Mar. 3, 1925. 1,528,206

W. E. GREENAWALT

APPARATUS FOR TREATING ORE PULP WITH GAS

Filed April 2, 1923

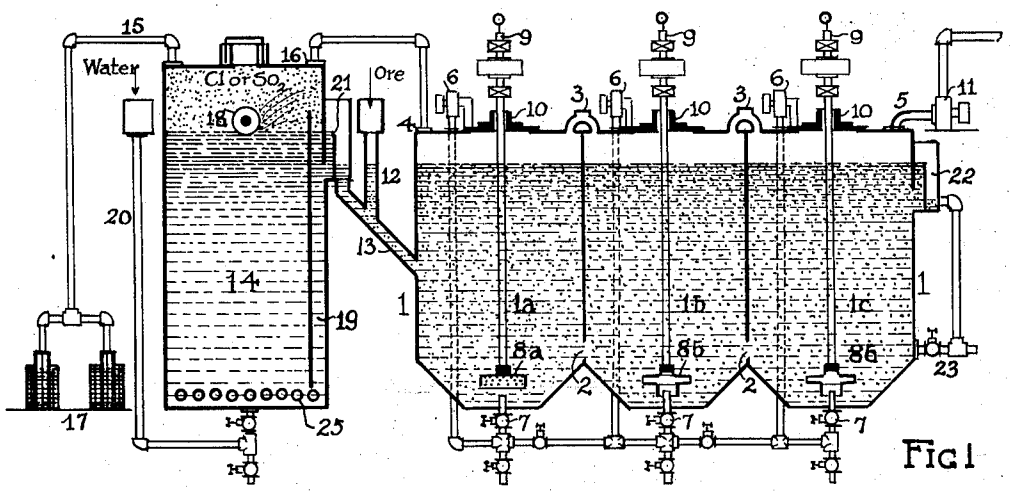


Fig 1

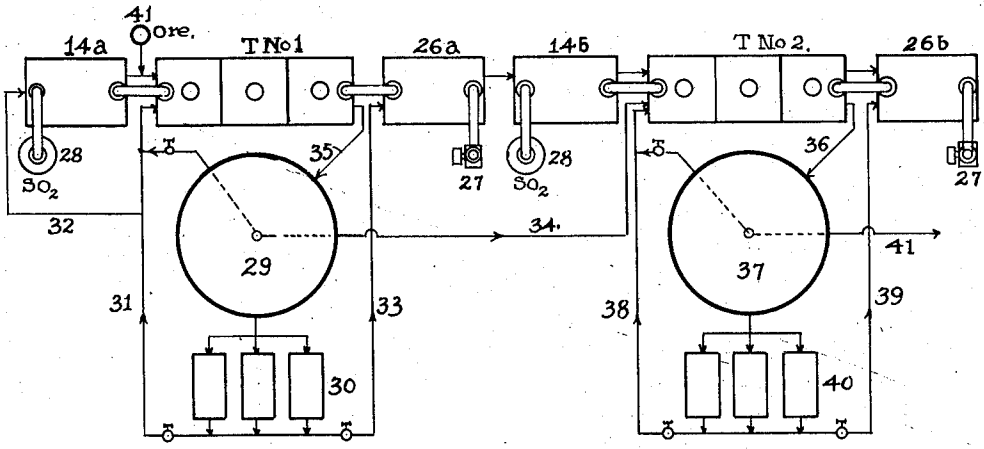
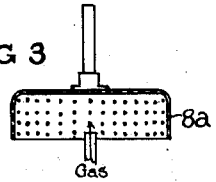


Fig 2

Fig 3



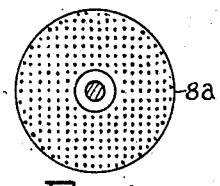
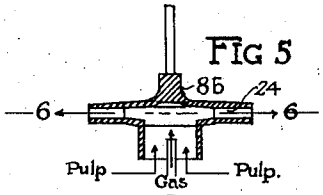


Fig 4

Fig 5



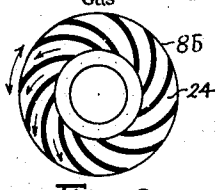


Fig 6

INVENTOR

William E. Greenawalt

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UNITED STATES PATENT OFFICE.

WILLIAM E. GREENAWALT, OF DENVER, COLORADO.

APPARATUS FOR TREATING ORE PULP WITH GAS.

Application filed April 2, 1923. Serial No. 629,360.

To all whom it may concern:

Be it known that I, WILLIAM E. GREENAWALT, a citizen of the United States, residing in the city and county of Denver and State of Colorado, have invented certain new and useful Improvements in Apparatus for Treating Ore Pulp with Gas, of which the following is a specification.

The invention has as its object the effective treatment of ores, especially ores of copper containing precious metals, with gases, especially corrosive gases, such as chlorine or sulphur dioxide. The effective treatment of finely ground ore with a corrosive gas, has always presented a difficult problem, and it cannot be said to have been effectively solved. Rotating barrels have been generally used, but barrels are expensive to install, expensive to operate, and are very unsatisfactory, owing largely to the fact that the treatment is intermittent, and that the gas cannot be progessively applied.

Agitation in a stationary tank is quite simple if air is used as the agitating gas. No difficult impregnation problem is involved in that case, and compressed air can easily be introduced into the bottom of the tank to agitate the liquid and then be allowed to escape at the top. With corrosive gas agitation and impregnation it is entirely different. The gas has to be used to agitate and to impregnate the liquid, and conditions have to be arranged so that none of the gas, or but very little of it, is wasted. The gas should be progressively applied, so that all, or nearly all, is consumed. In addition to this, if ore sludge is treated, the gas has to be applied in such a way as to keep the ore particles under continuous agitation, to get the desired extraction of the metals, and also to prevent the ore from settling, and thus clogging the apparatus and making it inoperative. If clogging occurs, except at rare intervals, the entire apparatus would become impractical.

One object of this invention, therefore, is to provide an apparatus for the treatment of ore pulp, in which the gas can be progressively applied to agitate and impregnate the liquid, and so that the gas will be progressively consumed.

At the present time, as also in the past, the application of corrosive gas to fine ore pulp, has had to be applied in small units, and when large capacity was desired, the units, such as chlorination barrels, had to be indefinitely multiplied. The capacity of chlorination and similar barrels rarely exceed ten tons of ore at a charge, and the amount of ore treated per day rarely exceeds 50 to 60 tons. Besides, the gas could not be effectively applied, and usually inferior results are obtained.

Another object of this invention is to provide an apparatus of large unit capacity, exceeding, if need be, units of 1000 tons of ore per day, and in which the operator will at all times have excellent control of both the gas and the ore pulp to get the results desired. Other uses will be evident.

The apparatus can best be described by referring to the accompanying drawings, in which Fig. 1 is a longitudinal section; Fig. 2 a diagrammatic plan, or flow sheet, of the application of the apparatus to the treatment of finely ground copper ore with sulphur dioxide to extract the copper; Figs. 3 and 4 are details of one form of agitator, or atomizer; Fig 3 being the section and Fig. 4 the plan; and Figs. 5 and 6 are details of another form of agitator, or atomizer; Fig. 5 being the section, and Fig. 6 the plan.

In the drawings, 1 is a treator, taken as a whole, and is preferably composed of a number of units, or tanks, 1^a, 1^b, and 1^c. The number of tanks, in practice, will depend on the amount and the nature of the material to be treated. The treator 1, is adapted to contain a liquid, or ore sludge, and to confine a gas over the liquid, and preferably arranged so that the liquid in the respective tanks can flow progressively from one tank to the next of the series, through communicating passages 2, which will ordinarily be located in the lower portion of the tanks, especially if the ore to be treated is rather coarse, so that the ascending gas would be unable to elevate it to any considerable height. It is also desirable to have communicating passages 3 in the upper portion of the tanks, so that the gas can flow progressively from one tank to the next, in its passage through the treator, from the gas inlet 4 toward the gas outlet 5. Each tank composing the treator is provided with an exhauster 6 which exhausts the gas from the upper portion of the respective tanks and forces it into the lower portion, through the pipes 7. These pipes are arranged so that the gas from the exhausters can be delivered to the same tank

from which it was exhausted, or to the adjacent tank, or a portion to both tanks. Suspended within each tank and submerged in the liquid is a rotary agitator, or atomizer, 8, so designed and arranged that the gas delivered into the lower portion of the tank will pass through the agitator in its ascent through the liquid and be distributed in finely divided particles into the surrounding liquid in the tank.

The agitators may be of the form shown by 8^a, or by 8^b. Either form will give good results. The material to be treated will largely determine the details of the agitator. The agitators will usually be made of acid resisting metal, such as antimonial lead. The shaft 9, will usually also be covered with lead to protect the steel from the corrosive action of the gas and liquid. A stuffing box, 10, where the shaft enters the tank, will prevent any leakage of gas. The stuffing box is made removable and large enough so that when it is removed, the agitator may be withdrawn from the tank through the opening. An exhauster 11 creates a flow of gas through the various tanks, and maintains a suction inwardly, so that there will be no escape of corrosive gas to contaminate the atmosphere in the vicinity of the apparatus and thus make annoying conditions for the workmen. The ore, which will usually be in the form of a thick sludge or fine powder, is introduced into the treator through the inlet 12. Whether the ore is dry or in the form of a thick sludge, it will be necessary to add more water, or solution, to give it the proper consistency for the most effective results in the treator.

Under these conditions, it is desirable to first treat the liquid with the gas, so that the liquid will be charged with the gas before it comes in contact with the ore. This saves time, besides, the charging, or treating, of the liquid with the gas, when the liquid is free, or comparatively free of insoluble particles, is very much easier than to start the impregnation of the ore pulp in the treator. For this reason it is desirable to have a relatively large tank, or impregnator 14, adapted to contain a relatively large pool of the liquid, and means adapted so that the liquid of the pool can be under continuous treatment of the gas. In this way, all the preliminary reactions with soluble matter in the liquid will take place in the impregnator, and the liquid will be charged with the gas, as it enters the treator, and thus effect a saving of time and expense, in the more expensive treatment in the treator. The impregnator 14, consists essentially of a tank adapted to contain a pool of liquid and to confine a gas over the pool, and has a gas inlet 15 and a gas outlet 16. The gas inlet communicates with the gas producer 17, and the gas outlet communicates with the gas inlet 4, of the treator 1. Within the impregnator 14 is a horizontal rotary sprayer 18, so arranged that the liquid of the impregnator is continuously sprayed into the gaseous atmosphere above the liquid. This sprayer throws a considerable portion of the liquid against the sides of the tank, at a higher elevation than the normal level of the liquid, so that the spray, charged with the gas, falls into the duct 19, and thus produces a circulation of the liquid within the impregnator, so that all the liquid in the impregnator is at all times treated with the gas, and can be drawn in a continuous stream into the treator 1. The liquid flows into the impregnator 14 in a continuous stream through the pipe 20, and overflows through the weir arrangement 21, which maintains a constant liquid level in the impregnator 14. The treated liquid, overflowing in a continuous and regulated stream through the weir 21, from the impregnator 14, is mixed with the fine dry ore, or thick ore sludge, introduced through the pipe 12, and the mixture then flows into the treator through the pipe 13. A weir overflow 22, in the treator 1, maintains a constant liquid level in the treator. The overflow, or outflow, is so arranged that if there are any heavy sand particles in the pulp which cannot readily be lifted to the weir, they can flow out through the pipe 23, near the bottom, in regulated amounts. A small continuous stream of sand and liquid will, in such cases, flow out through the pipe 23, to take the heavier particles of suspended matter, while the main stream will overflow through the weir 22.

The exhauster 11, creates a flow of gas from the gas generator 17 through the entire system; this prevents escape of gas, and overcomes the annoyances when the gas is used under pressure. It is desirable to treat the liquid in the impregnator 14 with the strongest gas, and then pass the excess on through the apparatus, preferably, in the same direction as the main stream of material being treated. The advantage of this is, that most of the gas is consumed in preparing the liquid, and in the first reactions with the ore pulp, and once these more energetic reactions have been completed, it is quite easy to keep the pulp saturated, or charged, with the gas. In this way, the reactions start at once, and the treatment is effective from start to finish.

While the exhauster 11 creates a general flow of gas through the entire system, the exhausters 6 must be adapted to have a greater suction than the exhauster 11, so that a portion of the gas in all the tanks can be withdrawn from the main stream, above the surface of the liquid, and again introduced into the liquid through the bottom of the tanks, to pass through the rotary atomizers

8 in its ascent through the liquid. In this way the ore pulp in the treators is effectively agitated and impregnated.

The action of the atomizers can best be described by referring to the details, in Figs. 3, 4, 5, and 6. Referring to Figs. 3 and 4: the gas introduced through the bottom of the tank rises through the liquid, and as it ascends it enters the rotary hooded and perforated atomizer 8^a, so that a continuous stream of gas and ore pulp passes through the perforations while the atomizer is rotating at the rate of from 200 to 400 R. P. M. This thoroughly agitates and impregnates the liquid, or ore pulp, and maintains the pulp charged with the gas. Referring to Figs. 5 and 6: the operation is a little different, although the result is much the same. The gas and some of the pulp enters the atomizer 8^b, and the atomizer, rotating at a speed of from 200 to 400 R. P. M., ejects the mixture of gas and liquid through the discharge passages 24 into the surrounding liquid in the tank, and in this way the gas is atomized in the liquid while the liquid, or pulp, is under continuous agitation, both on account of the rotation of the atomizer and on account of the ascending atomized gas.

It is evident, that when corrosive gases are used, such as chlorine or sulphur dioxide, and quite certainly also in such cases where an acid solution is used, the construction of the agitator, or atomizer, is of importance. Neither the atomizer itself nor that portion of the shaft that is within the tank, can be constructed of the ordinary material, such as iron. It is on this account that the apparatus presents some advantages in construction. The atomizers 8^a or 8^b may be easily cast of some acid resisting material, such as antimonial lead, and the portion of the steel shaft inside of the tank can readily be covered with lead. This does not present any unusual difficulty. The shaft outside of the tank, as also the bearings and driving mechanism, may be constructed as usual and with the ordinary materials. A stuffing box 10 is arranged in the cover of the tank to prevent the leakage of air in, or of possible leakage of gas out. This stuffing box is made a little larger than the atomizers, so that when it is desired to renew or repair an atomizer the stuffing box 10 can be unscrewed from the top of the tank, and the entire agitating mechanism lifted vertically with a block and tackle and removed through the opening.

In an arrangement of the sort described, where there is a main stream of gas flowing through the apparatus above the liquid and secondary streams circulated through the liquid in the various tanks composing the apparatus, difficulty is likely to develop on account of the possible or probable uneven volumes of gas handled by the respective exhausters. It is largely on this account that the communicating gas passages 3 are provided for. If the volume of gas handled by the respective exhausters 6 is not the same, or the consumption of gas in the respective tanks is different, an equalization effect is obtained through the communicating gas passages throught the entire system, while, nevertheless, the main stream of gas is always from the gas inlet toward the gas outlet. The exhauster 11 is supposed to work only under enough suction to prevent the escape of gas from any portion of the apparatus, and to always maintain only a slight suction inwardly.

A brief description of the apparatus will now be given in its application to the treatment of ores, with a chloride solution, containing, say, copper, gold, and silver, and possibly lead and other metals. The extraction of gold from copper ores by a wet process has always presented great difficulties, and in most cases these difficulties have been practically insurmountable.

The impregnator 14 and the treator 1 may be presumed, in starting, to be filled with leaching solution obtained from previous operations, and it may be assumed as an acid chloride solution. The chlorine cells 17, in which common salt is decomposed into chlorine and caustic soda, are started to operate, and the chlorine is flowed, by means of the exhauster 11, into the impregnator 14, where the solution is charged with the gas and where the preliminary solution reactions take place, such as the conversion of ferrous iron to ferric iron. If there is gold in the ore, the solution in the impregnator 14 is saturated with chlorine. The rotary sprayer 18, which may be considered as a number of lead discs about a foot in diameter mounted on a horizontal shaft, and rotating at about 1000 R. P. M., fills the gas space above the liquid with a mist and fine spray, which effectively charges the sprayed liquid with the gas, and thus the entire pool of liquid becomes charged with the gas. A portion of the liquid is sprayed against the side of the tank, and drops into the duct 19 and produces a mild circulation of the entire mass, and thus the entire pool of liquid is always charged, or treated, with the gas. The charged liquid flows from the impregnator 14 into the pipe 13, where it is mixed with the ore from the pipe 12, and the mixture of ore and liquid, as also the stream of excess gas, flows into the treator 1. The gas absorbed by the liquid in the impregnator is quickly consumed, and to make the treatment continuous and effective, a portion of the main stream of gas is exhausted from above the liquid, and introduced into the lower portion of the liquid, and in its ascent through the liquid, or pulp, it is

atomized and distributed by the atomizers 8[a] and 8[b], and thus the liquid is charged with the gas, in the treator, as rapidly as the gas is consumed in acting on the ore pulp, or other gas consuming compounds in the liquid. The agitation helps to dissolve the metal values, and effectively prevents any settling of ore particles. If, for any reason settling should occur and the agitators become stopped, the ore could easily be agitated by increasing the volume of gas, temporarily, and thus clear the obstruction. In the way described, the ore is treated for several hours, and the stream of pulp through the treator is regulated so that the rate of flow is proportioned to the extraction desired, as determined by experience. The time of treatment will usually vary from one to three hours. It will usually be desirable to heat the liquid; this can be done by means of the steam or hot water pipes 25 in the impregnator 14. The excess gas, after the entire treatment, will probably be small: it is preferably exhausted into another impregnator, similar to 14, filled with fresh solution, where it is quickly and completely absorbed. The treated ore pulp, in which the metals are now in solution, mostly in the form of chlorides, is then flowed into a separator tank, where the liquid is separated from the gangue, and the gangue wasted. The metals may be precipitated from the clarified solution by any of the well known methods, and the depleted solution returned to the impregnator, to be passed through another cycle, as the one described.

The application of the apparatus, as applied, for example, to the treatment of oxidized copper ore with sulphur dioxide, will now be described, reference being made to Fig. 2, more particularly, but having also in mind the other figures. It is well known that copper sulphite, produced from leaching copper ore with sulphurous acid, is not very soluble in water, and hence, the ore usually requires several treatments with the gas.

The water, or solution, is charged with the gas in the impregnator 14[a], as described for 14, in Fig. 1, and the solution, mixed with the ore, is then flowed into the treator, T No. 1, where the ore pulp is agitated and charged with the gas as rapidly as the gas is consumed. The treated pulp, now containing a considerable portion of the copper in solution as the sulphite, flows into the separator 29, which may be presumed to be something after the order of a Dorr thickener, where the clear copper solution is separated from the insoluble residue. The insoluble residue, without any particular washing, is then flowed from the separator 29 into the treator T No. 2, through the pipe 34, where it is again treated with a sulphur dioxide solution practically free from copper, so that more copper can be brought into solution, and this is continued until the copper is sufficiently extracted. The barren residue may then be wasted through the pipe 41. The clear copper solution, issuing from the separator 29, is flowed into the precipitator 30 where the copper is precipitated, in whole or in part, by any of the well known methods, such, for example, and preferably, by electrolysis or hydrogen sulphide. By either of these methods an amount of acid is regenerated corresponding to the amount of copper precipitated. A portion of the depleted copper solution may be returned to the impregnator 14[a], through the pipe 31, or to the treator T No. 1, and another portion, or the whole, as the case may be, is flowed, through the pipe 33, into the impregnator 26[a], which is like the one shown by 14, Fig. 1, in which the excess gas is absorbed by the solution. Since the solution is entirely depleted of gas, recovery of the excess gas by the solution, is not difficult. The solution, now having absorbed the excess gas from treator T No. 1, is then flowed into impregnator 14[b], where the solution is saturated with fresh gas. The outflowing charged solution from the impregnator, mixed with the ore residue from the separator 29, is again treated in T No. 2, as described in treator T No. 1. The excess gas flows into the impregnator 26[b], where it is absorbed as described for 26[a]. The treated ore pulp flows into separator 37, where the clear copper solution is separated from the insoluble residue. If the copper is sufficiently extracted, the residue may be wasted; if not, the cycle is repeated. The clear copper solution, now containing some of the copper as sulphite, and some as sulphate, due to the regenerated acid from the previous precipitation, in precipitators 40, and the solution, depleted in copper and regenerated in acid, returned to the residue, applied to fresh ore, or wasted, as the conditions may determine.

As an illustration of the large unit capacities of which the apparatus is capable of being installed, tanks 10 feet square and 20 feet high, having a depth of liquid of 15 feet may be considered. Each tank would hold about 45 tons of pulp and not less than 10 tons of ore. If there are ten tanks in series, and the time of ore treatment is 2.4 hours, the capacity, per day of 24 hours, would be about 1000 tons of ore.

The treator portion of this invention may be considered as a modification, or continuation in part, of the invention shown in my Patents No. 1,340,826, May 18, 1920, and No. 1,374,500, April 12, 1921. The impregnator 14, or modification of it, is more fully described in my Patent No. 1,353,995, Sept. 28, 1920, and in my pending application, Serial No. 485,884, filed July 12, 1921.

The rotary member, or impregnator, 8^b, creates quite a suction in the gas pipe communicating with it and with the gas over the liquid. If properly designed, and if the liquid is not too deep, the exhauster 6 may be dispensed with, and the flow of gas from the upper portion of the tank through the impregnator 8^b induced by the suction of the impregnator alone.

Obviously, the gas, instead of passing from the first treator (Fig. 2) into the second treator, may be applied direct to the second treator, T No. 2. This would be desirable, for example, in the treatment of copper ores containing other metals, such as gold, silver, cobalt, nickel, etc., in which it would be desirable to leach out the copper from the ore, or a portion of it, before applying free chlorine to extract the remaining metals.

I claim:

1. In metallurgical apparatus, a tank adapted to contain a pool of liquid and to confine a gas over the pool, means arranged for flowing liquid through the tank and mingling it with the pool, suction means for flowing gas through the tank over the liquid, suction means for exhausting a portion of the gas from above the liquid and introducing it into the lower portion of the tank through a stationary pipe, and means arranged in the lower portion of the tank for subdividing the gas in its ascent through the liquid.

2. In metallurgical apparatus, a tank adapted to contain a pool of liquid and to confine a gas over the pool, means arranged for flowing liquid through the tank and mingling it with the pool, means for flowing gas through the tank over the pool of liquid, means for withdrawing a portion of the gas from above the liquid and introducing it below the surface of the liquid through a stationary pipe, and a hollow rotary member open at its lower portion and having discharge passages suspended within the tank and submerged in the liquid which receives the gas in its ascent through the liquid and ejects it in finely divided particles into the surrounding liquid in the tank.

3. In metallurgical apparatus, a tank adapted to contain a pool of liquid and to confine a gas over the pool, means arranged for flowing liquid through the tank, means for flowing gas through the tank over the liquid, a hollow perforated rotary member open at its lower portion suspended within the tank and submerged in the liquid, and means for withdrawing gas from above the liquid and introducing it into the lower portion of the tank through a stationary pipe, said pipe and rotary member being arranged so that the gas in its ascent through the liquid will pass through the rotary member and be ejected in finely divided particles into the surrounding liquid in the tank.

4. In metallurgical apparatus, a tank adapted to contain a relatively large pool of liquid and to confine gas over the liquid, a hollow rotary member having discharge passages mounted on a vertical axis and journaled within the tank, means arranged for flowing liquid through the tank and mingling it with the pool, means for flowing gas through the tank over the liquid, means for withdrawing gas from above the liquid and introducing it in the lower portion of the tank through a stationary pipe, said pipe and rotary member being arranged so that the gas in its ascent through the liquid will pass through the discharge passages of the rotary member, and means for maintaining a slight suction inwardly in the tank.

5. In apparatus for treating liquids with gases, a tank adapted to contain a relatively large pool of liquid and to confine gas over the liquid, a rotary member journaled on a vertical shaft suspended within the tank and submerged in the liquid, suction means for flowing gas through the tank over the liquid, means for withdrawing a portion of the gas from above the liquid and introducing it in the lower portion of the tank through a stationary pipe, said pipe and rotary member being arranged so that the gas in its ascent through the liquid will be atomized by the rotary member, and a removable section in the cover of the tank surrounding the shaft through which the rotary member may be inserted in and removed from the tank.

6. In metallurgical apparatus, a series of tanks communicating with one another and adapted to contain pools of liquid and to confine gas over the liquid, rotary members journaled on vertical shafts suspended within the respective tanks and submerged in the liquid, means for flowing liquid progressively through the respective tanks, suction means for flowing gas through the respective tanks over the liquid, means for withdrawing gas from above the liquid in the respective tanks and introducing it through stationary pipes into the lower portion of the tanks, said pipes and rotary members being so arranged that the gas in its ascent through the liquid will be atomized by the respective rotary members.

7. In metallurgical apparatus, a series of tanks adapted to contain liquid and to confine gas over the liquid and arranged with communicating passages between the tanks for the gas and the liquid, rotary members mounted on vertical axes suspended within the respective tanks and submerged in the liquid, means for flowing a stream of liquid progressively from one tank to the next of

the series, suction means for flowing a stream of gas progressively through the tanks over the liquid, and means for withdrawing gas from the main stream above the liquid and introducing it in the lower portion of the respective tanks to be subdivided by the rotary member in its ascent through the liquid.

8. In metallurgical apparatus, a series of tanks adapted to contain liquid and to confine gas over the liquid and arranged with communicating passages between the tanks for the liquid, means for introducing gas into the tanks above the liquid, exhausters for withdrawing gas from above the liquid of the respective tanks and introducing it below the surface of the liquid, and means arranged for equalizing the gas pressure in the respective tanks due to variations in the operation of the respective exhausters.

9. In metallurgical apparatus, a series of tanks adapted to contain pools of liquid and to confine gas over the liquid, means for exhausting gas from above the liquid of the respective tanks and introducing it in the lower portion of the tanks through stationary pipes, means for sub-dividing the gas in its ascent through the liquid in the respective tanks, and means arranged to flow the gas and liquid progressively through the respective tanks.

10. In metallurgical apparatus, a series of tanks adapted to contain pools of liquid and to confine gas over the liquid, means for exhausting gas from above the liquid of the respective tanks and introducing it in the lower portion of the tanks through stationary pipes, means for subdividing the gas in its ascent through the liquid in the respective tanks, and means arranged to flow the gas and the liquid progressively through the respective tanks in the same direction.

11. In metallurgical apparatus, a treator comprising a series of tanks adapted to contain pools of liquid and the material to be treated and to confine gas over the liquid, an impregnator comprising a separate tank adapted to contain a pool of liquid and to confine gas over the liquid, means for treating the liquid in the impregnator with the gas, means for flowing both the liquid and excess gas from the impregnator into the series of tanks comprising the treator, and means for treating the liquid and the material in the respective tanks with the gas by withdrawing the gas from above the liquid of the respective tanks and introducing it in the lower portion of the tanks.

12. In metallurgical apparatus, a series of tanks communicating with one another and adapted to contain ore pulp and to confine gas over the pulp, an impregnator communicating with the series of tanks and adapted to impregnate a liquid with a gas, means for introducing ore pulp and the impregnated liquid into the series of tanks, means for introducing the excess gas from the impregnator into the series of tanks, means for withdrawing gas from above the liquid of the respective tanks and introducing it in the lower portion of the tanks, and suction means for flowing the gas through the liquid impregnator and series of tanks over the liquid.

13. In metallurgical apparatus, a series of tanks adapted to contain pools of liquid and to confine gas over the pools, means for flowing a stream of liquid through the tanks and mingling it with the respective pools, means for withdrawing gas from above the surface of the liquid and introducing it into the lower portion of the respective pools, rotary members in the respective tanks adapted to agitate the liquid and to subdivide the gas introduced in the lower portion of the tanks in its ascent through the liquid, and means for progressively advancing the excess gas from one tank of the series to the next.

14. In metallurgical apparatus a tank adapted to contain liquid and to confine gas over the liquid, a hollow gas distributing member within the tank submerged in the liquid having a vertical fluid inlet in its lower portion and horizontal fluid discharge passages in its upper portion and adapted to receive separate streams of gas and liquid and to eject a mixture of gas and liquid in substantially horizontal streams into the surrounding liquid in the tank, and means for delivering gas from the tank above the liquid into the lower portion of the hollow gas distributing member.

15. In metallurgical apparatus a series of tanks communicating with one another and adapted to contain liquid and to confine gas over the liquid, hollow gas distributing members within the tanks submerged in the liquid having vertical fluid inlets in their lower portions and horizontal fluid discharge passages in their upper portion said hollow gas distributors being adapted to receive separate streams of gas and liquid and to eject a mixture of gas and liquid in substantially horizontal streams into the surrounding liquid in the tanks, and means for delivering gas from above the liquid of one tank into the hollow gas distributing member of the next tank of the series.

16. In metallurgical apparatus, a tank adapted to contain a relatively large pool of liquid and to confine gas over the liquid, a hollow gas distributing member within the tank submerged in the liquid having a vertical fluid inlet in its lower portion and horizontal fluid discharge passages extending outwardly from its central portion toward the periphery said hollow gas distributing member being adapted to receive separate streams of gas and liquid and to eject a mix-

ture of gas and liquid into the surrounding liquid in the tank, means for flowing liquid through the tank and mingling it with the pool, and means for delivering gas from the tank above the liquid into the interior of the hollow gas distributing member.

17. In metallurgical apparatus, a tank adapted to contain liquid and to confine gas over the liquid, a rotary member journaled within the tank and submerged in the liquid and having its lower portion in communication with the liquid in the tank and adapted to suck fluid through the opening and eject it into the surrounding liquid in the tank, and a stationary pipe communicating with the gas in the upper portion of the tank and with the interior of the rotary member.

WILLIAM E. GREENAWALT.