**The Works of John Arthur Phillips at Pontgibaud**

**METHOD OF TREATMENT OF LEAD ORES AT PONTGIBAUD. 1854**

*Extract of pages 522/523. Phillips's Manual of Metallurgy or A Practical Treatise on the Chemistry of Metals. 2nd Edition. By John Arthur Phillips. Published London by Richard Griffin & Co. 1854.*

Method of Pontgibaud - The treatment of lead ores formerly employed at Pontgibaud, in the vicinity of Clermont (Puy de Dôme), was peculiar to this establishme1nt, and had been adopted in consequence of the exceptional composition of the ores operated on, and the high price of fuel in the district. The mineral, when brought to the surface, is generally poor for lead, but contains a considerable amount of silver, and is consequently subjected to a careful mechanical preparation. This concentration of ore cannot, it is stated, be carried beyond a certain limit, as the lighter substances thrown away as sterile are found to contain a considerable quantity of silver, and the washing is there only carried so far as to allow the ores being successfully subjected to metallurgical treatment.

The largest proportion of the ore reaches the foundry in the form of finely divided sand or schlich, which, from the large amount of siliceous matters which it contains, does not admit of being smelted in the ordinary reverberatory furnace, and which on the other hand, is, from its fine state of division, unfit for immediate treatment in the low blast furnace of the Hartz.

Before being treated for metallic lead, these ores were roasted in a reverberatory furnace, having an extremely long hearth, and of which two were arranged one above the other. On the first of these the mineral was roasted, whilst on that placed nearest the fire-bridge they were agglomerated into masses, suitable for subsequent treatment in the ordinary low continental furnace. his second fusion for metallic lead was conducted in the Hartz, with the addition of metallic iron, and various other fluxes. The following mixture is that with which the furnace was ordinary charge :-

| | |
|---|---|
| Roasted ore | 1,000 kils.[1] |
| Fluoride of calcium | 100 " |
| Carbonate of lime | 240 " |
| Old iron (in small fragments) | 100 " |
| Cupel bottoms, abstrich sweepings from furnaces, &c. | 60 " |
| Rich slags from furnace operations | 500 to 600 " |
| [1] Kilogramme = 2.205 lbs. avoirdupois | |

This was thrown into the furnace alternately with suitable quantities of hard coke. When in good working state, each furnace was capable of running down three times the above amount in the course of 24 hours, and when preliminary roasting had been carefully performed, no matt was obtained, but merely metallic lead, together with a fusible and liquid slag. The cupulation of the rich lead was performed in the ordinary German refinery, with a bottom 9 feet in diameter, covered by a floor composed of 1,400 kils. of calcareous marl, 280 kils. of slaked lime, and the same quantity of mixed clay. As in the various German establishments, the plate of silver obtained was afterwards subjected to a second treatment, by which the last traces of combined lead were removed.

The management of this establishment has, however, been recently transferred to the Messrs. Taylor, of Queen-street Place, London, by whom all the more modern improvements employed in this country have been introduced with the greatest success.

*(The method of the ore reduction process adopted at Pontgibaud was of great interest to mining engineers and Phillips was not the first in publishing details of the process. French engineers had also given the subject their attention. J. Fournet, a Director of the Pontgibaud mines published, in the 1830s in the Annales, a series of articles giving details of the reduction process. M. Rivot and M. Zeppenfeld published in Paris in 1851 their 'Description Des Gites Métallifères, De La Prepáration Mécanique Et Du Traitment Métallurgique Des Minerais De Plomb Argentiféres De Pontgibaud').*

## *TREATMENT OF ARGENTIFEROUS GALENA AT PONTGIBAUD. 1867*

*Extract of pages 515 to 543 (Chapter XXII). The Mining and Metallurgy of Gold and Silver. By J. Arthur Phillips. Published London by E. & F. N. Spon, 1867.*

PREPARATION OF LITS DE GRILLAGE—ROASTING—PREPARATION OF LITS DE FUSION —SMELTING IN CASTILLIAN FURNACE—IMPROVING OR CALCINING—CRYSTALLISING—REFINING—REDUCING—RE-SMELTING RICH SLAGS—ROASTING MATTS— TREATMENT OF CALCINED DROSS—TREATMENT OF LEAD CINDER—TREATMENT OF LEAD FUME—LOSSES OF LEAD AND SILVER—SUMMARY OF COSTS.

THE method of smelting employed at Pontgibaud affords an example of the treatment of highly silicious lead ores rich in silver (The gangues of the Pontgibaud ores are similar in composition to those of many of the silver-bearing veins of Mexico, Nevada, and other parts of the American Continent. We shall consequently describe, with considerable detail, the various operations conducted in that establishment, since the system there employed is well adapted for the treatment of argentiferous minerals containing a large amount of silica, wherever fuel and lead ores can be obtained at reasonable prices. The mines of Pontgibaud, Puy-do-Dôme, France, have at various periods afforded large quantities of argentiferous galena, but were never so productive as at the present time. The re-working of the concessions was commenced by a local company in 1825, and the operations were continued under the management of French engineers until the year 1852, when the property was transferred to an Anglo-French Association, under the management of Messrs. John Taylor & Sons, of London. We were at that period for some time occupied in remodelling the smelting works, and introducing into them various modern appliances, but great improvements have been since made, and more particularly in the apparatus employed for roasting the ores and their preparation for the blast furnace. The various ameliorations introduced into the system of treatment at Pontgibaud are, to a great extent, due to Mr. W. Hutchison, the present manager of the Smelting Works, to whom we are indebted for the drawings of the different furnaces, and for very copious and admirably arranged notes, affording the practical results of the several operations as now conducted.)

These ores occur in large veins of quartz and feldspar traversing gneiss. The average produce of the ore, as extracted, scarcely exceeds 6 per cent of lead, and consequently very large quantities must be passed through the different washing processes in order to obtain the amount of mineral, averaging about 50 per cent., which is annually smelted in this establishment. As much as possible, however, of what is called *massif* or cobbéd ore is carefully selected, in order to avoid exposing it to unnecessary mechanical loss. Recently the proportion of massif to washed ore has become much greater than formerly, particularly since the discovery of a new mine yielding ores very rich in silver. The effect of this has been to render the ores more refractory, since the assay of hand-picked ores for lead is seldom higher than 40 per cent, whilst the proportion of silicious gangue is much greater than in the washed ones.

It is to the uniformly silicious nature of the Pontgibaud ores, together with the impurities contained in the work lead obtained, that many of the difficulties experienced in smelting them are due, and which have rendered necessary the adoption of the special processes employed at this establishment. These difficulties are further increased, particularly in the matter of cost, by the remoteness of the locality in which the mines are situated; Pontgibaud being at a great distance from any centre of industry from which fuel and fluxes can be obtained at moderate prices.

All the ores are delivered at the smelting works in a state of fine powder; that is to say, the coarsest will pass through a sieve with apertures of 4 m.m. in diameter. As many as seven varieties are received monthly from the different mines belonging to the company. They vary considerably in richness, both as regards lead and silver, and the amount of gangue which they contain; this gangue is *always silicious,* although generally associated with small quantities of sulphate of baryta, arsenical pyrites, iron pyrites, blende, &c.

The produce of each mine is sampled on the 1st of each month, and immediately delivered to the smelting works; where the operations are so conducted that all the ores received during one month may be converted into pig lead before the next month's deliveries take place. This system, besides its convenience, has the advantage of enabling the smelter to check the calculated produce by the actual monthly returns. Each sample of ore is tried by two assayers, one on the part of the mines and the other on that of the smelting works; if their results differ to the extent of 1 per cent. each repeats his assays. In case of a constant difference, a sample is sent to a professional assayer, and the result he obtains is considered final; but this course is seldom resorted to.

All the assays are made in an iron crucible, and when properly conducted yield results quite as high as those obtained by the humid way; a circumstance probably owing to the impurities in the lead button compensating for the slight loss by volatilisation. It will be necessary to bear this in mind, in comparing the losses of lead at the Pontgibaud works, with those experienced in other establishments where ores of a different nature are treated, and where the assays are, generally speaking, less carefully executed.

In the treatment of these ores nine distinct operations are necessary, Viz.:-

| | |
|---|---|
| 1.—Preparation of *Lits de Grillage.*<br>2.—Roasting.<br>3.—Preparation of *Lits de Fusion,*<br>4.—Smelting in Castillian blast furnace. | 5.—Improving.<br>6.—Crystallising.<br>7.—Refining.<br>8.—Reducing.<br>9.—Re-smelting rich slags. |

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In addition to the above, the routine of the establishment renders four supplementary operations necessary, viz:—

| |
|---|
| a.—Roasting matt.<br>b.—Treatment of calcined dross.<br>c.—Treatment of lead cinder.<br>d.—Treatment of lead fume. |

1. *Preparation* of *Lits de Grillage.—*Although the ores do not differ materially as regards the nature of their gangues, they vary considerably in richness; and consequently also in the proportion of earthy matters present. It has, therefore, been found important, before commencing their treatment, to prepare a uniform mixture of the whole sampling.

On this depends the regularity of the subsequent operations, and, in a great measure, their economical working. As it is impossible to thoroughly mix the whole weight of the various parcels of ore (often amounting to upwards of 300 tons), a *lit* of twenty tons, or a little more than the quantity usually roasted per diem, is prepared by weighing out, and spreading in thin layers, one above another, the exact proportion of twenty tons, which each parcel bears to the total weight delivered (Tons of 1,000 kilos).

The "lit" being finished, the charges are made by successively cutting down with a shovel the pile of stratified ore; and in such a way that every ton of the mixture removed shall have nearly the same composition as the entire mass.

Experience has proved the advantage of this arrangement over that of charging the hoppers direct from the several heaps in the ore magazine. The following will serve to show the kind of ore comprised in an ordinary monthly sampling :—

| | Dry Ore Kilos. | Assay Lead per cent. | Assay Silver per M. kilos*. |
|---|---|---|---|
| A. Washed Ore | 134,504 | 56½ | 1.100 grammes |
| B. Massif | 37,520 | 40 | 0.725 " |
| C. Washed Ore | 21,960 | 47½ | 1.137 " |
| D. Washed Ore | 9,393 | 66¾ | 1.650 " |
| E. Massif | 41,378 | 47 | 2.300 " |
| F. Washed Ore | 29,515 | 49 | 1.206 " |
| G. Washed Ore | 26,528 | 66¾ | 0.380 " |
| Total | 300,798 | | |

* The average produce of these ores for silver will be found to be about 39 o**z.** per English ton.

To this mixture of ores are added the matts resulting from the previous month's smelting in the blast furnace, which are, after being ground and roasted *dead* in a reverberatory furnace, treated exactly as ordinary ores. The total weight of matt mixed with the ores in the above instance was 35 tons, containing 14 per cent. of lead, and 400 grammes of silver per ton of 1,000 kilos.

For preparing a lit de grillage of 20 tons, the proportion required of each of the above parcels (wet weight) was as follows :—

| | |
|---|---|
| Ore A - 8,094 kilos | Ore E - 2,454 kilos. |
| B - 2,174 " | F - 1,780 " |
| C - 1,374 " | G - 1,594 " |
| D - 570 " | Matt - 1,960 " |

The average amount of moisture contained in these ores was 6 per cent.

It will be observed that the proportion of roasted **or** calcined matt in the above mixture is about 10 per cent.; but this proportion constantly varies from month to month. The object of adding it to the lits de grillage is, that its oxide of iron may serve as a flux in the subsequent operation.

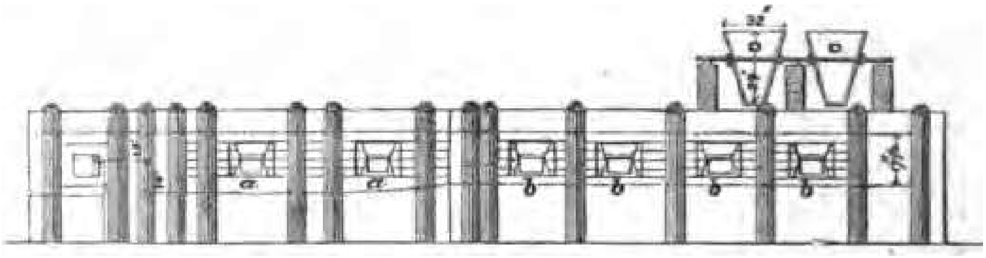
In some cases, i.e. when the ores are more than usually quartzose, 10 per cent. of matt is found to be insufficient for this purpose**,** and ground *scories de forge,* or mill cinders, are added as a substitute : not infrequently the previous month's production of matt does not amount to 10 per cent,, and then also iron slags are employed. As - a rule, 10 per cent. of matt, or 15 per cent, of mill cinder, is sufficient, but it often happens that these proportions must be considerably exceeded.

It would perhaps appear preferable to add iron slag directly to the mixture prepared for the blast furnace, as is done in some other works; but repeated experiments have led to the adoption of the method now employed; since its value as a flux in roasting, by the Pontgibaud system, is almost as great as its subsequent utility during the operation of smelting.

Two men are employed in the preparation of the roasting mixture; they are paid two francs each per day, and in that time prepare the mixtures, and charge each furnace with eight tons of ore. The cost of this operation is 0.25f. (2½ ) per ton.

2. *Roasting*.—The ores are roasted in very large reverberatory furnaces worked from both sides. There are three of these at Pontgibaud, but two only are in constant operation; all have exactly the same form and dimensions; their great width, as well as their great length, is a most important feature as regards economy of fuel.

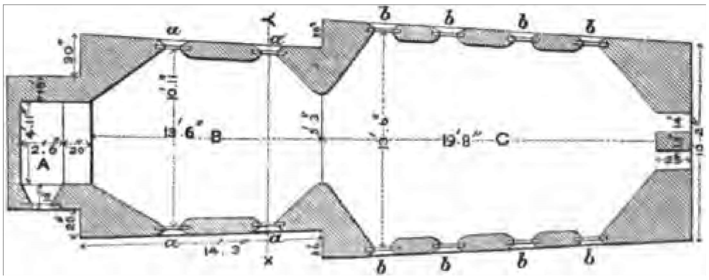
Fig. 75.



**Roasting Furnace.**
*(Elevation.)*

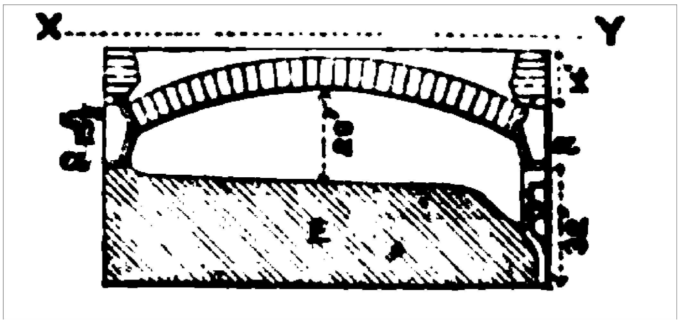
Fig. 75 represents an elevation, Fig. 76 a horizontal section through the working doors, and Fig. *77* a vertical section, on the line x *y,* of the roasting furnace. The exterior is built of cut lava, and the sides and roof of firebrick; the sole is laid with hard common bricks. The outside is plated with iron between the bottoms and tops of the doors a, *b,* as shown by the horizontal lines. The doors nearest the fireplace are a little smaller than the others. The fireplace A is divided from the fusing hearth B**,** by a firebrick bridge 20 inches in width; the ore being admitted into the hearth *C,* through the hoppers D**.** The bottom E**,** beneath the lining of common bricks, is composed of a mixture of sand and slag well beaten in. The tap hole is shown at *c,* Fig. 77. This apparatus requires but little repair.
When working, this furnace contains six tons of dry ore and matt, divided into three charges of two tons each, severally occupying about one-third the surface of the entire sole. There are six doors on either side, two of which correspond with one or other of the charges, and enable the workmen to turn or advance the ore when required.

Fig. 76.



**Roasting Furnace**
*(Vertical Section)*

Fig. 77.



## Roasting Furnace.

*(Vertical Section)*

The different parts of the furnace occupied in succession by each charge may be distinguished as follow :—

1st. Drying bed, immediately under the hoppers.
2nd. Desulphurising or oxidising bed, widest part of furnace.
3rd. Agglomerating bed, next to fireplace.*

* The agglomeration of the ores at Pontgibaud is in reality a fusion, without reduction.

The first two are on the same level, the third about 20 c.m. lower than the others.
The peculiar form of the agglomerating or fusing bed has for its object the equalisation of the temperature over that portion of the furnace in which the greatest heat is required.
The ore arriving on this bed is fused and run out in tile form of a liquid slag. At intervals of six hours a charge of melted ore is withdrawn, and the other charges in the furnace are advanced a stage; whilst a fresh charge is let down through the hoppers upon the drying bed. The time each charge remains in the furnace is consequently 18 hours. Eight tons of ore and matt are thus roasted in each furnace in the course of 24 hours, with a consumption of about 2,000 kilos. of coal, and 6 per cent of lime. The consumption of iron slags averages 7 per cent; but, whatever the proportions of this flux, or of lime, may be, the quantity of ore charged remains constant—that is to say. 1,800 kilos.

Four men are employed at each furnace, per shift of 12 hours; the foreman is paid 2.20f per day, the others 2f. The general system of roasting in this furnace will be understood from the foregoing description; but, in order that it may be fully comprehended in all its various details, it may perhaps be necessary to explain the mode of working more minutely.
Let us, for this purpose, suppose that the usual regularity of the operations has been uninterrupted during the night, and that at six in the morning we accompany the men to their work. We shall find the bed next to the grate empty, the charge having, about two hours previously, been run out upon the floor, on one side of the furnace. The charge in the middle bed having been roasted dead, is heaped up in the throat ready for being advanced into the agglomerating bed, which is still at a red heat, although the fire has been allowed to burn down in the grate. The foreman begins by throwing a shovelful of coals on the fire to create a blaze and light up the interior, so that the men may see their work. All hands then commence busily advancing the ore with long paddles. Two men advance it upon the agglomerating bed, and pile it up as near the bridge as they can; whilst two others push forward the ore from the drying bed into the middle or desulphurising hearth. In the latter, the ore is spread evenly over the sole, and two or three shovelfuls of slaked lime are afterwards scattered over its surface; especially on the side next the fire, to prevent the formation of a crust of partially-agglomerated ore which is very difficult to calcine.
The time required for advancing the two charges is about forty minutes. A flue charge is now let down from the hoppers D**,** and spread over the drying bed with a rake. The doors are then all closed, the grate charged with coals, and the fire increased until the furnace has acquired a bright red heat.
In about three quarters of an hour the ore in the middle bed has become sufficiently hot to scintilate when stirred, and to give off sulphurous acid vapours. Two men, one on each side, now commence turning over the charge with paddles, which they do repeatedly, first forwards towards the fire, and then backwards towards the flue; taking care that the whole of the ore is turned, and that fresh portions are constantly exposed to the action of the heated air. From time to time a shovelful of slaked lime is thrown in and worked up with the ore to keep it “dry” especially on the side next the fire, where it is most liable to clot. The operation of turning is continued without interruption until the charge in the agglomerating bed is ready to tap, when, during the time of tapping, &c. there is an interval of nearly half an hour; but it is afterwards renewed and continued until the expiration of six hours, or at least until the ore has been roasted dead. When the mixture of ores is good, i.e. when it is moderately rich in lead, and contains at the same time a good deal of oxide of iron, the charge in the

agglomerating bed requires but little working. It then melts easily, and in about two hours and a half after the firing commences it is ready to draw. But, should the mixture contain an excess of silica, it is difficult to get the ore into a liquid state. Part of the charge attaches itself to the sole, and another portion is drawn out, after great trouble, in a tough pasty condition. A great loss of lead, and considerable waste of fuel, are the consequences. For this reason it is advantageous to add oxide of iron to the ore, and the cheapest way of doing this, at Pontgibaud, is in the form of iron slags, although their cost is 27f. per ton.

Assuming the charge worked to be easily fusible, it is only requisite to paddle it once towards the bridge; about three quarters of an hour after beginning to fire. It is also necessary, just before tapping, to rake over the bottom, to be certain that none of the ore is sticking to it, and that the whole charge is perfectly fluid. When this is found to be the case, the tap hole is unstopped, and the charge run out upon the floor; where it is prevented from spreading beyond certain limits, by a small dam or ridge of ore and sweepings &c. reserved for that purpose. No lead is reduced in this process, but a certain quantity of very rich sulphide of lead is generally met with at the bottom of the charge. This is particularly the case when the ore is rather rich in lead, and has been imperfectly roasted.

The bulk of the charge of roasted ore is composed of a clean black slag containing from 30 to 40 per cent. of lead. The whole of the sulphate of lead formed in the middle bed is subsequently decomposed by the silicic acid present. As soon as the charge has been run out, the tap hole is examined, and any adhering ore is cut away with a long chisel; after which it is again stopped. The bridge and sides are then looked at to ascertain whether they require repairs; since holes are often eaten out by the melted ore, which require to be stopped with clay after almost every charge. The fire is now suffered to burn down, to allow of clearing the grate of clinkers. The damper is at the same time partially closed, and preparation is made for the advance of another charge, when the time for doing so shall have arrived. Charge thus succeeds charge at regular intervals of six hours: the loss of weight in roasting amounts to about 10 per cent, of the quantity charged.

The loss of metal by volatilisation is extremely difficult to estimate, as it is scarcely possible to obtain a fair sample of the roasted ores. Several experiments, undertaken with this object, have fixed the loss of lead at from 2 to 3 per cent. of the total quantity present. The loss of silver is still more difficult to determine, and no result which can be depended on has yet been obtained.

The cost of roasting ore per ton is as follows (the dry ore per charge being 1,800 kilos.) :—

| | | |
|---|---|---|
| Coal | 280 kilos at 35f. | 9.80f. |
| Lime | 60 kilos at 24f. | 1.45 |
| Scories de forge | 70 kilos at 27f. | 1.90 |
| Labour | | 2.90 |
| Tools and repair | | 0.80 |
| Sundries (including superintendence) | | 2.90 |
| | | F. 19.75 = 15s 9.6d. |

3. *Preparation of Lits de Fusion*.—The lits de fusion are composed as follow :—

| | |
|---|---|
| Roasted ore | 10,000 kilos. |
| Scrap iron | 1,000 " |
| Limestone | 1,600 " |
| Flour spar | 300 " |

The above figures give the average quantities of flux in the furnace mixtures. They are, however, modified with the nature of the ore; the proportions of limestone and fluor spar varying most considerably. Two men are employed at this work, and receive 2f each per day. They prepare a lit and a half in that time—15 tons consequently the cost is 0.27f. per ton of roasted ore, and 0.25f. per ton of crude ore

4. *Smelting in Castillian Furnace*.—There are two of these at Pontgibaud, but it is seldom that more than one is in blast at a time. Fig. 78 represents a front elevation of one of these furnaces, which are constructed of cut lava and are very inexpensive to build.

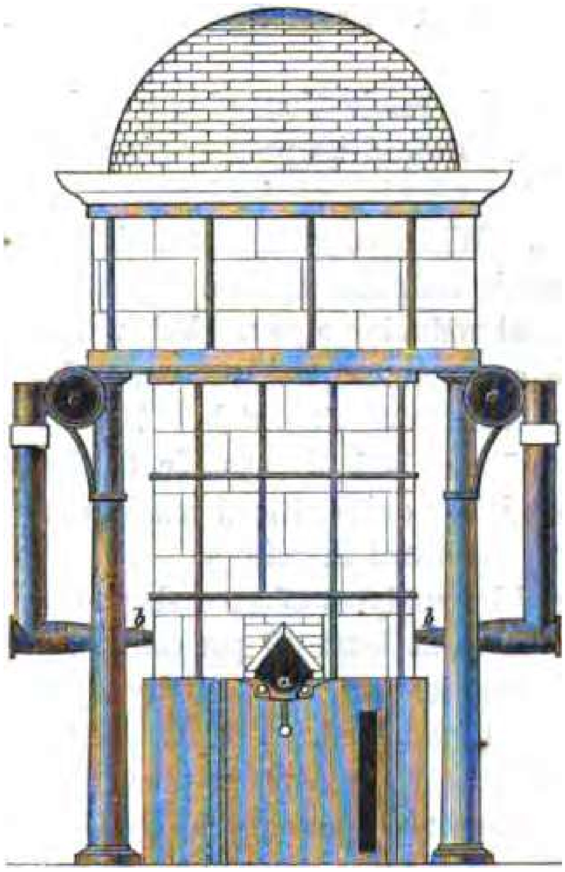


Fig. 78.

**Castillian Furnace, Pontgibaud.**
*(Front Elevation.)*

Their height from the slag-overflow *a* to the charging door is 5 feet, internal diameter *35* inches; diameter of tuyere 3 inches; pressure of wind about 4 inches of water. These furnaces are supplied with the blast by the nozzles *b,* of which there are three, connected with the main *c***;** water tuyeres are not employed in the Pontgibaud furnaces.

The mode of charging is similar to that employed for other furnaces of the same kind.

The ore is distributed around the sides, the coke in the middle and against the breast. The furnace is kept constantly full, and particular care is taken not to let the flame appear above the charge; it being considered important to keep the top as dark as possible. A large breast pan, capable of holding 20 pigs at a time, is preferred, but it is sometimes difficult to maintain it of that size.

From 14 to 16 tons of ore are smelted in 24 hours, with a consumption of one ton of coke, or about 7 per cent of fuel.

The quantity of lead obtained in the same time is from 100 to 120 pigs, or from 5 to 6 tons. From 7 to 10 per cent. of matt is also produced.

It is found that the production of a certain quantity of matt cannot be prevented. Indeed its presence is regarded as being in no way prejudicial to the working of the furnaces, unless it be formed in too great an excess. When very little matt is produced, the slags are generally rich in lead. Sulphide of iron appears to act on the silicate of lead as a powerful reducing agent. Whenever oxide of iron does not abound in the ores smelted, the presence of matt alone does not prevent the slags from becoming rich. The presence of a large quantity of oxide of iron is indispensable to the production of poor slags, since without it the oxide of lead remains combined with silicic acid, and cannot be separated therefrom.

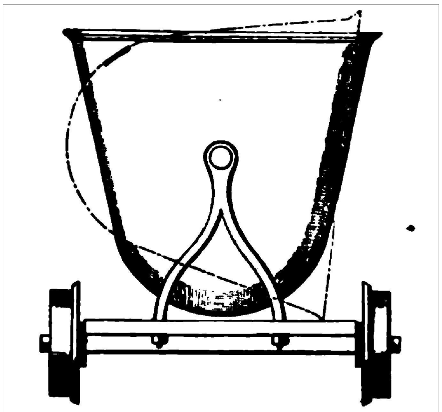
It has been found by analyses of poor slags that those most easily freed from lead contain at least 40 per cent. of oxide of iron. This base may be however, in part, replaced by lime, especially if fluor spar be at the same time added. Yet, although by this means poor slags can be obtained, they are never so poor as when oxide of iron is present in slight excess; the amount of lead volatilised is also considerably increased. The proportion of slags produced is from 65 to 70 per cent. of the ore smelted.

The slags formed under the most favourable circumstances do not contain less than 2 per cent. of lead. When they exceed 3 per cent they are re-smelted in a furnace of similar construction to those already described, but situated in another part of the works.

The slags, as they flow from the furnace, are received into cast iron waggons, which, when full, are drawn away to the waste heaps on a small tramway constructed for that purpose. The waggons employed at Pontgibaud, of which Fig. 79 is a side view, Fig. 80 an end view, and Fig. 81 a plan, are very convenient in form, and but little liable to break. The depth of the pan is 20 inches, and its width 21 inches. These have been in constant use for the last five years, and have scarcely ever needed repairs, except to the wheels and axles.

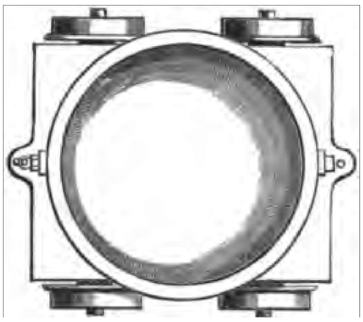
Fig. 79.


Fig. 80.



**Slag Waggon**

Fig. 81.



The men employed at this furnace per shift of 12 hours are :—

| | | |
|---|---|---|
| 1 Foreman | Paid | 2.50f. Per day. |
| 1 Charger | " | 2.20f. Per day. |
| 3 Trammers | " each | 1.80f. Per day. |

The costs per ton of *roasted* ore are as follow :-

| | | |
|---|---|---|
| Iron | 110 kilos at 95f. | 10.45f. |
| Limestone | 160 kilos at 20f. | 3.20 |
| Fluor spar | 30 kilos at 15f. | 0.45 |
| Coke | 70 kilos at 48f. | 3.35 |
| Labour | | 1.85 |
| Tools and repairs | | 0.75 |
| Sundries (including superintendence) | | 3.35 |
| | | F.23.40 = 18s 8.6d. |

The cost per ton of *unroasted* ore is therefore 21.06f. or 16s. 10.1d. The cylinders of the blowing machine are 134 in., or 52 inches in diameter.

Length of stroke, 52 inches.

Number of strokes per minute, 12.

The lead obtained from the Castilian furnace contains nearly all the silver originally present in the ores smelted, excepting a small proportion combined with matts, or retained in the slags. The usual assay of matt is from 15 to 20 per cent. of lead, and 400 to 500 grms., or from 12 oz. 17 dwt. to 16 oz. 2 dwt. of silver per ton; the average assay of the lead is about 3 kilos. = 96½ oz. per ton. The whole of the silver in the matt, and a portion of that in the slags, is recovered in the subsequent operations; but a small fractional part of that metal is nevertheless unavoidably lost. This loss amounts to 10 grins., or 64 dwt. per ton of slag, or 0.568 per cent, according to assay, of the total quantity contained in the ores.

A certain amount of silver is also volatilised with the lead, but how large a proportion is, from this cause, entirely lost cannot be accurately ascertained. That it is, however, exceedingly small is probable, from the known properties of silver, and the small amount found in the fumes collected in the flues and condenser. The proportion of silver thus volatilized or mechanically carried off, and again recovered, in all the different processes, including cupellation, amounts to only 0.470 per cent, of the total quantity, according to assay, contained in the ores. The loss of lead in smelting ores in the blast furnace amounts to about 17 per cent. of the total quantity contained in them.

It has been ascertained that about 5 per cent. of all the lead is retained in the slags, and about 12 per cent carried off in fumes. Two per cent is, however, afterwards recovered from slags by resmelting, and about 34 per cent from the fumes. The actual loss, therefore, in -the operation is equal to 11¾ per cent, of the total quantity of lead contained in the ores.

It will be seen from the foregoing that the system of roasting and smelting at Pontgibaud has undergone very important alterations since the publication, in 1851, of Rivot and Zeppenfeld's *"Description des Gites Métallifères &c. de Pontgibaud,"* which appears to be still regarded by many continental engineers as a description of what is being done at the present time. In proof of this it may be stated that in a lengthy paper on the Metallurgy of Lead, published in the "*Revue Universelle des Mines*," as recently as 1863, the engraving of a roasting furnace shown in Rivot and Zeppenfeld's work is reproduced as though it were still in use; whereas, in point of fact, it had been demolished ten years previously.

It is, however, in the treatment of the argentiferous lead obtained that the system now employed differs most essentially from that in use in 1851. At that period, the whole of the lead obtained from the blast furnace was immediately cupelled in a large German cupelling furnace, and the silver separated and refined in the usual way. The litharge produced was afterwards submitted to a complicated mechanical preparation in order to render it fit for sale; the whole, or very nearly the whole, of the lead thus converted into oxide being sold in that state. The small quantity of metallic lead sent to market was obtained, after great loss, by the reduction of a portion of the litharge, and was of very inferior quality. At the present time it would be extremely difficult to find a sale for so much litharge as the Pontgibaud works could now produce, as the yield of the mines has been enormously augmented. There is, however, never any difficulty in disposing of pig lead.

In the method employed at Pontgibaud since the works have been under the direction of Messrs. John Taylor and Sons, the object in view has been to convert the whole of the lead into metal of first-rate quality, and to obtain at the same time as complete a separation as possible of the silver: this is accomplished by means of Pattinson's process. The advantages of this method have been long appreciated both in England and on the Continent, and it is now generally adopted, either in combination with the old continental method, or with some modification of it suitable to the locality and the nature of the ores treated. The principal advantages of Pattinson's process, as compared with the old Pontgibaud method, are the following :—

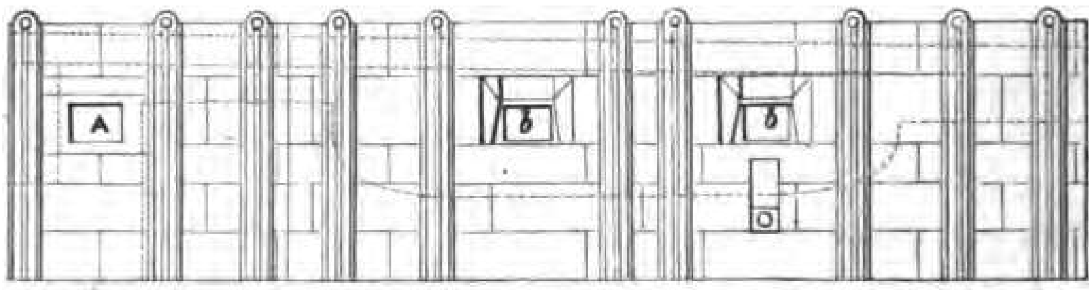
| | |
|---|---|
| 1st | Direct production of metallic lead. |
| 2nd | A greatly diminished loss of metal. |
| 3rd. | A higher yield of silver |

In the treatment of the argentiferous lead obtained from the blast furnace, four distinct operations are necessary, viz. :—

| |
|---|
| Improving or softening. |
| Crystallizing. |
| Refining. |
| Reducing. |

5. *Improving or Calcining.*—The whole of the work lead produced at Pontgibaud must be purified before it can be treated by Pattinson's process, and this is done by exposing it at a low red heat to partial oxidation in a reverberatory furnace specially adapted for that purpose. The chief impurity contained in the lead is antimony; the others are sulphur, iron, arsenic, and copper. All are in relatively small proportion, but are still in sufficient quantity to render the lead hard**.** The accompanying drawings, Figs. 82, 83, and 84, show the arrangement and dimensions of the furnace employed.

Fig. 82.




**Improving Furnace.**

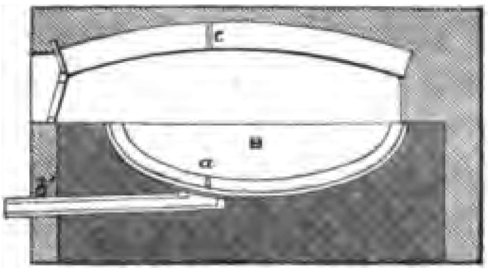
*(Elevation.)*

Fig. 82 is an elevation; Fig. 83 a horizontal section at the level of the top of the pan; and Fig. 84 a vertical section through the tap hole. The fireplace A is separated from the pan B, by a bridge 3 feet 3 inches wide, and the furnace is provided with two doors *b***,** through which the dross may be removed. In principle this resembles the ordinary softening furnace with its cast iron pan, but its greater size and solidity of construction render it much more economical than the furnaces usually employed for the purpose.

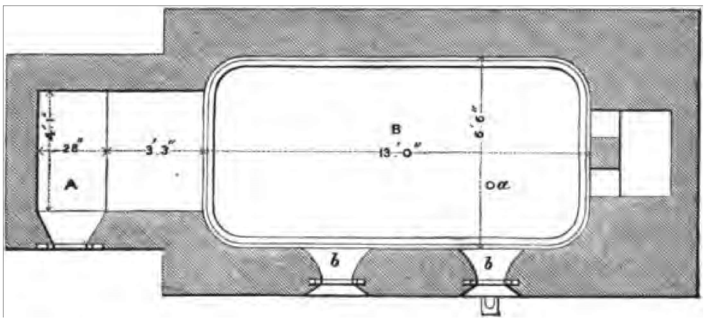
On reference to the drawing, it will be remarked that the pan is not only much larger than those commonly employed, but has also a rounded form; the object in giving it this shape being to diminish the tendency to crack, to which all square-sided pans are so liable. Another essential feature in the construction of these furnaces is to make them perfectly lead-tight, in case the iron should break. This is most effectually done by setting the pan on a bottom of wellbeaten brasque two feet in thickness, resting on a solid foundation of masonry. The sides of the furnace must be either of thick iron plates or of large cut stones. In either case the space between them and the pan should be at least a foot wide, and well filled with hard beaten brasque.

The lead is tapped from the pan through a small hole *a*, three-fourths of an inch in diameter, bored in the bottom of the pan, and communicating with a thick cast iron tube *b*, fastened to it by means of stud-bolts screwed into about half the thickness of the metal. Before charging, the hole in the bottom is plugged by a long pointed bar passed through an opening *c,* Fig. 84, in the roof, corresponding with the tapping hole, and placed vertically over it. This bar will not generally stop the hole quite tight; especially after the furnace has been working a long time. The tube is, therefore, partly filled with bone-ash, firmly rammed in; a bar having been previously placed in the tube in such a way that the channel left, after its withdrawal, shall correspond with the hole in the pan. This horizontal bar is even more necessary than the vertical one; the use of the latter being to take off the pressure of the lead in the pan, and regulate the flow of metal in tapping. The horizontal bar is put in and withdrawn by the aid of a sledge; in much the same way as, though more easily than, a tapping bar at the blast furnace.

Fig. 83




**Improving Furnace**
(*Horizontal Section*)
Fig. 84.




**Improving Furnace.**
*(Section through Tap Hole.)*

Two of these furnaces have been erected at Pontgibaud; one for common work lead, the other for the hard lead reduced from calcined dross. The former has been almost constantly in use for upwards of five years; and although the pan is now cracked, the furnace is as tight and serviceable as ever.

Both improving pans were originally lined with bricks, as shown in the drawings, Figs. 83 and 84, to protect the iron from corrosion by the oxides formed on the surface of the metallic bath. This precaution is now thought to be unnecessary; all that is required being to avoid overheating the furnace, and the consequent fusion of the dross. It is also found that a dull red heat is the best temperature for calcining Pontgibaud lead; and at that point the oxides neither melt, nor exert any corrosive action on the pan, especially if a little lime be from time to time added. The usual charge of a pars without lining is about twenty tons. The brick lining diminishes its capacity by about one-fifth. A charge of twenty tons of common work lead requires sixty hours to become sufficiently soft for treatment by Pattinson's process, the whole time necessary for the operation, including charging and discharging, being three days.

Three men are employed in filling and emptying the pan, and are paid 2f. each per charge. The pigs of lead are introduced through one of the working doors by means of a long charging bar, and the charging is effected with great ease and rapidity. Except for charging and discharging, scarcely any labour is required, as the firing is attended to by one of the men working at the Castillian furnace.

An ordinary month's work at this furnace is as follows :—

| Work Lead in Tons. | Soft Lead out Tons. | Percentage of Soft Lead Obtained | Dross Tons | Coals consumed Tons. | Lime used kilos. |
|---|---|---|---|---|---|
| 139.150 | 131.528 | 94.7 | 8.675 | 11.560 | 534 |

The small consumption of coal is partly due to the employment of cinders picked out from the imperfectly burnt ashes at the pots, and mixed with the coal ; their cost per month being equal to a boy's wages, viz. 20f. per month. The cost of calcining one ton of blast furnace lead is—

| | |
|---|---|
| Coal, 83 kilos at 35f. | 2.9f. |
| Cinders | 0.15 |
| Lime 7.5 kilos at 24f. | 0.18 |
| Labour | 0.45 |
| Sundries | 0.60 |
| | F.4.28 = 3s. 4.8d. |

Cost on ton of ore 1.90f. = 1s. 6.2d.

The drosses resulting from the calcination of the work lead contain, besides the various impurities, a large proportion of lead, partially in the form of oxide, and partly in the metallic state. These drosses are subsequently treated in the reducing furnace.

The lead reduced therefrom is very impure and exceedingly hard, and, as it contains a considerable proportion of silver, 1,400 grammes, 45 oz., per ton, it is again calcined in the ordinary way. The hard lead obtained in the treatment of the lead cinder left as a residue in the reduction of litharge and pot dross is also calcined in the same furnace.

The hard lead contains a large amount of antimony and other impurities very difficult to separate, and consequently the process of softening in this case becomes long and costly. The average time required for calcining 20 tons of hard lead is about four weeks. The usual quantity treated per annum, with results and costs, is as follows :—

| Hard Lead in Tons. | Soft Lead out Tons. | Percentage of Soft Lead obtained. | Coal Consumed Tons. | Lime Consumed Tons. |
|---|---|---|---|---|
| 148.845 | 96.978 | 65.1 | 99.90 | 5 |

*Cost per ton of Hard Lead*

| | |
|---|---|
| Coals, 665 kilos. at 35f. | 23.27f. |
| Lime, 33 ½ kilos at 24f. | 0.80 |
| Labour | 0.43 |
| | F. 24.50 = 19s 7.2d. |

Cost of ton of ore smelted 1.03f. = 9.6d.

The dross skimmed from this hard lead yields on reduction about 55 per cent. of a very hard lead, assaying 600 to 700 grammes, 19 oz. 5 dwt. to 22 oz. 10 dwt., of silver per ton; which is generally mixed with the ordinary hard lead and treated in the same way. In the statement of costs, all the hard lead, of every kind, is included. Occasionally, when a sufficient quantity has accumulated, it is worked separately. It then gives a dross which on being reduced yields an extremely hard lead. This, whenever it contains too little silver to pay the costs of extraction, is immediately disposed of for making certain alloys containing a large quantity of antimony. But this seldom happens, as it is only after repeated calcinations and reductions that a hard lead is obtained too poor in silver to pay for again working over. The proportion of poor hard lead produced at Pontgibaud is therefore exceedingly small.

6. *Crystallising*.—At Pontgibaud there are twelve pots in one set— eleven ten-ton pots, and one six-ton, or market pot. The system of working is by thirds. The ladles used are 20 inches in diameter, and 6 inches deep, and of the ordinary English pattern. The cranes employed are also of the usual form.

The average assay of the work lead is, as before stated, about 3,000 kilos., 96k oz., of silver per ton. it is charged in the tenth pot.

The usual assays of the whole series of pots, tops and bottoms, are as follows :—

| No. of Pots. | SILVER PER TON | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | Top. | | | | Bottom. | | | | |
| | Grammes | oz. | dwt. | gr | Grammes | oz. | dwt | gr. | |
| 1 | 15 | | 9 | 15 | - | - | . | - | |
| 2 | 30 | | 19 | 7 | 60 | 1 | - | 14 | Poor Lead |
| 3 | 60 | 1 | 18 | 14 | 120 | 3 | 18 | 4 | |
| 4 | 120 | 3 | 17 | 4 | 220 | 7 | 17 | 11 | |
| 5 | 230 | 7 | 7 | 21 | 400 | 12 | 1 | 5 | |
| 6 | 400 | 12 | 17 | 5 | 720 | 23 | 17 | 0 | |
| 7 | 700 | 22 | 10 | 3 | 1200 | 38 | 3 | 16 | |
| 8 | 1150 | 36 | 19 | 12 | 1800 | 57 | 11 | 12 | |
| 9 | 1850 | 59 | 9 | 16 | 2900 | 93 | 17 | 21 | |
| 10 | 3000 | 96 | 9 | 4 | 5000 | 160 | 4 | 8 | |
| 11 | 5200 | 16 | 3 | 22 | 8500 | 273 | 15 | 1 | Charging |
| 12 | 8500 | 7 | 6 | 1 | 16000 | 514 | 6 | 1 | Out |
| | | 27 | | | | | 9 | | |
| | | 3 | | | | | | | Rich Lead |

In working the rich pot, the whole of the bottom is not ladled out; it is found to be more advantageous to ladle out the liquid only, and leave the crystals behind. When the ordinary quantity, or about two-thirds, of the lead has been turned into the eleventh pot, the remaining one-third consists of a mixture of crystallised and uncrystallised alloy. The latter, being much richer than the former, is separated as completely as possible; and this portion only, amounting to a little more than half the bottom, is sent to the refining furnace.

The work of removing the liquid is readily effected by means of what the French workmen call a *panier,* which is made of a piece of sheet iron, pierced with numerous small holes, turned up and fastened with rivets in the form of the frustum of an inverted cone, it is provided with two handles for, putting it into and taking it out of the pot. By its use, a well is readily formed in the middle of the crystals, which facilitates the draining of the liquid metal from the surrounding mass, and allows of the lead being easily ladled into moulds. The right moment for introducing the panier, and ladling out the liquid, is easily determined by practice. When it is desired to take out much liquid metal, the pot is, on approaching the bottom, worked thin; but when the contrary is required, the work of stirring is continued until the crystals have become thick. In all cases, it is necessary to remove the whole of the liquid lead, otherwise the crystals left behind may be too rich.

The proportion of rich lead, viz. 18-2 per cent., cupelled at Pontgibaud is necessarily large, as the original lead is itself comparatively rich in silver, It is, therefore, very important to concentrate the rich alloy as much as possible before taking it to the refinery, where it is necessarily exposed to considerable loss from volatilisation. Experiments made by Mr. Hutchison, with the object of enriching lead to a much higher degree than is usual, have demonstrated the impossibility of doing so beyond 2 per cent. of silver; and this degree of concentration is only attained after repeated and very careful crystallisations, and by at last drawing off a small quantity only of liquid alloy. When the converse of this operation is tried—i.e. when lead, enriched in the cupelling furnace so as to contain about 8 per cent. of silver, is fused in a pot, and cooled down in the ordinary way, the portions which first solidify are much richer than the liquid drained from them; the latter, after repeated drainings, invariably containing about 21 per cent. It therefore appears that the remarkable property of crystallisation, discovered and utilised by Pattinson**,** arrives at its turning-point when, the lead - as acquired a richness of from 2 to 21 per cent. of silver. (Mr. Hutchison remarks: “I have never seen any explanation of the reason for stopping the concentration at from 400 to 600 oz. per ton. We are generally told it would not be economical to push the concentration further; but this is not altogether true, as further concentration would certainly effect a saving of a part of the lead now volatilised during cupellation.”)

In the ordinary way of working, it is remarked that in proportions the concentration advances, it becomes more and more difficult to obtain the same degree of enrichment per pot or per ton of lead crystallised which is possible with poorer lead. An ordinary month’s work at the pots may be tabulated as follows :

| CHARGED | | | OBTAINED | | | |
|---|---|---|---|---|---|---|
| Calcined Lead Tons. | Reduced Lead Tons | Total Tons. | Market Lead Tons | Rich Lead Tons | Coals consumed Tons | Wages f. |
| 135.000 | 63.000 | 198.000 | 130.000 | 23.400 | 61.000 | 960 |

Four pairs of men are generally employed, whose time is divided into twelve-hour shifts**.** Four, and sometimes five, pots are worked by each pair per shift. The crystallisers are paid 0.60f. each per pot, and the stokers 2f. per shift.

The cost of crystallising per ton of market lead produced is as follows :—

| | |
|---|---|
| Coal, 470 kilos at 31f. | 14.57f. |
| Wages | 7.40 |
| Wear and tear of pots | 1.70 |
| Tools and repair | 0.60 |
| Sundries, including superintendence | 4.00 |
| | F. 28.27 = 22s 7.4d. |

Cost of crystallising per ton of ore, 12.39f. = *9s.* 10.9d.

The loss of lead in the process of crystallisation proper is trifling, as the losses incidental to the process chiefly occur in the cupellation of rich lead and the reduction of dresses, and will be indicated under their respective headings. There is, however, a certain loss of silver in the market lead sold, since it invariably retains about 15 grammes, 9 dwt. 15 gr., of silver per ton; but this quantity amounts to only 0.53 per cent, of the total weight of silver contained in the ore according to assay.

7. *Refining*.— The ordinary English furnace is employed at Pontgibaud for the cupellation of rich lead. The operation is conducted in the usual way, except that the tests are deeper than those generally used. About four tons of rich lead are passed in twenty-four hours; but a certain quantity, amounting to one-fifth, is tapped out about every eight hours, or whenever the lead in the cupel has attained, by concentration, a richness of about 8 per cent. of silver. The bottoms of enriched lead thus accumulated are cupelled, as usual, at the end of the operation. About 15 tons of rich lead are usually worked at one *time,* and a plate of silver, weighing from 240 to *250* kilos. (7,720 to 8,042 oz.), is obtained. When cleaned, the silver is tapped at the back of the test into moulds, and afterwards melted down in large black-lead crucibles. It is then cast into ingots of from 20 to 25 kilos. each, suitable for the market. These ingots contain 999 thousandths of silver.
The cost of cupellation per ton of rich lead is as follows:—

| | |
|---|---|
| Coal, 290 kilos. At 35f. | 10.15f. |
| Bone-ash 17 kilos at 275f. | 4.67 |
| Pearl-ash 0.17 at 1,765f. | 0.30 |
| Repairs | 0.30 |
| Refiners wages | 8.23 |
| Sundries, &c. | 3.80 |
| | F. 27.45 = 21s 11.5d. |

Cost of refining per ton of ore smelted, 2.27f. = 1s. 9.8d.

The loss of lead in refining is about *7* per cent. of the weight of lead worked, or 1.252 per cent. of the total work lead obtained from the blast furnace. The loss of silver volatilised with the lead vapours, although very minute, is probably greater during cupellation than in any of the other processes. Its amount cannot be determined with accuracy.

8. *Reducing.*—The furnace employed for reducing the litharge, pot dross, and calcined dross, is similar in form to the Welsh reverberatory furnace, but has only four working doors, two on the back side, and two on the fore side.

Its principal dimensions are as follow :

| | |
|---|---|
| | m. ft. in. |
| Height of Furnace | 1.75 = 5 8.8 |
| Height from fire-bars to top of | 0.52 = 1 8.4 |
| bridge | 0.25 = 0 9.8 |
| Height from bridge to crown of | 0.75 = 2 5.5 |
| arch | 1.35 = 4 5.1 |
| Width of fireplace | 0.60 = 1 11.6 |
| Length of fireplace | 3.70 =12 1.6 |
| Width of bridge | 2.80 = 9 2.2 |
| Length of sole | |
| Average width of do. | |

In the reduction of litharge and and pot dross the operations are conducted in the usual way.

The average cost of reducing one ton of litharge and pot dross is :-

| | |
|---|---|
| Coal, 140 kilos of 35f. | 4.90f. |
| Wages | 1.15 |
| Tools and repairs | 0.40 |
| Sundries, including | 1.00 |
| superintendence | F. 7.45 = 5s 11.5d. |

Cost on ton of ore, 1.73f. = 1s. 4.6d.

Nearly one-third the weight of market lead produced is skimmed off the different pots as dross, and passed through the reducing furnace. This large proportion of dross is due to the richness, of the lead worked, and the consequent repeated crystallisations to which it must be submitted. The proportion of litharge reduced is nearly the same as that of the rich lead refined. The total weight of lead reduced from pot dross and litharge, and returned to the pots, is equal to nearly one-half the market lead made.

9. *Re-smelting rich Slags.—*The slags are smelted in a blast furnace of similar construction to those employed for smelting the ore. About 260 tons are smelted per month, and are derived principally from the ores actually worked during that time. Their average assay for last year was 3½ per cent of lead.

The slags, after passing through the furnace, are thrown away, but still retain about 1¼ per cent, of lead. A very large proportion of the lead they contain is volatised, but part of it is afterwards recovered in the flues, though in what proportion it is impossible to ascertain. Only 1¼ unit was obtained last year as pig lead (assay 750 grammes of silver per ton), and yet it was more than sufficient to pay the expenses of treatment; the fume collected in the flues of itself affords a fair profit. At present the slags are far too poor to make it advantageous to melt them over again, and it is probable that as the slags produced direct from the ore are gradually obtained poorer, this process will either be abandoned altogether, or only employed when the accumulation of rich slags may render it desirable.

The costs of smelting one ton of slag are the following :-

| | |
|---|---|
| Coke, 100 kilos. | 4.80f. |
| Smelters wages | 0.90 |
| Tools and repairs | 0.45 |
| Cartage and breaking | 0.77 |
| | F.6.92 = 5s 6.4d. |

## *SUPPLEMENTARY OPERATIONS.*

*a.—Roasting Matt.—*The matt produced in the blast furnace is returned to the ore magazine, and mixed with ores in the "Lits de Grillage," as already explained; but before being mixed, it is ground in a mill to a coarse powder, and calcined in one of the reverberatory furnaces employed for roasting ore. A charge of matt weighs 2½ tons; each charge remains in the furnace double the time allowed for ore.

Every twelve hours a charge is withdrawn, and a fresh one introduced. The matt is worked on the bed next the fire, and as soon as a charge has become sufficiently hot, which takes place after about half an hour's brisk firing, it is, uninterruptedly, turned with paddles, during the whole time. Rapid oxidation of the metallic sulphides then commences; and as sufficient heat for calcination is thereby maintained, the fire in the grate is allowed to burn down, but not to go out, since in that case too much cold air would enter the furnace, and lower the temperature of the charge. When the charge has been properly calcined it becomes almost black, contains very few lumps, and emits scarcely any sulphurous fumes. It is then drawn through the working doors, by means of iron rakes, and is thence removed to the ore magazine.

The cost of roasting one ton of matt is as follows :—

| | |
|---|---|
| Coals, 150 kilos<br>Labour<br>Grinding and cartage | 5.25f.<br>3.30<br>1.00<br>F.9.55 = 7s 7.6d. |

Cost of roasting matts on ton of ore, 1.05f. = 10d.

*b.—Treatment of Calcined Dross.*—The drosses skimmed from the work lead, and from the hard lead, in the process of improving, are treated in the reducing furnace, and the residues smelted in the blast furnace. The object of this preliminary operation is to separate all the metallic lead by liquation, and to reduce as much as possible the amount of the material to be treated in the Castillian furnace. It has been found that this is best effected by working it in small charges mixed with a certain proportion of fine coal. Five tons, divided into four charges of 14 ton each, are usually worked in twenty-four hours. The charge is turned and frequently paddled to facilitate the drainage of the lead from the mass, which acquires, after a short time, a rather pasty consistence. The cinder drawn out on the floor at the end of each operation is subsequently smelted in the manner described under the head of "*Treatment of Lead Cinder.*" About 56 per cent, of hard lead is thus obtained, with a consumption of 30 per cent. of coal.

The cost per ton of stuff is as follows :-

| | |
|---|---|
| Coal, 305 kilos at 35f.<br>Wages | 10.68f.<br>2.22<br>F.12.90 = 10s 3.8d. |

Cost on ton of ore, 0.68f. = 6.5d.

*c.—Treatment of Lead Cinder.*—These residues include the cinder from the reduction of the pot dross, calcined dross, and litharge. They are smelted in the blast furnace, with about twice their weight of common slag; no other fluxes are necessary. The coke employed as fuel, together with the carbonaceous matters contained in the cinder, effects its complete reduction. None but the usual precautions are necessary in smelting this cinder. Particular attention must, however, be paid to the charging, and to the proportion of slag added, otherwise there will be great risk of choking the furnace.

The quantity of cinder smelted per annum, with results, is as follows :—

| Cinder smelted Tons. | Lead per cent. | Slag employed Tons. | Coke consumed Tons. | Lead produced Tons. |
|---|---|---|---|---|
| 119.340 | 38.9 | 240.000 | 19.980 | 46.440 |

or 85.26 per cent. of total lead contained in stuff smelted.

The above quantity was smelted in twenty days, and cost for

| | |
|---|---|
| Coke<br>Smelter's wages<br>Cartage | 959.00f.<br>404.00<br>214.80<br>F.1577.80 |

or per ton of cinder—

| | |
|---|---|
| Coke, 16.7 per cent<br>Wages<br>Cartage | 8.00<br>3.40<br>1.80<br>13.20 = 10s 6.7d. |

Cost on ton of ore smelted, 0.45f. = 4.3d.

*d.—Treatment of Lead Fume.—Roasting.*—Owing to the peculiar nature of the fumes collected in the flues at the Pontgibaud works, it has been found impossible to smelt them advantageously alone, as is done in various other establishments. Several methods have been tried and abandoned, but the best hitherto devised, and that which is now adopted, is to mix with the fume a certain proportion of silicious ore, and fuse them together in a common roasting furnace. The fused mass thus obtained, has the appearance of a clean black slag, and closely resembles ordinary roasted ore. It is subsequently smelted in the blast furnace in precisely the same manner as already described when treating of the smelting of ores.

| | |
|---|---|
| Fume 60 parts, assay 62.7 per cent. Lead. | |
| Ore 40 parts, assay 40.0 per cent. Lead. | |
| 100 | |

This mixture is divided into charges of 2½ tons each, and treated in exactly the same way as ore which has been roasted dead. It is charged *á la pelle* through the working doors of the furnace, upon the middle bed, where it is left undisturbed until the preceding charge has been melted and run out from the agglomerating bed. The charge on the middle bed is then immediately advanced towards the fire and piled up near the bridge; care being taken to move the mixture of ore and fume as gently as possible, otherwise considerable loss may occur from the fine particles being carried away by the draught. The whole of this charge having been advanced, and a new one introduced through the doors of the middle bed as before, the fire is urged so as to melt the mixture as quickly as possible, which is accomplished in from two to three hours. Five charges, or 12 ½ tons, can thus be passed in one furnace in twenty-four hours, the loss of weight in roasting being about 15 per cent.

The same number of men are employed as in roasting ore, but, instead of being paid by the day, they receive one franc each per charge. The consumption of coal is 17 per cent., and of lime 3 per cent. of the weight of stuff roasted.

The cost of roasting one ton of a mixture of fume and ore is as follows : -

| | |
|---|---|
| Preparation of mixture | 0.25f. |
| Coal, 170 kilos at 35f. | 5.95 |
| Lime, 30 kilos at 24f. | 0.70 |
| Labour | 1.30 |
| Cartage | 1.00 |
| | F.9.20 = 7s. 4.3d. |

Cost of roasting fume on ton of ore, 0.4f. = 3.8d.

*Smelting.*—The roasted stuff is broken and made into lits de fusion in much the same way as ordinary ore, but the proportion of fluxes added is much greater than usual.

The lits de fusion for fume and ore are composed as follow : -

| | |
|---|---|
| Fume and ore | 10,000 kilos |
| Iron | 1,200 kilos |
| Limestone | 3,500 kilos |
| Fluor spar | 300 kilos. |

The above quantity is usually smelted in twenty-four hours, with a consumption of 9 per cent. of coke.

The following are the costs of smelting one ton of the mixture of fume and ore in the blast furnace :

| | |
|---|---|
| Preparation of lits de fusion | 0.40f. |
| Iron 120 kilos at 95f. | 11.40 |
| Limestone 350 kilos at 20f. | 7.00 |
| Fuor spar 30 kilos at 15f. | 0.45 |
| Coke 90 kilos at 48f. | 4.32 |
| Labour | 2.02 |
| | F.25.59 = 20s. 5.6d. |

Cost per ton of unroasted mixture, 21.77f. = 17s 4.9d.

Cost of smelting fume on ton of ore, 0.95f. = 9.1d

The quantity of fume collected annually in the flues is about 154.900 tons, averaging 56.8 per cent, lead and 132 grammes, or 4 oz. 5 dwt. silver per ton. The richness of the fume varies considerably in different parts of the flue, but in general the percentage of lead increases, whilst the proportion of silver diminishes, with the distance from the furnaces. The lead obtained from fume by the process described, amounts to 78.57 per cent of the quantity found by assay, or 3.67 per cent of the total weight contained in the ores treated.

When it is considered how large a proportion of lead is lost by volatilisation in the form of fume by every known method of smelting lead ores, it evidently becomes a matter of importance to condense as large a proportion as possible of the metal thus driven off in order to reduce this loss to a minimum. Particular attention is now being devoted to this subject at Pontgibaud, and considerable improvements have been introduced with a view of recovering a larger proportion of fume than has been hitherto found possible.

Losses of Lead and Silver.—From 100 parts of lead contained in the ores treated, 85.75 are obtained either directly from them, or indirectly from slags or fumes, viz. :—

| | |
|---|---|
| Direct from ores | 80.04 per cent. |
| From fumes | 3.67 per cent. |
| From slag | 2.04 per cent. |
| Total | 85.75 |

In desilverising the lead thus obtained, a loss of 3.25 per cent, is experienced, the total weight of poor lead produced for sale being 82.50 per cent. of the quantity contained in the ores.

The loss in desilverising is distributed as follows :—

| | |
|---|---|
| Refining | 1.25 per cent. |
| Improving and reducing | 2.00 per cent. |
| Total | 3.25 per cent. |

The loss of lead in the three principal divisions of the Pontgibaud process is therefore :-

| | |
|---|---|
| In roasting | 2.50 per cent. |
| In smelting | 11.75 per cent. |
| In desilvering | 3.25 per cent. |
| Total | 17.50 |

The percentage losses on the total quantity of silver contained in the ores are* :-

| | |
|---|---|
| In slags | 0.568 per cent. |
| In Market Lead | 0.533 per cent. |
| Total | 1.101 per cent. |

*These losses are indicated by the assay of the slag and market lead, since the amount of silver annually obtained is, nevertheless, considerably in excess of the weight determined by assay.

The process now employed for the extraction of the silver is not only much superior to the old Pontgibaud method, but is even more perfect than the best methods of assaying at present known, since, in the large way from 3½ to 4 per cent. more silver is obtained than the assays indicate.

Of 100 parts of silver produced—

| |
|---|
| 98.82 are obtained direct from the ores. |
| 0.64 are obtained from the slags. |
| 0.54 are obtained from the fumes. |
| 100.00 |

The quantities of lead and silver sold from the Pontgibaud Smelting Works for the years ending June, 1865, and June, 1866, were as follow :—

| Year | Product | Value |
|---|---|---|
| 1865 | Lead 1391 tons | |
| | Silver 124230 oz. | £61,582 |
| 1866 | Lead 1550 tons | |
| | Silver 145,280 oz. | £69,582 |

Summary of Costs. :-

| | Cost per Ton of Ore Smelted. | | | Cost per Ton of Lead Produced. | | Cost per kilo of Silver Produced. | |
|---|---|---|---|---|---|---|---|
| | f. c. | f. c. | £. s. d. | f. c. | £. s. d. | f. c. | £. s. d. |
| Preparation of "Lits | 0.25 | | | | | | |
| de Grillage" | 19.75 | | | | | | |
| Roasting Ore | 1.05 | | | | | | |
| Roasting Matt | 0.40 | 21.24 | 0 17 19 | 48.94 | 1 19 | 16.78 | 0 13 5.0 |
| Roasting Fume | 0.25 | = | | = | 1.8 | = | |
| Preparation of "Lits | 21.06 | | | | | | |
| de Fusion" Smelting Ore | 0.95 | | | | | | |
| | 0.45 | 22.71 | 0 18 2.0 | | | | 0 14 2.6 |
| Smelting Fume | 1.90 | = | | 51.82 | 2 1 5.4 | 17.77 | |
| Smelting Lead cinder | 1.03 | | 0 2 4.1 | = | | = | 0 1 10.0 |
| Improving} | | 2.93 | | | 0 5 4.2 | | |
| Ordinary work Lead | | = | 0 9 | 6.69 | | 2.29 | 0 7 9.1 |
| Improving} Hard Lead | 1.73 | | 10.9 | = | 1 2 7.4 | = | 0 1 5.0 |
| Crystallising | 0.68 | 12.39 | 0 1 9.8 | | 0 4 1.7 | | 0 1 6.0 |
| | | = | 0 1 | 28.27 | 0 4 4.8 | 9.70 | 0 3 9.8 |
| Refining | | 2.27 | 11.1 | = | 0 11 | = | 2 3 11.5 |
| Reducing }Pot Dross | | = | 0 4 | 5.18 | 1.6 | 1.77 | |
| / Litharge | | 2.41 | 10.6 | = 5.50 | 6 8 2.9 | = | |
| Reducing Calcined Dross | | = | 2 16 2.4 | = | | 1.88 | |
| | | 6.10 | | 13.92 | | = | |
| Smelting Slag | | = | | = | | 4.77 | |
| | | 70.26 | | 160.32 | | = | |
| | | = | | = | | 54.96 | |
| | | | | | | = | |

N.B. General Expenses are not included in the above statement.