A Comparison Between the Automated Filter Press (AFP) and Counter Current Decantation (CCD) for Solution Recovery from Acid Leach Tailings

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ABSTRACT

Comparisons of capital and operating costs are made between two copper leaching operations: Minera Rio Tinto, a copper mine in northern Mexico using Automated Filter Press (AFP), and CS Mining, a copper leach operation in Utah using Counter Current Decantation (CCD) (Ref 1). Our study indicates there are significant capital cost savings with the AFP installation: Cost for stainless steel tanks alone in the CCD circuit add 38% more cost compared to the AFP installation; total capital cost is 2.3 times greater for the CCD; and operating expense for the CCD circuit is approximately $2.00 per ton of ore greater due to the additional required flocculant.

INTRODUCTION

CCD has been the industry standard for solution recovery for well over a century (Ref 2). It is comprised of multiple thickeners in series, where the solids in the underflow are moved sequentially downstream while the supernatant solution is moved continuously upstream against the flow of solids, hence the name Counter Current Decantation. Capital and operating cost for the CCD facility can be substantial. Until recently CCD was the only viable option for solution recovery from corrosive slurries. However, the development of higher capacity and lower cost AFPs provides a viable alternative to CCD with the advantage high solution recovery and dry stack tailings. With the regulatory trend moving toward dry stacking tailings, the AFP is finding application in areas where water recovery is paramount and/or corrosive or toxic tailings require expensive impoundments for long-term storage and disposal.

COMPARATIVE OPERATIONS – CCD AND AFP

The CS Mining (Milford, Utah) sulfuric acid copper leach mine processes about 3,000 tons per day (TPD) of oxide copper tailings. CS Mining employs a four-stage CCD circuit for solution recovery from the pregnant acid leach solution. The CCD circuit is comprised of a 90-foot diameter 1st thickener followed by three 65-foot thickeners. In contrast, the Minera Rio Tinto Copper Mine produces 1,000 tons per day of leach tailings that are dewatered using a single 2x2 meter AFP with 120 chambers. Tailings from the AFP are moved to heap leaching for further copper recovery.

Table 1. Summary of Design Factors

Parameter	CS Mining – CCD Copper Leach	Minera Rio Tinto – AFP
Ore Production (TPD)	3,000	1,000
Process	Four stage CCD	Single Automated Filter Press
Solution Recovery	91.7% (by solution balance)	88% (no cake rinse or cake blow employed)
Tailings Future	Acid slurry tails require lined impoundment for disposal	Dry stacking tails are moved to leach heap for further recovery

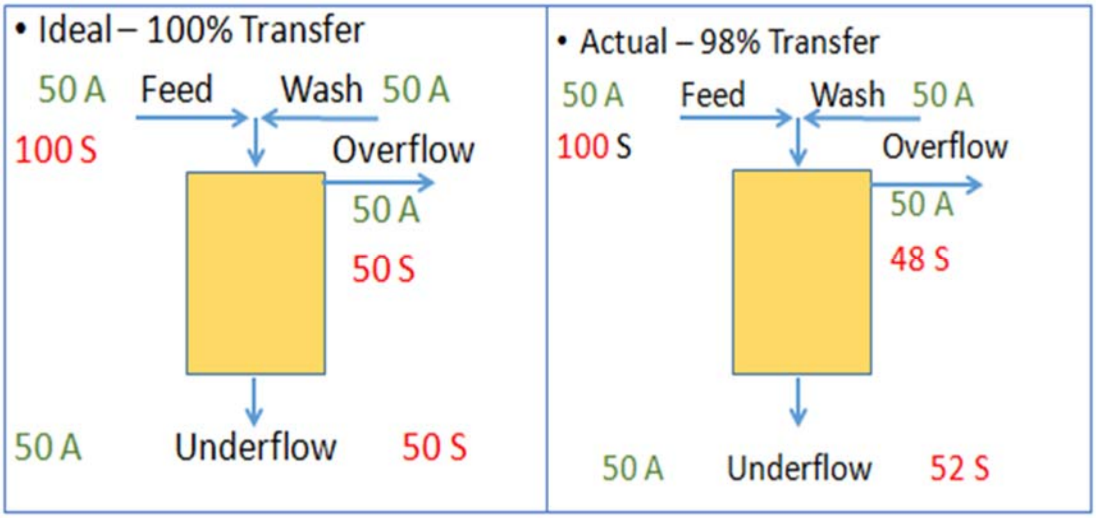
Note that in Table 1 the solution recovery (91.7%) for the CCD circuit is based on the solution balance alone. In practice, the solution recovery is also impacted by the mixing efficiency of the feed and wash solution for each stage plus the ***mass transfer coefficient*** (MTC) between the solid and liquid phases. The following section explains the Mass Transfer Coefficient as it pertains to thickener operations.

MASS TRANSFER COEFFICIENT & IDEAL RECOVERY

The MTC depends on the mineralogical composition of the slurry and represents the relationship between the retention and transfer time in the CCD circuit. For example, high clay slurries that require high dosing to create flocculation in high rate thickener designs are particularly affected by this parameter. This is due to the reduced diffusivity of the solute species from the flocculated particle. The MTC can have a significant impact on solution recovery within the CCD circuit and is often ignored in the design of a CCD circuit due to lack of representative testing.

The example in Figure 1 illustrates a single CCD stage with ideal and actual MTCs where green denotes the aqueous phase and red represents the dissolved copper portion. In both cases, the mixing efficiency is assumed to be 100% and the recovery lost is due to the incomplete transfer of the solute from the flocculated particle to the ***wash solution***; the wash solution being equal in volume to the aqueous portion of the feed slurry. In practice, the efficiency of a single thickener stage is a combination of both the mixing efficiency and the MTC.

Figure 1. Mass Transfer Coefficient, Ideal (left) and Actual (right)



A = Aqueous Phase, S = Dissolved Copper (Solute)

In this example, the feed-to-wash ratio is 1:1—meaning that an equal volume of barren wash solution is mixed with the feed solution prior to entering the thickener. In the ideal case, the copper in solution divides evenly between the aqueous phase and the overflow. In the actual case, the MTC is 98% which means 2% of the dissolved copper does not report to the aqueous overflow; consequently only 48% of the copper in the feed reports to the overflow. This is due to the time required for the dissolved species to diffuse out of the flocculated particles. The time allowed for diffusion is limited to the separation zone in the upper area of the thickener. Once the slurry enters the compression zone in the lower zone of the thickener, the majority of the dissolved species in the flocculated particles will report to the underflow. This is especially significant in highly flocculated clay ores since they are frequently encountered in copper, uranium and gold ore bodies.

For CCD circuits with perfect mixing and ideal transfer of dissolved species to the overflow, the recovery of a CCD circuit can be calculated by:

$$C_n = C_1 - C_w / 1 + WR^1 + WR^2 + \ldots\ldots + WR^n \qquad \text{Equation 1}$$

where:

- n : Number of stages in the CCD circuit
- C_n : Concentration in stage n
- C_l : Concentration in the slurry feed to the CCD circuit
- C_w : Concentration in the wash water
- WR : Wash ratio = wash water flow / aqueous phase of slurry liquor flow. (Ref. 3)

If the MTC is included in Equation 1, the numerator would be multiplied by the transfer coefficient to the n^{th} power, i.e.,

$$C_n = MTC^n \times (C_1 - C_w) / 1 + WR + WR^2 + \ldots\ldots + WR^n \qquad \text{Equation 2}$$

Even with a MTC as high as 99%, the impact would be 0.99^5—which would generate a 5% recovery loss in a five stage CCD circuit.

COMPARATIVE DESIGN FACTORS FOR CCD VERSUS AFP

In the following analysis capital costs for impoundment of slurry tails versus dry stacking tails and excavation for the footprint of the facilities are discussed briefly, but are not included in the cost comparisons because these parameters are site-specific.

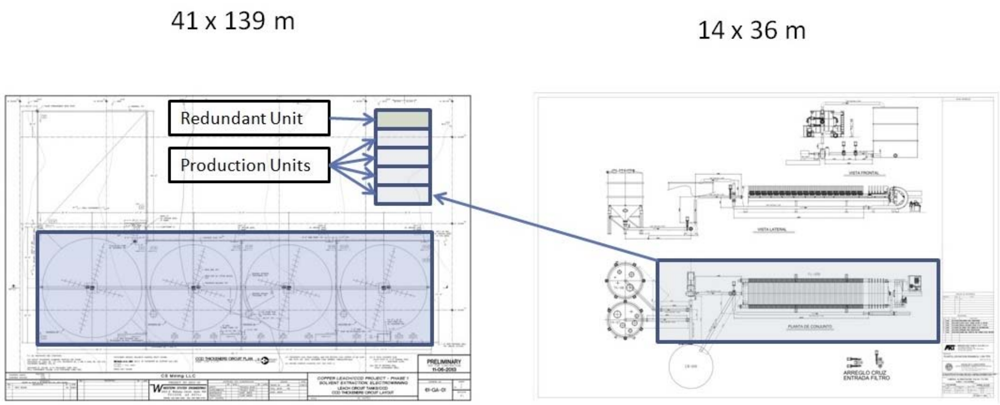
In the following comparisons, the MRT/AFP facility has been normalized to 3,000 TPD to match the throughput of the CS Mining CCD circuit. Table 2 shows the comparison of the footprint, loading and solution recovery parameters for CCD and AFP.

Table 2. Comparative Design Factors

Parameter	Counter Current Decantation	Automated Filter Press
Footprint	Large	Small
Loading	≈0.15 $MT/h/m^2$	0.4 to 0.6 $MT/h/m^2$
Solution Recovery	Restricted to wash ratio, mixing efficiency and MTC	Enhanced by cake wash and membrane squeeze

Comparative "footprints" for each facility are represented by the shaded areas in Figure 2. The footprint of the AFP installation has been scaled to match the CCD circuit and is superimposed on the CCD plot plan on the left. Four production and one redundant AFP units have been used to match the throughput rate of the CCD circuit. The feed and filtrate tank are not included in the AFP circuit; an AFP installation employing multiple presses and a common feed and filtrate system would be used for all the units.

Figure 2. Comparative Footprints of CCD and AFP



Clearly, one can see that the AFT footprint reduces the processing area footprint by about 85%.

Operation and Cost Comparisons

Operating factors such as series versus parallel operations, flocculent consumption, and mixing efficiency (the transfer efficiency between the solid and solution phases in the CCD circuit) are also important considerations.

Operating factors for the two approaches are listed in Table 3. The most significant factor between the two approaches is that the CCD system operates in series whereas the AFP operates in parallel. Parallel units facilitate the installation of a redundant spare, which in the case of the AFP guarantees 100% uptime. Catastrophic failure in a series system interrupts the entire operation. Consequently, the need for redundant spares for multiple underflow pumps and bypass systems increase capital and operating costs.

Table 3. Comparative Operating Factors

Factor	Counter Current Decantation	Automated Filter Press
Uptime	In-series system, one unit down effects entire line	Parallel units allow simple installed redundancy
Flocculent	0.7 kg/MT	Little to no reagents consumed
Spare Parts Inventory	Redundant pumps & bypass systems raise availability but with increased costs	Shared feed and filtrate tanks and pumps lower costs
Catastrophic Failure	Catastrophic failure of one thickener results in long down time for cleanout and repair	The possibility of catastrophic failure is essentially eliminated
Maintenance Cost	High	Low

Table 4 lists comparative costs for the two approaches. The most significant cost differential are the capital costs for the AFP circuit, which is 50 percent lower than CCD. This cost does not take into account other significant factors as listed in Table 4, such as excavation, permitting, impoundment and tailings closure costs. Excavation and impoundment costs also are increased significantly in mountainous terrain.

Table 4. Comparative Costs

Item	Counter Current Decantation	Automated Filter Press
Capital Cost	$14 million (installed)	$6 million (installed)
Excavation	Up to $9/m^3$ (Engineered cut and fill, steep terrain)	Approximately 1/10th the cost of CCD
Flocculent	$2.00 / MT	None
Pumping	4 times greater than	Feed and filtrate only
Maintenance	Significantly Higher	Significantly Lower
Permitting	Less favorable, high liabilities	Regulatory Acceptable
Monitoring	Long Term	Short-term closure possible

Flocculent cost is also significant and variable. High rate thickeners are particularly consumptive of flocculent, whereas the AFP requires little to no flocculation. Also, the cost of water in dry climates has not been included because it is a site-specific parameter.

SUMMARY

AFP is a more cost effective alternative for metal recovery from corrosive mineral slurries and is also a viable alternative for the recovery of water from all process waste tailings. AFP shows advantages in capital and operating costs and also provides more attractive auxiliary benefits including:

- Allows dry stacking tails
- Enhanced regulatory approval for new projects
- Higher solution recovery
- Greatly reduced footprint
- Low downtime and reduced maintenance cost

CONCLUSION

AFPs have dropped in cost, are more readily available and offer a host of advantages over Counter Current Decantation for solids recovery from corrosive slurries. AFP technology should be included in feasibility studies for tailings disposal in any new mine design. AFPs can also contribute significantly to solving disposal problems on existing mine sites.

With reduced capital costs and high capacity per unit, AFPs have gained acceptance as a viable alternative to CCD in the mining industry for the production of dry stacked tailings. Examples of mines employing filtration and dry-stacking for tailings disposal are:

- Minera Rio Tinto – 1,000 TPD copper leach in northern Mexico
- Efemcukura – Gold cyanide leach in Turkey
- Mantos de Oro La Coipa in Northern Chile
- Green's Creek – Silver/Cyanide leach in southeast Alaska

Additional benefits of dry-stacked tails are reduced risk and liability, greater pubic and regulatory acceptance and reduced closure costs. The recent failure of the Mount Polley Mine tailings impoundment in British Columbia (Ref. 4), among others, has again focused regulatory attention on alternative disposal techniques such as the AFP approach using below-grade disposal. Closure costs and ongoing monitoring costs are reduced through utilizing a dry-stacked tails facility. And AFP allows for smaller tailings impoundments and constructability in steep terrain and high seismic areas.

REFERENCES

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