

DLA
Thesis
Tb
C182
1928
c.2

Some Problems in the Treatment of Old-Time Tailing

A THESIS

SUBMITTED TO THE FACULTY OF THE MACKAY SCHOOL OF MINES

IN CANDIDACY FOR THE DEGREE OF

ENGINEER OF MINES

By

DONALD CALLEB CAMERON

MCGILL, NEVADA

1928.

Mines Library
University of Nevada
Reno, Nevada 89507

117
MINES
LIBRARY
Prof.
10

SOME PROBLEMS IN THE TREATMENT OF OLD-TIME TAILING.

In the reduction of ores from western mines during the last half of the last century, the science of metallurgy had not attained its present state of development. Consequently, at the opening of this century there were in many places accumulations of the residues from these early-time operations which already, due to the growing knowledge of present-day processes, had taken on an economic value and so offered opportunities of profit from retreatment.

This growing knowledge, like the history of all progress, has been recorded in certain definite steps or achievements, among which none is of quite so much importance as the cyanide process. Its discovery and application to gold, and later to silver ores was so revolutionary that in a comparatively short time it had found a place, to some extent at least, in the scheme of treatment of practically all of the world's mills treating gold and silver ores.

Then later came the flotation process and duplicated for the base-metal ores what the cyanide process had done for precious-metal ores. It, too, has been instrumental in making possible the profitable retreatment of vast tonnages of residues from early-time operations. However, the scope of this paper will be limited to a discussion of the problems encountered in the treatment by cyanidation of old-time gold and silver tailing, and is based on the experiences of the writer who treated several of these dumps in Central Nevada during the period from 1913 to 1923.

The first and foremost question to be answered in the consideration of a tailing proposition is, - does it contain sufficient gross value, which if recoverable to a high degree, would justify the installation of a treatment plant. If this can be answered in the affirmative it is worth further investigation; if in the

negative; it can be dropped. The answer to this preliminary question is obtained by means of assay of a representative sample or of many samples. Following this it is necessary to know to what extent the values are soluble in cyanide solution. Should results on these points be ^f found favorable enough to offer promise, there is still much information necessary before it can be determined that the proposition is workable. This information should be as full and complete as possible, particularly in those cases where, due to certain conditions, such as low total value, the proposition is near the border line of profitable working. In fact many of these projects have been recorded as failures due, either to too scant information, or lack of judgment in evaluating that information.

The following is an enumeration of some of the points on which information is necessary:-

1. Assay value of the whole deposit, or in certain cases, of the constituent parts.
2. Tonnage, total, or of constituent parts.
3. In what sizes the values lie— determined by screen analysis.
4. The maximum solubility of the values in the various sizes.
5. Best strength of solution to use, also time of contact necessary.
6. The quantity of free gold or sulphides present.
7. Consumption of cyanide and lime.
8. Is need of concentration, regrinding or any preliminary treatment indicated.
9. Base metals present,- copper, lead or mercury, in a form soluble in cyanide.
10. Is precipitation satisfactory.
11. Is fouling of solution indicated.
12. Rate of settling of slime.
13. Rate of percolation of sand.
14. Topography in the immediate vicinity of the deposit. This affects the following considerations,-(a) plant site and the selection of a suitable location of same; (b) dumping ground; (c) delivery of tailing to the plant and the selection of best method of same.
15. Concentration of deposit; is it compact or much scattered.
16. Physical condition of the deposit, with respect of these features,- sand or slime; clean or dirty; wet or dry; cemented or loose; baked; overburden; sagebrush; sewage or other organic

- matter, etc.
17. Water supply, affecting ^{the} question of disposal of residues, as well as, of maintenance of operating solutions.
 18. Power available.
 19. Accessibility, - roads, grades, etc.
 20. Distance from supply point.
 21. Length of working season.
 22. Camp site or available living quarters.
 23. Livestock, - may be necessary to impound residues and fence.
 24. Distance from ranches or agricultural centres, affecting the cost of horse-feed, etc.
 25. Ownership, - price, terms, royalty, etc.

Obviously, the last of these points must be satisfactorily settled first. Some deal involving option to purchase or lease must be made before committing oneself to an investigation and the expense incident thereto. Many of these old dumps were not considered of much value, so could be purchased for a favorable figure for cash, and in many cases this was the most satisfactory way to secure ownership.

Sampling.

Having secured the right to proceed, the next thing would be the sampling of the deposit. Since this is exposed on the surface and already in a fine state of subdivision, it is usually easy to obtain satisfactory samples, bearing in mind the basic requirement that any sample must represent, in value and character, the particular fraction of the whole that it is intended to represent. By dividing the whole deposit into a large enough number of these fractions, any desired degree of accuracy can be obtained. In practice it is usually convenient to assume a horizontal ^{plane} covering the deposit, and to divide this plane into regular geometrical figures. At central points of these, or at the corners, sample holes are then put down completely through the deposit.

If the tailing has been deposited by water, there will be

stratification, also a progressive sizing of the material from coarse sand at the outlet, to slime at the lower extremity of the pond. But a large number of holes will take care of this difference in character. If the tailing has been stacked by belt-conveyor, or dumped from cars, stratification will be absent and the deposit is **likely** to be more uniform in both character and value, so should require relatively fewer holes. At the same time, this material will be much less dense, a fact to be taken into consideration in estimating tonnage.

In taking the sample, two methods are commonly employed, - the auger; and the shaft; the objective in either case being to obtain a cut throughout a vertical section of the pile or pond. Usually, the auger method is more rapid and convenient, and can be used for depths up to twenty feet or more. For these greater depths the auger should be jointed. In cases where the hole runs, or the material, due to dryness, will not cling to the auger, a little water poured in before each load is taken, will cement the sides of the hole, and keep the sample on the worm of the auger. In cases where water is not at hand, a casing made of light weight sheet-metal, in which the worm of the auger will just pass freely, can be worked down to confine the borings. In all cases a light tripod with block and tackle, will make the whole job easier.

The shaft method can be used to any depth, and consists of pits or shafts sunk to the bottom of the deposit at such places where it is desired to sample. The sample is then taken by cutting a groove down the side of the shaft.

The number of holes necessary to properly sample will vary with the nature of the deposit and the conditions under which it

was laid down. Most tailing deposits are the result of operations at mills where orebodies, changing in character, have been worked. Here, the surface or oxidized ores generally have been treated first, and the tailing therefrom probably lies at the bottom of the deposit, being overlaid by the later-made sulphide tailing. Then, too, the early-day method of treatment was often changed, with a resulting change in the value and character of the tailing. One pond is recalled, where the following different methods of treatment had been used in succession, - barrel-chlorination for gold; amalgamation with table and blanket concentration for mixed values; chloridizing roast with hyposulphite leaching for silver; and the same with pan-amalgamation, also for silver. With these facts in mind, it is not hard to realize the necessity for numerous holes, and in some cases, several samples from the same hole. While it is usually desirable to make assays of each hole, it is sometimes permissible, or even desirable, to combine more than one from strata of similar character, for a single assay. However, it is very important that samples showing marked differences in character, be run separately and tonnage estimates of these made. Then later, a composite sample representing the whole deposit can be made up. Or, as sometimes may be found desirable, a certain kind of tailing may be left out, tests having shown its objectionable character, and indicated a separate treatment. In this segregation for differences in character, color is perhaps the best indicator and criterion.

In marking the samples for identification, something more durable than paper is required for this. A satisfactory and convenient method is to carry numbered brass tags on a wire ring in consecutive order. Each sample on being taken is given a tag,

and detailed description, including character, color, depth, or any other pertinent feature which might have a bearing on future tests, is entered in the note book along with the number corresponding with the tag. It is also desirable to make a sketch map of the deposit, on which is located the number and depth of each sample hole.

Precautions.

In sampling deposits which have previously been treated by cyanide, care must be taken that a salted sample is not obtained, due to taking too great a proportion of the enriched surface. In the case of auger samples, the first five or six inches should be scraped away and discarded before the hole is started. This danger will not be present in newly-sunk shafts; while, with old ones, a new surface can be exposed by scraping down the wall before the sample groove is cut.

In those cases where the settling rate is an important factor in the information sought, it is imperative that the samples be put immediately into air-tight containers, since, even a partial air drying is apt to have a marked influence on the settling rate. It is a well known fact that laboratory drying of slime samples hastens the settling rate. The explanation sometimes given, that the clays have their silicates in a measure de-hydrated, is hard to accept since the ~~XXXXXXXXXXXX~~ phenomenon is characteristic of roasted, as well as unroasted tailing. Also, it is inconceivable that a few minutes' exposure to the air could remove water from the molecule of a hydrous silicate. The colloid chemist could undoubtedly throw some valuable light on this question.

Testing.

Since the objective of testing is to determine if the prop-

osition is economically workable, the tests should be carried out wherever possible, in conformity with conditions encountered in actual production. However, small-scale laboratory tests, being easily made, are indispensable in that they will indicate a course of procedure for large-scale tests and future operations for production, and should always be made as a preliminary to such. These preliminary tests can be relied upon to give accurate results on the chemical consumption of cyanide and lime, also the maximum dissolving of values, for any given strength of solution used, and any given time of contact.

A common procedure in carrying out these preliminary tests is by the bottle method, in which about 200 grams of the representative sample and from 400 to 600 c.c. of solution are used in the different series of tests. So-called quart bottles are the proper size, and all that is necessary is a means of keeping them agitated. There are many ways to accomplish this. To furnish the power, a line-shaft in mill or laboratory, or a small water-motor is usually available. A dozen, or two dozen bottles can be rigged to the two flanges of an empty electric-wire reel, or, if heat is needed, it can be furnished by light bulbs within a rotating insulated box mounted on an axle and belted to the shaft.

Of the many points on which information is sought, the three most important, from the standpoint of these preliminary tests are; first, the rate of solution of values; second, the strength of solution required; and third, the degree of fineness necessary. By running series of tests, in which one of these factors is varied at a time, the desired information can be obtained. The results of these early tests will generally indicate the need of further

information concerning such factors as, - the benefits of auxiliary reagents; need of preliminary treatment of some kind; degree of alkalinity, etc., in which event further tests along these lines should be made.

From the information so obtained a tentative plan of treatment can be drawn up, and the results verified by large-scale tests, in which the details of that plan are followed. The apparatus for these tests will depend very much on what is at hand. The main point is that whatever is used must have capacity enough to treat a few hundred pounds of charge. For agitation tests, a stirring mechanism mounted in a barrel, or, if compressed air is available, a small Pachuca tank, can be improvised. For percolation tests, a porous bottom fitted into a section of smoke-stack or a wooden box, can be made to serve the purpose. The ore column should be of the same height as intended to use in practice. In addition to checking the results so far obtained, these tests can be made to show if anything of a detrimental nature is likely to be encountered in practice, that has not already shown up in the small tests. The most important of these possibilities is a tendency of the solution to get foul with repeated use. By repeating the cycle of dissolving, clarifying, and precipitating several times, using a fresh charge of ore but the same solution, brought up to the required strength, each time, any tendency in this direction will be discovered. If the solution after several cycles has its ^{undiminished} dissolving activity, it is safe to assume there will be no trouble from this cause; but, should the solution in its later passages through the ore, show a decreased dissolving effect, it can be inferred that deleterious elements or radicals are accumulating.

A chemical analysis of this solution should be made to determine the offending substances.

The greater quantities of ore and solution used in these tests provide a good opportunity for making precipitation tests, also observations of settling and leaching rates. For precipitation tests a miniature zinc-box can be made from a two-litre bottle, preferably square, and of clear glass. By cutting out the bottom and fitting a tray to hold zinc shaving, near the neck, it can be inverted and hooked up for upward flow of solution. The rate of flow can be controlled by a screw pinch-cock, while the action on the zinc can be observed through the sides of the bottle. Usually, silver gives no trouble in precipitation, although, one case is recalled where, in the treatment of pan-amalgamation tailing, due to the great quantity of mercury present, the ordinary zinc-box could not be used. The action of the mercury was so rapid in shorting the zinc, that in a few hours the trays would become so loaded that no contact between the solution and zinc could be maintained. In this case recourse was had to zinc dust in a tank fitted up with stirring arms and filter-bottom. The precipitate was later retorted for the mercury.

To determine the settling rate, the agitating mechanism in the apparatus used, is stopped, and the rate at which clear solution forms above the charge is measured, from which can be calculated the length of time required to make it possible to draw off certain fractions, say 60, or 75 per cent of the total solution in the charge.

If percolation tests are being run, the rate at which solution above the charge subsides, is measured after the charge is

thoroughly saturated. If the ore column used in the test is about four feet, an initial rate of anything greater than one inch per hour, is satisfactory. Using a five day treatment, with allowance for aeration, this would permit passage through the charge of about one and one-half tons of solution per ton of tailing treated. This is generally sufficient to dissolve and wash out the value.

The question of water supply in Nevada is usually considered only in terms of quantity. But, in some localities, the character of the water may have a bearing. However, waters with compositions varying from strong alkalinity, to strong acidity, and with hydrogen-sulphide, have been successfully used in cyanidation, so, it is not probable that insurmountable difficulties will be encountered from this cause. In most cases a slight increase in the consumption of lime or cyanide would be the extent of the trouble. At any rate, if the tests have been carried out with the water expected to be used, allowance for these detrimental features will automatically have been made. However, if there should be any doubt on this point, a careful check of the tests should be made.

Selection of Scheme of Treatment and Design of Plant.

If all the foregoing steps of sampling and testing have been carried out, with due regard for any points of weakness that may be inherent therein, the experienced operator can rather definitely foretell the returns from any tailing proposition, and will be able to design a treatment plant that will achieve those returns. He must not, however, enter into the project with an over-amount of self-assurance that he knows everything about it, and that he can work it in exactly the manner planned. As stated before, each project has its own problems, and the probability is

strong, that, before he has finished, he will have encountered some condition not met before. But, all of these may not be of an adverse nature; he may discover something whereby he can cheapen his process, as well as something to increase his expense.

It is scarcely probable that the scheme of treatment decided on will be that which the tests have shown to give maximum recovery. Other considerations would enter into the question. For instance, the tests may have shown—as they usually do—a higher recovery after regrinding or concentration, but on account of insufficient tonnage, or high power costs, the increased recovery may not justify the cost of extra machinery or additional treatment. Also, there is the possibility that a large part of this increased recovery can be made by a cheaper and simpler method, namely, an increased time of contact, or by using a stronger solution.

Another consideration is the possibility that there may be on hand, or easily procurable, certain equipment that may be used. The problem in this case is to devise a method of treatment that will fit in with this.

Another possibility in this connection might be this,—it may have been shown in the tests that a high per cent of the total recovery possible was obtained on only a very short contact, while the remainder went into solution very slowly. In this case a short, simple treatment might be more profitable than to strive for maximum recovery. An example of this is met with in many oxidized silver ores in Nevada, where the silver exists largely as chloride, but also, appreciable quantities of tetrahedrite are present. Since these silver minerals occupy positions at either extreme of the scale of solubility in cyanide solution, the condition above mentioned can be readily understood. In all cases the

selection of a scheme of treatment and design of plant will be governed mainly by these factors,- maximum recovery, cost of operation, cost of plant, and simplicity of treatment. It will often be a compromise, with the ultimate selection depending upon which of these factors is paramount, under the attending conditions and circumstances. Generally with tailing, with the attending low values, the factor of operating costs will be paramount. Also, since the cost of supplies is more or less fixed, the problem will become one of low costs in handling the ore.

Consideration of this phase of the problem resolves itself into two parts,- that of reclaiming the tailing and delivering it to the plant; and that of disposing of the residue. It might be generally supposed that the first of these were the most important. However, in many cases it is not. Where the tailing is spread out on a comparatively level terrain, and one is denied the aid of gravity, the cost of disposal might be prohibitive. Then, too, since the tailing is delivered to the plant in a dry condition, it offers a wide choice in the selection of cheap methods of handling; while the residue, in addition to having increased in weight from 15 to 30 per cent by reason of contained moisture, is also in a more difficult physical condition for handling.

In the selection of a method of getting the tailing into the plant, one has a wide choice of various types of mechanical appliances; as well as, the time-tried method of horses and mules, with some type of scraper. Of the former, might be mentioned the drag-line, which often might be particularly suited to this work. There are also at his disposal, belt conveyors and bucket elevators, both very efficient where conditions are favorable, and worthy of consideration where installation costs are warranted.

Of scrapers drawn by animals, it might be said that unit costs would in general be higher than with mechanical methods, although conditions present might often dictate their use, for a part at least, of the process. In this connection, might be mentioned a recent development in dirt-handling methods which was perfected by contractors in highway construction. This is a type of revolving dump scraper drawn by a light caterpillar tractor, and operated by three driver through an ingenious hitch. One of these devices with a single driver will do as much work as from two to three scraper units consisting of a driver and four animals each. This should merit consideration, especially in those localities where the cost of horse-feed is high.

For disposal of the residue no method can compete with flushing, or, as the hydraulic miner says, sluicing, where conditions are favorable. The necessary conditions consist only of a water supply under pressure, and sufficient slope below the plant. In fact, so appropriate is this method, that conditions can often be altered to make it applicable. A scant water supply can be made to do additional work by impounding and pumping ^{it} back for re-use. Insufficient pressure can be boosted by interposing a pump in the supply line. Also, absence of adequate slope can be remedied by a mechanical elevator or pumps, or, the treatment tanks can be elevated enough to provide a gravity run-off. If, for any reason, sluicing is not possible, the residue can be dewatered and stacked by a belt conveyor, or trammed away in dump cars.

Slope of Tail Race.

The amount of slope in a tail race necessary for uninterrupted disposal of residue, depends on several factors, and varies within wide limits; therefore, a statement of any definite figure

would be useless, unless based on a given set of conditions involving those factors. The principal of these factors are,- (1) the size of particles making up the residue, (2) the relative proportions of solids and liquid, (3) the presence of clay and colloid material, (4) the character of the surface of the race, (5) the profile, and alignment of the race, (6) the size, and form of the race.

There are certain laws governing the carrying power of streams, which involve several of the above factors. Also, the relationships among these have been written down in formulas, derived, both from pure theory, and experimental data. However, since these are based on the velocity and flow of clear streams, their application to the point under discussion, which involves a stream loaded to the maximum with solids, is very doubtful. They might, however, be useful as an indication of the effects of varying the different factors, and so, from that standpoint, be valuable as an aid in the design of a tail-race. One of these laws states that the carrying power of a stream varies as the sixth power of the velocity; while Chezy's formula states that the velocity varies as the one-half power of the sine of the slope angle. Combining these, the carrying^{power} of a stream should vary as the cube of the sine of the slope angle. Whether this strictly true is problematical. The main point, however, is that a comparatively slight increase in the slope gives a relatively great increase in the carrying power. This is noticeably borne out in practice.

The proportion of solids to water will^{be} controlled by the available water supply. So that here, the problem may often be that of getting the highest possible duty from the water at hand. The duty of the water can always be increased by increasing the

slope. But this is not always desirable, and at any rate, there is another factor which can be made use of, and one which, while helping here, at the same time, serves another desirable purpose.

This factor is the presence in the tailing of clay and slime-forming minerals and has a marked influence upon the carrying capacity of the tail-race. The explanation for this is that the colloids of the clay form with the water a dense mixture having the nature of a viscid, true liquid, whose high density greatly increases its power to hold in suspension the solid grains. In operating a leaching plant, the maintenance in the charge of not too great an amount of this slime, serves the purpose of helping to dispose of the residue and, at the same time, of providing a cheap method of treating this class of tailing.

The character of the surface of the race is ordinarily not a factor of great importance inasmuch as any race made from the ordinary materials of construction is reasonably smooth. However, should it be a trench cut in rock or rocky soil, it should be made moderately smooth.

The alignment and profile are important in that any change of direction increases friction and reduces velocity. Where turns are necessary, a short section at, or immediately below the turn, should be given additional slope. The profile is important in that any changes in the grade tend to cause the stream to flow in surges, a very undesirable condition. In the ebb portion of the stream the velocity may decrease to the point where the coarse^r material will settle out and actually come to rest. Once at rest, they are again started moving with difficulty by the succeeding surges. Also, once at rest on the bottom of the race, the grade

is thereby further decreased and the surface roughened, both conditions tending to exaggerate the trouble.

The size of the race will be kept within reasonable bounds by consideration of cost, although it should never be made so small that temporary obstructions of small boulders will cause it to overflow; neither should it be made so large that the stream is spread out too thin. The form or section of the race, theoretically should be such that the least possible surface is in contact with the stream, although facility of cleaning out will probably outweigh this consideration in the design. In the reclaiming of tailing there will always be a certain admixture of foreign material, mostly surface soil containing pebbles and boulders. These are apt to settle out of the stream and hang up in the race, so, have to be cleaned out periodically.

A form of race meeting these requirements can be easily made from one-inch lumber having the bottom member one foot in width. With sides of six-inch or wider boards nailed to this, a race is obtained which is easy to install, easy to clean out, and yet is large enough to serve a fairly large plant. The one-inch lumber will last a long time. A race constructed as above carried nearly twenty thousand tons and was apparently good for as much more.

As previously stated, no definite figures can be given for the slope of a race without a knowledge of the material it is intended to carry, and the supply of water available. However, the following table, in which is given comparative figures of the minimum slope necessary to transport various mixtures of material, may be accepted as a safe guide. It is here assumed that at least

one ton of water is available per ton of solids carried

Mixture of material.	Minimum slope necessary.
All slime	2 %
Fine sand 50%, clay slime 50%	3
Fine sand 75 , clay slime 25	4
Medium fine sand 50%, clay slime 50%	4
Medium coarse sand 75%, clay slime 25%	5
Medium coarse sand 100%(Mostly 10 mesh)	7.5

While it has been assumed in the above table one part of water as a minimum to carry one part of solid, the actual minimum can be made much less than this by altering some of the other conditions. During a summer dry spell and a temporary shortage of water it was possible to operate for several weeks with the water having a duty of three. Here the outfall race had a slope of six and a quarter per cent, but a high per cent of slime was loaded with the charges.

So far, this paper has been a discussion in general terms of problems that would be apt to be met in any tailing project. It must be borne in mind, however, that each project has its own set of conditions and its own definite problems. In order to make clearer the bearing of some of these points and principles, their application in the actual handling of a tailing dump will be described.

This particular dump was an accumulation of silver-bearing tailing from a flotation mill and was spread out on the gentle slope of a broad valley. The discharge stream from the mill had carried it down the rather steep ^{slope} for a quarter of a mile, but on encountering the lessening grade below, had deposited it. Here it had spread out in a pear-shaped deposit, in which the finer and lighter portion formed a fan at the lower edge. The whole deposit covered about eight acres, and the maximum depth was about thirty

inches. Since the slope had been covered with sagebrush, and even yet, a large portion of the area was supporting a luxurious growth, it was estimated that possibly fifteen or sixteen thousand tons could be reclaimed. As a matter of fact, more than nineteen thousand tons, ~~more~~ or practically the whole of the deposit, was treated, the sagebrush not having proven so troublesome as expected.

From a great number of assays the silver content of the clean tailing was found to be 3.95 ounces with negligible amounts of gold. Tests showed that of this amount about .6 or .7 ounce was absolutely insoluble in cyanide in a reasonable time, also, that the physical condition was such that, by proper^{ly} mixing fine with coarse material, the whole pond could be leached to a residue of 1.1 ounce. It was decided to treat it by this method.

Water could have been pumped from a shaft near the plant site, but was also available at a spring about a mile farther away. The cost of, and attention required by a pumping system, was balanced against the cost of a pipe-line for the greater distance, and the pipe-line was selected. This was ordered made up from No. 26 gauge galvanized sheet steel and cost about ten cents per foot delivered. It was possible to lay a large portion of this pipe in a trench, made and back-filled with a plow to a depth of six inches. Since, at no place, did it have to withstand a pressure of more than a few feet of water, the ten foot sections were connected by slip joints and sealed with asphalt roofing pitch. This line delivered water to a pressure tank on a hill 1700 feet from, and at an elevation of 60 feet above the plant. This tank and the plant were connected by a four inch pipe-line, in order to cut down the friction losses and make usable as much

as possible of the available 60 foot head.

In order to so use water to dispose of the residue, it was necessary to secure additional slope for the tail-race. This was done by elevating the treatment vats so that their tops were 15 feet above the ground surface. By using a five-eighths inch nozzle the 60 foot head maintained a satisfactory sluicing velocity, and the 30 ton vats were emptied in an average time of an hour and ten minutes. At another installation, with greater head and an inch nozzle, the same vats were emptied in as short a time as twenty-five minutes.

To ~~xxxx~~ minimize the total distance of haulage and to use as short a tail-race as possible, the plant was located somewhat below the centre of haul for the entire pond. Below the plant, 300 feet of tail race, made of foot boards with six inch sides, and having a uniform slope of $4\frac{1}{6}$ per cent, was erected on trestles. At the end of this, a large area, which was covered up to about a foot in depth with fine, but rather high grade tailing, was cleared off to receive the first residue made. The tailing from this was piled near the plant to be mixed with coarse material from other parts of the pond as fast as possible. The posts for the understructure of the vats were cedar and pine, cut on the Forest Reserve near at hand, while the bracing was two-by-four inch fir spiked to the sides.

The tailing was elevated and delivered to the vats by a bucket elevator feeding onto a belt conveyor which ran above them. A uniform feed was secured for the elevator by means of a short flight of screw conveyor beneath the loading trap, which was placed low enough to allow the teams to work nearly on a level. The loading trap was a hopper-shaped bin holding about a ton, with the

screw feeder in the bottom, and a grating, with openings three inches wide, on top. Large boulders and sagebrush were thus kept out of the ore charge.

The elevator was of the open-bucket type and consisted of eight-inch malleable iron buckets fastened to a single strand of No. 88 conveyor chain by attachment links. The conveyor belt was mounted on a low carriage on wheels and arranged to be rolled along a track over the vats. This arrangement, along with provision for reversing the direction of travel, made it possible to use a belt less in length than half the distance across the vats, and, at the same time, dispensed with the need of a dumping device. Motion was transmitted to the belt by a shaft running the full length of the carriage. To this shaft a split sprocket, driven from the head shaft of the elevator, could be clamped in the position necessary for discharging into any one of the six vats. The belt, elevator, and screw feeder were all driven by a six horsepower gasoline engine, the screw feeder being turned by the tail shaft of the elevator through mitre gears. The six thirty ton vats were in a row, and it was possible to load two of them from a single position of the belt by reversing its direction of travel. When necessary to change, it required about five minutes to roll the carriage along and hook up for the next pair of vats.

In operation one vat was loaded each day, so that a charge was in contact with solution or being water washed something less than six days, the operations of sluicing and reloading requiring less than four hours. The tailing from distances up to about 200 feet was dumped into the trap from slip scrapers with one handling; while that from the remainder of the pond was hauled in wheeled

scrapers and dumped near the plant. The horses were kept busy at this work during the time when loading was not being done, also during those periods at the beginning and close of the running season when the weather was too cold to operate. In the use of the wheel scrapers, which were equipped with aprons, no snatch team was used; but the drivers finished loading them with shovels from the tailing behind, which was too thin to be taken up with the scrapers. In this way, an average load of three-quarters of a ton was hauled, also a clean face was maintained, against which to work.

On account of the sizing that had taken place in deposition, it was necessary to make up each charge from different places in the pond. In the earlier operations, when it was desirable to get the fine material from the lower part of the pond out of the way of newly-made residues, precautions had to be taken not to get too much of this material into any one charge. Fortunately there was a quantity of clean, wind-blown, coarse sand to mix with this, and so maintain a satisfactory leaching rate.

In addition to a proper proportioning of the charge, an important point to be heeded was to have the slime part finely pulverized. This was accomplished by plowing, discing, harrowing, and floating. The practice was to plow an area and leave it exposed to the sun just long enough so that it could be crumbled fine by working, and not long enough to cause it to bake.

It was found better to have the tailing appreciably moist when loading, since too dry a charge packed too densely and gave a slow leaching rate; also, on account of dust. Then, too, when the tailing was too dry it did not discharge well from the buckets. The vibration set up by the chain and sprockets so settled the material in the buckets that a vacuum was formed, which held back

some of it long enough to escape delivery onto the belt. To overcome these difficulties, it became the practice during dry periods to sprinkle part of the tailing loaded, with cyanide solution.

In loading the vats with this moist material a certain amount of handling and tramping was necessary in order to get in sufficient charge, and also, to prevent channeling when the solution was first run on. It was especially necessary to have that part of the charge next to the wall, well packed. The vats were considered properly loaded when, after settling, there was a space of six or seven inches for solution above the charge; and when the first solution on was absorbed within a reasonable time without channeling. This leveling and tramping of the charge required about half of one man's time when loading. Always, when beginning the loading of a vat, a few scraper-loads of clean sand were run up first and spread over the canvas bottom to prevent it being blinded in local areas by patches of slime.

Alkalinity was maintained by sifting a shovelful of slaked lime into the loading trap at frequent intervals. This became thoroughly mixed with the charge by the time it arrived in the vat. It had been previously slaked to a rather dry powder, since, in this condition, it did not dust badly, and yet was fine enough to be dissolved in the vats. By using four and a half pounds of 85 per cent lime, the alkalinity of the stock solution was kept at .8 or .9 pound of CaO per ton.

In applying the first solution to the charge the practice finally adopted, after experimenting with various combinations, was to run on from the top ten tons of a strength of 6.5 pounds of free KCy, and allow to stand over night with the discharge

valve open. Two or three tons of solution, part of which was moisture loaded with the charge, would drain off during the night, and leave the whole depth of charge wetted by the strong solution. Early next morning the top of the charge was raked level and flooded with barren plant solution of 2.5 pound strength. Washes of this barren solution were repeated during the following days of the cycle, except the last, when water was substituted. The quantity of water used was controlled by the amount just necessary to maintain proper amount of solution in the circuit. It was found necessary to have but one strength of solution.

The strong solution was made up by pumping ten tons of barren sump solution to the strong tank, and adding enough cyanide to bring its strength up to 6.5 pounds. This was run on the newly-loaded vat as fast as it was absorbed without channeling, and required from six to ten hours. The cyanide added for this purpose was generally all that was used for the whole treatment, although, occasionally it was necessary to strengthen a succeeding wash solution. In washing, the vats were kept flooded at all times during the day; but were allowed to drain and aerate at night. If, however, a very slow-leaching charge should have been loaded, it was kept flooded day and night, and not allowed to drain and pack. The cyanide used was the commercial sodium variety, obtainable under the trade name "Cyanegg". The consumption of this averaged almost exactly one pound for the whole dump.

In precipitation, the solution running off the new charge for the first twenty-four or thirty-six hours, was run through a separate zinc-box after passing through a clarifying tank. For the remainder of the cycle, it was precipitated in another box without clarification. The advantages gained from this arrange-

ment were,- the quantity of short zinc was greatly lessened; the grade of precipitate was raised; and less attention was required. In dressing the boxes, it was the custom to put all of the short zinc in the head compartments of the box receiving the first run-off of the vats. This solution, being high in silver value, was an active solvent of the short zinc. The first compartment was fitted with multiple-trays, on which this could be spread in thin layers. These two higher compartments were the only ones requiring attention except at long intervals. The precipitate obtained in this way assayed from 75 to 80 per cent silver, which is very satisfactory for a tailing plant. Also, precipitation was good, a factor of prime importance in a leaching plant, when the necessity of maintaining a wash solution, practically barren, is considered.

An interesting feature in connection with the precipitation of this first run-off solution was a regeneration of cyanide. At all times the free cyanide strength of the solution leaving the box was higher than that entering by from a half to two pounds, as indicated by the standard test for free cyanide. No increase of strength was noticeable in the regular box. That this was a genuine case of regeneration, and not a mistaken ^{inclusion} of part of the double cyanide in the reading, is attested by the decrease in the actual cyanide consumption from that shown in the tests. Part of this regeneration could be accounted for by the presence in the tailing of some oxidized copper minerals, although the high grade of precipitate suggested that there were other agencies responsible. The total quantity of solution precipitated per day was from 40 to 45 tons, or nearly one and one-half tons per ton of tailing leached.

In this plant where a high per cent of slime was being leached along with the sand, the one factor largely determining

good or poor results, was the leaching rate. One of the conditions tending to reduce the leaching rate was the blinding of the filter cloths by accumulation of lime-carbonate. Since the presence of a filter cloth is not in any way necessary to the production of a clear solution in the ordinary operation of a leaching vat,—the charge itself is a very good filter—its only justification is its convenience in emptying the vats. At that time it forms a very good type of bottom from which to sluice the charge. In practice here, the cloths were kept porous by removing them from the vats and washing them in acid solution for a few hours. For this, a solution of five per cent HCl was used, after which they were washed in water. An extra cloth was kept for this purpose, and the time required to change them, which was done after running ten charges, was about an hour. The cloths were of eight-ounce canvas duck, laid on a thick sheet of cocoa-matting.

For convenience in cleaning up, a box with filter-bottom and a decanting pipe was erected near the zinc-boxes, and at a higher level. The precipitate from beneath the zinc-box screens was handled in buckets to this box and the contained moisture either decanted or filtered back to a compartment of the zinc-box. When the precipitate had drained here for a time, it was transferred to a drier and further dried to a moisture content of ten or fifteen percent, in preparation for melting. The details of construction of the clean-up box and drier are shown in Figures 2 and 3, appended hereto.

Melting was done in a pouring furnace, made from a large oil-drum by giving it a refractory lining. This lining consisted of a mixture of graphite and fire-clay, wetted with sodium silicate and tightly rammed around a form to a minimum thickness of four

inches. The graphite of the mixture was obtained from old melting crucibles, crushed to a fineness of about six mesh; while the proportions used were as follows,-

crushed graphite crucible	3 parts
fire-clay	1 "

This was wetted to a good ramming consistency by a mixture of sodium silicate and water in equal parts. The fuel was stove-oil, of a gravity of 27 degrees Baumé, and atomized by air from a blower, at 7 ounces pressure. The advantages of this furnace were its low installation cost; economy of operation, since no crucibles were required; and its large capacity. The details of construction of this furnace are shown in Fig. 4.

The precipitate was melted after being mixed with flux on the hearth of the drying furnace. For the regular high grade precipitate, a mixture having the following proportions was made up,-

precipitate	100 parts
borax-glass	12 "
sodium carbonate	6 "
quartz sand	3 "

For the final clean-up of a season, when there was much short zinc, it was handled in this way,- the zincy precipitate was dried in the usual way, but the zinc was burned to complete oxidation. After cooling, a mixture, which might run as high as the following in flux was made up,-

zincy precipitate	100 parts
borax-glass	20 "
sodium carbonate	20 "
quartz sand	10 "

In melting, the fluxed precipitate was charged into the already heated furnace in portions of about 100 pounds, which were allowed to nearly melt down before a new portion was added. When an amount, more than sufficient to produce two bars, had been added, the

temperature was brought up very, ^{high} accompanied by a periodic rocking of the furnace. In pouring, most of the slag was first drawn off into slag-molds and dumped. Two bullion-molds, which had been previously greased, were then placed on the top of a slag-mold on the truck, and poured full of bullion, while any over-flow was caught in the mold below, and added to the charge for the next bars. The partly cooled bars were plunged into water to loosen any adhering slag. In this way, bright, clean bars of a fairly uniform weight of 1800 ounces, Troy, were produced. The high temperature of this furnace made possible extremely fluid slags, with their consequent low silver losses. The fineness of the bullion varied from 940 down to 800. The bars after weighing and stamping, were shipped to the United States Mint at San Francisco.

The operating costs for the treatment of this dump totaled \$1.06, made up as follows,- labor .50; cyanide .28; zinc .07; lime .08; horse-feed .08; power .03; assay supplies .01; melting flux and fuel .01.

The methods used in the handling of this dump are not here described with the belief that they represent the best practice, metallurgical, and mechanical. They do not. They are simply given here as an example of how a certain set of conditions were met, and the problems incident thereto, solved. As stated elsewhere, each project has its special conditions to be met. So, the method of handling it would be of a special nature, one that would best suit those conditions.