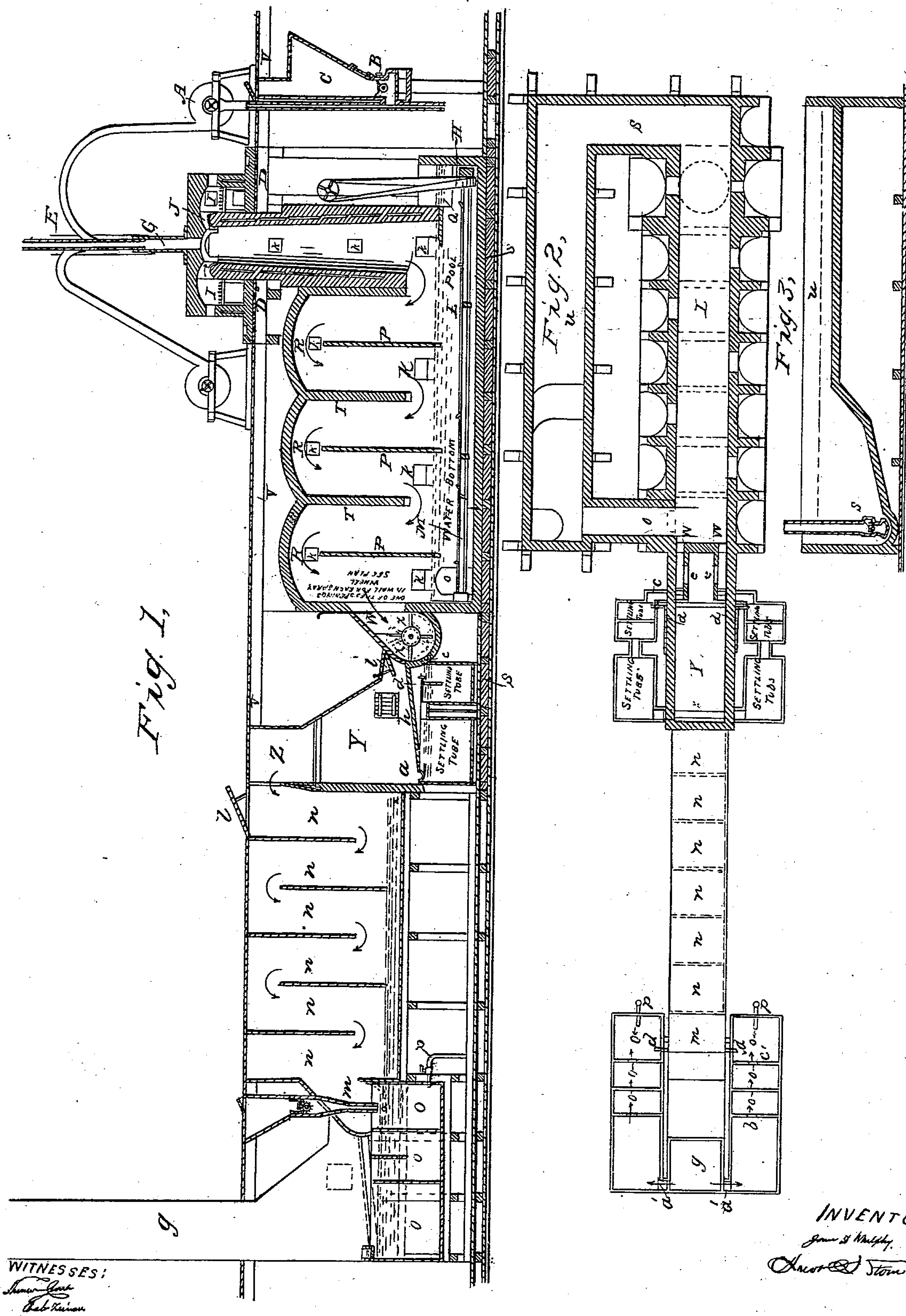
4 Sheets—Sheet 1.

WHELPLEY & STORER.

Shaft Furnace.

No. 59,696. Patented Nov. 13, 1866.



WITNESSES:

INVENTOR.

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

4 Sheets—Sheet 2.

WHELPLEY & STORER.

Shaft Furnace.

No. 59,696. Patented Nov. 13, 1866.

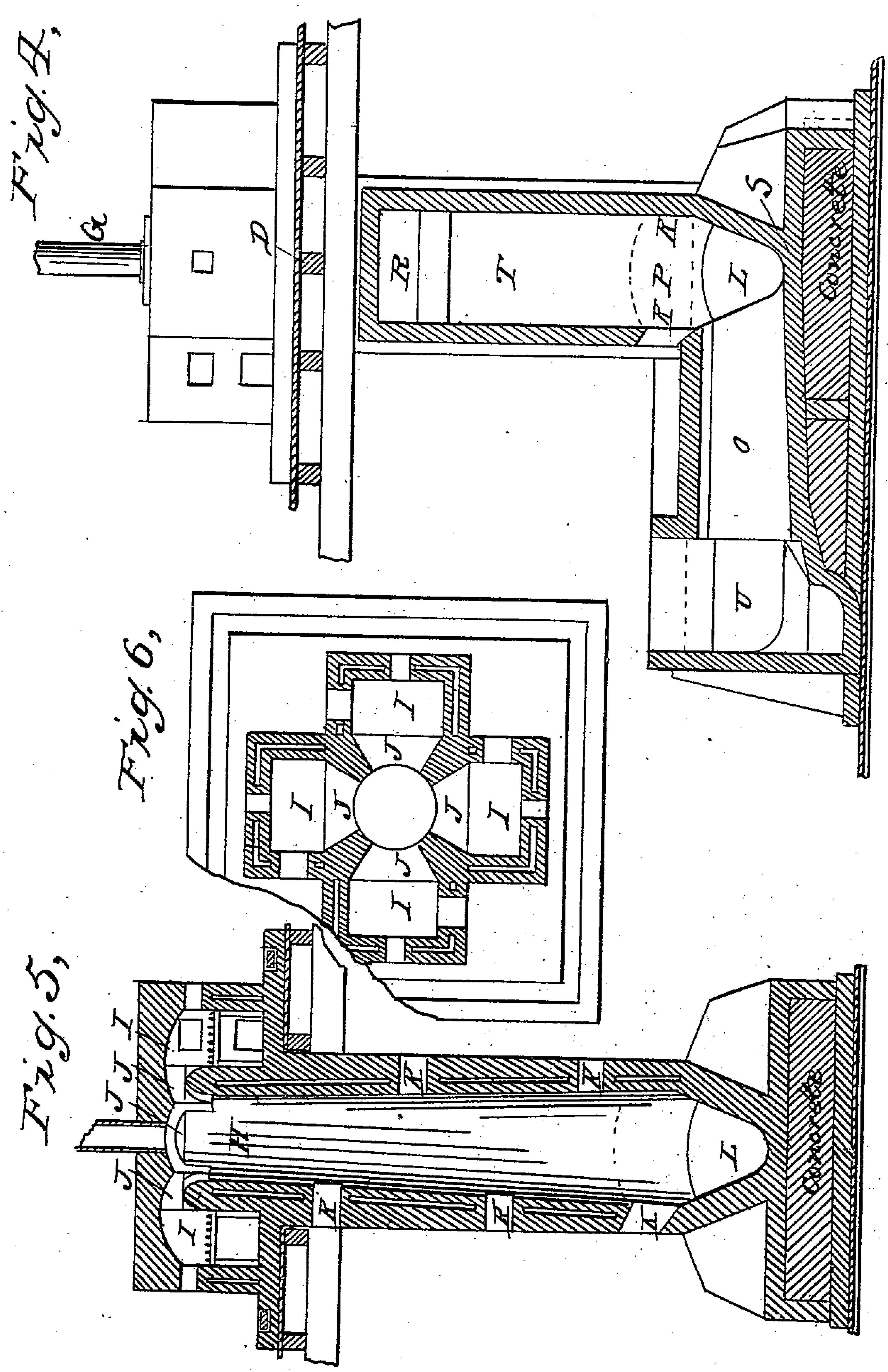


Fig. 4,

Fig. 6,

Fig. 5,

Witnesses:

Inventors

4 Sheets—Sheet 3.

WHELPLEY & STORER.

Shaft Furnace.

No. 59,696. Patented Nov. 13, 1866.

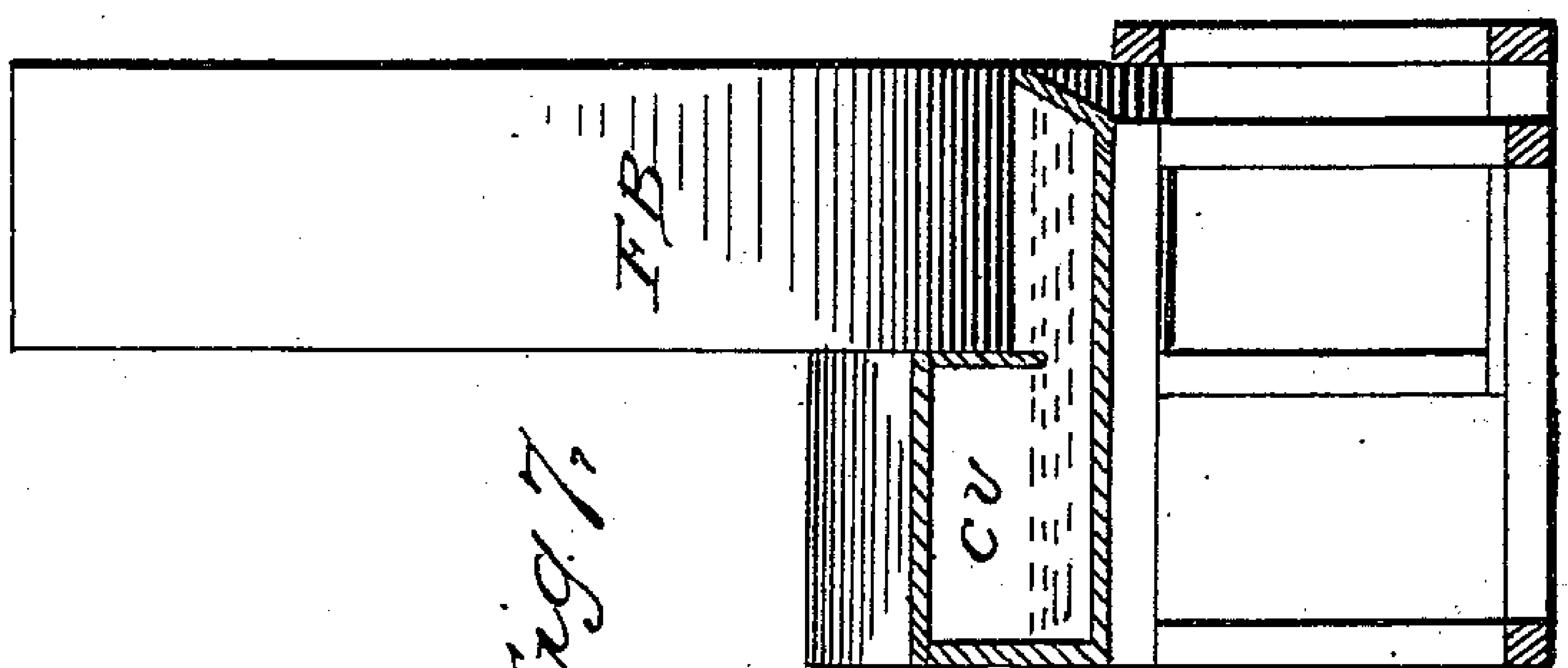


Fig. 7.

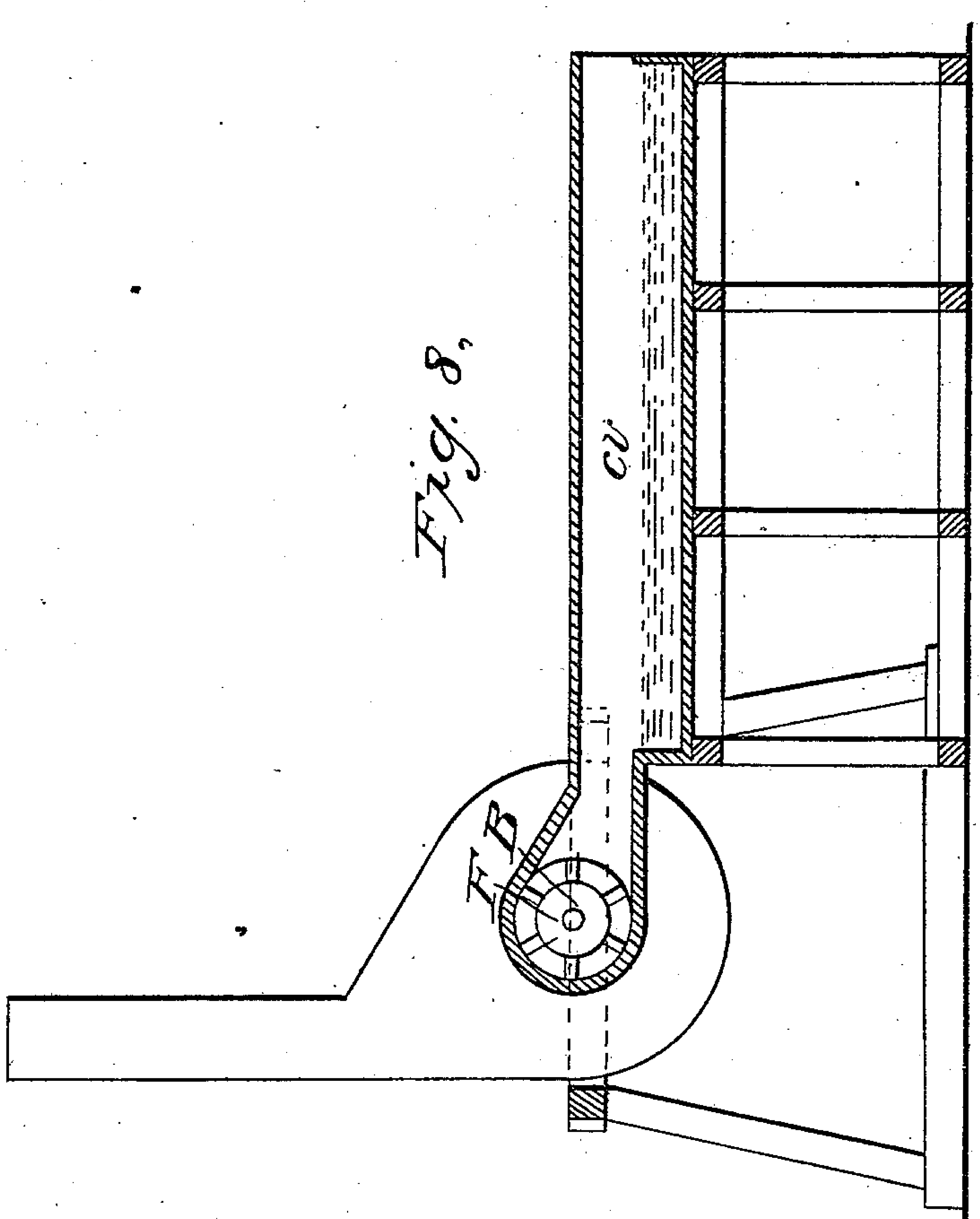


Fig. 8.

Witnesses:

Charles Batteman.

Inventors:

James D. Whelpley

Jacob Jones Storer

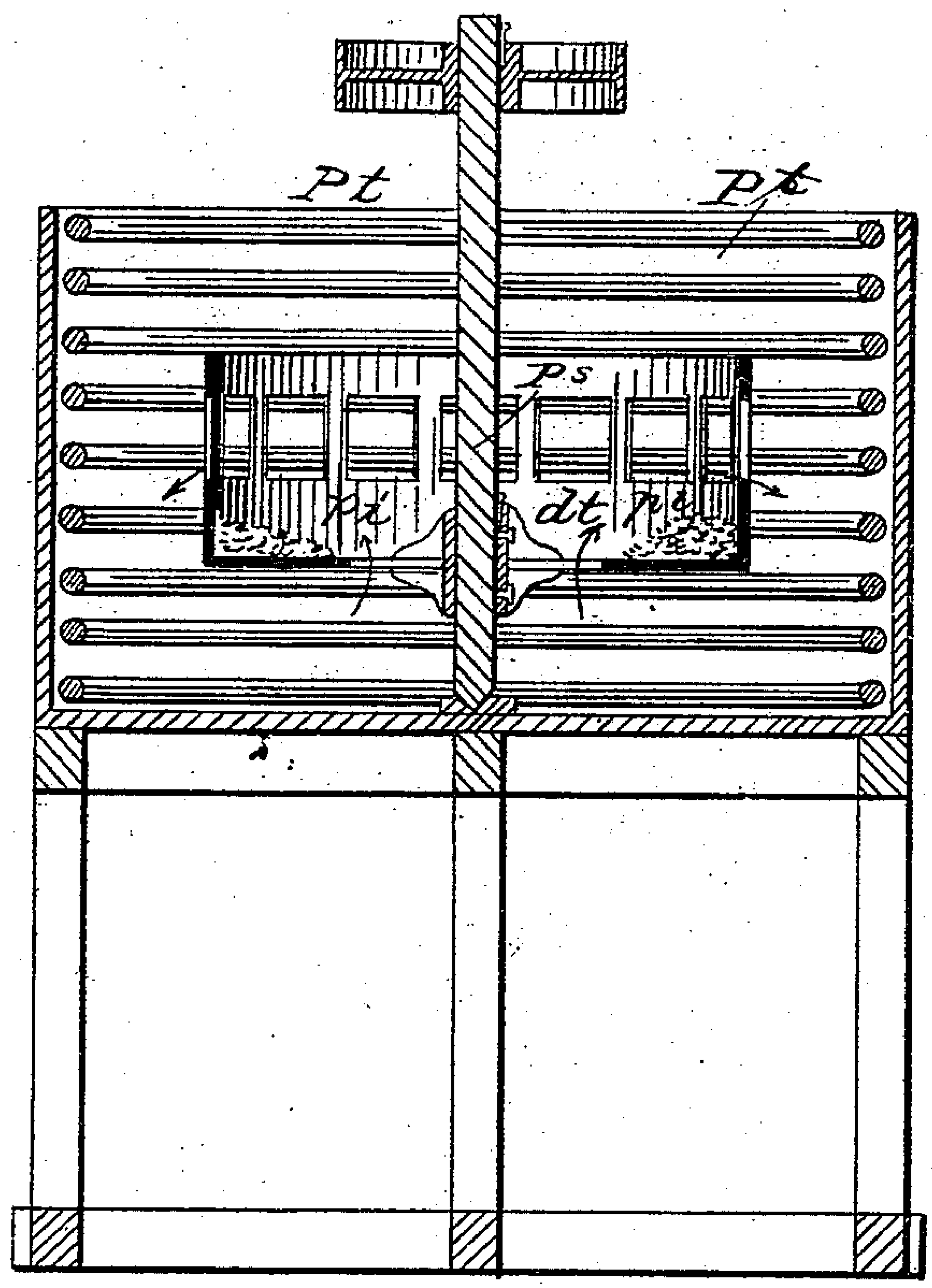
N. PETERS, Photo-Lithographer, Washington, D. C.

WHELPLEY & STORER.

Shaft Furnace.

No. 59,696. Patented Nov. 13, 1866.

Fig. 9.



Witnesses:

Thos. Wm. Clarke

Charles Bateman.

Inventors:

James D. Whelpley

Jacob J. Storer.

UNITED STATES PATENT OFFICE.

J. D. WHELPLEY AND J. J. STORER, OF BOSTON, MASSACHUSETTS.

IMPROVED PROCESS AND MACHINERY FOR OBTAINING METALS AND OTHER PRODUCTS FROM ORES AND MINERALS.

Specification forming part of Letters Patent No. **59,696**, dated November 13, 1866.

To all whom it may concern:

Be it known that we, JAMES D. WHELPLEY and JACOB J. STORER, of Boston, in the county of Suffolk and State of Massachusetts, have invented a new and useful Process and Machinery for Obtaining Metals and Salable Products from Ores and Minerals; and we do hereby declare that the following is a full, clear, and exact description of the construction and operation of the same, reference being had to the accompanying drawings forming a part of this specification.

Metals seldom are found in nature pure. Gold, silver, copper, and platinum are perhaps the only, certainly the most notable, exceptions. More usually they appear as combinations with other metals, or as binary combinations with other metallic substances, or as insoluble salts. The most generally diffused combination is that with sulphur, sometimes as an insoluble salt, like gypsum, more usually as a binary compound called a sulphuret; but even the sulphurets are seldom of a simple character. Pyrites, the most common of all, is frequently a double sulphuret of iron and copper, or if it be a simple one it contains mingled with it, either mechanically or otherwise, gold or other metal. Galena (sulphuret of lead) almost always contains enough silver to render extraction profitable.

To work an ore properly, we should be able to make of every constituent part a salable commodity, and, if possible, the expenses of working should be paid by the sale of those constituents of the ore, except the matrix, which we wish to drive away to get the most valuable results. Thus the iron and sulphur of the gold ores of Colorado should be sufficient in amount, if properly collected, to pay the cost of working, leaving the precious metal to bear the expense of mining only. In order to do this we must have an apparatus which shall give us economically on a large scale the results, or nearly the results, of laboratory practice.

The methods heretofore in use for the reduction of metals from ores are of two classes, the dry and the wet.

In the dry method the mineral is roasted and smelted, with or without fluxes and reagents in contact with air, until the chemical equivalents which mineralize the metal to be reduced are eliminated, leaving either the metal or a regulus.

We have all heard of the Bessemer process for making steel from cast-iron. Now, if we take a refractory earthen pot, put into it a metallic sulphuret with a suitable flux, liquefy it by sufficient heat, and through a tuyere inserted to the bottom of the crucible blow a sufficient quantity of air, the air will act successively on the oxidizable equivalents in the order of their affinity for oxygen at the temperature employed. By this means the sulphur and other impurities may be completely eliminated. This would be the typical dry method. In Swansea, Wales, in the copper works in this country, and in Germany modifications of the dry method are used. The English process, as practiced in Wales, Cornwall, at Baltimore, in Boston, differs from the above application of the Bessemer process only in the apparatus used, the numerous heatings the ore undergoes, and in the fact that the oxygenation is superficial, and not in the body of the ore. The mineral, broken to fine gravel size, is spread upon the floor of a reverberatory furnace and heated and stirred, and taken out and rebroken, and again and again worked over, so many as eight successive roastings being frequently given to one batch of ore. In Germany two modifications of the process are in use. In one the ore is piled with fuel into a heap and set on fire. It burns slowly and continuously, often for three months in the open air, until the larger part of the sulphur is burned out; or it may be loosely piled in the open air, and allowed slowly to oxidize by the action of the atmosphere, and so the process of atmospheric roasting will last three years. Another German method is to sift through the top of a reverberatory furnace finely-powdered ores, which drop upon obstructing oblique shelves to retard their fall, and, passing through the flame, are oxidized and fused, and collect as a mat on the sole of the furnace. This process is rapid, but less certain than the other, and is used mostly for the formation of sulphuric acid. In every event all the subdivisions of the dry method are two: first, slow roasting of coarsely-broken ores; second, rapid roasting of finely-powdered ores.

In the dry method we require to break and comminute the ore at each successive heating, in order to obtain the full action of the atmosphere upon it, and at the conclusion of each heating we have an intractible mat, just as we did before we commenced it. This led metallurgists to consider if there were no way to avoid this difficulty, and developed the wet method, which consisted in washing the ore at the conclusion of each heating, partly to render it friable and avoid the expense of breaking, and partly to dissolve out of it soluble salts that might have been formed during the atmospheric roasting. Such were the plans of Bankart and Monnier in Europe, and upon this principle a recent American method proceeds, which heats the matrix of the metal intensely and then plunges into water or prepared chemical baths. These earlier wet methods, though steps in the right direction, do not proceed far enough. The most expeditious means to reduce a metal from ores in which it is combined with sulphur and other analogous volatilizable impurities is to form those portions of the ore which are capable of the reaction into soluble salts and at once lixiviate.

Our process is the lixiviation of incandescent sulphurous ores hot, immediately after rapid roasting, in presence of heat and oxygen; and to avoid merely superficial action we pulverize the ore to be treated so finely that the action which on coarser pieces would be superficial penetrates throughout the particle. To do this we require machinery specially devised for the purpose, carefully arranged with reference to the intended result, and also for the employment of certain subsidiary processes, which facilitate the working of the furnace, for which we already hold patents.

In the drawings, Figure 1 is a longitudinal section of the furnace and trough, conductor, and wetting and lime wheels. Fig. 2 is a plan of the furnace, settling-tank, conductor, wetting and lime wheels, and settling-tubs. Fig. 3 is a vertical longitudinal section of the settling-tank. Fig. 4 is a vertical cross-section of the chambers, settling-tank, and water-exit. Fig. 5 is a vertical cross-section of the tower and fire-boxes. Fig. 6 is a plan of the fire-boxes and top of the tower. Fig. 7 is a cross-section of the crystallizing-vat; Fig. 8, a longitudinal section of the same, and Fig. 9 is a vertical section of the precipitating-tub.

Figs. 1 to 6 have corresponding letters to indicate like parts, and Figs. 7 and 8 are lettered alike.

A wedge-shaped trough, with rounded bottom about twenty inches in diameter, is first constructed about four feet wide at its top and two and one-fourth feet deep, to contain the water bottom and pool of the furnace. A cross-section of this is shown at L, Figs. 4 and 5, and a longitudinal section at L, Fig. 1. Over this trough we erect a furnace, consisting of tower H and horizontal flue, as already described in our previous patent. The tower should be from ten to twenty feet high, in general interior form a truncated cone, and about three feet in diameter at the top near the crown, and four or five feet in diameter near the bottom. It connects with the horizontal flue, as shown in Fig. 1. The horizontal flue is arched, as shown at R, Fig. 1, and divided into precipitating-chambers by partitions T from the spring of the arches R downward, but not reaching the water-bottom, and P from within the water-bottom upward, but not reaching the crown of the arches, so that the course of the horizontal flue is serpentine, as shown by the arrows, Fig. 1. The sides of the chambers where the arrows point upward is called the "rise," and where they point downward the "drop," of the chambers.

Inspection-holes K, of sufficient size to allow the introduction of a scraper or hose to clean or wash the interior of the furnace, are made, as shown in Fig. 1, and are closed with fire-brick, soap-stone, or other suitable material. At the junction of the sides of the trough are side openings, *k*, beveled downward on their lower edge, to allow of cleaning the bottom and sides of the trough. The trough L communicates with the settling-tank U by water-entrance O and water-exit Q. A long propeller or conveyer, M, supported on four journals, one at each end and two intermediate, is placed in the axis of the rounded part of the trough, and is revolved by band N.

Around the top of the tower are four fire-boxes, I, forming a Greek cross with voided circular center, and at the re-entering angles of the cross are the springs of the cap of the furnace, which is dome-shaped. The fire-boxes connect with the interior of the tower by arched flues J, their arches forming groins with the arch of the dome. The lower part of the flues J is made by the fire-bridge, curved on its upper surface, as drawn, Fig. 1, and in its horizontal section a quadrant minus the width of the groined spring of the flue and dome arches. There are inspection and draft doors in the fire-boxes over the level of the fires, two conical inspection-holes in the cap of the furnace, and a cylindrical opening for the chimney-pipe in the center of the dome. This pipe, immediately above the furnace, is constructed as a telescopic tube, G, sliding over the chimney F, flanged at the bottom, and raised and lowered by chains, as shown in Fig. 1, so that a cleaning-tool or hose may be introduced.

The chimney F opens to the external air, and the draft is downward. It has a valve to close the draft, and is entered on the side by pipe E, which supplies air and floated fuel, ore, and fluxes to the furnace. This pipe E is the peripheral exhaust of a fan-blower, A, about three feet in diameter, with sheet-steel fans ten by five inches, and making about two thousand revolutions a minute. The fan-blower is supplied with air from two pipes, E′, entering at its center, and thence extending downward, opening at the bottom to receive air. These pipes are somewhat smaller at the bottom than where they enter the fan-case, being enlarged at where the pipes from the feed-hoppers C enter the supply-pipes E′. One of the feed-hoppers C contains the finely-powdered ore to be acted on; the other the fuel and fluxes, similarly powdered. Each hopper is furnished at its bottom with the apparatus B, described in our application for a brightening-machine, consisting of a revolving brush and discharging-bar, which scatters the dust in the track of the air-blast before entering the fan-blower.

At the opposite extremity of the horizontal flue from the tower are two openings from the chamber, conducting into the central opening in the case of a draft-and-spray wheel of the kind described in our patent of March 6, 1866, but with spray-arms on both sides of the fan-blower. This wheel is to carry a greater body of air than the fan-blower at the opposite end of the furnace, and discharges the air, spray, and dust passing through it into spray-chamber Y, which has a bottom, *h*, at its origin, as high as the axis of the wheel and inclining away from it. Upon this the condensed spray and the matters it has wetted down fall, and are conducted from the spray-chamber by a pipe, *a*, into the first settling-tub, from which the overflow *b* carries the water into the second settling-tub, which has a perpendicular partition extending from its upper edge toward the bottom, by which the solid matters are thrown entirely to the bottom. From this tub there is an overflow, *c*, into the water-chamber of the spray-wheel again, and a fourth overflow conveys superfluous water from the spray-box to the furnace-trough. As some of the spray is carried off in the form of steam, a supply-pipe, *d*, furnishes fresh water to the second tub, to preserve the constant level of the water into which the spray-arms dip. This wheel is supplied with water only, and is called the "wetting-wheel."

The spray-chamber has a man-hole, by which it can be entered and cleaned, and opens into a conductor, Z, provided with precipitating partitions to divide the flue of the conductor into chambers with rise and drop. This conductor has a swinging door, *l*, opening to the outer air, the use of which is to balance the draft of the wetting and chemical wheels. At the extremity of the conductor is placed another draft-and-spray wheel, *m*, carrying the same, or nearly the same, body of air as wetting-wheel, and at the same rate. This wheel is supplied with chemicals either mingled with or dissolved in the spray it furnishes. We call this the "chemical-wheel."

Outside of the chambers, and at a level somewhat lower than the trough forming the water-bottom and pool, is the settling-tank U, into which flows the water that has been used in the furnace. In this tank the pulp driven from the water-bottom by the conveyer is deposited, and the water thus purified is conducted by a return-conduit back to the furnace through water-entrance Q, Figs. 1 and 2.

To construct the furnace a foundation of timber and plank is laid, on which will rest the trough. Upon this rests the foundation S of the trough, of solid masonry laid in hydraulic cement, and heavily buttressed at the sides to obviate thrust and sustain the weight. Above this the chambers and tower are erected, also of masonry, lined with fire-brick, and built with air-spaces. The chimney and pipes of the air and dust feed are of sheet metal, the fan-blower of iron and steel, the case of the wetting-draft and spray-wheel is of brick below and soap-stone or metal above. The upper part of the case is made with a slot to enable the wheel to be lifted out of its place to be repaired. This case rests on a solid masonry foundation, as does also the spray-chamber, which is of masonry, covered with copper-lined wood. The conveyer, working in the bottom of the trough, is of wood. It is supported by strong timbers set in the masonry, and revolves on copper. Its blades are faced with copper. The belt which drives it is of rubber. The ore and coal hoppers may be of wood or sheet metal. The settling-tanks are of masonry; the settling-tubs of wood. The wetting-wheel must be made of copper. The conductor is of wood, and its chambers may be lined with lead, to collect sulphuric acid. The chemical-wheel will be of iron. A plank platform, V, is to be laid over the top of the precipitating-chambers, and over the coal and ore hoppers, which will project upward through it for convenience in feeding. The fire-boxes are supported by plank and timber platforms. Band all masonry with iron.

To set the furnace in operation the trough is filled with water about three feet deep, so as to rise somewhat upon the sides of the partitions P. That part of this wet hearth beneath the tower and first chamber is called the "pool," and under the remaining chambers, the "water-bottom." Fires are then started in the fire-boxes, the draft-wheels set in motion, and the furnace heated. Ore and pulverized fuel are then fed in through the feed-hoppers B, and delivered into the furnace through the feed-pipes by the action of the revolving fan A. The advantages of feeding into the air-blast before it enters the fan are that coarse material is surely precipitated by gravity in opposition to the current of air; that the fuel and ore are more perfectly mingled with the air; the fan works with less labor, and can never be loaded with more material than the blast can easily carry; the ore and fuel are more evenly supplied; and the advantage of using two hoppers and feeding the different materials, fuel and ore, separately is, that we can change the ratio of ore and fuel at once and without trouble, and the ore and fuel are more perfectly mingled with each other. We consider these very important improvements.

The ore and fuel pass into the head of the furnace, are fired by the radiation and the heat from the fire-boxes, drop to the bottom of the tower, and wind their way along the horizontal flue toward the wetting-wheel.

Most of the solid material has by this time been deposited, a large majority of it in the pool. The air, laden with gases and some impalpable dust, is carried through the wetting-wheel to the spray-chamber, where it deposits all its dust, and the gas-laden air proceeds through the conductor toward the chemical wheel, much of the spray and it has brought over condenses in the chambers of the conductor, absorbing sulphurous acid and changing to sulphuric acid. The remainder is carried to the chemical wheel, where it is again wetted and supplied with alkaline reagents, which completely purify the air from sulphurous gas and discharge it into the atmosphere with very slight contamination, and that only of carbonic acid. During all this operation the conveyer, moved by its belt, is revolving in the trough below the pool and water-bottom, and pushing forward the solid matters to the water-exit, through which they are removed by pump or otherwise. An automatic transfer of water thus takes place through trough and settling-tank. The ingredients of the ore which, on lixiviation, are soluble are to be found in solution; the insoluble portions are in the pulp of the settling tank and tubs, from which they can be readily separated. No slag ever forms on the interior, first, because the inclined walls of the tower and the arched and curved fire-surfaces allow no chance for it to cling to them; and, secondly, because most of it is precipitated in the pool at first entering the horizontal flue or chamber. The whole interior may be washed clean by a hose.

To illustrate the method of working ores and the manner of treating them after being reduced to the condition of soluble salts, we will take the example of an ore of copper. Let us suppose that the furnace has been worked as we have described till the water in the trough and settling tank and tubs is comparatively saturated with soluble salts.

One method of proceeding would be to evaporate to dryness. The residue will consist of crystals of impure sulphate of copper, which we render anhydrous by heat, and eliminate the sulphuric acid by appropriate means, of course collecting and preserving the same. We shall then have remaining oxide of copper with a small percentage of impurity, which we can disregard. This oxide of copper becomes valuable in a part of the process to be hereinafter described; or we may reduce it to the metallic state by roasting with a reducing-flame on the floor of a reverberatory furnace; but this branch of our process we reserve for another application. Instead, however, of using heat to evaporate our sulphate solution, we economize our fuel by taking advantage of the variable solubility of sulphate of copper in water of different temperatures. At the boiling-point we can dissolve about twice as much of the salt as at 60°. It is the capacity of the air for water that is an efficient agent in evaporation; and if we constantly replace the stratum of saturated air by a stratum of dry air we can evaporate any watery solution much quicker than by boiling. So from a well in the corner of our tank we draw off the clear liquid by means of a steam siphon or pump, of wood, lead, copper, or india-rubber, into shallow vats, unitedly large enough to hold the entire charge of, say, twenty-six tons of liquid, containing from ten to thirteen tons of sulphate of copper in solution. These vats may be superposed on each other, with a passage for air between, and over the surface of the liquid contained in them is drawn or forced from a large fan-blower a blast of air. This apparatus is represented in the drawings, in which F B is the fan-blower, and C V the crystallizing-vats. The vats may be made of wood, and should be lined with asphalt paper or cloth.

One-half or more of the sulphate of copper will be thrown down in crystals by evaporation and cooling. This method of crystallization and evaporation is, of course, valuable whenever any salt possesses variable solubility at different temperatures.

The mother-liquor is now either drawn back into the furnace, to be further charged by the continuation of the process of lixiviating the ore by our method, or it is transferred to the precipitating-tub, to be reduced to metallic copper in the photosulphate, (CuO,SO_3.) The precipitating-tub is a wooden vessel about three feet deep and capable of containing some ten tons of water. By reference to Fig. 9 its operation will be well understood. P *t* is the tub. Around its interior is coiled a steam-pipe, preferably of lead, and within it is placed a disturber, consisting of a perpendicular shaft, *p s*, which revolves at a velocity of about fifteen turns in a minute. To this shaft is fixed the disturbing-tub *d t*, pierced with holes at the bottom and sides, and carrying in its interior masses, fragments, or powders of iron, *p i*. This apparatus is intended to produce a relative motion in the presence of heat between sulphate-of-copper waters and metallic iron, by which the metallic copper is thrown down in fine powder, the iron is dissolved, and sulphate of iron remains in solution. Any apparatus that will produce this relative motion of iron and sulphate-of-copper water in presence of heat will produce this result, which we claim as our own discovery.

The solution of sulphate of iron we may evaporate and crystallize as we did that of sulphate of copper.

The metallic copper thrown down is shoveled from the tank, washed, and is a marketable article, being almost chemically pure.

To prevent mistakes in the use of this method, we will state that iron filings and turnings—wrought or sheet iron—are not desirable; scrap, cast, and broken pig-iron are better; and the best of all is "revived iron," as we call it, a powder to be obtained by a method of which we shall treat in another application.

We now return to the method of using oxide of copper previously alluded to. In operating the water-furnace, as described in the earlier part of this specification, we were obliged to use a chemical-wheel, to save a portion of the sulphurous acid and to prevent the fumes of the furnace from passing into the atmosphere. By the following method of employing oxide of copper we avoid this necessity, and render the chemical-wheel little more than a simple draft-wheel, obtain sulphate of copper as a product instead of gypsum or sulphate of an alkali or alkaline earth, and thus reduce the cost of metallic copper still more by rendering more valuable a product of the process. This oxide of copper, obtained by the elimination of the sulphuric acid from the sulphate, is introduced into the air-blast in conjunction with the ore and fuel, and passes into the furnace. The result is that very little or no sulphurous acid passes the wetting-wheel, that the production of sulphate of copper is increased, and that but a trifle of the oxide is found in the furnace, and then always in the last chamber, which we wash into the trough with a hose, after which it gives us no trouble and we find no further trace of it.

We take the reaction to be as follows: The sulphuret, in presence of heat and oxygen, becomes sulphurous acid, which abstracts the oxygen from the oxide of copper and forms sulphuric acid, and thus at once combines with an oxide of copper formed of the same equivalent of copper just set free, and which has, meantime, combined with an equivalent of sulphate of copper, and is dissolved in the water of the trough. The following diagram illustrates the supposed reaction:

$$\left\{\begin{array}{l} \quad \nearrow CuO \\ {}^{0}CuO \qquad > Cu,SO_3 \\ SO_2 > SO_3 \end{array}\right\}$$

One hundred and eighty-five pounds of finely-pulverized charcoal, fed through the air-blast and the head of the furnace and burned in aerial combustion, will sustain a column of incandescence equal to that of a wind-furnace or a puddling-furnace. The finely-powdered ores of copper, however, do not require so great a degree of heat; but if the ores contain bismuth, tellurium, or titanium in any quantity, the amount of floated charcoal or other pulverized fuel must be very nearly two hundred pounds per hour; but every six pounds of carbon require sixteen pounds of oxygen or eighty pounds of atmospheric air for complete combustion, and for the salification and oxidizing of the equivalents in the ore still greater quantities of air are required; so that for a furnace whose tower is three feet in diameter at the dome, four at the base, and eighteen feet high, we provide fans capable of throwing from sixteen to twenty tons of air an hour, which will contain three or four tons of oxygen. Our experience shows us that not more than half the oxygen of the atmosphere is promptly available for immediate combustion, so that twenty tons of atmospheric air will give us but two tons of available oxygen. This can readily be delivered to the furnace by the fan-blower A; but as sudden increase of heat causes a sudden and violent expansion of the air as it enters the furnace, we must make the capacity of the draft and spray or exhaust wheels five or six times greater than that of the feed-wheel, and as the air-opening into the furnace is a circle of a foot in diameter, the succeeding flues are all made with at least a sectional area of six superficial feet, and as a general rule the air-openings should enlarge as their distance from the focus of heat increases, to allow for the expansion by heat and the addition of several volumes of carbonic acid and other gases generated by combustion and the action of the furnace on the ores.

With good management the consumption of coal in the four fire-boxes ought not to exceed one hundred pounds of carbon an hour; and for the generation of steam and the movement of the fans, draft-wheels, and other incidental machinery of the furnace, one hundred pounds an hour, or a ton and a quarter in twenty-four hours, of good anthracite coal should suffice.

With this quantity of fuel—namely, four hundred pounds an hour—co-operating in these different ways, it is possible, and even easy, to expel the sulphur from three or three and a half tons of ten per cent. copper ore, for it is conjoint action of the incandescence of the ore in oxygen and its lixiviation in water or sulphuric acid co-operating at the water-line that gives great rapidity of action to this furnace and process.

To estimate in advance how much ore can be lixiviated hot in a given time would be almost impossible. The elements to be considered are the absolute quantities in the ore to be treated of sulphur, arsenic, bismuth, lead, iron, copper, and other oxidizable equivalents; the temperature of the water-bottom in which, and not in the air, the process of lixiviation is effected; the quality of the fuel, the spongy charcoals and lighter mineral coals giving better results than other fuel, owing doubtless to more rapid combustion; the dryness of the atmosphere, for though steam is decomposed into combustible gases its effect is inferior to that of pure dry carbon; and the condition of the ores with regard to moisture must also be considered. Those ores, too, which consist chiefly of iron and sulphur, like the Colorado gold ores, give the best results, for the iron gives forth an intense heat while in combustion; and by no means the least important element in calculating the value of the water-furnace as a metallurgic instrument will be the intelligence of the foreman and his attention to his work. He can waste fuel at his option unless it is withheld by the proprietors; but by making his wages depend on the quantity of ore lixiviated and the value of the returns after deducting the cost of labor and fuel consumed to accomplish it, we can render him economical and careful, and in well-managed works this rule will eventually obtain.

The disulphurization is very imperfectly and partially effected before the ore strikes the water, although the whole tower and first chamber are filled with flame. Perhaps one-fourth to one-half may be separated by heat in the tower; but from the instant the heated particles strike the water its disulphurization is complete. Ore caught in the air before reaching the water bottom must be boiled in two baths of dilute sulphuric acid before complete separation of metal and sulphur is effected, and this renders the dry method exceedingly troublesome and expensive.

No proper means have yet been found to reduce the ores to powder sufficiently fine for this treatment, save the mills invented and patented by us, which pulverize by mutual attrition.

In the pulp of the settling-tank will be found silica, and, generally, a small portion of alumina, oxide of iron, chiefly magnetic. If the ore contained lead it will appear as oxide or sulphate. Zinc may be found as oxide; but if there be sulphuric acid present, as there will after the furnace has been worked, the protoxides will be dissolved and be found in the solution as sulphates. Gold will appear in its native condition in small particles, and the surface of the particles will be brightened, by passing through a heated atmosphere and plunging at once in water, so as to be admirably adapted for amalgamation, while the simple heating of gold in an atmosphere of oxygen does not have this effect. Silver will always take the metallic form when the ores are passed through the furnace at sufficiently high temperature, since any oxide that might be found would be decomposed by the intense heat into metallic silver in a spongy form and oxygen. If we use chloride of sodium as a flux or auxiliary chemical, chloride of gold would be found, which would be reduced by the salts present, giving pure metallic gold as the result.

By careful management of the water-furnace we can produce solutions of many other metals, and several in their native forms; but we do not propose in this application to describe all the results. In treating ores of bismuth a temperature of 3000° is necessary. The action of our precipitating-tub, with its disturber, Fig. 9, is not confined to salts of copper; the combined effect of heat and a relative movement of the solution and precipitating agent is equally marked in the case of bismuth and silver. We may accelerate this action by passing electric or galvanic currents through the liquid. If, for instance, we have obtained a salt of silver by the action of the furnace or in some subsequent operation, it will be well to use a copper surface, as the pole of a galvanic battery, to favor its deposition. In such case, however, we should employ two metals attached to the sides of the disturber or revolving tub, and connected across by wires. In every case the solution should be kept hot, in no instance less than about 200°; and when we simply replace the copper in a solution by iron the temperature cannot be too high, rapid ebullition being the best condition for obtaining large results of precipitated copper. The galvanic circuit between the iron and copper is in this case of little benefit.

In the drawings, the first sheet, representing the longitudinal section of the interior, is lettered and explained by a syllabus on the drawings.

What we claim as our invention, and desire to secure by Letters Patent, is —

1. The construction of the interior of the tower in the form of a hollow truncated cone, for the purpose of securing perfect combustion and the exposure of all the material, especially the fuel, to heat and oxygen.

2. The construction of the head of the furnace with dome and arched flues above the fire-boxes, forming groins at their springs, substantially as described, for the purpose of forming a focus of combustion near the head of the furnace.

3. The arrangement of the chimney F and telescopic slide G, with its counterpoise and flanges, as drawn, substantially as and for the purpose described.

4. The arrangement of the feed apparatus so as to discharge the ore and coal to be supplied to the air-blast on the side of the fan-blower A away from the furnace, as and for the purpose described.

5. The division of the horizontal flue into chambers, substantially as described, to secure more perfectly the hot lixiviation of the ores, and the similar division of the conductor L into chambers, as and for the purpose described.

6. The arrangement and combination of the settling-tank U with the water-bottom and pool by means of water-exit and water-entrance, and the further arrangement of the propeller or conveyer M in combination with said water-bottom and pool, as and for the purpose described.

7. The employment of a wetting-wheel succeeded by a chemical wheel to remove dust and gases from air when said wheels are sufficiently separated to allow the effect of the first to be complete before the air to be purified comes under the action of the second, and the arrangement of a trap or valve in the intermediate conductor to balance the draft and projection of the two wheels.

8. The arrangement of the inclined floor *h* of the spray-chamber, in combination with the overflow *a*, settling-tubs, and their overflows *b* and *c*, and with the water-chamber of the spray-wheel, substantially as described.

9. The employment of oxide of copper or other reducible protoxide, fed into the head of the furnace, substantially as described, and for the purpose stated.

10. The means of brightening gold herein described by the employment of heat and instantaneous plunging into water or dilute acid.

11. The evaporating apparatus, substantially as described, consisting of shallow tanks or vats, forming the bottom of an air-flue, through which is drawn or forced an artificial current of air, when employed to evaporate a heated solution of sulphate of copper, which cools as the operation proceeds, in order to effect the crystallization of the salt to its greatest practical extent.

12. As a manufacturing process, to effect from a solution of sulphate or chloride of copper, or other soluble metal, the precipitation of pure metal in quantity, as distinguished from assay, by the substitution of another metal, such as iron, in the solution, the employment of heat and relative motion between the solution and the precipitating metal, and with or without auxiliary galvanic currents distinct from those of local action, substantially as described.

13. The employment of heat and relative motion between the solution and the poles of a battery to accelerate the action of the galvanic current in electro-precipitation of metals, substantially as described.

JAMES D. WHELPLEY.
JACOB J. STORER.

Witnesses:
THOS. WM. CLARKE,
CHARLES BATEMAN.