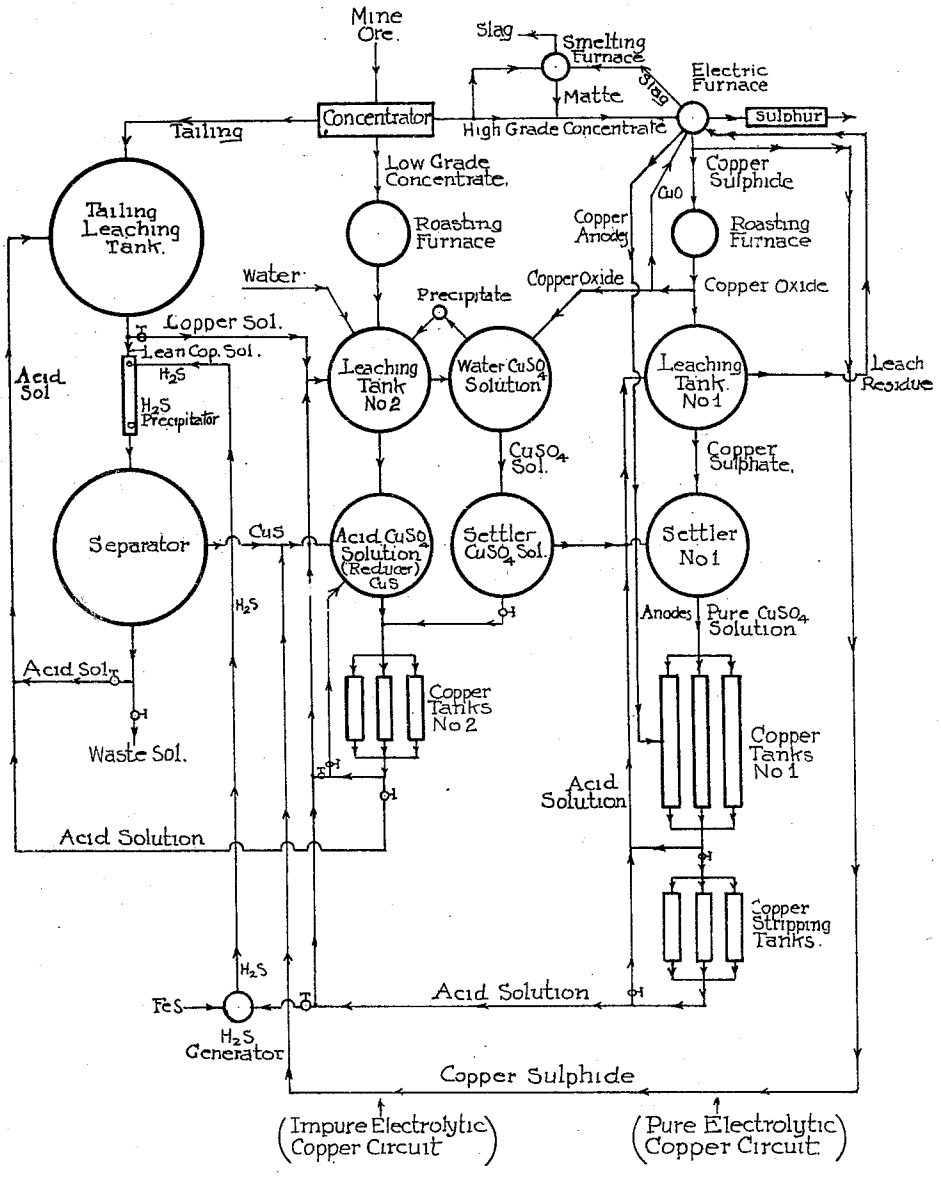
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COPPER EXTRACTION PROCESS

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INVENTOR

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COPPER-EXTRACTION PROCESS

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The object of the process is to combine the hydrometallurgy of copper with the pyrometallurgy in such a way as to produce an economical treatment for copper ores at the mines, which is capable of being operated either in small or in large units as occasion may require, with the production of the copper as the electrolytic metal. If there are precious metals associated with the copper, these may also be recovered in elemental form.

Copper ores, as mined, are usually concentrated to eliminate barren material, or gangue. The concentrate is then usually smelted to matte, the matte blown to blister copper, and the blister copper is then refined to obtain the electrolytic metal. Or, the concentrate may be roasted, leached with sulphuric acid, and the copper deposited electrolytically to obtain the electrolytic metal.

The concentrate may be obtained from the original ore either by gravity or flotation concentration, and the concentrate will usually vary from 15% to 25% copper, depending on the nature of the ore, but principally on the mineralogical combinations in which the copper occurs.

If the concentrate is smelted, roasting is usually necessary, and usually considerable fluxing is required to slag off gangue material associated with a low grade concentrate, and the gangue material also requires fuel for smelting. By smelting a relatively low grade concentrate, a relatively large plant is required, relatively large amounts of fuel and flux must be provided, and the labor item is high; all of which means increased expense.

If the concentrate is treated by roasting, leaching, and electrolysis, the copper can be converted directly into the electrolytic metal, but the roasting of a concentrate containing from 15% to 25% copper, presents some difficulties, both of the extraction of the copper and the fouling of the acid leach solutions. Much progress has been made in roasting high grade copper ore or concentrate to get a high extraction of the copper, and the fouling of solutions is not necessarily harmful, and may be beneficial, as set forth for example in my Patent No. 1,483,056, Feb. 5, 1924, nevertheless, if a treatment can be evolved which largely overcomes the difficulties mentioned, as in the present process, a considerable advantage would result at least under many conditions.

In describing the process reference may be made to the accompanying drawing, which is a flow sheet of the process in diagrammatic plan.

Most mines, or mining districts, produce large amounts of low grade copper ore, usually in the form of sulphide, or as the sulphide and oxide (including carbonate) mixed. In either case the general method of procedure is to separate the sulphide mineral from the gangue to form a concentrate. This concentrate is usually of relatively low grade, as compared with the theoretical percentage of copper in the mineralogical combination of the copper minerals, and is so contaminated with iron, silica, alumina, etc., that vigorous fluxing is required for good smelting conditions, and this makes a smelting process expensive to install and expensive to operate in most mining districts. Where power is cheap and fuel is costly, electric smelting would appear to present some advantages, but the complications arising from the fluxing of large quantities of material and the large amount of electricity required to smelt a relatively low grade ore or concentrate, has led to failure or disappointment wherever it has been tried.

In the concentration treatment of mine ore, either by gravity or flotation, a certain amount of very high grade concentrate may be separated from the large amount of the ordinary sulphide concentrate, but the relatively small amount of very high grade concentrate will contain a relatively large

amount of the total copper. Usually this relatively small portion of high grade concentrate will be in the form of the relatively pure minerals, chalcocite, bornite, and chalcopyrite. Pure chalcocite contains 79.8% copper and 20.2% sulphur; pure bornite contains 55.58% copper, 28.6% sulphur, and 16.36% iron; pure chalcopyrite contains 34.6% copper, 34.9% sulphur, and 30.5% iron.

The conditions of concentration can best be illustrated by taking a specific case in the treatment of 100 tons of ore assaying 1.5%, or 30 pounds, of copper per ton, or containing a total of 3000 pounds of copper. If the ratio of concentration is 10 into 1, we would have, as the result of the concentration treatment:

90 tons tailing, 0.25% copper (5 lbs.)..... 450 lbs. total
10 tons concentrate, 12.75% copper (255 lbs.)..... 2,550 lbs. total

The ten tons of concentrate may be separated into:

1.5 tons high grade concentrate, 50% copper (1,000 lbs.) 1,500 lbs. total
8.5 tons low grade concentrate, 6.2% copper (124 lbs.).. 1,050 lbs. total

Or, preferably, into the following:

1.0 tons high grade concentrate, 60% copper (1,200 lbs.).. 1,200 lbs. total
9.0 tons low grade concentrate, 7.5% copper (150 lbs.).. 1,350 lbs. total

There should not be a great deal of difficulty under most conditions in getting a 50% or a 60% copper concentrate in relatively small amounts as indicated, if much of the copper in the ore is in the form of either bornite or chalcocite. The 60% copper concentrate is preferred and will be assumed for the purpose of illustration, altho it will be understood that the process is not particularly limited to the percentage of copper in the high grade concentrate, but that the higher the grade of the high grade concentrate, the better the process can be operated.

If there is gold or silver in the ore, the high grade concentrate will contain the precious metals in about the same proportion as it contains the copper from the original ore. That is to say, of the total precious metal content in the concentrate, 47.5% will be in the one ton of 60% copper concentrate, and 52.5% will be in the 9.0 tons of 7.5% copper concentrate.

Having made the separation of the mineral from the gangue and divided the mineral into a relatively small amount of high grade concentrate and a relatively large amount of low grade concentrate, the method of procedure is as follows:

The high grade concentrate, assumed as consisting of 60% copper with its combined sulphur and a small amount of iron with its combined sulphur, is preferably smelted in an electric furnace, to dissociate or volatilize the sulphur and to slag off the relatively small amount of iron, so as to obtain, as nearly as possible, pure copper sulphide. The first atom of sulphur of the iron of the concentrate is easily volatilized. The sulphur of the resulting matte which is combined with the iron, and with the copper as cupric sulphide, CuS, is easily volatilized at a comparatively low temperature, but it requires a high temperature—practically a white heat—to volatilize the sulphur from cuprous sulphide, Cu_2S. It is usually preferred therefore to maintain the temperature of the electric furnace such that the sulphur of the iron sulphide and the cupric sulphide are quickly volatilized while avoiding the higher temperature necessary for the complete dissociation of the cuprous sulphide. The extent of the reduction of the cuprous sulphide may vary to suit the operator to get the greatest ultimate economy. There is no definite end point in the process, but the object would be to get all or nearly all of the copper in the condition of cuprous sulphide, and if circumstances indicate greater economy by continuing the reduction so as to obtain a portion of the copper in elemental form, that may also be done, as will be described later. For the present it may be assumed that the copper after being treated in the electric furnace is in the form of practically pure copper sulphide—principally as cuprous sulphide. The charge in the electric furnace is treated so as to slag off or eliminate the iron as completely as practical.

The volatilized sulphur can be condensed and recovered as the elemental sulphur, and the elemental sulphur will usually be an asset in the operation.

On account of the high grade of the concentrate charged into the furnace, its easy fusibility, and the relatively low temperature necessary to volatilize sulphur and slag off impurities, the cost of smelting will be very low, per charge, and still relatively smaller, per pound of copper produced. The power, or electric energy required to smelt such material is quite within good economy at ordinary prices for electricity, and where power is cheap, the economy will be marked.

If the charge is smelted to cuprous sulphide, a ton of the original charge will be concentrated into Cu_2S, weighing about 1500 pounds, as a result of the elimination of the iron and most of the sulphur. This relatively pure copper sulphide is then ground to a suitable fineness and roasted. The resulting copper oxide is then leached with acid, preferably with dilute sulphuric acid, and the copper is then deposited from the resulting pure copper sulphate solution as the very pure electrolytic metal.

One of the principal points in this connection is, that by eliminating the iron by cheap smelting of the high grade concentrate, no ferrites or ferrates are formed in roasting, and hence the extraction or solution of the copper from the resulting copper oxide can be made complete or practically so. The one outstanding difficulty in the treatment of

copper ores or concentrates by roasting, leaching, and electrolysis, has been the formation of ferrites and ferrates in roasting, which makes it difficult, if not at times impractical, to get the high extraction necessary or desired in the treatment of high grade copper concentrate. By the method of procedure of this process, the extraction of the copper, as also the precious metals, from high grade copper concentrate can be made practically complete, and the difficulty incident to the formation of ferrites and ferrates, in roasting, is confined to the low grade concentrate, and will not usually be large.

Another outstanding point of interest is, that with the elimination of the iron from the high grade concentrate, electrolytic difficulties, due to the presence of iron in the electrolyte, are entirely avoided, or practically so, and this makes possible high efficiencies and smooth operation in the deposition of the copper. It also makes possible easy stripping of the waste copper solution, should it be necessary to strip solutions either on account of excess acid or relatively small amounts of impurities which may accumulate in the cyclic operation of the process.

It will be seen that with the elimination of the iron from the high grade concentrate by fusion, the resulting copper sulphide, amounting to about three fourths of the original concentrate, is quickly and easily roasted and quickly and easily leached with dilute sulphuric acid. This indicates a minimum roasting and leaching expense both of installation and operation. If the concentrate contains rare or precious metals they will be found in convenient form in the leached residue, from which they are easily recovered or separated.

The initial acid for leaching may be obtained as such, but this will not be necessary. Some of the concentrate may be roasted to sulphate, and the resulting copper sulphate when electrolyzed will give the acid to make the process cyclic and continuous.

The pure, or relatively pure, copper sulphate solution flows from the leaching tank to the settler, and from the settler the clarified copper sulphate solution flows into the lectrolytic copper tanks No. 1, where the copper is deposited and an equivalent of acid is regenerated. Theoretically, by this process, the amount of acid consumed in dissolving the copper from the copper oxide will be regenerated in the deposition of the copper, so that theoretically, at least, the process requires very little care in regulating solutions, and if the solutions are maintained at the desired copper content, an efficiency approaching the theoretical should be realized in the deposition of the copper.

It is thought, therefore, that this method of procedure, involving cheap smelting, easy roasting, the elimination of iron in injurious amounts from the electrolyte, and with copper of exceptional purity as the end product, offers decided advantages over ordinary roasting, smelting, converting, and the refining of the resulting blister copper, and that it also offers advantages over the general hydrometallurgical process, involving roasting, leaching, and electrolysis, in the treatment of the entire concentrate, with its attendant difficulties in roasting and leaching to get a high extraction, and the difficulties incident to the fouling of solutions, where such fouling is undesirable.

In treating the high grade concentrate in an electric furnace, it may be desirable at times, or always, to reduce some of the copper to elemental metal, altho this elemental metal will be impure. In such a case, the impure copper from the electric furnace is cast into anodes, and refined in the pure, or relatively pure, electrolyte obtained from leaching the pure, or relatively pure, copper oxide resulting from roasting the pure, or relatively pure, copper sulphide. One advantage of this method of procedure would be that less power would be required to deposit the copper, in the proportion of from .3 to .4 volt with soluble copper anodes, as compared with about 1.75 to 2.0 volts for insoluble anodes. The volume of current would be the same in both cases. On the other hand more power would be required in reducing the cuprous sulphide to the elemental metal in the electric furnace, and a further disadvantage would be the extra work in casting anodes and changing them, whereas, with insoluble anodes the operation would be reduced to extreme simplicity, and should be preferred where the cost of electric power is cheap or normal, and the alternative method where the cost of electric power is excessively high. A small amount of metallic copper in the sulphide, if fine, would be converted into the oxide by roasting, and if some of the copper is in the form of shot, it can be dissolved with ferric sulphate in the treatment of the low grade concentrate.

The low grade concentrate, assumed as nine tons containing 7.5% copper, is roasted with the view of making as much as possible of the copper soluble in water, and a high percentage soluble in dilute acid. It is not difficult to roast a low grade concentrate to make from 75% to 85% of the copper soluble in water, and from 85% to 95% soluble in dilute acid. It is difficult, if not impractical, to roast copper ore or concentrate so as to make a high percentage of the copper soluble in water or dilute acid without at the same time making some of the iron soluble. This soluble iron in the leach solution is usually considered detrimental if the copper is to be deposited electrolyti-

cally. Ferric iron is formed to some extent in the roasting, and to a greater extent in the electrodeposition of the copper. The ferric iron is harmful in the electrodeposition of the copper because it re-dissolves the deposited copper largely in proportion to its presence in the electrolyte. This difficulty can be effectively overcome as described, for example, in my Patent No. 1,483,056, Feb. 5, 1924. In view of the fact, however, that in the present process a very large portion of the copper is electrolytically deposited from a solution practically free from iron, as described, it is preferred to also deposit a large portion of the copper obtained from leaching the roasted low grade concentrate, from a relatively pure and rich copper solution.

To do this the roasted low grade concentrate is first leached with water. The water will dissolve the water soluble copper, as sulphate, amounting to about 75% of the total copper in the roasted low grade concentrate. The resulting copper solution can be made very rich in copper, especially since the water will be hot as a result of leaching the hot roasted concentrate. A water saturated solution of copper sulphate at 70 deg. C. will contain 12.93% copper, and while the solution, in practice, will probably never be saturated, there should be no difficulty in maintaining the water solution at about 10% copper. The lean tail water solution from one charge can be used as the head water solution for the next charge. The rich water solution of copper sulphate will be practically neutral and will not contain a great deal of iron, for, as is well known, the amount of water soluble iron in roasted copper ore or concentrate is small as compared with that soluble in dilute acid.

The water solution of copper sulphate from leaching the roasted low grade concentrate is flowed into the water $CuSO_4$ solution tank, where it is treated with the relatively pure copper oxide obtained from roasting the copper sulphide from the smelting furnace. The iron is precipitated, while an equivalent of copper goes into solution. This rich copper solution, practically free from iron in injurious amounts, is then transferred to the electrolytic circuit for depositing copper obtained from leaching the high grade copper oxide. In this way, under the assumed conditions, from 75% to 80% of the total copper in both the high grade and low grade concentrate can be deposited as the electrolytic metal from a solution practically free from injurious impurities, and the copper so obtained should be of exceptional purity, even for electrolytic copper.

It is evident that if the copper solution obtained from leaching the roasted low grade concentrate with water, is transferred to the high grade concentrate circuit, excess acid will be produced, since the copper dissolved as the water soluble sulphate will, on electrolysis, render an equivalent of acid without consuming acid. In order to maintain the best conditions for electrolysis for practically all of the copper deposited electrolytically, the copper solution in the copper tanks should be as nearly normal as possible in acidity and the copper content of the solution should be such as to give the highest ampere efficiency for the current density used, and the current density under the conditions, can be maintained fairly high. These general conditions can be practically carried out by bleeding off the excess solution, or the solution which is too high in acid, or which should become too impure, and stripping the copper from the bled solution in the copper stripping tanks. It should be practical to impoverish the solution in the copper stripping tanks to as low as 0.10% to 0.25% with a fairly high ampere efficiency and with the production of excellent copper. It may not be necessary nor desirable to strip the copper as low as that, since the excess acid is used to dissolve the copper from the roasted low grade concentrate which is not soluble in water.

The acid solution, impoverished in copper, is transferred to the circuit for leaching the roasted low grade concentrate to extract the copper which is not soluble in water, but which is soluble in a dilute acid solution. This acid solution will dissolve the acid soluble copper, as also a considerable amount of iron and other acid soluble impurities. The impure copper solution flows into the acid $CuSO_4$ solution tank, or reducer, where it is preferably treated with copper sulphide, preferably as obtained from smelting the high grade concentrate, or from precipitating copper from lean and foul solutions with hydrogen sulphide. This reduces the harmful ferric iron to the practically harmless ferrous iron, and makes practical a high current efficiency in the deposition of the copper from solutions high in iron. The impure copper solution, containing salts of iron, flows into copper tanks No. 2, where the copper is deposited and acid and ferric iron are regenerated. Ferric iron is injurious largely in proportion to its presence in the electrolyte; the solution is therefore circulated in a sort of closed circuit between the solution tank, or reducer, containing copper sulphide, and the copper tanks to keep down the ferric iron. The solution issuing from the copper tanks No. 2, should not contain over 0.25% ferric iron, and this should be almost completely reduced in the solution tank, or reducer. When the solution is sufficiently impoverished in copper, the resulting acid solution, or a portion of it, is returned to the roasted low grade concentrate leaching tank No. 2. Excess acid will be pro-

duced in the electrolysis of the solutions obtained from treating the roasted low grade concentrate as described. If the concentrator tailing does not contain any copper as oxide (including carbonate) soluble in an acid solution, the lean solution may be treated with a precipitant, such as hydrogen sulphide, and the copper precipitated. The solution may then be wasted.

If, however, the concentrator tailing contains copper worth recovering at no extra acid expense, the concentrator tailing is treated, without any particular refinements, with the excess acid produced in the leaching and electrolytic circuits. The resulting solution will be very dilute in copper and quite heavily charged with all kinds of soluble impurities. It is preferred therefore, to precipitate the copper from these lean and foul solutions chemically, preferably with hydrogen sulphide. The hydrogen sulphide may be conveniently and economically generated from iron matte and the relatively pure and strong acid solution obtained from electrolyzing the relatively rich and pure copper solution in the high grade concentrate circuit. The solution and the precipitate flow into the separator, where the copper sulphide precipitate settles very quickly. The overflowing acid solution may be wasted or returned to the concentrator tailing leaching tank. The copper sulphide precipitate may be transferred to the solution tank, or reducer, of the low grade concentrate leaching and electrolytic circuit, where the copper is redissolved with the reduction of ferric iron, and the re-dissolved copper is then deposited as the relatively pure electrolytic metal.

If a portion of the copper solution from leaching the concentrator tailing is rich enough, it may be transferred to the electrolytic circuit of the low grade concentrate, and the copper deposited therefrom directly as the electrolytic metal.

If power for electric smelting is expensive, or if the high grade concentrate contains considerable amounts of impurities, it will usually be desirable to smelt the high grade concentrate in a blast furnace to slag off most of the iron and other impurities and run the molten matte into the electric furnace for the further elimination of iron and to concentrate the copper to the condition desired. It is difficult to get the desired elimination of the iron in the electric furnace without producing slag fairly high in copper. The high copper slag from the electric furnace is therefore returned to the blast furnace, so that the only metal loss in the slag is that in the blast furnace slag, and this will usually be quite small. If desired, air or steam may be introduced into the electric furnace to assist in the desired reactions.

The total elimination of the iron so as to produce pure copper sulphide is probably impractical on a commercial basis, and while a chemically pure copper sulphide is not contemplated in this process, it is desirable to eliminate the iron as completely as practical, consistent with economical commercial operation. The small amount of iron remaining in the copper sulphide will largely be converted into the insoluble oxide on roasting. If a small amount of iron goes into solution on leaching, it will, or may, be precipitated out of the solution by the large amount of copper oxide, obtained from roasting the copper sulphide, which acts as a strong base. Thus the iron may be kept out of the solution, except in amounts so small as not to be noticeably injurious in the commercial deposition of the copper from the leach solution.

The tendency in leaching the practically pure copper oxide, containing perhaps variable amounts of copper sulphate, is to produce excess acid. Bleeding of the solution may be regulated so that the acid and impurities in the leach solution and electrolyte may be kept at a desired standard. In any event, the amount of impurities in the solution in the high grade concentrate leaching and electrolytic circuit can be kept exceedingly low.

In eliminating iron in the electric furnace and producing as nearly as practical pure copper sulphide, when the copper concentrate reaches the composition of chalcocite, Cu_2S, or about 80% copper, some of the copper is likely to separate out as the elemental metal. Under certain conditions it may be desirable to carry the treatment in the electric furnace so far as to obtain some of the copper in the form of sulphide and some in the form of the elemental metal. The sulphide would then be roasted and leached as described, and the elemental impure copper, or even copper sulphide containing elemental copper, would be cast into anodes, and the anodes would be refined in the relatively pure copper solution obtained from leaching the relatively pure copper oxide, resulting from roasting the relatively pure copper sulphide. The separation between the sulphide and the metal, in the electric furnace, need not be carefully made; if a little sulphide gets mixed with the copper in the anodes, it will do no particular harm, and if some finely divided copper gets mixed with the sulphide, the elemental copper, like the sulphide, will be converted into the oxide on roasting. Should any metallic copper be left in the residue after leaching, it can be returned to the electric furnace.

The production of metallic copper may be facilitated by adding high grade copper oxide to the fused high grade sulphide. The copper oxide may be obtained from roasting a high grade sulphide, obtained from roasting a high grade copper concentrate, or the high grade copper sulphide obtained from smelting. The copper sulphide and the copper

oxide in the electric furnace will react to produce elemental copper and sulphur dioxide, a reaction which is well known.

Where power is expensive, the saving in power in the deposition of the copper from a soluble anodes as compared with depositing the copper with insoluble anodes, would be considerable. No strict line of demarcation between the sulphide and metallic copper would have to be followed, but the process admits of wide variation, without much special apparatus.

If a portion of the copper sulphide is reduced to the metallic state in the electric furnace, part of the copper, on electrolysis, will be deposited from soluble copper anodes and another portion will be deposited from the leach solution with insoluble anodes. Antimonial lead anodes seem to be the most satisfactory for this purpose, for insoluble anodes.

In roasting the concentrated copper sulphide obtained by smelting the high grade concentrate, some copper sulphate is formed, but this copper sulphate does not interfere with the general working of the process. The relative amounts of copper oxide and copper sulphate in the concentrated copper oxide may be controlled in the roasting. The excess acid produced by leaching the concentrated copper oxide, including the sulphate if present and electrolyzing the resulting copper solution, may be used in extracting copper from lean oxidized ore, or from the concentrator tailing.

Copper ores frequently contain small amounts of rare or precious metals, which in the usual methods of treatment by solvent processes would not be worth the extra step for their recovery. In the present process the rare or precious metals will be concentrated by gravity or flotation in about the same proportion as the copper. That is to say, about 47.5% of the total precious metal content of the concentrate will be in the high grade concentrate and 52.5% in the low grade concentrate, under the assumed conditions. In order to facilitate and cheapen the recovery of any residual copper and the rare or precious metals in the high grade concentrate leached residue, the residue is returned to the smelting furnace until the precious metals have accumulated sufficiently to make their recovery in elemental form most profitable, and then the leached residue is given a special treatment for the recovery of the rare or precious metals by any of the well known methods.

By separating the concentrate into a high grade concentrate and a low grade concentrate, the low grade concentrate leached residue can also be treated with greater facility for the recovery of the precious metals, especially with cyanide. Copper is a strong cyanicide, and in high grade or medium grade copper concentrate it is extremely difficult, and highly uncertain, to get the copper leached residue sufficiently low in copper to make economic cyaniding practical for the recovery of the precious metals. It is easily practical, however, in leaching roasted low grade concentrate, to get the copper so low in the residue that cyaniding of the residue will not present any unusual difficulty. The separation of the concentrate into a high grade and a low grade concentrate offers certain definite advantages in the recovery of the precious metals by the process described.

In leaching the roasted low grade concentrate to dissolve the water soluble copper, it may be desirable to add a little of the regenerated acid solution to the water to make a very dilute acid solution with which to dissolve the water soluble copper. This will dissolve an appreciable amount of the acid soluble copper, but only a very small extra amount of the acid soluble iron. The idea would be to leach the water soluble copper with an acid solution so dilute that the solution after leaching would be neutral or nearly so, and that the small amount of iron dissolved would be precipitated with the excess, or concentrated, copper oxide. The iron precipitated out of the solution with the copper oxide would be redissolved by the acid leaching of the roasted low grade concentrate, but as this copper solution, containing salts of iron is electrolyzed under conditions in which the iron is not particularly harmful and may even be beneficial.

In leaching the copper leached residue in leaching tank No. 1 to extract the precious metals, it is not necessary to make a close extraction of the precious metals if the leached residue is returned to the smelting furnace, since the residual copper and rare or precious metals will be recovered in a new matte or copper sulphide, so that the only metal loss would be that in the slag from the smelting furnace and that escaping as fume.

I claim:

1. A process comprising, treating copper ore to separate a high grade and a low grade copper concentrate, roasting the low grade concentrate, smelting the high grade concentrate to produce highly concentrated copper sulphide, roasting the concentrated copper sulphide to produce concentrated copper oxide, leaching a portion of the concentrated copper oxide with an acid solution to extract the copper, electrolyzing the resulting copper solution to deposit the copper and regenerate acid, returning the regenerated acid solution to the concentrated copper oxide, leaching the roasted low grade concentrate to extract a portion of the copper, treating the resulting copper solution with a portion of the concentrated copper oxide, and electrolyzing the resulting purified copper solution with the copper solution obtained from leaching the concentrated copper oxide.

2. A process comprising, treating copper ore to separate a high grade and a low grade copper concentrate, roasting the low grade concentrate to make a portion of the copper water soluble and a portion acid soluble, smelting the high grade concentrate to produce a highly concentrated copper sulphide, roasting the concentrated copper sulphide to produce concentrated copper oxide, leaching the concentrated copper oxide with an acid solution to extract the copper, electrolyzing the resulting copper solution to deposit the copper and regenerate acid, returning the regenerated acid solution to the concentrated copper oxide and repeating the cycle, leaching the roasted low grade concentrate to extract the water soluble copper, and adding the water soluble copper solution to the concentrated copper oxide leaching and electrolytic circuit.

3. A process comprising, treating copper ore to separate a high grade and a low grade concentrate, roasting the low grade concentrate, smelting the high grade concentrate to produce concentrated copper sulphide, roasting the concentrated copper sulphide to produce concentrated copper oxide, separately leaching the roasted low grade concentrate and the concentrated copper oxide, adding the richer and purer portion of the copper solution resulting from leaching the roasted low grade concentrate to the richer and purer solution obtained from leaching the concentrated copper oxide, and electrolyzing the solution.

4. A process comprising, treating copper ore to separate a high grade and a low grade concentrate, roasting the low grade concentrate, smelting the high grade concentrate to produce concentrated copper sulphide, roasting the concentrated copper sulphide to produce concentrated copper oxide, separately leaching the roasted low grade concentrate and the concentrated copper oxide to extract the copper, electrolyzing the richer and purer copper solution obtained from leaching the roasted low grade concentrate and the concentrated copper oxide in one electrolytic circuit, and electrolyzing the relatively lean and impure copper solution obtained from leaching the roasted low grade concentrate and the concentrated copper oxide in another electrolytic circuit.

5. A process comprising, treating copper ore to produce a copper concentrate, smelting the concentrate to matte, treating the matte to eliminate sulphur and slag off iron so as to produce a concentrated copper sulphide, roasting a portion of the concentrated copper sulphide to produce concentrated copper oxide, leaching the concentrated copper oxide to extract the copper, electrolyzing the resulting copper solution to deposit the copper and regenerate acid, treating another portion of the concentrated copper sulphide to eliminate more sulphur so as to produce impure metallic copper, casting the impure metallic copper into anodes, and refining the anodes in the copper solution obtained from leaching the concentrated copper oxide.

6. A process comprising, smelting copper concentrate to matte, treating the matte to eliminate sulphur and iron so as to produce concentrated copper sulphide, roasting a portion of the concentrated copper sulphide to produce concentrated copper oxide, leaching a portion of the concentrated copper oxide to extract the copper, electrolyzing the resulting copper solution to deposit the copper and regenerate acid, applying a portion of the concentrated copper oxide to a portion of the heated copper sulphide to eliminate sulphur so as to produce impure metallic copper, casting the resulting impure metallic copper into anodes, and electrolytically refining the anodes with the copper solution obtained from leaching a portion of the concentrated copper oxide.

7. A process comprising, treating copper ore to separate a high grade and a low grade copper concentrate, roasting the low grade concentrate, leaching the roasted low grade concentrate to extract the copper, smelting the high grade concentrate to produce concentrated copper sulphide, roasting the concentrated copper sulphide to produce copper oxide, applying the copper oxide to the copper solution obtained from leaching the roasted low grate concentrate, and electrolyzing the solution.

8. A process comprising, treating copper ore to separate a high grade and a low grade copper concentrate, roasting the low grade concentrate, treating the high grade concentrate to convert a portion of the copper to the concentrated copper oxide and a portion to the impure metallic copper, leaching the roasted low grade concentrate to extract the copper, treating the resulting copper solution with the concentrated copper oxide and refining the impure metallic copper in the copper solution as the electrolyte.

9. A process comprising, separating copper ore into a high grade and a low grade copper concentrate, roasting the low grade concentrate, to make a portion of the copper water soluble and a portion acid soluble, leaching the roasted low grade concentrate to extract the water soluble copper, smelting the high grade concentrate to produce concentrated copper sulphide, roasting the concentrated copper sulphide to produce concentrated copper oxide, applying the concentrated copper oxide to the water soluble copper solution to precipitate iron and other impurities from the solution, and electrolyzing the purified solution to deposit the copper.

10. A process comprising, treating copper ore to separate a high grade copper concen-

trate and a low grade copper residue, treating the high grade concentrate to produce concentrated copper oxide, leaching the concentrated copper oxide with an acid solution to extract the copper, electrolyzing the copper solution to deposit the copper and regenerate acid, treating metal sulphide with the regenerated acid solution to produce hydrogen sulphide, and precipitating copper from lean or foul solutions with said hydrogen sulphide.

11. A process comprising, treating copper ore to separate a high grade copper concentrate and a low grade copper residue, smelting the high grade concentrate to produce concentrated copper sulphide, roasting the concentrated copper sulphide to produce concentrated copper oxide, leaching the concentrated copper oxide with an acid solution to extract the copper, electrolyzing the copper solution to deposit the copper and regenerate acid, and applying the regenerated acid solution to the low grade copper residue to extract the copper therefrom.

12. A process comprising, treating copper ore containing rare or precious metals to separate a high grade and a low grade copper concentrate, smelting the high grade concentrate to obtain concentrated copper sulphide, roasting the concentrated copper sulphide to obtain copper oxide, leaching the copper oxide to extract the copper, returning the leached residue to the smelting furnace and repeating the cycle until the residue is desirably enriched in the rare or precious metals, and then treating the residue to recover the rare or precious metals.

13. A process comprising, smelting copper concentrate containing precious metals to concentrate the precious metals into concentrated metal sulphide, roasting the concentrated metal sulphide, leaching the resulting roasted material to extract the copper, smelting the leached residue to concentrate the precious metals and residual copper into an impure concentrated copper product, and electrolytically refining the impure concentrated copper product to separate the precious metals and recover the copper as the electrolytic metal.

14. A process comprising, treating copper ore to produce a copper concentrate, roasting a portion of the concentrate, leaching the roasted concentrate to extract a portion of the copper so as to obtain a relatively pure and relatively rich copper solution, then separately leaching the roasted concentrate to extract the remaining copper and thus obtaining a relatively lean and relatively impure copper solution, smelting another portion of the concentrate to produce an impure concentrated copper product, casting the impure concentrated copper product into anodes, and refining the anodes with the relatively pure and relatively rich copper solution obtained from leaching the roasted copper concentrate as the electrolyte.

15. A process of treating copper concentrate comprising, smelting the concentrate to matte, electrically heating the matte to dissociate the sulphur and iron so as to produce concentrated copper sulphide, roasting a portion of the concentrated copper sulphide to produce concentrated copper oxide, and adding the concentrated copper oxide to the electrically heated copper sulphide to eliminate more sulphur.

16. A process comprising, treating copper ore to separate copper concentrate, roasting a portion of the concentrate to make a portion of the copper water soluble and a portion acid soluble, leaching the roasted concentrate to first extract the water soluble copper and then leaching the roasted concentrate to extract remaining acid soluble copper, separately precipitating the copper from the water soluble and from the acid soluble copper solutions, smelting another portion of the concentrate to produce a highly concentrated fused copper product, casting the highly concentrated fused copper product into anodes, and electrolytically refining the anodes in the water soluble copper solution obtained from leaching the roasted concentrate.

17. A copper extraction process comprising, treating copper ore to separate a high grade and a low grade copper concentrate, roasting and leaching the low grade concentrate to extract the copper, smelting the high grade concentrate to produce concentrated copper sulphide, electrically heating the concentrated copper sulphide, adding concentrated basic oxide to the electrically heated copper sulphide to eliminate the sulphur and to produce impure metallic copper, casting the resulting impure metallic copper into anodes, and electrolytically refining the anodes.

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