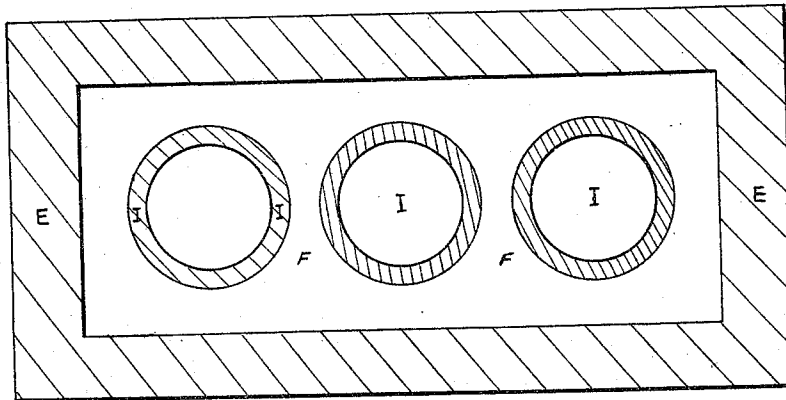


FIG 3

Inventor:

T. S. Blair

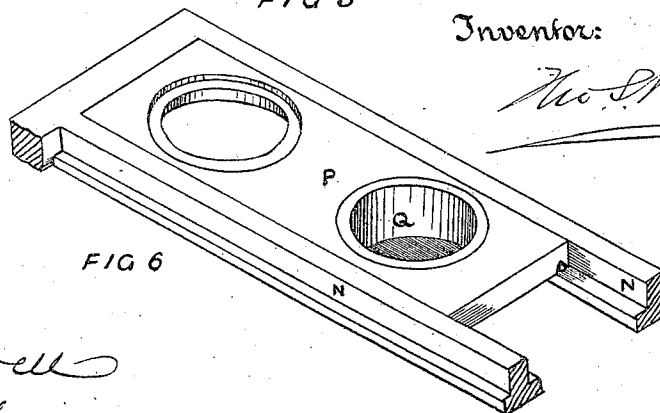


FIG 6

Witnesses:

N. Bakewell
E. Miller

T. S. BLAIR.

Improvement in Process and Apparatus for Reducing the Ores of Iron.
No. 126,922.

Patented May 21, 1872.

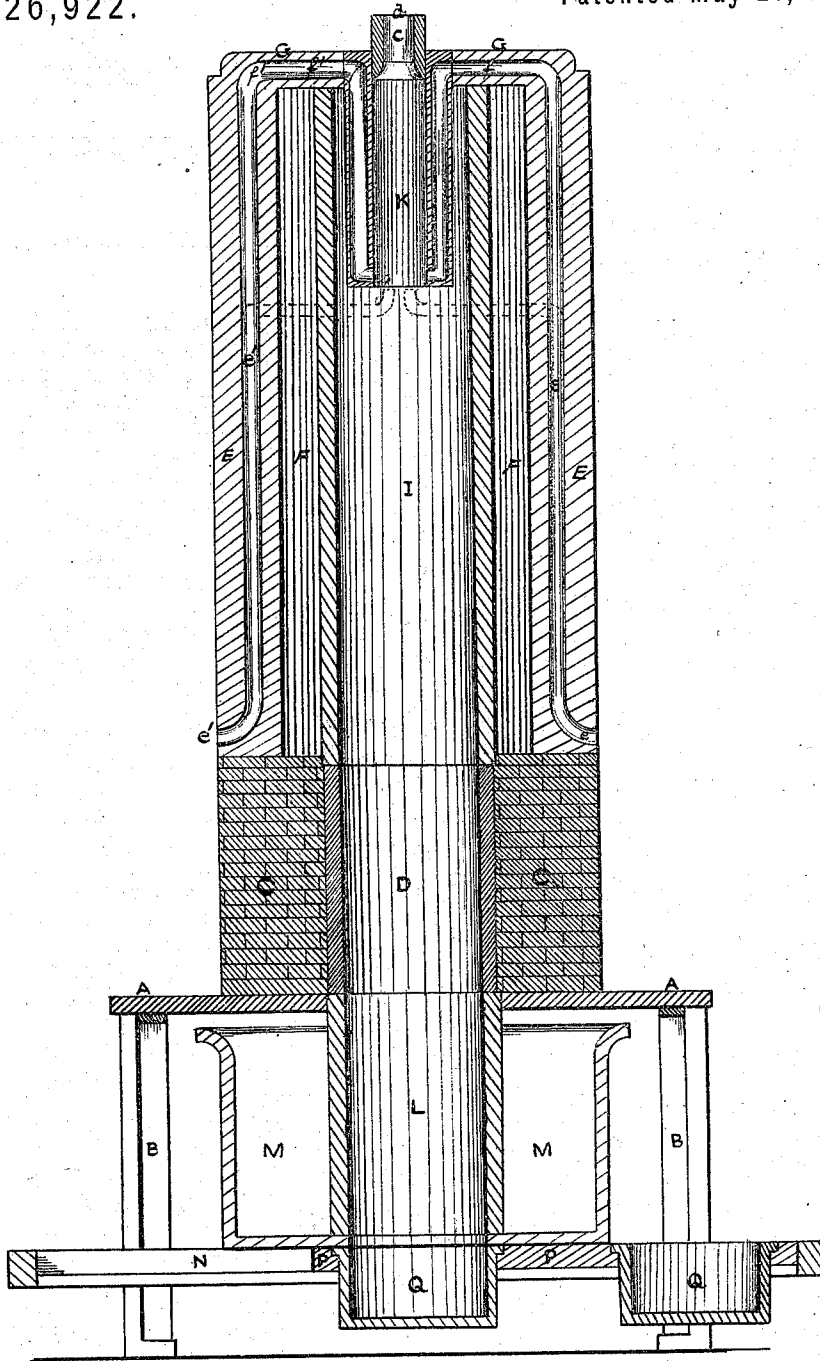


FIG 5.

Witnesses:

N. B. Bakewell

J. J. Miller

Inventor:

T. S. Blair

UNITED STATES PATENT OFFICE.

THOMAS S. BLAIR, OF PITTSBURG, PENNSYLVANIA.

IMPROVEMENT IN PROCESSES AND APPARATUS FOR REDUCING THE ORES OF IRON.

Specification forming part of Letters Patent No. 126,922, dated May 21, 1872.

SPECIFICATION.

To all whom it may concern:

Be it known that I, THOMAS S. BLAIR, of Pittsburg, in the county of Allegheny and State of Pennsylvania, have invented a new and useful Improvement in the Manufacture of Metallic Iron from the Oxides of that metal; and I do hereby declare the following to be a full, clear, and exact description thereof.

This invention relates to the manufacture of metallic iron from the oxides of that metal.

It is well known that oxygen thus combined with iron can be dissociated from it if the oxide be placed in contact with solid carbon, the whole being maintained for a certain time at a red heat, and without access of other oxygen. In such case the oxygen combines with the carbon, and leaves the iron in the metallic state. It is also known that this metallic iron will absorb oxygen with great avidity if exposed to it while at a red heat, but does not readily combine with the oxygen of the atmosphere, if brought into contact with it while it is at the ordinary temperature of the latter.

It follows from these well known facts that the only conditions necessary for producing metallic iron from its oxides are these: Contact, at a red heat, of oxide and carbonaceous matter for a certain time; then cooling to the temperature of the atmosphere; the whole to be conducted with perfect isolation from the air until the cooling is perfected.

Such is the problem. It is of extreme simplicity of theory, but in practice it has hitherto baffled every effort. There is not, at this day, a single establishment that makes use of this form of iron for any purpose, save only the few and very limited cases in which an extremely imperfect article is worked in bloomeries as a sort of intermediate system between the treatment of raw ore and that of pig-iron.

The attempts to obtain iron in this shape have been so numerous that it would be impracticable to explain in detail the several defects which caused their failure; but, in a general way, it may be said that they did not sufficiently provide against one or other of two difficulties, to wit: First, the difficulty of conduction of heat through a medium so ill-fitted to the purpose as is the material to be treated. From this arises imperfect reduction of the

mass furthest removed from the heat, and consequent irregularity of product. Second, the difficulty of perfectly excluding the air from the metallic iron until cool. Unless this is accomplished, reoxidation is inevitable. But the air is so mobile, so searching, that no mere device of valves, traps, &c., can be depended on.

Conspicuous among these attempts are those of William N. Clay, in England, Adrien Chenot, in France, and James Renton, in the United States, as described in the patents granted to them, respectively. In the cases of Clay and Renton—and the same remark applies to all the processes in which it has been attempted to transfer the sponge hot from the reducing-chamber to the place of after treatment—the exposure to reoxidation was inevitable and fatal. In the case of Chenot, the defective conduction of heat to the center of the mass, and the want of adequate provision for exclusion of the air from beneath, combine to render his results useless, except in the shape to which I have above referred, viz., the production of a mass of more or less deoxidized and reoxidized ore, capable only of being worked advantageously in the bloomery fire, as a process intermediate between the working of raw ore and the employment of pig-iron.

In proceeding to explain the system by which I overcome both the difficulties above referred to, I shall reverse the order in which they are stated above, and will first describe the arrangement by which I secure the exclusion of air during the whole period of treatment.

Let Figure 1 represent a vertical pipe, of which the portion above the line Z Z is surrounded by a red-hot atmosphere, and the portion above the line Y Y and below the line Z Z is surrounded by cool water. It will be seen that if this pipe is kept constantly filled with a loose material, such as pebbly or granular ore, small charcoal, coke, or the like, and this material is constantly, or at intervals, partially drawn away at the space between the bottom of the pipe and the floor X X, the contents of the pipe will, if their downward movement be properly regulated, be arranged in three different zones, blending into each other at the planes of contact, but each having in its main body a distinct character. These zones are, first, the upper zone V to W, wherein the

material is acquiring the requisite degree of heat. This is the zone of preparation. Second, the middle zone W to Z, wherein the material, having required the requisite heat, is subjected to the chemical action desired. This is the zone of reduction. Third, the lower zone Z to Y, in which the material gives up its heat, until it reaches a temperature at which it may safely be exposed to the air. This is the zone of cooling.

Now, let W to Z be regarded as a retort, whose contents are to be treated according to the conditions of the problem as before stated. It will be seen that we have secured the contact of materials, and the heat, and the duration of exposure. How as to the exclusion of air? Above, there is the superincumbent material of the zone V to W, through which there is a constant outward flow and pressure of the gas generated in the zone W to Z. It is obvious that it is a mere question of having sufficient depth in V to W, and the prevention of a downward movement of air becomes perfect. Below, there is the mass of material in the zone Z to Y, compacted by the pressure of the material above it, and saturated with the same gas as passes up through V to W, the said gas in this lower zone having a tension considerably above ordinary atmospheric pressure. Here, again, it is obvious that it is a mere question of the depth of Z to Y, and the extent to which the mass of material shall be left to envelope and guard the discharge, and the prevention of an upward movement of air is secured. Thus the material under treatment is itself the packing which excludes the air, and the zone W to Z becomes a reducing-chamber, which is perpetually sealed, yet continuously working.

Returning now to the question of imparting the heat to the material, it will be understood that the difficulty referred to will not be seriously felt where the area of the pipe or chamber is small, say within six inches diameter. But to work on a large, and consequently economical scale, we should deal with diameters of several feet. If, then, we had a reducing-chamber of three feet diameter, necessitating the conduction of heat a distance of eighteen inches through such a medium as our material supplies, the time required would be a fatal objection. This difficulty I meet in the zone of preparation. Instead of having this portion of the apparatus a mere prolongation of the chamber W to Z, Fig. 1, I transform it into one or more conductors to convey the material into W to Z, taking care that said conductors shall have such a shape as that no particle of the material, while passing through them, shall be a greater distance than, say, two inches from a heating surface. By this arrangement it is only necessary to take care that the conductors shall have sufficient length, and the object is readily accomplished.

Having thus explained the two special fea-

tures of my invention, whereby I avoid the chief causes of failure in former efforts, I now proceed to describe in detail the apparatus whereby I have succeeded in manufacturing, with ease and economy, true metallic iron sponge.

The accompanying drawing represents the reducing-furnace which I employ for practising my improved process.

Figure 2 is a vertical section of the furnace through the axis of the reducing-chambers. Fig. 3 is a horizontal cross-section of the reducing-furnace at the line *xx* of Fig. 2. Fig. 4 is a horizontal cross-section at the line *xx* of Fig. 1. Fig. 5 is a vertical sectional representation of one of the reducing-chambers at right angles to the section shown in Fig. 2. Fig. 6 is a perspective representation of the discharging apparatus.

In the several figures like letters of reference denote similar parts of the apparatus.

The reducing-furnace, represented in section in Fig. 2, is an oblong chamber of brick-work or masonry built upon a base-plate, A, which is supported, at a convenient height above the surface of the ground, on a sufficient number of pillars, B B, so as to afford access to the discharging apparatus at the lower extremity of the reducing-furnace. The furnace shown in the drawing is furnished with a single row of three retorts, the number of which may be more or less, as may be desired. The height of the furnace above the base-plate A may be about twenty-four feet, although this and other dimensions which are given in this specification need not be exactly observed, but are merely stated by way of illustration. The lower portion C of the furnace, for about one-fourth of the height above the base-plate A, is built solid, of brick-work, if necessary, around the cylindrical cavities D D D, which form the lower, but not the lowest, zones of the retorts. These cavities D may be about thirty-six inches in diameter, and are made either of fire-brick material or of iron, which may be incased in the fire-brick material, being cylindrical pipes set in the masonry C. The outside walls E of the reducing-chamber are built on the masonry C, about eighteen inches in thickness to the top of the chamber F, which is covered over with a cap, G, having no opening at top to the external air, but a flue or flues, H, to allow of the escape of the waste heat and gases from the furnace. At the lowest point of the chamber F are openings *a* in the outer walls E for the entrance of heat from a gas-furnace or other furnace for heating the reducing-chamber. Higher up in the outer walls E are small apertures at different heights, which serve as spy-holes *b b*, through which the degree of heat in the cavity F of the reducing-chamber may be observed from time to time by the workman. These spy-holes *b* are closed when not being used by means of plugs or stoppers, as at *b'*, in Fig. 2. Above each of the cylindrical cavities D

is a retort, I, made of fire-brick material, corresponding in internal shape and diameter with the cavity D, and forming with it a continuous cylindrical pipe extending to the top of the reducing-chamber F, and communicating at top with the external air. The retorts I have no openings in their sides, there being no communication between the reducing-chamber F and the cavity of the retorts I. K K K represent cylinders of iron protected by an interior lining of fire-brick material, open at their lower extremity, and furnished with a movable cap, c, at their upper end, through which cap a pipe, d, allows the escape of gas from the interior of the cylinder. Each of these cylinders is of smaller external diameter than the interior diameter of the retorts I, so that when inserted into the cavity of the retort there is an annular space of about four inches all around it. One such cylinder, K, is introduced into each retort I at the top, being suspended or supported in such a manner as not to close the top of the annular space around it, and extends downward about one-third of the distance between the top of the retort and the top of the tube D. These cylinders K are heated by means of a stream of gas introduced from the outside of the reducing-furnace through a suitable pipe or passage, e, in the outer wall F, (see Fig. 5,) at the top of which it communicates with the pipe f, and thence down through the body of the cylinder K, whence it emerges at the opening g, near the lower end of the cylinder. The gas thus passing through the wall of the furnace and cylinder, receives additional heat on its passage to the point of exit. Similar passages e' f', on the opposite side of the reducing-furnace, conduct atmospheric air to the interior of the cylinders K, which becomes heated in its passage, and, uniting with the heated gas, causes vivid combustion sufficient to heat the cylinder. The flues or passages e' e', instead of passing up to the top of the wall E, may be turned inward, (as shown in dotted lines in Fig. 5,) and be connected with pipes entering the chamber I, to lead the gas and air into the cylinder K at the bottom. Below each pipe D is an iron pipe, L, of the same internal diameter, and forming an extension of the retort below the base-plate A. The pipes L are open at their lower extremity, and they are surrounded by a trough, M, through which a current of cold water is kept running. The trough is so connected with the bottom of the pipes L that the water cannot enter them, the cavity of the pipe extending through the bottom of the trough, as seen in Figs. 2 and 5. Attached to the bottom of the trough M, or to the flanges surrounding the lower end of each pipe L, are ways N N, (see Fig. 5,) placed parallel to each other, between which slides a table, P, the upper surface of which is in close contact with the under surface of the lower extremity of the pipe L. This frame has two circular openings in which are inserted two

pots, Q Q, having flanged rims flush with the upper surface of the table P. The table P being slid between its ways N N, brings one or other of the pots Q under the bottom of the pipe L, so that a portion of its contents may be discharged into the pot, and when the slide is drawn back again the pot, with its contents, may be removed from the table P without exposing the interior of the retort to access of the external air. If preferred, a single pot may be used, the surface of the table serving to seal the lower end of the pipe L whenever the pot is withdrawn from its position under the pipe L.

As a substitute for this discharging apparatus the lower end of the pipe L may be covered by a perforated plate, R, (see Fig. 2,) to the center of which is pivoted another similarly-perforated plate, S, so that when the perforations in the two plates are made to coincide, by turning the lower plate S any desired quantity of the contents of the retort may be discharged, and then the opening be closed by turning back the plate S. As the contents of the lower portion of the retort (in the pipe L) are cold (or nearly so) before being removed from the retort, no damage will accrue by the opening of the perforated plate for the period of time required for removing the desired quantity.

I will now proceed to explain my process for reducing iron ore to metallic sponge by the use of the apparatus above described.

The ore, if in large pieces, should be crushed. I do not find that it makes any difference in the result whether the pieces are fine or coarse, excepting that each charge should consist of particles of about the same size, as the larger pieces require somewhat longer treatment than those which are smaller, and hence, by classifying them, I am enabled to secure uniformity of result. The ore is then mixed with solid carbon to prepare the charge for the furnace. In order to determine the requisite proportions of carbon and ore, I first ascertain the average chemical composition of the ore to be treated, in order to ascertain the relative proportion of oxygen which it contains. Then, as the combining-weights of carbon and oxygen are, respectively, six to eight, and as the combination by my mode of treatment is CO, (the heat employed being low,) the minimum amount of carbon used should be in the same proportion to the oxygen in the ore—that is, three-quarters of the weight of oxygen; and as a perfect mechanical mingling and contact of the particles of carbon and oxygen cannot be secured, I use an excess of carbon, adding about ten per cent. to the amount of carbon indicated by the formula above stated—that is to say, making the proportion by weight of carbon and oxygen about nine to ten.

It might be supposed that by using a slight excess of carbon particles of metallized ore would, after reduction by contact with the carbon, become more or less carburized by ce-

mentation, so that the product would be partly steel, and thus an element of irregularity would be introduced; but this I have found, in practice, not to be the case, owing to the fact that at the low heat at which the reduction is effected by my process, cementation does not take place during the time for which the exposure is continued.

The carbonaceous matter employed should be charcoal, coke, or anthracite coal, in preference to substances containing much hydrogen, which would disturb the uniformity of action of the furnace. As the amount required is only about one-third by weight of the metallic iron produced, it will usually pay to wash the coal from which the coke is made, and to select the anthracite, so as to have the smallest possible amount of inert and injurious matter in the reducing agent.

In mixing the ore and carbon together I find it expedient to mix coarse ore with fine carbon, or coarse carbon with fine ore. The reason is, that if both are coarse the mixture is not a sufficiently perfect packing to perform fully its duty as an isolator, as the air will search in through the large interstices; and if both are fine or powdery they are apt to "pack," thus interrupting the regular descent through the retorts, and producing irregular action.

The charge of ore and carbon being prepared and intimately mixed, in the proportions above stated, is then introduced into the retorts I from the top, at the annular space around the cylinders K, care being taken to fill the retorts up to the top. They are kept full during the continuance of the operation by supplying the charge at top as fast as the product is removed from below. Before the retorts are charged they are heated by means of heat and gas communicated, as before stated, from without, through the flues *a a*. The furnace being hollow from the point above the solid masonry C to the top, the retorts I are surrounded externally by a heated atmosphere which is maintained at a suitable temperature, (a bright red, approaching yellow.) As it is very important to keep the heat uniform, and not to increase it up to the point at which cementation would commence or the material become sticky, the workmen must be required to observe it frequently by looking through the spy-holes *b*, and by removing the caps *c*, or by spy-holes through them, to look down into the cylinders K. The heat is regulated from the furnace in the usual way, varying of course according to the description of furnace employed. The interior of the cylinders K (into which the charge of ore and carbon is not introduced) are heated and preserved at proper temperature by means of heated gas and air introduced through the pipes *e* and *f*, as before described.

The first portion of my process is the initial heating of the "charge" of ore and carbonaceous matter. This initial heating is, as I have ex-

plained, one great cause of the success which attends my process. It is very difficult to heat uniformly and thoroughly a large mass of ore and carbon without exposing it either to a high temperature or to a lower temperature for a long period of time, and without carburizing the outer surface of the mass, while the interior is not thoroughly deoxidized.

This difficulty I overcome by heating the charge in a comparatively thin sheet during the first stages of the process, and before it is brought together in a mass in the body of the retort. This I term "initial heating," and is effected as follows: The upper portion of the charge, contained in the annular space between the external surface of the cylinder K and the wall of the retort I, is in a thin sheet, and is subjected to the heat which surrounds the retort externally and also to the heat generated by the combustion of the gas within the cylinder K. In this annular passage, which, in this case becomes the "conductor" already alluded to, the material becomes thoroughly and uniformly heated to the proper temperature for the chemical action required, and when it has passed out of the annular space into the main body of the retort I the process may be said to be fully established, and it is only necessary to maintain throughout the charge the degree of heat already communicated to it. This enables me to use a retort, I, of a diameter within practical limits, one great difficulty in all prior attempts having been the impracticability of using retorts of sufficiently large diameter without an irregular and imperfect reduction of the ore. After entering the main body of the retort I, the charge is kept up to the required heat by the surrounding heating atmosphere of the reducing-chamber F, and nothing remains to be done but to retain the proper temperature, to regulate the discharge, and to keep the retorts filled.

Another great obstacle to the successful manufacture of iron sponge is the difficulty of leaving it in the sealed retort until it is cold enough to be removed without danger of oxidation from contact of the atmospheric air, and at the same time carrying on a continuous reduction of the ore. This removal I effect by means of the peculiar construction of my apparatus. While the charge is in the main body of the retort I, it is kept at a uniform bright-red heat, but as soon as it descends into the zone D, which is incased in masonry, it is of course no longer surrounded by the heat of the furnace, and while in the zone D it begins gradually to cool, while the operation of deoxidation, if not complete, is still progressing, the masonry C receiving and serving to retain the heat aiding this result. From the zone D the deoxidized charge sinks into the lowest zone L of the retort, which is surrounded by a trough of cold water, so that there the charge is cooled until it ceases to be colored by the heat, and is then ready to be discharged, which is effected by means of the

apparatus hereinbefore described. The discharging apparatus removes only the contents of the lowest part of the retort, which have become sufficiently cool, and the contents of the retort not being sticky and adherent, the removal of a portion at the lower end causes a downward movement of the entire mass.

The frequency with which the charges of deoxidized ore can be withdrawn depends upon the rapidity with which the process is carried on, which will be found to vary considerably; that which is close-grained and hard requiring a longer time. The entire contents of a retort such as I have described will pass through the apparatus and be converted into sponge in from 6 hours to 3 days, according to the texture and quality of the ore under treatment.

When a charge is withdrawn the workmen can tell immediately whether the reduction is complete by the appearance and feel of the sponge, which if thoroughly deoxidized will be of a grayish color, lead-like in feel, easily indented by the finger-nail, and chewing like lead between the teeth. If there is any hardness in the grains it indicates the presence of imperfectly-reduced ore and consequently the necessity of prolonging the intervals between the drawings. Proper attention to this and to the maintenance of a uniform and proper heat, is all that is required to the successful operation of my process and apparatus.

After the sponge is withdrawn from the reducing apparatus, as above described, it will be cold enough to be thrown in a pile without any special protection from the atmosphere. It is, however, still mixed with some particles of solid unconsumed carbon owing to the excess of carbon used in the charge, for the reason before stated. This excess of carbon may be removed to a great extent by sifting, if the carbon used in mixing the charge be in either larger or smaller particles than the ore. When there is a decided difference in size most of the separation can be thus effected.

In case it is desirable to effect this separation more thoroughly, it may be readily accomplished by washing the sponge in pure water in the manner practiced in washing coal, as the difference in gravity between the iron sponge and the carbon separates them at once. I have found by repeated trials that the sponge is not oxidized by saturation with clear water unless it be afterward exposed in a wet condition for a considerable time to the action of the air, and by compressing the sponge soon after the washing no injurious consequences ensue.

All the carbonaceous matter separated from the sponge by sifting or washing is used over again, not only to avoid waste of the carbon, but also to secure any particles of iron which may be associated with it.

By the use of my apparatus in the manner hereinbefore described, the elements of irregularity are brought under control, and I am

enabled to realize in practice the long-desired result of effecting the deoxidation of ore without fusion and without carburization, and of securing the resulting sponge without exposure to the danger of reoxidation by the action of the atmosphere, and with sufficient rapidity to be practically useful.

It is not absolutely necessary that the apparatus should work vertically. The same system of isolation can be applied horizontally by having the material thrust by mechanical force through a conduit, pipe, or chamber, the middle portion of which is heated, and a sufficient body of the material under treatment maintained both before and behind said middle portion to secure the isolation desired. Such an apparatus will be far simpler, as to construction of the heating arrangements, than the vertical system, and would hence be preferable for working upon a small scale and where first cost of "plant" was a great consideration.

As this article—really well made—has never before been seen in any quantity, having in fact hitherto been a mere laboratory curiosity, its nature and uses have been but little understood. Its intense chemical sensitiveness and activity may, however, be conceived when we consider that from every particle of iron has come away a solid particle of oxygen, leaving a vacant place for any other particle of matter possessing the chemical properties that fit it for that place, and leaving also a channel whereby to reach it. Again, the state of minute subdivision in which the iron remains can scarcely be apprehended. The particles cohere so feebly that the whole can readily be ground to powder, and thus we have iron presented in a mechanical condition which adapts it to purposes to which it has hitherto been inapplicable, opening new fields of employment. Again, in sponges—that is, in the shape in which lumps of ore are left—whether in its metallic condition, or (by heating in air) oxidized, it becomes an agent for special filtering purposes.

Having thus described my improvement in the manufacture of metallic iron from its oxides, what I claim as my invention, and desire to secure by Letters Patent, is—

1. The process of reducing oxides of iron to the metallic state by subjecting them to a red heat in contact with carbonaceous matter in a chamber constructed, substantially as hereinbefore described, so that the material under treatment shall supply the packing which excludes the air therefrom.

2. As a part of the process of the continuous operation of reducing metallic oxides by admixture with carbon and subjection to heat, the initial heating of the materials under treatment in masses of smaller diameter than that of the reducing-chamber, for the purpose of thoroughly and uniformly heating them before they are introduced into the reducing-chamber, substantially as hereinbefore described.

3. A reducing-chamber, constructed without

other aperture for the access of gas or air than at the charging and discharging extremities, and of such length below the point at which the heat is externally applied as that the oxide under treatment shall in the carrying on of a continuous operation have sufficient time to become cool before it is discharged, substantially as hereinbefore described.

4. The cylinder K or its equivalent in combination with the reducing-chamber or retort I, for the purpose of forming a conducting channel of relatively-small diameter, within which to effect the uniform initial heating of the mixed ore and carbon before their introduction into the reducing-chamber or retort, substantially as and for the purpose hereinbefore described.

5. The sliding table P with the inserted pot

or pots Q, in combination with the cooling-pipe or section L of the reducing apparatus, for the purpose of discharging its contents without the admission of the external air, substantially as hereinbefore described.

6. The combination of the double perforated grating R S with the cooling-pipe or section L of the reducing apparatus, for the purpose of discharging its contents without the admission of the external air, substantially as hereinbefore described.

In testimony whereof I, the said THOMAS S. BLAIR, have hereunto set my hand.

THO. S. BLAIR.

Witnesses:

MORRISON FOSTER,

THOS. B. KERR.