CHAPTER 10.4

# Vat Leaching

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## BASIC CONCEPT

In vat-leaching processes, crushed and sometimes agglomerated ore is piled in a vessel. Leach solution is flooded into the vessel and usually irrigated upward through the ore charge. The emerging pregnant leach solution (PLS) is collected and sent for metal recovery, while the depleted ore is disposed of in residue dumps (Gray 1975; Knobler and Werner 1962; LaChapelle and Dyas 1993; Tapia and Kelley 1998).

A typical flow arrangement is shown in Figure 1 and a typical equipment arrangement is shown in Figure 2.

## VAT-LEACHING FLOW SHEET

Ore is usually crushed to –6 to 12 mm. In some cases, the ore is deslimed or agglomerated. Reagents such as acid, lime, or cyanide may be added during the vat loading process. The vats are loaded with ore. Leaching solution is introduced from below and completely submerges the ore. Solution continues to pass through the vat charge for 24 to 168 hours. The solution is then drained from the vat, the waste is removed, and the vat is loaded with a new charge of ore to begin a new cycle. The ore loading is done in short lifts to avoid the concentration of fines or coarse material in one area of the vat, which may make the flow of leach solution uneven.

Because the vats are completely flooded shortly after the ore is loaded, agglomeration cure times are very short. Hard, discrete agglomerates that are formed for heap leaching are not typically achieved in a vat leach. Because the vat solution irrigation is upflow, the strength and durability of agglomerates in a vat are not as important as they are in a heap leach.

Solution flow rates are typically between 300 and 1,000 L/$m^2$/h. The solution may pass through vats several times in a recirculation, countercurrent, or intermediate-leach-solution (ILS) flow arrangement. Vat-leaching-solution flow rates are designed to control one or more of the following:

- **Reagents concentration.** If the ore consumes reagent quickly, then a faster solution flow rate is required.
- **PLS tenor.** If downstream processes require a certain tenor of PLS, then the flow rate through each vat may be manipulated to achieve it.
- **PLS turbidity.** If there are a lot of fines, then flow rates may be low to reduce entrainment of fines in the PLS.
- **Reagent penetration.** If reagents are consumed quickly, then a higher flow rate may be selected to achieve similar leaching conditions throughout the vat.

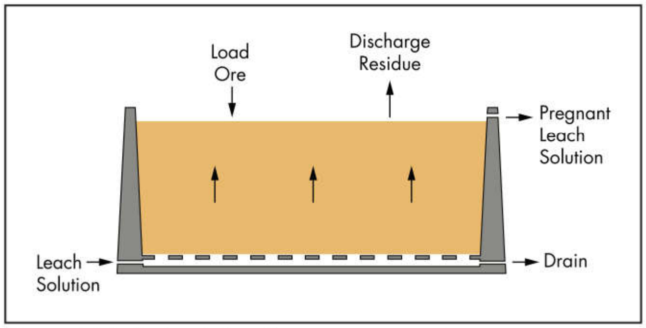


**Figure 1 Typical solution flow arrangement**

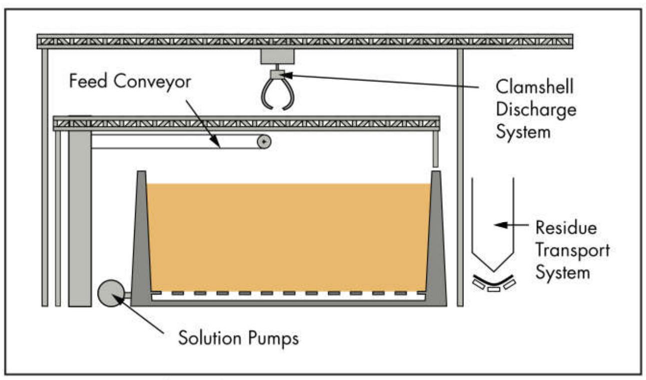


**Figure 2 Typical equipment arrangement**

Carbon dioxide gas is generated in acid leaching of ores that contain a significant amount of carbonate minerals. This gas forms as pockets in the ore bed, which grow in size until they achieve enough buoyancy to break through the ore bed and form a channel to the surface. These channels become the paths of least resistance to the leach solutions and become progressively larger as the solution flow increases in the channel

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and washes out the finer material. A typical vat-leaching circuit is shown in Figure 3.

On a larger scale, vats lost favor in the 1980s when activated carbon and solvent extraction were developed to recover gold and copper, respectively, from low-tenor PLSs. Since then, there have not been any major new vat-leaching facilities developed.

Although a heap leach solution typically approaches chemical equilibrium with the ore that it is in contact with, a leach solution passes through a vat quickly, so the entire height of a vat is in contact with a similar leaching solution.

Vat leaching has some technical advantages over heap leaching (Coburn et al. 1976), which may lead operations to select this technology (Cope 1991):

- Faster leaching times
  - Lower ore and metal inventory
  - Lower reagent consumption
- More homogeneous contact between ore and leaching solutions
- Less area required
- Less personnel required for operations
- Upflow irrigation, which is less prone to channeling or blockages
- Lower surface area affected by evaporation or rainfall
- Ability to have several stages of countercurrent flow between the ore and the leaching solution, which facilitates
  - The ability to generate higher PLS,
  - Less solution pumping, and
  - Better washing efficiency for lower soluble metal losses.

However, there are also several disadvantages that must be evaluated:

- Higher capital cost of installation
- Less flexibility for leaching times
- Typically a finer crush size required
- Unstable PLS tenor
- Possible undesirable chemical reactions
- Low leach time, which negates slower leaching mechanisms, such as bioleaching
- Anaerobic conditions, because it is a flooded system and air cannot be added

Vat leaching is typically slower and achieves lower recovery compared to agitated tank leaching, but it has the advantage of lower comminution costs, and the residue can be stacked rather than requiring a tailings dam (Murdoch 1990).

## WASTE REMOVAL

The vats are drained by gravity before the solids are removed. The drain solution can have some suspended solids entrained and should be throttled to avoid high initial flow rates.

Overhead clamshell reclaimers, operated by an electric motor on a traveling crane arrangement have been the most successful approach to large vat unloading. The equipment is easy to maintain and would be easy to automate.

The following alternatives have been attempted:

- **Backhoe or mechanical excavator.** This type of machine has limited reach, requiring that the vat be narrow.
- **Front-end loader.** This requires that one of the walls of the vat be dismountable or that there is a ramp to drive the equipment in. This arrangement can be problematic because of operations and maintenance issues. The doors themselves can leak and stress, and the walls and subfloor irrigation can be damaged by the front-end loader.
- **Hydraulic removal by fluidizing the charge.** This has the advantage of allowing for a semicontinuous leaching process (Mackie and Trask 2009).

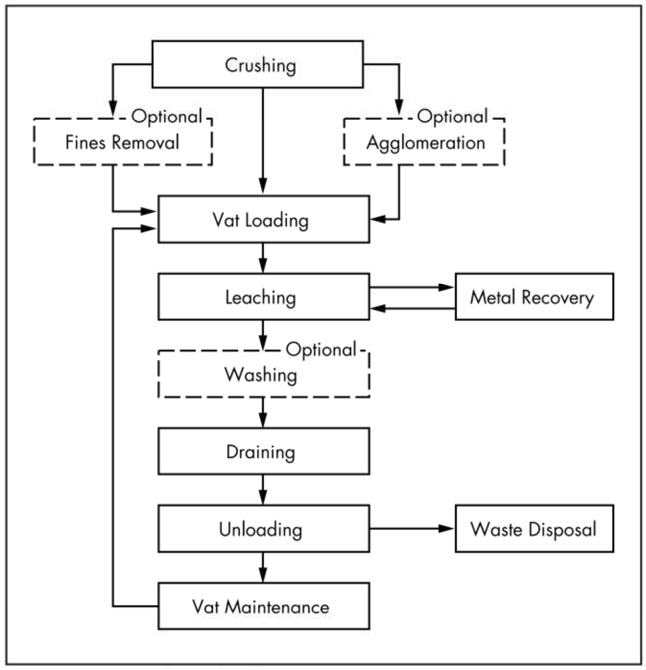


**Figure 3 Typical vat-leaching circuit**

## VAT CONSTRUCTION

Circular steel vats have been used, but larger plants have used concrete rectangular boxes, reducing construction costs and allowing for bulk unloading methods.

If acid proofing the concrete is required, then high-density polyethylene sheeting, polymer panels, asphalt, and sulfur concrete have been used. The height of the vats is usually dependent on the optimization of the reinforced concrete structures. All of the major concrete vat facilities that have been built have had a live leaching height of approximately 6–7 m. The width of the vat is dependent on the ore loading and discharging technologies to be used. If a tripping conveyor and clamshell arrangement is to be used, then the vats would typically be 25–35 m wide. Vats may be either joined together in rows or stand separately. The inner walls have to be able to withstand a charge on one side but not the other. False floors are installed into the vat that must

- Provide structural support to the charge above,
- Allow for even irrigation of the leach solution,
- Be resistant to the unloading equipment, and
- Allow for drainage of the void solution before the vat is unloaded.

In some cases, wooden sleepers have been used to build the floor, then a polymer or canvas mesh has been installed over the top layer of sleepers, supported by a wooden lattice. A further layer of sleepers can be installed over the mesh to provide further support of the charge as well as protection from the discharge equipment.

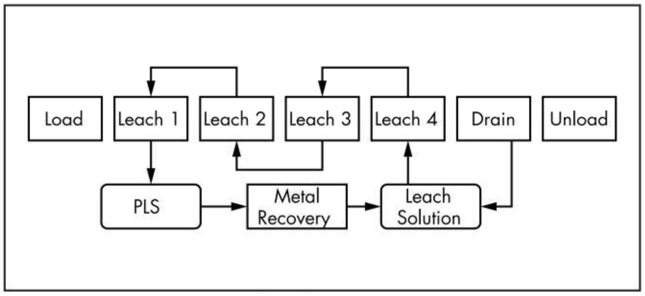


**Figure 4 Countercurrent leach arrangement**

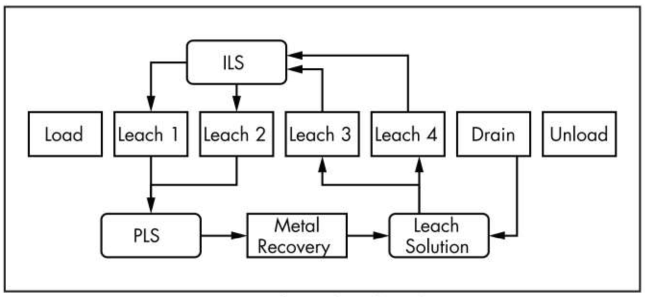


**Figure 5 Common intermediate-leach-solution arrangement**

Other alternatives such as formed concrete blocks with solution channels have been used but are not favored because of their high cost. In acid environments, they have been made from sulfur or polymer concrete to protect from the acid.

In gold operations, oxygen may be added to the incoming leach solution at this point as it is under pressure. The vat walls must also be protected from acid solutions. Solution pumps can be arranged at either the top or bottom of the vat.

## SOLUTION MANAGEMENT

Existing vat operations have only used one or two ILSs, though the plants were designed for complete countercurrent operation. Countercurrent operation allows for more predictable performance with less operator interaction but produces a very high-grade PLS and does not allow for flexibility on cycle times and conditions for each vat. Figure 4 shows a countercurrent leach arrangement.

In some instances, solution has been recirculated in the same vat to continue leaching while achieving a higher PLS tenor. Figure 5 shows a common ILS arrangement. The first PLS to emerge from the vats will have high concentrations of suspended solids. Typically, this would be treated in a clarifier before recovering the metal from the solution.

## TEST WORK

Conventional bottle-roll leaching tests do not typically give a good representation of the vat-leaching performance. In a bottle roll, there is attrition of the particles, breaking passivation layers of precipitates. Constant reagent concentrations are hard to control in a bottle-roll test, especially if consumption is high.

It is recommended that the test work be done with upflow column leaches, where the solution is either recirculated or has a single pass, depending on requirements for reagent control. The parameters that should be tested are

- Particle size, including crush size and deslimed sands;
- Solution flow rate;
- Reagent concentration; and
- Agglomeration and cure.

The tests should be controlled for temperature because the thermodynamics of a small test may be significantly different to an industrial-sized vat. The leach solution should be prepared from either a mature process solution or a synthetic solution that has the same chemical composition as the projected process solution. Some tests should be done at the full vat height and final projected conditions to ensure that the performance is stable and efficient throughout the entire height.

No information is available about scaling up recovery or leaching kinetics between batch laboratory tests and industrial tests. Empirical observation suggests that well-run batch tests in the laboratory will give similar extraction rates to an industrial vat.

## ENVIRONMENTAL CONSIDERATIONS

The residue that is discharged from the vats may or may not have been washed with water. Typical industrial applications do not wash with water so that the solution that is lost in the residue acts as a bleed for unwanted species that accumulate in the process solution, such as iron, chlorides, or copper. Consequently, the residue that is discharged will have residual metals in solution, reagents, and will be saturated with solution that will continue to drain. Therefore, containment or treatment of the residues should be considered to avoid this drainage from contaminating ground and water. The residue also contains fine solids that could cause dusting and acid mine drainage.

## REFERENCES

Coburn, J.L., Keane, J.M., Chase, C.K., and Bhappu, R.R. 1976. Analysis of submerged vat leaching versus trickle leaching. SME-AIME Preprint No. 75-AS-348. New York: SME-AIME.

Cope, L.W. 1991. Vat leaching—Historic gold processing technique again viable. *Min. Eng.* 43:1131–1132.

Gray, R.E. 1975. Vat leaching practices at Anaconda's Yerington mine operation. SME-AIME Preprint No. 75-AS-306. New York: SME-AIME.

Knobler, R.R., and Werner, J. 1962. The Mantos Blancos operation: Chile's new integrated copper producer. *Min. Eng.* 14:40–45.

LaChapelle, G.W., and Dyas, J.S. 1993. Cyprus Miami property overview and mine modernization. *Min. Eng.* 45(4):344–346.

Mackie, D., and Trask, F. 2009. Continuous vat leaching—First copper pilot trials. In *Proceedings of ALTA Copper 2009*. Melbourne, Victoria: ALTA Metallurgical Services.

Murdoch, R.B. 1990. Small scale vat leaching. In *Pacific Rim Congress 90: An International Congress on the Geology, Structure, Mineralisation, Economics and Feasibility of Mining Development in the Pacific Rim, Including Feasibility Studies of Mines in Remote, Island, Rugged and High Rainfall Locations*. Melbourne, Victoria: Australasian Institute of Mining and Metallurgy.

Tapia, G., and Kelley, R.J. 1998. Leaching practices at Mantos Blancos. In *Latin American Perspectives: Exploration, Mining, and Processing*. Edited by O.A. Bascur. Littleton, CO: SME. pp. 249–257.