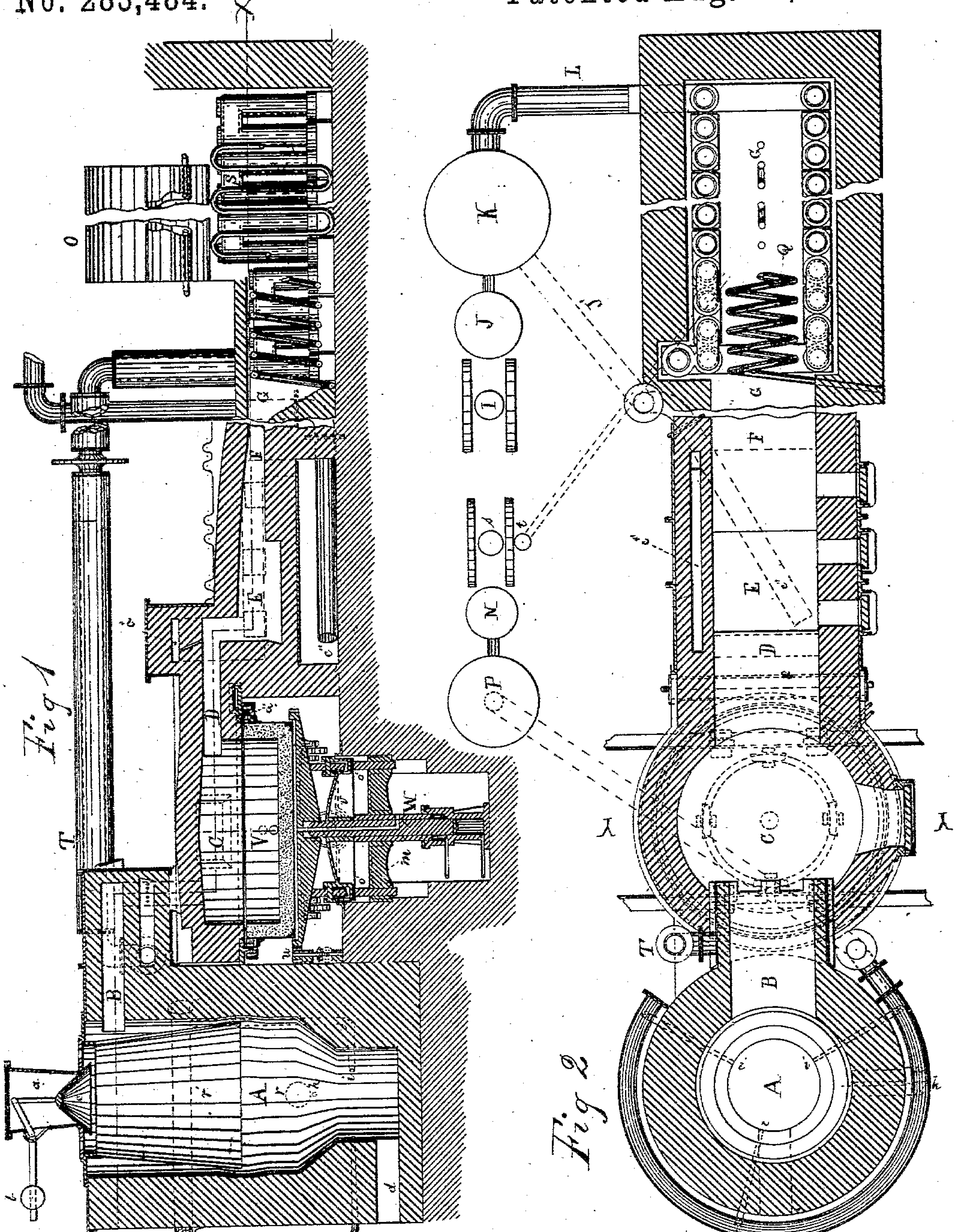
(No Model.)

3 Sheets—Sheet 1.

# J. HENDERSON.

## ART OF MANUFACTURING IRON AND STEEL.

No. 283,484. Patented Aug. 21, 1883.




WITNESSES:

Arthur S Henderson

C B Hamm

INVENTOR

James Henderson

BY

ATTORNEY

(No Model.) 3 Sheets—Sheet 2.

# J. HENDERSON.

## ART OF MANUFACTURING IRON AND STEEL.

No. 283,484. Patented Aug. 21, 1883.

*Fig. 3*

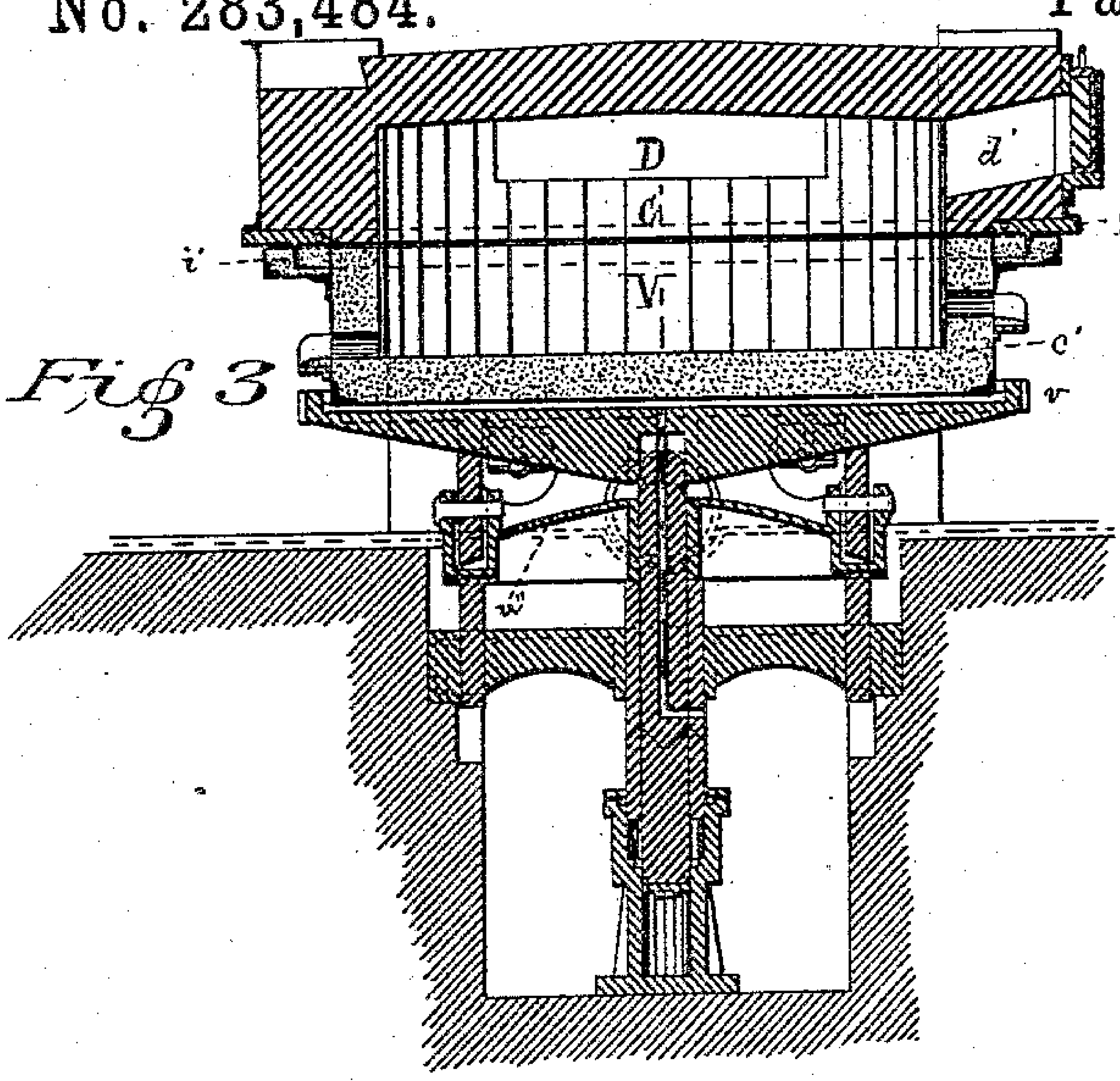



*Fig. 8.*

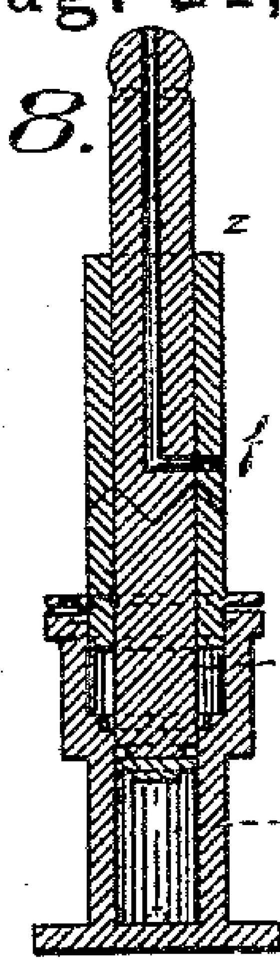



*Fig 9*

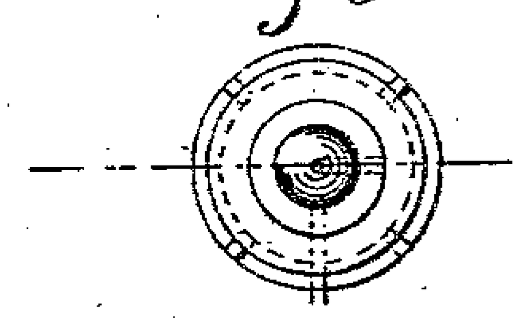


*Fig 5*

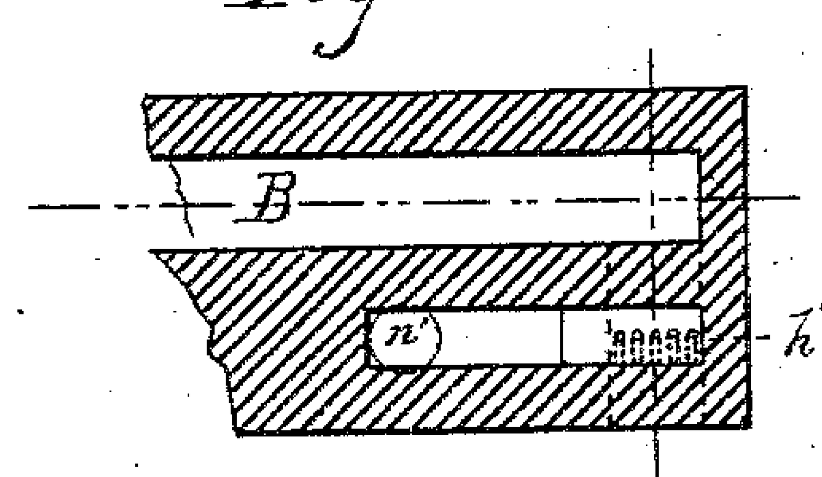



*Fig 4*

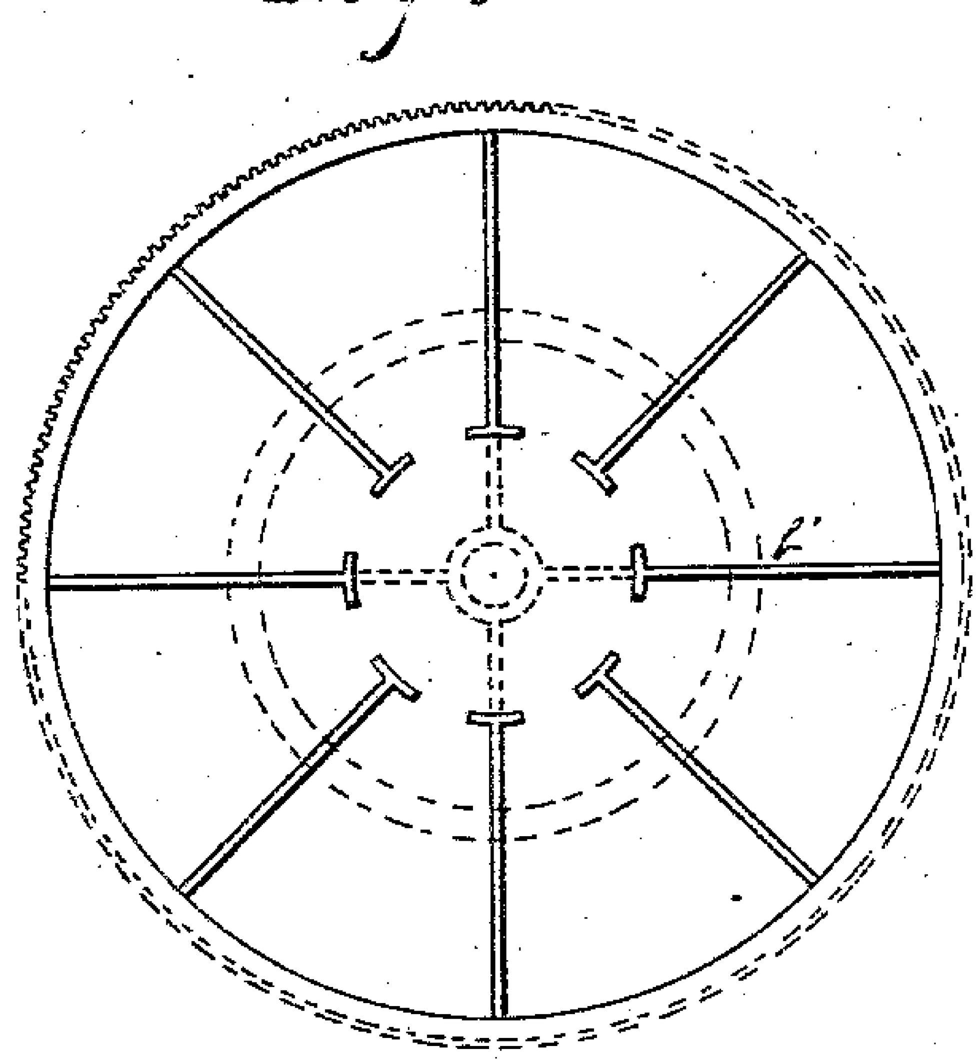


*Fig 6*

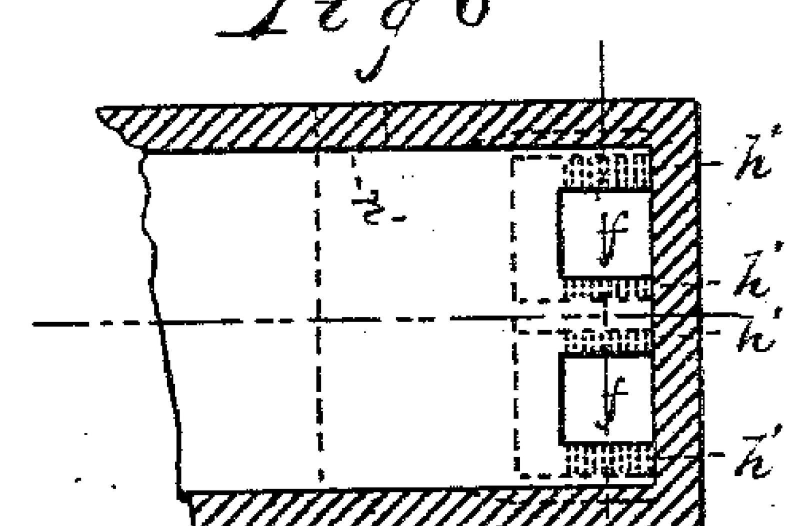
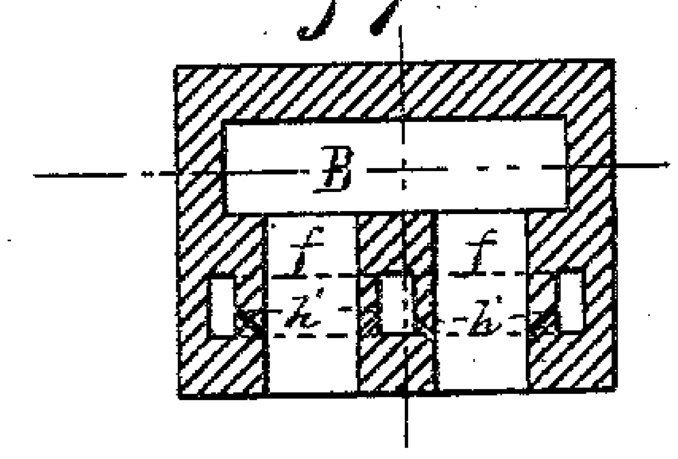



*Fig 7*

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(No Model.)

3 Sheets—Sheet 3.

J. HENDERSON.

ART OF MANUFACTURING IRON AND STEEL.

No. 283,484. Patented Aug. 21, 1883.

Fig. 10.

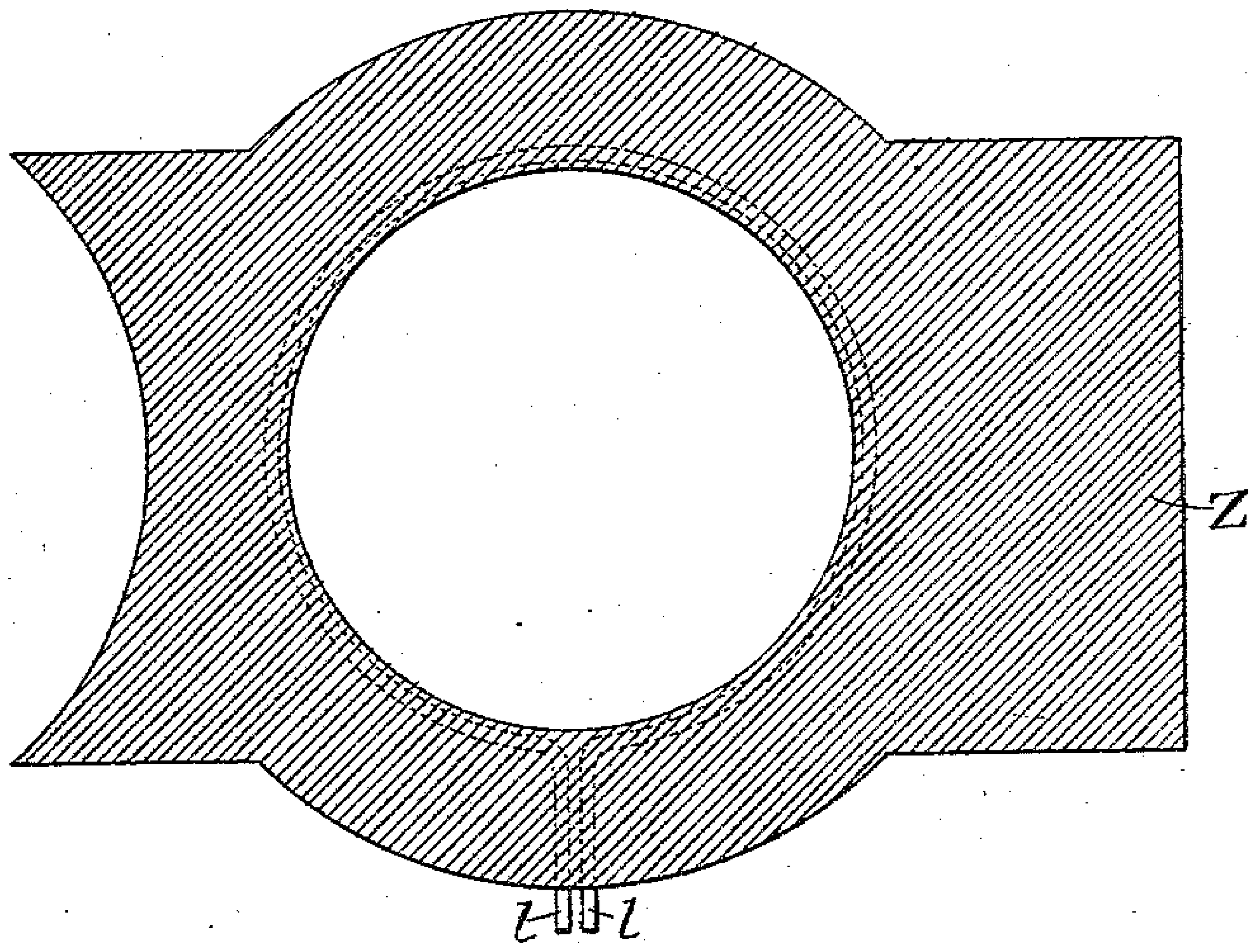
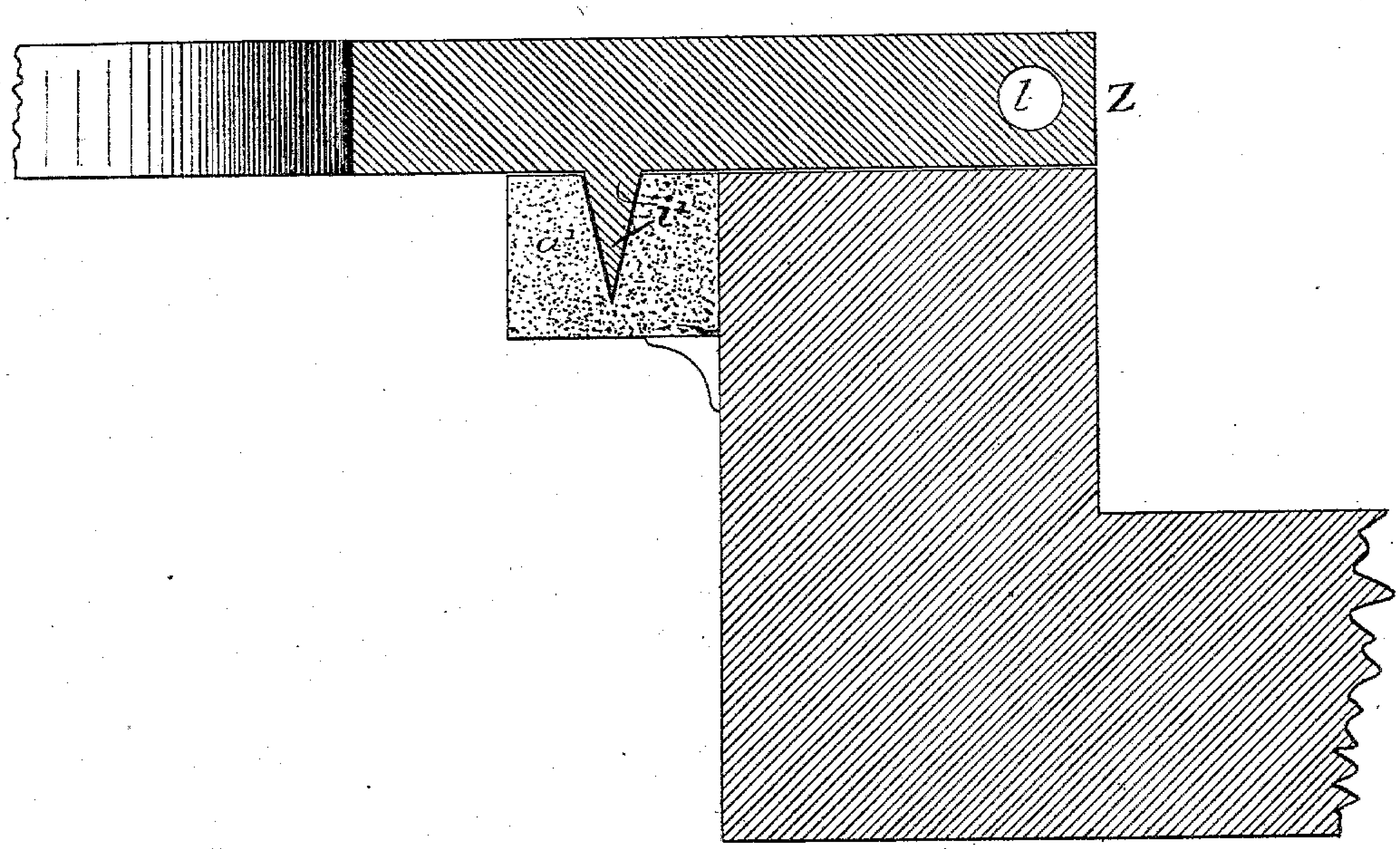



Fig. 11.




WITNESSES

Wm. A. Skinkle.

Alfred C. Newman

INVENTOR

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By his Attorney

N. PETERS. Photo-Lithographer, Washington, D. C.

# UNITED STATES PATENT OFFICE.

JAMES HENDERSON, OF BELLEFONTE, PENNSYLVANIA.

## ART OF MANUFACTURING IRON AND STEEL.

SPECIFICATION forming part of Letters Patent No. 283,484, dated August 21, 1883.

Application filed March 2, 1883. (No model.)

*To all whom it may concern:*

Be it known that I, JAMES HENDERSON, of Bellefonte, county of Centre, and State of Pennsylvania, have invented certain new and useful Improvements in the Art of Manufacturing Iron and Steel, of which the following is such specification as will enable those skilled in the art to understand and practice the same.

This my invention is based on the discovery that iron, when exposed to an oxidizing-flame which also contains the elementary constituents of water, either in the state of combination or dissociation, and when iron is not covered or protected from the action of the flame and vapor of water by covering of cinder, slag, or oxidizing agents, the iron may be purified of sulphur, phosphorus, and carbon by the action of the flame, which removes these elements without the aid of other reagents.

In an application for Letters Patent filed on or about July 11, 1881, I have described a furnace and a producer for making combustible gases from solid carbonaceous fuel, which gases are hydrogen, carbonic oxide, and carbureted hydrogen mixed with nitrogen, which is derived mostly from the air-blast used in the production of the gases. These gases are burned in admixture with air in exact amount or excess of that required for perfect combustion in such manner as to insure thorough admixture and perfect combustion before the gases impinge upon the iron, which is contained in a hearth placed under the reverberatory chamber of the furnace and outlet-flue of the gas-producer. In the aforesaid application I have specified the use of solid oxidizing, purifying, and decarbonizing substances for the conversion of the iron into homogeneous malleable iron or cast-steel, which may after treatment be poured or run from the hearth. This is unlike my present invention, which consists in decarbonizing, dephosphorizing, and desulphurizing crude or partially-purified or desiliconized iron by the use of a practically homogeneous flame, produced before it is permitted to impinge upon the metal by the combustion of gaseous fuel containing carbonic oxide and hydrogen, either dissociated or combined with other elements.

In carrying out this my invention I prefer to use a gas-producer and furnace as shown in the drawings, in which—

Figure 1 is a longitudinal section. Fig. 2 is a horizontal section of the apparatus through the line X X of Fig. 1. Fig. 3 is a vertical transverse section on the line Y Y, on an enlarged scale, of Fig. 2. Fig. 4 is a plan view of the cast-iron truck, showing the ribs upon which the hearth V rests. Fig. 5 is a longitudinal section of the gas and air passage in the outlet-neck of the producer. Fig. 6 is a plan view, and Fig. 7 a transverse vertical cross-section, of the same on an enlarged scale. Fig. 8 is a transverse vertical cross-section of the hydraulic ram, and Fig. 9 is a plan of the same. Fig. 10 is a plan view of the cast-iron plate supporting the roof of the reverberatory chamber C, and Fig. 11 is a sectional view of the seal-joint which closes the space between the roof and hearth of the reverberatory chamber C.

The same letters refer to the same parts in the different figures.

The principal parts of the furnace represented in the said drawings are the gas-producer A, from which the flue B of the inlet-neck of the furnace is the outlet for the resulting gases as well as the inlet into the heating-chamber C, the movable revolving hearth V, the flue D of the outlet-neck of the furnace to a second heating-chamber, E, the flue F of the outlet-neck of the second heating-chamber to the boiler-heating chamber G, beneath the boiler O, and thence through its flues to the chamber to the external air. The hearth or bottom of the furnace V is moved vertically by being mounted on a table or platform, *v*, raised and lowered by the upper end of a hydraulic ram, W, and also has wheels on the bottom of the truck upon which it sets, so that it may be moved away from under the arch after being lowered. The top of the hydraulic ram is spherical, which fits into a corresponding socket in the bottom of the truck, and thus forms a pivot and a ball-and-socket joint, so that the hearth may revolve around it and be kept in its place when tipped to pour its contents. A platform with wheels upon the top, fitted in brackets, carries the hearth, when it revolves, by means of a track corresponding to the wheels cast on the under side of the hearth. The surface of wheels is beveled or inclined to correspond to the bevel or inclination of the track. The brackets are arranged, as shown, with hollow space for water, in which the wheel revolves. Wooden disks may be placed between the wheels and the outside bracket to take up the friction. The hearth is revolved by means of the spur-wheel *u*, working in corresponding teeth in the rim of the hearth. The hearth is maintained in its vertical position by the guide-plate *m* and the four guide-rods *o'*, passing through it. The hearth, when in its raised position in the furnace, is sealed, so that there cannot be any passage of heat or gases from it to the external air, by an annular box, *a'*, at the top, filled with sand or water, in which a ring, *i'*, on the bottom plate, Z, Fig. 3, supporting the chamber C, dips nearly to the bottom. The plate is provided, near its inner edge, with an iron pipe or passage, *l*, cast therein, in which water or air circulates to cool the plate and prevent injury from the heat of the furnace.

Fig. 10 is a plan view of the plate Z, showing the cooling-chamber in dotted lines; and Fig. 11 is a sectional view of the sealed joint made by the ring *i'* on the bottom dipping into the annular box *a'*.

The hearth V is preferably divided in two parts. The hearth proper, in which the iron is treated, is preferably made of rolled plates of pure soft steel, low in carbon, and having great extension under pulling stress—say under 0.10 per cent. of carbon, with twenty-five per cent. extension under strain—to enable it to expand and contract with heating and cooling without liability to bursting. This pan or hearth rests in the cast-iron platform upon raised ribs or projections *b'*, (shown in Fig. 4,) and the platform, having the sides reaching to the under side of the lower spout or tap-hole of the hearth, forms a shallow dish, which enables the use of water or air therein for cooling the bottom of the hearth. If desired, there is a narrow open space about one inch wide surrounding the hearth and between it and the sides of the pan, which enables the ingress or egress of air for cooling the hearth, if air is used. The air or water is introduced through the opening in the middle of the hydraulic ram, as hereinafter described.

The movable hearth or bottom V is provided with a lining, *c'*, of refractory material, which may be coke or plumbago and fire-clay—such as is used for steel-melting crucibles—oxide of iron, lime, magnesian lime, magnesia, sand, or silicious linings, depending upon the amount of heat required and the kind of operation performed therein, as hereinbefore described. When reagents are used, they are generally spread over this lining by introducing them through the door *d'*, or by lowering the hearth from the chamber C for that purpose. The iron used or treated may be placed in the hearth in the same way, or the roof may be made movable and removed for these purposes.

The gases employed to heat the reverberatory chamber C and operate upon the charge pass through the flue B. The combustible gases pass from the flue B, descending thence by the vertical flues *f f* to chamber C, which confines the metal so that the flame may impinge upon it. In the flues *f f* these gases are mixed with regulated quantities of atmospheric air, preferably heated to from 700° to 1200° Fahrenheit, whereby the gases are inflamed and perfect combustion takes place, producing a substantial homogeneous flame before it enters the chamber C. From the chamber C the products of combustion are conveyed away by the flue D. The heated air passes into such flues or passages *f f* from the tuyeres *h'*, Figs. 5, 6, and 7, which communicate at their rear with air-passages to a flue, *m'*, and thence by the pipe T, Figs. 1 and 2, to the cast-iron air-heating pipes S, placed at each side of the boiler-chamber G, where the air is heated by the spent gases from the furnace, (or the air may be heated in any other suitable air-heating apparatus, either attached to or detached from the furnace,) which is connected with a pipe, L, leading from the blast-receiver K.

The gas-producer A is constructed at one end of the reverberatory furnace, which generator is of sufficient size to generate gas sufficient for the furnace. The interior of the gas-producer is formed of two fuel-chambers, *r r'*, the former, *r*, being beneath the iron reservoir or hopper *r'*, and being therefore designated the "lower fuel-chamber," while the hopper or reservoir *r'* is a distinct fuel-chamber, where a different gas process is carried on. It is therefore designated as the "upper fuel-chamber." It is designed that the interior of the gas-producer A shall at all times, when working, be charged to the top with fuel, that will fall automatically as it burns away at the bottom, thus supplying the fire, while the fuel becomes gradually heated, decreasing in temperature to the top. *a* is the top of the fuel-hopper; *b*, a weighted lever to close the hopper air-tight by raising the cone *c* when charging the fuel at *a*. *d* is a port or opening at the bottom of the gas-producer for removing the contents and igniting the fuel.

In operating the apparatus, kindling is inserted at *d* and the fuel at *a*. The kindling being ignited, the fuel-blower N is brought into action. The air from it passes by a pipe to a reservoir, P, to equalize the pressure, and thence by a pipe surrounding the gas-producer. From this circular pipe the air enters the lower fuel-chamber, *r*, through the air-passages or tuyeres *i i*, and acts upon the fuel in the gas-producer, decomposing the fuel. The gases resulting from the decomposition rising up through the interstices of the fuel escape by the gas-flue B and gas-channels *f f* into the reverberatory chamber. The heat incident to the decomposition of fuel in the lower fuel-chamber, *r*, acts upon the fuel in the coal-reservoir or upper fuel-chamber, *r'*, effecting a distillation of the fuel therein and causing the fuel to evolve gases. These gases are forced by the pressure made by their distillation down and into contact with the incandescent fuel in the chamber *r*, whereby the tarry matters therein become decomposed, and their products pass with the other gases through the annular space between the retort and the wall of the gas-producer, and pass thence into the space about the upper retort to the flue B.

As perfect combustion of carbonic oxide is effected when mixed with one third of its volume of hydrogen, in order to obtain the hydrogen I preferably introduce superheated steam in regular measured proportions, injected through one or more tuyeres, *h*, in the gas-producer, from twelve to twenty inches above the air-tuyeres *i i* when cold air is used and the fuel is of small size, (if coke or anthracite, of size of walnuts;) but if the coal employed is of such quality as to yield the requisite quantity of hydrogen, as is the case with some kinds of cannel coal, the introduction of steam into the gas-producer is not essential.

A pump, *t*, is attached to the crank-shaft of the blast-engine *s*, so that the revolution of the blast-engine *s* pumps a certain amount of air, and also pumps a certain required amount of water. The water passes through a pipe placed in one of the boiler-flues, entering the front end of the boiler-flue, passing to its rear end, and thence under the boiler back to the front in zigzag vertical form, and the pipe terminates in a coil. This arrangement enables all of the water to be gradually converted into steam, and to become highly-superheated steam by the time it reaches the end of the coil. The superheated steam then passes through a covered pipe (not shown in the drawings) to the tuyere *h* in a highly-superheated state, or at a temperature of 600° to 800° Fahrenheit, and thence into the gas-producer among the incandescent fuel, where it decomposes to hydrogen and oxygen, the latter combining with part of the carbon of the fuel to form carbonic oxide. The carbonic oxide and hydrogen thus produced mix with the carbonic oxide formed by the combustion of the fuel with the air from the tuyeres, and pass from the producer through the flue B to the flue *f*, where they are burned with heated air.

When anthracite coal is used as the fuel in the gas-producer, about three-fourths of a cubic inch of water reduced to superheated steam is the proportion that I have found it expedient to introduce in the lower part of the gas-producer *r* for every four cubic feet of air, to give the required proportions of hydrogen and carbonic oxide to produce perfect combustion when the gases are subsequently burned with sufficient air.

In order to increase the durability of the superheating apparatus, the part where the superheating takes place, and from thence leading to the gas-producer, should be made of cast-iron. The part where steam is formed should be of wrought-iron, as the superheated steam rapidly oxidizes wrought-iron and has but little effect on cast-iron, and, as there is practically no appreciable pressure used, cast-iron is better than wrought-iron for this purpose.

I preferably effect the combustion of the gases passing through the outlet B by air supplied by a distinct blast-machine, of which I is the steam-cylinder and J the air-cylinder, the pistons being connected by a cross-head. The air passes from the blast-cylinder through an air-conduit system as follows: K is an air-receiver, into which the air is delivered from the blast-machine J in a measured quantity. The pipe L delivers the air, when combustion with a neutral or oxidizing flame is required, to vertical cast-iron pipes S, Fig. 1, arranged under the boiler along the side walls, as shown in the plan in Fig. 2. The blast enters the rear end of this system of pipes and passes up and down through these pipes, which are heated by the waste or spent gases of the furnace. The air thus heated passes from the pipes to the pipe T, thence to the channel *n'* in Fig. 5 in the outlet-neck of the gas-producer to the tuyeres *h'*, Figs. 5, 6, and 7, where it impinges upon the gases passing through the flue B and the vertical flues *f f*.

When the fuel used in the gas-producer is anthracite and the greatest intensity of heat is required, the blast-machine should deliver to the cast-iron air-heating apparatus about four hundred and forty-five cubic feet of air to burn each pound of hydrogen in the anthracite and that produced by the decomposition of the superheated steam, and 72.5 cubic feet of air for each pound of carbon converted into carbonic oxide in the producer by the oxygen of the air and the decomposed superheated steam therein acting upon the incandescent fuel, and when an oxidizing-flame with less heat is required a greater quantity of air should be used. If one-half more air is used, the temperature is reduced to about two-thirds of that realized from the use of the above proportions. For practicing the present invention the excess of air over what is necessary to produce complete combustion approximately should not exceed fifteen or twenty per cent., as these proportions give an oxidizing-flame sufficiently hot to melt crude iron and to decarbonize it. The proportions of air in the exact amount to produce a neutral flame should be used at the end of the operation of the steel conversion to give it greater liquidity.

The gases from the chamber C, including the carbonic oxide given off during the action of the flame upon cast-iron, pass through the flue D into the chamber E. During their passage they are acted upon by jets of air, which is delivered from the receiver K to the pipe J', to the chamber *c''*, where it serves to cool the bottom of the chamber E. The air from the chamber *c'* enters the channel *c'''* in the side wall of the chamber E, Fig. 2, and passes thence to chamber $a''$ over the flue D, in the roof of which there are pierced numerous holes, which deliver the air diagonally forward into the gases, which effects their complete combustion when this result is desired and the proportions are correct for this purpose.

The air-supply is regulated by increasing or decreasing the quantity of blast, and its division is effected by opening a valve in the pipe J′, which allows one portion to be delivered into the chamber E and the other portion to be delivered into the gas-flues into the chamber C. I, however, prefer to use in the flues leading to the chamber C the exact amount of air for perfect combustion from the blast-machine J when treating cast-iron to produce cast-steel, and to employ an auxiliary fan or blower to deliver air to the surplus carbonic oxide which is eliminated by the burning of the carbon in the crude iron in the chamber C, such air being applied through the chamber $c''$, and thence to the chamber $a''$ above the outlet end of the flue D.

Anthracite has been mentioned as the fuel used; but charcoal, coke, or bituminous coal are equally available, care being taken to use air in proper proportions, according to the chemical equivalents involved and the result desired, and to reduce or discontinue the supply of superheated steam when bituminous coal is employed, according to its capacity to supply hydrogen.

The construction of the gas-producer and furnace permits the production of well-defined proportions of combustible gases or gaseous fuel and the mixture of heated air with the said gases or gaseous fuel in any required proportions in such manner as to give perfect control of the intensity and chemical nature of the flame, and to make it practically homogeneous before it enters the chamber C to act upon the articles under treatment by being blown down upon them constantly while they are revolved. Hydrogen burns before carbonic oxide by reason of its greater affinity for oxygen, and as this operation takes place in the vertically-descending portion of the outlet-flue of the gas-producer, the operator has perfect control of the carbonic oxide, which may be converted into an oxidizing agent by the use of an excess of air or into a neutral flame by the use of the exact proportions of air for complete combustion.

Fig. 8 shows the hydraulic ram of Fig. 1 on an enlarged scale, for raising and lowering the hearth V of the furnace. The head of the ram $o''$ is spherical and fits into a socket, $u''$, in the platform $v$, Fig. 3. The socket is preferably made of hard wood when water is used in the table $v$, or when air is used Babbitt or other metal or iron is used, care being taken to make either air or water tight joints. The ram is recessed slightly below the head to allow it to turn in the socket and keep the joint tight. $f'$ is a central passage in the ram, through which the air or water passes in or out of the table or platform $v$. The air or water is pumped through the passage $f$ of the ram to the space beneath the wrought-iron hearth V, and cools it as far as the table extends up its sides. The platform rests upon the top of the ram, which fits in its socket and on the shoulder $z$. When it is desired to pour the contents of the pan or hearth, if water is used, the water is run out of the table through opening $f$, and the ram lowered by discharging the water from the chambers $g'$ and $g''$. The platform and hearth resting then on the shoulder $z$ and the head $o''$, the side opposite the spout is then raised enough to give proper inclination to the hearth to pour the metal. When the hearth is again ready for use, the water is again pumped into the ram, and thus raises the hearth to its required place in the furnace.

The metal to be treated is placed upon the hearth of the chamber C and the flame is made to impinge upon it, and in the process of melting it removes a large portion of the carbon, sulphur, and phosphorus, and after melting the purification continues until the metal is in the condition of steel or malleable iron, which, when cast into ingots, is in the condition to be hammered or rolled. The time occupied with the conversion of crude cold-blast charcoal-iron rich in graphitic carbon is about twenty minutes from time of melting of the iron in the furnace, and with coke pig-iron, in which the carbon is all combined and the silicon is in very small amount, the decarbonization is effected by the time the metal is melted. I prefer to use metal that contains as little silicon as possible, in order to avoid the production of silicious slags by the oxidation of the silicon. In this process it is desirable and necessary to have the surface of the metal exposed as much as possible to the action of the flame, and the less slag or cinder present the better the result. For this reason I prefer to use either cold-blast pig-iron low in silicon, or iron that has been desiliconized by the Bessemer process by blowing jets of air into the metal, or that which has been desiliconized by the use of oxides in a reverberatory furnace, or the desiliconized metal of the refinery, or the metal produced by the use of fluorides and oxides by a process for which Letters Patent of the British Government were granted to me, No. 1,544 of 1870, or metal reduced in silicon, which has been produced by melting wrought-iron or steel with cast-iron, or metal which has been desiliconized by any other process. If, however, silicon is present in the crude metal, I prefer that the metal also contains enough manganese, so that after a portion of the whole is oxidized into slags the slags will contain sufficient oxide of manganese to render them basic, in order that they will retain the phosphorus which may enter them during the purification of the metal. The manganese in the metal should be twice or three times the amount of the silicon, and when manganese is not present it is preferred to add it by previously melting spiegeleisen with the crude iron in a cupola before charging it into the chamber C. The slags may be tapped off through one of the tap-holes and the decarbonization be completed by the flame.

The steely property and the removal of red-shortness may be obtained by adding spiegeleisen, or ferro-manganese, or other compound of iron, carbon, and manganese, after desiliconization is effected, as described in application 37,559 made by me for Letters Patent, filed on or about July 11, 1881, or after decarbonization in cases where the metal does not contain sufficient manganese to effect these objects without them.

If the metal after desiliconization—for example, after treatment in the Bessemer process—contains from one and one-half to two per cent. of manganese, a further dose of manganese or spiegeleisen, or its equivalent, will not be required where cast-steel is produced.

When the object to be obtained is the production of homogeneous malleable iron or cast-steel, which is run or poured from the furnace, and phosphoric iron is used for its production, I line the hearth with calcareous or magnesian furnace-linings, or a mixture of them, as described in several Letters Patent of the United States granted to me therefor; or any other suitable calcareous or magnesian lining may be used.

In order that the gases may be properly burned before impinging upon the iron, it is necessary, in order to produce the best effect, that they should be composed of at least one-third volume of hydrogen to the carbonic oxide in admixture with the gases. The hydrogen is preferably obtained by injecting superheated steam, as hereinbefore described.

I do not wish to be understood as limiting myself to any special form of gas-producer or furnace, as any gas-producer that will furnish the carbonic oxide and hydrogen in the requisite proportions, and preferably at least one-third volume of hydrogen (more is no disadvantage) to two-thirds of carbonic oxide, will answer the purpose when used in connection with an open hearth provided with suitable appliances whereby the gases may be intimately mixed with the proper amount of air, so as to produce a substantially homogeneous flame before it impinges upon the metal.

I do not claim the use of carbonic oxide and hydrogen gases, broadly, in the manufacture of iron and steel.

If desired, the metal, after decarbonization, may be balled up and squeezed or hammered and rolled, as in the hand-puddling process; but in this case, if the iron is to be purified of phosphorus, the lining of the furnace must be composed of one or more of the basic materials previously mentioned—such as oxide of iron, lime, magnesian lime, or magnesia—which, if necessary, may be mixed with a small portion of fire-clay.

I do not claim the heating or melting of metal by gas in a Bessemer converter prior to the conversion of such metal by the Bessemer or any other process, when the gases and air are introduced in separate conduits and combustion takes place wholly in the converter or furnace, as such combustion is imperfect and does not effect the object which I have in view.

I do not herein claim the process above set forth when basic reagents are used, as this forms the subject of another application for Letters Patent now pending.

I do not claim the herein-described apparatus, as the same is set forth and claimed in application No. 99,605, filed on the 29th day of June, 1883, as a division hereof.

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

1. The process of purifying metal in the manufacture of iron and steel, which consists, first, in confining the melted metal (whether crude iron or iron that has been desiliconized) in a suitable chamber; secondly, in the combustion of gaseous fuel containing carbon and hydrogen by the admission of air thereto in quantity properly regulated to produce complete combustion and a homogeneous flame previous to its admission to said chamber; thirdly, in causing the homogeneous flame to impinge in a downward direction upon the metal in said chamber, all substantially as described, thereby producing the purification of said metal without the aid of jets forced up through it.

2. The process of purifying metal in the manufacture of iron and steel, which consists, first, in confining the melted metal (whether crude iron or iron which has been desiliconized) in a suitable chamber; secondly, in the combustion of gaseous fuel containing carbon and hydrogen by the admission of air thereto in quantity properly regulated to produce complete combustion and a homogeneous flame previous to its admission to said chamber; thirdly, in causing the homogeneous flame to impinge in a downward direction upon the metal in said chamber, and, fourthly, in recarbonizing the metal by the use of a compound of iron, carbon, and manganese, all substantially as described, thereby producing the purification of said metal without the aid of jets forced up through it.

3. The process of purifying metal in the manufacture of iron and steel, which consists, first, in confining the metal (whether crude iron or iron which has been desiliconized) in a chamber lined with basic material; secondly, in the combustion of gaseous fuel containing carbon and hydrogen by the admission of air thereto in quantity properly regulated to produce complete combustion and a homogeneous flame previous to its admission to said chamber; thirdly, in causing the homogeneous flame to impinge on the metal in the said chamber, all substantially as described.

4. The process of purifying metal in the

manufacture of iron and steel, which consists, first, in confining the melted metal (whether crude iron or iron which has been desiliconized) in a chamber lined with basic material; secondly, in the combustion of gaseous fuel containing carbon and hydrogen by the admission of air thereto in quantity properly regulated to produce complete combustion and a homogeneous flame previous to its admission to said chamber; thirdly, in causing the homogeneous flame to impinge on the metal in the said chamber, and, fourthly, in recarbonizing the metal by the use of a compound of iron, carbon, and manganese, all substantially as described.

JAMES HENDERSON.

Witnesses:
H. H. BENNER,
C. P. HEWES.