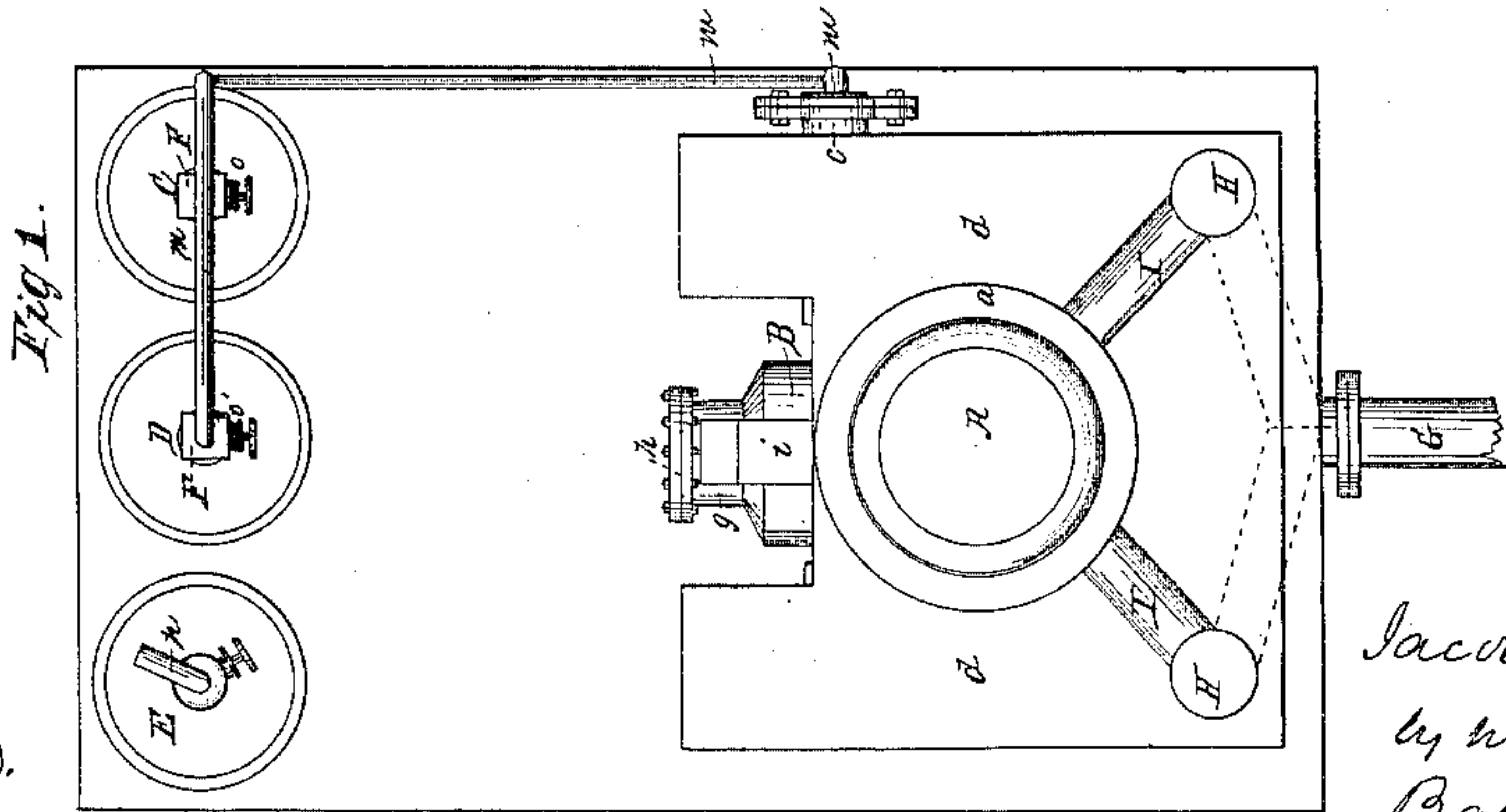
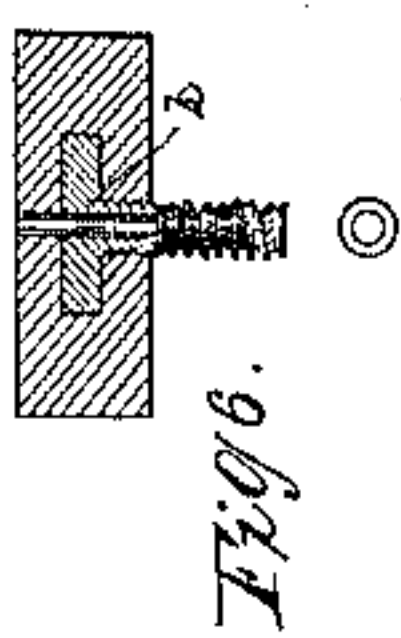
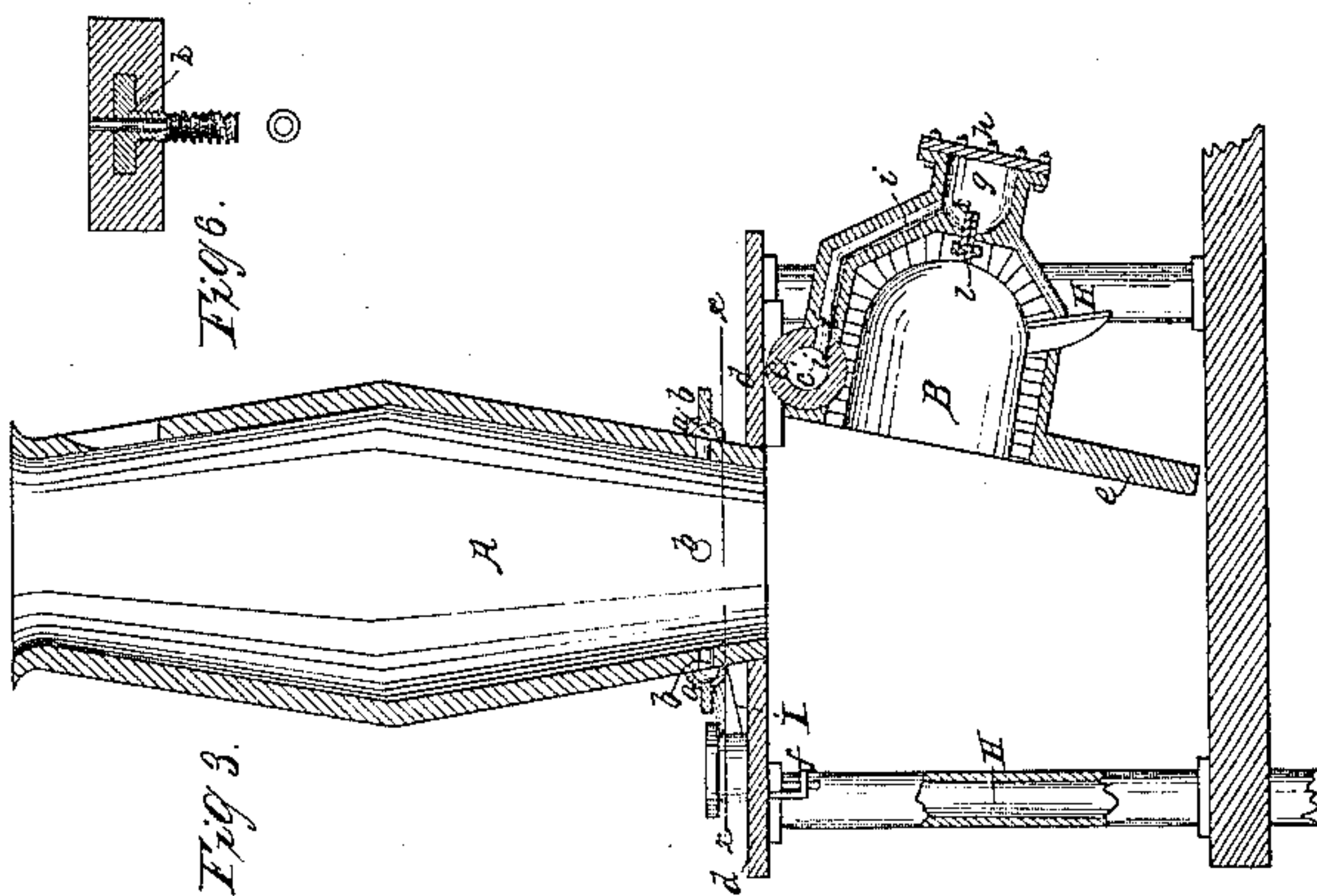
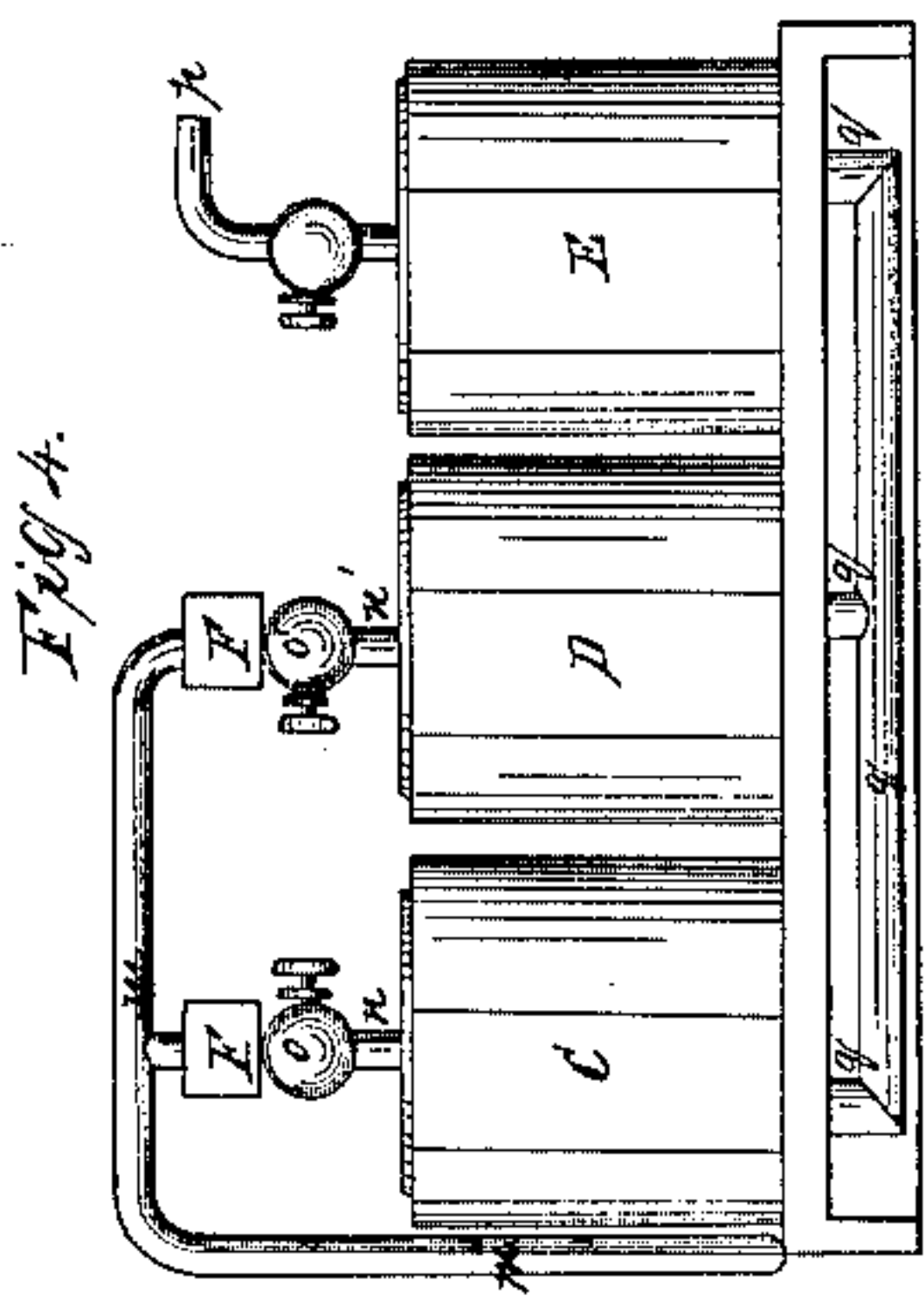
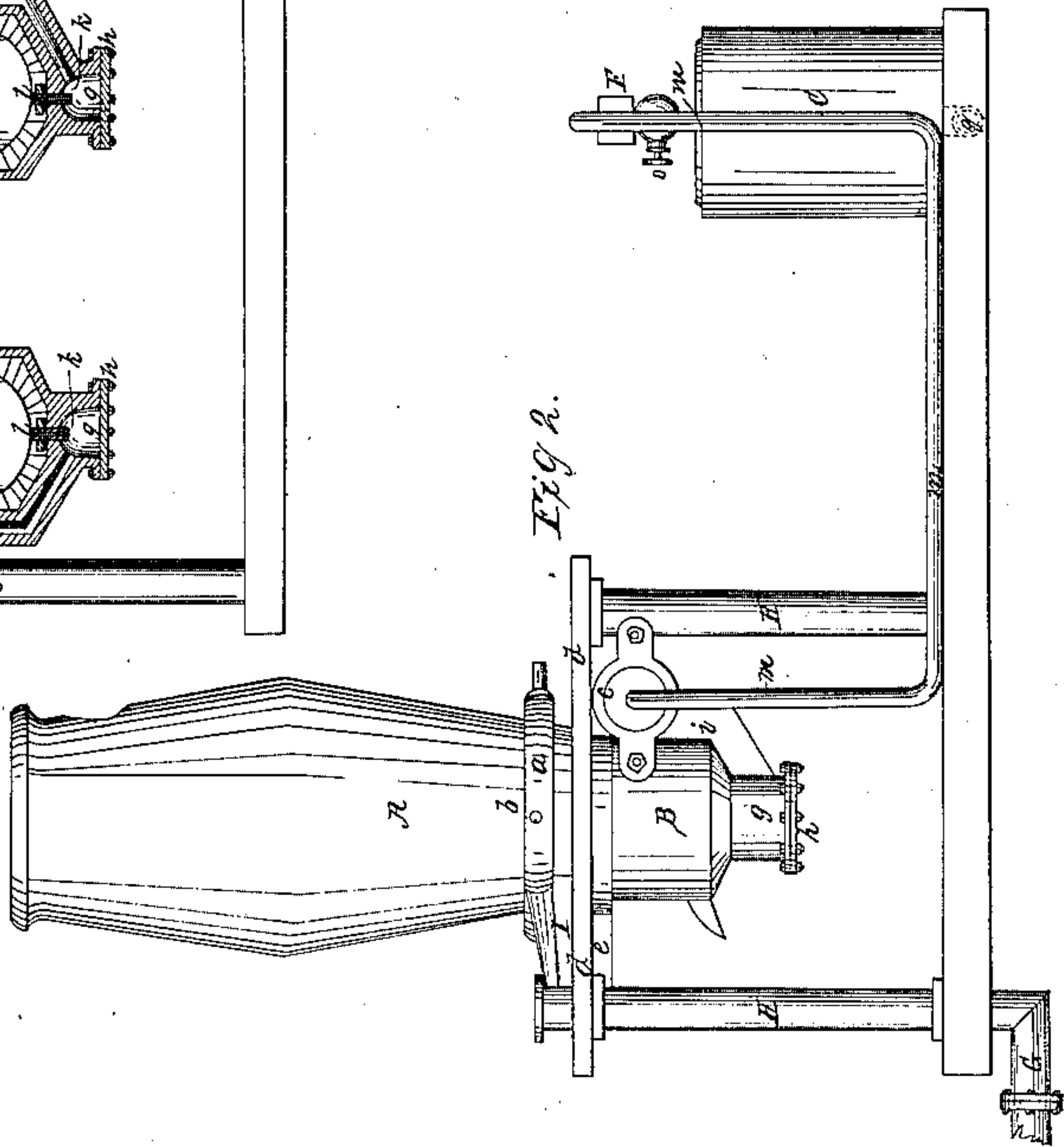
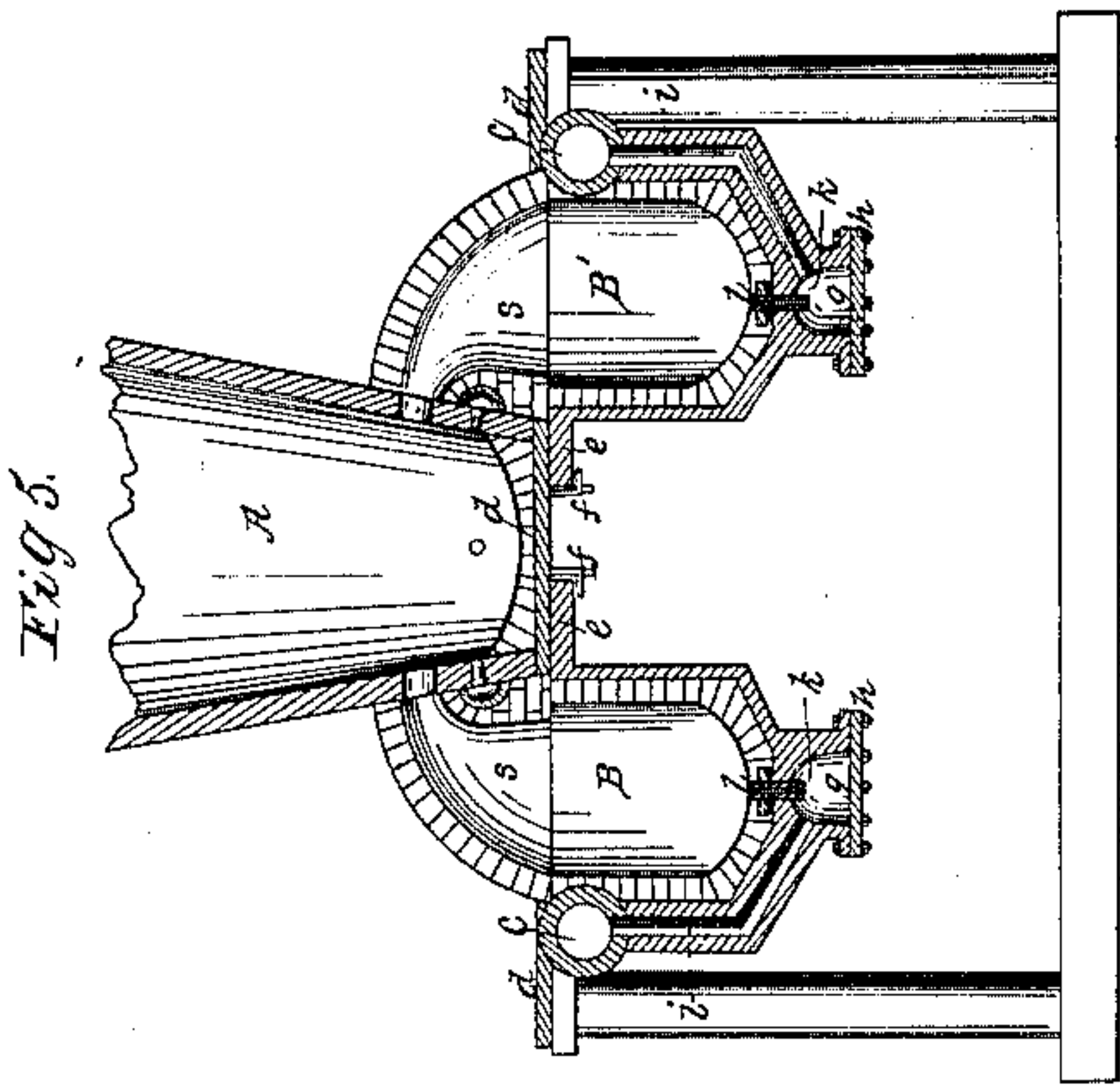


*J. Reese,*

*Reducing Metallic Oxides, and Refining the Metal Resulting Therefrom*  
*Nº 57,969.*

*Patented Sep. 11, 1866.*



*Witnesses:*  
*Geo. W. Gregory*  
*Henry T. Munson.*

*Inventor:*  
*Jacob Reese*  
*by his attorneys*  
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# UNITED STATES PATENT OFFICE.

JACOB REESE, OF PITTSBURG, PENNSYLVANIA.

IMPROVEMENT IN REDUCING METALLIC OXIDES AND IN REFINING THE METAL RESULTING THEREFROM.

Specification forming part of Letters Patent No. 57,969, dated September 11, 1866.

*To all whom it may concern:*

Be it known that I, JACOB REESE, of the city of Pittsburg, in the county of Allegheny and State of Pennsylvania, have invented a new and useful Improvement in the Reducing of Metallic Oxides, and the Refining of the Metal resulting therefrom; and I do hereby declare that the following is a full, clear, and exact description thereof, reference being had to the accompanying drawings, forming part of this specification, which illustrate the apparatus employed in the process, and in which—

Figure 1 is a plan or top view of my improved apparatus. Fig. 2 is a side elevation thereof. Fig. 3 is a vertical section through the cupola and reducing-chamber. Fig. 4 represents the tanks used for holding the water and hydrocarbon fluid used in my improved process. Fig. 5 is a section of the lower part of a cupola furnished with two reducing-chambers. Fig. 6 is a representation of a tuyere-pipe.

In the several figures like letters of reference denote similar parts of the apparatus.

On the 19th day of June, 1866, Letters Patent of the United States were granted to me for an improved mode of reducing metallic oxides, in which, after the metallic oxide or ore is melted in a cupola and run into a detached chamber or reducer, it is deoxidized by the application of a hydrocarbon in either a liquid or gaseous form.

The invention which I am about to describe in this specification is an improvement on the process forming the subject-matter of my former patent; and it consists in fusing the ore or metallic oxide to be reduced in a cupola, with or without carbonaceous fuel, and by the aid of a blast of atmospheric air, and running the melted ore, before it is reduced to a metallic state, into a reducing-chamber placed under the cupola, and reducing the melted ore in such chamber below the influence of the atmospheric blast by means of a compound or mixture of hydrogen and carbon, by which the metal is also refined and purified.

My invention also consists in the compound of hydrogen, carbon, and oxygen employed in reducing the ore and refining the resulting metal; also, in the construction and application of apparatus employed for the purposes

described, and in the mode of using the waste heat resulting from the chemical reduction of the metallic oxides for the melting of the ore previous to its reduction.

My improved process is applicable to the reduction and refining of the oxides of various metals; and the removal of sulphur, phosphorus, and other impurities therefrom; but, for the sake of perspicuity, I shall confine my description to the application of my invention in the manufacture of iron in its various forms of malleable iron, semi-steel, cast-steel, and crude or cast iron.

One of the important features of my improvement, in its application to the manufacture of iron, is the removal of sulphur and phosphorus, which results from the use of my invention. Many of the best ores of iron contain a large amount of sulphur, which, having a greater affinity for iron than for either oxygen or carbon, is extremely difficult to remove; and when these ores are smelted in a blast-furnace with coal or coke, which likewise contain sulphur, they take up an additional quantity, and the resulting metal becomes very red-short. Phosphorus, in the condition of phosphate of lime, or of phosphoric acid, is also found in some valuable ores of iron, and is so very difficult to remove that it is seldom attempted. It is sometimes done, as in the case of the magnetic iron ores of Lake Champlain, by mechanical means, after the ore has been crushed by stamps, as this ore is very rich; and, when freed from phosphorus, peculiarly adapted for making the best brands of cast-steel; whereas, if not thus purified, it would produce iron too cold-short for that purpose.

By the use of hydrogen in the fusion and chemical reduction of ores containing sulphur or phosphorus, these impurities having a greater affinity for the hydrogen unite with it and leave the iron neutral—that is, neither red-short nor cold-short. The hydrogen forms no chemical combination with the iron, but passes off as sulphureted or phosphureted hydrogen, while the iron thus purified is more ductile, has greater tensile strength, and is in purer and better condition for carburization in the manufacture of steel or cast-iron.

The advantages of my improved process over the ordinary mode of smelting iron in a



blast-furnace, by which the iron is highly carbonized, and then decarbonizing it by puddling or boiling, or by the pneumatic process of forcing atmospheric air through the crude molten metal, as stated in my former patent before referred to, apply fully to the process I am about to describe, and need not be repeated.

My improvement is designed to effect the production of malleable or wrought iron, steel or cast-iron from the ore, in the first instance, by fusing the ore in a cupola or other furnace, without thereby reducing it to its base, and then deoxidizing the liquid ore by means of hydrogen or carbon, or a mixture of those elements, these deoxidizing agents being exhibited in such quantities as to produce the desired results—that is to say, the hydrogen unites with the oxygen of the ore and is burned, and also unites with and carries off the sulphur or phosphorus, and the carbon, uniting with the oxygen of the ore, produces vivid combustion and a high degree of heat, (which is utilized in melting the ore in the cupola above,) no more carbon being employed than is necessary for that purpose, so that the iron is not carbonized, unless it is desired to produce semi-steel, cast steel, or cast-iron, in which case the requisite percentage of carbon is supplemented.

In the practical application of my invention the vapor of petroleum, or the liquid itself, may be used as described in my former patent; or hydrogen may be obtained from water, steam, petroleum, or other substances, or carbureted hydrogen in the shape of coal-gas may be employed. The carbon employed in the process may be used in a liquid, gaseous, or solid form, as may be most convenient, and may be extracted from coal, petroleum, or otherwise, or used in the shape of pulverized coal, coke, or charcoal. The apparatus used may be modified to conform to these various conditions, so that I do not wish to limit myself to the specific details herein described.

To enable others skilled in the art to make use of my invention and apply the process to the manufacture of metals from their oxides, I will proceed to describe the construction and operation of my apparatus.

In the drawings, A is the cupola in which the ore is melted. It is furnished with an annular blast-pipe, *a*, having tuyeres *b*, by which a blast of atmospheric air is introduced at or near the base of the cupola, for the purpose of supplying sufficient oxygen to keep up the heat necessary to fuse the ore.

The bottom of the cupola is not closed, as is usual, by a plate, but is left open, so as to communicate with the mouth of the reducing-chamber B, placed directly below it, so that the ore, as it is melted, may run down immediately into the reducing-chamber below the influence of the atmospheric blast.

The cupola thus constructed and arranged differs from a blast-furnace in this respect, that the blast-furnace is made with boshes tapering

downward so rapidly as to form a support for the charge of ore and fuel in the furnace and hold the burden up from the hearth until it is thoroughly deoxidized and charged with carbon, while my cupola is made with sides only slightly inclined, so as to allow the ore to pass down rapidly as soon as it is fused, and without being deoxidized, into the reducing-chamber B.

The result of this difference of construction is, that in the blast-furnace the ore is deoxidized before it is melted, and is in a metallic state before it runs down below the blast-line *x x* into the hearth, while in my improved reducing-furnace the ore is only fused or liquefied in the cupola above the blast-line *x x* and passes down below that line, as an oxide, into the reducing-chamber, where it is oxidized and reduced to a metallic state below the influence of the atmospheric blast.

In the blast-furnace the metal is wasted by oxidation while passing from the boshes through the blast, and forms black cinder, the carbon in the metal being burned out, thus forming white iron instead of good grey pig.

My cupola is lined with fire-brick or other refractory substance which will resist the action of the heat necessary to fuse the ore.

The reducing-chamber B is a shallow cylindrical pot, made of wrought-iron, supported by a frame of cast-iron. It is lined with such material as will resist the heat and chemical action of reducing and refining, which may be varied according to the chemical composition of the ore under treatment. Thus, if the iron ore contains little or no silica or alumina, (as the Edwards iron ore of Lake Superior,) pure lime or oxide of calcium may be used for lining the reducing-chamber, while with ores of other metals the lining may be pure alumina.

The reducing-chamber B has a shaft, *c*, at one side, placed at its upper edge, by means of which it is supported on pillow-blocks, in suitable bearings, and is adjusted so as to fit closely up to the base-plate *d*, to one side of the cupola. By this shaft *c* the reducing-chamber B is pivoted so that it may swing away from the bottom of the cupola, as shown in Fig. 3, in order to give free access to it, as well as to the cupola, for the necessary repairs.

When in use the foreplate *e* of the reducing-chamber is raised up, the shaft *c* turning in its bearings, until the foreplate *e* rests against the under side of the base-plate *d* of the cupola, where it is fastened by a latch, *f*, and thus held in place, with the open mouth of the reducing-chamber coinciding with the open bottom of the cupola.

The shaft *c* is hollow from one end to the point where it intersects the passage *i*, formed on the outside of the reducing-chamber B. This passage *i* leads from the cavity *e'* of the shaft *c* downward to the cell *g*, a small chamber formed under the bottom of the reducing-chamber B, and cast in one piece with it.

The bottom of the cell *g* is hermetically closed by a cap-plate, *h*, fastened on by screws.



The passage *i* opens at its lower end into the cell *g*, and the cell *g* communicates with the interior of the reducing-chamber B only by means of one or more tuyeres, *l*, of peculiar construction. (Shown on a larger scale than the rest of the drawing in Fig. 6.) These tuyeres are made of any material capable of resisting the heat and chemical action, and are inserted into the hole opening through the bottom of the reducing-chamber B into the cell *g*. A piece of gas-pipe or other metallic tube, *k*, with a flanged head is embedded in the tuyere while it is in a plastic condition, with the tubular end projecting below the tuyere, on which end screw-threads are cut, and the tube *k* is then screwed into the casting between the reducing-chamber B and cell *g*, as shown in the drawings, and is thus held in place.

The diameter of the bore of the tuyere will be greater or less according to the capacity of the reducing-chamber and the character of the deoxidizing agent employed in the process. If this be in a liquid condition a single tuyere of one-fourth inch diameter will ordinarily suffice, as the liquid expands enormously when it passes into a gaseous condition on entering the molten mass in the reducer; but if the reducing agent be a gaseous body the tuyeres should be increased in number, and may be constructed as described in my former patent before referred to.

The hollow end of the shaft *c* is closed by a cap, to which is attached one extremity of the pipe *m*, which passes over the two tanks C and D, and has branches *n n'*, which enter the top of the closed tanks C and D, respectively. Through the pipes *n n'* the liquid contents of the tanks C D are forced into the cavity of the shaft *c*, and thence into the cell *g*, and through the tuyere *l* into the reducing-chamber B.

The tanks C and D hold the deoxidizing agents, and a similar tank, E, contains water. From the top of the water-tank E a steam-pipe, *p*, leads to a steam-generator.

The pipes *n* and *n'* are each furnished with a registering-meter, F, to indicate the amount of gaseous or liquid reducing agent passing through them. They have also cocks or valves *o* to regulate the flow.

The pipe *m* does not enter the water-tank E, but the three tanks C, D, and E are connected together underneath by the pipe *q*, which opens into the bottom of each tank.

The tanks may be made of any convenient size, of ordinary boiler-iron, one-fourth of an inch thick, and with heads three-eighths of an inch thick.

For a reducing-chamber capable of making five tons of metal per hour, the tanks C and D should have a capacity of not less than ten barrels each. The water-tank E should be somewhat larger, as it is designed to supply the requisite pressure to the liquid contents of the two tanks C and D.

The blast of atmospheric air is supplied to the cupola by means of a blast-pipe, G, which

communicates with the two upright tubes H H, which also serve as two of the supports of the cupola. The blast is conducted from the top of the tubes H H to the annular blast-pipe *a* by means of the connecting-trunks I I.

Having thus described the construction of my improved apparatus, I will proceed to explain the manner in which the operation is performed.

The process which I employ depends on the same general principles as that which is described in my former patent of June 19, 1866. Instead of smelting the ore with carbon in the process of deoxidation, and thereby not only reducing it to a metallic state, but saturating it with carbon, as a first operation, and then reversing the process and decarbonizing the metal by forcing oxygen over or through it, I propose to manufacture malleable iron, semi-steel, cast-steel, or cast-iron from the ore at one operation, by first melting the oxide or ore of iron with sufficient air and carbon to melt without deoxidizing it, and then, during the same process, to treat the melted oxide of iron with carbon or hydrogen, or a mixture of carbon and hydrogen, in a receptacle placed below or beyond the reach of the atmospheric blast, until the oxygen is removed, when the product will be malleable iron; or to continue the supply of carbon until such percentage may be taken up by the melted metal as will yield the product desired, whether semi-steel, cast-steel, or cast-iron.

The cupola A being charged with the iron ore, (oxide of iron,) and a sufficient amount of coke to create the necessary heat, and such purifying and fluxing ingredients as may be desirable, the furnace is lighted and the blast applied. The ore, as it melts, drops downward into the reducing-chamber B, through the open bottom of the cupola, passing below the blast-line *x x*, and therefore out of the influence of the blast, in the condition of a melted oxide. In this condition, being naturally combined with oxygen, (as an ore of iron,) the atmospheric blast has no effect to oxidize it any further, and there being no excess of carbon in the cupola beyond the amount requisite for fuel, the ore is not either deoxidized or carburized. As the liquid oxide of iron accumulates in the reducing-chamber B it floats the coke upon its surface.

The tank C is filled with benzole, or other liquid hydrocarbon, to be used in reducing the melted oxide to its base; the tank D with petroleum-tar, or other vehicle of carbon, which is employed after the reduction of the oxide to add the required percentage of carbon in the formation of steel or cast-iron; and the tank E with water.

Just before the ore melts and runs into the reducing-chamber, the valve *o* to the steam-pipe *p* is opened, and steam is let into the water-tank E, which, pressing upon the surface of the water, forces it out through the pipe *q*, causing it to enter the bottom of the tank C, but not into the tank D, which is



shut on by a cock. The pressure thus applied to the contents of the tank C forces out the benzole or light hydrocarbon through the pipes *n m*, and causes it to enter the hollow shaft *c*, and pass through the passage *i* and tuyere *l* into the reducing-chamber B. The water from the tank E, being heavier than the benzole, remains in the bottom of the tank C, displacing and forcing out the benzole, which rushes with great force through the contracted aperture of the tuyere *l* into the mass of melted ore in the reducing-chamber B. The degree of force thus applied is regulated at pleasure by the admission of steam through the valve *o* in the pipe *p*.

The liquid light hydrocarbon thus injected into the mass of melted ore expands with great force, producing great disturbance of the particles of molten ore, and causing an intimate mixture therewith of the hydrogen and carbon. The hydrogen rapidly unites with the oxygen of the ore, forming water (HO) or steam; and the carbon, uniting with the oxygen and forming carbonic acid, (CO<sub>2</sub>), thus effectually deoxidizes the ore without carburizing it. The hydrogen also unites with the sulphur and phosphorus in the ore, carrying off these impurities where they exist.

The union of the carbon and hydrogen with the oxygen of the ore produces vivid combustion and high heat, and the heat and flame thus produced pass up into the cupola, and obviate the necessity of using other fuel to melt the ore contained therein, enabling the amount of coke employed for that purpose to be reduced to a very small quantity.

This operation is continued until the oxygen is all expelled from the ore, which is thereby reduced to a metallic state. If the process be suspended at the point of complete deoxidation, the product will be malleable iron, which may be run out of the reducer through the tap-hole *r* into suitable molds. The amount of light hydrocarbon used in the operation of reducing the melted oxide to its base is indicated by the registering-meter F on the top of the tank C, and when once ascertained will serve as a guide for future operations with the same ore.

If semi-steel, cast-steel, or cast-iron be desired, they are obtained by adding the requisite percentage of carbon. This I effect by the introduction of any convenient form of carbon into the melted metal. In the apparatus shown in the drawing, the tank D is designed for this purpose, containing petroleum-tar, or other substance rich in carbon. The connection between the tank C containing the light hydrocarbon and the reducing-chamber B having been closed when the reduction is effected, the cock or valve *o'*, connecting the top of the tank D with the reducing-chamber B is opened, when the pressure of water from the tank F, produced as before described, forces the heavy carbon into the melted metal. As soon as the requisite percentage of carbon is taken up by

the metal the valve *o'* is closed and the operation of carburizing the metal is complete.

The operation thus described may be carried on continually, the cupola being charged afresh as soon as the contents of the reducer resulting from the first charge are removed. The ore will begin to melt in about twenty minutes from the time the charge is put in, and the operation will be completed in from one to two hours, depending on the quantity of ore used. If, however, it is desired to make the operation unintermittent or continuous, it may be readily accomplished by a slight modification in the construction of the furnace, as shown in Fig. 5, in which there are two reducing-chambers, B and B', placed one on each side of the cupola, instead of vertically under it. In this case the contents of the cupola rest on the bottom plate, and the melted ore is run through channels *s s* into the reducers, first into the one and then into the other, alternately. When one reducer is filled with melted ore, the supply is stopped and turned into the other, so that while one reducer is being filled the contents of the other are being reduced by the application of the stream of hydrocarbon. Thus the process may be kept up without intermission.

After the melted ore in the reducing-chamber has been thoroughly deoxidized, and, if desired, carbonized up to the desired point, it may be refined by the use of a compound, which I call "hydrelaion," or "hydroline," being a mechanical compound or mixture of hydrogen, carbon, and oxygen, in the proportions in which they will combine chemically. This mixture, the nature of which I shall particularly explain, is forced through the melted metal in the reducing-chamber by means of tanks, such as before described. As soon as it enters the melted mass, the elements composing the hydroline form an immediate chemical union in a gaseous state, and in so doing give out an intense heat, which is communicated to the metal, and at the same time cause it to boil violently. By this means the metal is refined, and whatever sulphur or phosphorus may yet remain is carried off.

Hydrelaion or hydroline, the mixture of which I use for refining the metal, is composed of carbon-oil or petroleum, or other oil, and water, in the proportion of one atom of water to one of oil, or in such relative proportions (depending on the kind of oil employed) as will produce the chemical equivalents of water and the oil used, supposed to be H<sub>2</sub>OC.

By means of this combination I provide a compound which contains in itself the elements required for combustion, without decomposing or wasting the metal, in the presence of which it is chemically combined.

Hydroline may be procured by mixing water and petroleum in a vessel and agitating it by mechanical means until it assumes a soapy appearance, when it will remain in mechanical combination for many days, if not heated; or



it may be made for immediate use by mixing the vapor of petroleum or coal-gas with steam, but I prefer the use of liquid hydroline, as more convenient and efficient than the gaseous mixture, and it will be found more easy to mix the oil and water in the exact proportion desired, if they are in a liquid state.

Instead of using steam in connection with the water-tank E for forcing the contents of the tanks C and D into the reducing-chamber, the force of a head of water, as from the reservoir of a water-works, may be used when it is convenient to do so. The use of the water-tank E, with the pressure of either steam or water, is much more efficient and economical than the ordinary cumbersome and expensive blowing-cylinders; and with live steam, any required degree of pressure can be readily attained and easily controlled.

The steam might be applied directly to the top of the oil, &c., in the tanks C and D, without the use of the water-tank E, but it would vaporize the hydrocarbons, which is not desirable; besides, the steam would condense and settle at the bottom of the tank, and the water would be forced into the reducing-chamber with the oil, &c.

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

1. The manufacture of iron or other metals from their ores in a furnace, in which the ore, having been fused with the aid of a blast of atmospheric air, is then reduced to its base with a hydrocarbon.

2. The process of fusing iron ores and other metallic oxides by the aid of a blast of atmospheric air in a furnace, and the waste heat from the reducing-chamber, without the use of other fuel, or with so little fuel as not to deoxidize the ore in melting, and running the melted ore immediately into a receptacle below the influence of the atmospheric blast, in which it is deoxidized by the injection of any hydrocarbon into the molten mass, in the manner substantially as hereinbefore described.

3. The use of an atmospheric blast for fusing metallic oxides, in combination with the use of hydrogen or carbon or a hydrocarbon for the reduction of the melted oxide to its metallic base, substantially as hereinbefore described.

4. The use of the compound of water or steam and oil in a liquid or vaporous condition, in the proportions hereinbefore described, as a new material for the refining of melted metal.

5. Combining with a cupola or melting furnace one or more reducing-chambers, placed, for the reception of the melted ore, below the point at which the atmospheric blast is introduced into the furnace, for the purpose of running the melted ore directly from the furnace into a reducing-chamber, in which it may be deoxidized, carbonized, and refined, away from the influence of the atmospheric blast, substantially as hereinbefore described.

6. Connecting the reducing chamber or chambers to the bottom of a cupola or melting furnace by a hinge or pivot, so that they may be swung away from the furnace without impairing their connection with the vessel containing the reducing agent.

7. The use of the hollow shaft *c*, in combination with the reducing-chamber B and connecting-passage *i*, for the purpose of hanging the reducer to the cupola, and allowing of the introduction into the reducing-chamber of the liquid or gaseous agents for the reduction of metallic oxides.

8. The combination of the water-tank E with one or more tanks for holding the liquid deoxidizing or carburizing agents, for the purpose of applying the pressure of live steam or of a head of water to forcing the deoxidizing agents into the reducing-chamber, substantially as hereinbefore described.

9. Constructing the tuyere forming the communication between the interior of the reducing-chamber and the cell below it of fire-clay or other refractory material, in combination with a tubular metallic screw-stem projecting therefrom, substantially as and for the purpose hereinbefore set forth.

10. The use of lime or oxide of calcium as a lining for reducers or furnaces, wherein ores or metals are decomposed or refined.

In witness whereof I have hereunto set my hand.

JACOB REESE.

Witnesses:

ALLAN C. BAKEWELL,  
JAMES M. TAYLOR.