GOLD RECOVERY FROM COPPER GOLD GRAVITY CONCENTRATES USING THE INLINE LEACH REACTOR AND WEAK BASE RESIN

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ABSTRACT

Gekko Systems has developed a process, using its InLine Leach Reactor, to recover gold metal from a complex gold copper gravity concentrate produced by Hargraves Resources at Brown’s Creek. The process involves intensive cyanidation under controlled conditions followed by gold recovery onto Aurix®, a proprietary weak base resin. The resin selectively recovers gold from the mixed gold copper leach solution. The loaded resin is stripped with caustic solution in a single step to provide a solution for electrowinning. From a concentrate containing about 15000 ppm gold and 6% copper, over 95% of the total gold will be recovered into an 80% gold bar.

BACKGROUND

Hargraves Resources operates a gold copper mine at Brown’s Creek, NSW, Australia. The mine treats 450,000 t/y of ore containing 5.6 g/t gold and 0.4% copper, producing about 72,000 oz/y of gold and 1500 t/y copper using a mixture of gravity and flotation. Overall gold recovery is about 90%.

The mill has a gravity recovery circuit comprising one 30 inch Knelson treating screened cyclone underflow. This produces a high grade gold concentrate containing 1 to 4% gold and 5 to 7% copper, which is upgraded on a table with recoveries of about 70%. This gravity circuit recovers about 50% of gold in feed. The table tails are returned to the mill and eventually pass into flotation where gold recovery is approximately 80%.

Gold recovered in flotation is about 40% of mill feed, however payment terms for the concentrate represent considerable operating and capital costs for the operation. Gold in concentrate attracts a 2% treatment charge and late payment which, at AUD$450/oz, represents about AUD$290,000 /y treatment costs and AUD$1.8M in operating capital. This is a considerable economic incentive to maximise gravity gold recovery.

There is considerable potential to increase gravity gold recovery. This is shown by the observed increase in cyclone overflow and flotation tail grade as table tails are returned to the mill circuit. Furthermore, both coarse and fine free gold is observed in the flotation tails. This shows a portion of gold in table tails escapes both the mill circuit and the flotation circuit. So reducing gold in table tails by increasing recovery from the Knelson concentrate will certainly increase gravity gold. Furthermore the presence of free gold in final tails clearly shows the potential to increase overall gold recovery.

The InLine Leach Reactor (ILR) is designed and manufactured by Gekko Systems to obtain high gold recoveries from gravity concentrates by replacing tabling with a fully automatic intensive cyanidation
reactor. The commercial development and installation of the ILR has been described by Gray and Katsikaros (1999) and Lewis (1999). The potential at Brown’s Creek to produce more gravity gold was recognised by the Mill Superintendent, Paul Fallon, and an experimental program undertaken.

**PROCESS DEVELOPMENT**

The high levels of copper in the concentrate were immediately recognised as having potential to reduce gold recovery and increase reagent costs. Mineralisation was known to be a mixture of bornite and chalcopyrite and it was unclear how the copper minerals would behave during intensive cyanidation. As a result two flowsheets were initially considered.

One involved pre-leaching with ammonia and ammonium sulphate to remove copper followed by cyanide leaching of the gold. The second flowsheet involved intensive cyanidation of the concentrate, absorbing the gold onto resin to reject the copper if necessary, then electrowinning the gold from the strip solution.

Initial leach tests showed that the ammonia leaching route was not effective in completely removing the copper, with less than 25% being leached. Furthermore the residues, when cyanided, gave low gold recoveries of about 10% and high reagent consumption in the subsequent cyanide leach.

In contrast initial direct cyanidation tests gave variable gold and copper recoveries up to ~70% without prohibitive reagent consumption. So the direct leach option was selected for further investigation. This also had the added advantage of a simpler flow sheet with fewer unit operations and reagents.

As well as high gold recoveries in leaching it was necessary to develop an effective method to recover the gold from leach solutions containing high levels of copper.

Published data presented by Virnig et al (1996) shows gold can be selectively absorbed onto Aurix® resin while largely rejecting the copper. Aurix® is a proprietary weak base resin manufactured by Henkel. The advantages of Aurix® for this application are its selectivity for gold over copper and the simplicity of stripping the gold directly into a caustic solution suitable for electrowinning.

**EXPERIMENTAL**

The aim of the experimental work was to establish robust operating conditions, yielding high recoveries, and to understand the effects of major operating parameters, rather than to optimise the process for any particular sample of concentrate. It was recognised early that the high economic value of the concentrate meant the economic optimum would be primarily determined by gold recovery rather than reagent addition or unit efficiency.

Testwork was performed by Gekko Systems, Ballarat, Victoria and by Metallurgy International, Castlemaine, Victoria.

**Leaching**

Gravity concentrate samples were obtained from Brown’s Creek and used in a series of tests to investigate gold and copper leaching under intensive cyanidation conditions. Tests were conducted in rolling bottles with solution samples taken during the leaches to establish gold and copper leaching kinetics and reagent consumption. Oxygen addition, when used was added directly to the bottle.
Tests investigated the effect of cyanide level, oxygen addition, lead nitrate addition and LeachWell addition. In the following discussion the effect of various conditions and reagents are investigated however the exact test conditions used are Gekko Systems proprietary information and not disclosed.

The effect of increasing either the cyanide level or of adding oxygen was to increase the kinetics of both copper and gold leaching. Without oxygen addition gold recoveries were lowered.

The effect of lead nitrate addition was to increase gold leach kinetics and suppress copper leaching. However the magnitude of the effect varied considerably resulting in a range of gold recoveries being measured. The lead nitrate is believed to suppress leaching of sulphide minerals resulting in higher free cyanide and a more favourable gold leach potential.

LeachWell had a similar but much more pronounced effect on leach kinetics, leading to a marked increase in gold leaching and slowing of copper dissolution. This appears to be due to a more effective delivery of the active reagents to the reaction site.

The effect of LeachWell addition is illustrated in the figures below. Figure 1 shows leach kinetics where the concentrate was leached using a stoichiometric excess of cyanide, relative to complexing all copper in the feed as \( \text{Cu(CN)}_4^{2-} \), with lead nitrate and oxygen addition. It is seen that copper leaching is rapid, reaching 94% in 6 hours, while gold leaching appears linear, reaching 98% after 24 hours. Cyanide levels were monitored and maintained, allowing cyanide consumption to be monitored. Cyanide consumption corresponded to copper leaching, and may have been limiting in the first few hours. In similar tests, with lower cyanide additions, results showed similar trends but with lower recoveries, especially for gold.

Figure 2 shows typical leach results where LeachWell was used as well as lead nitrate and oxygen, and at a lower level of cyanide. This results in a virtual reversal of the copper and gold kinetics with gold leaching reaching 98.4% at 4 hours and 99.8% at 24 hours. Copper leaching quickly goes to 20% then slowly rises to about 50% at 24 hours. It is clear that the use of LeachWell has resulted in a suppression of copper leaching and an acceleration of gold leaching. Furthermore cyanide consumption was reduced by a factor of about 3.5.

![Graph showing leach kinetics with LeachWell](image)

**FIGURE 1. Leach Kinetics with Very High Cyanide, without LeachWell.**
Resin Loading.

Solutions from the leach tests contained up to 11 g/L copper and 5 g/L gold. These solutions were unsuitable for direct electrowinning due to the high levels of copper and the presence of LeachWell which is known to slow electrowinning, as noted by Lethlean (1999). To produce a solution suitable for electrowinning the solutions were contacted with Aurix® resin which was then stripped with a caustic solution.

Loading tests were carried out at room temperature by agitating solutions with resin at 200g resin/L solution. To maximise resin selectivity pH is maintained at 13.1. Typically ~95% of gold and only 5% of copper was absorbed after an hour of contact time. A typical absorption curve is shown in Figure 3.

Resin loadings can be very high. Loadings varied up to 30,000 ppm gold in some tests; however loadings will be kept to about 10,000 ppm in practice.

Resin Stripping.

At full scale stripping of loaded resin is performed by recirculating strip solution in a closed loop with electrowinning at 60°C. At laboratory scale this is simulated in a three step batch strip at ~100 g resin/L where the resin is contacted with three batches of fresh strip solution containing 40 g/L NaOH and 140 g/L sodium benzoate.

Typical results are shown in Figure 4. About 85% of gold and all the copper are stripped from the resin under these conditions, with most of the stripping occurring in the first batch. The gold which is not stripped remains on the resin as a recirculating load, raising the total gold loading but not lowering the overall gold recovery for the full scale process.
In a combined strip electrowinning circuit stripping is expected to be higher. This is because the gold is being continually removed from solution by electrowinning so the driving force for desorption is greater. In another series of tests on a different material stripping recovery improved from 83% in batch tests to 98.5% in a simultaneous strip electrowinning test.

These results show that, in the worst case where all copper loaded is stripped and electrowon, the final gold bar produced will have a gold to copper ratio of about 5:1, or about 85% gold.

![Figure 3: Loading Kinetics of Gold and Copper onto Aurix® Resin.](image-url)

*Figure 3* Loading Kinetics of Gold and Copper onto Aurix® Resin. (200g/L resin, 25°C, pH 13.1)

![Figure 4: Batch Resin Stripping Results](image-url)

*Figure 4* Batch Resin Stripping Results
(100g/L resin, 58°C, 40g/L NaOH, 140g/L NaBenzolate)
PLANT DESIGN

The proposed plant flowsheet is shown in figure 5. The design is for an InLine Leach Reactor, model ILR100, followed by resin columns and a standard electrowinning cell.

In the InLine Leach Reactor the concentrate is de-watered, mixed with fresh reagents and recycled stripped liquor from the resin columns, then leached in the rotating drum. Leached slurry overflows into the solution recovery section where the solids are recovered and clarified pregnant solution is pumped to the resin columns. The resin columns will be operated in split cycle; one column will load while the next is stripped and electrowon at elevated temperature.

Several tailings options are possible including:
- precipitating copper with sulphide or polysulphide and adding to the concentrate settler.
- electrowinning copper from solution, which also recovers some cyanide.
- disposal into the main tailings stream.

As well as treating the current Knelson concentrate the plan is to increase recoveries into gravity by shortening the dump cycle. The plant will initially operate at ~50kg/h but has the capability to operate at up to 120 kg/h at an 8 hour residence time. This will allow the Knelson concentrator to be operated at its shortest dump cycle time to increase the recovery of gold into the gravity circuit.

**FIGURE 5 Simplified Process Flowsheet**
ECONOMICS

The economic benefit of the process is dependant on the amount of extra gold reporting to gravity and any increase in overall plant recovery. The economic analysis that follow are approximate with capital costs and benefits annualised over two years.

The capital cost is estimated at about AUD$300,000 not including the electrowinning cells which are available on site. Operating costs are estimated at about AUD$3.50/oz. These costs are dominated by reagent costs which are yet to be optimised.

For the conservative case where there is no overall increase in recovery, the economic breakeven occurs when gravity recovery is increased to 60% of the feed. At this point the savings in working capital and refining charges balance the capital and operating costs of the new system. A 60% gravity recovery would be predicted if, in the current flowsheet, half the current table tail leaves the milling circuit but is completely recovered in flotation.

For Brown’s Creek, given the observed behaviour of cyclone overflow and flotation tails when returning table tails to the circuit, it is likely that some increase in overall recovery will be realised. Given an increase of 2% to 92%, the benefit will be about AUD$0.7M/y.

The potential of this process can be seen if we consider a hypothetical plant where gravity recovery is limited by the size of the Knelson concentrator. In this case the gravity recovery would rise to about 70% of gold in feed. With no increase in overall gold recovery this would be worth AUD$0.25/y. If gold recovery in flotation was maintained at 80% the overall gold recovery would rise to 94% and the economic benefit would be AUD$1.7M/y.

At Brown’s Creek a benefit of approximately AUD$0.5M/y can be predicted.

CONCLUSION

Gekko Systems has developed a simple, robust process for the recovery of gold from high soluble copper concentrates. The process uses proven technology combined with advanced resin technology: the InLine Leach Reactor and Aurix® resin. The process chemistry of concentrate leaching, resin loading and resin stripping has been demonstrated at laboratory scale and can be predictably scaled up. The use of LeachWell is critical in controlling the leaching.

When installed at Brown’s Creek Gold Mine the process will reduce operating capital, reduce concentrate treatment charges and is likely to increase overall recovery, which could give a benefit of AUD$0.5M/y.

REFERENCES