5 Sheets--Sheet 1.

T. J. CHUBB.

Improvement in Process and Furnace for Making Gas, Iron, and Steel Direct from the Ore.

Patented Nov. 19, 1872.

No. 133,202.

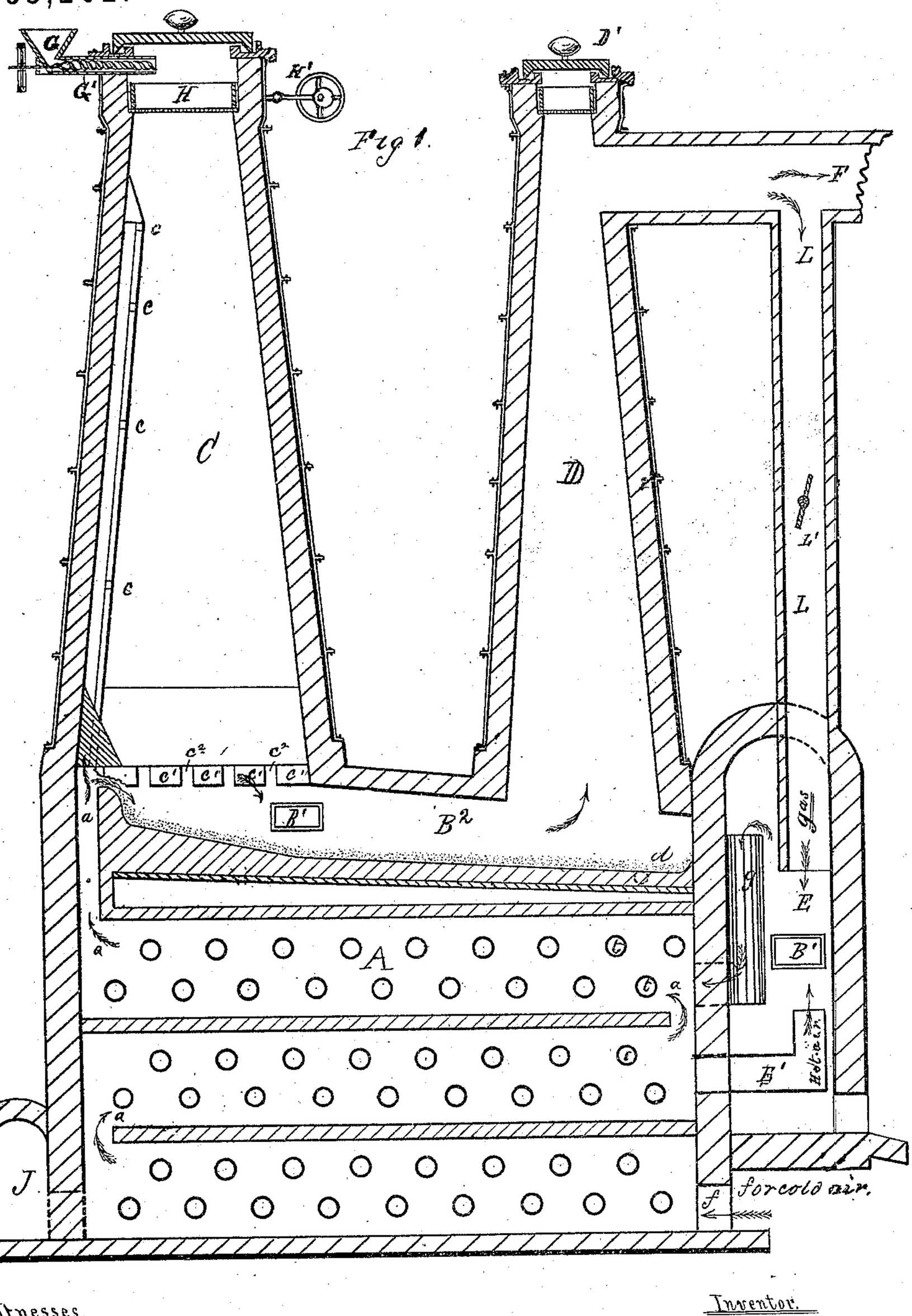

Fig 1.

Witnesses.

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Inventor.

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5 Sheets--Sheet 2.

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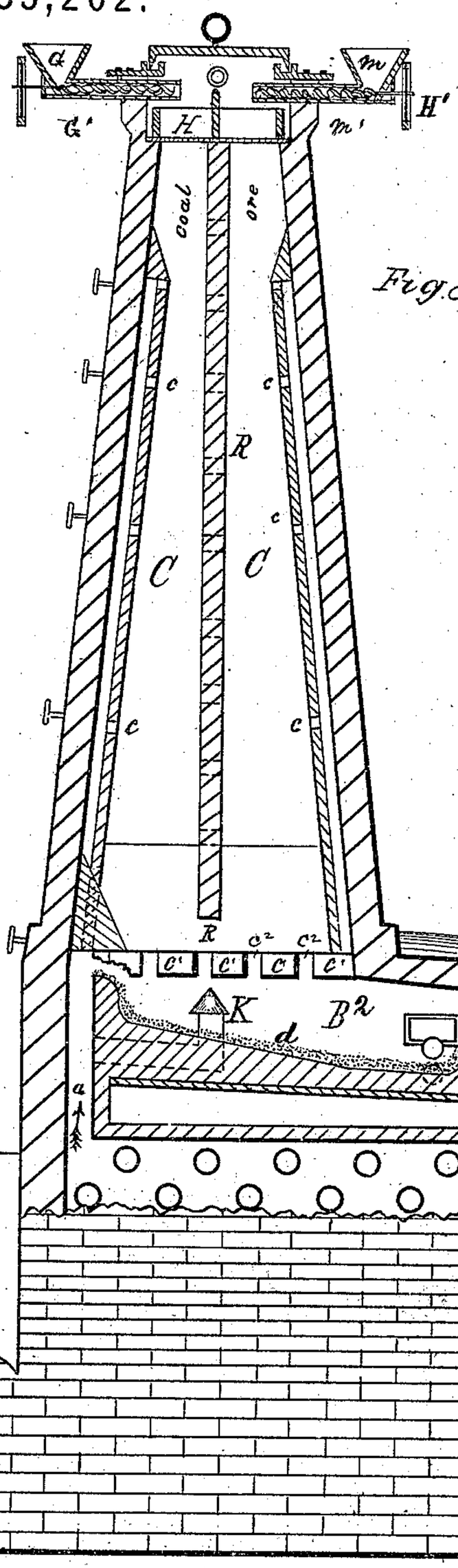


Fig. 3.

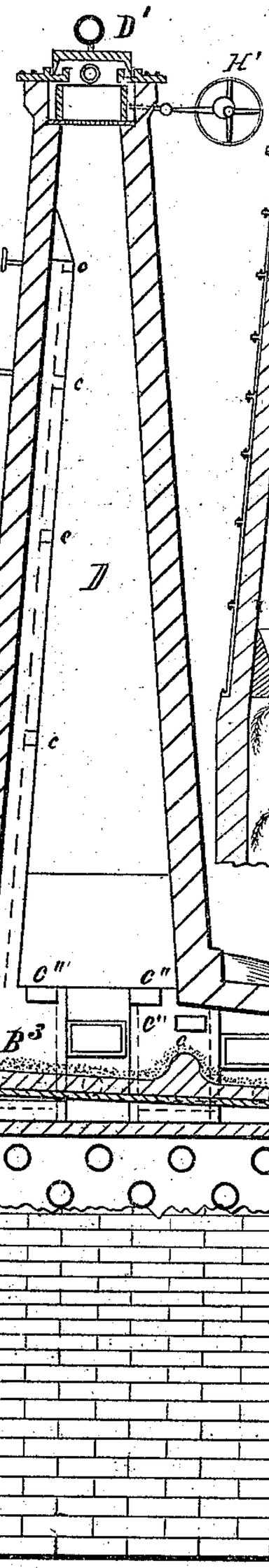
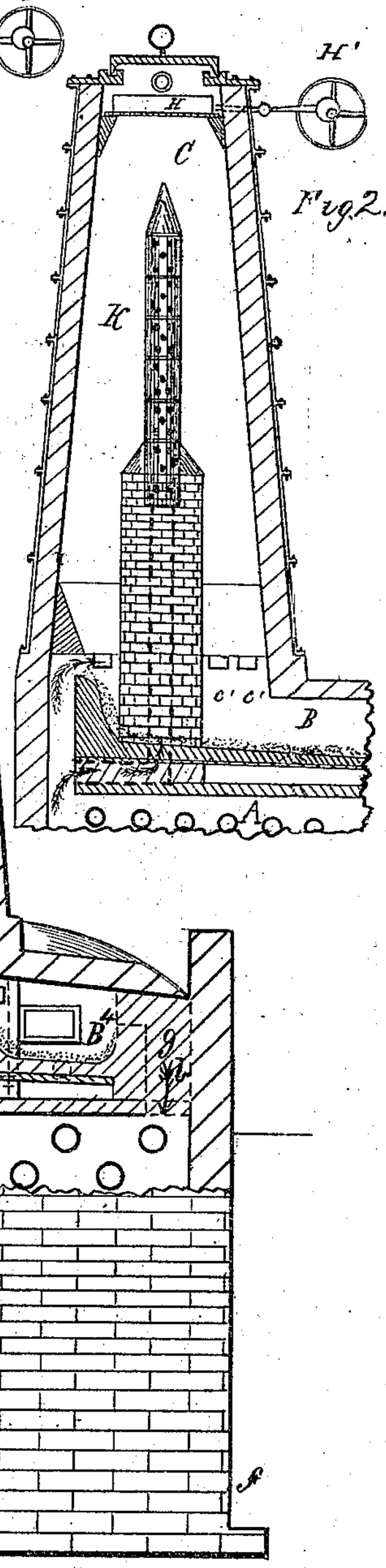


Fig. 2.



Witnesses

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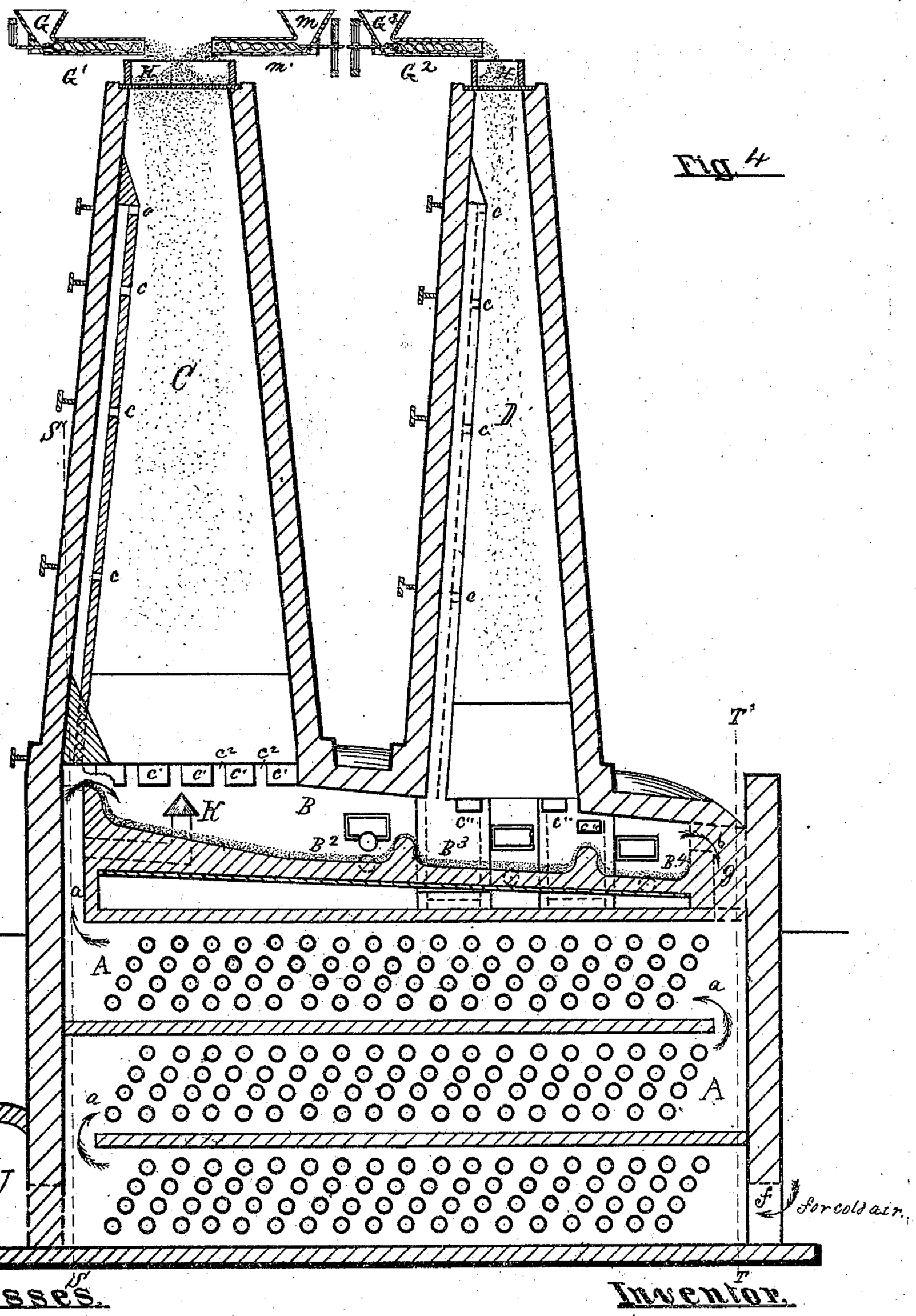

Fig. 4

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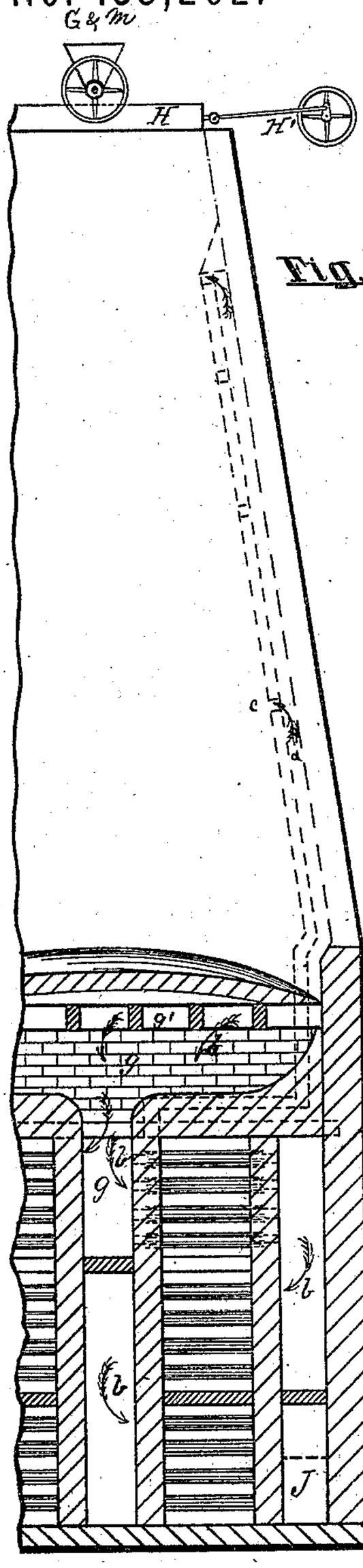

Fig. 5

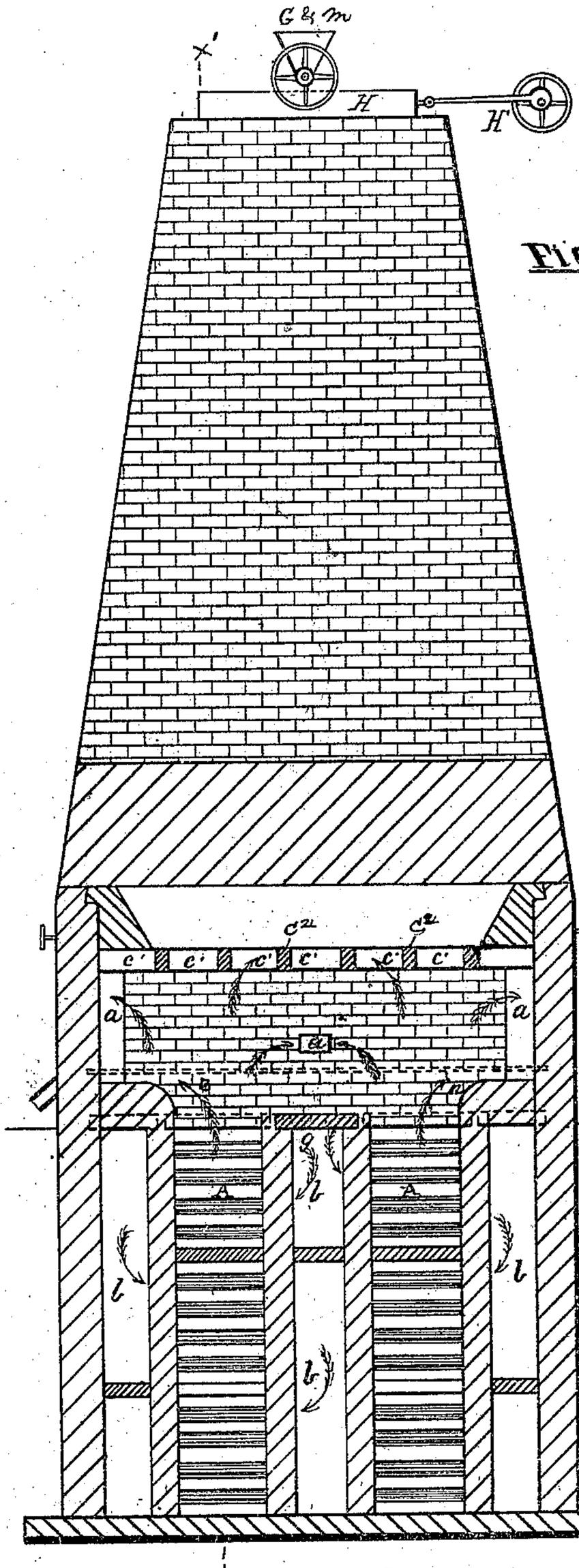

Fig. 6

Witnesses.

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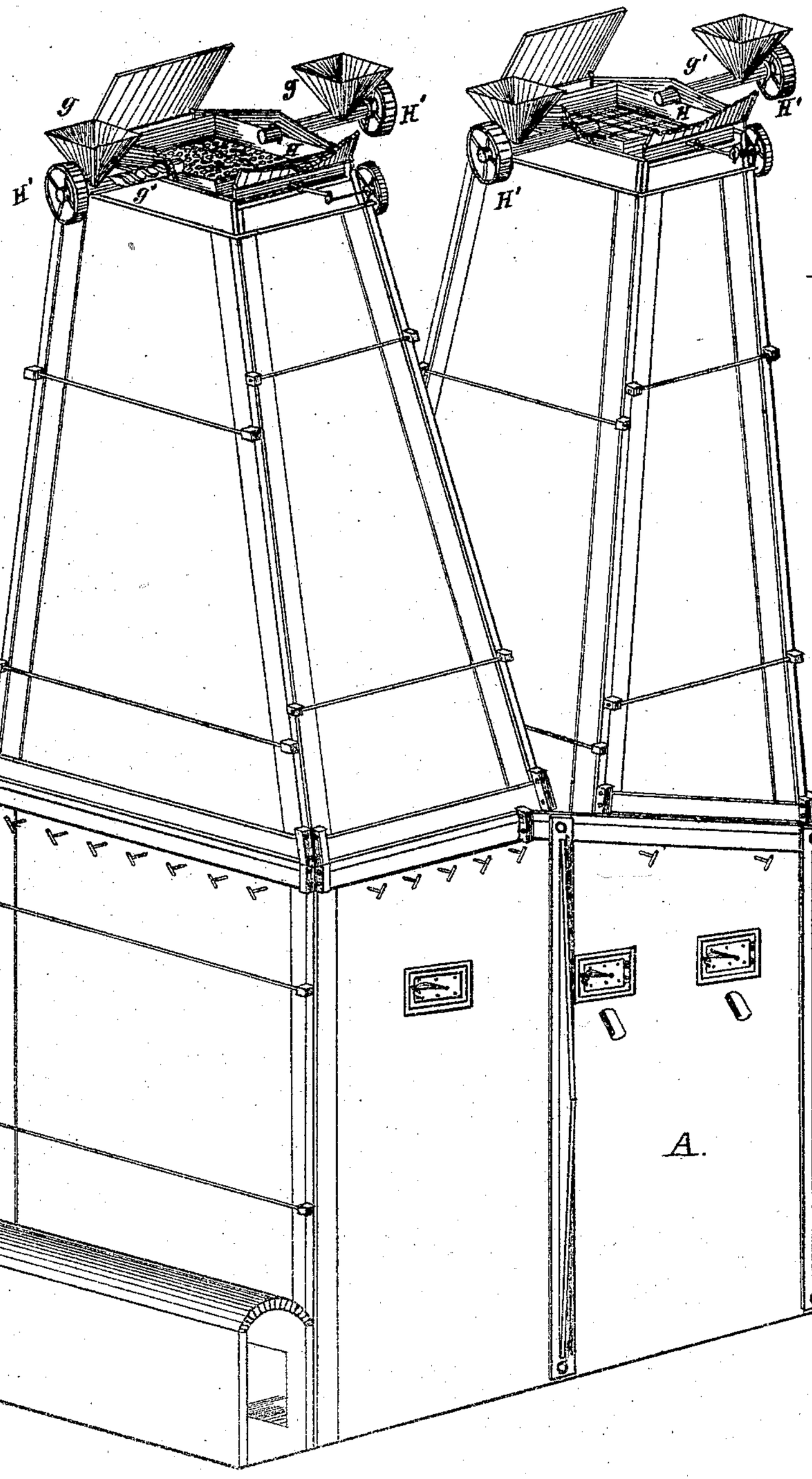

Fig. 7.

Witnesses.
Edw. S. Brown.

Inventor.
Thos. J. Chubb

UNITED STATES PATENT OFFICE.

THOMAS J. CHUBB, OF WILLIAMSBURG, NEW YORK.

IMPROVEMENT IN PROCESSES AND FURNACES FOR MAKING GAS AND IRON AND STEEL DIRECT FROM THE ORE.

Specification forming part of Letters Patent No. **133,202**, dated November 19, 1872.

To all whom it may concern:

Be it known that I, THOMAS J. CHUBB, of Williamsburg, Kings county, New York, have invented certain new and useful Improvements in Processes and Apparatus for Making Gas, and for Making Iron and Steel Directly from the Ore; and I do declare that the following is a full and exact description of the same, reference being had to the accompanying drawing and to the letters of reference marked thereon.

In making gas from coal for illumination or for heating purposes, it is desirable, from motives of economy as well as to get a better and more uniform article, that the process should be continuous and equable; that the costly and frail retorts in common use should be dispensed with; that the usual residuum (coke) from the coal should be utilized in the form of gas, and the remainder converted into a fluid state for convenience of removal without interrupting the work of the furnace. It is also highly important to employ such processes that the poor and now nearly worthless coals and coal-dust may be capable of conversion into an excellent quality of gas.

In making iron and steel of various grades directly from the ore, in the desire of dispensing with the great outlay connected with the construction of blast-furnaces, many processes and much apparatus have been invented for treating ore in what is known as the "sponge method." This method, however, has not proved entirely successful, because the "sponge" was of such a structure and composition that a large portion of it in treatment became converted into slag or cinders. Moreover, iron ore in its natural state commonly contains so large a portion of foreign matter, and mineral coal has frequently so much sulphur, phosphorus, and other noxious elements, that the "sponge" requires so much melting, remelting, and refining to bring it to a proper quality that the process becomes too expensive.

To avoid these difficulties a method has been adopted of grinding iron ore into fine dust, and forcing the same by swift currents of cold atmospheric air into the furnace. This method is faulty in use, because it is difficult to obtain or maintain sufficient heat to deoxidize the ore in its rapid transit to the hearth, and it produces an injurious action of the ashes of the coal upon the molten metal.

The object of my invention is to provide processes and apparatus which shall be free from the general objections before named, and which shall utilize inferior iron ore, and coals, and coal-dust, now practically worthless, and produce excellent varieties of iron and steel, and gas of a superior quality.

My invention consists, first, in making gas from coal-dust or coal crushed or reduced to considerable fineness by dropping the same in a long vertical flue or chamber made air-tight or protected from the outer air in such manner so that each particle in dropping is submerged and enveloped in an atmosphere of intensely or highly heated air or oxygen gas, nearly in a state of rest, and contained in such flue or chamber. To produce, however, a highly inflammable and pure gas, I mechanically separate and purify the coal before I use it in the furnace, preferably by the process and apparatus patented to me August 13, 1872, No. 130,478, by means of which all foreign matters are extracted mechanically from the coal; and the use of such mechanically-prepared and purified coal, for the purpose of making a purer gas, is the second part of my invention.

To employ this gas thus made most effectively in the reduction of iron ore, it is essential to dispose of the coke or residuum of the coal by converting the same, through the action of intensely-heated air, or of intensely-heated air and gas acting together, in part into an additional supply of gas, and in part into a fluid state, in which it can be conveniently tapped and drawn off; and this constitutes the third part of my invention.

To this gas thus generated, purified, and intensely heated, and filling the long vertical chamber before named, in a state, nearly, of rest, I subject pulverized iron ore, by dropping the same and a proper portion of coal-dust or pulverized coal into said chamber from the top or near the top thereof, the ore dropping through the gas and through the particles of coal, and simultaneously assisting in the conversion of the coal into gas, and being assisted by such conversion in a change from ore to iron; and this process is the fourth part of my invention.

To the process just described of converting pulverized iron ore directly into iron, I subject ore mechanically prepared and separated, preferably by the process and apparatus patented to me August 13, 1872, No. 130,478; and when said ore is converted into iron, as before described, in a continuation of the same process, it is drawn off into refining-chambers, successively, and becomes refined iron or steel, as desired; and this is the fifth part of my invention.

The method of submerging and enveloping ore, mechanically prepared and separated as described, in an atmosphere of gas heated to a temperature of 1000° Fahrenheit, or over, for the purpose of producing a better article of iron and steel; and the method of intensely heating steam by passing it through a regenerator, or similar heating apparatus, alone or mixed with oxygen gas, or with atmospheric air, and employing it for making gas, or refining metals; and the method of distributing the highly-heated air into the gas-chamber so as to avoid any fast currents; and the method of feeding pulverized ore, or coal-dust, or both, into a vertical chamber in such a manner that said material or materials shall serve to prevent the escape of the hot air or gas upward out of the said chamber, or the entrance of cold air therein, form the remaining part of my invention, as included in arts, processes, or methods.

In addition to these I employ a peculiar construction and arrangement of a shaking-box, screw conveyer, and hopper, operated by suitable means, so that there may be a continuous equable supply of pulverized ore, or of coal-dust, or both, into a vertical chamber in such a manner as to prevent the escape upward, from said chamber, of heated air or gas, or of both air and gas, or the entrance of cold air therein. I also employ, in combination with a furnace, a long vertical chamber or hearth, and means for feeding and distributing pulverized ore, or coal-dust, or both, into the top, or near the top, of said chamber. I also arrange and combine, in one furnace, an air-heating apparatus, a gas-producing apparatus, a deoxidizing, a melting, and a refining chamber. I also combine an air-heating apparatus, a gas-producing apparatus, a deoxidizing, a melting, or a refining chamber so arranged as to be operated together; and these constructions, combinations, and arrangements constitute the remaining part of my invention, as included in apparatus, all substantially as hereinafter more fully described and explained.

Like letters denote like parts in each figure in the drawing, which are described as follows, viz:

Figure 1 is a vertical section of my furnace; Fig. 2, a similar section of a modification of the gas-producing portion; Fig. 3, a similar section of my furnace with a modification of Fig. 1; Fig. 4, a similar section with another modification of Fig. 1; Fig. 5, a vertical transverse partial section through the lines T and T′ of Fig. 4; Fig. 6, a vertical transverse section through the lines S and S′ of Fig. 4; and Fig. 7, a view in perspective of my furnace partially broken away at the top.

In the furnace, which is built of the usual materials, and commonly with a rectangular base, from which spring two rectangular stacks, A denotes the regenerator or air-heating apparatus, divided into compartments by divisions extending horizontally from one of the side walls alternately, as shown in Fig. 1, and provided with pipes arranged as shown in said figure. Above this are arranged the melting-chamber and connecting-flue, having a hearth, *d*. Over one end of this melting-chamber is erected the gas-producing chamber C, pyramidal in form, and having much greater height than breadth. This chamber should have an altitude of from twenty to one hundred feet, according to the kind of coal used, anthracite requiring the greatest altitude and the most intense heat, and has connection with the melting-chamber by means of the opening c^2 between the partitions c^1. Over the opposite end of the melting-chamber is erected the uptake-flue D, having a cover, D′, the stack of which flue is of about the same altitude as the stack containing the gas-producing chamber C. From a point near the top of the flue D is a gas-flue, F, Fig. 1, for conducting the gas to the reservoir or place of consumption, and connected again with the flue is a down-take-flue, L, provided with a valve, L′, for closing the same, which flue enters into an independent furnace, E, for heating in the first instance the regenerator A and its tubes. Connected with this independent furnace is a door, B^1, and beneath it is a hot-air flue, E′, and between it and the end of the regenerator is a conducting-flue, *g*. Arranged beneath it and in the lower part of the regenerator is an opening for the entrance of cold air, and on the opposite side of the regenerator is a flue, *j*, connecting with the chimney for conducting off the waste gases from the furnace E after they have passed in a tortuous course through the pipes or tubes. Within the gas-chamber C, made of fire-clay or other refractory material, is a flue, K, perforated with openings *c* at suitable distances, as shown, and arranged in any convenient order. In the top of said gas-chamber is a shaking-box, H, with a perforated or rectangulated bottom, above which box again, and arranged so as to play into it, is a conveyer-screw, G^1, connected with a hopper, G. Motion is communicated to the shaking-box H by means of the pulley H′ and an intervening eccentric. Arrows *a* show the course of the heated air, and arrows *b* the course of the waste gases.

The above description is particularly applicable to Fig. 1.

In Fig. 2 is a modification of the fire-clay flue, shown by the letter K, cylindrical in form, and centrally arranged in the gas-chamber, and suitably perforated.

In Figs. 3 and 4 is shown a modification of the gas-chamber, having a central division or wall therein for separating the ore from coal, and having an additional conveyer, *m'*, and hopper *m*.

In what is shown as the uptake flue-stack in Fig. 1 there is a vertical reduction-chamber, provided with hot-air flue, conveyer G^2, hopper G^3, and shaking-box. The hearth of the melting-chamber is also divided, by bridge-walls, into several melting and refining chambers, B^2, B^3, and B^4. There is also shown a hot-air pipe, K, arranged in the melting-chamber under the vertical chamber C. This modification is employed for making iron, refined iron, or steel, as desired.

I make use of my processes and apparatus in the following manner: To make gas I take the prepared coal and convey it into the hopper G from a large supply-hopper above, (but not shown,) or by any means that will keep the hopper G continuously supplied when in operation. I then kindle a fire in the furnace E, Fig. 1, and also on the hearth of the chamber B^2, the fuel being put in by means of the door, (B^1 being at other times closed.) I then close a valve in flue F (not shown) and open the cover D' on the top of chamber D to form a draft for the fuel on the hearth B^2. When the chambers A, B^2, and C are sufficiently heated I put the shaking-box H in motion by means of the eccentric H', and also the screw conveyer G', which conveys the coal from the hopper G into the box H, where it is evenly distributed over its perforated bottom, and gradually and evenly falls through the holes in the bottom of the box, (which is not a sieve or used for sifting or sizing, but only as a distributer,) so that the coal falls into and down through chamber C in an open disintegrated manner, and the highly-heated air enters in the direction indicated by the arrows *a a a*, and through the openings c^1 c^1 c^1 into the chamber C, and fills it full of highly-heated air. The coal, falling through it, is converted into gas; and, when the quality of the gas is sufficiently good, then the cover D' is put on, and the valve in the flue F is opened and the gas conducted away to the place of consumption. I then open valve L' in branch flue L and let part of the gas into chamber E for heating the air around the tubes *t t;* or the tubes *t t* may be continuously heated by any other equivalent means.

The hopper G being continuously supplied with coal, which falls continuously into the highly-heated air, the process of making gas is continuous; and any residuum from the coal falling upon the hearth of chamber B will be melted, and may be tapped out at the tap-hole at the lower end of the hearth in a fluid condition. This tap-hole may be opened and closed in the usual way with a lump of clay, care being taken that not a particle of cold air be admitted at any part of the furnace, except into the regenerator at opening *f*, or the quality of the gas will be depreciated. Care should also be taken that the smallest possible amount of air be admitted by the regulating-valve (not shown) at the opening *f*, through the regenerator into the chamber C, consistent with the amount of coal converted into gas.

To make refined iron and steel I take the black crystallized oxide of iron, so abundant, particularly on the Western Continent, and preferably such ore as has been recently mined from below the surface, where it has been submerged in perpetual water, and not submitted or exposed for a long time to the action of air. Such ore retains all the original crystallization of its phosphates, sulphurets, and other matter. I crush this ore into mechanically-detached crystals by any of the well-known crushing-machines, but preferably by rollers, and then mechanically separate the pure crystal of the oxides of iron from all the foreign matter, preferably by my separators, hereinbefore mentioned. If these separated pure crystals of oxides of iron, in the form of sand, are not small enough for speedy deoxidation, I further reduce them in size by crushing them. Large quantities of black sand (iron ore) are found on banks of rivers and ocean beaches, and in alluvial deposits and placer gold mines, suitable for this process, and may be profitably converted into metal. I take the prepared ore and place it continuously into one of the hoppers *m* on top of the chamber C of a furnace like that shown in the drawing, Fig. 4, the other hopper G on top of chamber C being continuously supplied with fine particles of coal. A fire is then kindled on the hearth in the back of the furnace beneath the chamber C so as to heat up all parts of the several chambers in the furnace, and when all are sufficiently heated the shaking-box H and the screw conveyer G' connected with the coal-hopper G are set in motion, and the heated air from the regenerator or air-heating apparatus A is turned into the chamber C, the coal falling into and through the atmosphere of highly-heated air; then the process of making gas is commenced, and when the chamber B becomes heated by the combustion of the gas, and a further supply of highly-heated air being admitted into chamber B through openings c^1 c^1 c^1 and c^2 c^2, up to an intense heat, then the screw conveyer *m'* attached to the ore-hopper *m* is set in motion and the ore is fed into the shaking-box H with the coal, and becomes thoroughly mixed by the shaking motion of the box, and falls with the coal through the chamber C. Part of the highly-heated air having been shut off from chamber C, by valves not shown, the coal depends on the oxygen of the ore for part of its oxygen. The affinity of the intensely-heated carbon becomes so great under these conditions that the small particles of ore take fire in this atmosphere of intensely-heated carbon, and burn with a glowing heat, increasing the intensity of the heat so that nearly all the heated air has to be shut off. The metal cannot be burned up, but becomes carbonized into a carburet of

iron and falls on the hearth below in a melted condition. The melted metal flows toward the lower end of the slightly-inclined hearth, where it may be tapped out in the form of cast-iron or be allowed to flow through an opening in the bridge-wall between section B^2 and section B^3, which opening is opened and closed at the option of the workman, in the usual way, well known to iron-makers, by a lump of fire-clay or otherwise. In this second division of the hearth B^3 the metal may be boiled and refined in the usual way of operating a puddling-furnace, and be balled up and taken out in the consistency of refined iron, puddle-steel, or tapped out as cast-steel, or it may be allowed to flow or be otherwise removed into the third section of the hearth B^4 and there converted into refined cast-steel. Over the section B^3 there is a second gas-generator, D, or the hot air may at times be dispensed with in this chamber D, and fine coal or other substances, such as manganese, speigeleisen, or other proper material may be thrown in, or it may be dropped in or on the surface of the metal, further carbonizing or recarbonizing, or decarbonizing of the metal, at the option of the workman; and by aid of a reducing or carbonizing flame, or otherwise by the management of the supply of coal or the heated air, the same effect upon the metal may be produced. Chains (not shown) are arranged to hang down close to the furnace-doors or other convenient place so that the workman can change the speed of the several screw conveyers, increasing or decreasing the supply of coal or ore at his option, and as practice will dictate. The valves and their connections (not shown) regulating the supply of heated air to all or any special parts of the furnace are conveniently arranged so as to command immediate action of the air for any and all the various purposes the metal-worker may require.

Gas produced by this process may be employed for all illuminating, mechanical, and chemical purposes, and this furnace also may be employed for manipulating other metals. For very refractory ore I employ oxygen gas, admitted at opening *f* of the regenerator A; or steam admitted at the opening *f*, with or without atmospheric air, will operate differently, and produce different results than can be produced from steam admitted into an ordinary coal-fire or gas-generator. The steam admitted at *f* and allowed to pass through the regenerator becomes so intensely heated that it will decompose immediately what it comes in contact with, the fine particles of intensely-heated coal or particles of carbon struggling to get some other matter to combine with to form into gas. The oxygen of the steam attacks one portion of the carbon, forming carbonic oxide, while the hydrogen of the steam attacks another portion of the carbon and forms carbureted hydrogen. Thus gas is produced without any or very little nitrous-acid gas. When air alone is used, it being composed of eight parts of nitrogen to one of oxygen, more or less nitrous-acid gas must be the result of its combustion. When the gas is employed, and suffers total combustion in the same furnace, the waste heat and gases may pass down the downtake-flue *g* into the regenerator A and be employed for heating the incoming or cold air, oxygen gas, or steam, as shown in Fig. 5 and indicated by the arrows *b b b*, and the arrows *a a a* in cross-section, Fig. 6, which indicate the direction of the incoming air. Arrangements are also made with valves, dampers, (not shown,) or otherwise, so that the internal pressure inside the furnace and the external pressure of the atmosphere are about the same, whereby no cold air will be driven or forced into any part of the furnace except at opening *f*. Should any of the sands of ore fail to be fully carbureted or melted in their fall through chamber C they will drop upon the furnace-hearth, directly underneath chamber C, and the particles of coke or coal, or partially-converted coal, should be allowed to fall also on the hearth, so as to be mixed with the partially-deoxidized ore, and thereby a total combustion of the coal takes place and completes the carbureting and melting of the ore or metal. With some kinds of ore, the coal and the ore should be kept separate in the chamber C, which can be done by the parting wall R extending down to near the hearth in chamber C, as shown in Fig. 3. By cold or moderately heated air I mean air that can be conveyed and delivered into the furnace in iron pipes without destroying them. By highly-heated air I mean air heated to a temperature of 500° to 2000° Fahrenheit; by intensely-heated air I mean a temperature 2000° to 7000° Fahrenheit. I prefer using two regenerators under the furnace, so that an extra supply of highly or even intensely heated air can be brought into use at any moment that the workman may require it, without interfering with the general operation of the furnace or any part thereof. Should there be any ashes or residuum from the coal it will be melted into slag or fluid cinder, and tapped and removed in the usual way of tapping and drawing out the fluid cinder in blast-furnaces.

My process and apparatus differ from the following apparatus in the manner described, and such processes and apparatus are disclaimed by me.

I am aware that they use in the old blast-furnaces the coal and iron mixed together, and fed in at the top of a perpendicular expanding-chamber, that hot air is used, and the metal and slag or cinder are tapped off in a fluid condition. So far this process agrees with mine. They pass their waste gases out at the top of the chamber; I pass my gases out at the bottom of the chamber. Their ore and coal lie in a solid mass; my ore and coal in an open, disintegrated, continuously-falling condition. They melt the impurities with the ore, causing them to chemically combine with the metal; I mechanically remove the impurities

before submitting them to the fire. They produce common crude, cast, or pig iron; I produce refined iron and steel.

I am also aware that there is a class of furnaces which have an outside or independent fire or gas producer, and pass the heat or the gas over into the deoxidizing-chamber. I employ all the heat produced in converting the coal into gas to aid the deoxidizing of the ore, and the oxygen of the ore assisting to convert the coal into gas. They introduce large volumes, currents, or blasts of cold or moderately-heated air, which have a tendency to lessen the degree of heat required in refining iron or steel in a reverberatory-furnace, and blow, by the force of their currents, large quantities of ashes over onto or into the metal; I employ every possible means of keeping out the large volumes, currents, or blasts of cold or moderately-heated air, and by this means so lessen the volume and increase the degrees of heat that the ore is successfully deoxidized, carbureted, melted, and settled in one chamber, an effect impossible where large volumes, blasts, or currents of air are used. They produce iron that will not make a good quality of cast-steel without further heating, melting, refining, converting, &c.; I produce refined cast-steel direct from the ore at one operation.

I am also aware that there is a class of furnaces which employs blasts of cold air from a blower, in which is mixed a quantity of very fine floating coal-dust, (called carbonized air,) blown into a combustion-chamber through iron pipes and tuyeres, and then over into the deoxidizing, heating, melting, or refining chamber. Some of their inventions also mix a portion of heated air with the cold-blast, and some blow the ore or coal in on top of a chamber resembling chamber C in the accompanying drawing, and cold air is also drawn or forced in at intervals along and down the sides and into said chamber. All these inventions employ more or less cold air introduced into the deoxidizing, heating, melting, or refining chamber; I do not. They desulphurize, deoxidize, or melt the metal only; I produce gas, refined iron, and steel all in one and the same furnace, and at one continuous heat or operation direct from the ore.

Having thus described my processes and apparatus, what I claim as new therein, and my own invention, is—

1. The process herein described of making gas continuously without retorts by subjecting coal-dust falling continuously in a flue to the contact of intensely-heated air without blasts or currents sufficient to prevent the dust from falling through said heated air.

2. The method of producing gas by submerging small particles of coal into highly-heated air in a perpendicular chamber, and melting the residue, so that it may be removed from the furnace in a fluid condition, substantially as described.

3. The combination of a furnace constructed for making gas with a regenerator or other equivalent air-heating apparatus and a means of feeding the coal and removing the residue in a fluid condition.

4. The employment of highly-heated air for converting, or assisting to convert, coal into gas and melting the residue into a fluid condition, for the purpose and substantially as set forth.

5. The method of heating the air and introducing into the gas-producer, for the purpose and substantially in the manner as set forth.

6. The process of making iron direct from the ore, as herein described, in combination with the process of making gas herein described.

7. The process of making refined iron and steel direct from mechanically purified or separated ore at one continuous heat and operation and in one furnace, and by aid of gas produced substantially as described.

8. The arrangement of a gas-producer, a deoxidizing-chamber, a melting-and-refining chamber, and an air-heating apparatus, all in one structure, substantially as shown and described.

9. The combination of a gas-producer, deoxidixing-chamber, a melting-and-refining chamber, and an air-heating apparatus, so as to be operated together, as described.

10. The employment of a gas-producer, a melting-and-refining chamber, and an air-heating apparatus, so arranged that they may be operated together, for the purpose set forth.

11. The method of keeping out currents of cold air from the interior of the furnace, substantially as described.

12. The method of submerging and enveloping the prepared ore into an atmosphere of highly-heated gas, for the purpose set forth.

13. The method of feeding the material into the chamber C in such a manner that the top of the furnace can be kept air-tight, substantially as and for the purpose set forth.

14. The method of distributing the air into chamber C so as to avoid any fast currents, substantially as shown.

15. The method of intensely heating steam by passing it through a regenerator or similar heating apparatus, alone or mixed with oxygen gas or with atmospheric air, and employing it for making gas or refining metals.

16. The arrangement of the box H, conveyer G′, and hopper G, constructed substantially as described, for the purpose of feeding material into the flue, as set forth.

17. The employment of the improvements herein set forth in combination with the process and devices set forth in my Patents No. 67,497 and No. 67,498 applicable hereunto.

THOS. J. CHUBB.

Witnesses:
EDM. F. BROWN,
H. C. SMITH.