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C. W. Siemens' Apparatus for producing Cast Steel from Iron Ores.

113584 PATENTED APR 11 1871

Sheet 1.

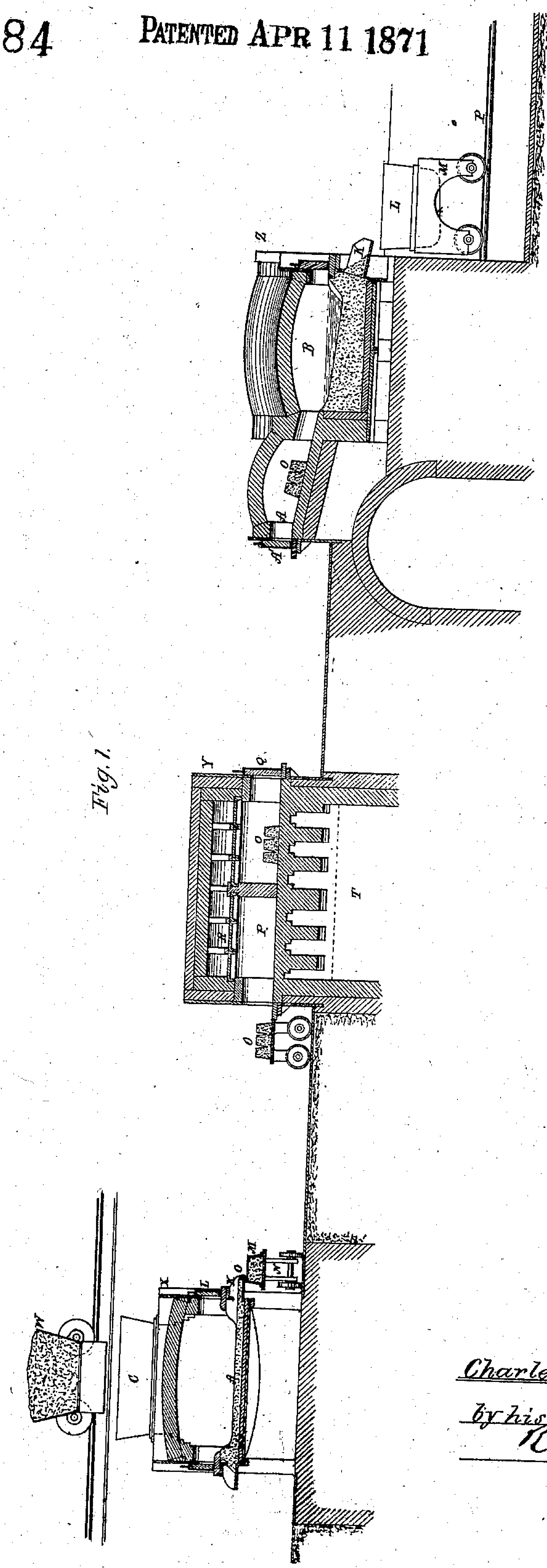

Fig. 1.

Witnesses.
S. N. Piper
J. R. Snow

Charles W. Siemens.
by his attorney.
R. H. Eddy

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Sheet 2.

Fig. 2.

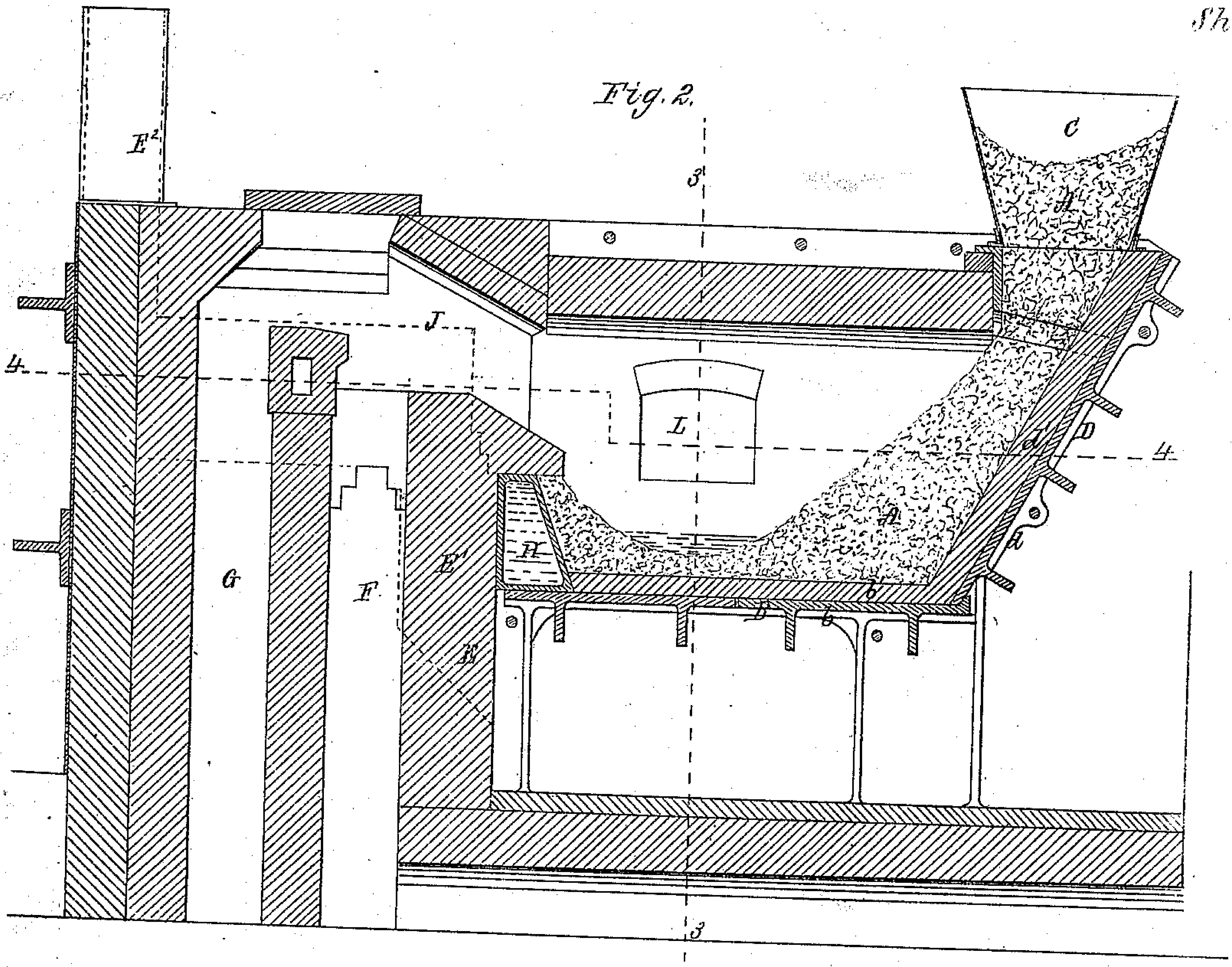

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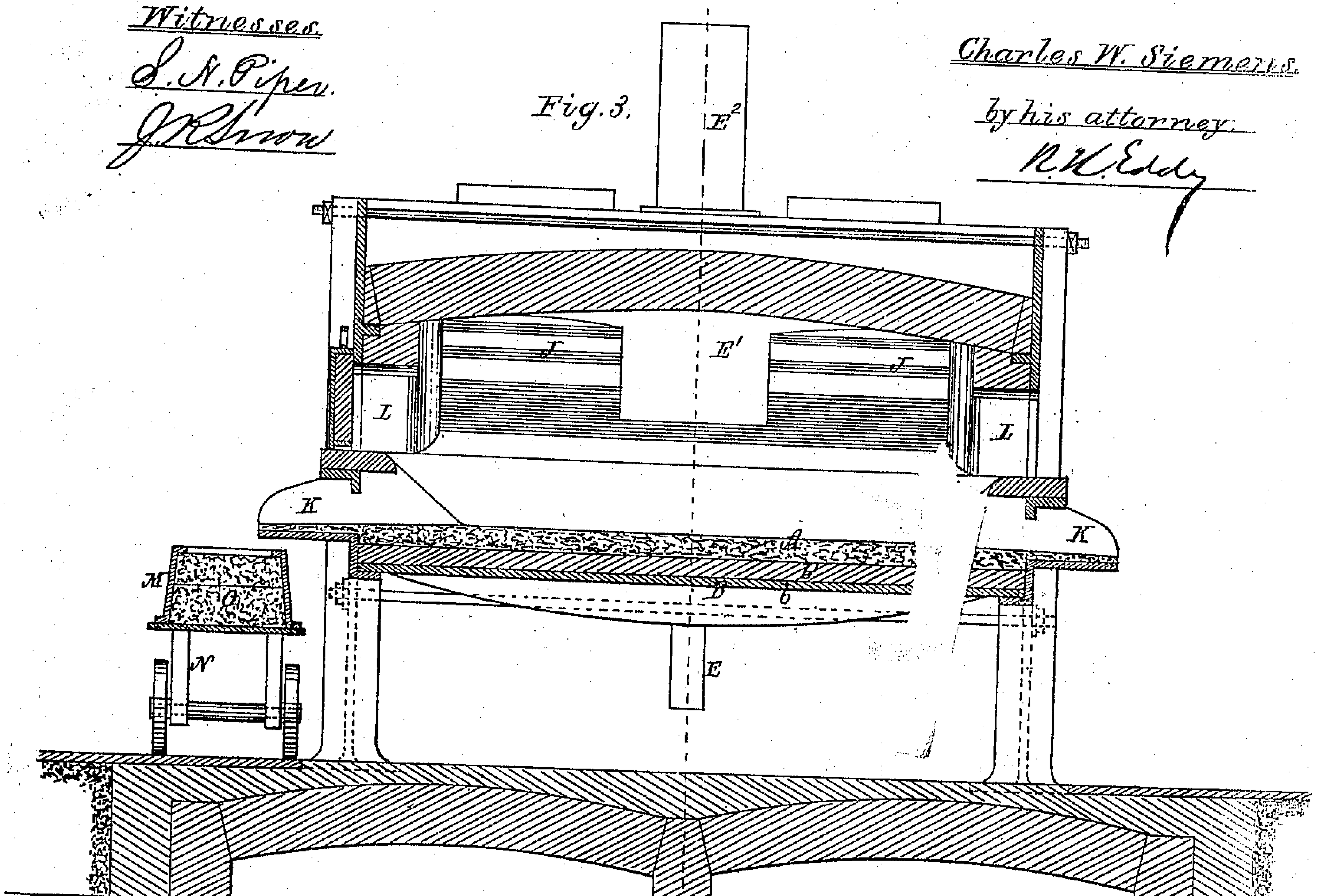
Fig. 3.



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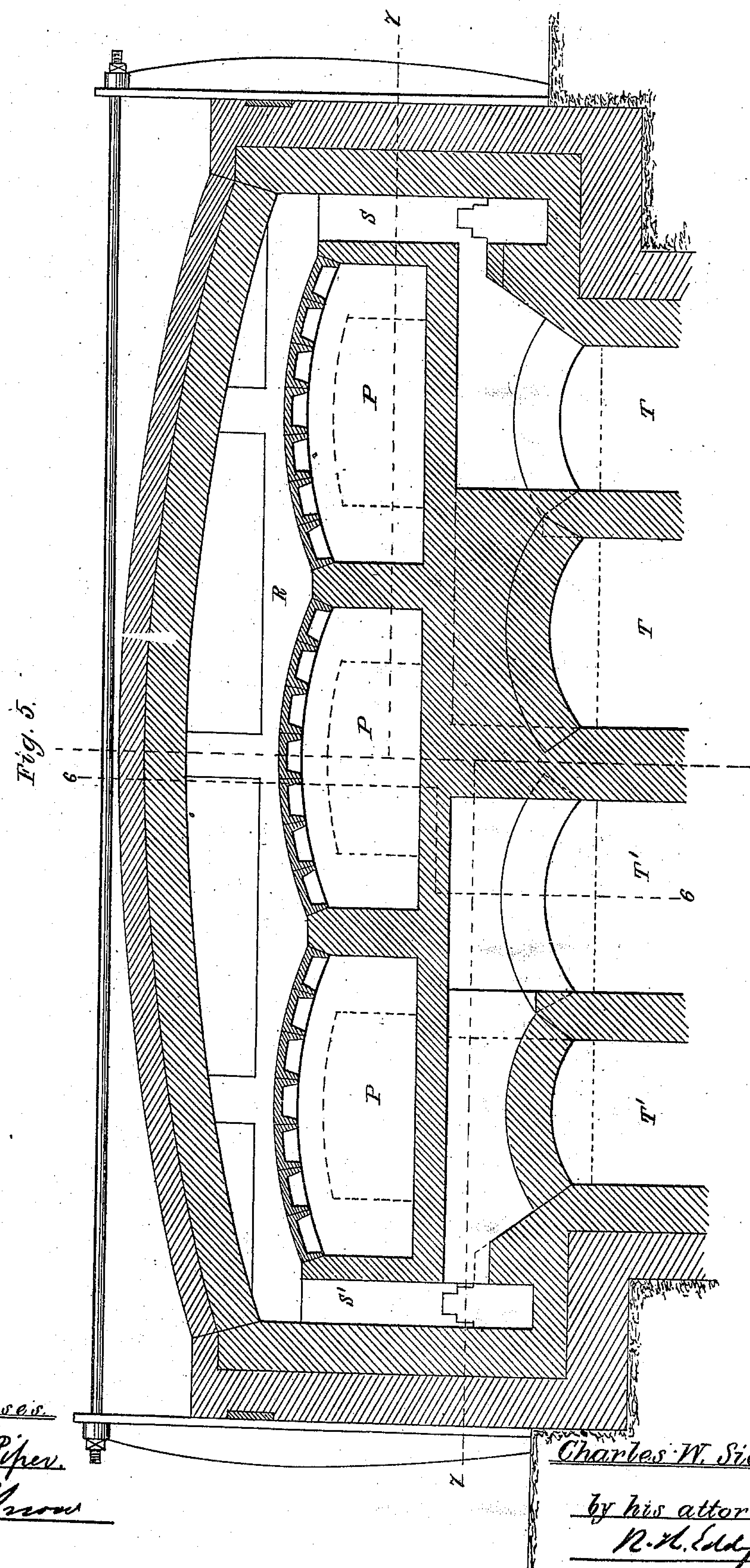

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Fig. 6. Sheet 4.

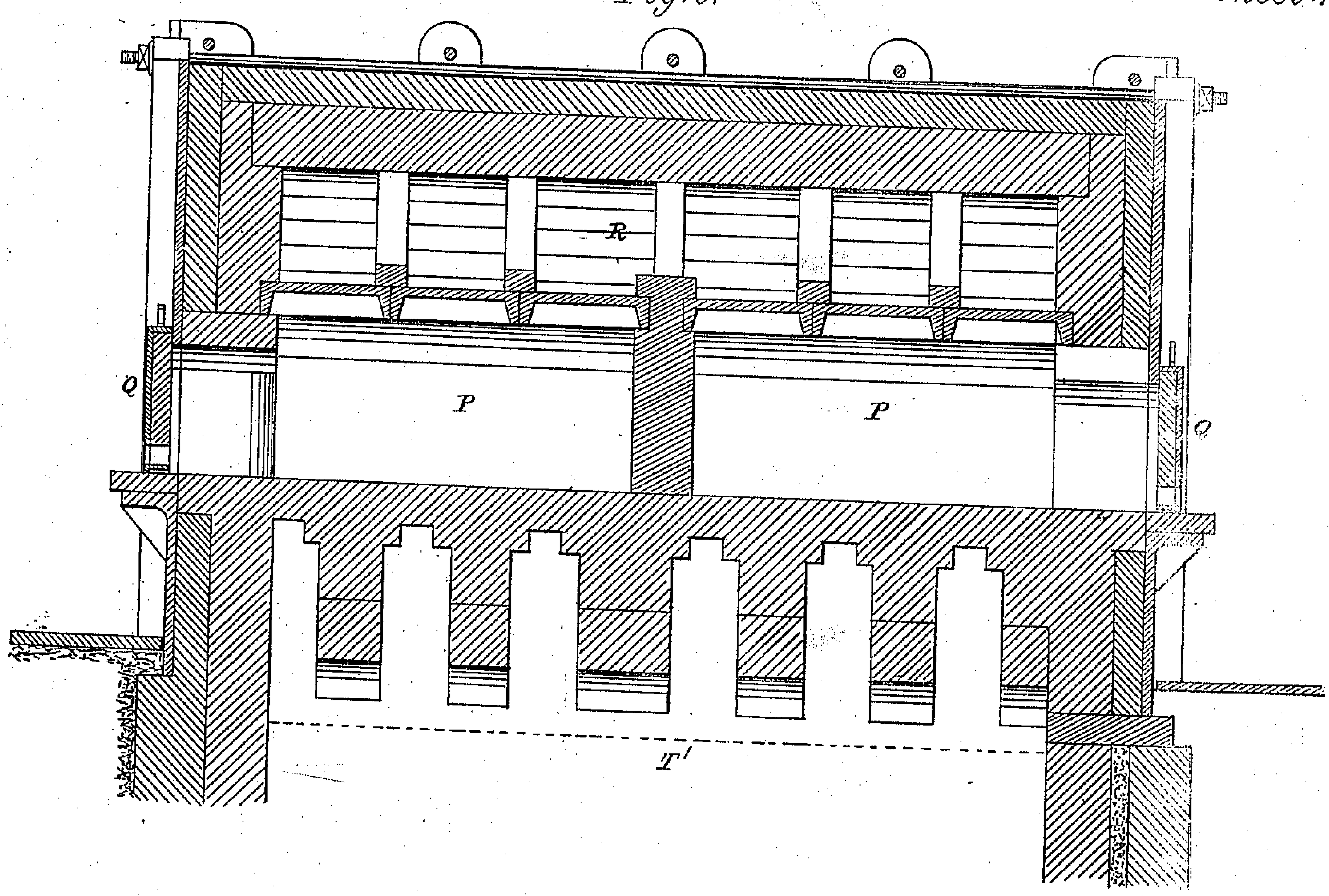
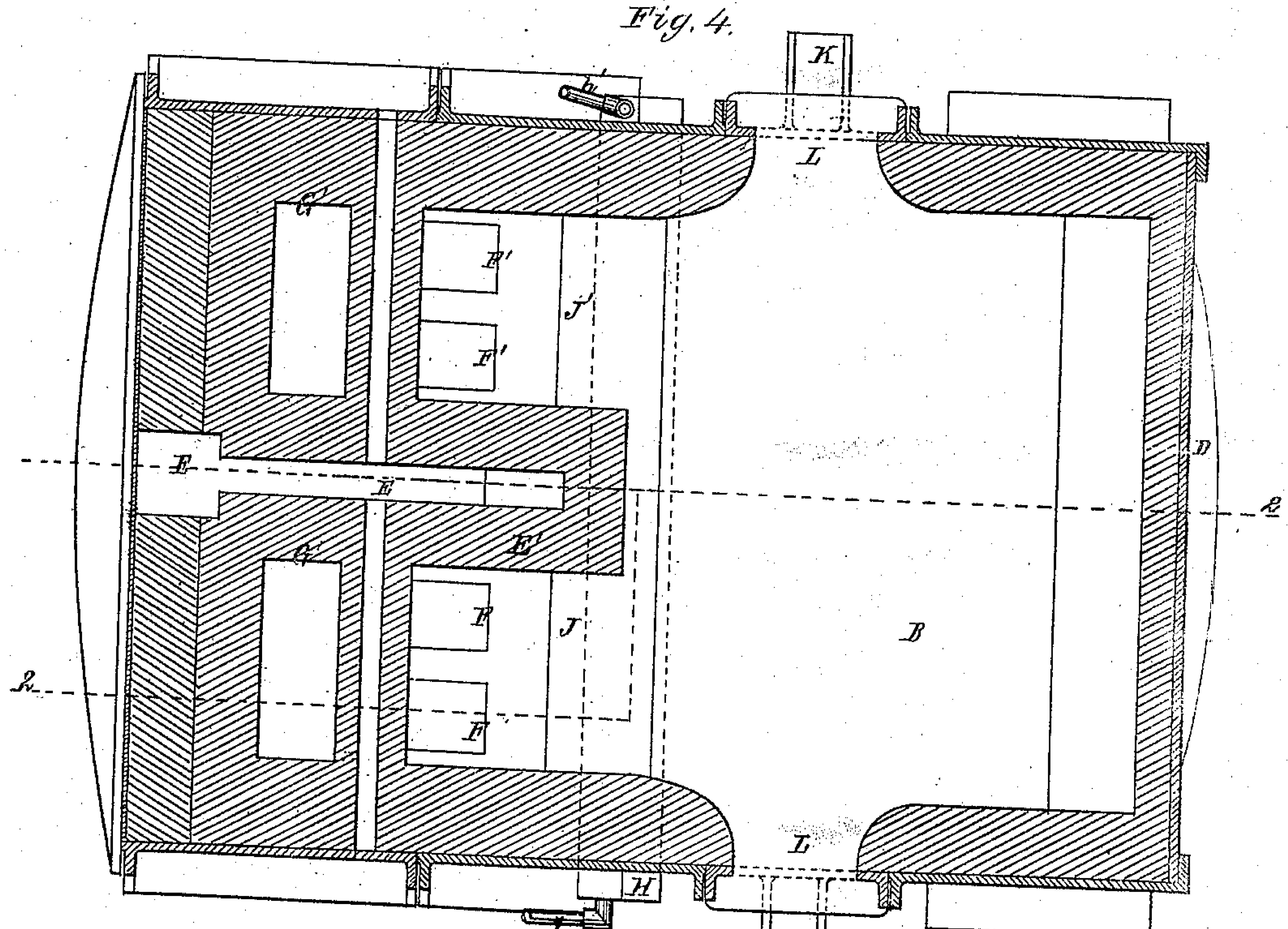


Fig. 4.



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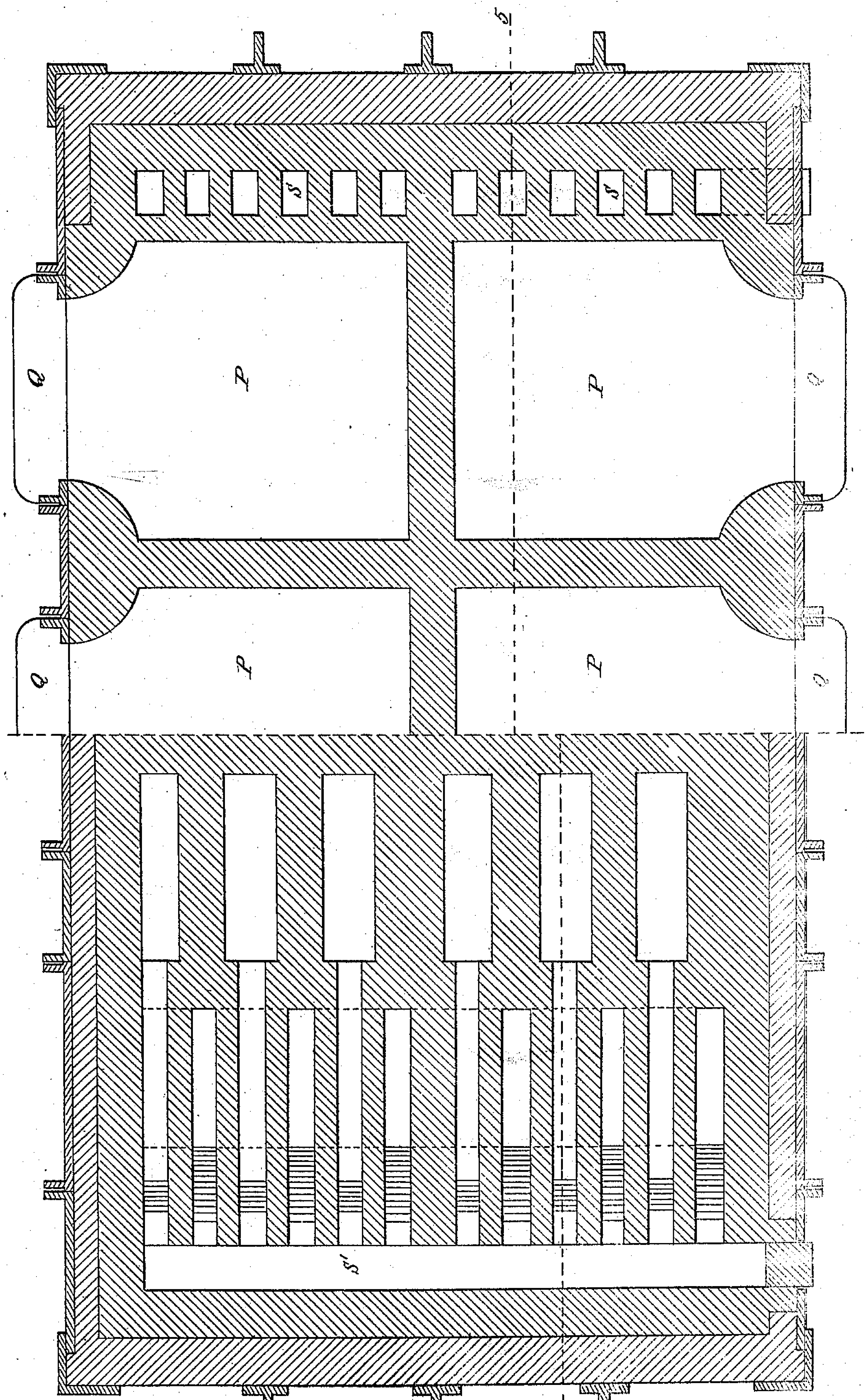
Sheet 5.

Fig. 7.



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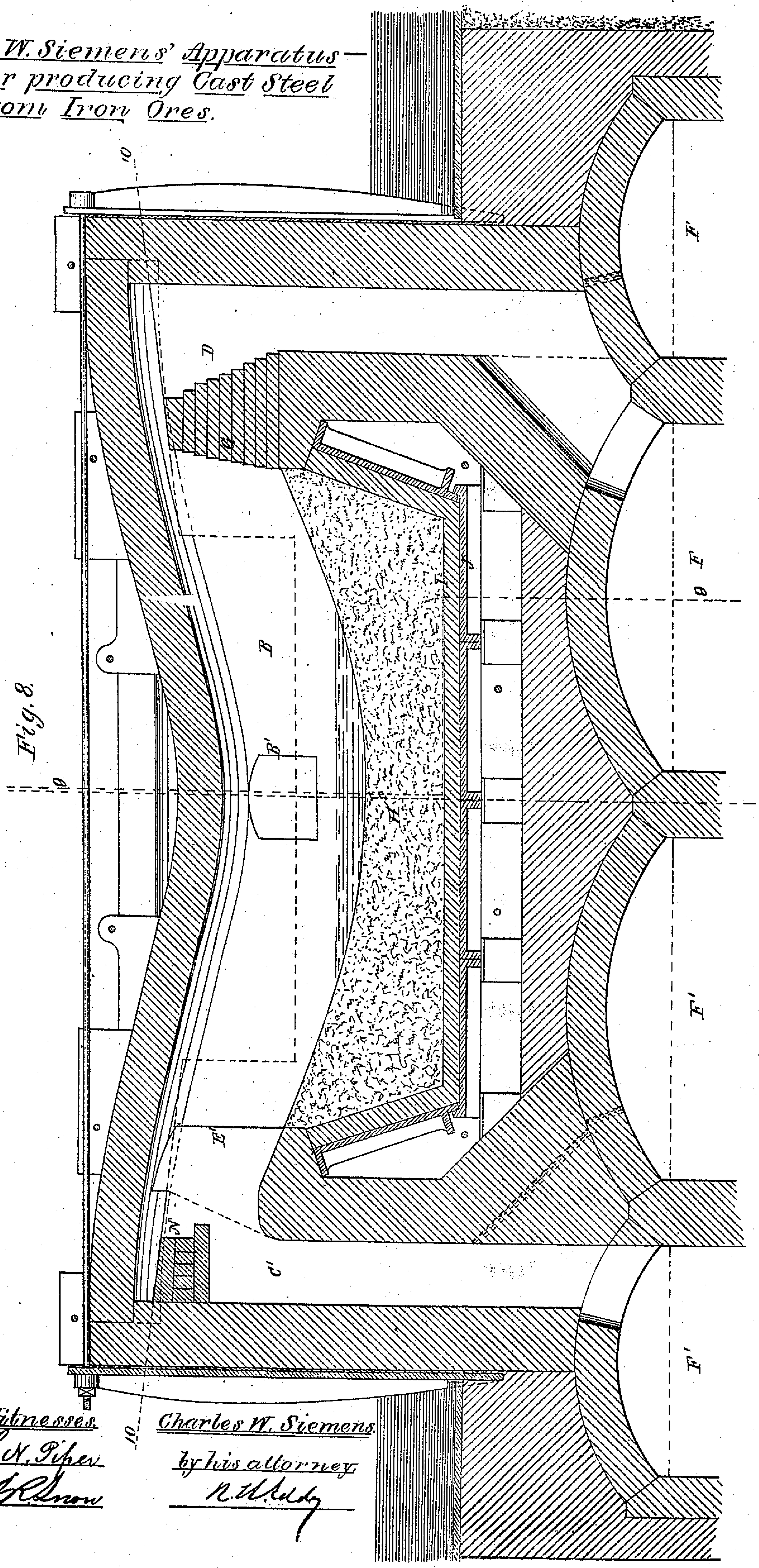

Fig. 8.

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Sheet 7.

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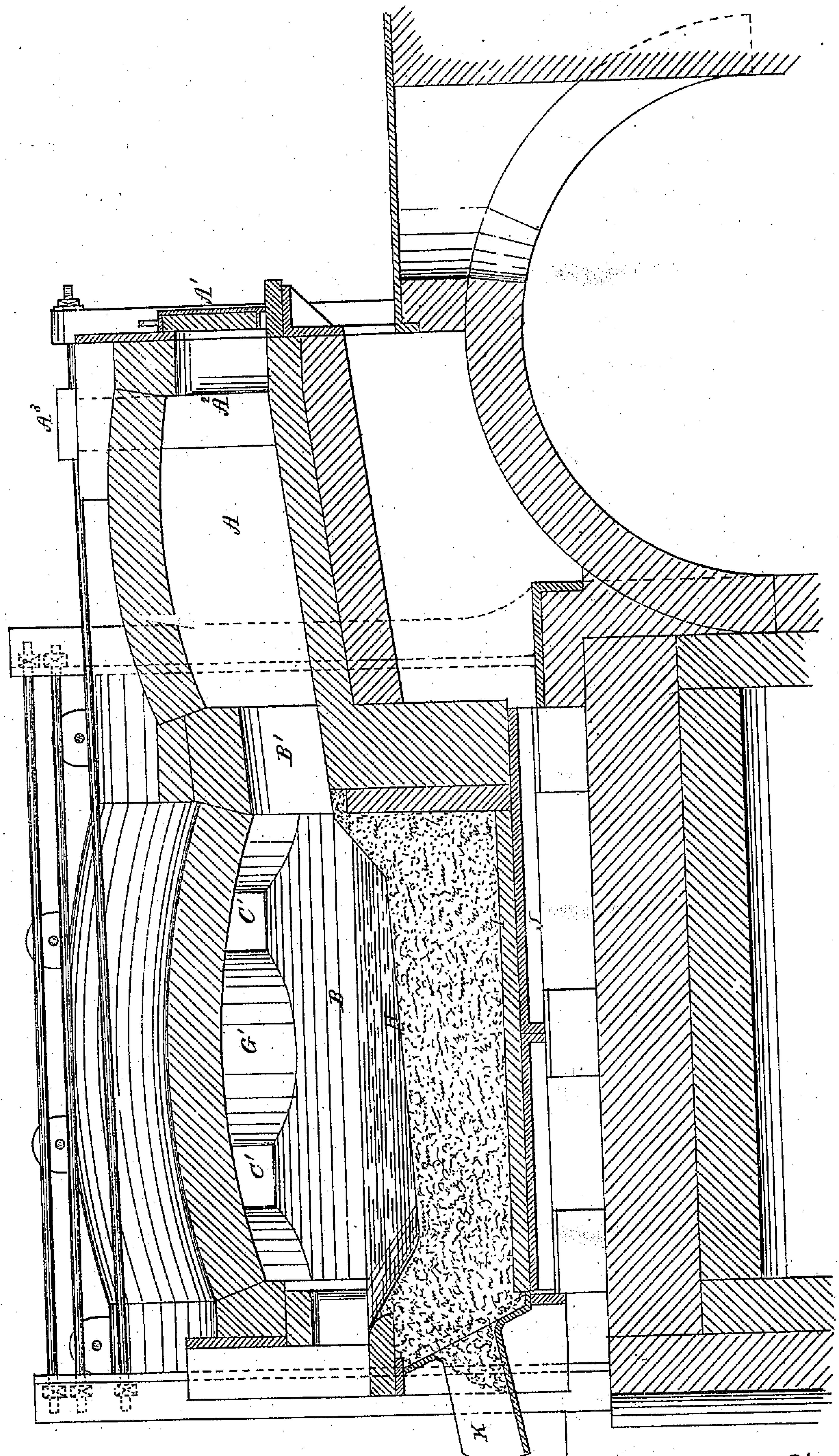
Fig. 9.



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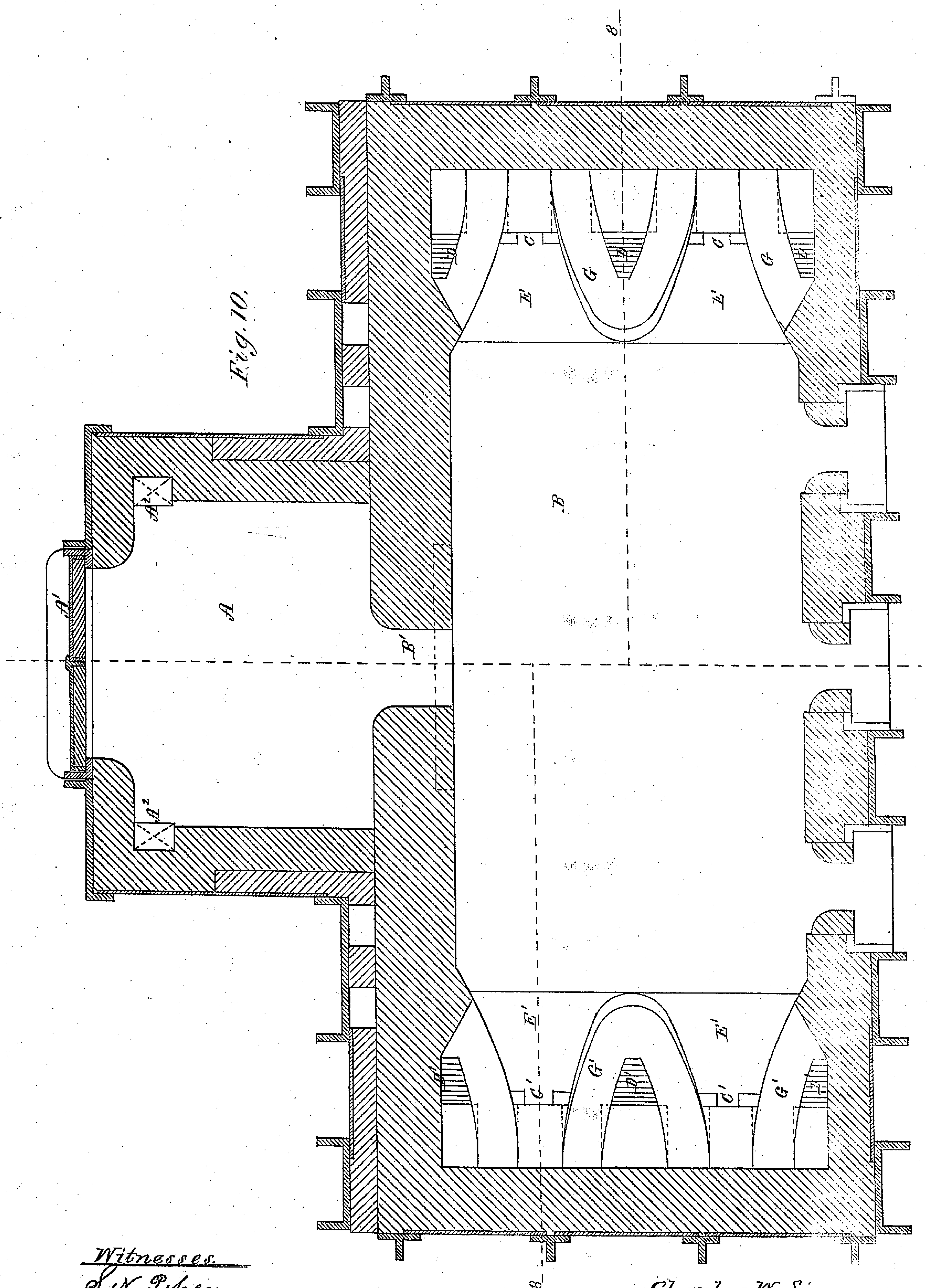
Sheet 8.

Fig. 10.



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Sheet 9.

Fig. 13.

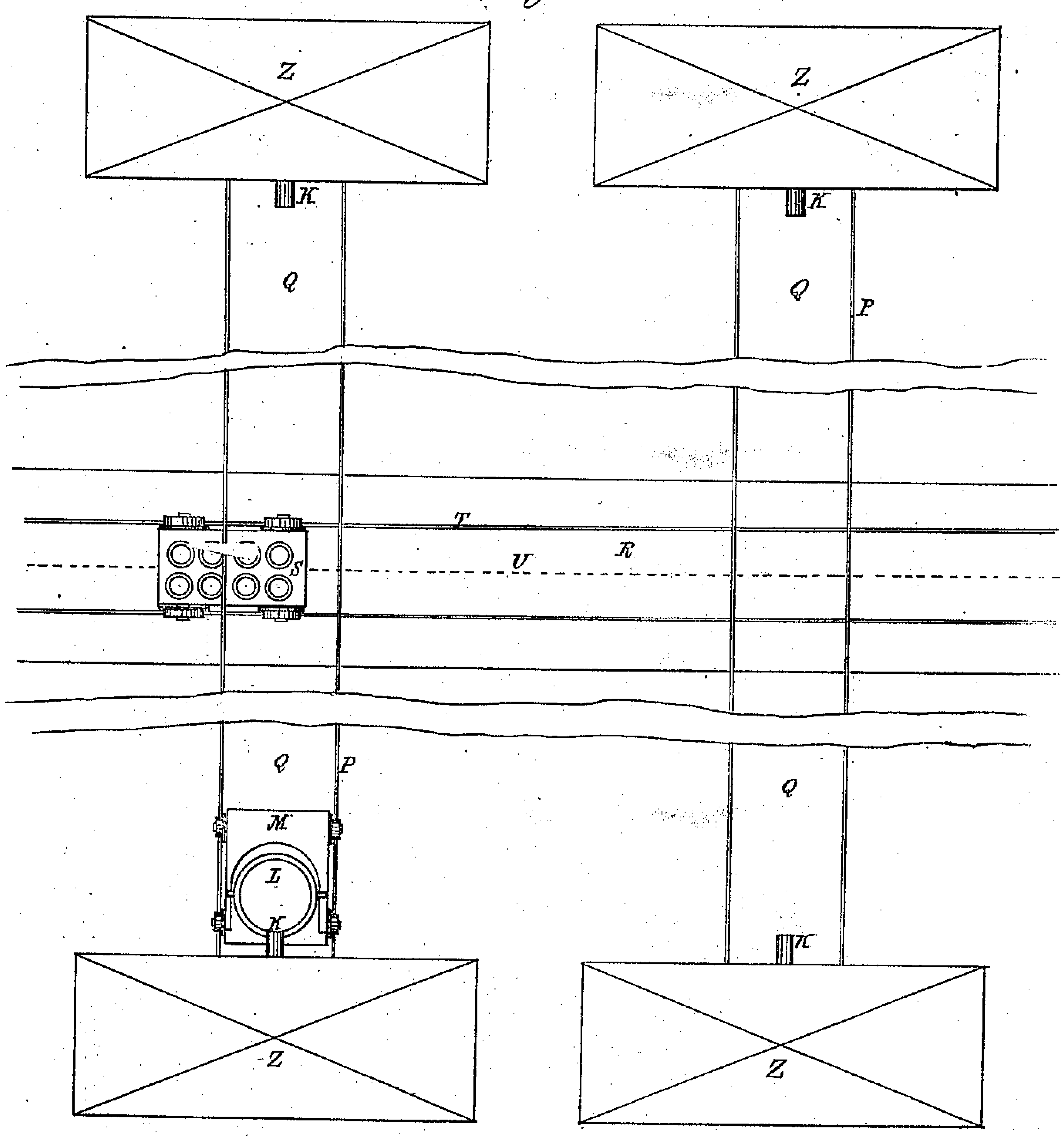


Fig. 11.

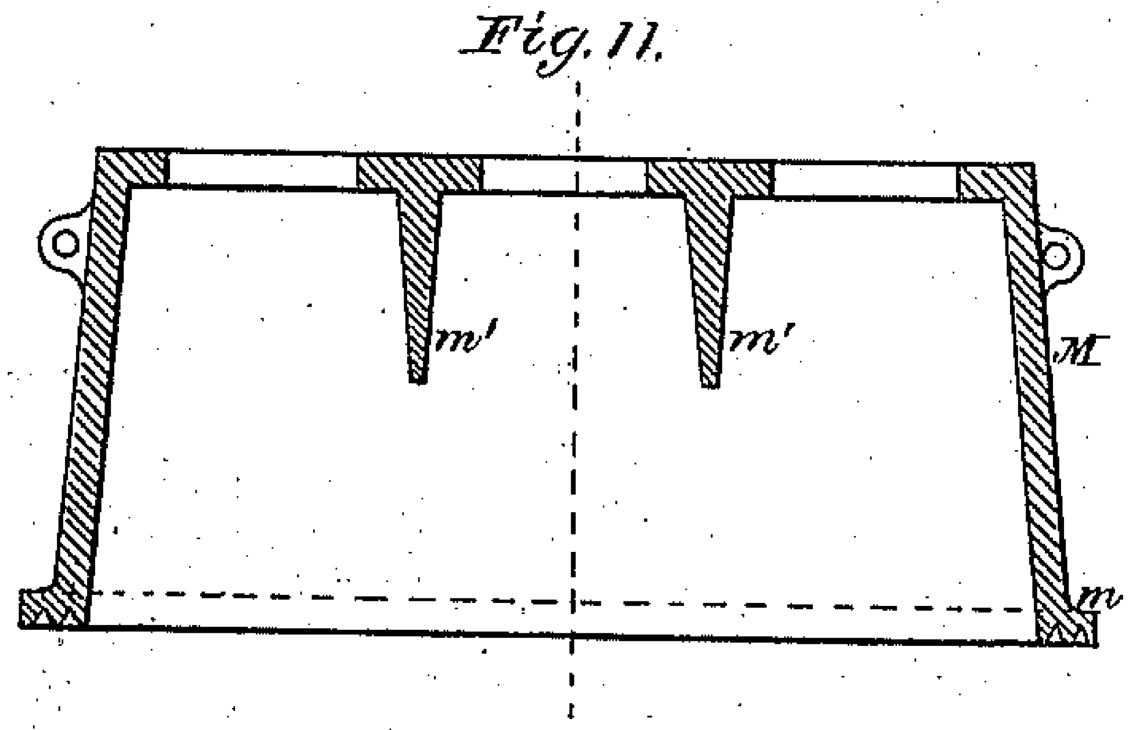
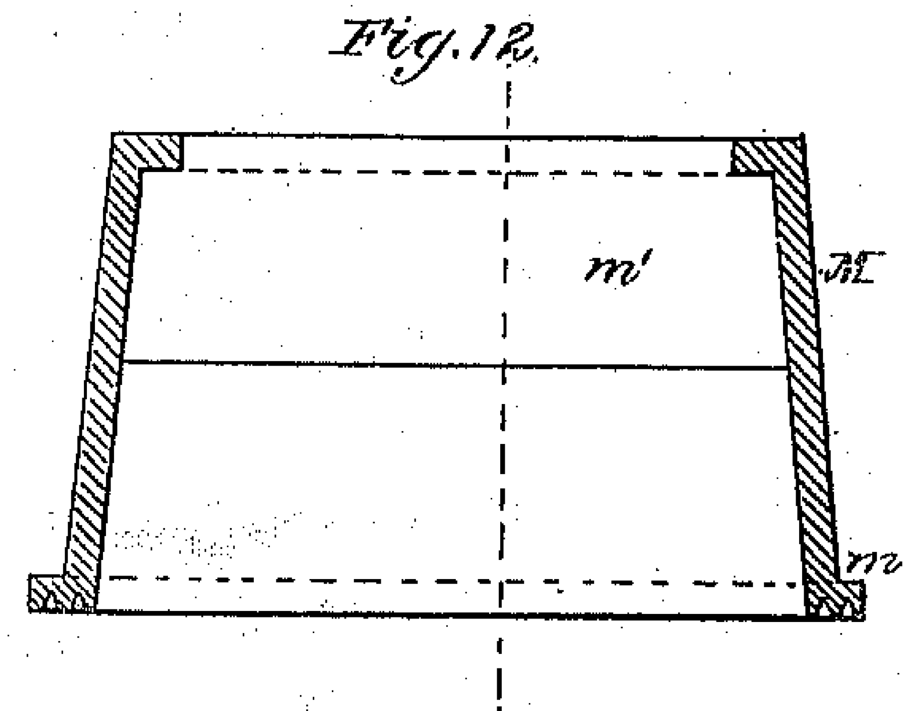


Fig. 12.



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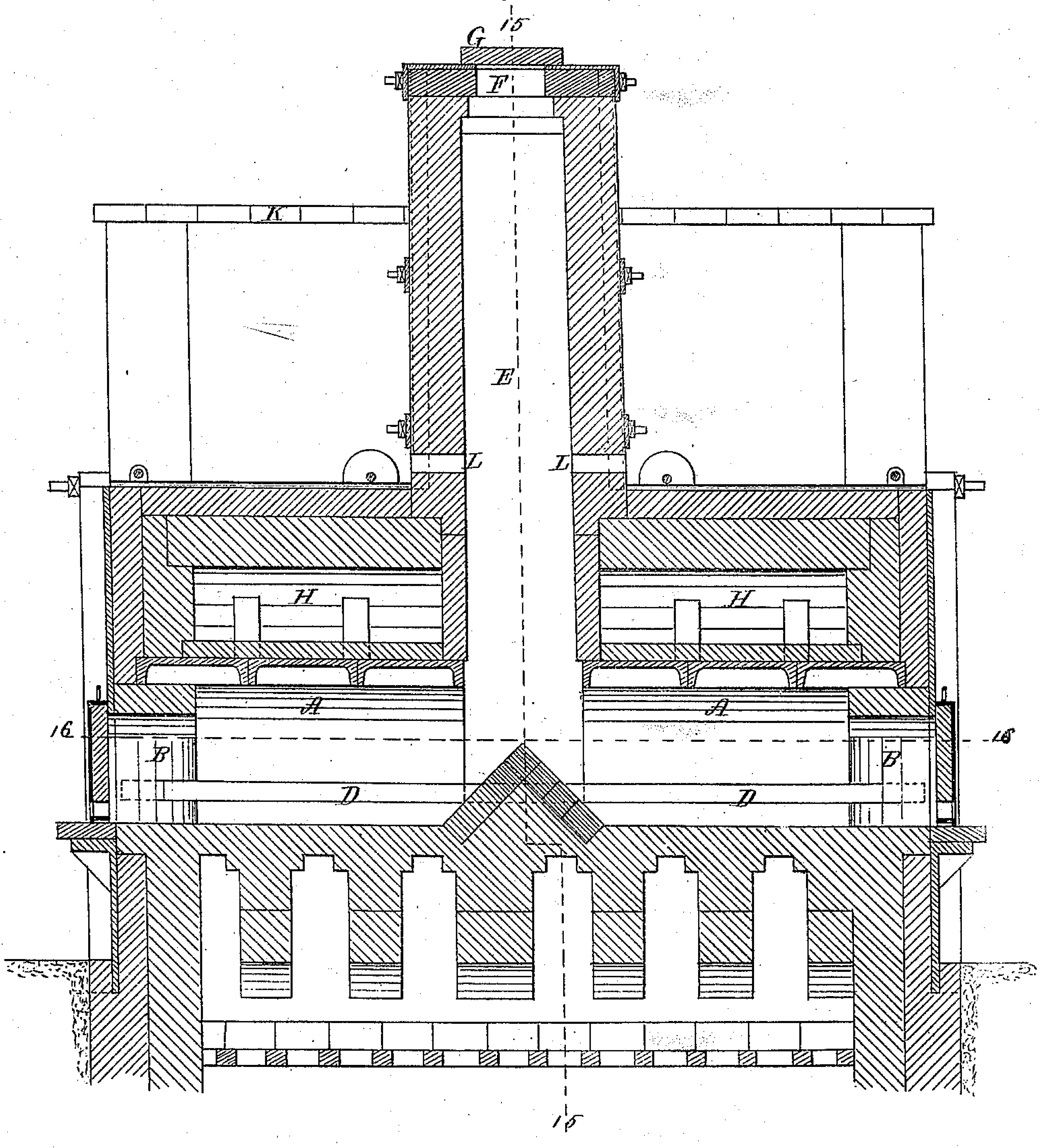
Sheet 10.

Fig. 14.



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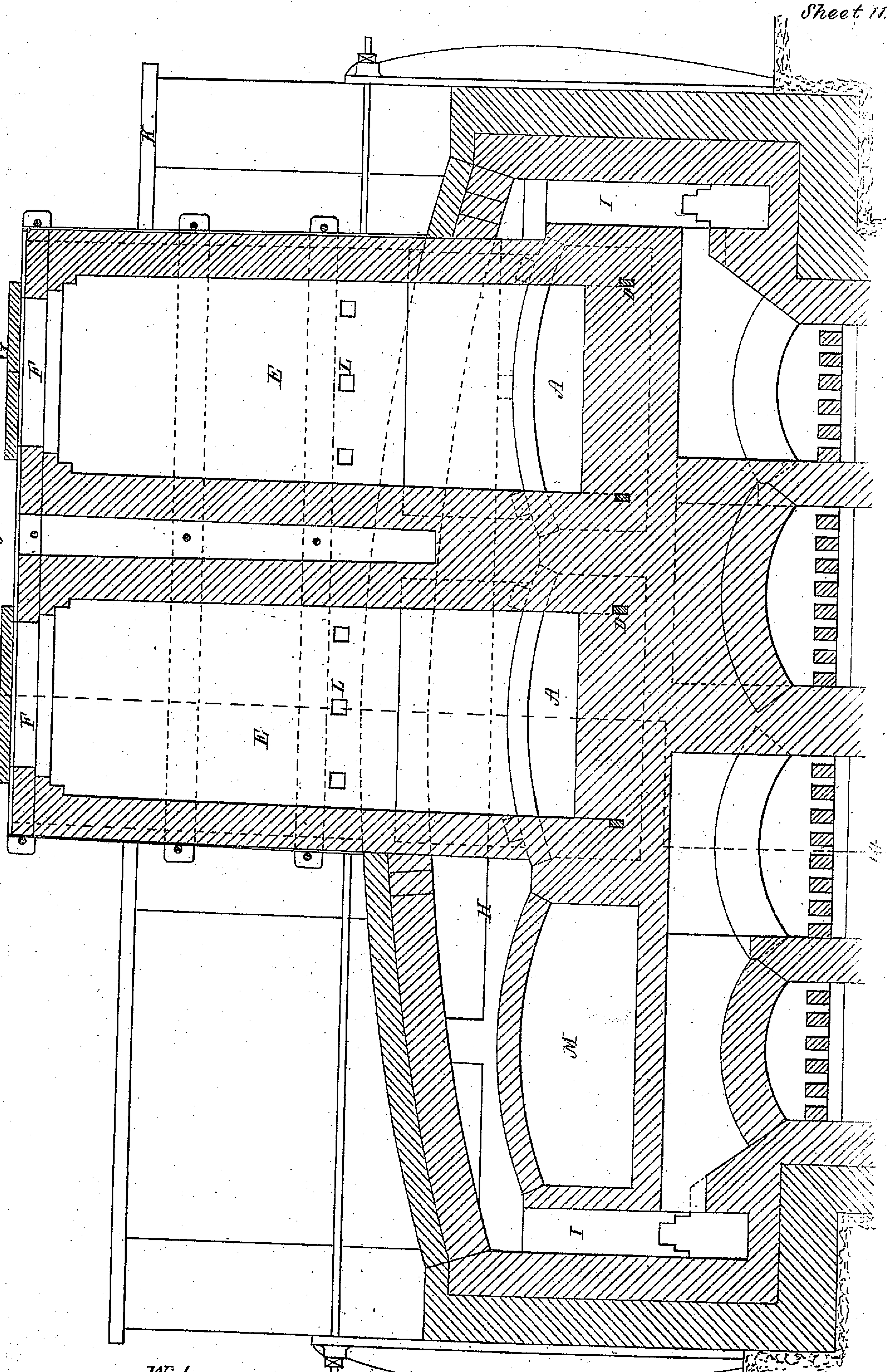

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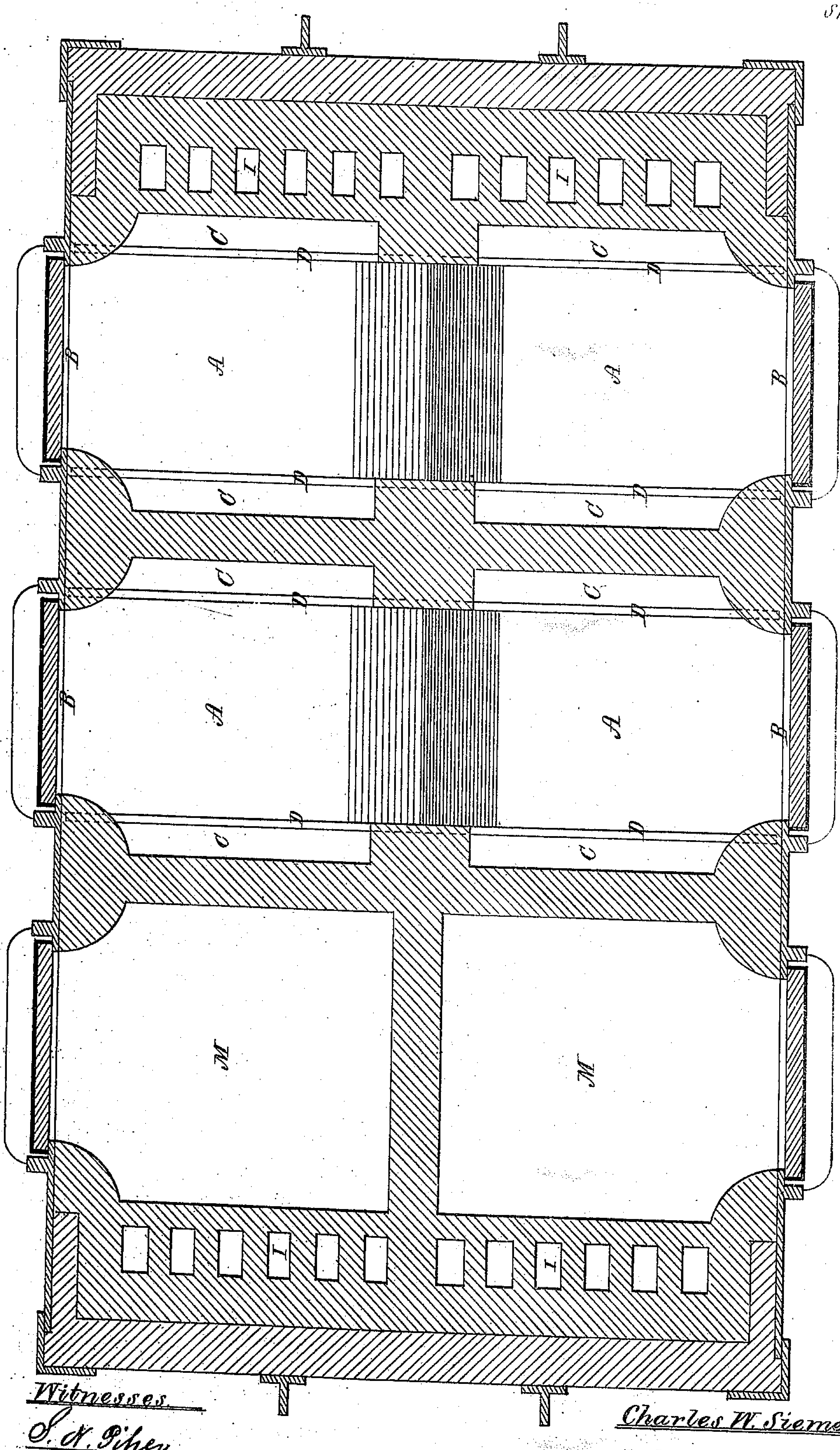
Fig. 16.



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UNITED STATES PATENT OFFICE.

CHARLES WILLIAM SIEMENS, OF WESTMINSTER, ENGLAND.

IMPROVEMENT IN PROCESSES AND APPARATUS FOR THE PRODUCTION OF CAST-STEEL FROM ORES.

Specification forming part of Letters Patent No. 113,584, dated April 11, 1871.

To all whom it may concern:

Be it known that I, CHARLES WILLIAM SIEMENS, of Westminister, in the county of Middlesex, England, civil engineer, member of the Royal Society, doctor of civil law, (Oxford,) have made a new and useful invention of Improvements in Treating Iron Ores, and in processes and apparatuses for the production of cast-steel where such ores are employed; and I, the said CHARLES WILLIAM SIEMENS, do hereby declare the nature of the said invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement thereof, reference being had to the accompanying drawings, and to the figures and letters marked thereon—that is to say:

In my British Patent of 1866, No. 2,413, I described a process and apparatus for the production of cast-steel directly from the ore, with or without the addition of pig-iron, and of ferro-manganese or spiegeleisen.

This process consisted, essentially, in effecting the reduction or deoxidation of the ore by the reaction upon it of carbonaceous matter under the influence of intense furnace heat, and in effecting the liquefaction of the reduced ore within the same furnace by the further addition of carbonaceous matter. It was found, however, in practice, that the deoxidation of the ore and the adjustment of the chemical condition of the metallic bath were attended with great difficulty under those circumstances; to remove which I subsequently separated the process of deoxidizing the ore from that of effecting its liquefaction and chemical adjustment by the introduction of vertical or other retorts, or of rotating muffles, as described in my British patents of the 21st of August, 1867, No. 2,395, and of the 10th of June, 1868, No. 1,892, respectively.

Nothwithstanding these improvements it was difficult to realize all the conditions necessary to insure a satisfactory result. The reduction of iron ore in close retorts or muffles is essentially a slow and expensive process, and the pulverulent iron produced thereby, upon being introduced into the melting-furnace, floats upon the metallic bath for a considerable length of time without being incorporated with it. Being exposed, in the meantime, to the oxidizing and sulphurizing action of the flame, the metallic oxide thus produced corrodes the banks of the metal bath, and, being a non-conductor of heat, causes the fluid metal below to set.

According to my present invention cast-steel is produced by the concerted action of two separate processes, the one serving to convert the raw ore into lumps or loaves of calcined, fluxed, and partially or wholly deoxidized material, and the other to smelt and convert this material, with or without the addition of pig metal into cast-steel of any desired temper.

The first or preparatory process may be carried out in several different ways. According to one method a furnace is employed (by preference a regenerative gas-furnace) resembling in form a copper-smelter's or large puddling-furnace, having charging-doors at the sides or in the roofs, and a door in front, for withdrawing the smelted material into pig beds or molds. This latter door, according to one arrangement, has its sill-plate on a level with the bed of the furnace, but has false sills or bricks placed upon it for retaining the fluid material in the furnace until the completion of the operation, when these false sills or the bricks are removed, and the semi-fluid contents of the furnace are raked forward into molds arranged in front of the furnace; or stoppered discharging-apertures may be formed below the ordinary doors of the furnace. The bed and sides of the furnace are made conveniently of aluminous bricks resting upon iron plates; but refractory iron ore, such as hematite, may be used with advantage in repairing the sides from time to time.

The chemical operation performed in this furnace, according to one arrangement, is as follows: The ore to be operated upon, which I will suppose to be hematite ore containing ten per cent. of silica, being crushed to the extent that no pieces exceed the size of walnuts or apples, is mixed with about five per cent. of crushed limestone, (or with other fluxing material,) and with about three per cent. of small coke or anthracite. A ton (or other quantity) of this batch being prepared, the furnace is heated to whiteness, and charged, first, with about one hundred-weight of light coke, such as gas-coke or charcoal spread uniformly over the bottom, whereupon the batch is introover the bed of the furnace. The furnace-doors are thereupon closed, and a good welding-heat is maintained for three or four hours. By the reaction, under the influence of heat, of the three per cent. of carbon mixed with the ore, the peroxide of iron of which it consists is converted into fusible magnetic oxide, while the silica which it contains combines with the limestone, forming a fusible slag. This action commences at the surface and extends downward until the layer of carbon is reached, when a further reaction upon the fluid ore (accompanied by ebullition) ensues, resulting in its partial deoxidation. Before the boiling has quite ceased the mass is stirred, and on the barrier on the sill of the tapping-door being removed the semi-fluid mass partially flows and is partially raked forward into the molds. Previous to discharging the furnace these molds should be charged, first, with a layer of débris of partially-reduced ore from previous operations, and, next, with hard carbonaceous matter, such as coke or charcoal, amounting to from five to ten per cent., by weight, of the ore charged into the furnace.

The fluid portion of the mass discharged from the furnace fills the interstices of the coke and débris, and binds the whole together into lumps or loaves, ready for use in the smelting furnace; but, owing to a reaction between the heated oxides or cinder and the imprisoned coke, a further deoxidation of the latter is effected within the molds, or within a heated chamber or hot-store furnace near the melting-furnace, to be presently described, where the loaves should be kept in a reducing-atmosphere until they are actually required. The process of deoxidation of these loaves may thus be carried to a greater or less degree of completion, according to the percentage of carbon employed, and according to the time of exposure to heat in a reducing-atmosphere.

If the available reducing agent is binding-coal, containing only a small percentage of sulphur, the operation of the preparatory furnace may be varied by mixing the crushed ore and flux with from twelve to sixteen per cent. of crushed coal, (according to the degree of deoxidation or carburization required,) and by charging this mixture into the furnace either continuously or in batches. If fed in continuously, as is preferred, the mixed ore and coal are charged through a hopper in a thick layer down the inclined side of the furnace, where the flames, in acting upon the surface of the layer, cause the reduction of the ore, which runs down in a more or less liquid condition onto the bed of the furnace, and from which it is removed from time to time into the molds, as before described.

If the ore is introduced in batches, the bed of the furnace is divided into compartments by putting flat iron or steel bars on edge, or by means of bricks or slabs of fire-clay put on edge. If iron or steel bars are used, the thickness of mixed ore charged should exceed the height of the bars, in order to cover them completely and save them from oxidation.

Heat being applied for several hours, the mixture will have formed into partially or wholly deoxidized lumps or loaves, which may be used in the melting-furnace instead of the lumps produced by fusion of the ores; or, the mode of producing these lumps may be varied by forcing the ore mixed with fluxing materials and binding-coal into molds, and by exposing the consolidated bricks or lumps to furnace-heat in a closed heated chamber or hot-store furnace, such as before mentioned, in order to effect the deoxidation of the ore.

According to another method, I produce lumps of reduced iron ore by placing masses of raw ore together with solid fuel into a closed hot-store muffle or kiln, heated externally, (the construction of which will be hereinafter described,) the solid fuel employed in such chamber being, by preference, placed in a separate compartment or compartments, by which means the carbonic-oxide gas generated in the first instance from the heated fuel is caused to react upon the heated lumps of ore, taking up oxygen from the same, while the carbonic-acid gas thus formed, in returning by a general circulation of the gases to the heap of solid fuel, takes up another equivalent of carbon, converting it back into carbonic oxide, which again attacks the ore, and this action continues until the ore is wholly reduced into metallic iron, (excepting its earthy constituents,) in which state it may then be charged into the steel-melting furnace. Such reduced masses of ore may also be employed for other purposes than for making steel in an open-hearth furnace.

The before-mentioned hot-store muffle or kiln is, by preference, so arranged as to effect the heating and calcining of the ore in a shaft, in connection therewith, preparatory to the introduction of the ore into the hot-store, as will be hereinafter described.

The steel-melting furnace employed is similar to the furnace described in my British Patent No. 1,892, of 1868, except that the air and gas are mixed differently, that the furnace bottom is prepared in a manner to be described hereinafter, and that the furnace is provided with a charging-chamber at the back. A steel-melting heat having been reached in this furnace, pig-metal is charged to form a metallic bath, when the loaves or lumps from the preparatory furnace or furnaces, before described, are introduced into the charging chamber, and are successively pushed forward into the melting-furnace, in order to become fused or incorporated with the metallic bath. The loaves, consisting partly of deoxidized iron and partly of oxides, will, by virtue of their gravity, sink to some extent below the surface of the liquid bath of the melting-furnace, and will cause an active ebullition, resulting from the reaction between the oxide and the carbon of the fluid metal, which ebullition, in causing intermixture, promotes the dissolution of the loaves and the decarburization of the liquid bath to the requisite degree. This degree is ascertained by taking samples of the metal from time to time, which, when chilled in water and broken with a hammer, should no longer break short, but should show considerable toughness, and a fractured surface of honeycombed and silky appearance.

Metal presenting this appearance contains from 0.1 to 0.15 per cent. of carbon, and in adding spiegeleisen to the bath the percentage of carbon may be increased to the extent required for producing the desired temper, while at the same time manganese is introduced, which is necessary to prevent red-shortness; or, in place of using spiegeleisen, the requisite carbon and manganese may be introduced in the form of lumps, made according to one of the methods hereinafter described.

Before adding the spiegeleisen either in the solid or liquid form, or the lumps of reduced ore containing manganese, it is necessary to stir the metallic bath well with an iron hook or rake, which operation is accompanied by an active or even violent ebullition. Care must also be taken that the cinder covering the metallic bath never exceeds one or two inches in thickness, that it is always liquid, and that it presents, when cooled and broken, a glossy light brown appearance.

If the slag should, during the operation of melting the loaves, accumulate to a greater thickness, it is removed by skimming or discharging it over the sill-plate of the front door of the furnace, which latter may be raised or lowered by placing upon it or removing the false sills, loose bricks, or iron packing-bars. If the cool and fractured slag presents a dark or crystalline appearance, time must be given for its clearance, which will be accelerated by stirring the bath. Should the metal become too soft before the slag is sufficiently clean, it is necessary to add small quantities of pig-iron. The ladle skulls and scrap from previous meltings may also be reintroduced into the furnace before the spiegeleisen is added, or pulverulent iron, produced by other processes, may be introduced in addition to the loaves hereinafter described. The process may be varied between wide limits, according to the relative abundance and quality of the materials used. If pig metal, of sufficient purity from sulphur and phosphorus, can be had in abundance, and rich or pure ore is scarce or expensive, it will be advantageous to deoxidize the ore only partially in the preparatory furnace, in order that it may retain the power of decarburizing two or three times its own weight of pig metal in the melting-furnace, whereas if rich ore (which may be hematite or spathic ore or clay, ironstone, or a mixture of several) is cheap, as compared with hematite or other good descriptions of pig metal, the deoxidation of the ore should be carried further in the preparatory process, by adding a larger proportion of carbon in the preparatory furnace or in the molds. Although the use of pig metal in forming the primary bath in the melting-furnace, and the use of spiegeleisen in completing the operation, are extremely convenient, where those metals of a suitable quality can be obtained at a reasonable cost, yet both or either of these may be entirely dispensed with. In this case three descriptions of lumps or loaves of deoxidized ore should be used, the first containing a considerable excess of carbon beyond what is necessary for its mere reduction, the second being of the nature and proportions before described, and the third being again a highly-carburized compound of the ores of iron and manganese, which may be made according to one of the following methods: Ore rich in manganese, titanium, or other oxidizable metal, intended to be incorporated with the bath, may be reduced in lumps in proximity to solid carbonaceous matter in hot-store furnaces heated to a considerable degree, or may be crushed and well mixed with crushed dry clay, and binding-coal free from sulphur, in the proportions of about one hundred parts, by weight, of ore, twenty-five parts of coal, and ten parts of clay. This compound is then sprinkled with water, and mixed till it barely binds in the hand, after which it is filled into molds and consolidated by pressure, as before described, with reference to ordinary iron-ore. These lumps or bricks are stacked in a hot place (over a furnace) for, say, two days, and are then charged into the before-mentioned heated chamber or hot-store furnace, where they are kept for twenty-four hours or more, and whence they are taken in a hot state to be charged into the bath of the steel-melting furnace, toward the end of the operation. In working solely with these deoxidized and carburized ores, the bed of the melting-furnace is first covered with a layer of coke, charcoal, or anthracite, upon which the highly-carburized loaves first mentioned are charged in a heated condition, which in melting will form a metallic bath covered with cinder, and form a foundation for the after operation.

Instead of using any hematite ores in these processes, I prefer to mix the same with argillaceous or spathic ore in such proportions that the gangue of both ores forms a fusible slag, whereby the use of lime is avoided. Titanic iron-sand may also be used with advantage. The success of this process depends greatly upon the foundation of a sound furnace bottom in the melting-furnace. Sand, or a mixture of sands, has hitherto been mostly employed to form such bottoms, but these frequently melt or rise in large masses to the surface of the metal bath, in which case the thickness of the slag is greatly increased, and the metal frequently "sets" in the deepened bottom of the furnace.

These difficulties are, in a great measure, avoided by forming the furnace bottom in the following manner: Pure silicious sand is oba great measure avoided by forming the furnace-bottom in the following manner:

Pure silicious sand is obtained, which is baked, in order to destroy any organic matter that may be mixed with it, and is passed through a sieve, in order to separate lumps or foreign matter. If the sand contains iron or lime it is first of all washed with muriatic or other acid. One hundred parts of this purified dry sand are mixed intimately with about three per cent. of fine glass powder by passing both together through a sieve, and the mixture is put aside for use.

In making a new bottom, the iron-plated furnace-bottom is first covered with bricks, and the heat of the furnace is raised to whiteness. A layer of the dry mixture of sand and glass powder is thereupon spread over the brick bottom to the thickness of about two inches, after which time is allowed until the surface has commenced to harden, in consequence of the particles of glass melting, and thus binding adjacent particles of the white sand together without being sufficient in quantity to fuse them. Another and somewhat thinner layer of the dry powder is next applied, and the heat is raised, so as to produce a more complete fusion of the glass powder, and consequently a greater degree of hardness and cohesion of the mass. A still thinner layer of the mixture is then applied, and this process is repeated until a bottom of the requisite form and thickness is obtained. The furnace-doors are thereupon thrown open, and the admission of gas and air from the regenerators is reduced, in order to allow the bottom to set hard, when it is ready for receiving its charge of pig metal and reduced ore. The same method of charging the dry mixture is resorted to for mending the bottom between the charges.

The melting-furnace which I employ is, as before stated, similar to those I have described in some of my former British patents; but I improve the arrangement for mixing the heated combustible gases and the heated air arising from the regenerators by raising the vertical air-ports very nearly to the roof of the furnace, and by bringing the side walls of the flues forward toward the heated chamber in a convergent manner until they meet. By this arrangement the gas is introduced into the heated chamber below the air through channels increasing in width toward the furnace, where it is met by the air passing in in diverse directions, effecting its thorough combustion while traversing the heated chamber, the uncombined air being at the same time prevented from coming into contact with the metal in the bed of the furnace.

In arranging steel-works I place several melting-furnaces side by side, with their fronts or tapping-holes facing the foundry; or I place two such rows opposite to each other, with the foundry between them. From each center of the furnace or tapping-hole a trench extends at right angles to the line of furnaces into a wider and deeper trench, running through the middle of the foundry, parallel with the line of furnaces.

A line of rails is laid upon the edges of the cross-trenches, and across the central trench, upon girders, which line of rails carries the ladle-carriages, by which a ladle, when suitably lined and heated, may be drawn close up to the tapping-hole to receive a charge of steel, and be moved by a wheel and pinion or other agency over the central trench. A line of rails at the bottom of this latter carries trucks, upon which the molds to receive the fluid metal are arranged. These mold-trucks may be conveniently moved to and fro by an endless traveling chain passing over pulleys at the bottom of the pit, and being actuated by means of a small winding-engine fitted with reversing-gear. By opening the stopper in the bottom of the ladle these molds are filled, and the truck upon which they are mounted is moved out of the foundry to a crane, or into an annealing-stove, if the castings are not to be hammered or rolled. By this general arrangement the preparation of the molds and the removal of the cast ingots or castings is greatly facilitated.

Having thus described the nature of my invention, and in what manner the same is to be performed, I will now proceed more particularly to describe the arrangement of furnaces which I prefer to employ for carrying out the before-described processes, for which purpose I shall refer to the accompanying drawings.

Figure 1 shows sectional elevations, respectively, of the preparatory furnace at X, for preparing the lumps or loaves, as before described, and the heated chamber or hot-store furnace at Y, for maintaining the lumps or loaves in a heated reducing-atmosphere until required for conversion in the steel-melting furnace at Z. The construction of each of these furnaces is shown more clearly to an enlarged scale in Figs. 2 to 10. Fig. 2 shows a longitudinal section of the preparatory furnace on line 2 2, Fig. 4. Fig. 3 shows a transverse section of the same on line 3 3, Fig. 2; and Fig. 4 shows a sectional plan on line 4 4, Fig. 2.

In this furnace the crushed ore A A, mixed with the requisite percentage of flux and carbonaceous matter, as before described, is fed continuously onto the bed B through the hopper C, into which it is charged from trucks W, running on rails, as shown at Fig. 1. The ore is caused to pass gradually from the hopper in a thick layer down the inclined side D of the furnace, situated opposite the gas and air ports, which are all placed on one and the same side of the furnace, in a similar manner to arrangements already patented by me both in England and in the United States. The bed B and inclined side D of the furnace are constructed of strong metal plates *b d*, covered with fire-brick *b′ d′*, the plates being entirely open to the air, so as to be kept cool;

purpose below the bed by the formation of a chimney-flue, E, passing through the partition-wall E^1 between the two sets of gas and air passages F G F′ G′, and communicating with a chimney, E^2, above the furnace, as shown. The bed of the furnace is inclosed on the inner side by means of a water-bridge or box, H, through which cold water is made to circulate by means of the pipes *h h′*, Fig. 4, in order to keep the bridge of the furnace cool. The combustible gas and air rise from the regenerators below the furnace respectively through, say, the passages F and G, the air-passage G being raised somewhat above the gas-passage F, as shown, and in entering into combustion in the passage J the resulting flames are caused to impinge in a downward direction upon the layer A of mixed ore, coal, and fluxing material. After acting upon this compound the products of combustion escape through the passages J′, F′, and G′ into the other set of regenerators, in a manner well understood. The heat thus produced in the furnace effects the before-described partial reduction and fusion of a portion of the ore.

When a sufficient quantity of ore has thus been acted upon, the more or less liquid mass is stirred up by means of tools introduced through the side doors L L, after which one or both of the side apertures K, below the doors L, are opened by removing the ore or slag with which they are closed up, as shown in Fig. 1, and the liquid mass is raked out through them into the boxes or molds M, brought up to the spouts of the apertures upon the trucks N.

The construction of these molds is shown in enlarged longitudinal and transverse sections at Figs. 11 and 12. They are open at top and bottom, and are made to rest with the grooved flange *m* upon a layer of sand, clay, or carbon upon the table of the truck N. Before filling them with the partially-converted ore, they receive layers of débris of partially-reduced ore, and of coke or charcoal, as before described. The fluid portion of the ore, on flowing into the molds, fills the interstices and binds the whole together into lumps or loaves O. When the mass has solidified, it is removed from the mold, the ribs *m m′* of which form deep grooves in the loaves O, as indicated at Fig. 1, in order that the whole mass may be more uniformly acted upon in the subsequent processes. These loaves are then removed to the reducing oven or muffle at Y, Fig. 1, the construction of which is shown, to an enlarged scale, at Figs. 5 to 7. Fig. 5 shows a longitudinal section on line 5 5, Fig. 7. Fig. 6 shows a transverse section on line 6 6, Fig. 5, and Fig. 7 shows a sectional plan on line 7 7, Fig. 5.

This furnace consists of a series of inclosed chambers, P P P, accessible through doors Q Q, which chambers are contained within the furnace R, in which a full red-heat is maintained by the combustion of air and gas passing in through the passages S S′ at the one end or the other from the regenerators T T T′, in the usual manner. The tops of the chambers P are formed, by preference, of hollow fire-bricks, as shown, in order that the heat of the furnace may be readily transmitted to the interior of the chambers. Into these chambers the lumps or loaves of partially-converted ore mixed with carbon, or the consolidated and unconverted lumps of ore mixed with carbon and fluxing materials, as before described, are introduced and maintained at a full red-heat in a reducing-atmosphere, so as to promote their reduction, for which purpose either solid or gaseous carbonaceous matter may be introduced into the chambers. In either case the chambers are entirely inclosed so as to exclude any sulphurous gases arising from the combustion taking place in the surrounding furnace. As the lumps or loaves are required for use they are removed from the heated chambers or hot-store furnace and carried to the steel-melting furnace at Z, Fig. 1.

Figs. 14, 15, and 16 show my before-mentioned hot-store furnace, muffle, or kiln, for reducing the lumps of ore entirely by means of carbonaceous gases, according to the last process hereinbefore described. Fig. 14 shows a transverse section through the hot-store on line 14 14, Fig. 15. Fig. 15 shows a longitudinal section on line 15 15, Fig. 14, and Fig. 16 shows a part sectional plan on line 16 16, Fig. 14.

The reducing muffle or kiln is here shown constructed in duplicate, the two separate muffles being employed either for reducing one and the same kind of ore, or two different kinds of ore, as hereinafter explained.

The muffle consists of a chamber, A, of fire-brick, with a discharging-opening, B B, at each end, which, when the muffle is in operation, are effectually closed against the entrance of air. On each side of the chamber A separate spaces C C are formed, by means of longitudinal bars D D, which spaces are provided to receive the carbonaceous materials serving to act upon the ore, and which are charged into such spaces through the doors B. The ore is introduced into the central part of the chamber A through the vertical shafts E, which are charged from a staging, K, through the opening F at the top, provided with a slide, G. The chambers A are inclosed in the furnace H—by preference a regenerative gas-furnace, as shown—into which the heated gas and air rise through the passages I I, communicating with the regenerators below, arranged and operating as ordinary regenerative gas-furnaces.

The operation of these reducing-muffles is as follows: Assuming the chambers A to be charged with ore and carbonaceous matter, as described, and heated externally by the flames in the furnace H, carbonic-oxide gas is first generated from the fuel in the spaces imperfect combustion with the air contained in the chambers. This carbonic-oxide gas passes among the heated lumps of ore, and, in taking up oxygen therefrom, is converted into carbonic-acid gas, which again passes to the fuel, where, taking up another equivalent of carbon, it is converted into carbonic oxide, which again attacks the ore; and this action continues until the charge of ore has become entirely reduced. This reduction takes place very thoroughly and at a quick rate, inasmuch as the circulating carbonic-oxide gas is virtually free from nitrogen, which latter retards the operation of reduction in ordinary kilns or blast-furnaces. While this operation is going on the excess of carbonic oxide gas generated in the chambers A rises in a heated condition into the charging-shafts E E, filled with raw ore. In these shafts are formed air-holes L L, so that, as the gas rises, it is brought in contact with jets of atmospheric air entering through these holes, and consequently enters into combustion therewith, the gaseous products of this combustion being allowed to escape at the top by partially opening the slide G. By this means the ore, in gradually descending in the vertical shaft, becomes more and more heated, and is thus deprived of its volatile constituents, including water and sulphur, until it reaches the air-holes L, whence downward it passes, through a gaseous reducing-atmosphere, into the heated chamber A.

If necessary, the heat in the shaft E may be further increased, either by the admission of combustible gases, separately generated, or by mixing solid fuel with the ore charged in at the top, or by heating the shaft externally. The solid fuel employed in the reducing-chambers A might also (but not so advantageously) be mixed with the ore.

The construction of these hoppers and hot-stores may be materially modified. Thus the hoppers may be inclined, and, instead of being in the middle of the hot-chambers, may be placed at one end, and may, moreover, be arranged in form to resemble a kiln, with a staging and valve arrangement at the top, onto which the ore is lifted in the usual manner.

When the reduction of the ore in the chambers A has been completed, the doors at B B are opened, and the charge is drawn out into scoops on wheels or pivots, to be introduced into the steel melting furnace, or to be employed for other purposes. A fresh charge of calcined and partially-reduced ore then descends into the chambers A from the shaft E, which is filled up from time to time with raw ore at the top.

As before stated, the two or more separate chambers may with advantage be charged with ores of different descriptions. Thus, if three reducing-chambers are provided, and the one is charged with hematite, the second with spathic ore, and the third with clay ironstone, it will be possible to use so much of the reduced ore from the one and the other that the earthy matters contained in them form a fusible slag in the steel-melting furnace, and render the use of separate fluxing materials unnecessary; or the masses of reduced ore may be charged conjointly with lumps produced by fusion of ores with lime or other fluxing material, as hereinbefore described, which lumps or loaves may conveniently be contained in the hot-store M at the side of the reducing-muffles, as shown at Fig. 15; or these reduced masses may be used together with metallic lumps produced in any other way. In working upon only one description of ore the solid lumps may be picked out and reduced by the process above described, whereas the small ore may be consolidated and mixed with the necessary fluxing agents by the methods previously described.

The construction of the steel-melting furnace is shown to an enlarged scale at Figs. 8 to 10. Fig. 8 shows a longitudinal section on line 8 8, Fig. 10. Fig. 9 shows a transverse section on line 9 9, Fig. 8; and Fig. 10 shows a sectional plan on line 10 10, Fig. 8. This furnace is mainly of the same construction as those previously described by me in the specifications to my former patents. The principal difference consists, first, in the addition thereto of the heating-chamber A, for the reception of the lumps or loaves of more or less converted ore before introduction into the melting-chamber B of the furnace; and, secondly, in the peculiar construction of the combustible gas and air passages C D C′ D′, for effecting the mixture of the heated combustible gases and air rising up from the regenerators F F F′ F′. The air-passages D D′ are raised very nearly to the roof of the furnace, while the gas-passages C C′ open into the chamber B at a considerably lower point, as shown at Fig. 8, and the side walls G G′ of the air-flues are brought forward toward the chamber B in a converging manner until they meet, as shown at Fig. 10, thus forming widening passages E E′ for the gas to issue through, the gases, on their ascent, being deflected and directed into such widening passages by means of the slabs N, fixed over the vertical passages C C′, while the air is caused to enter the furnace in diverse directions, above the combustible gases, so that these gases, in rising, become thoroughly mixed with the air, and thus their complete combustion is effected, while any uncombined air, in remaining at the roof of the furnace, is prevented from coming into contact with the metal on the bed H of this furnace. This bed is formed of pure silicious sand, prepared and mixed with glass powder, and then laid in layers upon the fire-brick lining I of the iron bed J, in the manner as fully hereinbefore described.

The iron bed J is open to the surrounding air, in order to cool the same, as in former constructions of my furnaces.

For tapping off the bath of steel when ready for use, a hole is formed in the sand bottom by the introduction of a tool through the spout the bath of steel when ready for use, a hole is formed in the sand bottom by the introduction of a tool through the spout K, through which hole and spout the steel then flows off into the ladle L on the carriage M, shown in Fig. 1. The deoxidized and carbonized loaves O, having been introduced into the charging-chamber A, through the door A^1, are there heated to the requisite degree by the radiated heat or by flame from the melting-chamber, a portion of such flame or hot gases being caused to enter the chamber A through the aperture B′, and to circulate through the same by means of the chimneys A^2, the tops of which are provided with slabs A^3 for regulating the draft. When sufficiently heated, the loaves are successively pushed forward through the aperture B′, into the bath of molten metal in the chamber B, where they are melted, and the process of preparing the bath is carried on in the manner hereinbefore described. A charge of molten steel having been received from the furnace in the ladle L, the carriage M is run upon the rails P, either over a mold-carriage running upon rails in a longitudinal trench, as hereinbefore described, or the ladle is conveyed to wherever required.

Fig. 13 shows a plan of the before-mentioned arrangement of steel-melting furnaces with transverse and longitudinal trenches and tramways. Z Z are the furnaces, arranged in two opposite rows, from the discharging-spouts K of which rails P P, laid along the sides of transverse trenches Q Q, extend toward and across a longitudinal trench, R, so that the ladle-trucks L M can be run over the latter. In the longitudinal trench is the mold-carriage S, moved along upon the rails T, either by a chain, U, driven by an engine, or by any other suitable means. A charge of liquid steel having been run into the ladle L, the carriage M is moved over the trench R, and the mold-carriage S is run underneath it, so as to enable the metal to be discharged from the ladle into the molds. These are then conveyed by the carriage to wherever required.

Having thus described the nature of my invention, and the best means I am acquainted with for carrying the same into practice, I wish it to be understood that what I claim is—

1. Producing cast-steel by first converting ferruginous ore into lumps or loaves of partially or wholly reduced metal, either with or without admixture of fluxing materials, and by then charging these lumps in a heated condition into an open-hearth steel-melting furnace, to be there liquefied by being brought into contact with a bath of cast-iron or with other carbonaceous matter, substantially as hereinbefore described.

2. The method of reducing masses of iron ore, whereby the ore is subjected to the action of carbonic-oxide gas, generated from carbonaceous materials contained with the ore inside a close chamber heated externally, while the resulting carbonic-acid gas is again converted into carbonic oxide by contact with the heated fuel, substantially as set forth.

3. Preparing loaves of wholly or partially reduced iron ore, by melting the ore or mixture of ores with fluxing materials in contact with carbon, and by charging this fluid mass into molds containing coke, charcoal, or other solid carbonaceous matter, which loaves are thereupon maintained for some hours at a full red-heat in a reducing-atmosphere within a heated chamber or hot-store furnace before they are charged into the steel-melting furnace, substantially as described.

4. Preparing loaves similar to those aforesaid by crushing the ore, by mixing it intimately with fluxing materials and with binding-coal, by forcing or placing the mixture into molds, and exposing the same for a considerable number of hours to a full red-heat in a closed heated chamber or hot-store furnace, substantially as described.

5. Preparing loaves similar to those aforesaid from ores rich in manganese, or other equivalent easily-oxidizable metal, together with an excess of carbon, to be charged into the fluid bath of the steel-melting furnace toward the end of each operation, in order to impart those metals to the bath, substantially as described.

6. Constructing hot-store furnaces, muffles, or kilns for reducing iron ore, wherein the ore is contained together with carbonaceous materials inside a closed chamber or chambers situated inside a regenerative gas furnace or other furnace, substantially as described.

7. Constructing hot-store furnaces, muffles, or kilns for calcining or reducing iron ore, wherein the ore, in the form of lumps, is caused to descend through a vertical or inclined shaft onto the bed of a close chamber heated externally, in which chamber carbonaceous materials are placed, the excess of carbonaceous gases being caused to rise through the vertical shaft, where they are made to enter into combustion with atmospheric air introduced through side apertures, so as to effect the calcination of the descending ore, substantially as hereinbefore described with reference to Figs. 14, 15, and 16 of the drawings.

8. Arranging in hot-store reducing-furnaces, as described in the sixth and seventh claims, a separate receptacle or receptacles for the carbonaceous materials, so as to bring the ore only in contact with the carbonaceous gases generated from such carbonaceous materials, substantially as described.

9. Constructing the steel-melting furnace with a charging-chamber, through which a portion of the hot gaseous products of combustion can be made to circulate, into which the aforesaid lumps, as well as the pig metal or other materials to be used, are introduced, to be thence pushed forward in a heated condition into the melting-chamber, substantially

10. Constructing the bed of the steel-melting furnace of a mixture of pure silicious sand with glass powder, substantially as hereinbefore described.

11. Constructing the air and gas ports of a steel melting furnace in such manner that the vertical air-ports rise nearly to the roof of the furnace, while the side walls of the flues are extended forward in a convergent manner until they meet, in order that the air may issue into the furnace in diverse directions above the combustible gas, substantially as hereinbefore described with reference to Figs. 8 to 10 of the accompanying drawings.

12. Arranging one or more rows of steel-melting furnaces with their tapping-holes facing a longitudinal trench, with lateral trenches leading to each of the furnaces, upon the edges of or over which trenches rails are fixed, crossing the main trench, ladle-carriages being arranged to run over the lateral trenches, in order that the fluid metal may be discharged into molds carried upon rails in the central trench, facilitating their preparation and removal, as hereinbefore described.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses this 23d day of December, 1870.

C. WILLIAM SIEMENS.

Witnesses:
L. CROWE,
EDWD. W. PACE.