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The Effects of Lime on the Amalgamation of Gold.

Rolloen R. Wells

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THE EFFECTS OF LIME ON THE
AMALGAMATION OF GOLD

by

ROLLIEN R. WELLS

A Thesis
Submitted to the Department of Metallurgy
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Metallurgical Engineering

MONTANA SCHOOL OF MINES
BUTTE, MONTANA
MAY, 1956
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THE EFFECTS OF LIME ON THE
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* * * *

Amalgamation

An amalgam is an alloy of mercury with other metals, and amalgamation is the art of making or forming amalgams. In metallurgical language the word is limited to the means adopted for the recovery of gold and silver from their ores by the use of mercury.

Mercury wets those substances with which it amalgamates just as water wets glass. The surface tension of mercury is very high, and the tendency is to pull within itself any substance that amalgamates with it. To those substances with which mercury does not amalgamate, its surface tension acts negatively and is strongly repellent to them.

Kasentseff* showed that mercury dissolves 0.11 per cent gold at 0° C., 0.126 per cent at 20° C., and 0.65 per cent at 100° C. Investigations by T. T. Read** brought forth the following statements:

1. Gold is soluble in mercury, at 20° C., to the extent of about 0.06 per cent; this solubility increases to about 0.25 per cent at 100° C., and probably decreases to zero at the freezing point of mercury.

2. There are two definite compounds of gold and mercury, one carrying 13.62 atomic per cent of mercury, corresponding nearly to the formula \( \text{Au}_{19}\text{Hg}_5 \), and the other 17.44 atomic per cent, corresponding nearly to \( \text{Au}_{19}\text{Hg}_4 \).

* Bibliography--6.
** Bibliography--7.
In ordinary work it is considered that gold is soluble in mercury to the extent of about 0.1 per cent at ordinary temperatures, and that when the mercury becomes saturated a solid compound of the two metals then is formed, which can be separated from the excess mercury by filtration.

In order that the union between the two metals may take place, clean mercury and clean gold must be brought into intimate contact. This contact can be brought about by one of three methods:

1. By grinding in mercury.
2. By surface contact amalgamation.
3. By immersion in mercury.

The first method, grinding in mercury, is the oldest, but its popularity is steadily waning due to the high consumption of mercury and to the length of time involved. This method is quite extensively used, however, for the amalgamation of silver and for the recovery of gold from blanket and table concentrates. The grinding is done in iron pans or in an area enclosed by masonry, either of which is convenient for the addition of chemicals and hot water. The latter is used to stimulate the solubility of gold in mercury, and thus increase the rate of amalgamation.

Surface contact amalgamation was not used until 1860, in California, when the surface of copper plates was first coated with quicksilver and the crushed ore and water allowed to flow over them in a thin sheet. This method has revolutionized the amalgamation of gold in ores. Surface contact amalgamation is efficient and inexpensive, and is extensively
used for the recovery of gold from its ores.

The method of passing a stream or ore through a bath of mercury has been tried time after time with very poor results. Economically this method was a failure because of the high mercury losses, due to excessive fouling. A poor recovery was obtained because of the fact that the time of contact between the ore and the quicksilver was so short, and the likelihood of the gold particles being surrounded by a film of air or gangue material was so large, that actual contact between the two metals, and consequently, their union did not take place. Amalgamation by immersion in mercury was tried in Europe and Australia, but it has been almost entirely abandoned.

There may be a loss of gold due to improper liberation of the gold particles from the gangue material. Screen sizing, with amalgamation tests on each size, will show if this is the case, and a remedy can be effected by finer grinding. "Overstamping", or crushing to a degree of fineness that is neither required or beneficial, is a rather common mistake in operation, especially if the ore contains a large percentage of sulfides. The gangue, crushed too fine, slimes, and this slime forms a film or coating on the gold particles. "Rusty" gold is free gold covered with a film of some substance other than air or the gangue rock in which it is contained. The coating may be due to oxides of iron or copper, or to compounds of other base metals; to an oily or greasy mineral peculiar to the ore, like graphite; or to silicates of magnesia or alumina. Such gold sometimes may be amalgamated if it is polished in a grinding pan. Usually, though, "rusty" gold is caught in riffles or
on blankets. One of the most important things for an amalgamation mill operator to remember is that when gold is coated, whether by gangue, slime, or some other film, the film prevents the gold from making contact with the mercury. Gold, in order to amalgamate, must be clean so that it may be readily wetted by the quicksilver.

For the same reasons clean mercury is necessary. The purity of the mercury as purchased cannot be depended upon because it absorbs so many metals, such as copper, lead, zinc, antimony, and bismuth. Redistillation does not effect a complete separation from the more volatile metals, unless the last 10% to distill is caught in a separate container. This last 10% is said to contain nearly all of the impurities. Distillation with quicklime and iron filings removes any sulfur that may be present. Several treatments with acids or alkalies, as well as several methods of agitation have been suggested, but the best method found is to agitate with air for twenty-four hours with a solution of dilute nitric acid (about 1 to 5). The agitation brings to the surface any particles of bismuth, iron, zinc, or tin which are then dissolved by the acid. Very clean mercury can be obtained by distillation with lime and iron filings, followed by the nitric acid treatment described above.

Mercury that has been broken into extremely small globules is said to be "floured". This is quite common when the quicksilver is fed into the stamp battery, due to excessive pounding. Flouring is not detrimental when there is no film formed on the mercury particles, and these particles will coalesce readily. However, it is rare for flouring to take place without there ensuing a fouling or contamination of the globules. This is known as "sickening", and is caused either by the
formation of some non-coelescing amalgam, such as antimony amalgam, or to the coating of the mercury particles by a film of some non-amalgamating substance, preventing coelescence and rendering the quicksilver inoperative. Sickening may be caused by grease or oil, clay, talc, free sulfur or arsenic. Metallic antimony and antimony in the form of stibnite are very harmful, as is decomposed pyrite, which is usually in the form of acid iron sulfate.

Various methods are used to restore fouled mercury to its normal condition. The addition of cyanide is beneficial in that it neutralizes the grease and dissolves the oxides. The use of sodium amalgam reduces the base metal oxides to their metallic state, in which form they will enter the mercury. Since the oxides will readily form again, this reduction is only temporary, and an attempt should be made to remove the base metals entirely. This can be done by distillation followed by treatment with a nitric acid solution as has already been explained.

In standard amalgamation practice two of the previously mentioned methods are used; viz., grinding in mercury and surface contact amalgamation.

The first method, generally known as "inside amalgamation", is now used very little. Inside amalgamation is accomplished in either of two ways:

1. The quicksilver is fed to the grinding equipment in proportion to the amount of gold in the ore, and is expected to form an amalgam. Some of the amalgam passes out through the screen and is picked up by the outside plate; the major part of it sinks to the bottom. A portion of the
amalgam retained in the mill forms on the exposed iron surfaces, but most of it is recovered from the sands.

2. The other method of inside amalgamation is to place amalgam plates within the stamp battery, near the dies, for the collection of the amalgam. Practically all of the pulp comes in contact with these plates, and thus there is accomplished both grinding and surface contact amalgamation.

There is a wide variation of opinion on the merits of inside amalgamation. Obviously, when the mercury is introduced into the grinding equipment there is a greater opportunity of flouring and sickening. One of the strongest claims made for inside amalgamation is that it prevents stealing. This is not true. Any millman who intends to steal can do so, no matter which type of amalgamation is used. A distinct disadvantage of inside amalgamation, when used in a stamp battery, is that solid amalgam is packed under the die and into any cracks or holes that may exist in the die or stamp shoe and is very difficult to recover. Those favoring inside plates claim that the gold should be recovered as soon as possible after crushing to prevent its escape into the tailings. However, it has been found that outside plates are just as effective, and, this being true, it is better to use outside plates alone.

The use of the outside plate or table is common practice among amalgamators. The principle underlying the outside amalgamation plate is to provide an abundant mercury- or amalgam-covered area, over which the pulp is passed in a shallow stream of such dilution and at such speed as will afford time for the gold particles to sink to the bottom and come in contact with the amalgamated plate. The dilution of the
pulp and the slope of the table are determined experimentally, and are changed as often as necessary to keep the pulp flowing over the plate in a succession of wavelets. The pulsation created by the irregular flow from the mill, and the friction at the immediate contact between the plate and the pulp, aid in causing the rippling effect, the purpose of which is to bring about a continuous interchange of mineral particles and allow every amalgamable particle to come into direct contact with the plate.

Where either a stamp mill or a Chilean mill is used, the plates are placed immediately beneath the screen, without any intervening distributing device, thus utilizing the pulsating discharge of the mill to help in forming the wave effect described above. Such being the case, the width of the plate is dependent upon the width of the discharge screen. When a tube or ball mill is used, a distributing box is necessary, and the plates are of no definite width.

There are two types of plates in general use in America: plain copper plates, and those which are silver plated. A third kind, rarely adopted, is made of Muntz metal (an alloy of 60% copper with 40% zinc).

The first, common copper plates, are made of the finest annealed copper sheet obtainable, about one eighth of an inch thick. They are laid on a tongue and grooved deck with leak proof sides, and held in place by quarter round cleats. There should be no screws or nails put through the plate where the pulp will pass over it. Thomson* suggests turning up the edges of the plate to prevent possible leaks. Cold work

* Bibliography--5.
hardens metal, and hard copper is much more difficult to amalgamate than soft copper. Hence, the edges of the plate should be turned up prior to annealing. When preparing a copper plate, first scour it with fine, clean sand to remove the coating of copper oxide formed and expose a fresh copper surface. The next step is to wash it with a hot lye solution to remove all traces of grease. The surface is then washed with a dilute solution (3 to 4%) of cyanide or a 5% solution of ammonium chloride to dissolve the film of oxidized copper that forms. The plate is amalgamated by sprinkling on mercury from a canvas- or chamois-covered bottle, then brushing with a whisk broom, using a strong rotary motion. The more work done in brushing, the better the surface obtained.

Many amalgamators believe in silvered plates in spite of their high cost because they are easier to keep in shape, and because they become gold catchers more quickly than plain copper plates since silver or gold amalgam amalgamates gold more readily than copper amalgam or pure mercury. These plates are made of annealed copper with a coating of pure silver, about one fourth ounce per square foot of surface. This silver coating is usually put on electrolytically. The preparation of these plates is similar to that of the copper plates, except that the scouring with sand is omitted. The silver plate amalgamates much more readily than the copper, thus eliminating a good deal of work.

Sometimes, when preparing plates, a silver amalgam is spread on to make it a more efficient gold collector. The first step in the preparation of this amalgam is to dissolve a piece of silver in nitric acid. When the metal has dissolved, the solution is slowly evaporated to dryness and heated until the copper present has all been converted to the
insoluble oxide. The mass is then treated with water, the silver nitrate dissolving and being precipitated as metallic silver by the action of iron. Mercury unites with this pure, finely divided silver to form a pasty amalgam, which is spread on the plate.

Muntz metal plates are sanded and washed with a dilute sulfuric acid solution, followed with a water wash and the application of amalgam as in the case of the copper plates. These plates were first used in New Zealand because of a temporary shortage of copper sheet. Muntz metal is cheaper than copper, and it is claimed that plates made of it are more easily kept in condition, particularly in the case of ores that have a tendency to form films on the surface of the amalgam.

No matter which type of plate is used, the surface strived for is one that has a thick coating of pasty amalgam, not too wet, not too hard. Ridges from one sixteenth to one eighth of an inch deep can be put into the surface of a well prepared plate by drawing a whisk broom across it. In practice the plate is redressed about every four hours. This is accomplished by turning off the feed or switching it over another plate. The plate is washed down, and any hard places are treated with more mercury, which is worked in until the spot is soft once more. If the amalgam is allowed to become hard it will flake and roll off the end of the plate. At regular intervals, when the amalgam coating is built up sufficiently, mercury is sprinkled over the surface, and the softened amalgam is removed by the use of a rubber "squeegee". All of the amalgam is not removed because, as has been mentioned before, amalgam is a much better amalgamator of gold than is pure mercury.
The amalgam, after removal from the plates, is placed in a grinding pan or amalgam barrel with additional mercury, and run for one half to two hours. The amalgam is then removed and caught in riffles or a dolly-barrel. The tailings are sent back to the head of the mill. The amalgam is squeezed by hand through a piece of chamois or canvas, or it is squeezed in an amalgam press, which is essentially a steel cylinder with a heavy piston that may be actuated by a screw. The bottom of the cylinder is heavy canvas, held in place by a plate through which small holes have been drilled, and through which the free mercury runs when the piston is moved downward. The amalgam is squeezed until it forms a hard lump; then hot water is poured over the press. The heat makes the remaining free mercury more fluid, thus making it more easily separated. The solid alloy of gold and mercury that remains in the cylinder is removed and sent to the retort.

Because the boiling point of mercury (\(359^\circ\) C.) is far below those of gold, silver, and copper, a separation from them is easily made by heating in a covered vessel that has an exit leading to a condenser.

The number of dopes and nostrums which have been proposed as infallible aids to the recovery of gold by amalgamation is almost endless. McFarren* says that it is best to dispose with all of them. But most authorities say that some of these so-called panaceas have some value. Sodium amalgam, especially, is well thought of for certain uses. A small amount of it will keep the plates bright and prevent the accumulation of a layer of metallic oxides on the surface. This action is probably due

* Bibliography—3.
to the liberation of hydrogen. Caustic soda also results and is useful in "cutting" any grease present. Cadmium and zinc amalgams have their supporters, but the effects of neither have been thoroughly investigated. Electrolytic amalgamation seems to work similar to sodium amalgam, the electrolysis liberating hydrogen by the decomposition of water. Cyanide is widely used in dressing the plates, as has been mentioned, but it is rarely used in the pulp water. It has been found, for no reason that can be explained, that cyanide hardens the amalgam on the plate and is likely to cause gold losses by the breaking up and loss of this hard material. The use of lime, caustic soda, caustic potash, and wood ashes, to neutralize the free acid of an oxidized ore, is widespread. But the true value of these additions is unknown. It is the general consenus of opinion that an alkaline pulp is best. Thomson* recommends the use of such agents. Some, however, believe that the addition of lime to an acid ore pulp causes calcium sulfate to form and coat the gold particles, thus hindering amalgamation. D. E. Powrie**, for example, found from an experiment covering six months, that nearly five per cent more gold was caught when acidified water was used than when the pulp was alkaline. The purpose of this experiment is to throw some light, if possible, upon this little known subject.

There has been much controversy about the temperature at which the best results are obtained. In most cases it has been found that the use of hot water on the plates increases the amount of gold recovered.

* Bibliography--5.

** Bibliography--2.
but the cost of heating the water is far out of proportion to the value of the increase in recovery.

The importance and wide use of amalgamation in modern gold and silver production is not always realized. Although it is one of the oldest methods of recovering precious metals, it is still of great importance as a method for the recovery of gold, and is the leader in the United States production. In 1933, of the gold bullion produced in the United States, 893,678 troy ounces, or 38.8 per cent, was recovered by amalgamation. Second in importance was recovery by placer methods, which accounted for 25.2 per cent, while cyanidation was third with only 15.3 per cent. In spite of the wide use of amalgamation, there are many things about it that are not understood. There is room for extensive research and experimentation in this field.
Equipment

The equipment used in the laboratory for this experiment was simple and needs no lengthy description.

The grinding pan used (see cuts I and II.) consisted of a heavy cast iron pan, nine inches in diameter and about five inches deep. A heavy shoe turned inside with about one quarter inch clearance. The bottom of the shoe was so designed as to bring about no crushing of particles when turned, but merely to polish the gold particles and make them more readily amalgamable. A handle, fitted into the top of the shoe, completed the polishing equipment.

The retort (see cut III.) was a simple pot retort, often found in laboratories, and, in larger sizes, in the clean-up room of small gold mills. The retort consisted of three main parts:

1. The pot, which was made of cast iron about three-eighths of an inch thick. It was four inches deep and three inches in diameter at the top, tapering slowly to the bottom. When the retort was put into use, the pot was lined with clay to prevent the gold from alloying with the iron.

2. The lid, to which was fastened the exit tube. The lid was made of cast iron, and was fashioned so as to fit tightly against the top of the pot. An asbestos gasket was used to make certain there was no escape of vaporized mercury. There was no condenser attached to the exit tube, the condensing being done in a beaker of water in which the end of the exit tube was placed.

3. The clamp, whose only purpose was to hold the other two parts tightly together.
Procedure

The usual procedure followed in making amalgamation tests is to add a weighed amount of mercury to a weighed amount of ore, agitate to bring about contact between the mercury and the amalgamable particles, separate the mercury from the gangue material by panning, weigh the mercury to make certain that there has been no loss, then retort it. The retort residue is assayed for gold.

Several tests were made in the above manner, but the results obtained were unsatisfactory. Since the ore used had been ground for some time, and oxides had had a chance to form on the gold, it was decided to polish the ore before the addition of mercury and to make the contact between gold and mercury by further grinding in the grinding pan. This was tried and much better results were obtained. However the best results gave only a 38 per cent recovery of the gold. This is due to some peculiar characteristic of the ore, perhaps to the large amount of graphite that is present.

In the first tests it was found that there was a considerable loss of mercury in panning. This was due to finely divided mercury being washed out of the pan when eliminating the heavier sands. This loss was corrected by panning the last of the concentrate in a watch glass.

In running the first experiments the mercury was washed, treated with a dilute solution of nitric acid to make it coalesce, then retorting. However, since the retorting was slow the procedure was speeded up by dissolving the mercury in nitric acid. The retort was then used only to
recover the mercury from the mercuric nitrate formed.

Since the only difference wanted between each test was the amount of lime added, the other factors which might have some bearing upon the amalgamation of the gold were carefully kept the same. In each test ten assay tons (292 grams) of ore were used to simplify the calculations. The ore was polished for thirty minutes, the grinding shoe being turned at an average rate of about thirty-five revolutions per minute. Then a weighed amount (as near 30 grams as possible) of mercury was added, and the polisher was turned for another thirty minutes. No attempt was made to regulate the temperature, but all of the grinding was done at room temperature, and the washing was done with cold tap water. Both the ore and the lime used were minus thirty-five mesh.

Preliminary tests to determine the acidity of the ore and the percentage of available lime present in the CaO used were run according to the schemes included in this paper.

The standard assay practice was used with a charge as follows:
Residue from retort or nitric acid treatment, or \( \frac{1}{2} \) A. T. ore.
1 A. T. sodium carbonate.
2 A. T. litharge.
3 grams argols.
5 grams borax.
Cover: 1 A. T. litharge.
Method for Determination of Percentage Available Lime

Make up a solution with two grams of finely divided lime, twenty grams of cane sugar, and water. Make up to one liter. Agitate for two to three hours. Let settle for at least twelve hours. Remove 250 cc. (1/5 gram CaO) and titrate with standardized potassium permanganate solution.

Method for Determination of Acidity of Ore

Make up a solution of sodium hydroxide of such strength that one cc. is equivalent to one pound per ton of CaO based on a fifty gram sample, or one cc. is equivalent to 1/40 gram of lime. A sulfuric acid solution is made equivalent to the sodium hydroxide solution. Place fifty grams of ore in a bottle, add 200 cc. water and 50 cc. of NaOH solution, agitate for several minutes, filter, and titrate filtrate with standard H₂SO₄, using phenolphthalein as an indicator. The difference between the number of cc. required to titrate to an end point, and 50 cc. is the number of cc. neutralized by the ore, or the number of pounds per ton of lime required to neutralize the free acid in the ore.
Grinding Pan

Cut I.

Cut II.
Acidity of ore.

Blank # 1--10 cc. NaOH neutralized by 10 cc. \( H_2SO_4 \).
Blank # 2--20 " " 20 " "
Blank # 3--50 " " 49.9 " "
Blank # 4--50 " " 49.9 " "

Test # 1--50 cc. NaOH added to ore, filtrate neutralized by 57.0 cc. \( H_2SO_4 \).
Test # 2--50 " " 36.9 " "
Test # 3--50 " " 36.7 " "
Test # 4--50 " " 37.2 " "
Average-- 36.95 " "

Number of cc. neutralized by free acid in ore = 49.9 - 36.95 = 12.95 cc.
Number of pounds of lime per ton of ore required to neutralize the free acid in the ore equals 13.0 pounds.

Available lime.

Potassium permanganate standard: 1 cc. = 0.01 grams of lime.

Test # 1.

Titration # 1--39.1 cc. of permanganate required.
Titration # 2--39.3 " " " "

Test # 2.

Titration # 1--39.4 " " " "
Titration # 2--39.0 " " " "
Titration # 3--39.2 " " " "
Average-- 39.2 " " " "

39.2 cubic centimeters = 3.92 grams of lime.

\[ \frac{3.92}{50} = 78.4\% \text{ available lime.} \]
Ore Assay.

Assay # 1 -- 0.47 milligrams gold on \( \frac{1}{3} \) A. T. charge.
Assay # 2 -- 0.45 " " " " " 
Assay # 3 -- 0.47 " " " " " 
Assay # 4 -- 0.47 " " " " " 
Assay # 5 -- 0.48 " " " " " 

Average assay -- 0.47 x 2 = 0.94 ounces per ton.

Amalgamation Tests.

Test # 1.

Water -- 250 cubic centimeters.
Weight of ore -- 292 grams.
Weight of mercury -- 35.5 grams.
Weight of lime -- 00.0 grams.
Gold in residue -- 2.91 milligrams.
Ore assay -- 0.94 ounces per ton.
Recovery -- 31 per cent.

Test # 2.

Water -- 250 cubic centimeters.
Weight of ore -- 292 grams.
Weight of mercury -- 31.2 grams.
Weight of lime -- 00.0 grams.
Gold in residue -- 2.89 milligrams.
Ore assay -- 0.94 ounces per ton.
Recovery -- 30.8 per cent.
<table>
<thead>
<tr>
<th>Test # 3</th>
<th>Water</th>
<th>Weight of ore</th>
<th>Weight of mercury</th>
<th>Weight of lime</th>
<th>Gold in residue</th>
<th>Ore assay</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>250 cubic centimeters.</td>
<td>292 grams.</td>
<td>32.6 grams.</td>
<td>1 gram $\times \frac{.784}{292} \times 2000 = 5.36$ pounds per ton of available lime.</td>
<td>3.50 milligrams.</td>
<td>0.94 ounces per ton.</td>
<td>35.1 per cent.</td>
</tr>
<tr>
<td>Test # 4</td>
<td>Water</td>
<td>Weight of ore</td>
<td>Weight of mercury</td>
<td>Weight of lime</td>
<td>Gold in residue</td>
<td>Ore assay</td>
<td>Recovery</td>
</tr>
<tr>
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<td>----------</td>
</tr>
<tr>
<td></td>
<td>250 cubic centimeters.</td>
<td>292 grams.</td>
<td>29.46 grams.</td>
<td>2 grams $= 11.72$ pounds per ton of available lime.</td>
<td>3.02 milligrams.</td>
<td>0.94 ounces per ton.</td>
<td>32.1 per cent.</td>
</tr>
<tr>
<td>Test # 5</td>
<td>Water</td>
<td>Weight of ore</td>
<td>Weight of mercury</td>
<td>Weight of lime</td>
<td>Gold in residue</td>
<td>Ore assay</td>
<td>Recovery</td>
</tr>
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</tr>
<tr>
<td></td>
<td>250 cubic centimeters.</td>
<td>292 grams.</td>
<td>29.97 grams.</td>
<td>3 grams $= 16.08$ pounds per ton of available lime.</td>
<td>2.19 milligrams.</td>
<td>0.94 ounces per ton.</td>
<td>23.3 per cent.</td>
</tr>
</tbody>
</table>
Test # 6.

- Water-- 250 cubic centimeters.
- Weight of ore-- 292 grams.
- Weight of mercury-- 33.10 grams.
- Weight of lime-- 4 grams = 21.44 pounds per ton of available lime.
- Gold in residue-- 2.18 milligrams.
- Ore assay-- 0.94 ounces per ton.
- Recovery-- 23.2 per cent.

Test # 7.

- Water-- 250 cubic centimeters.
- Weight of ore-- 292 grams.
- Weight of mercury-- 32.43 grams.
- Weight of lime-- ½ gram = 2.68 pounds per ton of available lime.
- Gold in residue-- 3.61 milligrams.
- Ore assay-- 0.94 ounces per ton.
- Recovery-- 38.4 per cent.

Test # 8.

- Water-- 250 cubic centimeters.
- Weight of ore-- 292 grams.
- Weight of mercury-- 29.70 grams.
- Weight of lime-- 1½ grams = 8.04 pounds per ton of available lime.
- Gold in residue-- 3.27 milligrams.
- Ore assay-- 0.94 ounces per ton.
- Recovery-- 34.9 per cent.
Conclusions

The results of experimental work conducted definitely show that, with the particular ore investigated, the additions of lime to the pulp, prior to amalgamation, at first give a slight increase in recovery, followed by a marked decrease to a constant value.

The only interpretation that can be given to the fact that the addition of a small amount of lime results in a slight increase in recovery, is that the effect of certain noxious constituents of the ore is inhibited (or restrained) by this addition. In regard to the constant recovery obtained, after the addition of about fifteen pounds of lime per ton of ore, it is suggested that when sufficient lime is added to react with all of the free sulfate in the ore, the maximum amount of calcium sulfate is formed and further additions fail to produce further precipitation.

In addition to the results obtained, further work, over a wide range of ore types, to reach definite conclusions, is required before generalizations can be made.
Acknowledgment

I wish to acknowledge the help and direction of Dr. Curtis L. Wilson and Professor J. U. MacEwan, under whose supervision this work was conducted.

Rollien R. Wells
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