amalgamating the silver in the open in a circular enclosure termed a *lorta,* the floor of which is generally built of flagstones. In order to facilitate the decomposition of the silver-mineral, salt and magistral, *i.e.* cupriferous pyrites roasted to convert the copper into soluble sulphate, which is the active agent, are worked into the wet pulp spread out on the floor. The amalgamation proceeds very slowly, as the sole extraneous heat is that of the sun. According to Laur ("Métallurgie de l’argent au Mexico,” *Ann. des mines,* series 6, vol. xx.), at Guanaxuato, Mexico, 92·79 *% of* the total silver recovered was extracted after 12 days, 97·55% after 25 days, 99∙1 % after 28 days and 100% after 33 days. The loss of quicksilver in the process is large, owing to the formation of calomel which is not saved. The yield in silver is low unless the ores are exceptionally free-milling; the bullion produced is high-grade, as refractory silver minerals are hardly attacked. The process is suited to easy ores and a region where the climate is warm and dry, and horse- or mule-power, labour and quicksilver are cheaper than fuel and water.

The *Washoe* process of pan-amalgamation, named from the Washoe district in the United States, is the leading raw-amalgamation process of the United States, where it was introduced in 1861 by A. B. Paul. It consists in wet-stamping coarsely crushed ore, settling the sands and slimes produced, and grinding and amalgamating them in steam-heated iron pans with or without the use of chemicals (salt and copper sulphate). The ores may contain a larger proportion of sulphides and complex silver minerals than with the Patio process and still give a satisfactory extraction. They are crushed to egg-size in a rock-breaker, and pulverized to pass a 40-mesh sieve in a Cali­fornia stamρ-mill, which treats in 24 hours about 3 tons per stamp. A 10-stamp mill is fed by one rock-breaker, and discharges the liquid pulp into 10-15 wooden settling tanks, 9 by 5 by 8 ft., the settled contents of which are shovelled out and charged into the pans. The pan in general use is the combination pan. It has a flat cast-iron bottom, 5 feet in diameter, and wooden sides about 30 inches high, the lower parts of which are lined with cast-iron. In the centre is a hollow cone, through which passes the driving shaft, geared from below. This turns the grinding apparatus (driver with “ muller ”), which can be raised and lowered. The speed is 60-90 revolutions per minute. To the bottom and muller are attached grinding plates (shoes and dies), which are replaced when worn; and to the sides three wings to deflect the moving pulp towards the centre, and thus establish the necessary pulp current. The lower side of the bottom has also a steam-chest. A ίο-stamp mill has 4-6 pans, which receive 2-ton charges. In working, the muller is raised ½ in., the pan charged with watcr and then with ore; the muller is then lowered, salt and blue vitriol added, and the charge ground for 3-4 hours. The pulp is heated with live steam to about 90° C., and kept at that temperature by exhaust steam in the bottom-chest. After grinding, the muller is raised and quicksilver added, and the silver up to 81∙04% then amalgamated in 4 hours.

In amalgamating without the use of chemicals, finely divided iron, worn from the shoes and dies in the stamp-mill and the pan, de­composes cerargyrite and argentite, and the liberated silver is taken up by the quicksilver; the process is hastened by adding salt. When salt and copper sulphate are added to the charge, they form sodium sulphate and cupric chloride, both of which are readily soluble in water. Cupric chloride acts upon argentite (Ag2S+ CuCl2=2AgCl+CuS), proustite (4Ag3AsS3+4CuCl2=8AgCl+ 2Ag2S+4CuS+2As2S3), pyrargyrite (2Ag3SbS3+3CuCl2=6AgCl+3CuS+Sb2S3), and is also reduced to cuprous chloride by metallic iron. This salt, insoluble in water but soluble in brine, also acts upon argentite (Ag2S+Cu2CI2=2AgCl+CuS+Cu) and pyrargyrite (2Ag3SbS3+Cu2Cl2=2AgCl+Ag2S+2Ag+2CuS+Sb2S3), and would give with silver sulphide in the presence of quicksilver, the Patio­reaction; metallic silver, cupric sulphide, and mercurous chloride (2Ag2S+Cu2Cl2+2Hg=4Ag+2CuS+Hg2Cl2), but the iron decom­poses the quicksilver salt, setting free the quicksilver.

The amalgamation is rapid. Thus Austin found that at the Charleston mills, Arizona, 92∙13% of the total silver recovered was extracted after 1 hour, 94∙10% after 2 hours, 95∙92% after 3 hours, and 100% after 4 hours. The loss in quicksilver is small, as there is no chemical loss inherent in the process; the yield is relatively high, but the bullion is liable to be low-grade, on account of copper being precipitated and amalgamated.

When the charge has been worked, the contents of the pan are discharged into a settler, in which the amalgam is separated from the sands. It has the same general construction as the pan. It is 8 ft. in diameter and 3 ft. deep. The bottom, slightly conical, has a groove near the circumference to catch the amalgam, which is withdrawn through a discharge-spout into a bowl. In the sides at different levels are three discharge-holes for water and sand. The muller reaches to within 3 in. of the bottom and makes 12-15 revolutions per minute. In settling, the pulp is diluted by a small stream of water, and the thinned pulp drawn off, first through the top discharge­hole and then through the other two, the bottom one being about 8 in. above the amalgam. Settling takes about half the time required to work a charge in the pan, hence one settler serves two pans. The amalgam is dipped out from the bowl into a canvas bag (the strainer), to separate the excess of the quicksilver from the pasty amalgam, which is then retorted and melted. The cost of treating a ton of ore in the western part of the United States is from $3 to $7. At some works treating ores containing sulphides which do not yield their silver to quicksilver, concentration apparatus (see Ore-Dressing) is inserted between the stamps and the settling tanks to remove the sulphides, which are worked by themselves; at other works they are recovered from the sands after these have left the settlers. In order to do away with the handling of the wet pulp, and to obtain a higher extraction, Μ. P. Boss has modified the ordinary plant by making the pulp flowing from the stamps pass through a grinding pan, then through a series of amalgamating pans followed by a row of settlers.

A 20-stamp mill is served by 12 men in 24 hours. The Washoe process is independent of the climate, but it requires cheap power and an abundance of water.

In the *Cazo, Caldron* or *Hot* process the pulverized silver ore is boiled in a copper-bottomed wooden vat, first with brine until the silver has been reduced by the copper, and then with quicksilver. The *Fondon* is an improvement on the Cazo. Bars of copper drawn over the bottom by mules or water-power (like the stone drags in the arrastra) grind off fine particles of copper, which hasten the reduction of the silver and dimimsh the formation of calomel. In the *Kröhnke* process introduced by B. Kröhnke into Copiápó, Chile, in i860, the silver mineral of the pulverized ore is decomposed in a revolving barrel by a hot solution of cuprous chloride in brine in the presence of zinc or lead and quicksilver (see B. Kröhnke, *Methode zur Entsilberung von Erzen,* Stuttgart, 1900).

*Chloridizing Roasting.—*In a chloridizing roast chlorine produces its effect as nascent chlorine or gaseous hydrochloric acid. The leading reagents are salt (NaCl), sulphur trioxide (SO3, produced in the roasting), and steam (H20). The decom­position of salt is expressed by 2NaCl+2SO3=Na2SO4+SO2+Cl2. In the presence of water-vapour the following reaction takes place: 2NaCl+SO3+H2O=Na2SO4÷2HCl. As some water­vapour is always present, hydrochloric acid will invariably be formed with the chlorine. The roasting is carried on in hand and mechanical reverberatory furnaces, and occasionally in muffle-furnaces. A chloridation of over 90% silver is the rule.

The *European Barrel* or *Freiberg* process consists in roasting the ground ore with salt which converts the silver sulphide into chloride. The mass, along with certain proportions of water, scrap-iron and mercury, is then placed in barrels, which are made to rotate so that the several ingredients are thoroughly mixed. The salt solution dissolves a small proportion of chloride, which in this form is quickly reduced by the iron to the metallic state. This solution and pre­cipitation is continuous, and the metal formed unites with the mercury to form a semi-fluid amalgam. The amalgam is pressed in linen bags to eliminate a quantity of relatively silver-free liquid mercury (which is utilized as such in subsequent operations), and the remaining solid amalgam is subjected to distillation from iron re­torts. This process was perfected at Freiberg, Saxony, but aban­doned there in 1856. In the United States it was used quite ex­tensively in Colorado and Nevada, but has now been given up. The main reasons for this are the length of time required to finish a charge, on account of the absence of any extraneous source of heat, and the great care with which operations have to be carried out in order to obtain satisfactory results.

The *Reese River* or pan-amalgamation process consists in dry­stamping crushed dried ore and dried salt (separately or together), charging them into a roasting furnace, and amalgamating the chloridized ore in an iron pan. The general arrangement and construction of a mill resemble those of the Washoe process. The apparatus for drying ore and salt varies greatly, drying-floors, dry-kilns and con­tinuous mechanical reverberatory furnaces with stationary and re­volving hearths being used. The general construction of the pan is the same as in the Washoe process; the management, however, differs. The steam-chest is not used to such an extent, as the bottom would be prematurely corroded; less water is used, as the pulp would become too thin on account of the soluble salts (sodium chloride, sulphate, &c.) going into solution; and the roasted ore is not ground, as the hot brine readily dissolves the silver chloride from the porous ore, and thus brings it into intimate contact with iron and quicksilver. Chemical reagents are sometimes added—lime or sulphuric acid, to neutralize an excess of acid or alkali; copper sulphate, to form cuprous chloride with sodium chloride; and iron and zinc, to make the galvanic action more energetic and reduce the consumption of iron. The rest of the apparatus (settler, retort, crucible, furnace) is the same as with the Washoe process. The Reese River process costs from half as much again to twice as much as the Washoe process.

The *Francke-Tina* process, named from Francke, German consul at Bolivia, and *tina,* the wooden vat in which the process is carried out, was developed in Bolivia for the treatment of refractory ores rich in zinc blende and tetrahedrite (fahl-ore). The ore is given only a partial chloridizing roast, on account of the great loss in silver that would be caused by the formation of zinc chloride. The large amount of soluble sulphates of iron and copper formed in the roast is made to act upon salt charged in a copper-bottomed amalgamating pan ; the chlorides formed finish in the wet way the imperfect cnloridation obtained in the furnace.