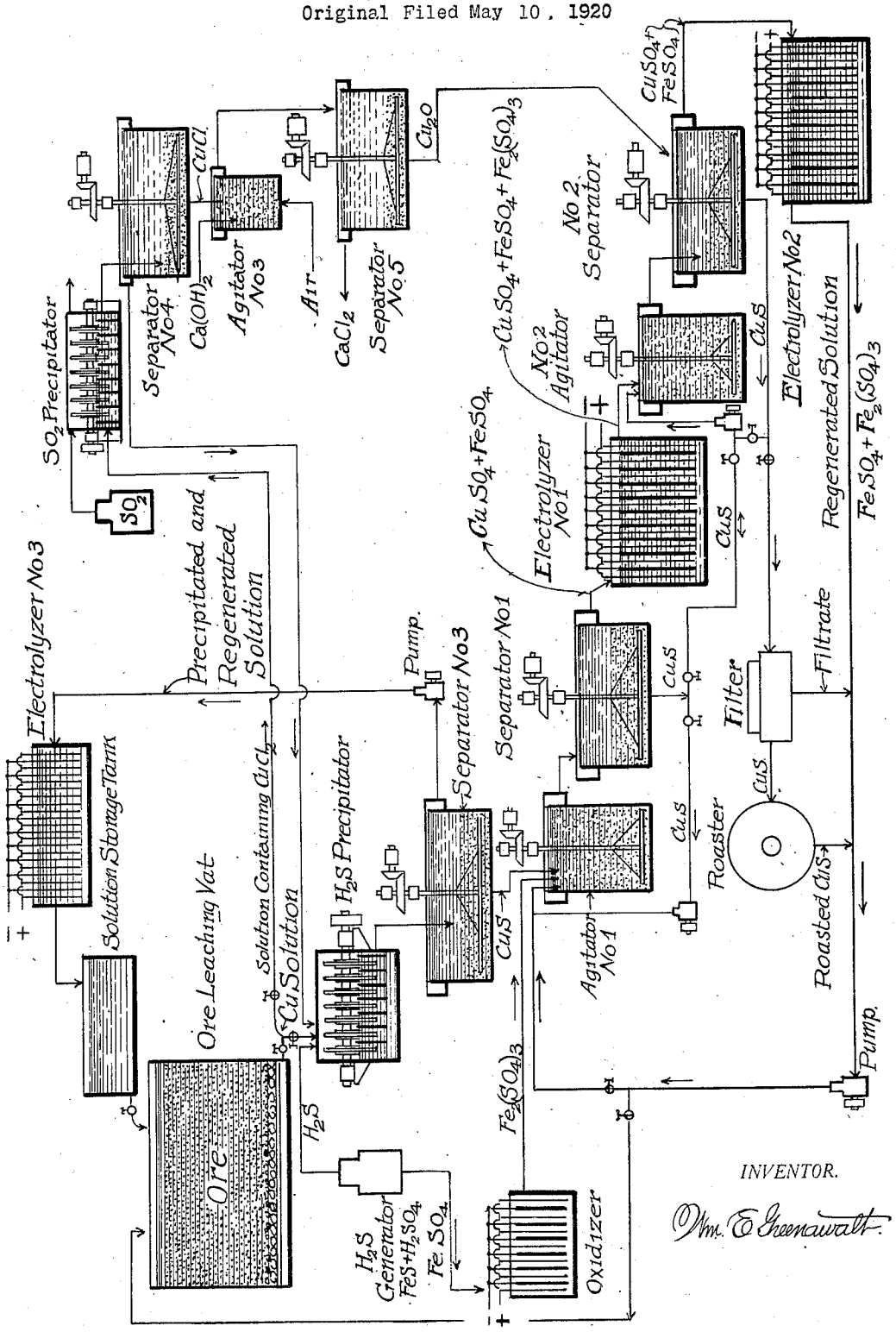
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W. E. GREENAWALT

METALLURGICAL PROCESS

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INVENTOR.

Wm. E. Greenawalt

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WILLIAM E. GREENAWALT, OF DENVER, COLORADO.

METALLURGICAL PROCESS.

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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 Metallurgical Processes, of which the following is a specification.

My invention relates more particularly to the extraction of copper from its ores by solvent processes. It has for its more immediate object the production of the metal by the indirect method of chemically precipitating the copper from its solutions and then obtaining the electrolytic metal from the chemical precipitate.

This process may be considered as a continuation in part of that disclosed in my co-pending application, Serial No. 15,583, filed March 19, 1915, and a modification of the processes disclosed in my co-pending applications, Serial No. 228,952, filed April 16, 1918, and Serial No. 239,255, filed June 10, 1918.

Serial No. 15,583, discloses the general idea of precipitating copper from its solutions with hydrogen sulphide and applying the copper sulphide precipitate to an electrolyte containing ferric iron. Serial Numbers 228,952, and 239,255, disclose methods in more or less detail, for practically carrying out the disclosure in Serial No. 15,583.

In the present application the same general idea is applied as in the above applications, but in a somewhat different way. In this process it is proposed to avoid the harmful effects in the electrolysis incident to electrolyzing foul leach solutions, by maintaining the leach solutions and the electrolyte entirely separate, and taking advantage of the property of ferric salts to quickly and effectively dissolve the copper from the sulphide precipitate, without subjecting the precipitate to any unusual preliminary treatment.

The processes set forth in the above applications will usually be preferred, but when the ore being treated has a very low copper content, and the resulting leach solutions are too low in copper and too highly charged with impurities to make electrolysis of the leach solutions advisable, the present process may be satisfactorily applied. This process may with advantage be applied to the large number of the present copper leaching installations in which the copper is dissolved with acid solutions and precipitated with iron. The precipitation of copper with iron is expensive, for the reason that the work cannot well be automatically performed, both the acid and the iron are irrecoverably lost, and the resulting cement copper is an undesirable end product which has to be smelted and refined in the usual way, the same as a high grade ore or concentrate. In my present process, by taking advantage of the broad disclosure in Serial No. 15,583, it is possible to carry out the precipitation automatically, and have as an end product the pure electrolytic metal, while at the same time regenerating both the leach solution and the electrolyte. The process may be variously applied, but the preferred method, on complex ores, may be described as follows, reference being made to the accompanying drawing, which represents a flow sheet in diagrammatic section.

The ore, containing copper and assumed to contain gold, silver, and lead, is crushed to a suitable fineness and charged into the leaching vat. If the ore is a sulphide, roasting, as a preliminary treatment, will be desirable, and if the ore contains silver and lead in considerable amounts, chloridizing roasting may be necessary. It is immaterial, so far as the process is concerned, whether the ore in the leaching vat is percolated or agitated.

If a chloride solution is used, all the metals may be dissolved from the ore. Gold chloride is readily soluble in water. Lead and silver chlorides or sulphates are fairly soluble in warm chloride solutions. Cupric chloride or sulphate are highly soluble in water, and cuprous chloride is fairly soluble in a heated chloride solution. Both ferric and cupric chloride act to chloridize some of the silver remaining unchloridized by the chloridizing roasting.

The metal solution issuing from the leaching vats flows into the H_2S precipitator, where the metals are continuously and completely precipitated with the hydrogen sulphide, with the simultaneous regeneration of an equivalent of acid, as is well known. The precipitated and regenerated acid solution flows into the separator No. 3, where the sulphide precipitate is separated from the regenerated acid solution. The acid so-

lution is returned to the ore to pass through another cycle.

The precipitate, thoroly washed to eliminate the soluble chlorides if a chloride solution is used as the solvent, is flowed as a thickened sludge from the separator No. 3 to the agitator No. 1. The solvent for the copper in the precipitate, in the agitator, is preferably a solution of ferric and ferrous sulphate. The gold, silver, and lead sulphides, as precipitated with H_2S, are quite insoluble in a ferric sulphate solution. The copper, of the precipitated copper sulphide, on the contrary, is quite readily dissolved with ferric sulphate, especially in a hot solution. The reaction is

1. $CuS+Fe_2(SO_4)_3=CuSO_4+2FeSO_4+S.$

The reaction is quite a rapid one with precipitated copper sulphide, and the reduction of the ferric salts can quickly be made complete, or practically so. The reduced iron solution containing the copper in solutions as sulphate, flows into the separator No. 2, where the sulphide precipitate is separated from the clear overflowing solution. The separated precipitate is either returned to agitator No. 1 or passed on to agitator No. 2, and progressively advanced through the system. The clear reduced copper sulphate solution preferably quite rich in copper flows into electrolyzer No. 1, where a portion of the copper is electrolytically deposited, with the simultaneous regeneration of the ferric sulphate. Under the perfect depolarization conditions of this process the amount of acid regenerated will be comparatively small: the oxygen liberated at the anode will mostly combine with the ferrous salts to convert them to the ferric salts. The ferrous sulphate acts as an efficient depolarizer. and this tends to materially reduce the E. M. F. in the deposition of the copper, especially if carbon anodes are used. It is believed that with agitation, a heated electrolyte, and with an electrolyte fairly high in ferrous iron, and a moderate current density, a practically complete depolarization can be effected so that carbon anodes will not show any unusual disintegration, as disclosed in my Patent, No. 1,314,742, Sept. 2, 1919. The rate of flow through the electrolyzers is preferably regulated so that the issuing electrolyte will not contain more than 0.25% ferric iron. A higher ferric iron content may materially reduce the efficiency and increase the danger of anode disintegration. The electrolyte, issuing from the electrolyzer No. 1, containing about 0.25% ferric iron and deprived of some of its copper, flows into agitator No. 2, where more copper is brought into solution by the ferric sulphate formed in electrolyzer No. 1, and the ferric sulphate is again reduced to the ferrous condition by reacting with the copper sulphide precipitate in the agitator. The mixture of electroyte and sulphide precipitate flows into separator No. 2, where the sulphide precipitate is separated from the electrolyte and the clear overflowing electrolyte is passed on to electrolyzer No. 2, where more copper is deposited and more ferric salts regenerated. In this way the cycle may be repeated as often as desired, and finally, the electrolyte may be returned to the first agitator, to pass through another complete cycle, as described.

The impoverished copper precipitate, containing also considerable sulphur, as shown by the following equation,

2. $CuS+Fe_2(SO_4)_3=CuSO_4+2FeSO_4+S,$

is flowed into the filter press to reduce its moisture. From the filter it is charged into the roasting furnace, where the sulphur is burned off and the remaining copper largely converted into the sulphate and oxide, and this roasted material may be applied to the electrolyte to dissolve the copper and reduce the excess acidity, if excess acidity develops. If the electrolyte becomes too acid. it is applied to the ore. A small portion of the electrolyte is preferably continuously discarded and applied to the ore, and replaced with a fresh iron salt solution.

The ferrous and ferric sulphate electrolyte is replenished from the ferrous sulphate formed in the H_2S generator by the action of sulphuric acid on matte:

3. $FeS+H_2SO_4=FeSO_4+H_2S.$

The ferrous sulphate is preferably electrolyzed in the oxidizer to convert a large portion of the ferrous salt into the ferric salt before applying it to the copper sulphide precipitate, since copper sulphide is unaffected by ferrous sulphate. The oxidized ferrous sulphate solution flows into agitator No. 1, and replaces an equivalent of discarded foul electrolyte.

Since ferric salts act on constituents in the ore which are not acted upon by either acid or ferrous salts, it may at times be desirable to convert some of the ferrous salts into the ferric condition before applying the leach acid solution to the ore. This may be done in electrolyzer No. 3. Ferric chloride is an efficient chloridizer of both silver and lead. If the ore contains gold the leach solution may also be charged with chlorine generated from chlorides, in electrolyzer No. 3.

The precipitated gold, silver, and lead sulphides will gradually accumulate in the precipitate, and when the amount is sufficient, the precipitate is filtered, and the filtered precipitate eliminated from the circuit, to be given further treatment as desired. The further treatment of this precipitate is not directly related to the present process.

It will be seen that this process involves

the use of two independent solutions, and that the nature of the leach solution, its foulness or its composition, is practically independent of the electrolyte. The electrolyte may be maintained as highly charged with copper as desired, and no impurities from the ore will find their way into the electrolyte in injurious amounts.

If copper is the only metal in the ore worth recovering, it will usually be found advisable to leach with a sulphate rather than with a chloride solution. The nature of the leach solution is more or less immaterial in the general operation of the process. Other solutions, such as hyposulphite, may at times be possibly used to advantage.

The process, in its application to copper leaching, offers marked advantages over iron precipitation. Hydrogen sulphide precipitation of copper from its leach solutions, has never come into general use, notwithstanding many of its evident advantages, and this is largely due to the voluminous nature of the precipitate and the difficulty and expense encountered in filtering, drying, smelting, and refining of this precipitate. The characteristic which is so undesirable in the fusion refining of the precipitate, is, however highly advantageous in my process, for the evident reason that the voluminous nature of the precipitate offers a large exposure of surface for the action of the ferric sulphate, and the precipitate is easily agitated, easily kept in suspension in the agitator, and easily shifted from place to place.

If chlorine should get into the electrolyte, either from the ore, or from the use of a chloride solution, its presence would be deleterious. This is readily taken care of in the present process by taking advantage of the intense reducing action of the copper sulphide precipitate to reduce cupric chloride to the insuluble cuprous chloride:

$$4.\ CuCl_2+CuS=2CuCl+S.$$

This cuprous chloride is readily converted into the cuprous sulphide, by the action of H_2S:

$$5.\ 2CuCl+H_2S=Cu_2S+2HCl.$$

The HCl is easily removed by washing, so that the pure Cu_2S remains, free from chlorides, and this Cu_2S, is then used as a reducing agent, to eliminate more chlorine:

$$6.\ CuCl_2+Cu_2S=2CuCl+CuS.$$

It will be seen therefore that in the ordinary operation of the process the chlorine may be automatically and effectually eliminated from the electrolyte.

Chlorine, in the electrolyte, has a very deleterious effect on lead anodes, as also anodes composed of ferrosilicon: it is, however, without action on carbon anodes, and carbon anodes may ordinarily be used in the operation of this process due to the very effective depolarization obtainable by the high iron electrolyte, as described.

It frequently happens that the ore or the leach solution contains considerable chlorine, and much of the copper is dissolved as the cupric chloride. In such cases I prefer to first apply sulphur dioxide to all, or a portion, of the leach solutions preparatory to hydrogen sulphide precipitation, and thus precipitate a large portion of the copper as the insoluble cuprous chloride. Sulphur dioxide precipitation is cheaper than hydrogen sulphide precipitation and regenerates more acid. On the other hand the copper precipitated with sulphur dioxide is in the more or less undesirable form of cuprous chloride, which does not readily lend itself to electrolysis. It is desirable to convert the copper in the cuprous chloride into some other combination. This is conveniently done by adding calcium hydroxide (quick lime) to the precipitated cuprous chloride, which converts the copper into the form of cuprous oxide, with the formation of calcium chloride. The cuprous oxide is then separated from the very soluble calcium chloride, and washed, which leaves practically the pure cuprous oxide. This cuprous oxide is then applied to the electrolyte to regulate its acidity, and to convert the oxide into the electrolytic copper.

If this step in the process is advisable, all, or a portion, of the leach solution containing cupric chloride is flowed from the leaching vat into the SO_2 precipitator, where the soluble cupric chloride is converted into the insoluble cuprous chloride. The precipitate and solution flow into the separator No. 4, where the precipitate is separated from the solution. The solution, still containing some copper, is flowed into the H_2S precipitator, and passes through the circuit, as already described.

The cuprous chloride precipitate is flowed into the agitator No. 3, where the calcium hydroxide is added and the mixture agitated. The calcium hydroxide reacts with the cuprous chloride to form cuprous oxide and calcium chloride. The mixture of solution and precipitate flows into the separator No. 5, where the calcium chloride is separated from the cuprous oxide precipitate. The cuprous oxide is thoroughly washed to free it from chlorides, and is then applied to the electrolyte, by flowing it into separator No. 2 and through the reducing system, as desired, to react with the excess acid formed by the electrolysis, and to convert the oxide into the electrolytic metal. In this way, all the copper may be converted into the electrolytic metal, while the electrolyte may be controlled both as to its acidity and its ferric iron content. The rate of flow

through the electrolytic system would also be a governing and regulating factor.

It is desirable to work with a fairly warm electrolyte, say, at 125 deg. F. It is also desirable to agitate the electrolyte. Heating and agitating the electrolyte reduces the E. M. F. required for the deposition of the copper due to effective depolarization, and a heated solution of ferric sulphate acts more energetically on the sulphide precipitate to dissolve the copper. Since the electrolyte is distinct from the leach solutions, it is quite easy to maintain the electrolyte at the temperature desired for the most effective work.

I claim:

1. A metallurgical process comprising treating ores of copper with a solvent for the copper, precipitating the copper out of the leach solutions as the sulphide, separating the sulphide precipitate from the leach solutions, treating the sulphide precipitate with a ferric sulphate solution to re-dissolve the copper of the precipitate with the simultaneous reduction of the ferric sulphate to the ferrous sulphate, and electrolyzing the resulting copper sulphate solution containing ferrous sulphate to obtain the electrolytic metal and regenerate ferric sulphate to dissolve more copper from the sulphide precipitate.

2. A metallurgical process, comprising treating ores of metals with a solvent for the metals, precipitating the metals out of the leach solutions as the sulphides, separating the sulphide precipitate from the leach solutions, treating the sulphide precipitate with a ferric salt solution to re-dissolve the metals soluble in a ferric salt solution with the simultaneous reduction of the ferric salt to the ferrous salt, and electrolyzing the resulting metal salt solution to deposit the metal and regenerate the ferric salt with which to dissolve more metal from the sulphide precipitate.

3. A metallurgical process comprising treating ores of copper with a solvent for the copper, precipitating the copper out of the leach solution as the sulphide, separating the sulphide precipitate from the leach solution, returning the leach solution to the ore, treating the sulphide precipitate with a ferric salt solution distinct from the leach solution to re-dissolve the copper with the simultaneous reduction of the ferric salt to the ferrous salt, and electrolyzing the resulting copper solution to deposit the metal and regenerate the ferric salt with which to dissolve more copper from the sulphide precipitate.

4. A metallurgical process comprising treating ores of metals with a solvent for the metals, chemically precipitating the metals out of the leach solutions, separating the chemical precipitate from the leach solutions, treating the chemical precipitate with a solution distinct from the leach solutions to re-dissolve the metals, and electrolyzing the resulting metal solutions with insoluble anodes to electrolytically deposit the metals and regenerate the solvent for the chemical precipitate.

5. A metallurgical process comprising treating ores of metals with a solvent for the metals, chemically precipitating the metals out of the leach solutions, separating the chemical precipitate from the precipitated leach solutions, returning the precipitated leach solutions to the ore, treating the chemical precipitate with a solution distinct from the leach solutions to re-dissolve the metals, and electrolyzing the resulting metal solution with insoluble anodes to electrolytically deposit the metals and regenerate the solvent for the chemical precipitate.

6. A process comprising precipitating copper from its solutions with hydrogen sulphide generated from ferrous sulphide and sulphuric acid, electrolyzing the resulting ferrous sulphate solutions to convert the ferrous salt into the ferric salt, treating the copper sulphide precipitate with the ferric salt solution so formed, and electrolyzing the resulting copper sulphate solution containing ferrous sulphate to deposit the copper and regenerate ferric sulphate with which to dissolve more copper from the sulphide precipitate.

7. A process comprising precipitating copper from its solutions with hydrogen sulphide generated from sulphuric acid and ferrous sulphide, treating the resulting copper sulphide precipitate with a solution of a ferric salt as an electrolyte, and adding the iron salt solution resulting from the generation of the hydrogen sulphide to the electrolyte.

8. A process of treating ores of metals comprising applying a chloride solution to an ore containing copper and other metals, applying a sulphide precipitant to the resulting metal chloride solution to precipitate the metals, separating the resulting sulphide precipitate from the solution, applying the precipitate to a ferric sulphate solution to dissolve the copper, electrolyzing the resulting copper sulphate solution containing salts of iron to deposit the copper and regenerate the ferric sulphate to dissolve more copper from the sulphide precipitate.

9. A process of treating ores of metals comprising applying a chloride solution to an ore containing copper and other metals, applying a sulphide precipitant to the resulting metal chloride solution to precipitate the metals, separating the resulting sulphide precipitate from the solution, treating the precipitate with a ferric sulphate solution to dissolve the copper, electrolyzing the resulting copper solution containing salts of iron

to deposit the copper and regenerate the ferric sulphate to dissolve more copper from the sulphide precipitate, and separating the sulphide residue from the electrolyte and recovering the metals other than copper from the sulphide residue.

10. A process of treating ores of metals comprising applying a chloride solution to an ore containing copper and other metals, chemically precipitating the metals from the chloride solution, separating the resulting precipitate from the precipitated chloride solution, returning the chloride solution to the ore, treating the chemical precipitate with a ferric sulphate solution to dissolve the copper, electrolyzing the resulting copper sulphate solution containing salts of iron to deposit the copper and regenerate the ferric sulphate to dissolve more copper from the chemical precipitate, and from time to time recovering the metals other than copper from the sulphide residue.

11. A process comprising precipitating copper from its solutions with hydrogen sulphide generated by reacting on ferrous sulphide with sulphuric acid and applying the resulting iron sulphate solution to the copper sulphide precipitate as an electrolyte.

12. A process comprising precipitating copper from its solutions as the sulphide, applying the sulphide precipitate to an electrolyte containing salts of iron and small quantities of chlorine whereby the soluble cupric chloride is converted into the insoluble cuprous chloride, and separating the insoluble cuprous chloride from the electrolyte.

13. A process comprising precipitating copper from its solutions as the sulphide, applying the sulphide precipitate to an electrolyte containing salts of iron and small quantities of chlorine to convert the soluble cupric chloride into the insoluble cuprous chloride, separating the insoluble cuprous chloride from the electrolyte, applying hydrogen sulphide to the cuprous chloride to convert the cuprous chloride into the sulphide, and applying the resulting sulphide to the electrolyte as a reducing agent.

14. A process comprising precipitating copper from its solutions as the sulphide, applying the sulphide precipitate to an electrolyte containing salts of iron and small quantities of chlorine to dissolve the copper from the precipitate and convert the ferric salts into the ferrous salts and the cupric chloride into the cuprous chloride, separating the insoluble cuprous chloride from the electrolyte, applying a reagent to the cuprous chloride capable of converting the chloride into the sulphide, and applying the resulting sulphide to the electrolyte.

15. A process comprising treating ores of copper with an acid solvent for the copper, applying hydrogen sulphide to the resulting copper solution to precipitate the copper, separating the sulphide precipitate from the regenerated acid solution, returning the regenerated acid solution to the ore, treating the sulphide precipitate with a ferric salt solution to re-dissolve the copper with the simultaneous reduction of the ferric salt to the ferrous salt, and electrolyzing the resulting copper solution to deposit the metal and regenerate the ferric salt with which to dissolve more copper from the sulphide precipitate.

16. A metallurgical process comprising treating ores of copper with a solution containing chlorine, applying sulphur dioxide to the solution to precipitate a portion of the copper as the cuprous chlorine, separating the solution from the precipitate and then applying hydrogen sulphide to the solution to precipitate the remaining copper as the sulphide, separating the solution from the sulphide precipitate and returning the solution to the ore, applying the sulphide precipitate to an electrolyte capable of being regenerated by the electrolytic deposition of the copper, converting the cuprous chloride obtained from the sulphur dioxide precipitation into the cuprous oxide, and applying the cuprous oxide precipitate to the electrolyte.

17. A metallurgical process comprising treating ores of copper with a solution containing chlorine, applying a reducing gas to the leach solution to chemically precipitate the copper, separating the resulting chemical precipitate from the leach solution and returning the leach solution to the ore, applying the chemical precipitate to an electrolyte separate and distinct from the leach solution which is capable of dissolving the copper from the precipitate and of being regenerated by electrolysis, and then electrolyzing the resulting copper solution to deposit the copper and regenerate for the chemical precipitate.

18. A metallurgical process comprising treating ores of copper with a solution for the copper, precipitating the copper from the resulting solution as a chemical compound, separating the resulting precipitate from the precipitated solution and returning the solution to the ore, applying the chemical compound precipitate to an electrolyte separate and distinct from the leach solution which is capable of re-dissolving the copper and of being regenerated by electrolysis, and electrolyzing the resulting copper solution to deposit the copper and regenerate the solvent for the copper in the chemical compound precipitate.

19. A metallurgical process comprising treating ores of copper with a solution containing chloride, precipitating part of the copper from the chloride solution as cuprous chloride and part as the sulphide, converting the copper in the chloride precipi-

tate into the oxide, applying both the sulphide and oxide precipitate to an electrolyte separate and distinct from the leach solution, and electrolyzing the resulting copper solution to obtain the electrolytic metal.

20. A metallurgical process comprising treating ores of copper with a chloride solution to dissolve the copper, applying sulphur dioxide to the resulting copper solution to precipitate a portion of the copper as the cuprous chloride, converting the copper in the cuprous chloride into a chemical combination free from chlorine, applying the resulting copper compound to a solution capable of dissolving the copper and capable of being regenerated by electrolysis, and electrolyzing the resulting copper solution to obtain the electrolytic metal and regenerate the solvent for the copper.

21. A metallurgical process comprising treating ores of copper with a solvent for the copper, precipitating the copper from the resulting solution as the cuprous chloride, converting the copper in the cuprous chloride into the oxide, and then electrolyzing the resulting oxide to obtain the electrolytic metal.

22. A metallurgical process comprising treating ores of copper with a solvent for the copper, precipitating the copper from the resulting solution as the cuprous chloride, separating the solution from the precipitate and returning the solution to the ore, applying calcium hydroxide to the chloride precipitate, separating the resulting calcium chloride from the resulting copper oxide, and re-dissolving the copper oxide in an electrolyte free from chlorine, and electrolyzing the resulting copper solution to deposit the copper as the electrolytic metal.

23. A metallurgical process comprising treating ores of copper with a solvent for the copper, precipitating the copper from the resulting solution as the cuprous chloride, separating the solution from the precipitate and returning the solution to the ore, applying calcium hydroxide to the chloride precipitate, separating the resulting calcium chloride from the resulting copper oxide, re-dissolving the copper oxide in a sulphate solution, and electrolyzing the resulting copper sulphate to obtain the electrolytic metal and regenerate the sulphate solvent.

24. A metallurgical process comprising treating ores of copper with a solvent for the copper, separating the copper solution from the ore, chemically precipitating the copper from the solution, separating the precipitate from the resulting depleted copper solution, and then electrolyzing the solution depleted of its copper and returning the electrolyzed solution to the ore.

25. A metallurgical process comprising treating ores of copper with a solvent for the copper, separating the resulting copper solution from the ore, chemically precipitating the copper from the solution, separating the resulting chemical precipitate from the resulting solution depleted in copper, electrolyzing the solution depleted in copper and returning it to the ore, re-dissolving the copper of the precipitate with a solution separate from the leach solution, and electrolyzing the resulting copper solution to obtain the electrolytic metal.

26. A process comprising, treating ores of copper with an acid solution to dissolve the copper from the ore, precipitating the copper from the resulting solution as the sulphide, applying the sulphide precipitate to a copper electrolyte containing salts of iron to reduce ferric salts formed by electrolyzing the solution to the ferrous condition, and then when the precipitate becomes impoverished in copper and containing undesirable impurities roasting the precipitate residue and applying the roasted precipitate residue to the electrolyte.

27. A process comprising, leaching copper ores to dissolve the copper, precipitating the copper from the resulting solution as the sulphide, returning the resulting barren solution to the ore, roasting the precipitate, treating the roasted precipitate with a solution separate from the leach solution to redissolve the copper, and electrolyzing the resulting copper solution to obtain the electrolytic metal.

28. A process comprising, leaching copper ores to dissolve the copper, precipitating the copper from the resulting solution with a chemical precipitant, returning the resulting barren solution to the ore, roasting the copper precipitate, treating the roasted precipitate with a solvent for the copper separate from the leach solution to redissolve the copper, electrolyzing the resulting copper solution to deposit the copper as the electrolytic metal, and returning the electrolyzed solution to the roasted precipitate.

29. A process of producing electrolytic copper from its ores in which the leach solution is maintained separate from the electrolyte, comprising, leaching the ore with a solvent for the copper, precipitating the copper from the resulting solution with a chemical precipitant, separating the precipitate from the solution, returning the barren leach solution to the ore, roasting the precipitate, re-dissolving the copper of the precipitate, electrolyzing the resulting copper solution to deposit the electrolytic metal and regenerate the solvent, and returning the electrolyzed and regenerated solution to the roasted copper precipitate.

30. A process comprising precipitating copper as the sulphide from relatively lean or relatively foul solutions, separating the sulphide precipitate from the denuded so-

lution, re-dissolving the sulphide precipitate in a relatively rich copper solution containing salts of iron, electrolyzing the solution to deposit copper and regenerate ferric iron, returning the regenerated ferric iron solution to the copper sulphide precipitate to re-dissolve more copper with the simultaneous reduction of the ferric iron to the ferrous iron, and repeating the cycle indefinitely to convert the copper of the sulphide precipitate into the electrolytic metal.

31. A process comprising precipitating copper from relatively lean or relatively foul solutions, separating the precipitate from the resulting solution, redissolving a portion of the copper of the unroasted precipitate in a relatively rich copper solution containing salts of iron, electrolyzing the resulting solution to deposit copper and regenerate acid and ferric iron, returning the solution to the precipitate to redissolve more copper with the simultaneous reduction of the ferric iron to the ferrous iron and continuing the cycle to convert the copper of the precipitate into the electrolytic metal, roasting a portion of the precipitate to convert the copper into the oxide, and applying the roasted portion of the precipitate to the electrolyte.

WILLIAM E. GREENAWALT.