

same material. A muffler is wrapped round the neck and lower part of the face, and a thick slouch felt hat drawn down as low as possible over the face. Thus protected the furnace-men experience little difficulty or inconvenience in dipping the bullion out of the white-hot retorts.

About 12 hundredweight of dry alloy is fed in per charge. The retort is filled up to the neck with lumps of alloy. As this settles the rest is fed in until the retort contains the whole charge. The condenser is then wheeled up in position, the mouth luted to the sides with fireclay, and the heat of the furnace raised. The condenser is of sheet-iron, lined with the same material as used for cupel buttons. The condenser is cylindrical in form, and inclines downwards from the furnace. The far end is flat, and has a small tap-hole, closed by cement, while a small vent is left on top of the cylinder. The length of operation is about $10\frac{1}{2}$ to 12 hours. The products are—Au-Ag-Pb bullion, or Ag-Pb bullion, distilled and condensed zinc dross, a small amount of blue powder and fume. The zinc is distilled off from the alloy, and is condensed in the cylindrical condenser, from which it is tapped from time to time. The zinc is returned for further use in the zinc pans. The fume, small in amount, is zinc with a little lead. It escapes from the top of the condenser, and is lost. The blue powder is sent to the blast furnace on refinery drosses. When the distillation is complete all the remaining zinc is tapped from the condenser into moulds, and the condenser removed, the dross skimmed off, and the bullion tipped out into moulds. The further treatment of the bullion and dross will be described later. Old retorts are broken up, and sent to the blast furnaces on refinery products.

TREATMENT OF ZINC CRUSTS AND DROSSES.

GOLD CRUSTS.

The pressed dross skimmings from the special gold pan are not retorted, but treated direct with litharge in a cupel furnace, in which most of the zinc is burned off. About 12 hundredweight is treated per shift, in lots of 4 hundredweight each. Before each lot is fed in, the crust, known as "gold sweatings," is skimmed off, and sent for further treatment to the blast furnaces on refinery products, and part of the bullion ladled out and sent to the concentrating cupels.

The gold-zinc alloy obtained from the "special gold pan" is sent to the retort furnaces, where it is fed into the retorts, and retorted for about 12 hours. The condensers are removed, and the zinc which has been recovered is returned for further use in the zinc pans. The dross is removed from the retorts,

and, together with the dross obtained in the previous partial retorting, is treated on sweat cupels. Retort bullion contains: Gold, 12oz. per ton; silver, 250-300oz. per ton. Retort dross contains: Silver, 120-130oz. per ton; lead, 60 per cent. The bullion is dipped out into moulds, and concentrated in cupels to about—

| | | | | |
|----------------|----|----|----|------------|
| 16,000oz. | .. | .. | .. | Ag per ton |
| 480 to 640 oz. | .. | .. | .. | Au per ton |

The bullion is then dipped out and refined in another cupel, and afterwards dried, as explained in the production of silver bullion. The doré bullion is placed in the strong-room until sufficient has been collected to run the parting plant, where it is treated towards the close of each half-year. Gold contents about 30 to 40oz. per 10,000 ozs. doré bullion.

TREATMENT OF SILVER CRUSTS.

A charge of 12 hundredweight of silver-zinc crusts are treated in a retort in the manner above described. The products are distilled zinc, dross, bullion, a small amount of blue powder and fume. The bullion is cupelled and the dross treated in the "retort dross furnace."

Retort bullion contains—

| | | | |
|--------|----|----|---------------------------|
| Silver | .. | .. | 3,000 to 3,500oz. per ton |
| Gold | .. | .. | Trace |
| Zinc | .. | .. | 1.3 to 3.3 per cent. |

The retort dross contains—

| | | | |
|--------|----|----|---------------------------|
| Silver | .. | .. | 2,200 to 2,500oz. per ton |
| Lead | .. | .. | 55 to 60 per cent. |

The bullion is equal to about 34 per cent., the dross to about 3 per cent., and the condensed zinc to about 10.5 per cent. of the charge.

Coal consumed equals about 15 per cent. of weight of alloy treated.

CUPELLATION.

The cupellation is undertaken in furnaces of the English type—that is, like a small reverberatory furnace, the hearth of which has a replaceable bottom cupel, or "test." The furnace is fired with coal on a hearth on one side. The flame and products of combustion pass across the minor axis of the test, and run down a flue at the other side. The test frame is an elliptical iron pan 5ft. by 4ft. by about 12in. deep. The pan is lined with a filling composed of—Marble, 300lb.; limestone, 120lb.; Portland cement, 120lb.; and fireclay, 60lb. All the constituents are finely ground and well mixed. The mixture

is moistened and thoroughly tamped into position. The well of the test is formed by placing an inverted mould in proper position, and well tamping the filling round it. After the mould has been removed the outlet gutter is cut. The width of the top of the filling is here about 9in., and at the far side about 4in. The tests are covered over with wet bags for some time, and stacked in a warm place for several months, to become thoroughly dry.

The tests for the concentrating cupel are water-cooled round the rims by a lin. water pipe, which enters near the outlet, passes right round, and is bedded in the upper portion of the side of the test. There is also a water-cooled outlet. A tuyere, with a horizontal slit nozzle, directs a current of air on to the bath of molten metal. The litharge as it is formed is blown across the outlet, and a fresh surface of metal exposed to the air current. The molten litharge runs continuously from the outlet into slag pots. The bath of metal is kept to its proper height by feeding fresh bars of bullion through a door specially arranged for that purpose. When the bullion has reached the desired concentration—viz., to about 50 per cent. silver, the blast is taken off, and the bullion is dipped out into moulds, and taken to the refining cupels. Concentrating cupels give about 18cwt. of litharge and 25 to 30 bars of bullion per shift of eight hours. Part of the litharge is kept for treatment in the retort dross furnace, and the rest sent to the blast furnace on refinery products.

The concentrated bullion is now further concentrated to crude silver in another cupel furnace, the test of which is similar to the previous, except that it is shallower and not water-cooled round the edge. The outlet, however, has a water-cooled block. The concentration is continued until the silver has very little lead in it. It is then dipped out into tapered rectangular moulds, containing about 1,000oz.

The crude silver is further refined, or "dried," on a finishing cupel similar to the former, except that no outlet is used. The test used is one that has never been used before. It is afterwards used for the preceding operation. After the silver has been melted down, a little lime or dry test compo. is thrown on the surface. The fire is strongly urged. The last trace of lead is volatilized or taken up by the powdered lime or compo. The latter is gathered together into a ball, and removed by an iron bar. The refined silver is dipped out into hexagonal moulds, containing about 700oz. The moulds are of a different shape, so that the bars of "dried silver" are not mistaken for those of "crude silver." The top of the solidifying ingot is stirred to prevent undue frothing and spitting during the cooling of the silver.

During the moulding a sample for assay is taken by pouring a little from several ladles into a pail of water. This rough-cast silver is almost pure, and has a "fineness" of about 998.5 to 999.2.

REMOULDING OF SILVER INTO MARKET BARS.

The rough hexagonal ingots are re-melted in plumbago crucibles, about 2,050oz. to the charge, and cast into two brick-shaped bars, slightly tapered to one side, weighing about 1,020oz. each, and a sample for assaying poured into water. A little pure copper is added to each charge to bring the "fineness" of the silver back to 996.0 to 996.2, as greater fineness than 996 is not paid for. The freshly-poured bars are skimmed, and when solidified turned out of the mould and plunged into water. The bars are freed from rough excrescences of surface by chiselling, scraping, and filing, the edges being slightly rounded. The upper surface and one end are hammered all over. Upon the hammered end is placed the company's brand, number of batch, number of bar, fineness of silver, and weight to the nearest half ounce. The silver bullion is sent away once a week in lots of about 100,000oz., its destination usually being India or China.

TREATMENT OF RETORT DROSS.

The retort dross is stored and treated periodically in a reverberatory similar to those for treating lead in softening and refining.

The retort dross is treated with litharge and fine coal. A bath of about five tons of lead bullion is first melted down, otherwise the dross sticks firmly to the bottom of the furnace hearth. A charge consists of—

| | | | | |
|--------------|----|----|----|--------|
| Retort dross | .. | .. | .. | 750lb. |
| Litharge | .. | .. | .. | 500lb. |
| Fine coal | .. | .. | .. | 25lb. |

Four charges are added for each eight-hour shift, producing 22 to 23 hundredweight of slag, which is removed once a shift in a similar manner to a skimming from a softening furnace. The bullion is tapped periodically into a small lead kettle, and then bailed out into moulds. This bullion is very rich in silver, and is cupelled without any intermediate process.

The slag, known as dross furnace slag, is sent to the blast furnace on refinery products. The products approximately contain—

Bullion—

| | | | | |
|--------|----|----|----|------------------|
| Silver | .. | .. | .. | 3,000oz. per ton |
|--------|----|----|----|------------------|

Slag—

| | | | | |
|--------|----|----|----|----------------|
| Silver | .. | .. | .. | 300oz. per ton |
| Lead | .. | .. | .. | 50 per cent. |
| Zinc | .. | .. | .. | 34 per cent. |

PARTING.

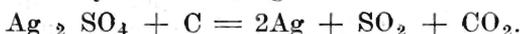
The doré bullion is parted by the use of Gutzow's modified process, which, in brief, is as follows:—The doré bullion is treated in cast-iron kettles, with a considerable excess of strong H_2SO_4 . The silver goes into solution as sulphate and the gold remains as metallic gold sludge. The strong acid and dissolved silver sulphate is syphoned off into a vat. The liquor is kept hot, and diluted by passing steam into it, and then cooled, the silver sulphate crystallizing out. The liquor is drawn off, the silver sulphate crystals washed, dried, and reduced by a small amount of carbon in a cupel to metallic silver. The gold sludge is further treated with H_2SO_4 , washed, treated with HCl , washed, and smelted into bars. There are three kettles of soft cast-iron, 2ft. 10in. by 2ft. 9in. deep and 2in. thick, and with a rim 5in. wide around the top. This rim rests on cast-iron plates 2in. thick, which in turn rest upon the brickwork of the furnace. There is a gutter around the edge of the cast-iron plate to catch any acid liquors which may be spilt, or in case the charge boils over. The gutters lead into a launder, which discharges into a lead-lined vat. Each kettle is separately fired from underneath. The bottom of the ash-pan is of cast-iron, sloping to one side, so as to catch any solution which may leak through should a pot crack or break. The kettles have cast-iron conical-shaped covers, which have a 12in. by 8in. working door in the side. The top of the covers is connected by a large lead pipe leading to the top of a lead-lined condenser, 16ft. long by 3ft. 6in. high by 3ft. 6in. broad. Another lead pipe leads from this condensing chamber to a tower 10ft. high by 2ft. 6in. by 2ft. 6in., filled with coke. A 4in. diameter pipe leads from near the bottom of the tower to a flue leading to the main stack, which produces the suction for the draught. The vaporised acid liquor which boils off from the kettle is caught in the condensing chamber or tower, any uncondensed acid vapour passing to the main stack. A small lead pipe leads from the bottom of the condensing chamber, and another from the cooling tower to a lead-lined vat, in which the liquor is concentrated to 58 degrees Baumé by means of a steam coil. The concentrated liquor is then elevated to the mother liquor tank for further use. Charges are run down in the first and third kettles, and the gold sludge afterwards sweetened in the second kettle.

A charge for each running down kettle consists of four bars of doré bullion, containing 4,000 to 4,800oz. About 600lb. of fresh, strong H_2SO_4 is now run in from the acid storage vat. The acid is first passed into a measuring tank, so that the quantity can be properly gauged. It was found that granulated doré caused too much frothing, so it is charged in large bars. The fire is then started, and urged strongly until the action is brisk. It should then be kept going at a steady rate until the whole is dissolved. The contents of the kettles are then allowed to cool down. When cool enough another liquor of 55 to 58 degrees Baumé is run into each kettle, until they are within four inches of being full, the whole being well stirred, so as to thoroughly mix the strong, thick sulphate of silver solution with the mother liquor. The fires are then re-started, and the contents of the kettles strongly heated. The gold sludge is now carefully removed in an iron ladle, draining it as free as possible of silver solution. The ladle is then passed into the sweetening kettle (which is half full of strong acid), and depressed below the surface of the acid before emptying, to prevent splashing. As much of the gold sludge is removed as possible. The running-down kettle is then steadily fired for a couple of hours, until the liquor is hot enough to run down into the pans. The solution is allowed to stop boiling, and then carefully syphoned off through an iron pipe into settling pans. These pans are of cast-iron, 6ft. by 3ft. by 18in. deep, with an outlet hole 1in. above the bottom. The object of these pans is to retain any gold which may have drawn over from the kettles. Prior to the liquor being syphoned off from the kettles the pans have four to six inches of mother liquor run into them. The object of adding the liquor is to loosen the small amount of crystals which form from the previous day's work when the pan gets cold. After standing for half an hour the liquor is run off into the crystallizing vats. These vats are of the same material and size as the settling vats, and are placed in another vat of cast-iron, leaving a 3in. space round the sides and under the bottom. This space is for circulating cooling water. The crystallizing vats have a half-inch diameter lead pipe reaching to within one inch of the bottom. The pipe is drawn to a nozzle. These pipes are used for steaming up the solution and also for reducing the strength of the silver sulphate solution.

When the solution in the kettle is ready for syphoning the steam is turned on rapidly to heat the liquor already in the crystallizing vat. The liquor is then syphoned off from the kettles, allowed to stand in the settling vats for 10 to 20 minutes, allowing any gold sludge to settle. During this time the kettles are recharged with doré and strong acid. The liquor

is then run from the settling vat into the crystallizing vat, and the steam quickly turned on. Before steam is turned on the liquor should be about 64 to 65 degrees Baumé. When it has been reduced to from 61 to 62 degrees the steam is turned off, and the pipe removed. Wooden bars, from which are suspended 2in. strips of sheet lead, are then placed across the vat. These strips reach nearly to the bottom. Silver sulphate crystals form on these strips, and prevent a too large crop forming on the bottom. After the pan has been cooling for about an hour the circulating water is turned on, and left running all night. By the morning the greater part of the silver sulphate has crystallized out. The outlet is opened, and the liquor drained off into a lower vat, where it is concentrated by a steam coil, and then elevated to the mother liquor supply tanks. The crystals are removed from the strips to a lead sieve in a washing-box, and washed about five times with cold, fresh water. The wash-water runs into lead-lined wooden vats, where the small amount of silver sulphate dissolved in the water is precipitated as silver sludge by means of sheets of copper. The copper sulphate is afterwards recovered as cement copper by means of scrap iron.

The washed silver sulphate crystals are dried, powdered, mixed with about 6 per cent. of fine coke, and reduced in an ordinary cupel furnace to metallic silver, which is skimmed and moulded ready for remelting.



The silver precipitated in the wash-water vat is collected and washed free from acid and copper sulphate solution on a lead sieve with hot water, dried, and mixed in the charge with the silver sulphate crystals.

When a fair quantity of gold (500 to 1,000oz.) has accumulated in the sweetening kettle it is boiled up five or six times of about two hours each, with about 300lb. of H_2SO_4 acid until it shows only a trace of silver in solution. When working continuously the acid from the sweetening kettle was sent to the running-down kettle in a single run. At present it is stored for future use. When short runs are made, the sides and covers of the running-down kettles are carefully washed down with a broom, and the sludge transferred to the sweetening kettle, which is likewise carefully washed down at the end of the sweetening. The gold sludge is carefully removed to a lead-lined wood vat, and boiled up with distilled or condensed water by means of a steam coil. It is boiled for 30 to 45 minutes, and then allowed to settle for the same length of time. The liquor is syphoned off through a flannel sieve into a similar trough, where NaCl is added to the liquor, to deposit any silver as AgCl , which is

run down in the cupel with the silver sulphate. The liquor is syphoned off through a flannel filter into the waste drain. Another lot of condensed water is added to the gold-residue tank, boiled, and syphoned off as described above. These boilings are continued until the water is free from silver, after which it receives two boiling washes. The gold residue is then carefully removed, and placed in a large earthenware crock, hydrochloric acid is added to remove any iron, lead, etc., remaining, and the liquor is heated by steam for a few hours. The acid is decanted off through a flannel, the gold transferred to a flannel filter, washed several times with boiling water, and dried. The flannel filters used to catch gold residue are afterwards burnt in the crucible when running down the gold. The gold is melted in plumbago pots, using borax, nitre, and common salt as a flux. The slag is skimmed off, and the gold poured into bars of about 400oz. each. A sample is granulated for assay. Fineness, 995 to 997.

TREATMENT OF REFINERY DROSSES.

Drosses and by-products not specially treated at the refinery are sent to the blast furnaces, one of which is specially set apart for their treatment.

The principal refinery by-products treated in this way are:—Copper dross from the copper softener, lead dross from the refining furnace, litharge from cupel furnaces, and dross furnace slag. These are added as an extra of from 800lb. to 1,600lb. to the ordinary blast furnace charge. The addition of these by-products has the effect not only to increase the output of the blast furnace, but also enables the furnace to treat a larger tonnage of ordinary charge per day. A small amount of 10 to 15 per cent. copper matte is produced during the treatment of the copper dross.

TREATMENT FOR RECOVERY OF GOLD IN BULLION

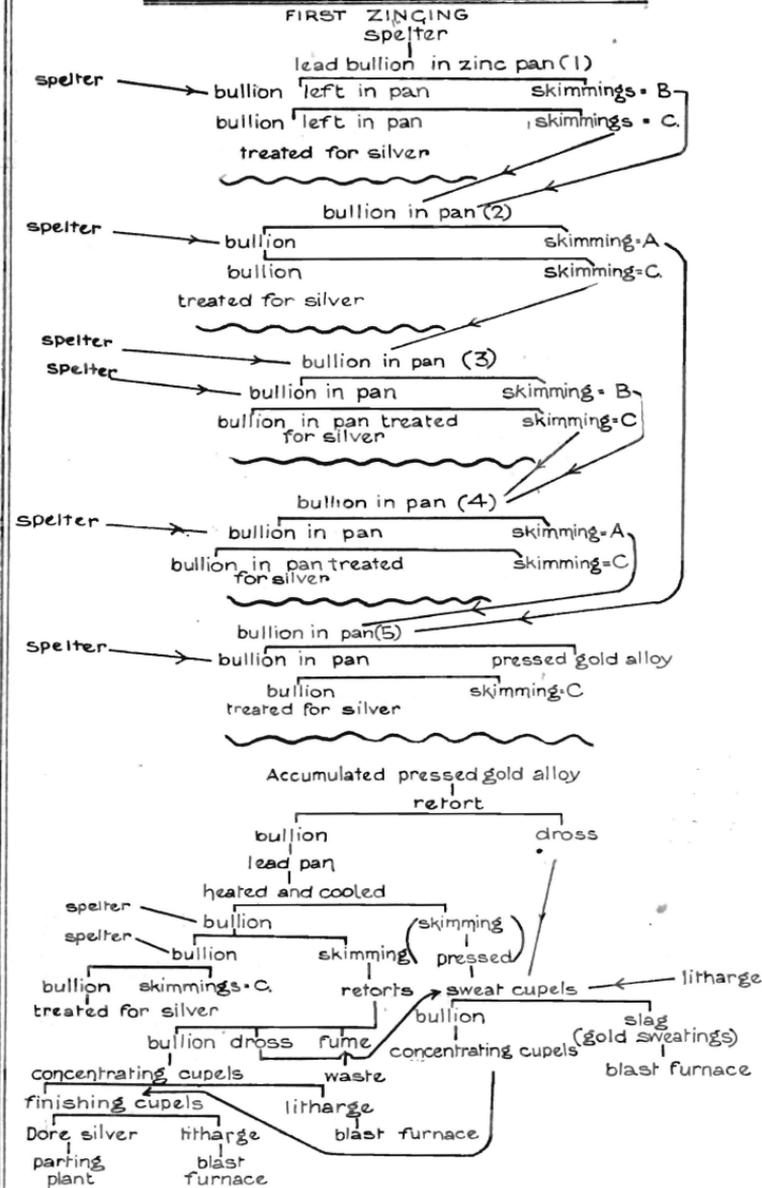


FIG. 2.

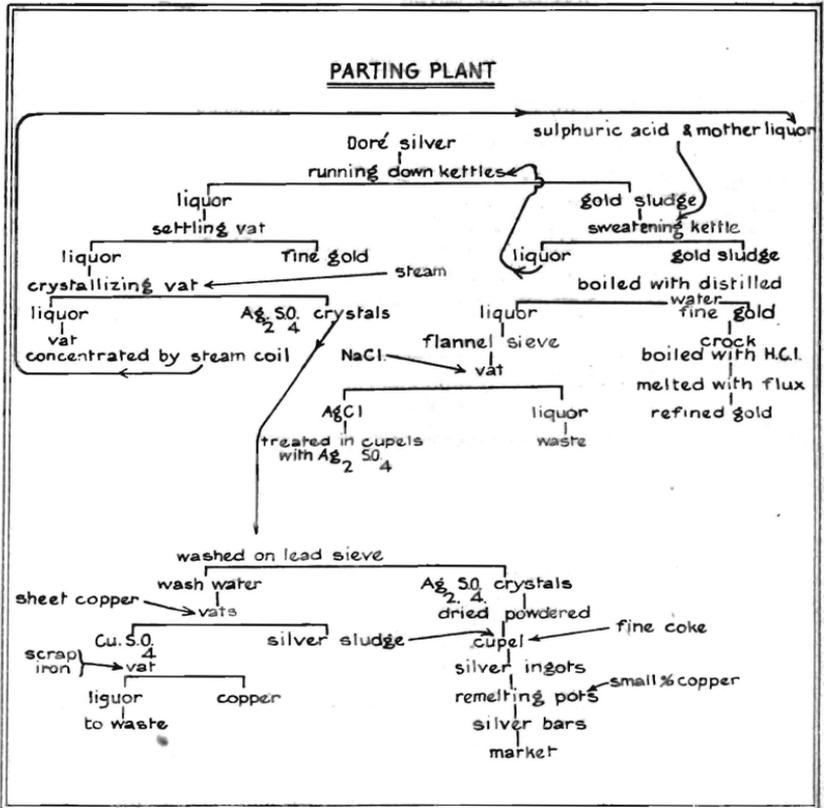


Fig. 3.

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