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A. SATTMANN & A. HOMATSCH.

PROCESS OF MANUFACTURING IRON OR STEEL.

No. 580,427. Patented Apr. 13, 1897.

Fig. 1.

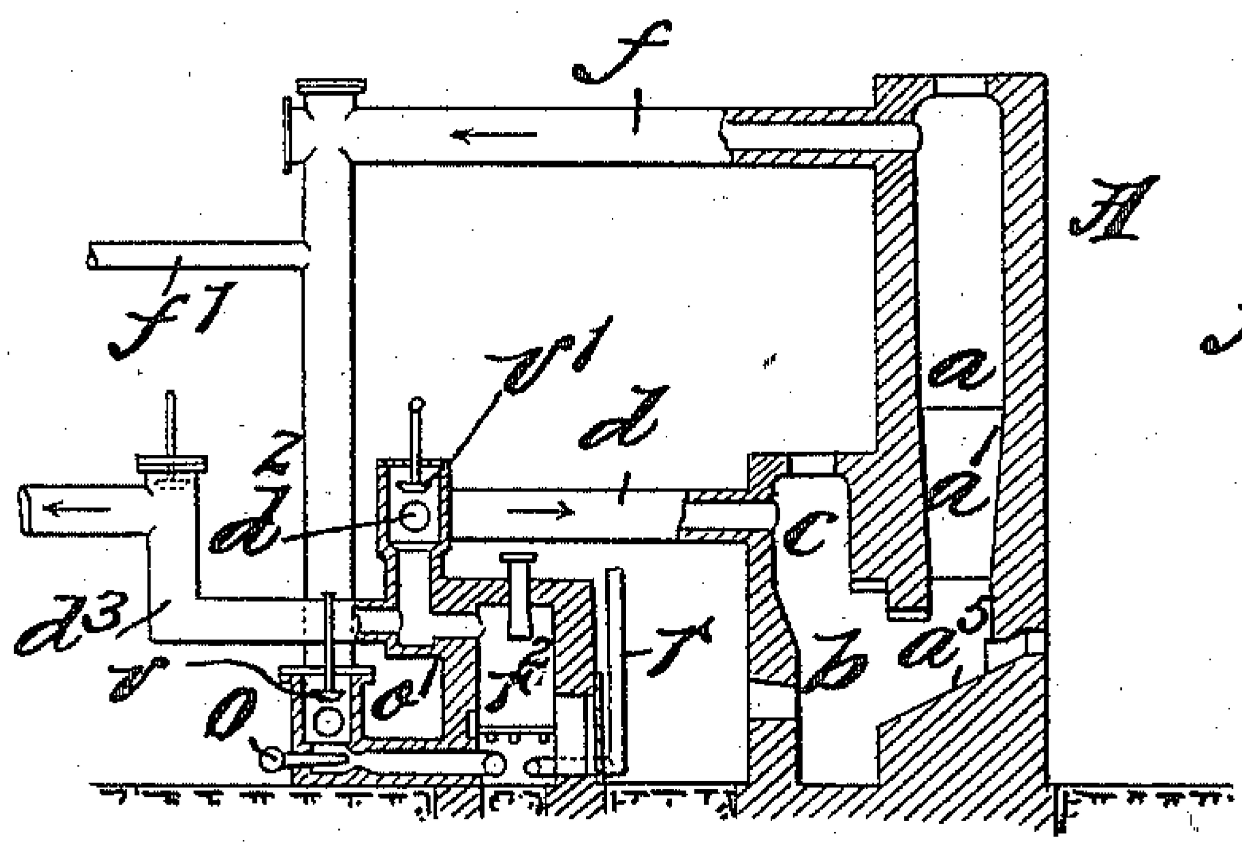


Fig. 3.

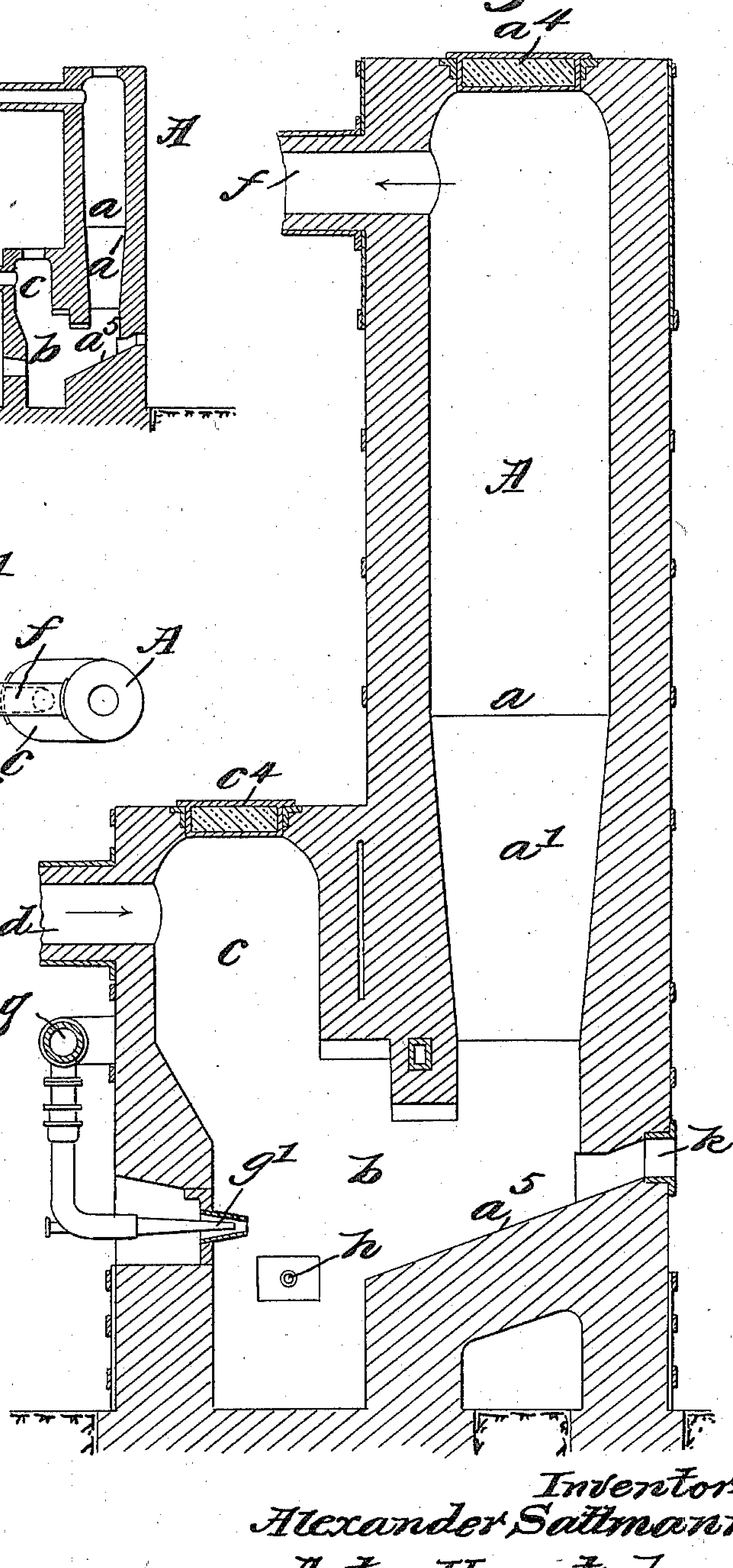


Fig. 2.

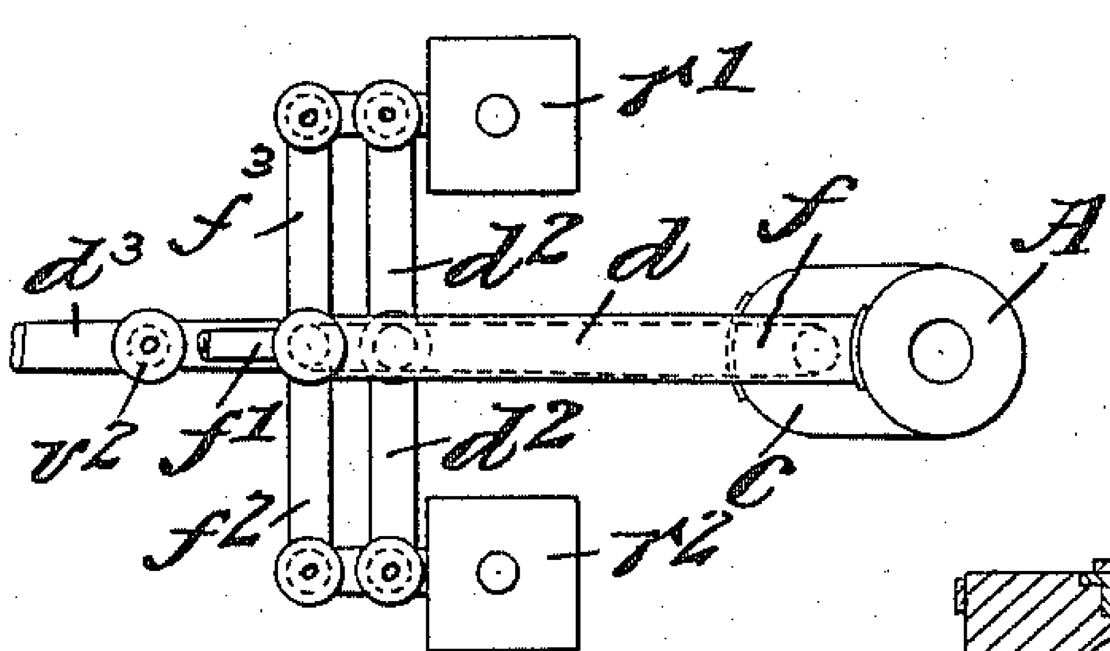
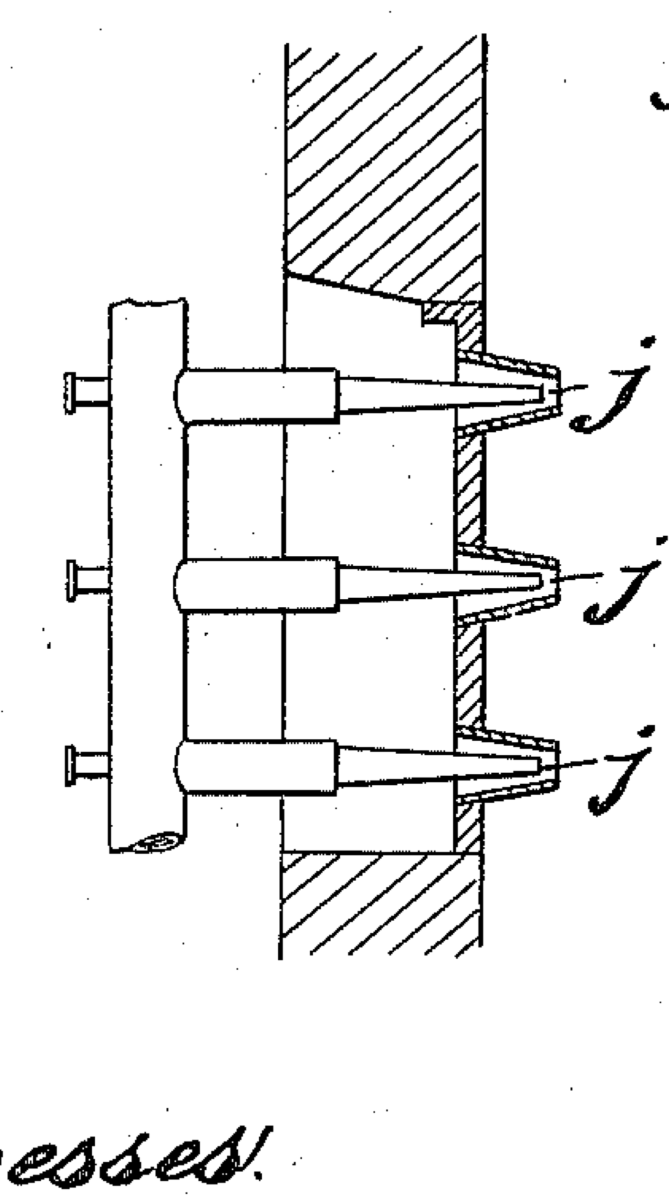


Fig. 5a



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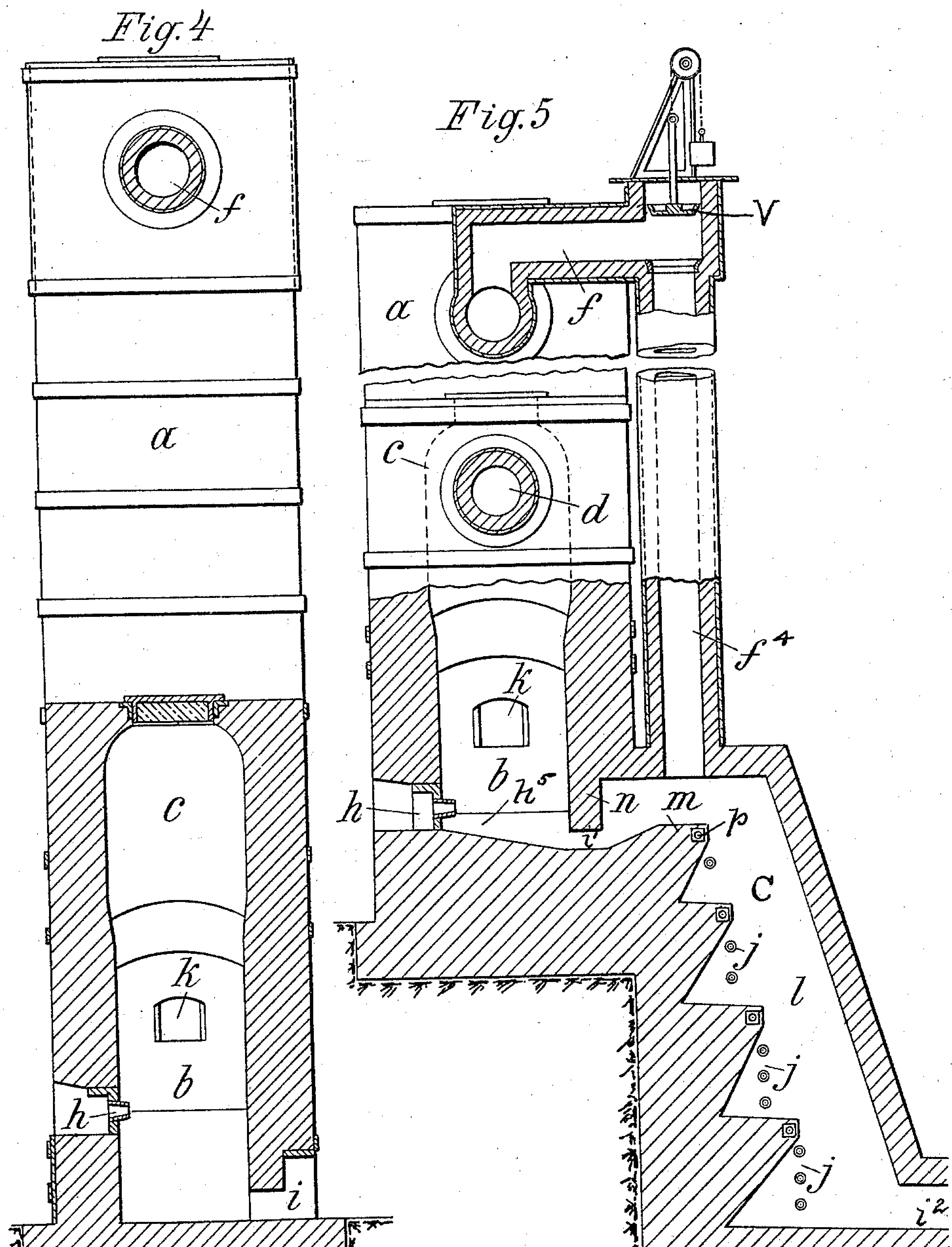

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PROCESS OF MANUFACTURING IRON OR STEEL.

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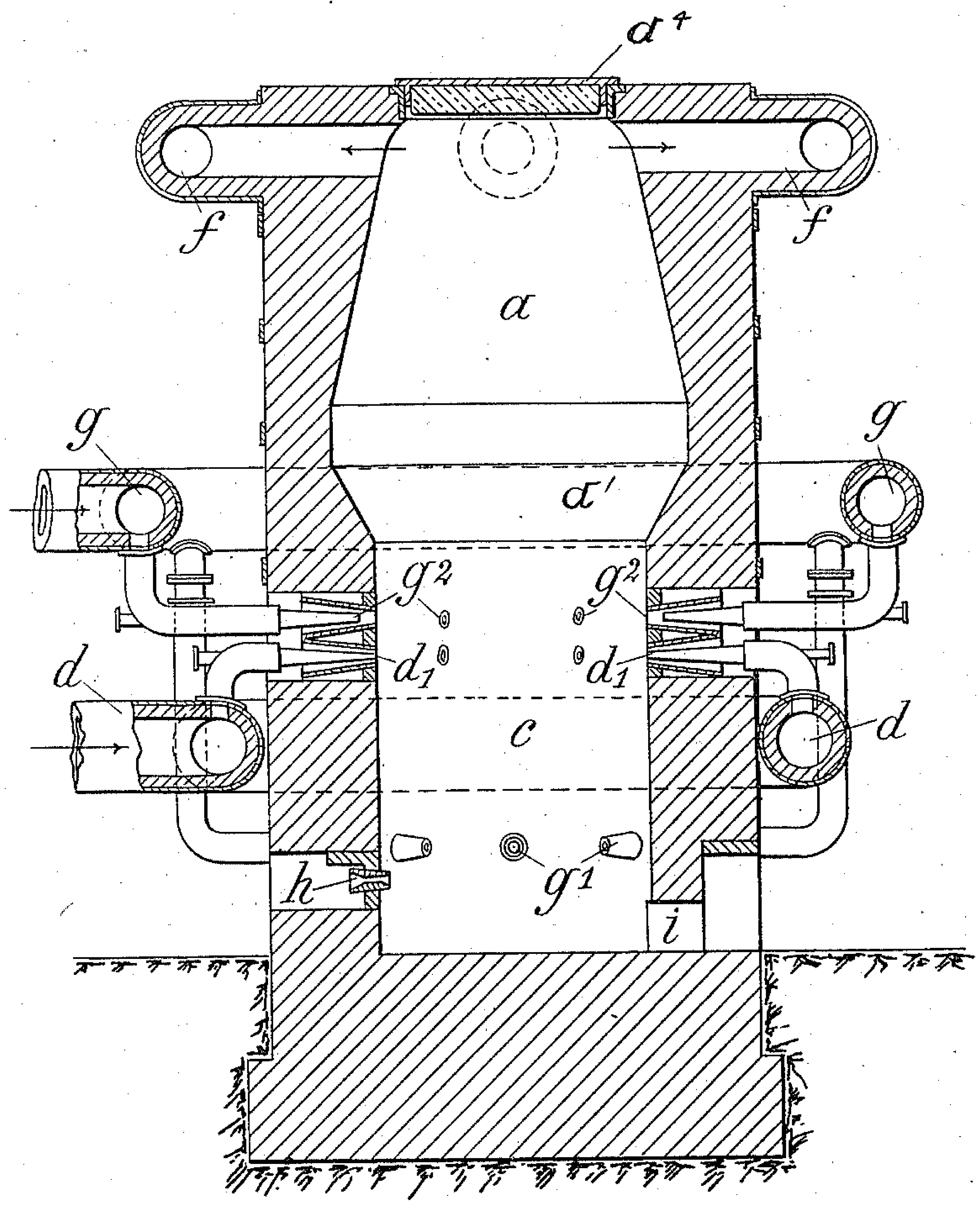
Fig. 6



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PROCESS OF MANUFACTURING IRON OR STEEL.

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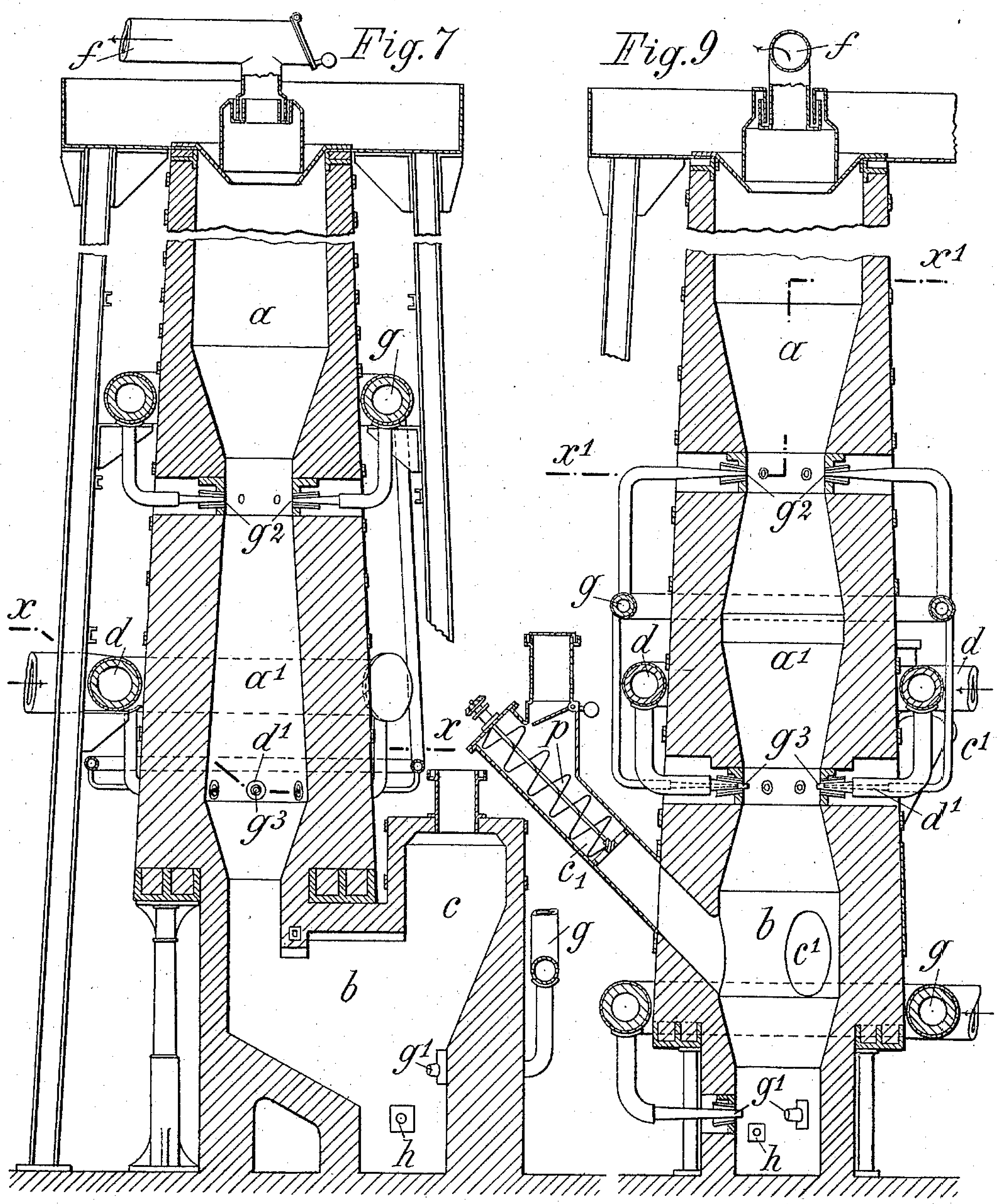

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PROCESS OF MANUFACTURING IRON OR STEEL.

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Fig. 8

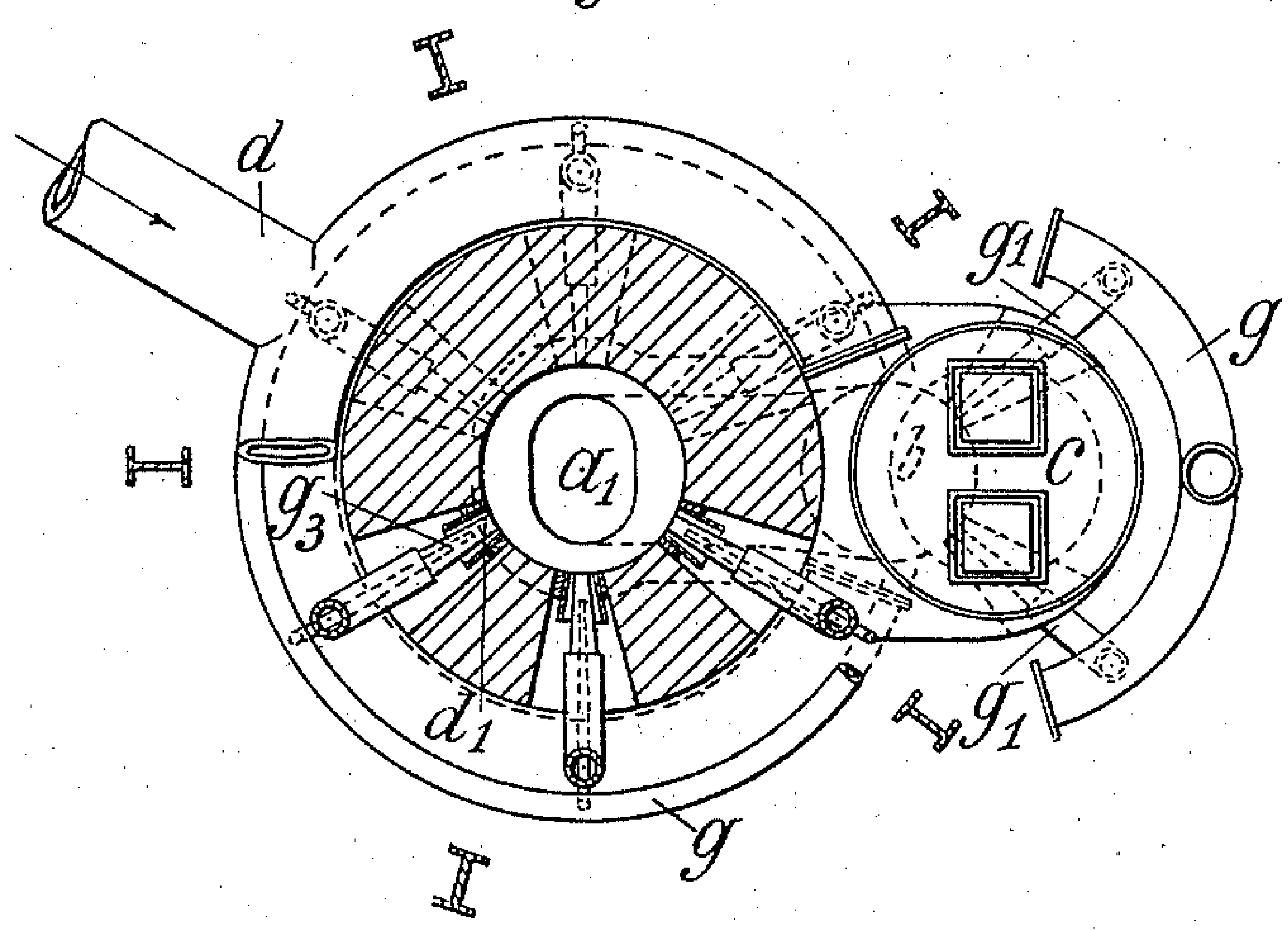
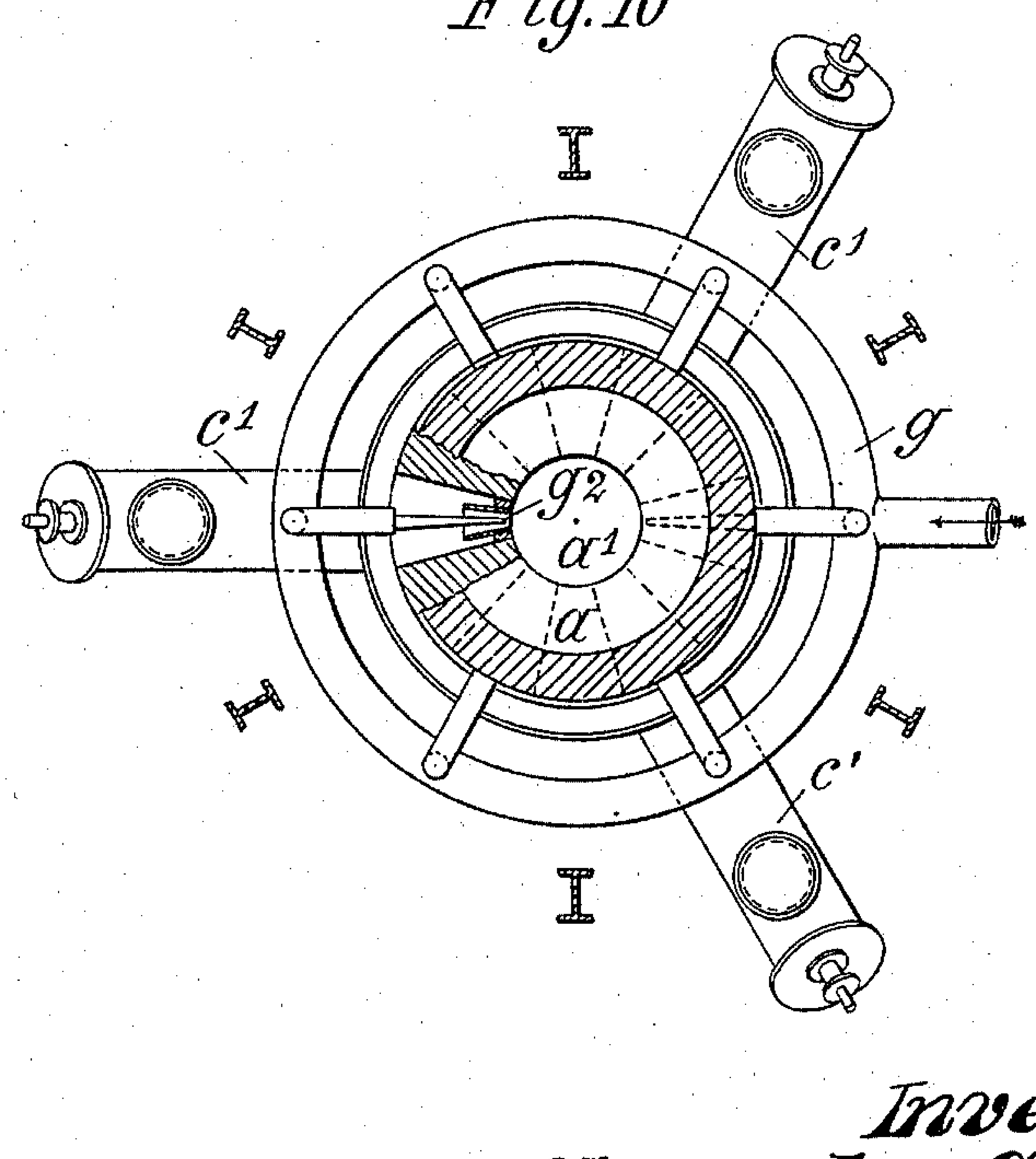


Fig. 10



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UNITED STATES PATENT OFFICE.

ALEXANDER SATTMANN AND ANTON HOMATSCH, OF DONAWITZ, AUSTRIA-HUNGARY.

PROCESS OF MANUFACTURING IRON OR STEEL.

SPECIFICATION forming part of Letters Patent No. 580,427, dated April 13, 1897.

Application filed June 6, 1893. Serial No. 476,774. (No specimens.)

To all whom it may concern:

Be it known that we, ALEXANDER SATTMANN and ANTON HOMATSCH, subjects of the Emperor of Austria-Hungary, residing at Donawitz, in the Province of Styria, in the Empire of Austria-Hungary, have invented certain new and useful Improvements in the Manufacture of Iron or Steel; and we do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same, reference being had to the accompanying drawings, and to letters of reference marked thereon, which form a part of this specification.

Our invention has relation to the manufacture of iron, as well as to the manufacture of steel, direct from the ore.

In the manufacture of malleable iron or steel the ore as a rule has heretofore been reduced to crude or pig iron in the blast-furnace. This operation involves the consumption of a comparatively expensive fuel, such as charcoal, coke, or anthracite coal, and where such fuel is not at hand the additional expense of transportation is incurred, either or both of which increase the prime cost of the crude metal, while the less expensive fuel, such as is usually found in the vicinity of mines or ore beds or deposits, as coal of inferior quality, brown coal, lignite, turf, or waste wood, is generally not available for use in the blast-furnace.

Our invention has for its object the provision of means whereby fuel of inferior quality, such as above referred to, may be made available in the manufacture of iron or in the manufacture of steel direct from the ore; and our said invention consists, essentially, in a novel process of melting or of smelting and refining or converting, furnaces of special construction being provided whereby the last-named operation may be more effectually carried out than in the reverberatory furnace by means of decarburizing gaseous agents brought into intimate contact with the crude metal.

The process forming a part of our invention involves the following steps: first, the preparing of the ore and fluxing materials for reduction either by simply preheating said materials or by roasting the ore and at the same time heating the fluxing materials; second, the reduction of the ore and the carburization of the spongy metal by means of a gaseous reducing and carburizing agent; third, the smelting of the spongy carburized metal by means of solid fuel, and, lastly, the refining or converting of the crude metal by means of a gaseous oxidizing agent and its conversion into a more or less decarburized metal.

The first and second steps in the process may be carried out by means of a variety of combustible gases or vapors, as, for instance, natural gas or gas or vapor obtained by the evaporation or volatilization of vaporizable or volatilizable combustible liquids or gases or vapors derived from the dry distillation or incomplete combustion of hydrocarbons or other carbonaceous materials, such as the cheaper fuels above referred to and found in the vicinity of mines or ore beds or deposits, as coal of inferior quality, brown coal, lignite, &c. On the other hand, the waste gases or products of combustion derived from the operations of heating or roasting and smelting may be utilized in similar subsequent operations or for the same purpose in a continuous process of heating or roasting, reducing, smelting and refining, or converting, which is of special advantage when natural gas is not available or when gases substantially free from nitrogen cannot be obtained at a reasonable cost.

We have above alluded to the use of gases substantially free from nitrogen, which is of great importance in our process in that the nitrogen present is not only an absolutely inert factor producing no useful result, but, on the contrary, is an absorbent of heat, so that the amount of heat absorbed by the nitrogen is practically lost. Hence the smaller the proportion of nitrogen in the gaseous combustibles used the less loss of heat. Thus in the use of the waste gases resulting from the heating or roasting of the ore or in the use of gases derived from incomplete combustion of such materials or fuels as hereinbefore referred to for the preheating or roasting and for the reduction of the ore and the subsequent carburization of the sponge, which gases contain already considerably less nitrogen and more oxygen than atmospheric air, or before the gas is allowed to come in contact with the heated or roasted ore, we carburet the same, that is to say, we charge or saturate it with carbon by passing it over, preferably through, a bed of incandescent carbonaceous material, not only for the purpose of charging or saturating the gas with carbon, but also for the purpose of still further reducing the percentage or proportion of nitrogen in the gas, and for this purpose the said cheap fuels rich in carbon may also be employed. The reduction in the percentage of nitrogen in the gases is due to the absorption by the latter of the oxygen evolved from the ore, the resultant gas containing more oxygen and less nitrogen than atmospheric air. On the other hand, when said gases are carburized, the proportion of carbon taken up will be equal to the proportion of oxygen present, whereby the volumetric percentage of the nitrogen is still further reduced. If such a gas is repeatedly used and each time subjected to the carbureting or saturating or restoring process referred to, the composition of the gas will finally become a fixed or settled one, as it were, in that nearly if not all the nitrogen combined therewith will have been eliminated, a portion of the gas being necessarily consumed in generating heat at each use, so that a final gas is obtained that is considerably poorer in nitrogen than even a gas derived from the incomplete combustion of a carbonaceous material or such materials as above referred to.

Under certain circumstances the heat necessary to the second step of the process, namely, the reduction of the ore, may be derived from solid fuel, in which case there will be a further reduction in the proportion of nitrogen in the resultant or waste gases, the reducing power of which will be correspondingly increased, though the operation will necessarily involve the use of the more expensive fuel hereinbefore referred to, otherwise required for smelting only and which we aim to avoid, yet inasmuch as the spent or waste gases resulting from the use of this more expensive fuel may be utilized the expense will be correspondingly reduced. By the use of gases poor in nitrogen and rich in carbon oxid the process of reduction is greatly accelerated, while in the subsequent use of the waste gases for other purposes more favorable results will be obtained than before, because less heat is lost in the escaping products of combustion by reason of the small proportion of nitrogen present.

When the ore is roasted in the presence of carbonates, the waste gases will become richer in oxygen by reason of the carbonic acid present being converted into carbonic oxid, and if these gases are repeatedly carburized or saturated with carbon a gas poor in nitrogen will at all times be available. By means of these gases the ore is heated and, if necessary, roasted and reduced, the sponge being at the same time carburized.

The third step in our process, namely, the smelting of the sponge is effected immediately after the reduction by means of a deoxidizing gas derived from the combustion of solid fuel rich in carbon. Inasmuch as a large proportion of the fuel is converted into carbonic-acid gas in the vicinity of the blast, it is necessary that the bed of incandescent fuel between the sponge and twyers be so proportioned that the major portion of the carbonic-acid gas before reaching the sponge will again be converted into carbon monoxid during its passage through the bed of incandescent carbonaceous fuel. The temperature obtained in this operation is quite sufficient to melt the spongy metal together with the slag present.

The fourth or refining step of the process is carried out by means of an oxidizing flame brought in intimate contact with the molten crude metal, which may be decarburized to any desired extent, dephosphorized, and freed from silicon after removal of the slag, so that any foreign substance that may still be combined with such crude metal and which it is desirable to remove will be wholly or partially consumed in the operation of refining.

If the temperature in the collecting-chamber for the crude metal is sufficiently high to maintain the metal in a fluid state, more or less refined crude iron or ingot iron or steel will be obtained. If, on the contrary, the temperature in said chamber is below that of the melting-point of the metal, a weldable iron or steel will be obtained.

The process may be carried out intermittingly or continuously, and we have devised suitable apparatus for either purpose, as illustrated in the accompanying drawings, in which—

Figure 1 is a vertical sectional elevation, and Fig. 2 a top plan view, of a construction of smelting plant suitable for carrying out the first three steps of the process. Fig. 3 is a vertical section of the reducer and smelter. Fig. 4 is a sectional end elevation of Fig. 3. Fig. 5 is a like view illustrating the combination with the reducer and smelter of a refiner or converter. Fig. 5^a is a detail sectional view illustrating the arrangement of the twyers in the converter. Fig. 6 is a vertical section of a modified construction of reducer and smelter. Figs. 7 and 9 are vertical sections of furnaces adapted for continuous operation; and Figs. 8 and 10 are cross-sections taken, respectively on, lines $x\,x$ and $x'\,x'$ of Figs. 7 and 9.

Similar symbols refer to like parts whenever such may occur in the figures of the drawings just described.

Referring now to Figs. 1 to 5, which illustrate a construction of plant for intermittingly carrying out our process, A indicates a stack the lower portion a' of which is gradually contracted from the portion a to, or nearly to, its lower end, and b indicates the combustion-chamber, located on one side of the stack A and extending below the hearth a^5 thereof to form a sump or reservoir for the molten metal and slag. The said hearth a^5

is, as shown, inclined toward the combustion or smelting chamber b to facilitate the flow of the molten materials from the lower end of the stack into said chamber. Both the stack A and combustion-chamber b are provided with charging-holes at their upper end adapted to be closed by any usual or other suitable means, as shown at a^4 c^4, respectively. Furthermore, the stack A is at or near its upper end connected with a gas-exhaust main f, and the combustion-chamber is at or near its upper end connected with a gas-supply main d. Immediately opposite the hearth a^5 is arranged the wind or blast twyer g' and a little below the same the slag-hole h, a suitable tap-hole i, Fig. 4, or a passage i', Fig. 5, leading to the converter or refiner hereinafter described being provided, as well as a manhole k, Fig. 3, for affording access to the hearth a^5 and walls of the stack for removal of material adhering thereto or for effecting repairs.

It has been stated that the crude metal may be more or less refined or converted immediately after smelting. To this end we combine the smelter with a converter C, as shown in Fig. 5, in which case the passage i' above referred to is so arranged as to constantly keep a body of metal on the hearth or floor a^5 of the smelter to prevent slag and cinder from passing over into the converter C. This we effect by means of a tymp n, extending across passage i' below the slag-hole, and by means of a bridge m within the converter about on a level with the lower edge of the tymp n to keep the passage i' sealed with molten metal, the hearth a^5 of the smelting-chamber sloping downwardly into the converter beyond the tymp n and then upwardly to the bridge-wall m. The face of the vertical wall of the converter-chamber l on the side of the bridge m is stepped, the tread of the successive steps m' from the bridge m downwardly increasing in width, so that the metal will flow in a thin sheet over the said bridge m, then over the successive steps m', during which time such metal will be exposed to the action of an oxidizing flame obtained by admitting waste gases from the exhaust-pipe f of the stack through branch pipe f^4 into the converter-chamber l and combining therewith a suitable proportion of air injected into the chamber l through blast-twyers j, (see also Fig. 5^a,) which, as shown, are arranged below and substantially on a line with the outer edge of each step m' and the bridge m, which constitutes the upper step of the series. The steps m' of the converter-wall are cooled by the means of a fluid, as cold air or water, caused to circulate through pipes p, extending through the steps near the outer edge of their tread, as shown in Fig. 5.

V is a valve in pipe f^4 for controlling or cutting off the supply of waste gas to the converter-chamber l, and i^2 is the discharge-gutter for the refined metal.

Instead of arranging the combustion and smelting chamber on one side of the stack A, as described, it may be arranged at the bottom of said stack, as shown in Fig. 6, gas and air supply pipes being arranged accordingly, g' g^2 indicating the blast-twyer connected with the air-main g, and d' the gas-supply jets or nozzles connected with the gas-supply main d, the charge of ore and fluxing material, as well as the solid fuel, being introduced through the charging-hole a^4. There are two sets of blast-pipes g' g^2, the former being located a little above the slag-hole h, while the latter are arranged above the space c, in which the solid fuel is contained when the furnace is in operation, the reduction of the ore taking place in the lower part a' of the ore-space a.

We have stated above that the waste gases from the furnace may be used over and over again, but when so used these waste gases are each time carbureted or saturated with carbon in order to convert the same into a reducing and carburizing gas. This we accomplish as follows: The gas-exhaust pipe f has two branches f^2 and f^3, Figs. 1 and 2, connected with the injector-casings o', in which are arranged steam-injectors o, said casings being connected each with a recuperator r' and r^2 below the grate thereof, and the spaces above the grates of said recuperators are connected by means of branch pipes d^2 with the gas-main d, leading to the upper part c of the combustion-chamber.

By means of the steam-injectors o and the air-blast g' or g^2, Fig. 6, in the smelting-chamber a circulation of the gases and products of combustion is insured, and the gas-exhaust as well as the gas-supply main are provided with a branch f' d^3, respectively, Figs. 1 and 2, by means of which the surplus gases not needed in the process may be conducted elsewhere and utilized, said branch pipes being in practice provided with suitable cut-off valves. The recuperators r' and r^2 are used alternately—that is to say, when the bed of incandescent fuel on the grate in one is exhausted that on the grate in the other is or has been lighted by injection of air through pipe r—suitable valves v being provided to divert the exhaust-gases from the exhaust-main f from one into the other recuperator, and a suitable valve or valves v' being provided whereby communication between one or the other recuperator and the feed-main d may be cut off or established, as the case may be. The jet of steam from injector o forces the gases coming from the exhaust-main f into one of the recuperators below its grate, thence through the bed of incandescent carbonaceous material on the grate thereof to the gas-supply main d and upper part c of the combustion-chamber b, the gases leaving the recuperators as reducing-gases, the carbonic acid from the fuel on the grate being converted into carbonic monoxid.

From what has been said it is apparent that the recuperation or conversion of the waste non-reducing gases into reducing-gases is carried on continuously or as long as the operation of reduction or smelting may last.

The operation in the construction of furnace described is as follows: The stack A having been charged with ore and flux and closed, the smelting-chamber b being of course also closed, reducing-gas is then admitted through main d and air through twyers g', the gases being ignited by means of sufficient incandescent fuel placed in the smelting-chamber b or by the heated furnace-walls due to prior operations. The ignited gases, which are either neutral or oxidizing, according to the proportion of air introduced into the furnace and mixed therewith, pass through the bed of ore and fluxes, heat the same, expel the carbonic acid if carbonates are present, and escape through exhaust-pipe f into one of the recuperators. When the charge of ore in the stack has been brought to a condition for further treatment, the volume of air admitted is so regulated that the gas supplied will produce a reducing and carburizing flame. Should any loss in heat occur in consequence of the reduction, a sufficient amount of solid fuel is burned along with the air supplied to the smelter. When the reduction of ore is completed, the supply of both air and gas is cut off and solid fuel is introduced into the smelting-chamber b, unless this has already been done after roasting the ore. Air is now admitted and the resulting heat melts the spongy metal nearest the source of heat or on or about the hearth a^5 of the stack A, the mass of ore and fluxes gradually settling as the lower portion thereof is melted and collects in sump or lower part of chamber b. As the sump or lower portion of chamber b fills the slag and cinders or solid products of combustion from the solid fuel are run out through tap-hole h, while the crude metal, after the charge has been melted, is run off through tap-hole i, a fresh charge of ore and fluxes being introduced into chamber a. The gases resulting from the smelting operation instead of recuperating them, as before described, may be utilized for any other purpose. The crude metal obtained may, however, be refined or converted as fast as it is melted by combining with the furnace a converter C, as above set forth and as shown in Fig. 5. Inasmuch as the converter C and the operation of converting or refining the crude metal have been fully described hereinabove, it is not necessary to again describe the same, except to say that by means of the described waste-gas and air supply the temperature of the crude metal is sufficiently raised to effect the decarburization. The crude metal and slag remaining on the hearth h' after the charge of ore has been melted and the metal converted or decarburized are discharged through a special tap-hole. (Not shown.)

In a furnace of the construction illustrated in Fig. 6 the operation may be briefly described as follows: The combustion-chamber is first supplied with a sufficient quantity of solid fuel, which in starting is introduced in a partly incandescent state, a bed of preferably comminuted ore and fluxes being spread over the fuel, so as to fill up the furnace to a point a little below the gas-nozzles d', the remaining space being then filled with ore of any size and fluxing materials, after which the charging-orifice a^4 is closed. A reducing and carburizing gas is then admitted through gas-nozzles d', together with the necessary amount of air to support combustion through twyers g^2. The preliminary heating or the roasting of the ore is effected in this furnace in the same way as in the furnace described in reference to Figs. 1 to 5, the air to support the combustion of the gases being supplied, as stated, by twyers g^2 and the air necessary to support the combustion of the solid fuel through the twyers g'.

In either construction of furnace the nature and composition of the final product may be varied at will, either by a more or less perfect reduction or the maintenance of suitable temperatures and the consequent more rapid or slower smelting of the reduced ore and the subsequent conversion of the solid metal.

In Figs. 7 to 10 we have illustrated a construction of smelter designed for continuous operation. The gas-exhaust pipe f is here arranged centrally in the head of the stack A, which is of such construction as to form in its interior the charging and preheating or roasting chamber or space a, the reducing-space a', and the smelting-chamber b, one below the other in the order named, the solid fuel being fed to the smelting-chamber b through lateral ducts c' by means of suitable conveyers p, as shown in Fig. 9, or said smelting-chamber b may be located on one side of the stack A, as in Figs. 1 and 3, this construction being illustrated in Fig. 7.

As shown in Figs. 7 to 10, the twyers or air-nozzles g^2 are connected by branch pipes with the air-main g and are interposed between the charging and preheating or roasting chamber or space a and the reducing chamber or space a', as in Fig. 6, while the twyers or air-nozzles g^3 extend into the gas-nozzles d', arranged between the reducing chamber or space a' and the melting-chamber b, as shown in Figs. 7, 8, and 9, said gas-nozzles d' being connected by branch pipes with the gas-main d.

In the construction of furnace, Figs. 9 and 10, we use a plurality of blast-twyers g' for the smelting-chamber b, preferably one for each fuel-duct c', of which we have shown three, (see Fig. 10,) said twyers being so arranged that the direction of blast will be substantially at right angles to the direction of feed of the solid fuel and on lines radiating to the center of the smelting-chamber. Although not shown, recuperators r' and r^2, as described in reference to Figs. 1 and 2, as well as a refiner or converter, may be combined with the form of furnaces described in reference to Figs. 7 to 10, as will be readily understood.

The continuous operation is as follows: The smelting-chamber *b* is supplied with solid fuel, the combustion being supported by an air-blast, preferably hot, supplied through twyers g', the supply of fuel being kept up either automatically by suitable conveyers and feed ducts or trunks, as shown in Fig. 9, or by hand or other supply, Fig. 7, sufficient heat being generated to smelt the reduced ore or spongy metal together with the slag formed during such reduction. This reduction of the ore is effected not only by the reducing-gases generated in the smelting-chamber, but by the reducing-gas derived preferably from the waste gases of the furnace previously carbureted or saturated with carbon, as described, a due proportion of air being supplied through the nozzles or twyers g', while the material is preheated or prepared for reduction or roasted by the excess of waste heat and by the excess of unconsumed reducing-gases supplied with a due proportion of air through the twyers g^2, the ore and fluxing material being fed to the stack in proportion as the contents thereof are reduced and melted. It is apparent that here also the nature of the final product may be controlled or determined, more especially when the furnace is constructed with automatic solid-fuel feed-trunks c', whereby the quantity of fuel supplied to the smelting-chamber may be readily varied, so that the process itself is to some extent made independent of the composition of the ore used, as well as of the quantity of moisture in the fuel or other similar incidental conditions.

The advantages of our process over the ordinary blast-furnace process may be briefly enumerated as follows: first, the substitution for the major portion of the expensive fuel heretofore used of a cheaper inferior fuel; second, a material reduction in the consumption of solid fuel, consequently a corresponding reduction in the amount of slag formed, and hence a saving in fluxing materials and labor; third, the possibility of dispensing with a separate roasting-furnace, if it be at all necessary to roast the ore, and the possibility of utilizing the gases evolved in the operation of roasting for the reduction of the ore; fourth, the operation with gases poor in nitrogen, possessing considerable heating and reducing power, by utilizing and recuperating or carbureting the waste or exhaust gases evolved in the process, using for the recuperation cheap carbonaceous materials; finally, the saving not only in fuel and labor, but in the cost of working, as compared with the cost of working the ordinary blast-furnace, and converting or refining the metal in a reverberatory furnace, in view of the fact that the conversion or refining may be carried out without reheating by running the molten crude metal into the converter, as described.

Having thus described our invention, what we claim as new therein, and desire to secure by Letters Patent, is—

1. A process of manufacturing iron direct from the ore, which consists in adding a charge of ore to a chamber, then treating it therein first with an oxidizing-gas then with a reducing-gas, then carburizing and smelting the resulting crude iron by means of a reducing-gas obtained from these operations and which has previously been recuperated, said gas being enriched with carbonic oxid and its temperature raised by bringing the same into contact with a body of incandescent solid carbonaceous material isolated from the ore, substantially as set forth.

2. The continuous process which consists in the following steps, to wit: adding a charge of ore to a chamber, treating it therein first with an oxidizing-gas and then with a reducing-gas, recuperating the gases resulting from these operations utilizing a portion of such recuperated gases with a reducing-gas obtained from carbonaceous materials in the process of reduction carburizing and effecting the smelting of the sponge by the action of the recuperated gases enriched with carbonic oxid and whose temperature has been raised by bringing such gases into contact with an incandescent body of solid fuel isolated from the ore, substantially as and for the purpose set forth.

3. The herein-described process of fining crude metal, which consists in causing the molten metal to fall in a thin sheet through space, and injecting an oxidizing-gas into such sheet in the direction of its width.

4. The herein-described continuous process, which consists in subjecting the ore to the action of a non-reducing gas and then to the action of a reducing-gas, smelting the resulting sponge by means of a deoxidizing-gas, and fining the crude metal by causing it to fall through space in the form of a thin sheet and injecting an oxidizing-gas into such sheet in the direction of its width.

In testimony whereof we affix our signatures in presence of two witnesses.

ALEXANDER SATTMANN.
ANTON HOMATSCH.

Witnesses:
CHARLES SEDLACRESH,
A. SCHLESSING.