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## NOTES ON THE TREATMENT OF SILVER ORES.

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As the treatment of ores generally is so closely connected with engineering, the author has thought that a few notes on this subject might prove of interest to the Association, and especially to those members who have hitherto given no attention to the subject.

The methods of treating silver ores may be briefly comprised under three general headings, viz.: Smelting, Amalgamation, and Leaching or Lixiviation, to either of which may be added Concentration, either of the original ore, or, as is sometimes the case, in amalgamation and leaching of the tailings from the mill. It is proposed to give in this paper a short sketch of the Smelting and of the Lixiviation processes, with a few words on the general nature of ores suitable for concentration, and the methods adopted.

Smelting may be termed a mixed process, being partly chemical and partly mechanical, and consists, as is generally known, in bringing the ore into contact with suitable fluxes at a high temperature, thereby forming a more or less fusible slag, and at the same time setting free the metal or metallic compound carrying the silver, which falls by gravitation to the bottom of the furnace, from whence it is drawn through the tap-hole. The silver present is taken up by the lead in the event of lead smelting, or by the matte in the case of matte smelting.

Smelting may be classified under two heads, viz. : reverberatory furnace smelting, and blast furnace smelting ; but, as the general principle is the same in each, an outline of the latter will be sufficient.

The chief constituents of an ore suitable for treatment by this method are silica, iron oxide, and lime, which form the slag and sulphur, and the metals lead and copper, which provide the bullion or matte, as the case may be, in which the silver is collected. The other ingredients usually found in ores, and which, when in sufficient quantity, tend to make smelting less profitable, are alumina and zinc, with sometimes baryta and magnesia.

Silver-bearing ores may be divided into two classes, viz. : sulphide ores and oxidised ores, the latter being found near the surface overlying the sulphide, which is invariably the class found at depth, and from which, through its decomposition, the oxidised ore is formed. During this decomposition the ore loses much of its sulphur, and many of the base metals from compounds from which are soluble in water which, in the course of time, are dissolved out and carried away by the rains, while the silver compounds formed, not being soluble to any extent, remain in the ore, so that it can be readily understood why the surface ores are so often the richest in the mine.

In the treatment of these sulphide ores they are first roasted to drive off the sulphur—a process which will be described further on—and they may then be treated as oxidised ores. It is only seldom that an ore can be found containing all the constituents, and in the right proportions necessary to form the slag required ; and it therefore becomes necessary to add whichever is wanting as fluxes. Most ores contain a larger proportion of silica than of either iron or lime, so that it is usually necessary to add both of these last to the charge. Some ores, however, contain only a small percentage of silica and a large proportion of iron or lime, and it then becomes necessary to add silica, which is most conveniently done, when

a siliceous ore is not at hand, in the form of crushed quartz. If this quartz contains either gold or silver, it is all obtained in the bullion, or matte, with the silver from the ore.

In the case of lead ores being smelted, the lead is reduced in the furnace, and falling through the charge to the bottom of the furnace collects and retains the silver, from which it is afterwards separated; in the event of "Matte" smelting care must be taken to leave enough sulphur in the ore to form the matte, which is a sulphide of iron and copper, and which then behaves in the same way as lead in lead smelting.

In treating silver ores on a large scale the mineral is, if "surface" or oxidised, taken direct to the smelter, if a sulphide ore it is taken first to the roasting sheds, where it is deprived of a greater part of its sulphur, and then is conveyed to the smelter to be treated in the same manner as the surface mineral. After being tipped into the bins at the smelter, the ore is analysed to find the percentages of silica, iron, and lime, and the amount of fluxes necessary to be added to form the required slag is calculated, and the charge made up. The composition of the slag will, of course, vary according to the nature of the ore and the ease or difficulty with which the two fluxes can be obtained. For instance, a typical slag used with very good results, where ironstone was plentiful, consisted of: Silica, 30 per cent.; oxide of iron, 40 per cent.; lime, 20 per cent.; allowing 10 per cent. for lime, alumina, &c. Another type used with equally good results, where ironstone was scarce, consisted of: Silica, 35 per cent.; oxide of iron, 27 per cent.; lime, 28 per cent.; allowing 10 per cent. as before.

When the composition of the slag to be made has been determined upon, the ore and fluxes are weighed out and mixed together and charged into the furnace alternately with the fuel. The slag, as it melts, descends to the lower part of the furnace and is tapped off about 10 in. from the bottom, while the matte, being heavier, sinks through this again, and is tapped out at a point level with the bottom of the furnace.

In the case of lead smelting, a crucible is used and the lead is ladled out from this in place of being tapped off, but the principle is the same. The slag is wheeled to the edge of the tip and thrown over, and the metal collected in suitable vessels, from which it is removed when cold and shipped away.

The blast furnace used in nearly all cases in silver smelting is the water-jacketed furnace, which possesses many advantages over the old style of brick or stone built furnaces, the chief of which is the comparatively small cost for repairs, and being able to run for long periods without having to shut down to effect these. Engineers appear to be divided as to the relative merits of wrought iron and cast iron jackets, although in many respects wrought iron would seem to be preferable.

#### ROASTING.

As this operation is carried on with all sulphide ores, whether treated by smelting, amalgamation, or leaching, it may be as well in this place to give a short account of the means used to effect this what is one of the most important parts of any process. It may be conducted in either open heaps, stalls, or furnaces, where a merely oxidising roasting is wanted, as in smelting, but can only be effected in furnaces when a chlorodising roast is required, as in amalgamation and leaching.

When roasted in open heaps the ore is first broken into pieces ranging from 3 in. to 6 in. gauge, is then screened to remove the smalls and fines, and the lumps are piled on a bed of wood in heaps and varying from 50 to 1,000 tons, a very convenient size being 250 tons. The smalls and fines are then thrown on the top and spread over the outside of the heap to prevent too great a draught, and the wood set on fire. The ore having once caught burns of itself until a very large proportion of the sulphur has been drawn off, which takes from eight to twenty weeks, according to the size of the heap; after cooling, the ore is carted away to the furnaces, or, if a cleaner roasting is required, is piled on a second heap, and the operation repeated with a larger quantity of wood; but, having only a

small amount of sulphur left, it will in the second roasting only burn for a short time.

Stall-roasting is conducted on the same general principle as the preceding, but the ore is confined by low walls pierced to allow for draught.

Either of these two methods are unsuitable when a very clean roast is required, but may often be carried on with great success when a little sulphur in the ore to be smelted is not objectionable.

Roasting furnaces are of a great variety of patterns, the essential principle in all being, however, essentially the same, viz.: the working of the crushed ore through a long flue, through which a strong heat is passing, which oxidises the sulphur and carries off the acid fumes with the draught in the oxidising roastings, and brings the materials to a sufficiently high temperature to effect the chemical changes required in a chlorodising roasting.

The oldest and most usual style of furnace is the reverberatory, with a flat hearth, or, as is often the case, with two, three, or four hearths. It is in construction a long, low furnace, having at one end a fire grate, and at the other a tall stack which creates the draught. In the case of the single hearth furnace, the ore is spread over the hearth, and kept constantly turned over, to prevent clotting, until it is sufficiently roasted—usually in from four to six hours—and is then withdrawn. When two or more hearths are used, the ore is charged first on the hearth further from the fire, and, after being turned over for a while there, is transferred to the next, and a fresh charge introduced on to the hearth No. 1.

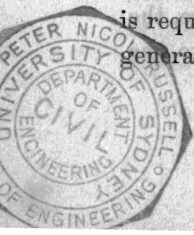
The advantage of having more hearths are: 1, The using of part of the waste heat to dry and start the roasting; 2, the gradual increase in temperature as the ore is moved nearer to the fire-box. But, unless the ore has sufficient sulphur to start the roasting at a comparatively low temperature, the second hearth is of no value practically. The limit to the

number that can be used economically is fixed by Mr. E. D. Peters at four in a furnace 70 ft. long, and even this number can only be used successfully when the ore contains a large percentage of sulphur. When the ore is to be smelted in a blast furnace it is usually advisable to sinter, or partly fume, the ore before it leaves the roasting furnace, as in this form it gives less trouble in the furnace than in fine powder. In reverberatory furnace smelting this is not required, the crushed ore being a more suitable form. In amalgamation or leaching great care must be taken not to allow the ore to sinter or clot, as this would prevent a proper chlorodising taking place, and would also have a bad effect upon the after treatment.

A number of mechanical contrivances have been made to work the ore through the furnace in place of using the hand-rabbles and rakes used in the ordinary reverberatory furnace. The limit of this paper will only admit of mention of the two most important of these, viz., the "Howell Furnace" and the "Stetefeldt Furnace."

The Howell furnace, which is suitable for an oxidising roasting, consists of a long inclined cylinder, lined with fire-brick, and with fire-brick projections or shelves running longitudinally through it from end to end. These projections serve to raise the ore as the cylinder revolves, and then allows it to fall again to the bottom to be taken up again by the other projections. At one end of the cylinder is a tall stack and at the other a fire-grate, as in a reverberatory. Sometimes even a small reverberatory is built on to the end of the cylinder for the purpose of smelting the ore. The ore is fed into the upper end of the furnace, and gradually works down to the lower end, where it is discharged; by altering the inclination of the furnace a longer or shorter roasting can be given at pleasure.

The Stetefeldt furnace, which has special merit in roasting certain classes of ore, and especially when a chlorodising roast is required, is essentially a shaft provided with a grate for the generation of such a degree of temperature which would be



lacking in the working of ores, so poor in sulphur as those usually required to be chlorodised, it is also provided with an auxiliary fireplace for the more perfect chlorodising of the flue-dust, which, owing to the fine pulverisation of the ore and strong draught essential to the proper working of the apparatus, is formed in very level quantities in the dust chambers. It has a very large capacity, a large furnace roasting from 60 to 100 tons per day. In chlorodising, the ore, mixed with salt, is conveyed to the top by means of an elevator and by means of an automatic feeder is fed into the furnace in a steady stream, falling through the heated air to the bottom of the furnace, where it is taken out and allowed to lie in heaps for some time to finish the chlorodising which goes on for some hours after the ore leaves the furnace. Although so successful in [this class of roasting, this furnace has so far not proved itself so suitable for the oxidising roasting as the other one mentioned, although experiments being made seem to show that it may become soere long.

As in any case of furnace roasting the ore has to be crushed first, the crushing plant adding to the cost of the roasting appliances, and so in blast-furnace smelting the fine state in which the ore is often delivered from the roasters causes considerable trouble it is better, where practicable, to roast ores to be treated by this means in the lump form, either in open heap or in stalls, or where this is impracticable to sinter the material before it leaves the furnace.

#### LIXIVIATION OR LEACHING OF ORES.

This process is comparatively so little known in the colonies, and gives promise of such extensive application, that it deserves more attention than is generally given to it. It is based on the property possessed by sodium hyposulphite of dissolving silver chloride, from which solution the silver can be precipitated as sulphide by the addition of sodium sulphide, All ores therefore in which the silver can be successfully converted into chloride can be treated by this process, which

was first introduced in 1858 by Von Patera, an Austrian metallurgist. Mr. E. H. Russell discovered that by the additional use of an extra solution, consisting of sulphate of copper dissolved in hyposulphate of soda, other compounds of silver, and even native silver, are attacked and rendered soluble, thereby overcoming the chief difficulty in Von Patera's process, which was the difficulty of obtaining the whole of the silver in the form of chloride; an extremely careful roasting being necessary. Through Mr. Russell's discovery, although it is still necessary to chlorodise the ore, this need not be done with such extreme care, as any of the silver which escapes the action of the salt is taken up by the extra solution and the tailings are left comparatively free.

#### THE SOLUTIONS.

The ordinary, or stock solution, is made by dissolving a proper quantity of the hyposulphite of soda in a measured quantity of water (usually from 1 per cent. to 2 per cent of the hyposulphite being used) in the storage tanks where it is heated, and kept at the required temperature by means of a lead pipe through which steam is passed. The solution is tested from time to time to ascertain its strength in hyposulphite, which is the active agent in the process, and is diluted or strengthened as found necessary. It would take too long to enter fully into the re-actions consequent on using this solution, but it will be sufficient to say that, in a general way, the solution may be used over and over again, the hyposulphite being regenerated by the re-action of the sodium sulphide upon the hyposulphite salts of the metals in their precipitation by this re-agent.

The extra solution of Mr. Russell's process is prepared by dissolving sulphate of copper in a solution of hyposulphite of soda, cuprous hyposulphite being formed which appears to have the property of decomposing the salts of silver other than the chloride and of rendering them soluble in the ordinary or stock solution of hyposulphite of soda. The extra solution is used sometimes before the ordinary solution, and sometimes after it