GOLD RECOVERY FROM GOLD COPPER CONCENTRATES USING THE INLINE LEACH REACTOR AND AURIX® RESIN

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ABSTRACT

Gekko Systems has developed a process using its InLine Leach Reactor and Aurix® resin to recover gold dore from gold copper gravity concentrates. This process makes it possible to improve recoveries and reduce costs in gold copper deposits where gravity concentration can recover a significant fraction of the contained gold or copper prior to further processing by CIP or flotation. The process involves leaching under controlled intensive cyanidation conditions followed by selective gold absorption from the mixed gold copper leach solution onto Aurix® resin. The loaded resin is stripped by a recirculating caustic solution in closed circuit with electrowinning resulting in good quality gold dore. When treating a gravity concentrate produced at Brown’s Creek Gold Mine, in Australia, containing 2% gold and 6% copper; over 95% of the total gold could be recovered into 80% gold dore.

INTRODUCTION

Copper gold ores often have complex mineralogical and chemical characteristics, demanding innovative and complex processing solutions. The extension of Gekko System’s intensive cyanidation technology to gold copper concentrates gives operators a new processing option for these materials.

Gekko Systems specialises in the design, development and implementation of innovative mineral processing equipment and processes with a particular focus on gravity separation. 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 secure, fully automatic, intensive cyanidation reactor. The commercial development and installation of the ILR has been described by Gray and Katsikaros (1999) and Lewis (1999).

Aurix® resin is a proprietary weak base resin developed by Henkel and described by Virnig et al (1996). This resin is highly selective for gold over many metals, including copper, and is stripped by strong caustic solution from which the gold can be easily electrowon using conventional cells. The chemical selectivity and simplicity of the final circuit makes Aurix® the logical choice for gold recovery from these solutions.

In principal the process is an extension of the general JAG circuit concept developed by Gekko Systems and described by Gray. The JAG concept involves the production of a gravity concentrate from the mill circuit containing valuable and/or difficult to treat minerals, which is intensively leached to recover the valuable minerals prior to disposal of any problem minerals.

For many gold copper ores production of a gravity concentrate from the mill circuit results in the recovery of much of the gold or copper into a relatively small stream. The remaining material can then be economically treated to recover the remaining minerals; generally by CIP or flotation.

The incentives to do this vary depending on the ore and downstream processing. Where the ore is to be treated by CIP the reduction of copper in mill feed generally increases gold recovery and decreases processing costs. Where the copper and gold is to be recovered by flotation the overall recovery of coarse and free gold is increased and the treatment charges and payment terms are improved by selling gold dore rather than concentrate.

Obtaining full value for the gold contained in the gravity concentrate, to date, has been a problem. Direct sale of the concentrate results in significant costs due to treatment charges and delays in payment; tabling often results in relatively low gold recovery to dore. The process developed by Gekko Systems now makes it possible to obtain a high recovery of gold into dore, maximising the benefit obtained by producing a coarse gravity concentrate.

PROCESS DESCRIPTION

The process involves four steps:
1. Production of a gravity concentrate from the mill circuit.
2. Intensive cyanide leaching of the concentrate in an InLine Leach Reactor.
4. Stripping and electrowinning of the gold from the Aurix® resin to give gold dore
5. Disposal or recovery of the dissolved copper from a bleed stream of barren leach solution.

The gravity concentrate is usually taken from the cyclone underflow and can be produced by a range of concentrators depending on ore mineralogy and yield of concentrate required to obtain the targeted processing benefits. The
InLine Pressure Jig (IPJ), described by Gray and Mooney and Gray, is an advanced jig developed and manufactured by Gekko Systems and is ideal for recovering most heavy minerals such as gold and sulphides or if the process requires higher concentrate yields of 1% to 10%. The higher yield allows maximum processing advantage by maximising recovery of both gold and copper. A continuous centrifugal concentrator could be used where mineralisation is very fine and medium yields are required. Batch centrifugal concentrators are suitable if it is possible to concentrate all the target minerals into a very small mass of concentrate. This might be the case if the aim was to recover only free gold from an otherwise gold free copper ore.

The remaining process steps are shown for a typical flowsheet in figure 1.

![Typical Process Flowsheet](image)

**FIGURE 1**

**Typical Process Flowsheet**

The gravity concentrate is leached in the InLine Leach Reactor under controlled conditions. The concentrate is de-watered, mixed with fresh reagents and recycled barren solution from the resin columns, then leached in the rotating drum. The leach conditions in the ILR are controlled to maximise gold dissolution while minimising copper dissolution. Because of the high grade of material being treated far more aggressive leach conditions are economically feasible and gold recoveries of over 95% can be obtained in most cases. Leached slurry overflows to the solution recovery section where the solids are recovered and clarified pregnant solution is pumped to the resin columns. The solids can be returned to the mill or pumped directly to tails, depending on the application. The ILR is available in a range of sizes to suit the application, from under 1 t/day to 10 t/h or more.

Gold is selectively absorbed onto Aurix® resin at controlled pH. Gold and copper can be loaded onto the resin at a ratio of ~5:1 from solutions containing thousands of ppm of copper. The pH is controlled to minimise absorption of copper without slowing gold absorption. The of the resin columns depends on the gold production, absorption kinetics and loading. Typically two or three columns holding 2-5 t of resin would be used. The columns are operated in a sequenced split cycle with one or two columns loading while the other is stripped. The column column operation is automatically rotated from load to strip on a regular cycle.

Stripping and electrowinning the gold from the loaded resin is performed at elevated temperature (~60C) by pumping high caustic solution in closed circuit from the electrowinning cell through the columns and back to the cell. Stripping efficiency can be improved by the addition of sodium benzoate, to increase the hydroxide ion activity. Electrowinning efficiency is relatively high due to the high solution grades and elevated temperatures. The electrowon gold is easy to recover and smelt and generally a purity of at least ~80% Au is expected.

Some or all of the dissolved copper is removed as a bleed stream from the circulating solution to control the concentration in solution. Otherwise it would build up to a level where resin selectivity is lost. Several options are possible depending on the specific application and amount of material to be treated. The simplest option, suitable where only a small yield of concentrate is treated, is direct disposal into the main plant tailings, with or without prior neutralisation. Alternatively, if copper is being recovered by flotation from the main stream, the cyanide could be destroyed and copper precipitated with sulphide or polysulphide before being added to the concentrate thickener to recover the copper values. An alternative way to recover the copper values is by electrowinning, either directly from the solution or after absorption onto resin at lower pH. The choice between these alternatives must be made on an economic basis and is highly dependant on the size of the bleed stream and the value of the contained copper.

Finally the entire plant is continuous and fully automated, requiring little or no operator intervention. All functions are controlled and monitored by a dedicated PLC that can communicate with the main plant SCADA system. This means labour and operating costs are minimised while plant availability is maximised.

**CASE STUDY – BROWN’S CREEK**

Much of the detail of Gekko Systems process was developed in response to a particular application at the Brown’s Creek Gold Mine at Brown’s Creek, NSW, Australia. The development and application of the process has been reported in detail by Gray et al (1999). Since publication the mine has been shut due to flooding of the pit.

**Background**

Hargraves Resources operated the gold copper mine, treating 450,000 t/y of ore containing 5.6 g/t gold and 0.4% copper, and produced about 72,000 oz/y of gold and 1500 t/y copper using a mixture of gravity and flotation. Overall gold recovery was about 90%. The gravity circuit recovered about 50% of gold in feed and comprised one 30 inch Knelson...
treated as a new source of copper concentrate and an experimental program undertaken by Gekko Systems, Ballarat, Victoria, and by Metallurgy International.

Process Development

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. The alternative flowsheet, involving preleaching with ammonia and ammonium sulphate, was soon discarded due to low gold recoveries and very high reagent additions in favour of using intensive cyanidation followed by Aurix® resin. 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.

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

Leaching

Gravity concentrate samples were obtained from Brown’s Creek Gold Mine and used in a series of tests to investigate gold and copper leaching. Tests were conducted in rolling bottles with solution samples taken during the leaches to establish gold and copper leaching kinetics and reagent consumption.

Tests investigated the effect of cyanide level, oxygen addition, lead nitrate addition and LeachWell addition.

High cyanide and oxygen levels were required for good gold leaching kinetics. Without oxygen addition gold recoveries were low.

The effect of lead nitrate or LeachWell addition was to increase gold leach kinetics and suppress copper leaching, with LeachWell having a much more pronounced effect. The lead nitrate is believed to suppress leaching of sulphide minerals resulting in higher free cyanide and a more favourable gold leach potential. It appears that LeachWell was more effective in delivering the active reagents to the reaction site.

The effect of LeachWell addition is illustrated in the figures below. Figure 2 shows leach kinetics where the concentrate was leached using a stoichiometric excess of cyanide, relative to complexing all copper in the feed as Cu(CN)₄²⁻, with lead nitrate and oxygen addition. Copper leaching was rapid, while gold leaching appears linear. Cyanide levels were monitored and maintained, allowing cyanide consumption to be monitored. Figure 3 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 rapid complete gold leaching and relatively slow copper leaching. It is clear that LeachWell suppressed copper leaching and accelerated gold leaching. Furthermore cyanide consumption was reduced by a factor of about 3.5.

![FIGURE 2](image-url)

**FIGURE 2**

Leach Kinetics with High Cyanide and no LeachWell

Fast Copper, Slow Gold.
Resin Loading

Solutions from the leach tests contained up to 11 g/L copper and 5 g/L gold. Resin loading tests were carried out at room temperature by agitating solutions with resin at 200g resin/L solution. To maximise resin selectivity pH was 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 4.

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 to maximise loading kinetics.

Resin Stripping and Electrowinning

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 at ~60°C.

Typical results are shown in Figure 5. 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.

Initial batch electrowinning tests with the strip solutions showed electrowinning was rapid and complete. Over 95% gold recovery was obtained in 20 minutes.

In a combined strip electrowinning circuit stripping is more efficient due to the gold is continually being removed by electrowinning increasing the desorption driving force. 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.

Closed Loop Continuous Tests

Following the batch testwork continuous tests were run using Gekko Systems bench scale ILR. The circuit was set up to mimic the proposed full scale design including continuous solids feed, full solution recycle, cycled resin operation and a continuous closed electrowinning circuit. An 8 hour leach residence time and 6 hour resin cycle time was used.

Figure 6 is a photo of the bench scale unit showing, from left to right, vibrating feeder, reactor drum (behind), Resin column (front), tails settling cone (above), screen and sump (below). The unit is capable of treating approximately 100g/h at 24 hours residence time, or 8 hours residence time with blanking rings fitted.

Generally results of batch testwork were confirmed with gold leaching of up to 98%. Continuous operation of the ILR and resin loading, resin stripping and electrowinning were demonstrated.

Unfortunately, following the closure of the mine, there was insufficient material to complete tests to optimise the long term behaviour of the circuit.
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 follows is 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 assuming no increase in overall recovery, the economic breakeven occurred if gravity recovery increased to 60% of the feed. At this point the savings in working capital and refining charges would balance the capital and operating costs of the new system. If half the current table tail left the milling circuit and was completely recovered in flotation and if this was leached to 95% in the ILR then a 60% gravity recovery would be realised.

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 would be about AUD$0.7M/y. At Brown’s Creek a benefit of approximately AUD$0.5M/y was predicted.

The potential of this process for other mines can be seen if we consider a hypothetical plant of the same performance 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.

The incentive for many operations could be higher since the table recovery of gold was relatively high at 70%. If the table recovery at Brown’s Creek was 50%, which is typical of many operations treating sulphide associated ore, the economic incentive could as much as double.

SUMMARY

Gekko Systems has developed a simple, robust process for the recovery of gold from high copper concentrates. The process uses Gekko System’s proven intensive cyanidation technology combined with advanced resin technology: the InLine Leach Reactor and Aurix® resin.

The process gives operators treating complex gold copper ore bodies another option to increase recovery and reduce costs. This is to produce a high grade concentrate containing difficult to recover gold and/or copper minerals followed by intensive cyanidation resulting in high recovery to gold dore.

Using concentrate from the Brown’s Creek Gold Mine the closed circuit process chemistry has been demonstrated at laboratory scale and can be predictably scaled up. The use of LeachWell was critical in controlling the leaching. For this application the process would reduce operating capital, reduce concentrate treatment charges and increase overall recovery, which would have given a benefit of AUD$0.5M/y.


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