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TREATING GOLD ORES BY AMALGAMATION

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Introduction

The variations of the amalgamation process are as diverse as are the ores that are treated or the metallurgists who treat them.

In this talk I will try to cover a little of the history, the hazards, and the theory of amalgamation. I will then try to show how this experience and theory can be applied in a practical way to the extraction of gold from its ores by describing examples of a couple of ancient but still viable devices. No attempt will be made to give you a cookbook type method since each ore will demand slightly different details. What I hope to do is provide a basic starting point that can be adjusted as necessary.

Historic Background

Amalgamation is one of the oldest methods of extracting gold from its ores. According to Herbert Hoover, in a footnote to his translation of Georgius Agricola's *De Re Metallica*, the amalgamation of gold possibly dates from Roman times. The extraction of silver by amalgamation is generally attributed to the Spanish in Latin America in the late sixteenth century even though Biringuccio describes the fundamental principals of the "patio process" about a half a century earlier.

The amalgamation of gold ores as described by Agricola in *De Re Metallica*, which was published in 1556, is essentially the same as modern practice. The only changes are in the machinery employed and the sources of power to grind, mix, and separate. The use of water wheels and of goats in a squirrel cage to provide power to wooden machines are just not too common any more. However, although the chemical and physical processes are more clearly understood by more recent authors, the actual "hands on" instructions are remarkably similar and *De Re Metallica* can still be used as a reference.

Safety

Before going any further into the subject of amalgamation, I will say a few words about the hazards of working with mercury. Like most things in our environment it is safe enough if it is treated with due respect and reasonable precautions are observed. However, the effects of mercuric poisoning are cumulative and it can do considerable damage if mistreated over a long period of time.

Mercury can be absorbed through the skin or inhaled in vapor form. Gloves should be worn whenever it is handled. Be sure that you are in a well ventilated area if there is any possibility of vapors forming. Avoid breathing any of the vapor at all costs.

Theory of Amalgamation

The physical and/or chemical characteristics that make amalgamation work are not clearly understood to this day. However, it is known that if clean mercury is brought into contact with clean gold, the gold is wetted and "drawn into" the mercury. This results in a solution of gold in mercury or an alloy of gold and mercury called amalgam. After the mercury has gathered in the gold it can be removed by dissolving it in nitric acid or by driving it off as a vapor by heat. The gold will remain behind.

The mill operator's problem is to get the gold and the mercury into intimate contact with each other. To do this he must: (1) liberate the gold particles from the gangue; (2) remove any coating which may be covering the gold; (3) keep the mercury clean and bright; and (4) bring the gold and mercury into intimate contact. Then he must allow the amalgam to coalesce, separate it from the pulp, and extract the gold.

Amalgamation generally works best on relatively coarse gold that can be liberated from the gangue and abraded clean without too much difficulty. Since mercury will not penetrate into minute crevasses or pores, the ore must be ground fine enough to expose the gold at the surface. If the gold is very fine, cyanidation is more effective and, in practice, a combination of amalgamation and cyanidation is usually employed. Gravity and flotation are also frequently used in conjunction with amalgamation.

Some of the things that tend to frustrate the millman's attempt to get the mercury and gold together are: (1) The existence of surface coatings or encasement of the gold in the gangue. Fine grinding and abrasion will usually solve this problem. (2) The presence of oil, grease, clay or iron and base metal sulfides may result in sickening or flouring of the mercury. Grinding in lime or some other alkali will usually prevent this occurrence. (3) The presence of carbon as graphite also sickens the mercury. In some instances it can be removed by flotation prior to amalgamation. (4) The presence of sulfides of arsenic, antimony or bismuth will cause flouring and sickening of the mercury. This usually makes the recovery of gold by amalgamation impractical.

There is some confusion about the meaning of the words flouring and sickening of the mercury. If the mercury will not wet or take up the gold or coalesce into larger globules it is said to be sick. Sickening is most likely caused by impurities in or on the surface of the mercury. The most common impurities are oil, grease, clay, manganese and iron sulfates, and base metal and iron sulfides. Flouring in the strict sense is the division of the mercury into extremely small globules. This gives it a white flour-like appearance. This is not bad in itself but the mercury seems to be more susceptible to sickening while in the finely divided state. Therefore, it does not coalesce but stays in a floured condition and is lost to tails. Any gold that it took up before becoming sickened is also lost to tails.

Mechanisms

The traditional use of amalgamation involved the stamp mill and amalgamation plates. A variation using agitation tubs for amalgamation was described in some detail in De Re Metallica. Today, with the exception of a few traditionalists,

the stamp mill has been replaced by the ball mill for this purpose. The mercury is fed into the ball mill with the ore and is then passed over prepared plates.

The plates, which should be of pure annealed copper, preferably at least 1/8 inch think to prevent buckling, must be scoured with sand and lye to remove any coating or oxidation. The resulting bright metallic copper is then rinsed with clean water and washed with a 2 to 3% solution of cyanide if available. Next a mixture of sal ammoniac and fine sand in equal proportions containing mercury is scrubbed onto the plate and as much mercury as the plate will adsorb is added. After coating the plate should be washed again with clean water and rinsed with the cyanide solution. Keeping the mercury clean will be a problem until the plate builds up a good gold amalgam coating. To alleviate this problem the plates can be silvered by applying silver amalgam to the prepared plate.

The size of plate required will vary with the character of the ore and the size of the gold particles. If amalgamation is used exclusively they should be in the range of 10 to 12 square feet per ton of ore per day. If used in conjunction with cyanidation the area can be reduced to about 1.5 to 4.5 square feet. They should be placed at a slope of 1 1/4 to 2 1/2 inches per foot. The slope should be adjustable to correct for inconsistencies in the ore.

Once the plates are loaded, as indicated by the hardening of the amalgam, mercury is sprinkled on the surface to soften it and it is then scraped with a hard wood or rubber scraper. After the amalgam has been scraped off, mercury is once more added to the surface and the plate is returned to service.

A more practical device for the small miner, and particularly the placer miner, is the barrel amalgamator. This is simply a horizontal rotating cylinder in which the slurry of finely ground ore and mercury are placed. The rotation brings the mercury into contact with the particles of gold. All the problems associated with flouring and sickening of the mercury must be guarded against as with plate amalgamation. This is nearly always a batch operation. A good rule of thumb is to use about 5 times the amount of mercury as there is gold in the batch. The addition of 3 to 4 pounds of caustic soda per ton of ore will help keep both the gold and the mercury clean. If necessary several rocks may be added to the batch to increase the agitation and the abrasion. A cement mixer with the lifts removed makes an ideal vessel for a small scale operation.

For testing or for extremely small scale purposes a copper pan can be silvered and used in the same manner as the copper amalgamation plate.

There is other equipment available for the amalgamation of gold but they are variations of the two basic types (1) passing the gold bearing slurry over silvered copper plates or (2) adding mercury to the gold bearing slurry and then retrieving the resulting amalgam.

Forgive me but I must bring up my favorite subject; the one thing that is most often ignored! Everything that goes into the process must be weighed, sampled, and assayed. Everything that comes out of the process must be weighed, sampled, and assayed. Otherwise the millman will be operating in ignorance and will have no chance at all of improving his process or technique.

Gold Recovery

After the gold has been taken up by the mercury the amalgam must be collected. The gold on the plates is scraped off as previously described. That still in the slurry must be brought together into larger globules and separated from the slurry. Gravity separation is usually employed. Sluices, jigs, tables, wheels, pans or any other gravity device can be used.

The excess mercury can be removed by squeezing it though damp chamois or canvas leaving a hard lump of amalgam. The remaining mercury can then be removed by retorting or by dissolving it in dilute nitric acid.

Because mercury vaporizes at a much lower temperature than gold it can be driven off by heat leaving the gold behind. In the retort the mercury vapors are captured and condensed so that the mercury can be reused. When using a retort the temperature should be increased gradually until the mercury begins to flow into the receiver, then backed off slightly and maintained until distillation ceases and then increased to a dull red finish. If heated too rapidly the amalgam may splatter and clog the outlet which could result in the explosion of the retort.

If a retort is not available, the mercury and silver can be removed by placing the amalgam in hot dilute nitric acid. One part acid to three parts water is the proportion that works best. The mercury and silver are dissolved leaving the gold. This solution can then be used to "silver" copper plates or pans or, if economics and convenience so dictate, it can be discarded.

Summary

To summarize, I want to once more stress the importance of the proper care in the handling and use of mercury. The wearing of gloves and the adequate ventilation of all work areas are simple precautions that can prevent serious health problems.

I also want to caution you. Don't get lost in the details and mechanics of the process and forget the fundamentals. Always keep in mind the fact that the whole process depends upon getting clean, bright mercury into contact with clean gold. anything that promotes this simple concept is good and anything that restricts it is bad.

I sincerely hope that this talk has given you enough information about amalgamation to make you want to learn enough to make it work for you.