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"The Erection of Silver-Lead Smelting-Works in Mexico."

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THE development of the mineral resources of Mexico during recent years, aided by the reductions in the price of coke owing to the extension of railways there, has led to the erection, in various parts of the Republic, of furnaces of the most modern type. The Author proposes to describe in detail the erection of a silver-lead smelting-plant, capable of treating 100 tons of ore daily, with provision for future extension, for the Michoacan Railway and Mining Company, of London, at Las Trojes in the State of Michoacan, Mexico, situated at an altitude of some 9,000 feet.

The general plan of the new works is shown in Fig. 1, Plate 4. An old slag-tip was converted into a charging-floor for the new works; the furnaces were erected on a lower level beyond the edge of the tip, the charging-doors being level with its surface; and on the same level were erected the blowers, engines, boilers, and general machinery. An outer retaining-wall was first built, running along the front of the works, as shown in Figs. 2, 3, and 4. It was founded on a soft porphyritic rock, and was only needed temporarily, as the running of the new furnaces would rapidly bury it altogether in slag. As this wall was erected, the filling behind it was simultaneously carried up to the level of the intended furnace-floor. During the erection of the new works, the old furnaces were running continuously, and these supplied some 40 tons of slag daily. In the ordinary course of working, the balls of slag from the slag-pots were placed at the edge of the old tip, and broken to pass through a 5-inch gauge-ring in order to separate any matte, speiss, or lead that they might contain; this slag was then further reduced in size until small enough to pass a 3-inch ring, and was used as filling. Soft stone was also obtained from the adjacent hill-side for the same purpose. Under the water-motor and engines, the filling was broken to pass through a 2-inch ring, and thoroughly rammed. The entire area was filled in layers, the smaller-sized filling under the foundations being always kept some 2 feet above the main portion until the level for the bottom of the foundation-blocks was reached, when the masonry was carried upwards in the same manner. Stone for

masonry was obtained from the bed of an adjoining stream, where there were many boulders of porphyry, rarely, however, exceeding 2 cubic yards in content. This porphyry was hard, durable, and well adapted for rubble masonry. It was all broken with dynamite. The larger stones which were required for the foundations of the furnaces, were plugged and feathered in the usual way.

When the filling was nearing completion, a series of bench-marks were fixed on the area, and some charges of dynamite were exploded without any subsidence being observed. Under each engine a block of masonry was carried up from a depth of 9 feet, with a horizontal section of 186 square feet—thus containing about 110 tons of masonry. A block of 840 cubic feet of masonry was also built under the Pelton water-motor which drives the machinery. These large masses of masonry were put in because there was much doubt felt as to the stability of the slag-filling under the vibration of the machinery. The foundation-blocks under the furnaces are 5 feet thick, and on these, immediately under the cast-iron columns, Fig. 5, large stones were placed running well under the main structure. The weight of each furnace with its burden is equal to $1\frac{1}{2}$ ton per square foot, which, however, as will be seen on reference to the figure, is taken up to a considerable extent by the four columns at the corners. The furnaces were supplied by Messrs. Fraser and Chalmers, of Chicago, and are of the water-jacketed rectangular type, each having, with the class of ore smelted at Las Trojes, an actual capacity of 90 tons of charge per 24 hours, not including fuel. Fig. 5 illustrates the furnace; its principal dimensions are: section at the tuyeres, 36 inches by 84 inches, in the shaft of the furnace, 66 inches by 84 inches, in the stack, 42 inches by 42 inches; from the centre of the tuyeres to the charging-floor, 12 feet 6 inches; from the tuyeres to surface of lead in the well, 11 inches. The lead-well is 21 inches deep and holds $6\frac{1}{2}$ tons of lead, which is tapped by an inverted siphon. The well has $\frac{1}{4}$ -inch wrought-iron plates covering the sides and bottom, to prevent the soaking of lead into the foundations. The water-jackets, Fig. 6, are of wrought-iron, and extend from 2 feet 10 inches above the tuyeres to 10 inches below them. The bottom of the smaller or end jackets extend down only to $2\frac{1}{2}$ inches above the tuyeres. The thickness of the inside plate of the jacket is $\frac{3}{8}$ inch, that of the outside plate $\frac{5}{16}$ inch, and the water-space between them is 6 inches. The side and end jackets are bolted together by $\frac{3}{4}$ -inch bolts and angle-plates. In the longer jackets, water enters at two points by pipes,

as shown in Fig. 6; the water is delivered well down in the jacket, and, entering at a lower temperature than that surrounding it, immediately sinks, thus causing good circulation. The hotter discharged water is taken off at the top and runs away through a gutter, shown in the figure.

In the rainy season in Mexico, the water is often heavily charged with organic and earthy matters in suspension. At such times, care should be taken to strain the water in some simple manner before it enters the jackets. Some jackets are also provided at the mud-hole with a gland and rod to which is attached a scraper or agitator, which can be drawn in and out so as to stir up any sediment that may have been deposited. (The Author has known a case of a smelter where, during heavy rain, the water-pipes and channels leading to the jackets were completely filled with stones, and the jackets had to be supplied by hand.)

The furnace has, at each side, five 3-inch tuyeres of the Devereaux type, 16 inches apart. By the use of this tuyere the inclination of the blast may be varied at will, and air can readily be shut off from any desired tuyere by a hand-valve. They are objectionable inasmuch as the furnace-man is at some distance from the furnace-contents, and, although movable, it is inconvenient to remove them on account of their weight; they are provided with mica eye-plates to allow of the furnace being watched. In working the furnace, the slag forms a skin on the jackets which effectually prevents any leakage of slag between them, and also tends to prevent undue chilling at the smelting-zone. The blast is supplied by the 3-foot main air-pipe, Fig. 2, leading from the blowers, and is carried round the jacket by a 15-inch galvanized-iron pipe. A specially woven 6-inch flexible pipe brings the air from this pipe to the tuyeres. The usual pressure of the air supplied is 17 inches head of water, or about 10 ozs. per square inch, but the furnace is adapted to much higher pressure. It is difficult, however, to form even an approximate idea as to the quantity of air supplied. The furnace is built with fire-bricks up to the level of the charging-door, and above this with ordinary bricks. A 3-foot wrought-iron down-take, Figs. 2, 4, and 5, carries the dust and fume to the main furnace-flue, and the furnace can be worked into this or not as desired. The main furnace-flue is 7 feet broad and 10 feet in height; it has an inclined brick bottom, and all deposits can readily be scraped out through the cast-iron doors shown in Fig. 4. This flue connects with the long flue running under the charging-floor, which it is ultimately intended to carry up the hill to a height of 350 feet. The flue is 6 feet by 8 feet in cross-

section. At the present time it terminates at the foot of the hill, and is surmounted by a temporary chimney.

In the design of the works, a large space is devoted to the erection of reverberatory furnaces, with provision also for extension. The furnaces are to be 74 feet in length, the roasting-hearth being 13 feet wide, and the fusion-hearth 11 feet long by 11 feet wide. The capacity of each furnace will be 5 tons of fine sulphide-ores roasted per 24 hours; and on the fusion-hearth some 8 or 9 tons of fine ore can be fritted together in the same time. There is, in the mines of the company, a large amount of fine ore, which needs to be treated in reverberatory furnaces and fritted together, to render it suitable for charging into the smelting-furnace, raw or roasted fine ore having a tendency to choke the furnace and lower the rate of driving. The reverberatory furnaces will discharge their smoke and fume into a flue shown in Fig. 1, connected with the main flue on the hillside. The furnaces are to be charged through hoppers, and a platform will run behind them, on which the supply of ore will be laid down.

The machine- and engine-house has several exceptional features. The line of shafting running down the centre of the shop is 4 inches in diameter and 3 feet above the floor; it is driven as required by either the Pelton wheel or by the engines at each end. The engines are coupled directly on to the shaft by clutch-couplings. They are non-condensing, and originally formed part of the old plant. They are intended to be held in reserve only, as a good supply of water is expected all the year round.

The Pelton wheel, Fig. 7, is 6 feet in diameter, and is supplied with water by a 12-inch wrought-iron pipe, from a tank at the end of the launder, 487 feet above the level of the nozzle. The 12-inch pipe-line is carried across the charging-floor, by a light trestle, at a height of 25 feet above ground-level, until it strikes the hill, after which it runs along the slope. The launder, which is built entirely of wood, is 7,462 feet long, having a sectional area of 4 square feet, and an inclination of 1 in 1000. Its maximum capacity is 350 cubic feet of water per minute—delivered at the wheel through a nozzle $2\frac{1}{2}$ inches in diameter. When the water in the launder is only 1 foot in depth, 150 cubic feet of water are delivered through a $1\frac{3}{8}$ -inch nozzle. The water available at the end of the dry season is never less than 150 cubic feet per minute; but, during the rest of the year, there is much more. The launder, running full, develops at the Pelton wheel 253 HP., and, running half-full, develops 108 HP. These powers are based on an efficiency of 80 per cent., guaranteed by the

Pelton Company; but the actual horse-power is probably higher. The tail-race from the wheel passes to the race of the turbine of the old works. It is 2 feet square in cross-section, and has an inclination of 1 in 100. The water from the water-jackets and the elevator is also discharged into this channel. Owing to the head of water, the boilers can be fed direct from the stand-pipe, the pressure of the steam in the boilers being 100 lbs. per square inch, and that of the water 207 lbs. per square inch; the "elevator," described below, is also actuated in the same manner. All these branch-pipes are connected, by a 6-inch Ludlow stop-valve, with the main 12-inch pipe-line. The Pelton wheel appears to be well adapted for use in districts where small quantities of water under considerable pressure are available. The best speed for the wheel is attained when the circumferential velocity is one-half that of the impinging jet of water—270 revolutions per minute at Las Trojes.

The blowers, arranged as shown in Fig. 2, are of the Baker type, and each one supplies 30 cubic feet of air at atmospheric pressure per revolution; all deliver directly into the 3-foot air-main. This main is made of $\frac{1}{8}$ -inch wrought-iron plate, with $\frac{5}{8}$ -inch cast-iron flanges, jointed with india-rubber washers. It has a relief-valve, in case of increase of pressure owing to any sudden drop in the furnace-charge. The main is led through the entire length of the machine-room, and out behind the furnaces. The main in the old works was below ground, but much difficulty was experienced owing to leakage and fracture, caused by the passage of vehicles over it. Under the blowers is a brick channel 3 feet wide by 4 feet deep, which projects 6 feet beyond the outside of the machine-building, its object being to prevent excessive aerial vibration in the house, and to ensure a good supply of air. The blowers are fastened to heavy 14-inch by 12-inch beams, which are bolted down to the brick-work. According to the makers, 17 HP. ought to be allowed for each blower. They are designed to run at 125 revolutions per minute, and three blowers are sufficient to supply two furnaces. The elevator between the machine- and furnace-buildings is for raising the silver-lead and matte produced, to the level of the charging-floor. The table is 8 feet by 6 feet, and has a lift of 16 feet. The ram is direct-acting, and is $10\frac{1}{2}$ inches in diameter, and $\frac{1}{4}$ inch thick. The water is admitted to the ram by a three-way rack-valve. From the charging-floor, railway-branches connect with the Ferrocarril Michoacan y Pacifico, which joins the Mexican National Railroad at Maravatio.

The ore treated in the furnaces described, is of a character not

generally considered suitable for smelting operations, being poor in lead. Indeed, the ore had for many years been treated altogether by amalgamation processes, until, as the mines were worked deeper, sulphides and leady ores were encountered, rendering amalgamation so expensive that it was finally abandoned. Even at the present time, lixiviation, after a preliminary separation of the leady portions, has been proposed by metallurgists who have reported on the ores of the district. The silver probably exists in the ore as sulphide and arsenide, finely disseminated through the various minerals composing it; attempts at silver-concentration have, up to the present, invariably proved a failure. On crushing and concentrating the ores from as much as 8 parts to 1, it has rarely been found that the concentrates contain double the percentage of silver in the original ore pile. The class of ores extracted differs widely in the various mines of the company, and, as received at the smelting works, their composition usually varies within the following limits:—

Lead	traces
Iron	10 per cent. to 30 per cent.
Zinc	2 „ 12 „
Antimony	traces
Copper	traces
Sulphur	18 per cent. to 25 per cent.
Silica	15 „ 30 „
Alumina	traces
Lime	traces

Ore carrying less than 28 ozs. per ton of silver, is not considered worth mining.

At present the ore is burned in heaps, and, in consequence of the amount of zinc present, a certain quantity of silver is lost in this operation. The burnt ore contains between 5 per cent. and 8 per cent. of sulphur. A typical mixture for smelting consists of—

Roasted ore	40 per cent.
Litharge	8 per cent. to 10 per cent.
Roasted matte	10 „
Slag	35 „
Lime	5 „

The litharge is produced by refining the silver-lead in German cupellation-hearths on the works. The lime is brought some 3 leagues by mules, and costs 19s. 6d. per ton delivered at the works. The mixture contains between 15 ozs. and 20 ozs. of silver per ton, between 2 per cent. and 8 per cent. of zinc, and 12 per cent. of lead.

A furnace-charge is 600 lbs., and takes 80 lbs. of fuel. The fuel is partly Connellsville coke, and partly charcoal—31 per cent. of the former, and 69 per cent. of the latter. The coke costs on the works £3 2s. per ton. The charcoal costs £1 1s. 7d. per ton; but it is of a very inferior description, and only some 50 per cent. to 70 per cent. of it is serviceable; it is burnt by Indians in the Company's forests, and is principally obtained from pine-wood, although a small amount of oak is found. The products of the furnaces are:—

(1) A silver-lead alloy termed "base bullion," containing 75 per cent. of the silver in the original charge; this alloy contains 0·4 per cent. of silver. (2) An iron matte with 20 per cent. of the silver in the original charge; it usually carries about 20 ozs. of silver to the ton; it is piled in heaps and burned—burning freely; and is then re-passed through the furnace. (3) A slag containing the remaining 5 per cent. of the silver in the original charge. This slag carries between 1 oz. and $1\frac{1}{2}$ oz. of silver per ton, and is a waste product. If at any time it is found to be too rich, it is used as required to make up the smelting-charge. The cost of smelting a ton of ore is between £1 17s. and £2 6s. The cost of smelting a ton of mixture is about 16s.; these prices include roasting the ores, and refining the "base bullion."

The problem of smelting in the Republic of Mexico, is unlike that in Europe or the United States, being affected by the circumstance that the labourers are apathetic in temperament, and physically incapable of continuous toil. For this reason, there is a tendency, in Mexico, to look with greater favour on 30-ton or 40-ton furnaces, as they do not require such heavy manual labour, and are managed and kept in order much more easily than those of larger size. These furnaces are generally round in section, with 5 water-jackets; one having a hinge at its upper portion, to facilitate cleaning out the zinc shell that has a tendency to form in all these furnaces with the class of ore met with at Las Trojes. These furnaces vary between 36 inches and 42 inches in diameter—the last dimension being, perhaps, a maximum; 36 inches at the tuyeres is usually found a satisfactory size; the larger sizes being only recommended where very little fine ore is smelted, and where good English coke is used. In the furnaces at Las Trojes, there are two charging-doors to each—the charge being shovelled in alternately from either side. A 4-feet by 7-feet iron plate, running smoothly into the furnace, is laid at the doors to aid in the handling of the charge. A rim, some 6 or 8 inches high at the door, is recommended, so that the ore must be lifted

and thrown in, in order to ensure a better distribution of the material. In smelters where sulphides are treated, the ore is roasted before entering the furnace. In Mexico this operation is almost invariably conducted by open-air burning in heaps, generally on the works. In the selection of a site for the roasting, care must be taken that the sulphurous fumes may not descend on to the charging floors, as much inconvenience is caused thereby. An inverted funnel-shaped apron should be affixed over the slag-tapping holes, and connected by pipes to a point above the main building, in order to prevent the smoke from hanging about where the men are working. By this means the disease known as "leading" may be entirely avoided, and the general health and comfort of the workmen ensured.

The Paper is accompanied by 2 tracings from which Plate 4 has been prepared.

[DISCUSSION.]

Fig. 1.

Scale for Fig. 1.
Feet 0 50 100 150 200 250 Feet.

Fig. 2.

Fig. 3.

Scale for Figs. 2, 3 & 4.
Feet 0 5 10 15 20 25 30 35 40 45 50 55 60 Feet.

Fig. 4.

Fig. 5.

Scale for Fig. 5.
Feet 0 5 10 15 Feet.

Fig. 6.

Scale for Fig. 6.
Feet 0 1 2 Feet.

Fig. 7.

Scale for Fig. 7.
Feet 0 1 2 3 4 5 Feet.