THE TREATMENT OF SILVER TAILINGS IN NEVADA.

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In every silver mill there are two streams, discharging one from the battery, and one from the settlers. As they are treated differently, different names are given to the residues which accumulate from them. The pulp which runs out of the settlers and agitators is called "tailings." That which comes from the stamps, and is not deposited either in the pulp or slime vats, is called "slimes" or "slums." The tails have been in contact with mercury,

of mercury and amalgam, and sometimes sulphurets containing gold, which will pay to concentrate and separate.

The battery slimes are poorer than the ore, but they generally will assay about 60 per cent. of its value. They contain proportionately much less gold than the ore. The quantity of slime depends upon the amount of water used in the battery, the method of settling, and the quantity of clay in the ore. With hard ores, the amount of slimes in the best mills will be 2 to 3 per cent., with soft ores it will be more than double that quantity. Whatever gold there is in them is very flaky and likely to float; the silver is in a very fine state of division and also likely to float, and is also to

pan of much larger dimensions are used, and that the slimes do not require grinding.

Generally the battery slimes are settled in a series of reservoirs. The richest material will always be in the first one. There are a large number of such slime reservoirs of great extent, that have been filled to the depth of 8 ft. to 10 ft. in Dayton Cañon, below Virginia City, Nevada, where a number of mills have been established to treat them; but the best of them do not get more than 60 per cent. of the assay of the slimes, even where they use very large amounts of chemicals, as most of them do. The bullion produced is never fine, and is less so as the amount of sulphate of copper

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the slimes or slums have not. There are thus slimes from the slime vats in the mill, which are treated with the pulp, and slimes outside of the mill, which, if caught, are collected in reservoirs. The part of the pulp which has been reduced to a slimy condition in the pan, is called pan slime, and hence there are three kinds of slimes: mill slimes, collected in the slime vats of the mill, which are treated in the pans; battery slimes, which are the overflow of the slime vats; and pan slimes, which discharge from the agitators with the tailings, and are only accidentally separated from them in the lower parts of large reservoirs. The battery slimes are usually allowed to escape, or are caught in large reservoirs below those for the tailings. The pan slimes and tailings are treated together in concentrators, or on blanket sluices principally, to catch the mercury and amalgam and heavy particles of ore, and the concentrates are treated in pans.

If the ore has been properly worked in the pans, no gold or silver can be extracted directly from the tailings and pan slimes. It is in the state of sulphurets, which cannot be separated without thorough oxidation, produced either by roasting, by chemical action, or long exposure to the action of the weather. They contain, however, a certain portion

some extent in the form of sulphurets. The slimes are worth from 15 dols. to 20 dols., and often more, and can be profitably treated. When water is scarce the slimes are very advantageously treated without any special arrangement being made for it, as all the water from the slime vats is pumped up with the slimes in it, and passes again through the mill.

By this method, there are no battery slimes. It is well worth consideration whether this method would not pay even when water was plenty. The amount of water to be paid for would be less, and the gain in yield would probably more than pay for the pumping, if properly managed.

The pan tailings and slimes could be caught with a sufficient number of tanks, but the mills have not usually been built with reference to it, and could often not be altered, as there is generally not sufficient space around them for the purpose. Frequently the slimes are not valuable enough to justify much expense, so that in most of the mills only a rough attempt is made to catch the mercury and amalgam, and very large quantities of them go to waste.

The treatment of the slimes varies but slightly from the treatment of the ore, differing only in these respects, that

is larger. The loss of mercury is so great that some of the tail mills (as mills treating tailings and slimes are called) purchase ore to mix with them. This loss has given rise to the invention of a number of machines for saving it.

The tailings are generally treated in blanket sluices, the attempts to treat them on concentrators not having been successful. The sluices are troughs 20 in. wide, with sides 2 in. or 3 in. high, and sometimes 1,700 ft. or 1,800 ft. long, with a grade of 6 in. to 10 in. in every 12 ft.; a number are usually placed side by side, generally three. Sometimes as many as 15 to 20 and even more are arranged together. They are covered with strips of coarse blanket, which are laid on the sluice, and can be easily removed to be washed. When the sluices are long, they are tarred on the underside to keep the blanket from rotting, in which case they are nailed to the sluice and swept. When not tarred they are taken up and washed. The tarring is done by drawing the blanket over a bath of hot liquid tar.

As the stream of tailings runs over these blankets the heavier portions are caught; the lighter portions are washed away. The loose blankets are taken up at intervals of about 12 hours, and washed in tanks; the tarred ones are cleaned

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by a man who walks over the blankets, brushing the surface lightly with a broom, thus disturbing and distributing the material, and aiding the action of the water. The material caught in the blankets is thus swept into under sluices beneath the main sluice, and is caught in tanks. While the blankets of one sluice are being cleaned by washing or sweeping, the stream is turned on to the others; so that whatever the number of sluices required to do the work may be, there must always be one more.

These sluices are sometimes owned by the mills, but generally by contractors; they usually cost about 1 dol. per foot, including the blankets. The concentrations from both kinds of blankets are worth from 18 dols. to 30 dols. per ton, and are treated in pans.

What passes the short blanket sluices is generally accumulated in reservoirs. Below Virginia City, there are immense quantities of these tailings, collected in artificially constructed reservoirs, from which, when they are full, the water is turned off, the dam and the sides removed, and the material which soon becomes thoroughly dry, carted to the mills for treatment. It is doubtful whether it will pay to save the residues of long sluices. As illustrations of the way this work is done, the Eureka Mill and Woodworth sluices have been selected.

At the Eureka Mill, the discharge from the agitators is run into a large tank, from which it is raised by an Archimedeal screw, 32 ft. long and 16 in. in diameter, which discharges into a head box 10 ft. long, 1 ft. wide, and 16 in. deep. This box has six gates which open on to the same number of sluices built side by side, each of which is 1,200 ft. long. They are 20 in. wide, and are separated by strips of $\frac{1}{2}$ in. board, 3 in. high. Five of these sluices are used at a time; the sixth is held in reserve in case of accident. The blankets are 10 ft. to 12 ft. in length, and are not cut. They are tarred on the underside, and are fastened with five tacks at the upper end, and by a cleat tacked to the sides. The lower end is loose and laps over the blanket below it from 6 in. to 12 in. Every 200 ft. there is an opening across the sluice 3 in. wide, which is covered during the time the tails discharge over it, with a sheet-iron cover, which communicates with a trough running across the sluice below. This opening is always placed at the head of a blanket, so arranged that the lap of the blanket covers it while the tails are running. When the blanket is to be swept the cover is removed, the end of the blanket drops over the edge of the opening, and the blanket concentrates are carried into the trough below. The upper end of the sluice is swept every four hours, the lower end once in six hours. Six tons of concentrates are collected in a day. It takes three men per shift of 12 hours to do the work. The concentrates here have the same assay value as the ore, and are treated in the same way with the addition of one-third of slimes.

The best example of long sluices is the Woodworth sluices of Dayton, Nevada, which were designed and constructed in 1874 by W. H. Armstrong, for the Dayton Mill, of which he was superintendent. They are the largest which have ever been built, and are designed to treat all the tailings from 25 to 30 miles in Gold Canon, or 262 stamps, being an average of two tons a day for each stamp. These are all collected in the sluice at the Bacon French Mill. This sluice is 18 in. square, $3\frac{1}{2}$ miles long, with an average grade of 4 in. to the rod. It is never cleaned, but carries the collected tailings to the Woodworth sluices, of a portion of which we give a perspective view on the previous page, and which are composed of 12 sluices, 8 side by side, each one of which is 19 in. wide. They are separated by strips of wood $1\frac{1}{2}$ in. wide and 3 in. high, and form together a table 23 ft. wide and 1,700 feet long. These sluices have a grade of 2 in. to the rod, and are supported on trestles $4\frac{1}{2}$ ft. apart. For convenience of working, the group is divided into sections of 150 ft., but each sluice is continuous. At the head of the sluice the tails are discharged from the sluice, A, into a head-box, B, made of two compartments included in the same structure. These are each 3 ft. long and 2 ft. deep, and the whole width of the sluices. The bottom of the first one, B, is 20 in. above the bottom of the sluice, and has three openings, 3 ft. wide and 4 in. high, which discharge into the distributing box, C, which has 12 openings, 4 in. by 8 in., one for each sluice. All the openings in C are provided with gates, D, so that all or any number of them can be closed at a time. In front of the box, B, is another one, E, of the same size and shape, which is fed by clear water, from the two lines of galvanized iron pipe, F, 5 in. in diameter and 2,156 ft. long on one side of the sluice, and on the other supplies it through the gate, S, to the side box, H, which is $8\frac{1}{2}$ ft. wide and $10\frac{1}{2}$ ft. deep, and carries the clear water to the head of the sections; it is consequently 150 ft. shorter than the whole sluice. Here it discharges through the openings, L, into boxes, M, 6 in. by 6 in., which cross the sluice at right angles, and have, like the clear water head-box, E, a 3 in. round hole, I, for each sluice, which can be closed with a plug when the blankets are not being washed. These troughs are 1 ft. above the sluice, and are supported on four inclined pieces shaped so as to leave the current free. At the end of each section there is a slot, K, in the bottom of the sluice, 3 in. wide and 17 in. long, closed by a sheet-iron cover, which opens into an inclined sluice 6 in. wide and 12 in. deep, which runs under the whole width of the table, and at right angles to it, and discharges into a trough, O, of the same size, which runs parallel to the table, and carries the concentrates to the reservoirs. This slot in the bottom of the sluice is closed when the sluice is working, and the blanket laid over it, as at the Eureka Mill.

At the end of 1,200 ft. there are ten settling tanks, 9 ft. long, 8 ft. wide, and 4 ft. deep, into which the sweepings are discharged. At the end of 1,600 ft., there are two of the same size, and at 1,700 ft. two more, making 14 in all; 140,000 ft. of lumber, 24,000 ft. of blankets, 19,000 ft. of which are in use at a time, 2 tons of nails and spikes, and 1,600 gallons of coal tar were used in the construction of the sluice. The total cost of construction was 21,500 dols.

The Woodworth sluice requires to operate it about 627 gallons of water per minute, which is pumped to a height of 2,156 ft. horizontally, through a 5 in. iron pipe. The pump is driven by the water-wheel of the Dayton Mill.

Each one of the sluices is covered with blankets 20 in. wide by 6 ft. long. They are tacked on the upper end with five eight-ounce tacks, and by one tack every 6 in. in the sides. Before they are put down they are coated with coal tar on the under side. This is done by laying the blanket on the hot tar in a tank made for the purpose, and drawing it over its surface, and then over the edge of a board at the opposite end of the tank to scrape off the excess of tar. This tank is 6 ft. long, 30 in. wide, and 12 in. deep. At one end the bottom is inclined to an angle of 35°, and reaches to the top of the tank. The blanket is drawn over the tar and out at this end. Only the under side is coated in this way, leaving the nap entirely free. The tarred blankets last nine to twelve months, but if not tarred they only last three months.

They are taken up every two months to be dried, and are then shaken, at which time the bottom sluices are carefully cleaned. The blankets work better as they get older.

To work the sluice, the slime from the sluice, A, is discharged into the tank, B, (Fig. 1), and from there into the distributing box, C. The amount of slime discharged by the sluice is from 60 to 70 cubic inches per minute. It is discharged upon the blankets from the gates, D, in the trough, C, the amount being regulated by opening or closing the gates. It is thus distributed over all the sluices but one, or as many as it is desirable to have working, and is spread over the blankets.

The first three or four sections are being constantly swept, so that each section will be swept every six hours. Before commencing to sweep, the supply is cut off, and clean water turned on to the sluice from the clean water box for half an hour. The opening in the bottom of the sluice at the end of each section, which is kept closed while the sluice is not being swept, is now opened, the cover is removed, and the end of the blanket allowed to drop into the sluice below, where it remains until the men clean up this sluice. The sweeping is done with an ordinary broom, clear water running all the time. The sulphurets caught in the nap of the blankets are thus discharged into the lower sluice. The length of time for sweeping is generally calculated on the upper sluices, so that three to four of them are washed in a little less than three-fourths of an hour. Each one of the sluices is thus swept in eight hours, or three times in the twenty-four. On the lower ones, they are swept only once an hour, so that each sluice is swept once in twelve hours. Seventeen men do the whole work of the sluices, twelve of whom are sweepers. They work twelve-hour shifts, and were paid in 1874, \$3 a day for sweepers, and \$4 for the overseers. Afterward Chinese labor was employed, so that now the sweepers get only \$1.54 a day. The work is arranged so that the sluices produce one ton of concentrated sulphurets for each sweeper. Fully three-fourths of this comes from the upper sluices. The actual cost of concentrating, with labor at \$3, was about \$4 per ton of sulphurets. The cost now is proportionately less. In any case the cost will be more than covered by the gain in mercury. The assay of the concentrates in October, 1874, just after the sluice commenced to work, was \$25.49. In November of the same year it was \$28.90. They are worked in the mill to 70 per cent. of their assay value.

The attempt to work the sluices by direct amalgamation was for a long time unsuccessful, owing probably to the precious metals being in the state of sulphurets which require to be roasted, or of their being included in pyrites so that they are not reached by the mercury. Roasting is generally too expensive, so that this material is either thrown back into the battery, or worked in the pans. Their quantity has been very much diminished by increasing the number of slime vats in the mill. They are now treated in pans by largely increasing the amount of chemicals—which are usually only salt and sulphate of copper—over that formerly used. The amount of chemicals and mercury must be determined in each case by making assays; for the baseness of the bullion produced increases with the quantity of sulphate of copper, and cases have been known where the silver produced has been only 0.099 fine. Having once determined the average fineness of the bullion for a given quantity, this quantity is the one best suited for the slimes in hand. In general the less the amount of chemicals, the finer the bullion, but the greater the loss of precious metal will be.

As slimes require no grinding, it would seem most advantageous to charge the quicksilver directly into the pan, but experience has shown that better results are obtained by charging the chemicals with the slimes, and thoroughly mixing them for about two hours with the muller up, and then adding the quicksilver. With slimes assaying from \$20 to \$30 a ton, the average quantity of sulphate of copper for tailings is from 10 lb. to 12 lb., and of salt from 20 lb. to 25 lb. The charge is worked for four hours, or six hours in all, and then drawn into the settler. About 60 per cent. of the assay value is obtained. The yield of the pan being from 60 to 75 per cent., if the slimes are successfully treated, may bring the yield of the ore up to 85 or 90 per cent.

In treating slimes the greatest source of expense is the apparently inevitable loss of mercury. With all the best advantages it will generally be as much as 4 lb. to the ton of ore. In the treatment of ore it will not generally exceed from 1 lb. to $1\frac{1}{2}$ lb., and sometimes averages as low as $\frac{3}{4}$ lb. This loss is probably owing to the slime forming a coating over the globules of mercury, and preventing their uniting. When ore is treated with the slimes the loss in mercury is always found to be less, and the yield of silver higher; this is probably owing to the more or less grinding action of the ore which cleans the mercury.

It was supposed for a long time that sodium amalgam, cyanide of potassium, and a number of other chemicals, would have the effect of preventing the loss of mercury to a very considerable extent, and they undoubtedly do temporarily "enliven" the quicksilver. But their action is only temporary, and it is doubtful whether it is of any great amount of use.

As these slimes, and sometimes low grades of ore, are poor, it is necessary to work them in very large quantities in order to make them pay. This is done by using very large pans, and it is mostly for this purpose that the largest pans have been invented.

The examples of the treatment of tailings, slimes, and concentrates from the blanket sluices in pans, are taken from the Woodworth and Lyon Mills in Dayton, Nevada. The Woodworth Mill treats the slimes mixed with ore worth \$20 a ton, and for that purpose has six batteries of four stamps each. It has twelve horn pans, six settlers, two agitators, and one clean-up pan. The Lyon Mill treats only tailings, slimes, and the concentrates from blanket washing. It has ten Wheeler pans with wooden sides and covers, five settlers, and one clean-up pan. The slimes have been deposited in reservoirs from the mills above. The dam and sides have been removed, and the material, which is perfectly dry, dug out of the bank, and carted to the mill. They are worth from \$30 to \$40. The concentrates come from the Woodworth sluices. In the Woodworth Mill the pans are 5 ft. inside diameter, have eight dies and six shoes which are 18 in. from side to side on the widest part. One end of the shoe is only 4 in. wide, the other is 18 in. The ends are joined with a curve, so as to form a decided point on the long side of the shoe. The diameter of the shoes and muller is 4 ft. 10 in., so that there is one inch between them and the side of the pan. The charge for the pan is 1,600 lb. of tailings and 400 lb. of pulp; but when of ore alone, the charge is 3,600 lb. The muller revolves 85 times a minute. Twenty pounds of sulphate of copper and 40 lb. of salt are put in with the charge. When slimes are treated the muller is never down, and 200 lb. of mercury are introduced at the end of two hours. The whole operation lasts $4\frac{1}{2}$ hours.

When ore is charged the pan grinds for three hours, then 100 lb. of mercury are added, and the operation continued with the muller up for $1\frac{1}{2}$ hours. When the operation is finished the contents of the pan are drawn into settlers.

The sides of the pan are made of sheet iron and lined with wood. This is done because it has been found that the mercury forces itself through the pores of the wood, and also that there is a loss of mercury where it leaks. This loss is prevented by the sheet-iron sheath, or if it takes place, the mercury is caught in the groove round the bottom of the pan.

In the Lyon Mill the pan is 5 ft. in the inside diameter and $4\frac{1}{2}$ ft. deep. The charge is three tons of dry tailings, which are mixed with water, discharged into a pan through a $1\frac{1}{2}$ in. pipe. During the time the charge is being made, the muller revolves 70 times per minute. The pan is filled to within 6 in. of the top, or just as full as it can hold without slopping, the pulp being in a state of thick mud. The shoes are always raised $\frac{3}{4}$ in. from the bottom. Half an hour after the charge is introduced, 40 lb. of salt and 74 lb. of acid sulphate of copper, containing a large amount of sulphate of iron, is added. This material is the refuse from the crystallization vats of the "bleedstone" manufactory owned by the mill. It could not be sold, and the company find it cheaper to use it in their own mill than to recrystallize it. One hour after, the charge of 100 lb. of mercury is introduced, the full amount being charged at one time. In 29 days 340 flasks of $76\frac{1}{2}$ lb. each were used on nine pans. The pan revolves for three hours after the mercury is added, and is then drawn into the settlers. In the Woodworth Mill the settlers are 10 ft. in diameter, 3 ft. deep, and the arms make 14 revolutions per minute. In the Lyon Mill they are 8 ft. in diameter, 4 ft. 8 in. deep, and make 15 revolutions a minute. No mercury is ever taken from the pan; it is all discharged into the settler from a pipe in the bottom. Water from a 2-in. pipe runs into the pan while it is discharging, until the settler is filled to within 6 in. of the top. It is emptied three quarters of an hour before the pan is ready to discharge. From the bowl on the side of the settler the mercury is dipped out to go to the strainers, which are surrounded by a sheet-iron sheath, reaching nearly to the bottom of a large iron vessel. After straining, the amalgam is weighed. It contains six parts of mercury to one of silver. It is retorted in the usual way, and is worth from \$50 to \$60.

The loss in mercury is only $\frac{1}{2}$ lb. to the ton; but this exceedingly small loss is owing to the fact that when blanket concentrates are treated, there is a gain in mercury from them which reduces the apparent loss. In one of the mills of this vicinity, where twenty pans were run on tailings alone, nine flasks of mercury were gained over and above all the losses in six weeks. The real loss is probably as great, if not greater than in working the pans. When ore is treated alone in the Woodworth Mill, the loss is $1\frac{1}{4}$ lb. — *Engineering.*

PROGRESS IN SHIPBUILDING.

THE additions that are now being made to the mercantile marine of the world may be said to have once more put the art of shipbuilding on its trial. Nearly a dozen steamers are being constructed at present that are expected to exceed in sailing qualities the finest vessels afloat. Every other month the English newspapers have announced that first this and then that great shipping company has contracted for the construction of two or three vessels that are to outstrip all their predecessors; and the latest announcement of the sort comes from the Cunard Company, who have ordered a screw steamship of 7,000 tons, to be built of steel, for their Transatlantic service. The success of the *Livadia*, and the continual improvements taking place in the Royal Navy, show that in other departments also the art of shipbuilding is making vast strides. But we have become so accustomed to changes and advances in shipbuilding that they cease to impress us with their rapidity or magnitude. At present it is premature to speak of their success; that can only be tested by actual working; and it will be two or three years before that test can be applied in the case of the largest additions to the mercantile marine. In the meantime, however, we can take stock of the changes already made and estimate their value, and from these data indicate the direction in which we are moving. For this purpose it is not necessary to go back into the ages of shipbuilding traditions. Events have occurred within living memory that sufficiently illustrate the movements of this department of art and industry. We call it an art in contradistinction to a science, because the most modern improvements are nearly as tentative in their character as the oldest were.

The first and foremost feature of the present shipbuilding trade is its birthplace. It is now considered trite to remark that England is the greatest shipbuilder in the world. But 20 years ago some of the highest authorities on the subject thought that this remark instead of being trite was not true. Thirty years ago an English naval architect, who had no superior in his profession, not only admitted as undeniable that the Americans were then ahead of the English shipbuilders, but thus accounted for the loss of England's character as mistress of the sea. The Americans, he said, constantly on the alert, have carried out and applied every new discovery to the advancement of navigation, while with the English, naval construction and seamanship are exactly that branch of practice in which science has not only been disregarded, but is altogether despised and set aside. The American ships show what can be done by modern science unflinchingly put in practice; the English show what can be done in spite of science and in defiance of its principles. The circumstances that occasioned these remarks prevailed for fully a dozen years. America was then considered the pioneer in shipbuilding. She produced the fastest sailing vessels afloat; she built some of the largest vessels in the mercantile marine; and she was the first to demonstrate the superiority of armor plating in naval warfare. America then appeared to be fast attaining naval supremacy. Now, we may exclaim, How have those promising shipbuilders fallen! In the beginning of 1862 the English Government found, on taking stock of that portion of its fleet fit for naval battle, that, measuring by the standard of efficiency which the Americans had reached, it had only one ship of the line. Now America has not a single ship of the line, except one on the stocks. In no country has shipbuilding declined so rapidly as in America; in none has it improved so steadily as in England; and the movement in both directions has been especially marked during the last ten years.

Another feature of recent improvements—perhaps the most prominent of any—has been the increased size used in the construction of the latest vessels. It is true that none of their dimensions have yet reached those of the "Great Eastern;" but they are so gradually approaching it