

W. E. GREENAWALT.
ELECTROLYTIC APPARATUS.
APPLICATION FILED JUNE 30, 1913.

1,187,903.

Patented June 20, 1916.

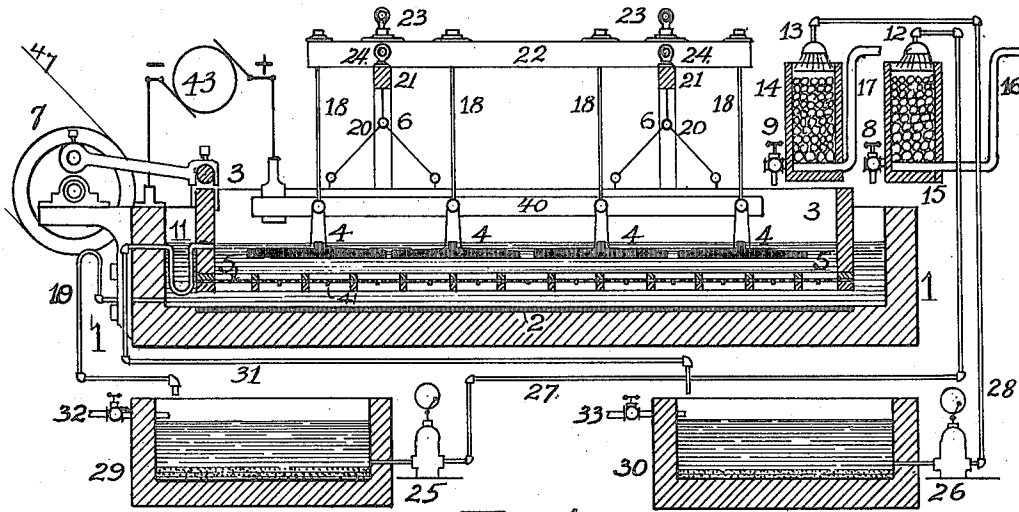


FIG 1

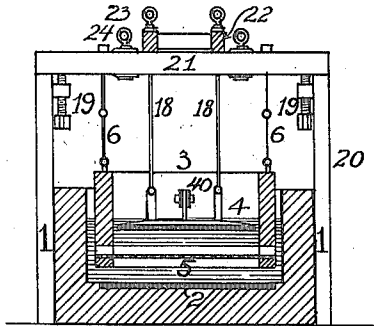


FIG 2

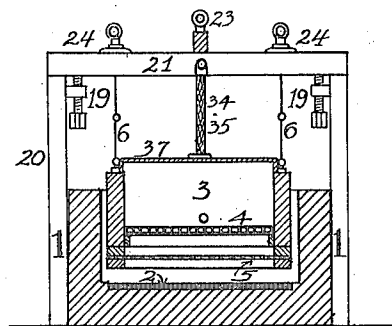


FIG 3

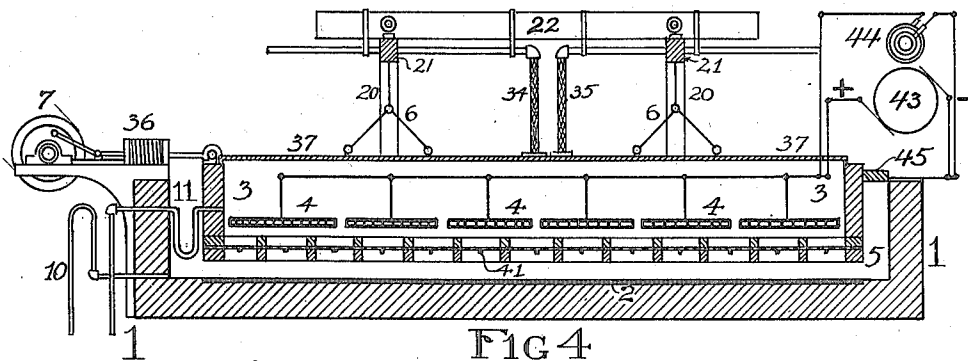


FIG 4

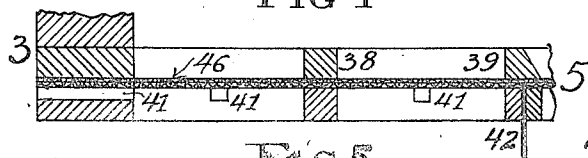


FIG 5

WITNESSES
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ELECTROLYTIC APPARATUS.

1,187,903.

Specification of Letters Patent. Patented June 20, 1916.

Application filed June 30, 1913. Serial No. 776,485.

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 Electrolytic Apparatus.

It has for its more immediate objects the more efficient application of the current by adequately agitating the electrolyte, retarding the disintegration of the electrodes, maintaining the electrodes free from hydrogen or other polarizing gases, and maintaining the apparatus in continuous operation for extended periods.

The apparatus may be successfully used in the electro deposition of copper from sulfate solutions with insoluble anodes, in the electrolysis of copper matte, copper sulfid precipitate, cement copper, zinc oxid, zinc sulfate, copper oxid, lead sulfate, lead sulfid, and the deposition of gold and silver from cyanid solutions, as well as numerous other uses which will be evident to any one skilled in the art.

One of the most interesting, as well as one of the most difficult problems in electro-metallurgy has been the deposition of copper from sulfate solutions, with insoluble anodes, and this problem has hitherto defied all attempts at successful solution on a commercial or practicable basis.

The principal difficulties which have hitherto militated against successful electrolysis of impure copper sulfate solutions are fairly well understood, but among these may be mentioned; first, the rapid disintegration of the insoluble anode with all of its attendant evils; second, inefficiency of the electrolysis due to fouling of the electrolyte; third, inability to build up the cathode to a suitable thickness except at very small current densities; fourth, polarization, which makes it impracticable to use reasonably high working current densities.

If an attempt is made at the ordinary electrolysis of impure copper sulfate solutions, as those obtained in leaching copper ores, with lead anodes, the lead is disintegrated at the rate of about 12 ounces, per pound of copper deposited. The peroxid of lead so formed increases the resistance, and consequently the power, short circuits the current by dropping from time to time to the bottom of the electrolyzer and coming in contact with the cathode. It is expensive

to frequently renew the lead anodes and to frequently remove the peroxid. And so far, no more suitable anode than lead, for sulfate solutions, has yet been discovered.

The principal result of the fouling of the electrolyte is current inefficiency, due to useless oxidation and reduction. One of the unavoidable results of treating copper ores with a sulfate solution is the soluble iron. This iron, in the ferrous condition, is quite harmless, but under the action of electrolysis, the ferrous iron is converted into the ferric iron at the anode, and finding its way back to the cathode, is again reduced to ferrous iron at the expense of the deposited copper, thus resulting in a loss of efficiency. This may become so aggravated, that under certain conditions no copper will be deposited.

The difficulties at the cathode are no less than those at the anode. Except for exceedingly low current densities the deposited copper is quite irregular, and unless closely watched, trees and nodule will build out to the anode, ultimately short circuiting the current, and thus temporarily throwing the electrolyzer out of commission until the difficulty is repaired. If the deposited metal is loose, spongy or granular, as will be the case with foul and almost neutral solutions or with moderately high current densities, the copper falling to the bottom of the electrolyzer mixes with the disintegrated anode material. The separation of this mixture offers an additional metallurgical difficulty.

Polarizing gases, except for very low current densities, are a matter of concern in the deposition of metals with insoluble anodes. Merely circulating the electrolyte, no matter how rapidly, does not satisfactorily overcome the trouble, and for high current densities, is entirely useless. In my apparatus all these difficulties are successfully surmounted, as will now be described in detail, having in mind, more particularly, the electrolysis of impure copper sulfate solutions obtained from leaching copper ores.

Referring to the accompanying drawings, Figure 1 represents a longitudinal section through the apparatus, and Fig. 2: the corresponding transverse section. Fig. 4 represents a longitudinal section through a modified apparatus, and Fig. 3 the corresponding transverse section. Fig. 5 represents an enlarged section through one end of the anode bell.

In the figures, 1 represents an electrolyte tank, containing the electrolyte and substantially horizontal cathode 2.

3 represents an anode bell containing the anolyte and substantially horizontal anodes 4, and having, preferably, a diaphragm 5, interposed between the electrodes, and attached to the anode bell, thus separating the anolyte from the catholyte.

10 The anode bell is suspended by hangers 6, so that it may be oscillated, preferably from fixed pivotal points, when actuated by the mechanism 7. Faucet 8 serves to introduce the catholyte into the apparatus, and the 15 pipe 10 serves to withdraw it. Faucet 9 serves to introduce the anolyte into the apparatus and the flexible tubing 11 serves to withdraw it. This tubing is flexible and is immersed in the catholyte; it is fastened to 20 the anode bell, passes through the catholyte and sides of the cathode tank, so that the anolyte may flow out unimpeded, while the anode bell is in oscillation, and without mingling with the catholyte. This prevents 25 the ferric iron at the anode from getting to the cathode and thus reducing the current efficiency. The degree of this efficiency will depend mostly on the nature of the diaphragm; if the diaphragm is dense, so that 30 little or no diffusion takes place, none of the ferric iron or regenerated acid in the anode compartment finds its way back to the cathode, and hence the current efficiency closely approximates 100 per cent. If the diaphragm 35 permits of more or less diffusion, the efficiency will still be quite good provided that the impurities in the solution are not great. If the electrolyte is reasonably pure a diaphragm of low electrical resistance 40 is preferred. In any event, the outlet for the electrolyte is preferably through the flexible tubing 11, rather than from the catholyte outlet 10.

It will usually be found desirable to introduce 45 a reagent into either the anolyte, the catholyte, or both. In such a case the solution is preferably sprayed into towers 14 and 15, through the sprayers 12 and 13, while the reducing agent, as for example 50 sulfur dioxide, is forced through the pipes 16 and 17 into the bottom and is absorbed by the solution. If lead anodes are used the introduction of sulfur dioxide into the electrolyte, in addition to acting as a depolarizer, 55 acts as an acid generator, and also tends to loosen the disintegrated anode material from the face of the anode, and thus prevent the excessive rise in voltage required for the continuous operation of the apparatus and carrying out of the process. 60 The loosening of the disintegrated or non-adherent electrode material may also be facilitated by simultaneously applying a small alternating current, in connection with the 65 direct current, as illustrated in Fig. 4. The

object of the alternating current is principally to loosen the lead peroxid or lead sulfate from the anode as rapidly as formed, or to make the deposited metal more or less nonadherent, so that it may be more easily 70 removed from the electrolyzer or from the sphere of influence of the electric current.

In any event, the disintegrated anode material will be more or less rapidly released from the anode and would ultimately be a 75 source of annoyance and expense unless frequently removed. Its removal, as ordinarily accomplished, necessitates the dismantling of the cell. In the present invention the apparatus is arranged to make its removal 80 from the sphere of influence of the electric current continuous and automatic, and to greatly facilitate its removal without dismantling the electrolyzer.

If the non-adherent electrode material is 85 intensely fine and readily held in suspension the simple oscillating action of the diaphragm and circulation of the electrolyte will facilitate or cause its removal from the sphere of influence of the current. If how- 90 ever, the disintegrated or non-adherent electrode material is rather heavy, coarse or granular, its removal from the sphere of influence of the current is facilitated or accomplished by giving to the oscillating or 95 moving diaphragm a differential motion, somewhat similar to that in ordinary concentrating tables, which movement is well known. To best accomplish this the speed 100 of the movement one way is more rapid or different than the speed of the return movement; or, as I have designated it, a differential motion. In Fig. 1, it may be transmitted by the driving belt; in Fig. 4 by the spring or toggle arrangement 36. A bumper 105 or spring 45 will answer the same purpose but not so well. This differential motion causes an advance of the insoluble and non-adherent electrode particles toward one end 110 of the diaphragm or electrolyzer, which may then be removed automatically and continuously through the ducts 11 or 10, or if too heavy to be removed with the electrolyte, they may be removed by hand from time to time from accumulations at the end of the 115 apparatus. These accumulations however, at the end of the apparatus, are not affected by the current nor do they interfere with its operation.

In order to further facilitate the advance 120 movement of the insoluble electrode particles, it will usually be desirable to slant the cross-pieces of the diaphragm, as shown at 39, while the other portions of the cross-pieces remain perpendicular, as shown at 125 38. In this way the advance movement of the particles over the slanting cross-pieces is facilitated, while any tendency toward retrogression is retarded by the vertical side. A quick forward movement of the dia- 130

phragm advances the insoluble particles over the slanting cross-piece, while a slower retrograde movement does not perceptibly displace it in the opposite direction, due both to the slower movement and vertical side. Either of these methods, the agitation of the particles in the electrolyte, the differential movement of the diaphragm or anode bell, or the variation in the shape of the diaphragm cross-pieces, may be used individually or collectively, depending upon the conditions and the nature of the non-adherent electrode material to be removed.

The results obtained by this apparatus are somewhat surprising. In the ordinary electrolysis of impure copper sulfate solutions, by circulating the electrolyte, it has been demonstrated by careful tests that about 0.8 lb. of lead is peroxidized for every pound of copper deposited. This amounts to about 1600 pounds of lead, per ton of copper. By using the apparatus herein described, this has been reduced to the phenomenally low amount of 40 pounds of lead peroxidized, per ton of copper deposited, in the ordinary process of working the electrolyzer; that is to say with the ordinary rate of oscillation and a current density of 30 amperes per square foot. On special tests, such for example with a current density of 100 amperes per square foot, the disintegration of the lead has been reduced to even as low as 20 pounds, per ton of copper. It is now further proposed to remove even this small amount of peroxid automatically, so that the electrolyzer can be operated indefinitely without any difficulty from the disintegration of the anode, or from any non-adherent electrode material.

It has been further observed in the operation of this apparatus, that abnormally large current densities can be used without detrimental results, or loss of efficiency. Tests with a current of 1000 amperes, and a current density of 104 amperes per square foot show an efficiency of about 99 per cent. with no evolution of hydrogen at the cathode. In the ordinary electrolysis using stationary electrodes and a circulating electrolyte, with insoluble anodes, a current density of even 10 amperes per square foot is hardly ever free from hydrogen at the cathode and its attendant evils. However, gases such as air, or hydrogen if developed, may become entrained by the diaphragm, and thus have a deleterious influence, especially in increasing the electrical resistance. To avoid this, means of escape of the gases, such as auger holes, grooves or sawcuts, are provided in the frame on the under side of the diaphragm, as shown at 41, by means of which the gases are at once released and offer no trouble. The movement of the diaphragm or anode bell greatly expedites the removal of such gases.

The high efficiency and results described are largely due to the agitation of the electrolyte at both electrodes, either with, or without a diaphragm. The reactions at the electrodes are greatly facilitated, and polarization almost entirely eliminated, thus increasing the current efficiency at the cathode and greatly decreasing the rate of disintegration of the anode.

In any commercial electrolytic apparatus, especially in a cell having a diaphragm, it has always been inconvenient and quite expensive to dismantle the electrolyzer, so that the deposited metal can be removed and the apparatus easily inspected. This difficulty is entirely overcome by the arrangement shown in the drawings. The diaphragm is supported by flexible suspenders 6, attached to a beam 21. The anodes are suspended independently of the diaphragm or anode bell by the rods 18, Fig. 1, from the beam 22, which preferably rests on the beams 21, underneath, and which, in turn, may be supported by uprights 20, alongside of the cell. Both 21 and 22 have suitable eye-bolts 24 and 23, by which the beams 21 and 22 may be elevated simultaneously or separately, say, by an overhead traveler, taking either, or both, the diaphragm and anode with them.

If, for example, the copper has accumulated sufficiently to make its removal desirable, it is quickly accomplished by disconnecting the actuating mechanism 7 and the electrical conductors 40, and then by means of an over-head hoist attached to the eye-bolts 24, the beams 21 and cross-beams 22, together with the diaphragm and anodes are all lifted up together to the height desired for conveniently removing the copper. The deposited copper may be fine, granular, or reguline; in either case it is easily removed from the electrolyte tank, and the superstructure, diaphragm and anodes, again lowered in position, when the cell may again be put into operation. If there is any insoluble material on the diaphragm, or the anodes require inspection, the hoist is hooked on to the eye-bolts 23, and all the anodes elevated, while, however, the diaphragm remains undisturbed. If the diaphragm needs repairs, or the anodes replacement, the entire superstructure may be removed from the cathode tank to the repair shop, while a duplicate is at once placed in position.

In this apparatus the nature of the deposit is more or less immaterial. It may be spongy, loose, granular, or reguline; in any case the deposit may be built up to any thickness desired, depending on the depth of the cathode tank, and the economy of so doing. To easily adjust the cell to the growing deposit, the diaphragm and anodes may be simultaneously elevated either by an

overhead hoist or preferably, by a device shown at 19, Figs. 2 and 3, by means of which the turning of a screw, or similar device, the superstructure may be elevated
 5 from day to day or from week to week, as the cathode deposit is built up. When the deposit is removed, say, at the end of one or two months, the cycle may be repeated. The distance between the anode and diaphragm
 10 requires only occasional adjusting, but when necessary it is accomplished through the suspenders 6 and 18. In this way, all possible adjustments can be made, even while the apparatus is in operation.

15 Circulation of the electrolyte is desirable, especially the anolyte, if that has in suspension insoluble, disintegrated, or non-adherent anode material. In this way the insoluble matter may be removed in suspension
 20 from the electrolyzer, settled out in the settling tanks 29 and 30, and the respective solutions returned to the apparatus by means of pumps 25 and 26. In returning the solutions, they may be first given a preliminary
 25 treatment in the towers 14 and 15 to facilitate the electrolysis when introduced into the cell. A treatment with sulfur dioxide is especially desirable in the electrolysis of
 30 impure copper solutions, as the gas reduces the required electromotive force in the cell, increases the acid regeneration, decreases the anode disintegration, and by reducing the bivalent salts to the univalent condition increases the efficiency of deposition.

35 If gases are released during electrolysis which are injurious to the health of the attendants, or which it is desired to use, such as oxygen, ozone, or chlorine, it is desirable to hood the anode bell, as shown in Fig. 4;
 40 in which case, the anodes are preferably oscillated with the anode bell and diaphragm, instead of being stationary, as shown in Fig. 1. The gases may be removed from the hood through the flexible tubing 34. If it is desired to introduce into the hood another gas
 45 to combine with the gas released during electrolysis, this may be admitted through a similar tubing 35, and allowed to flow through the hood. Similarly if a gas is to
 50 be strengthened or re-standardized, for use outside of the electrolyzer, the partially exhausted gas may be introduced into the hood through tubing 35 and withdrawn through
 55 tubing 34. The rate of flow through the hood may be regulated according to the strength of gas required.

In the electrolysis of impure copper solutions, especially at high current densities, it is quite possible to deposit the copper as
 60 a fine sponge and remove it automatically from the cell. It may then be settled out from the electrolyte in the settler 29 or 30, and the electrolyte returned to the electrolyzer.

65 While the apparatus has been particularly

described with the anode suspended within the electrolyte bell, occasion may require that the electrodes be reversed, and the cathode placed in the electrode bell. This may
 70 be quite desirable, or even necessary in some instances, as for example in the electrolysis of copper sulfid precipitate, cement copper, etc.

The preferred construction of the diaphragm 5, is clearly shown in the drawings. 75 It is preferably attached to an electrolyte bell 3, and the diaphragm frame composed of cross-pieces at suitable distances apart, which, while supporting the fabric 46, also acts as an efficient agitator of both the
 80 anolyte and catholyte. The cross-pieces are preferably at least as close together as the amplitude of oscillation, so that if any uneven building up of the cathode occurs they
 85 will act as eveners and prevent the deposit from building up excessively in one place, or of getting to the diaphragm fabric, and tearing it, if the deposit is hard. It is desirable, therefore, to have the amplitude of oscillation as great or greater than the distance
 90 apart of the diaphragm cross-pieces. If the deposit is loose, as in the case of sponge copper, these cross-pieces may be arranged similar to the modified top piece 39, so that the
 95 deposit may be continuously and automatically removed from the cell without interrupting the electrolysis.

In the electrolysis of gold or silver from cyanid solutions obtained from treating ores, a diaphragm may not be necessary, but the
 100 diaphragm frame, used as an agitator, is highly desirable, whether the fabric is included or not.

The difficulties in the electrolysis of cyanid solutions is their extreme dilution in the precious metals, and the formation of a
 105 scum on the surface of the mercury cathode. These difficulties are overcome by the present invention by the oscillation of the diaphragm whereby large volumes of solution are brought in contact with the electrodes, and the scum is removed from the surface of the mercury cathode by having a
 110 brush or scraper 42, Fig. 5, dip into the surface of the mercury and thus continuously exposing bright and fresh surfaces for the deposition and amalgamation of the precious metals. In the electrolysis of cyanid solutions resulting from the extraction of gold
 115 or silver from their ores, a mercury cathode is preferably used, as indicated by 2 in the drawings. With the mercury cathodes are preferably used iron anodes. The precious metals are deposited into the mercury and form an amalgam, which may be removed
 120 at suitable intervals, and the metals recovered by distilling the mercury, which may then be again used as the cathode. In this electrolysis the diaphragm frame may be used with or without the diaphragm fabric
 125
 130

46, but it is preferably used to prevent the iron cyanids formed at the anode from getting to the cathode compartment. Or the iron cyanids may be recovered from the anode compartment and reconverted into the cyanid of the alkali metals for reuse in extracting the precious metals. Amalgamation plates, by virtue of the mercury contained in them, may be regarded as the equivalent mercury in the ordinary condition.

If the anode is loose, or composed of pieces or fragments, it may be supported in an independent frame or basket. It will be noted that the phenomenal results obtained by the use of this apparatus are largely due to the space between the diaphragm and electrodes, and especially to keeping the anode from immediate contact with the diaphragm. If the anode is oscillated with the diaphragm and in contact with it, my experiments show that no benefits worth while are derived by the oscillation. The free circulation of the electrolyte about the electrodes gives the results sought for.

It is thought that from the full description of the apparatus now given that any one skilled in the art will find no difficulty in applying it to other uses than the ones specifically described.

If zinc sulfate or zinc oxid, for example, are to be electrolyzed, the salts are placed in immediate contact with the anode so that the regenerated acid at once combines with the salt and prevents the electrolyte from becoming impoverished or too highly acid. Similarly, cement copper, copper precipitate or copper matte may be at once refined without first converting it into blister copper.

I claim:

1. In electrolytic apparatus the combination of an oscillating diaphragm horizontally disposed, and means in connection with said diaphragm for facilitating the removal of the non-adherent electrode particles from the electrolyzer.

2. In electrolytic apparatus a horizontal diaphragm interposed between horizontal electrodes and means of imparting to said diaphragm a differential oscillating motion to facilitate the removal of the non-adherent electrode material from the electrolyzer.

3. In electrolytic apparatus an oscillating diaphragm having a differential oscillating motion to facilitate the removal of the non-adherent electrode material from the sphere of influence of the electric current.

4. In electrolytic apparatus having electrodes horizontally disposed, a diaphragm interposed between the electrodes; means for oscillating said diaphragm from fixed pivotal points, and means in connection with said diaphragm for facilitating the removal of the non-adherent electrode particles.

5. In electrolytic apparatus having a sta-

tionary cathode, a stationary anode and diaphragm interposed between the electrodes, means for oscillating said diaphragm, and means in connection with said diaphragm for facilitating the removal of the non-adherent electrode material from the electrolyzer.

6. In electrolytic apparatus the combination of a tank containing the electrolyte and horizontal cathode; an anode bell containing the anolyte and horizontal anode; cross-pieces attached to the anode bell and interposed between the electrodes, and means for oscillating said cross-pieces and anode bell from fixed pivotal points.

7. In electrolytic apparatus the combination of an electrolyte tank containing the cathode; an anode bell suspended within the electrolyte tank and containing the anode; cross-pieces attached to the bottom of the anode bell; means to agitate the cross pieces and the bell, and brushes attached to the cross-pieces to facilitate the removal of the non-adherent electrode material.

8. In electrolytic apparatus the combination of a tank containing the electrolyte and horizontal cathode; an anode bell suspended within the electrolyte tank; an anode suspended within the anode bell independently of the anode bell; cross-pieces arranged at the bottom of the anode bell and shaped so as to facilitate the progressive movement of the non-adherent electrode material, and means for oscillating the anode bell.

9. In electrolytic apparatus the combination of a tank containing the electrolyte and horizontal cathode; an anode bell suspended within the electrolyte tank and capable of oscillating; a stationary anode suspended within the electrolyte and anode bell and independently of the anode bell; cross-pieces attached to the bottom of the anode bell to act as agitators, and means for oscillating the anode bell from fixed pivotal points.

10. In electrolytic apparatus having an anode bell suspended within the electrolyte tank, cross pieces attached to the anode bell and shaped so as to facilitate the progressive movement one way of the non-adherent electrode material.

11. In electrolytic apparatus having horizontal electrodes and oscillating cross-pieces interposed between the electrodes, cross-pieces so disposed that they will be at least as close together as the amplitude of oscillation.

12. In electrolytic apparatus the combination of a tank containing the catholyte and horizontal cathode; a horizontal and stationary anode suspended within the cathode tank; an agitator interposed between the electrodes and suspended from fixed pivotal points, and means for oscillating said agitator.

13. In electrolytic apparatus having horizontal electrodes, a diaphragm interposed between the electrodes; means for oscillating said diaphragm from fixed pivotal points; 5 means of facilitating the removal of the insoluble products of electrolysis from the electrodes, and means for facilitating their removal from the electrolyzer.

14. In electrolytic apparatus having horizontal electrodes, a diaphragm interposed between the electrodes; means for oscillating said diaphragm; means for facilitating the removal of the insoluble products of electrolysis from the electrodes, and means 15 in connection with said diaphragm for facilitating their removal from the sphere of influence of the electrolysis.

15. In electrolytic apparatus the combination of an electrolyte tank containing the electrolyte and one electrode; an electrolyte 20 bell suspended within the electrolyte tank and containing the opposite electrode; a diaphragm interposed between the electrodes; means for moving said diaphragm; 25 means of simultaneously passing a direct and an alternating current through the electrodes.

16. In electrolytic apparatus the combination of an electrolyte tank containing the electrolyte and an electrode; an electrolyte 30 bell suspended within the electrolyte tank and containing the opposite electrode; a diaphragm interposed between the electrodes; means for moving said diaphragm; 35 means of simultaneously passing a direct and an alternating current through the electrodes, and means for removing the non-adherent electrode material from the sphere of influence of the electrolysis.

40 17. In electrolytic apparatus the combination of an electrolyte tank containing the electrolyte and an electrode; an anode bell suspended within the electrolyte tank and containing the opposite electrode; a diaphragm interposed between the electrodes; 45 means of introducing into the electrolyte a reagent; means for oscillating the diaphragm, and means in connection with said diaphragm for facilitating the removal of the insoluble non-adherent electrode material from the sphere of influence of the electrolysis. 50

18. In electrolytic apparatus the combination of an electrolyte tank containing the electrolyte and an electrode; an anode bell suspended within the electrolyte tank and containing the opposite electrode; a diaphragm interposed between the electrodes and arranged to facilitate the progressive 60 movement of the non-adherent electrode material and removing it from the electrolyzer, means for separating the non-adherent insoluble electrode material from the electrolyte, and means for returning the 65 clarified electrolyte to the electrolyzer.

19. In electrolytic apparatus the combination of a tank containing the electrolyte and horizontal electrodes; a diaphragm composed of a fabric supported by a suitable frame work interposed between the 70 electrodes; means in connection with the diaphragm for the escape of gases from the under side of the fabric; means for facilitating the removal of the insoluble non-adherent electrode material from the electrodes; means for moving said diaphragm, 75 and means in connection with said diaphragm for facilitating the progressive movement one way of the non-adherent electrode material. 80

20. In electrolytic apparatus having stationary electrodes, an oscillating diaphragm arranged to catch the insoluble non-adherent electrode material and continuously remove it from the sphere of the electrolysis. 85

21. In electrolytic apparatus the combination of a tank containing the electrolyte and stationary cathode; an anode bell suspended within the electrolyte tank; a stationary anode suspended within the anode 90 bell and independently of it; a diaphragm interposed between the electrodes and attached to the anode bell; means of adjusting the vertical distance between the diaphragm and cathode; means for adjusting 95 the vertical distance between the diaphragm and anode, and means for oscillating the diaphragm and anode bell.

22. In electrolytic apparatus a stationary anode; a stationary cathode; a diaphragm 100 interposed between the electrodes; means of moving said diaphragm; means for adjusting the vertical distance between the cathode and diaphragm; means for adjusting the vertical distance between the diaphragm 105 and anode, and means for simultaneously removing the diaphragm and one electrode from the electrolyte tank.

23. In electrolytic apparatus a stationary anode; a stationary cathode; a diaphragm 110 interposed between the electrodes; means for adjusting the vertical distance between the cathode and diaphragm; means for adjusting the vertical distance between the anode and diaphragm, and means for oscillating 115 the diaphragm from fixed pivotal points.

24. In electrolytic apparatus a stationary anode; a stationary cathode; a diaphragm interposed between the electrodes and suspended from fixed pivotal points; means for 120 adjusting the vertical distance between the diaphragm and cathode; means for adjusting the vertical distance between the diaphragm and anode; means for oscillating the diaphragm, and means of simultaneously 125 removing the diaphragm and one electrode from the electrolyte tank.

25. In electrolytic apparatus the combination of an electrolyte tank containing the electrolyte and a horizontal electrode of one 130

sign; a stationary horizontal electrode of the opposite sign suspended within the electrolyte tank and substantially horizontal with the other electrode; cross-pieces interposed between the electrodes and suspended independently of the electrodes; and means for oscillating said cross-pieces, thereby simultaneously agitating the electrolyte in contact with both electrodes.

26. In electrolytic apparatus having electrodes horizontally disposed, a mercury cathode, an agitator interposed between the electrodes, and means in connection with said agitator for removing any undesirable scum from the surface of the cathode which may interfere with satisfactory electrolysis.

27. In electrolytic apparatus having electrodes horizontally disposed, a mercury cathode, an agitator interposed between the electrodes, and means in connection with said agitator for maintaining the surface of the mercury in a condition to facilitate the amalgamation of the deposited metals in the mercury, and means for oscillating said agitator.

28. In electrolytic apparatus having electrodes horizontally disposed, cross-pieces interposed between the electrodes and supported by suspenders oscillating between the anode and sides of the electrolyte tank, and means for oscillating said cross-pieces independently of the electrodes.

29. In electrolytic apparatus a horizontal mercury cathode, a perforated and horizontal anode substantially parallel to the cathode, an agitator interposed between the electrodes and supported by suspenders passing between the anode and sides of the electrolyte tank, and means for oscillating the agitator and suspenders.

30. In electrolytic apparatus having elec-

trodes horizontally disposed, an agitator suspended by flexible supports from fixed pivotal points interposed between the electrodes, and means for oscillating said agitator horizontally between the electrodes.

31. In electrolytic apparatus an electrolyte tank containing a horizontal cathode, a horizontal anode substantially parallel to the cathode and suspended within the electrolyte tank so as to allow a space between the edges of the anode and sides of the electrolyte tank, an agitator interposed between the electrodes and suspended by supports passing between the anode and the sides of the electrolyte tank, and means for moving said agitator relatively to the electrodes.

32. In electrolytic apparatus an electrolyte tank containing a stationary horizontal cathode, a stationary anode substantially parallel to the cathode suspended within the electrolyte tank and arranged to allow a space between the edges of the anode and sides of the electrolyte tank, an agitator interposed between the electrodes and suspended independently of the electrodes by supports passing between the edges of the anode and sides of the electrolyte tank, and means for moving said agitator independently of the electrodes.

33. In electrolytic apparatus having electrodes horizontally disposed, an agitator interposed between the electrodes and suspended by supports passing between one of the electrodes and sides of the electrolyte tank, and means for moving said agitator independently of the electrodes.

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Witnesses:

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