

copper-silver matte may be successfully roasted, even if silver predominates slightly over copper. But assuming that the relation of silver to copper must be one to one, the amount of copper needed would not be very large where ores are treated by the Russell process, and a comparatively large amount of copper comes to precipitation. All this copper would be returned as sulphate.

The operations of the process would be as follows:

1. Matting and copperizing the sulphides in a cast-iron kettle. Sulphurous acid, produced by burning of an excess of sulphur, should be conducted to the muffle furnace and thence to the Roessler convertor, or to the latter at once. The matte may be removed from the kettle while in a pasty condition, i.e., before solidifying.

2. Pulverizing of the matte through a No. 40 screen.*

3. Roasting in a muffle furnace, with a Roessler convertor attached. The roasting should be conducted as was done by Hodges, i.e., for the formation of a maximum of silver sulphate. Should the sulphuric acid produced in the convertor be insufficient for dissolving all the copper oxide, pyritic ores, containing silver, could be roasted occasionally, at slight expense, to make up the deficiency; or sulphur could be burnt should this prove more economical.

4. Boiling the roasted sulphides (after separating sintered lumps by screening), in a lead-lined tank with the sulphuric acid obtained in the Roessler convertor.

In this operation either of two methods may be selected. One, as described by Hodges, consists in the separate precipitation of the silver sulphate from the solution by copper, if it is desirable to raise the fineness of gold in the insoluble silver residue; the other, in effecting the decomposition of silver sulphate at once by placing copper plates in the dissolving tank. The latter method is the simpler, requiring less apparatus and manipulation, and deserves preference when gold is absent, or present in sufficient quantity to stamp the bars.†

5. Crystallizing the copper solution, if necessary, after concentration.

Since all or most of the copper sulphate is used again in the mill, and not for sale, special attention need not be paid to the production of a fine looking or very pure article. In fact, small crystals are more desirable for the preparation of extra solution than large ones. Mother liquor from the crystallizing vats would be returned to the Roessler convertor.

The concentration of solutions I propose to effect by running them through a lead tower, with inclined shelves, against a current of hot air. The latter would be drawn from the chimney of the muffle furnace by a Koerting steam jet ventilator.

6. Washing of the silver residues (and cement-silver); pressing into cakes; drying and melting into bars.

7. Precipitating cement-copper by scrap iron from wash waters, weak solutions and from mother liquors in which too much iron has accumulated.

In some cases a surplus of copper sulphate over that needed for extra solution in the mill may result. Where this could not be sold at a profit, it should be precipitated by scrap iron, thus keeping in rotation the cement-copper for copperizing the matte.

It will be seen that the process in this form presents no essential technical difficulties, all its operations being well understood by metallurgists; nor does it require large, expensive or complicated apparatus. The refinery should be built on a scale to remain in operation and keep the men employed continuously during the daytime only.

Whether it will be more profitable to refine sulphides at the mill or sell them to smelters, must be calculated for each individual case and depends entirely on local circumstances.

I have no doubt that refining sulphides at the mill would extract a higher percentage of the precious metals, especially of the gold, than is shown by the commercial assay upon which settlement is made between the buyer and seller. Smelting works must have a margin in their favor, or they could not conduct their business with a sufficient profit at the rates they charge for treatment and the percentage they deduct from the commercial assay value. Even the Freiberg works, belonging to the government, have their *Huettenmedien* and extract so-called "plus" silver.

Having in view the erection of a refinery for sulphides at the Marsac mill, Utah, I made the following laboratory experiments.

EXPERIMENTS WITH SULPHIDES CONTAINING LEAD AND CALCIUM.

(Sulphides Unwashed).

The lot of Marsac sulphides, a sample of which was at my disposal, was said to have been produced after the precipitation by Solvay soda of lead and calcium from the solution; but either the precipitation of these metals was not complete, or the sulphides had become mixed with those obtained prior to the introduction of separate precipitation for lead and calcium. The sample contained 34.7 per cent. silver (9.0 ounces gold per ton), 19 per cent. copper and 2 per cent. lead; calcium and other constituents not determined. A few grammes

One cubic foot of matte, pulverized through a No. 40 screen, will weigh about 175 pounds.

† In connection with this point, I made the following experiment: An alloy of pure silver and copper, 500 fine in silver, was boiled with silver sulphate. Cement-silver was rapidly precipitated, although much more slowly than by the use of pure copper. I then took Ontario bullion, 440 fine, which is principally an alloy of silver and copper, and immersed a sheet of it in a silver sulphate solution. The reduction to cement-silver was very slow and ceased entirely after a short time. Probably the presence of a small amount of lead interfered with the reaction.

of these sulphides were digested with dilute hydrochloric acid. Carbonic acid and sulphuretted hydrogen were evolved, showing the presence of calcium carbonate* (and lead sulphide). The filtered solution was boiled with potassium chlorate, after which lead and a small amount of iron were precipitated by ammonia. From the filtrate a very perceptible precipitate of calcium oxalate was obtained. Most of the calcium however, remained, with the residue as sulphate.†

In roasting these sulphides in a clay dish: in the muffle of a cupelling furnace the free sulphur was burnt quickly, and then a rapid roasting at a very low temperature took place. In elevating the temperature as required for a dead roast, the sodium sulphate (during roasting, sodium hyposulphite and chloride are also converted into sulphate), commenced to fuse, and the final result was a granular mass of brittle, metallic globules, on which continued roasting did not seem to have much effect. On treating them with sulphuric acid of 15° B., not a trace of silver sulphate was found in solution, and after continued boiling only a small quantity of copper was extracted.

Now, 50 grammes of sulphides were mixed with 8 grammes of cement-copper, to raise the percentage of copper to that of silver, and heated in a small cast iron crucible. Some sulphur fumes escaped, and then quick and complete fusion took place at a low red heat. The very liquid matte was poured out. Not a particle of metal had separated, and the inside of the crucible was not visibly affected. The matte, pulverized and sifted through a No. 40 screen, was roasted at a temperature just sufficient to ignite. It behaved very well and did not bake in the least just then. But when the temperature was raised, after the blue flame of sulphur had disappeared, the sodium sulphate commenced to fuse, and the roasting dish was filled with a mass like mush. Under still further increase of heat, the charge commenced to foam, through decomposition of sulphates and reaction between oxides and sulphides, and shortly after it hardened into solid, porous crusts. These were pulverized and boiled with dilute sulphuric acid. Rapid solution of the copper oxide took place, and from this solution copper sulphate and a great deal of sodium sulphate crystallized. The metallic residue was fused with borax, yielding silver .790 fine. It can be seen, as observed at the beginning of this paper, that roasting and treatment as above of unwashed sulphides is not practicable. Under such circumstances the roasting is not only very difficult and incomplete, but the resulting silver is too low in fineness and the copper solution is contaminated with sodium sulphate.

The sulphides were now leached with water, and the purified product was subjected to the same treatment as formerly.

EXPERIMENTS WITH SULPHIDES CONTAINING LEAD AND CALCIUM.

(Sulphides Washed).

The direct roasting of washed sulphides proceeded better than that above described; but when the temperature was raised the charge became rather sticky, foamed and then hardened. It contained considerable copper oxide; and, after boiling with sulphuric acid, the insoluble residue, melted with borax, yielded a button about half metal and half matte. The matte contained 35 per cent. of silver and the metal was .897 fine.

After matting and copperizing a sample, as described before, I found that roasting could be carried on without the slightest difficulty, the charge behaving well from beginning to end. I made no attempt at Ziervogel roasting, which is rather difficult anyhow with small samples, and with material containing so much lead and calcium. The temperature was quickly raised after most of the sulphur had been oxidized. At the end the charge was kept at a good red heat. After boiling with acid, the residue yielded a bar .938 fine in silver. With slower and more careful roasting, fine silver would, no doubt, have been produced, although the presence of lead and calcium sulphate must also have exerted an unfavorable influence.

EXPERIMENTS WITH SULPHIDES ENTIRELY FREE FROM LEAD AND CALCIUM.

Having, at the time, no sulphides free from lead and calcium at my disposal, I produced them by converting 10 grammes of silver into chloride, dissolving the latter in sodium hyposulphite solution and adding 40 grammes of $\text{CuSO}_4 + 5\text{aq} = 10$ grammes Cu. The solution was precipitated with sodium sulphide and the sulphides were washed, dried and matted.

In roasting the pulverized matte great care was taken to regulate temperature so as to form a maximum of silver sulphate, especially by not allowing the charge to get too hot at the end of the roasting. This was accomplished remarkably well. In dissolving the roasted matte nearly all the silver went into solution and was precipitated as cement-silver. The final result was a bar .988 fine in silver.

* Concerning the presence of calcium carbonate in sulphides, see my paper, "The Precipitation of Metals from Hyposulphite Solutions," already cited.

† It is not astonishing that so little calcium carbonate should be found in and dissolved from the unwashed sulphides. In digesting the sulphides with diluted hydrochloric acid, the sodium sulphate present precipitates most of the dissolved calcium as gypsum. In subjecting the sulphides to steam drying, there is also opportunity for converting calcium carbonate into sulphate. Gypsum as such cannot be precipitated by Na_2S_2 from a sodium hyposulphite solution (as constituted after use in the mill), containing calcium.

EXPERIMENTS WITH SULPHIDES CONTAINING ONLY SMALL QUANTITIES OF LEAD AND CALCIUM.

(Sulphides Washed).

Finally, I obtained from the Marsac mill samples of a lot of sulphides containing only a trace of lead and much less calcium than the first lot.

The contents in silver were 34.6 per cent. (8.6 ounces gold per ton), and in copper, 20.0 per cent. Soluble salts, 13.2 per cent. After leaching out soluble salts, a part of these sulphides was matted directly and another part with incorporation of cement-copper, as described for former experiments. Both samples were now roasted with the intention of forming as much Ag_2SO_4 as possible. Only a small portion of the silver, however, was converted into sulphate. This was evidently due to the presence of calcium in the matte.

The sample to which copper had not been added was rather difficult to roast, requiring constant stirring and showing a tendency to sinter, while the copperized matte behaved very well, as described in previous experiments. The addition of copper is of decided advantage in facilitating the roasting, and, in consequence, raising the fineness of the silver after solution of the copper. The matted and copperized sulphides yielded silver .990 fine, while the sulphides matted without addition of copper yielded silver only .938 fine.

The roasting in all these experiments was done in the muffle of a cupelling furnace which held clay dishes of only $3\frac{1}{2}$ inches diameter. In consequence, the roasting of such small masses proceeded too rapidly, which was detrimental to the formation of silver sulphate, and favored the separation of metallic silver alloyed with more or less copper. There is no doubt that finer silver will result after careful roasting on a large scale. Sintered lumps, containing unroasted matte, should, of course, be separated by screening, and, after pulverizing, should be re-roasted with the next charge. The presence of small quantities of lead and calcium is evidently not injurious, although it interferes with a good Ziervogel roasting.

This paper would have possessed more value and interest if the experiments had been followed by analysis of the materials and all the products. To do this I had neither the facilities nor the time; besides, such work is done more profitably at the mill, for reasons that require no explanation. I hope the muscular lixiviators will wake up to the fact that their work cannot prosper without analytical help. The present condition of affairs is disgraceful, as has been more fully shown in my paper on "Precipitation."

I refrain from giving estimates of the profit and loss in refining sulphides by the process described above, hoping to do this at some future time, after its introduction in practice.

The Transmission of Power by Electricity.—The *Bulletin de l'Electricite*, in a consideration of the problem of the transmission of power by high-tension currents, states that the official experiments demanded by the German Government from the Berlin General Electricity Company and the Crefeld Metallurgical Works as to their method of transmission of 300 horse power to a distance of 180 kilos, have given results full of useful information. The problem of the electrical transmission of power seems wholly solved by the employment of high tensions, before which the notion of distance between the generator and receiver disappears. It was necessary, however, to make some reservations as to the possibility of utilizing a current of 30,000 volts on account of the difficulty of suitably insulating the dynamos and conductors, besides which it was necessary to determine the conditions under which the disruptive charges took place. The Crefeld experiments do not definitively determine the question, their deviation being too limited. In the experiments under notice an alternating current dynamo giving at high pressure a tension of 100 volts communicated with the circuit of a large transformer wire plunged in oil, of which the circuit of the thin wire was joined on to the line. This, formed of bare wire of 4 mm., was supported by posts supplied with insulators and presenting a working length of 7 kiloms., and comes at the limits of the circuit from the thin wire of a transformer also steeped in oil, of which the thick wire circuit communicates with the receiver. In the first experiment the tension at the beginning of the line was 15,000 volts, and 100 volts only at the limits of the generator. In the two other experiments the tension of the principal current was pushed to 30,000 and then to 33,000 volts, the receiver only receiving a current of 100 volts. Carefully taken measures showed that the insulation was perfect, and that no deviation was produced either in the machinery or on the line. The result of this is that it is possible to produce and utilize without losses a current of 33,000 volts; but one cannot judge how long the insulators will resist, and the Frankfurt experiments will enlighten us on this point. The dangers arising from a disruptive discharge are less to be feared than one would be tempted to suppose. Two thin wires had been fixed, one to each of the line wires, and their ends by degrees brought together; the discharge spark was only produced at a distance of 22 mm., under a difference of potential of 22,000 volts. The Helios Company have also made similar experiments and recognized that the spark burst at the respective distances of 28 and 64 mm. for tensions of 15,000 and 28,000 volts. Leaden circuit cutters being intercalated on the principal line, the formation of a short circuit was provoked, when the lead melted immediately and the current was interrupted. Such have been the Crefeld experiments, the consequences of which are of a kind to alter the present working conditions of electrical energy.