Supplies.						
Acid	1·0220	..	5,486·38	..		
Wood	1·5230	..	8,175·93	..		
Coal	·0543	..	284·80	..		
Furnace supplies	·0270	..	145·19	..		
Manganese and salt	·8095	..	4,345·86	..		
Pipe	·0089	..	47·90	..		
Generator fittings	·0038	..	25·93	..		
Leaching tanks	·0638	..	339·05	..		
Miscellaneous	·1353	..	727·26	..		
Rake-heads	·0360	..	193·50	..		
Car wheels	·0037	..	27·50	..		
Repair account	·1352	..	720·08	..		
Electric light acct.	·1077	..	578·49	..		
Haulage account	·0549	..	294.77	..		
	$3.9852	£0 16 7¼	$21,392·63	£4,456	15	11½
Total cost per ton of sulphides	$9·0164*	£1 17 6¾	$48,400·13	£10,083	7	2½

	Cents.		s.	d.
Mining	65	=	2	8½
Milling and concentrating	33	=	1	4½
Chlorination	19	=	0	9½
General expenses (mine)	8	=	0	4
General expenses (in San Francisco)	2	=	0	1
Bullion freight, etc.	5	=	0	2½
	$1.32	=	5	6

per crude ton of ore, but the average for some time previous was 6s. 3d. per ton.

The roasting at these works is done in Spence automatic furnaces, each with four hearths, which roast 8 tons per day. On the hearth next the lower one, 3 per cent. of salt is added with a special spoon. The ore, instead of being as formerly stirred by fixed rakes, is now rabbled by oscillating ones, which tip every three minutes. On the upper drying-hearth they last a long time, but on the lower ones, where the heat must be great to drive off the last traces of sulphur, their life is only about three months.

Formerly the rakes stopped between the forward and backward motion just over the flue, now they are made to go beyond it, and are no longer exposed, as they were at this point, to the sulphurous gases and hot falling ore, which clogged the end of the shelves and gave such trouble at the Haile mine, finally causing the abandonment of the Spence furnace there for roasting fine ores, although admittedly a most excellent mechanical roaster for coarser grades of material in its original shape.

With the important modifications above alluded to it seems doubtful (judged by the above facts) how far Mr. Thies' condemnation of the Spence furnace† (in works wtth a capacity of 3 to 4 tons) for fine ores (where a dead sweet roast is required) is entirely justified.

The labour involved in vat-chlorination on an average may be taken at :—

1 man, who works 10 hours, to bring in wood and ore..
1 man at the furnace, who works 8 hours.
1 chlorinator, " 8 "
3 labourers (1 on shift by day, and 2 by night).

At Sutton Creek it takes 8 men for the whole 24 hours, one chlorinator, one helper, five men at the furnace, and one who wheels ore.

The consumption of chemicals per ton of ore is about as follows :—

Salt in the furnace	40 lbs.
" " generator	6 "
Manganese	6 "
Sulphuric acid generator (66 degs. B.)	20 "

The stock of chemicals ordinarily kept on hand, on the scale of operations of the Alaska Treadwell Company, seems to be :—

	£	s.	d.	£	s.	d.
Salt, about 53 tons, valued at	2	17	11 ..	153	9	7
Manganese, 13 "	9	15	10 ..	127	5	10
Sulphuric acid, 35 tanks at	8	18	10½ ..	313	0	7½
Total value ..				£593	16	0½

The works in Grass Valley, where vat-chlorination is most extensively used, guarantee an extraction of 90 per cent. of the gold, and 60 per cent. of the silver, but the saving more often amounts to between 90 and 94 per cent. of the gold in pyritic-concentrates, and over 60 per cent. of the silver, if the tailings are leached to obtain it.

The ore to be properly roasted ready for leaching should maintain a nearly vertical face when made into heaps on the finishing hearth, and cut down with a spadelle. It should show no bright specks, but be inclined to become black, which will generally be in 7 or 8 hours. The largest amount of gold has been shown to be in the best condition to be leached and to consume the least amount of chlorine in chlorinating it, when the ore falling in the furnace, in turning it over, has a slight violet colour. When the ore sparkles, and the sparks are numerous and bright, it shows that the roasting is not properly finished, and more salt has to be used.*

A ton of roasted ore will occupy usually 24½ cubic feet. This quantity is derived from 2,800 lbs. of raw sulphides, which occupy about 13⅔ cubic feet per ton (2,000 lbs.). A ton of sulphides will weigh from 1,450 to 1,700 lbs. after roasting, and occupy about 17½ cubic feet. The roasted ore ought not to contain more than 1⅜ per cent. of sulphur.*

At the Plymouth Consolidated works, the Fortschaufelungs-ofen used for roasting is 12 feet wide by 80 feet long, including the fire-box, the hearth being a continuous plane, but the charges, of which there are three in the furnace at one time, are kept entirely separate. They are called by the furnacemen the drying, burning, and cooking compartments. In the middle division the ore is spread out very thin, and occupies about double the space of either of the others.

The furnace is worked by 8 hours' shifts, a charge being drawn and added in each shift. The charges weigh 2,400 lbs. and carry about 10 per cent. moisture.

The ore averages about 20 per cent. of sulphur, and just before the sulphur ceases flaming in the second division of the furnace 18 lbs. or ¾ per cent. of salt is added to the charge. Care must be taken to keep concentrates damp until they are reduced into the furnace, or a decomposition of the pyrites begins, forming lumps which do not roast, and consequently cause a loss of gold in the residues from leaching. The roasted ore from each shift is kept by itself on the cooling floor until a tankful (about 4 tons) has accumulated from a single man's shift, and it is then worked by itself. This enables the foreman to better control the work of roasting, for if one lot out of three works badly, it points to the fault being with the furnaceman; whereas, if all three give unsatisfactory results, it may be presumed to be owing to a change in the ore, and the roasting must be modified.

The vats† for chloridizing the roasted ore are 9 feet in diameter by 3 feet in height; they are four in number, and are slightly inclined forward to drain them completely. The bottom of each tank is composed of a filter about 6 inches thick, consisting of light strips of ¾ inch wood laid on the bottom at intervals of about a foot. Across these are placed 6 inch boards, spaced an inch apart. On this loose floor coarse lumps of quartz are spread, and on the top of this again quartz-sand, until a depth of 6 inches is obtained. Finally, this sand filter is covered over with another loose floor, the boards lying cross-wise to the loose floor beneath and pretty close together. This upper floor is merely to facilitate shovelling the charge out when it has been gassed to permit the removal of the leached ore without disturbing the filter.

The ore to be chloridized must be damp (about 6 per cent. moisture). The working test is to take a handful of ore and squeeze it, then open the hand, and if the lump immediately begins to crumble and fall apart (not run) the ore has the requisite amount of moisture. The damp ore is screened into the tank so as to lie as loose as possible and thus facilitate the penetration of the chlorine. A coarse screen of one-and-a-half mesh is used for this purpose.

The tanks are only filled up to within about 3 inches of the top, (to ensure the entire contents being covered with water in the subsequent leaching,) otherwise there would be great difficulty in washing out the soluble gold. As soon as they are full they are gassed. The gas is introduced into the bottom from two opposite sides, and is continued until ammonia held over the ore gives off dense flumes of ammonium chloride, which usually happens in about 4 hours. When this point is reached, covers are placed on the tanks and luted on.‡

The two gas-generators§ which are employed to charge a tank are allowed to work on till nearly exhausted, when they are disconnected, and the holes in tank are plugged up. The tanks are usually charged in the morning, and left standing two days. On the third day the ore is leached. The tank is first filled with water, and allowed to stand a few minutes to permit the water to penetrate the ore. If no more water is absorbed, the liquor is drawn off at the bottom, care being taken to keep the tank full of water during this part of the operation, which lasts 4 to 5 hours.

For charging the tank a gunny sack is laid on the ore and held down with a couple of bricks where the wash-water is afterwards to be introduced, in order to better distribute the water in the tank, and prevent it washing out holes and packing the ore.

The liquor from the leaching-vats is conducted to settling or storage-tanks, where about 40 lbs. of sulphuric acid is added (66 degrees B.) and it is allowed to stand 2 to 24 hours. It is then run into the precipitating-vats, where the gold is precipitated with sulphate of iron; the iron solution being added until after stirring, a further addition produces no purple colour. After the gold is precipitated it is allowed to stand from two to three days to settle, when the supernatant liquor is drawn off with syphons into a second settling-tank, where any gold drawn off by the syphons has a second opportunity of settling.

The liquor stands in this tank until it is necessary to run it off to make room for a fresh charge. Very little gold is found in this tank, so it is only cleaned out about once a year.

In the meantime fresh liquor has been run into the precipitating-tanks on the gold already precipitated there. In this way the gold is accumulated till the semi-monthly clean up, the precipitating-tanks being kept locked and covered. In making a clean-up, the supernatant liquor is syphoned off, the gold gathered up, and placed in a filter of punched iron, lined with filter-paper, and washed with water till all the acid and iron salts are removed. It is then dried, melted in crucibles, and cast into bars.

Under unfavourable conditions the cost of the chlorination process may run up as high as £4 3s. 4d. per ton, but in California it may generally be taken as costing £1 17s. 6d. to £3 1s. 6d, per ton, £2 14s. 2d. being in all probability a fair average on a basis of treating 3 tons or more daily.

Mr. G. F. Deetken is responsible for the statement* that with favourable conditions of cheap wood and freight rates, not counting interest, insurance and amortization of a capital of 3,000 dollars, the working expenses in some parts of California do not exceed £1 0s. 10d., and are sometimes as low as 16s. 8d. per ton.

In locating works of this kind it is important to secure a good fall, and they should be terraced and so placed with reference to the prevailing winds that noxious fumes will not be carried in the direction of valuable land or house property.

There should also be a supply of water at hand, delivering 40 to 60 gallons per hour.

Barrel-chlorination.

Mr. Thies, in a letter to Mr. C. N. Aaron (a well-known Californian authority), gives the cost of the Thies process at the Haile mine, North California, as follows :—

Using a double reverberatory furnace, which furnishes 2 tons of roasted ore every 24 hours, with an average consumption of 1 cord of wood, at 5s. 2½d. per cord, and employing four labourers, the cost of roasting the ore amounts to 10s. 11¼d. per ton. Two men can easily treat 4 tons in 10 hours, elevate the ore, and clean out the filter-tanks, of which there are four to each barrel. Arranged on this basis, the cost of roasting and chlorinating amounts to 19s. 3¼d. per ton, as tabulated below :—

	Cost per Ton.	s.	d.
Roasting 2 tons of ore—			
4 labourers at 4s. 2d.	8	4	
1 cord of wood at 5s. 2½d.	2	7¼	
	10	11¼	
Chlorinating 4 tons of ore—			
2 labourers at 3s. 9d.	1	10½	
1 chlorinator at 8s. 4d.	2	1	
40 lbs. of bleaching powder at 1½d.	1	3	
60 lbs sulphuric acid at 1d.	1	3	
Sulphuric acid, for making ferrous sulphate	0	6¼	
Repairs, wear and tear	0	10	
Power	0	6¼	
	8	4	
Total cost per ton	19s.	3¼	

We thus have the sum of 19s. 3¼d. for roasting and chlorinating 1 ton of roasted ore, representing 1⅓ tons of raw iron pyrites.

Inside of 7 hours from the time the ore is in the chlorinator, the solutions are ready for precipitation and the tailings are clean.

At the Phœnix mine, in North Carolina, the cost for roasting† and chlorinating by the Thies process is estimated at :—‡

	£	s.	d.
Roasting	0	9	1
Chlorinating	0	11	2
	£1	0	2

2,353 tons of concentrates are said to have been successfully treated by this process at the Haile mine and 5,000 tons at the Phœnix mine between May, 1888, and September, 1890.

At the Phœnix mine, a 12 feet revolving pan-furnace is used, which roasts 1 ton of raw ore in 12 hours, with a consumption of ⅜ths of a cord of wood, and 3s. 9d. worth of labour. The cost of power does not exceed 1s. 0½d. per ton.

At the Bunker Hill works, the concentrates are roasted with 1 per cent. of salt, in a reverberatory furnace 40 feet by 12 feet on the outside, with walls 18 inches thick, the stationary hearth of which (7 feet by 18 feet by 2 feet in height, with a working door on each side) terminates in a horizontal revolving hearth, 12 feet in diameter, set at a lower level (giving a fall of 6 or 7 feet). The discharge hole or cub is in the centre of this latter hearth, from which the ore drops into cars.

At the Deloro mine,§ Canada, where the Mears process was formerly in operation, the ore was roasted (after drying in a revolving drier) in a pair of cylinders,‖ one

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* In the six months ending November 31st, 1892, this charge was reduced to $8·42 = £1 15s 1d. per ton of sulphides. As an instance of economical management, the total costs of mining and milling per crude ton extracted may be cited as follows, the ore being quarried in open benches :—

† *Trans. Am. Inst. Min. Eng.*, vol. xix., page 610.

* The heat on the finishing hearth must be maintained at a lively bright red, but not at a white heat, else the gold particles would melt, which, with a good magnifying glass, can be easily detected; after washing off the iron the gold appears then in minute globules, the chlorniation of which is more difficult.

* Egleston, *Gold*, page 622.

† The vats should be coated on the inside with asphaltum varnish or a mixture of pitch and tar applied hot, but the former is preferable, as it penetrates better into the pores of the wood.

‡ It is usual to provide the covers of the tanks with two pieces of 1¼ inches gas pipe 6 inches long, and a square hole, 6 inches by 6 inches, closed with a wooden cover. These pipes are closed with balls of clay during the impregnation of the ore with gas. After gassing, the clay is removed, and one of the pipes is coupled to the hose of the water tank, whilst the other is connected either with another tank ready for chloridizing, or the ashpit of the roasting furnace, partly to utilize the surplus chlorine, as well as to protect the workingmen from its injurious effects

* When practicable, it is a good plan to heat the generators by steam in place of direct heat.

* *Eng. and Min. Jour.*, New York, vol. lv., page 244.

† Removing the sulphur to within 0·25 per cent.

‡ Phillips, *Trans. Am. Inst. Min. Eng.*, vol. xvii., page 321.

§ R. P. Rothwell, *Trans. Am. Inst. Min. Eng.*, vol. xi., page 191.

‖ Different furnaces require, on the average, it is said, the following weights of wood to roast a ton of ore (the weight being calculated on the basis of 2,200 lbs. per cord as an average):—White furnace, 300 lbs.; Bruckner, 900 lbs.; reverberatory, 600 lbs.; Stetefeldt, 200 lbs.—(Report, *Tenth Census, United States.*)