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PROCESS OF REDUCING IRON ORE WITH HEATED GASES.

No. 434,694. Patented Aug. 19, 1890.

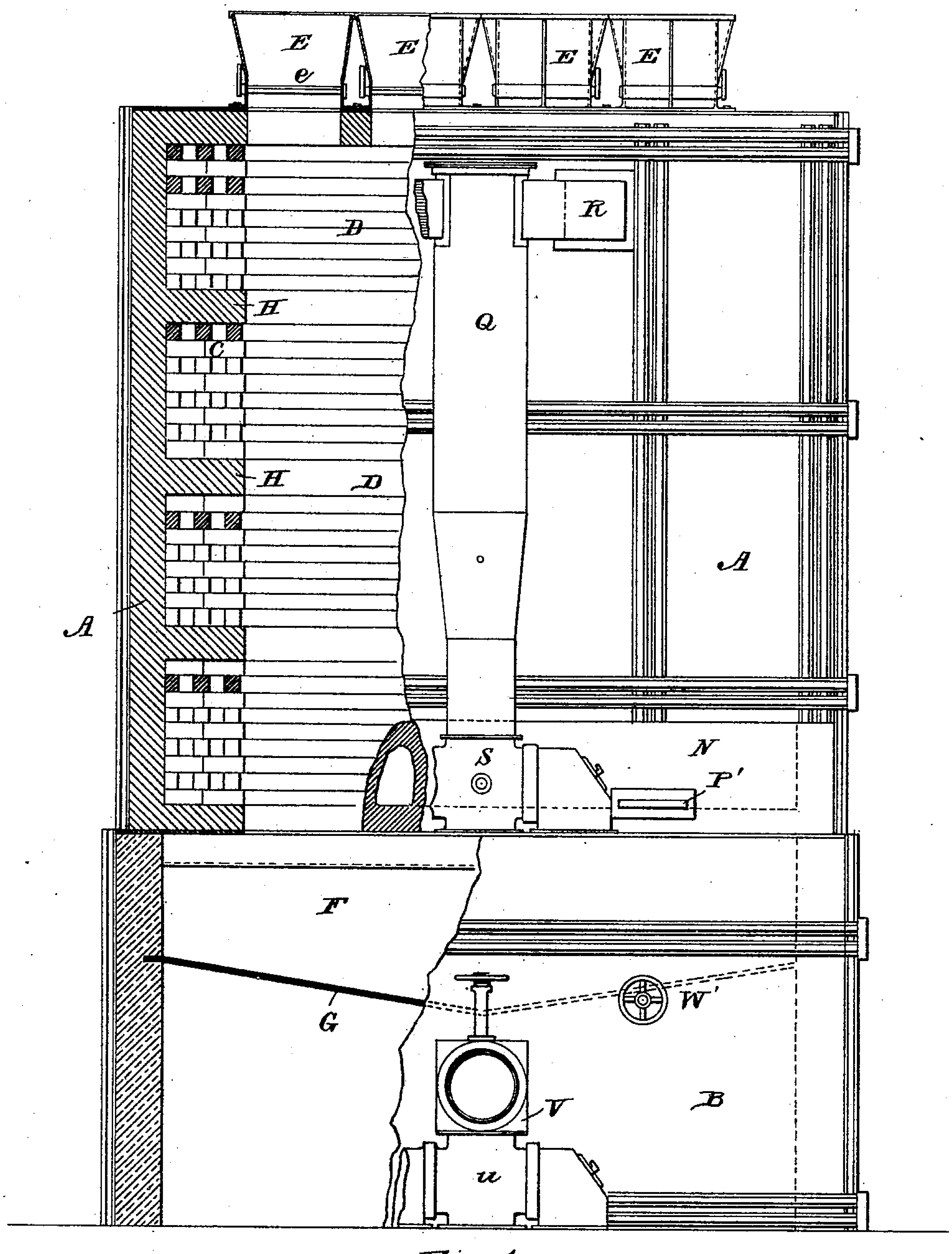

Fig. 1.

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Fig. 2.

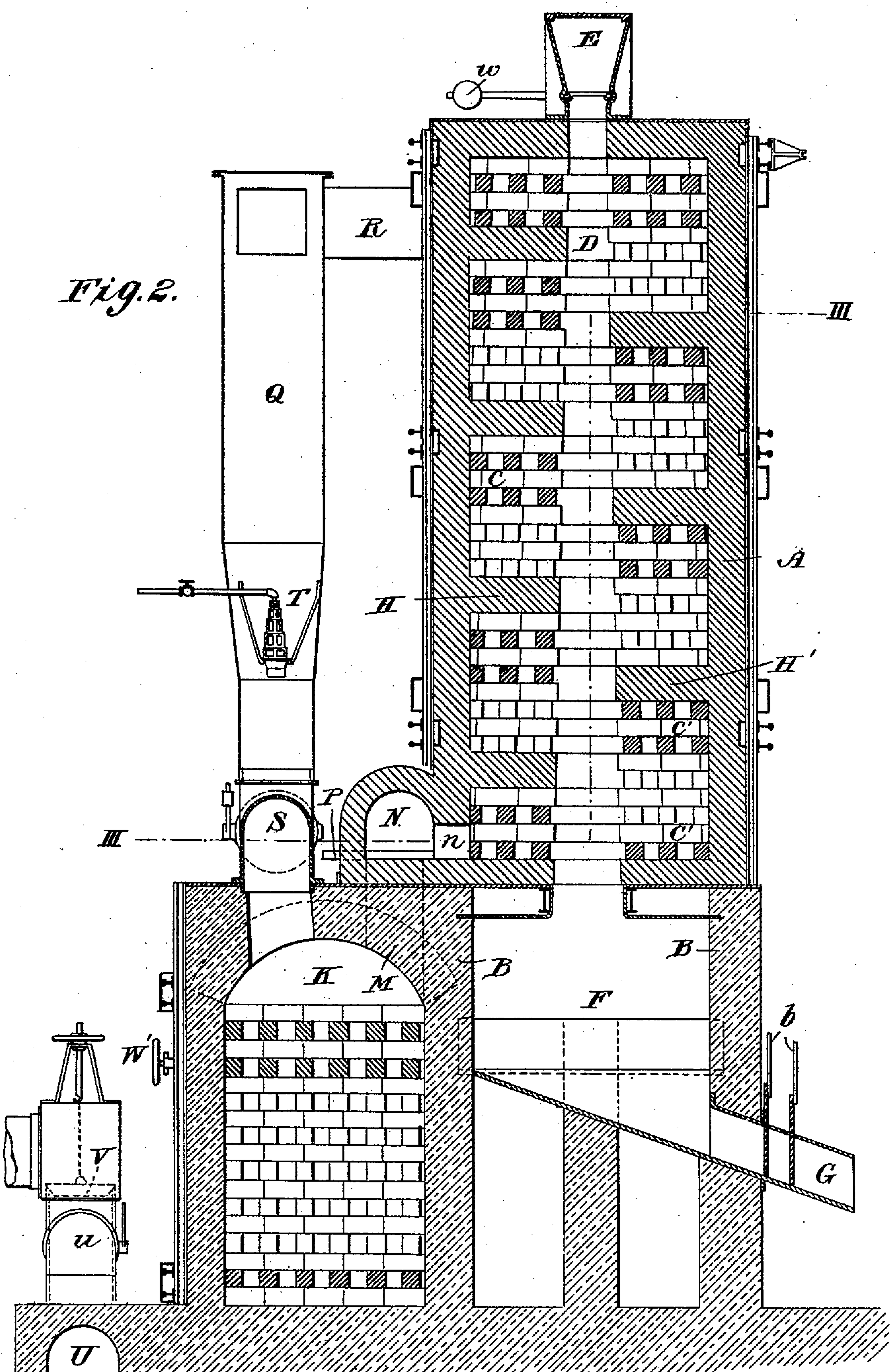

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Fig. 3.

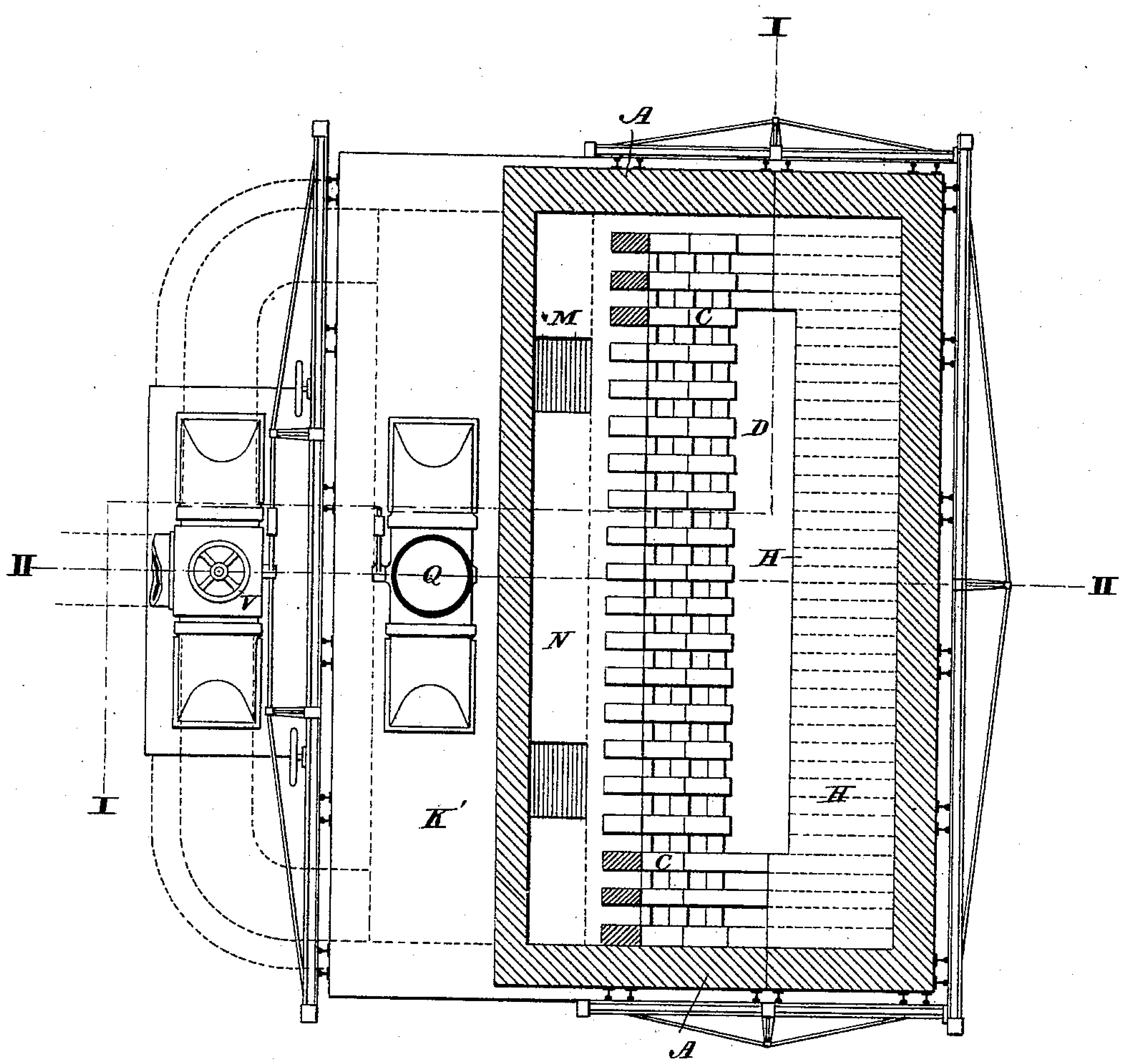

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Fig. 4.

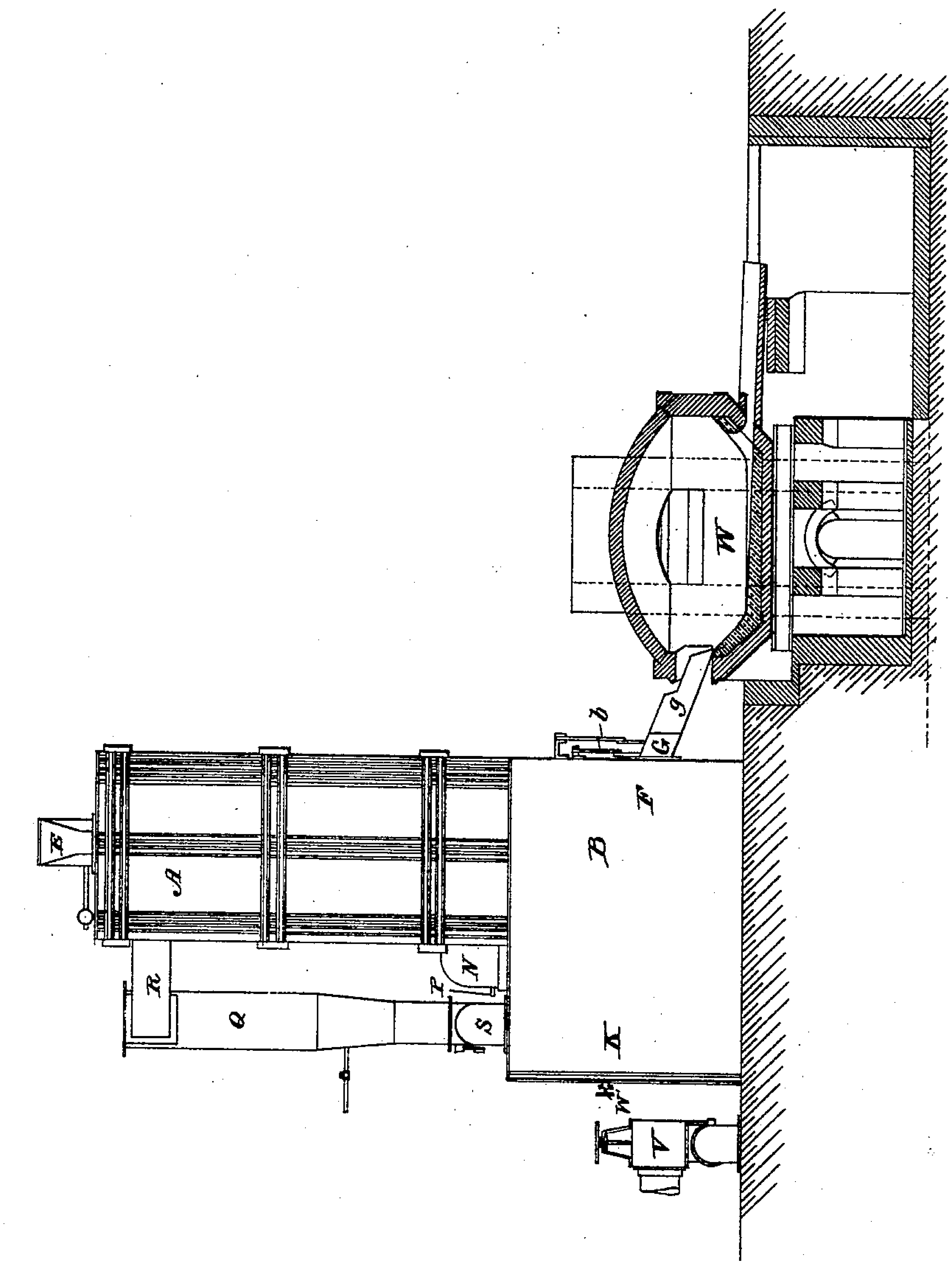

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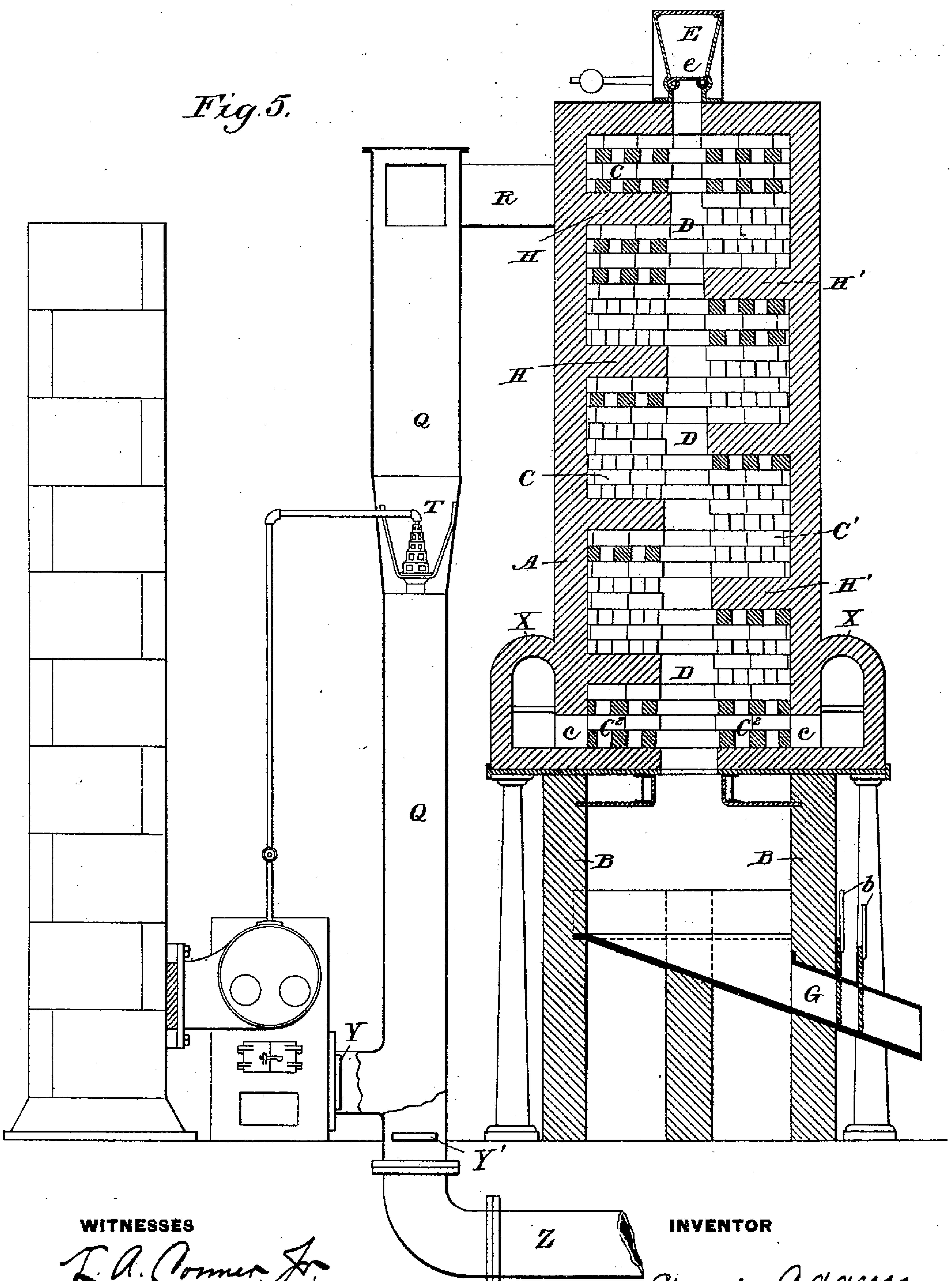
Fig. 5.



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UNITED STATES PATENT OFFICE.

CHARLES ADAMS, OF ST. LOUIS, MISSOURI.

PROCESS OF REDUCING IRON ORES WITH HEATED GASES.

SPECIFICATION forming part of Letters Patent No. 434,694, dated August 19, 1890.

Application filed September 6, 1889. Renewed July 2, 1890. Serial No. 357,468. (No model.)

To all whom it may concern:

Be it known that I, CHARLES ADAMS, of St. Louis, in the State of Missouri, have invented a new and useful Improvement in the Process of Reducing Iron Ores with Heated Gases, of which the following is a specification.

My improved invention of manufacturing iron and steel direct from the ore consists in subjecting the ore (iron oxide) to the action of a reducing or carburizing atmosphere of substantially the same character and at substantially uniform temperature until the ore is deoxidized or converted into sponge.

In the process of reduction of iron ore and its conversion into sponge it is practically a difficult thing to secure a uniform reduction of the entire mass without on the one hand leaving pieces of unreduced ore or on the other hand carrying the deoxidation so far as partially to carburize or even fuse the sponge. To effect a uniform and rapid reduction of the ore, I have found it very important to preserve uniformity throughout the apparatus in the character of the gas employed, avoiding at all times the presence of carbonic acid, and exposing the ore under treatment at all steps of the reducing process to a uniform degree of heat.

As my improved process involves the use of the apparatus herein described, or apparatus substantially the same, I will proceed to describe its construction and arrangement, and in connection therewith explain its function in the practice of my improved process. Said apparatus, being subject-matter of a separate application, Serial No. 322,813, is not claimed herein.

The accompanying drawings illustrate my invention. They consist of five sheets and figures.

Figure 1 is a vertical representation of my improved furnace partly in section. Fig. 2 is a sectional elevation of my improved furnace on the dotted line II II of Figs. 1 and 3. Fig. 3 is a horizontal plan and section on the line III III of Fig. 2. Fig. 4 is a side elevation of the furnace, showing its connection with an open-hearth furnace, the latter being in section. Fig. 5 represents a modification of my apparatus.

Like letters of reference denote the same parts of the apparatus in each of the figures.

A is the furnace, built of brick-work upon a foundation B, which, as shown in the drawings, is rectangular and oblong, but may be circular, elliptical, or other convenient shape. Suitable proportionate dimensions are a length of ten times its width and a height which will allow of the sufficient subjection of the ore to the reducing-atmosphere, say ten to fifteen times its width. These relative proportions, however, are not of the essence of the invention and are given merely as a statement of proportional size, which has been found successful in practice.

The interior of the furnace is furnished with checker-work C C′ of fire-brick arranged on each side and at the two ends of the furnace, as shown in Figs. 2 and 3, the checker-work C C′ being so arranged (as shown in those figures) as to leave a clear vertical space D from the top to the bottom of the furnace. In this space D the ore is charged and reduced. The space D is long and narrow, as shown in Fig. 3, and tapers upward in width, being narrower at top than at bottom, so as to give the necessary clearance for the descent of the charge. This working-space D is closed at top by a covered hopper E, which has besides its cover at the bottom of the hopper a hinged trap-door *e* for the admission of the charge, which is normally kept closed by a weight *w*. The working-space D is also closed at the bottom, either by a removable door of ordinary construction or preferably, as shown in the drawings, Fig. 2, by being placed over a tightly-closed reservoir F, which forms part of the foundation B. This reservoir F is the receptacle into which the reduced ore (iron sponge) is discharged from the working-space D of the furnace, and is provided with one or more inclined chutes G, from which the reduced ore is removed from time to time, double sliding doors *b b* being provided to each chute, so that one may be closed when the other is opened, so as practically to exclude the air from contact with the hot sponge.

The checker-work C C′, &c., in the interior of the furnace A is placed within a series of separate chambers formed by the horizontal shelves or diaphragms H H′, &c., which extend from end to end of the furnace and from each side to the central working-space D; but the diaphragms H on one side of the space D are not on the same level as those H′ on the opposite side, (see Fig. 2,) the diaphragm H on one side being placed in a horizontal plane about midway between two diaphragms H′ on the opposite side.

Below the furnace A are placed two regenerators K K′, fitted with brick checker-work L in the usual way. These regenerators are connected by uptakes M with a horizontal flue N, which extends the whole length of the furnace and connects by numerous adits n with the checker-work C^2 in the lowest checker-work chamber of the furnace on one side, as shown in Fig. 2. Valves P P′ (preferably made of fire-clay tile) are connected with the flue N, by which the regenerators K K′ are alternately connected with the checker-work C^2 in the lowest chamber in the interior of the furnace. A short horizontal flue R connects the topmost of the checker-work chambers C of the furnace with a downtake or draft-flue Q, which conveys the gas as it leaves the furnace downward to one of the regenerators K K′ through the butterfly-valve S, which can be set so as to admit the gas from the top of the furnace into either of the regenerators, the valves P, P′, and S being reversed from time to time, so that when the regenerator K′ is in connection with the furnace the other regenerator K is connected with the downtake-flue Q, and vice versa. A steam-ejector T, placed in the downtake Q, determines the direction of the draft downward from the top of the furnace A to the regenerators and regulates its amount and velocity. A flue U connects both of the regenerators K K′ with a stack or chimney to carry off the products of combustion, and a valve u, according as it is set, connects one or other of the regenerators with the flue and chimney.

The reducing-gas by which the ore is to be reduced may be either carbonic oxide (CO) or hydrocarbon gas or vapor, which is prepared in a separate gas-producer of any desired construction. If carbonic oxide is used, the common Siemens gas-producer may be employed; if hydrocarbon gas or vapor, it may be manufactured in any suitable apparatus, or may be simply a vessel charged with petroleum or other liquid hydrocarbon and heated sufficiently to vaporize it.

V is a valve for admitting the carbonic oxide or hydrocarbon gas or vapor from the producer to one or other of the regenerators K or K′, according as the valve V is set.

In case it is desired to dispense with the use of the regenerators K K′, a simpler construction of my furnace may be used, as shown in Fig. 5. The furnace itself, with the working-space D, partitions H H′, and checker-work C C′, placed in separate chambers, is the same as already described; but in place of the regenerators K K′, their flues and valves, and flue N and openings n, I place underneath the furnace a pair of fire-places X X, in which solid carbonaceous fuel is consumed by slow combustion, so as to produce carbonic oxide, which is introduced into the lowest checker-work chamber C^2 through a flue c. In this case the downtake Q is furnished with the ejector T, and the escaping gas from the top of the furnace is conducted under the steam-boiler to serve as fuel, or, if preferred, by closing the valves Y and opening the valve Y′ the gas will pass off to the stack or through the pipe z to be used for any purpose that may be desired.

The operation of the apparatus hereinbefore described as applied to the reduction of iron ores and the manufacture therefrom by a direct and continuous process is as follows: When the furnace is first used or when first used after having been emptied of its charge, the reservoir may be filled up to the bottom of the working-space D with ore, coke, coal, wood, or other suitable material which will not injure the reduced iron by its slow combustion and which will serve to sustain the burden of the charge of ore. The ore to be reduced is then charged into the furnace through the hopper E, which, by using the trap-door e, will serve, if desired, as a measure of quantity of the charge. The ore before being introduced may, if desired, have mixed with it a small quantity of some carbonaceous solid, such as coke, coal, charcoal, &c. I have found it advantageous to use for this purpose coke to the amount of ten to fifteen per cent., by weight, of the charge of ore. The working-space D is filled with this charge from top to bottom, forming a long and comparatively narrow or columnar mass, and if a continuous process is desired the working-space is kept filled up with ore (or ore and carbon) as the reduced ore gradually passes away below. Before commencing the operation of reduction the regenerators K K′ are both heated to from 800° to 1,200° Fahrenheit. The supply-pipe of the ejector T is connected with the live-steam space of a steam-generator. The hopper E is closed, as also the sliding doors b b in the chute of the reservoir F, so as to exclude as much as possible the external atmospheric air from the interior of the furnace A, and the valves S, P, and V are set so as to connect one regenerator, as K, with the flue N, and thus with the lower chamber C^2 of one side of the furnace A. The valve is set so as to connect the same regenerator K with the gas-producer, and the valve S is set so as to connect the downtake Q from the top of the furnace with the regenerator K′. The apparatus being thus adjusted, the carbonic-oxide gas from the gas-producer enters the flue, and thence passes up through previously-heated checker-work in the regenerator K and becomes thereby heated to a temperature of from 800° to 1,200° Fahrenheit, and thence arises through the uptake M into the flue N, and enters the lowest checker-work chamber C^2 at one side of the furnace through the adit n, heating the checker-work in the furnace as it traverses it. As the gas finds no passage-way upward, being obstructed by the partition or diaphragm H, it passes sidewise with the mixed ore and carbonaceous matter at the lower end of the working-space D. Here its upward passage through the superincumbent charge of ore being difficult, the gas, following the path of least resistance, enters the lowest of the chambers C′ on the opposite side of the furnace. Here it rises through the checker-work until it meets the obstruction of the first partition of that side of the furnace, which is at a higher level than the first partition on the other side, and is forced to pass again sidewise into the charge of ore, &c., in the working-chamber D, and, again taking the path of least resistance, it enters the checker-work on the side of the furnace at which it first entered, but into a chamber higher up, and thus, owing to the obstruction presented by the partition H H, &c., on one side and H′ H′ on the other side, and to the position of the partitions on one side of the space D being on a different level from those on the opposite side, the reducing-gas is compelled to follow a zigzag course backward and forward through the column of ore in the working-space D until it reaches the horizontal flue R, through which it enters the downtake Q and passes down through the valve S, set to conduct it into the other regenerator K′. Here the gas meets and combines with a current of atmospheric air admitted in any desired and regulated quantity, to secure complete combustion, by means of the valve W′ communicating its heat to the checker-work in the regenerator. The products of combustion thence pass off through one of the flues U and valve u to the stack or chimney, placed at any convenient point. The downward draft through the downtake Q, and consequently the upward current through the furnace A, is secured and regulated by the ejector T, situate in the downtake Q.

In order to preserve the required uniform temperature of gas passing through the furnace, the regenerator-valves should be shifted every ten or fifteen minutes, so as to turn the supply of gas from the producer into the regenerator which has just been heated up by combustion of the escape-gas from the top of the furnace, and thence through the valve P and flue N into the bottom of the furnace and to change the course of the escape-gas from the top of the furnace through the downtake Q by the valve S into the regenerator through which the supply-gas has just been passing.

The reactions produced by my improved process are as follows: The heated reducing-gas, (carbonic oxide,) passing through the body of the ore in the working-space D of the furnace, effects the deoxidation of the ore. The oxygen liberated from the ore has a tendency to combine with the carbonic oxide (CO) and form carbonic acid (CO_2), the presence of which would arrest the deoxidation of the ore, but this tendency is counteracted by the carbon when used mixed with the charge of ore; but chiefly by the constant access from the gas producer or source of supply to the interior of the furnace of fresh carbonic oxide or hydrocarbon gas or vapor preheated by passage through one of the regenerators and by the heat of the furnace, which is such that carbonic acid cannot exist in the presence of carbon. Furthermore, the desired degree and uniformity of temperature of the reducing-gas is maintained within the furnace by the heat communicated to and stored up by the checker-work in the several chambers of the furnace, which absorb and take up any excess of heat of the incoming gas which may occur, as in case of the reversal of the valves, turning the gas through a freshly-heated regenerator, and give out this stored-up heat to the gas when its temperature is reduced by the cooling of the regenerator previous to such reversal, and thus by means of my improved process and the use of the apparatus herein described the reducing quality of the gas, as well as the necessary uniform degree of heat, is maintained throughout the furnace and during its entire operation.

The result of my process, so far as described, is the production of deoxidized-iron ore, properly called "iron sponge." As this is formed without fusion, the pieces do not adhere together, but preserve very nearly the size and shape of the pieces of ore charged into the top of the furnace. In consequence of the reducing-gas passing back and forth through the charge of ore repeatedly before it escapes at the top of the furnace, and being unable to rise up directly through the charge, the ore is much more thoroughly treated than it can be in any other apparatus of which I have any knowledge, and as the gas after each passage across the working-space through the ore is compelled to enter the checker-work before returning through the ore, its temperature is regulated and rendered uniform, as hereinbefore explained. The iron sponge thus produced drops down gradually into the receptacle or reservoir F, which, extending under the entire length of the furnace, will hold a large amount of sponge. The doors b b being kept closed, the sponge is substantially protected from the access of external atmospheric air, which would rapidly oxidize the sponge, especially when in a heated condition.

My purpose is to continue the process to the extent of the manufacture of steel in an open hearth, for which hot sponge made by my process is especially adapted; but as such continuation of the process forms the subject of a separate invention of mine it need not be described more particularly in this specification.

I have described my process as applied to the reduction of iron ore by means of carbonic oxide without the formation to any injurious degree of carbonic acid and with the continuous reduction to carbonic oxide of any carbonic acid that may be formed. I have stated that the process may be conducted with the use of carbureted-hydrogen gas or of hydrocarbon vapor, in which case substantially the same results are produced. As in this case, however, no oxygen is present in the reducing-gas, but a larger proportion of carbon, there is less liability of the formation of carbonic acid, and a smaller proportion of carbon, or none at all, is needed in the charge; but the action of the carbon in deoxidizing the ore and the preservation of a uniformity of character and temperature of the reducing agent due to the construction of the furnace are preserved.

In case the furnace is used without the regenerators, as shown in Fig. 5, the combustion of the carbonaceous fuel in the furnaces is conducted with a limited supply of air, so as to produce carbonic oxide rather than carbureted hydrogen and fuliginous matter. The apparatus thus constructed is simpler and cheaper than that shown in the other figures and can be used to great advantage; but it is more difficult to preserve a uniform heat or a uniform quantity and quality of the reducing-gas, because every time the fire is stirred or fresh fuel is added to it more fuliginous matter is evolved and the production of carbonic oxide is decreased.

I have described my improved furnace as vertical and having a vertical working-space, and arranged with checker-work so disposed that the reducing-gas must pass upward and across through the charge, because I believe this to be the best arrangement; but I desire not to limit my invention to the use of apparatus having such vertical arrangement and upward movement of the gas, as it is quite possible to accomplish similar results with a horizontal or inclined furnace and a forced draft, the columnar mass of ore in such case being in a horizontal or inclined position, with the checker-work situate above and below or on both sides of the charge.

What I claim as my invention, and desire to secure by Letters Patent, is—

In the direct reduction of iron ores by heated reducing-gas, the process hereinbefore described, which consists in passing such gas back and forth through a mass of ore and through heat storing and equalizing chambers in alternate succession, substantially as and for the purposes described.

In testimony whereof I have hereunto set my hand this 4th day of September, A. D. 1889.

CHARLES ADAMS.

Witnesses:

W. B. CORWIN,

THOMAS W. BAKEWELL.