Improved Gold Recovery Economics at Target Gold Mine, South Africa

“Gravity Concentration 04, Perth March 2004”

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ABSTRACT

Target Gold Mine in South Africa, was commissioned as a brownfields operation starting in November 2001. Target took the decision to pioneer the use in Southern Africa of Gekko Systems’ InLine Leach Reactor to treat gravity concentrate and the first ILR100BA produced by Gekko Systems was installed at Target gold mine.

The gravity circuit was afforded a low priority by the commissioning engineers during start up, as the plant’s leach and adsorption circuits were designed to handle a feed grade of approximately 12 ppm. During the commissioning of the Inline Leach Reactor (ILR) minor problems were encountered in the form of pipe blockages, process water issues and low gold dissolutions. Once these commissioning issues were resolved jointly between Gekko and Target, the unit began achieving consistently good recoveries, allowing the manual tabling operations to cease, saving the company significant costs in toll treatment of table tails and improving refinery security.

Once the unit was commissioned, optimisation test work followed, including; reducing reagent consumptions, tailoring of process time to suit plant operations and comparisons between alternative oxidants.

The ILR now achieves consistent recoveries in excess of 98% at around US$0.70/oz recovered, with an additional recovery of 4871 ounces since commissioning resulting in a capital payback of approximately six weeks.

KEYWORDS

Gravity concentration, intensive cyanidation, leaching, increased recoveries and cost reduction.

INTRODUCTION

Background to the Target Project

Target is a new underground gold mine located in the Free State province of South Africa. Target is the northernmost point of the Free State mines and is North of the old...
Loraine Gold Mines (LGM). The ore mined is typical deep level Witwatersrand ore with a mill feed grade of 10 ppm. Target’s design philosophy was to move away from the old labour intensive design to a low labour complement at higher skill level.

Along with the initial milling test work in 1998 some primary gravity test work had been conducted. Due to the quantity of sample available and the quantity required to conduct test work, no secondary gravity test work was conducted before the plant design commenced.

Later during the detailed design some gravity results became available via the Loraine Gold Mine plant. This was in the form of basic generic leach tests conducted on gravity concentrates. There was a project time constraint, preventing the supply of samples to the various vendors to provide process guarantees.

The Target mine was planning to mine two reefs, Dreyerskuil and Elsburg. Mineralogical indications were that the free gold characteristics of these two ore bodies were very different. The order in which these reefs were to be mined changed once better rock mechanical information was made available. By this time the Target gold plant design was underway and changes had to be made to include the gravity circuit upfront rather than adding on at later stage.

As a result of the gold theft problem in the gold mining industry the design philosophy was to minimize the physical handling of gold concentrates. This implied that the traditional shaking table was not the equipment of first choice.

During the design it was decided to treat only 20% of the new feed stream through the primary bowl centrifugal concentrator because of the capital cost of gravity circuits.

The “low grade” leach and CIP circuits were designed such that the efficiency would not drop even if the gravity circuit was off line for a few days.

**Background to gravity and intensive cyanidation**

The last two decades has seen a resurgence in the recovery of gold using gravity - often in conjunction with a conventional Carbon-In-Pulp (CIP) or Carbon-In-Leach (CIL) circuit. Generally the gravity gold concentrates are high-grade with gold grades of 5,000 ppm and with relatively low mass at 0.03%\(^1\) of the plant feed. Bowl Centrifugal Concentrators (BCC’s) such as the Inline Spinner, Falcon and Knelson Concentrators invariably produce the gravity gold concentrates although flotation may also be utilized.

Treatment of these high-grade concentrates has usually been through amalgamation with mercury (a process route that has lost favour due to environmental and safety concerns) or by a second stage of gravity treatment commonly utilising tabling or a related process. In particular the tabling of gravity concentrates was proven to offer very low recoveries, often between 30% and 60%, much lower than expected by the mine sites operating these devices.

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\(^1\) Based on Target plant figures for the 2003 calendar year.
The research indicated that tabling was clearly a “below optimum” process. It was regarded as inefficient to achieve high recoveries in a high gravitational force unit like a centrifugal concentrator only to lose it in the next metallurgical process. Research also showed that the tabling of concentrates in a number of circuits resulted directly in instantaneously high cyclone overflow grades when the table middlings and tails are returned to the milling circuit and subsequent losses from the leach circuit to tails. This behaviour is illustrated in figure 1, which indicates the cyclone overflow grade of a Western Australian mine site and figure 2, which indicates the leach feed grades for Target Gold Mine as the Knelson concentrator bowl started to wear. Due to the classification characteristics of a hydrocyclone, misplacement of coarse gold particles to the cyclone overflow will occur. Particles that may not be dissolved prior to discharge to tails resulting in reduced recoveries and higher tail grades.

![Figure 1: Cyclone Overflow Grades During Tabling](image-url)
Intensive cyanidation is proven technology that gives high recoveries from gravity gold concentrates - this was achieved by either a high-speed agitator in a tank or vat leaching. Both methods had their problems due to either excessive wear and high energy requirements for the agitated systems or channeling of solution and loss of fine gold in the vat type systems, resulting in poor recoveries.

In 1997 Gekko Systems Pty Ltd introduced the Inline Leach Reactor - the first were continuous units and treated the gravity concentrates from either batch type concentrators or continuous concentrators such as jigs or flotation. An important breakthrough for the Inline Leach Reactor came with the introduction of the technology into the African market where the security issue created a compelling event. The Batch Inline Leach Reactor was subsequently developed to treat smaller masses of gravity concentrates than the continuous system.

Why Intensive Cyanidation?
Although there are a number of reasons why each mine site and organisation is attracted to this technology there are certain key factors, which include:

- Significant Gravity Recovery Improvements
- Proven Chemistry
- Security
- Safety
- Increased overall plant recovery

There are currently over fifteen mines worldwide using Inline Leach Reactors for intensive cyanidation of gravity gold concentrates. These include both batch and continuous units.
Significant Gravity Recovery Improvements

For this process to be viable it is necessary to reliably obtain high recoveries from the gravity concentrates - in excess of 97%. The only proven technology giving high gold recoveries from the gravity concentrates is intensive cyanidation coupled with either direct electrowinning or carbon adsorption.

Proven Chemistry

The chemistry of cyanidation is proven and well known with the majority of gold operations world wide using the process. Cyanidation as a process has been used for the extraction of gold since 1890. The reaction for leaching of gold is known as Elsner’s equation:

\[ 4Au + 8NaCN + O_2 + 2H_2O \rightleftharpoons 4NaAu(CN)_2 + 4NaOH \]

Oxygen is a critical reagent in the reaction and is provided either from atmospheric oxygen, hydrogen peroxide or gaseous oxygen. The level of dissolved oxygen required is determined from the initial test work and confirmed during plant commissioning.

Intensive cyanidation, typically using cyanide levels of 2% (2000 ppm), requires no exotic chemicals or materials and uses standard process operations. At these levels of cyanide the safety procedures currently used around a CIP/CIL refinery are readily applicable with only minor modifications.

Security

With no requirement for manual handling of the gravity gold concentrates and the harsh leach conditions, coupled with enclosed drum design a high level of security is obtained. Commonly the units are fenced or bricked off separately from the rest of the plant.

Safety

The generation of toxic fumes during the calcining and smelting process is minimized. Since there is no contact with what are commonly high sulphide materials the incidence of skin problems is also negated.

Why Gekko and why the ILR?

When the Target Gold Plant was originally designed the gravity circuit was designed in such a way that the concentrate from the Knelson Concentrator would have been processed over a series of Gemini tables to produce a final concentrate that could be smelted. However, due to the security risk that is normally associated with concentrate handling around tables and the presence of arsenic in the table feed it was decided to replace the Gemini tables with a leach reactor. The high intensity leach circuit was thus selected over tabling for the following reasons:

- High intensity leach is a hands off device and was in line with the required security philosophy
The smelting of the cathode sludge from the electrowinning circuit was cleaner and required less gas cleaning than the smelting of concentrates from the tables, containing relatively high levels of arsenic and lead originating from the ore.

The Gekko In Line Leach reactor was selected for the following reasons:

- The plant was very compact and could fit into the smelthouse.
- A local Gekko office with a support team had been established in South Africa.
- Gekko had other successful plant scale installations in Africa.

Although no test work had been conducted by Gekko and hence no process guarantees could be offered, there was enough confidence in the product and the supply company to install it at risk.

**FACTORS AFFECTING ECONOMICS ON START-UP**

Factors that had an influence on the economics of the gravity circuit during the start-up of the plant and the months that followed until the ILR was commissioned were:

- The low priority that was given to the gravity and ILR circuits
- Resistance to change of the refinery operators
- The cost of tabling

**The low priority given to the gravity and the ILR circuits**

As has been mentioned earlier, the leach and adsorption circuits on the plant were designed in such a way that they could cope with the additional gold when the gravity circuit is off line. As a result of this it was decided to only start-up the gravity circuit once the rest of the plant had been commissioned.

During the commissioning of the Target plant, the Loraine plant was still processing Target ore in order to ensure that there was sufficient cash flow for the mine and as a backup facility in case something went wrong on the Target plant during the commissioning. On the Loraine plant the gravity circuit consisted of a Knelson concentrator and a Gemini table to process and upgrade the Knelson concentrate. As this facility was available it was initially decided to process the concentrate from the Target plant’s concentrator over the Gemini table in the Loraine plant. This delayed the commissioning of the ILR even more. It was thus three months after the plant was commissioned that the ILR was commissioned.

**Resistance to change of the refinery operators**

The two operators working in the refinery at the Target Gold plant, also worked in the refinery at the Loraine Gold plant, where they processed the Loraine and Target concentrates over the same Gemini table. They were thus experienced in operating the table. Given the fact that there were the normal commissioning problems with the ILR (blockages etc.) when it was initially commissioned and that the two operators where regularly called out after hours and over weekends to fix these problems it is only logical to expect that they would prefer to process the concentrates over the Gemini table.
during working hours than use the ILR. It was only after most of the problems were sorted out that the refinery operators became more familiar and comfortable with the operation of the ILR.

- **The cost of tabling**

Although there are a number of components that contributed towards the cost of tabling i.e. labour, water and electricity none of them contributed as much as the toll treatment cost that the mine had to pay Rand Refinery to process the table tails in order to recover gold.

Initially the tails from the Gemini table was returned to the milling circuit, but due to the impact on the rest of the circuit and the fact that a large quantity of the gravity gold was remaining in closed circuit between the milling and the gravity circuits, it was decided to send the table tails to Rand Refinery for toll treatment. The benefit was that there was less chance that gravity gold could report to the leach circuit and the revenue obtained from the gold in the table tails was realized quicker than it would have otherwise have been. Figure 3 illustrates the amount of gold that was contained in the table tails while the Knelson concentrate was processed over the Gemini table and figure 4 illustrates the reduction in Rand Refinery cost when the ILR was commissioned.

![GOLD IN THE TABLE TAILS](image)

**Figure 3: Gold In The Table Tails**
Security concerns dominated the layout of the gravity circuit. As a result of this the distance between the centrifugal concentrator and the following process was kept to a minimum. As the final gravity stage was in the refinery, for security reasons, the Knelson was positioned close to the refinery rather than at the milling circuit, which is different to the Australian and North American approach.

Considering the plant layout the most practical take off point was the ball mill effluent as shown in figure 5. This draw off point however, complicated the design in that Knelson Concentrators required the feed to be screened to -2mm. Due to the length of the pipe and potential pipe blockages this screening could not be done at the concentrator so it had to be done at the mill and because the gravity circuit was included after the mill design was established, it would have been expensive to change the design. With some smart designing from Signet Engineering (the design engineering company) the ball mill trommel screen was divided into two segments, 3 rows of 6x32mm panels and 4 rows of 12x32mm panels, and a screen was fitted over the mill effluent sump to overcome the screening problem.

It had also been decided to remove steel from the gravity circuit prior to the concentrator, because of the damage the steel scats do to the bowl and the impact of the finer steel on the leach process. There was however an element of risk as no information was available on the amount of steel that would be recovered nor was the gold content of the steel known. As a result the design only allowed for the magnetic rejects from the magnetic separators to report to a bin system. It was acknowledged that once the plant was commissioned the production team would have to resolve the handling of the magnetic rejects.
The concentrator was finally positioned against the outside wall of the smelthouse in a caged off area. This allowed for operational and security supervision while access was limited to the concentrator.

The decision to install the Knelson concentrator was based on the fact that the Loraine gold plant was using a Knelson concentrator that had been proven to be reliable and a good working relationship had been built up with the suppliers. The senior management from the Loraine gold plant had also been earmarked to manage the new Target plant so they would be familiar with the Knelson concentrator.
Figure 5: Flowsheet Of The Main Plant At Target Gold Mine

**TARGET METALLURGICAL PROCESSING PLANT – GRAVITY CIRCUIT**

Ore Silo → SAG → BALL → Thickener → Stream containing dissolved gold

Woodchip Stockpile → Process Water Tank

Figure 5: Flowsheet Of The Main Plant At Target Gold Mine

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ILR INSTALLATION

The ILR was positioned in the refinery because of security concerns. It was also positioned in such a way that the distance between the Knelson concentrator and the ILR was kept to a minimum. The reason for this was the potential blockage of the concentrate pipe from the concentrator to the solid storage tank of the ILR as well as the pipe from the ILR to the gravity tails sump. Figure 6 shows the general layout of the refinery and as one can see from this drawing the concentrator, the gravity tails sump and the ILR are all positioned next to each other.

Figure 6: General Layout Of The Refinery

The ventilation pipes for the ILR, which are connected to the ventilation system for the refinery are illustrated in Figure 6.
The ILR operates as follows: The gravity concentrate gravitates to the solid storage tank of the ILR. In the solid storage tank the concentrate settles and the decanted water returns to the gravity tailings sump.

When the sequence starts, solids from the solid storage tank are batched to the reactor drum. The required reagents are pumped into the solution storage tank to produce the leach liquor. Once this is completed the leach liquor is circulated through the reactor drum back to the solution storage tank for a predetermined period of time. The hydrogen peroxide is also added for the whole duration of the leach cycle. On completion of the leach step, the solids in the pregnant solution are allowed to settle and these solids are returned to the reactor drum. The clear pregnant solution is then transferred to the pregnant storage tank. The solids in the reactor drum is then washed to ensure that most of the dissolved gold and the cyanide is removed from the solids. This wash solution is firstly pumped to the solution storage tank and once the tank reaches a set level the rest of the wash solution is pumped to the leach circuit. The barren solids are then pumped back to the gravity tailings sump and from there to the milling circuit. Lastly the pregnant solution from the pregnant storage tank is bled into the electrolyte tank of the electrowinning circuit. In the electrolyte tank the pregnant solution from the ILR is mixed with the eluant solution from the elution circuit.

**COMMISSIONING CHALLENGES AND RESOLUTIONS**

During the commissioning of the ILR a number of problems were experienced with the unit. These problems were:
- When the ILR was commissioned no oxidant was added to the reactor. However within the first couple of batches it became evident that there was very little dissolution taking place in the reactor due to a lack of dissolved oxygen. To solve this problem 50% strength hydrogen peroxide was added to the reactor during the leaching step. Initially the peroxide was added in batches when the leach step started, but this was later changed to continuous additioning to maintain the dissolved oxygen levels in the leach solution. Figure 7 below indicates a typical leach profile of a batch in the reactor, during commissioning, as the amount of peroxide added to the reactor is increased.
Currently the peroxide is continuously added to the reactor drum during the leaching step for the whole duration of the leaching step.

- Once the leach process has been completed the barren solids are returned to the milling circuit. Before this is done, the solids are washed to ensure that most of the dissolved gold and cyanide remaining in the solids is removed. During the commissioning it was found that soon after the ILR was commissioned there was a significant increase in the dissolved gold levels of the process water (see figure 8). The free cyanide content of this water however remained constantly low (< 5ppm). Sampling through the whole milling circuit indicated that the dissolved gold was coming from the ILR. The problem with the high dissolved gold levels in the process water was two fold:
  - It meant there was approximately 681 grams of gold locked up in the process water circuit.
  - The process water is used as wash water on the plant as well as dilution water in the residue sump. There was thus a potential to lose some of the gold to tails.

To solve this problem a T-piece was taken from the pipeline of the reactor to the pregnant solution storage tank to the refinery spillage pump. This pump, pumps all the spillage in the refinery to the leach circuit. The idea with this modification was to pump the wash solution that contains the high dissolved gold levels, to the leach circuit instead of the milling circuit. Later during the operation of the ILR the dissolved gold level in the process water would periodically increase again, although not as high as it initially was, but this time the problem was the gland on the ILR pump that was leaking. The pregnant solution that was leaking from this gland would report to the gravity spillage pump from where it would be pumped to the gravity tailings sump.

Figure 7: Dissolution Profile In The ILR During Commissioning

![Graph showing the dissolution profile in the Inline Leach Reactor (ILR) during commissioning. The graph displays the percentage of dissolution over time, indicating an increase in dissolution after the ILR was commissioned.]
With the introduction of the ILR pregnant solution to the electrowinning circuit the purity of the bullion bars dropped from an average in excess of 90% to an average of 85%. Some individual bars were even as low as 75%. This made the sampling of the bullion bars very difficult, as a representative sample could not be obtained by drilling. A visual inspection of the bullion bars indicated that the cause of this problem seemed to be iron. Samples of both the elution solution and the ILR’s pregnant solution were sent to an independent laboratory for a complete ICP analysis. Table 1 contains a summary of the key elements that were found in the solution.

**TABLE 1 - Results of the ICP analysis**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Elements (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Au</td>
</tr>
<tr>
<td>ILR Sample</td>
<td>745</td>
</tr>
<tr>
<td>Elution Sample</td>
<td>224</td>
</tr>
</tbody>
</table>

This table indicates that the concentration of most base metals was higher in the ILR sample than the elution sample, especially the lead, copper and iron concentrations, which would explain the poor quality of the bullion bars.

To solve this problem the following steps were implemented:

- It was found that the eluate solution to the ILR pregnant solution ratio had a significant impact on the purity of the bullion bars. As a result ILR pregnant solution is no longer treated through the electrowinning circuit on its own.
- Following this it was also decided that instead of filling the pregnant storage tank of the ILR with three or four batches before it was transferred to the electrolyte tank, each individual batch’s pregnant solution would be transferred to the electrolyte tank once the sequence has been completed. Currently the fineness runs on average 88%.
An additional problem that was experienced was the continuous blocking of the lines around the ILR itself, especially the lines from the solution storage tank to the inlet of the reactor and from the discharge sump pump to the solution storage tank. The reason for this seemed to be that not enough flow velocity was maintained in the pipelines to keep the solids in suspension and the presence of tramp oversize in the system. The problems with the blocking of the lines however required a number of changes to the process in order to solve. The following is a summary of the changes that were implemented to prevent the lines from blocking.

- A strainer box was installed around the outlet of the reactor drum to prevent +2mm material from going into the discharge sump. It was found that this material tends to build up in front of the sump discharge and then block it.
- For the line from the discharge sump to the solution storage tank a programming change was made that allows some of the solution to bypass the drum, direct to the discharge sump. This ensures that the discharge sump level increases, which in turn means that the ILR pump runs at a higher speed thus ensuring a higher velocity in the pipeline to the solution storage tank.
- A water point was installed on the solution transfer line from the solution storage tank to the reactor. The reason for this was to help flush any settled solids back to the reactor.
- In step 4, which is the settling and draining step, the valve that is situated on the line from the solution storage tank to the reactor drum, initially closed for 54 second and opened for 2 seconds to flush the solids, that have settled in the cone of the solution storage, to the reactor drum. The flush period (open period of the valve) was however not long enough to remove the solids that have settled. The result was that this line kept on blocking in this step. To overcome this problem the close period on this valve is now set at 26 seconds off and 4 seconds on. This prevents too big a plug forming in the cone of the solution storage, which in turn means the solids can be flushed away more easily.

Once these modifications were implemented, the blocking of the line reduced drastically although it does still occasionally occur.

POST COMMISSIONING OPTIMISATION

Once the ILR unit was commissioned and all the commissioning problems were sorted out, the optimisation program for this unit was started. This program included the following:

- The optimisation of the sodium cyanide and sodium hydroxide additioning.
- To determine the leach profiles by taking samples at various times during the leaching stage (step 3). The aim of this was to determine the optimum leach residence time and hence reduce the peroxide consumption and improve cost performance.
- To compare hydrogen peroxide vs. oxygen addition in the ILR.
- The optimisation of the hydrogen peroxide additioning.
Optimisation of sodium cyanide and sodium hydroxide additioning

The reagent optimisation was done using the same samples that were taken for the construction of the leach curves.

Initially when the ILR was commissioned and during the optimisation phase the reagent additioning to the solution storage tank was controlled by means of a level variance in the solution storage tank. This resulted in inaccurate reagent additioning of the reagents, especially the sodium hydroxide additioning, because of the fluctuating level on the surface of the solution storage tank. To improve the sodium hydroxide additioning to the solution storage tank, the set point for this reagent was increased by 0.9%. The result was an increase of 51.7kg sodium hydroxide per batch. Even after this change there were still problems with the additioning of the sodium hydroxide. To resolve the problem with the fluctuating level in the tank a timer was installed, which required the tank level to remain above the setpoint for a minimum period before the caustic additioning would stop. During last year it was decided to change the reagent additioning control from level variance to a timer, which means that the amount of reagents that are added is controlled by means of a timer. Since this modification has been implemented the caustic cost has been halved to USD 0.04 per ounce gravity gold recovered.

The cyanide additioning was initially based on a level variance of 3.8% in the level of the solution storage tank. This constituted approximately 113.09kg of 100% sodium cyanide added to each batch. Through optimisation the level variance was firstly decreased to 2.8% and later to 2.3%. This means that the cyanide consumption per batch has decreased by 44.4kg per batch, which is a total saving of USD 1 874 per month. Although there have been batches with dissolutions less than 98%, since the cyanide has been decreased, there is no evidence that the lower dissolutions have resulted from the decrease in cyanide because the residual cyanide remains constantly at 8000 ppm. The current cyanide cost is USD 0.31 per ounce gravity gold recovered.

Leach profiles

The leach profiles were constructed by taking samples at specific time intervals from plant batches. The results of these tests can be seen in figure 9.
The dotted lines represent the leach curves when hydrogen peroxide was used as an oxidant and the solid lines when pure oxygen was used as an oxidant.

As can be seen from figure 9, in the cases where hydrogen peroxide was used, more than 90% of the dissolution took place within the first 6 hours of the leaching step. This had the advantage that the leaching step could be reduced in order to process more batches per day. This conclusion was verified during the optimisation period when the leaching time was initially reduced to 12 hours and then to 10 hours in order to reduce the amount of gold locked up in the solids storage of the ILR. During this period the average dissolution was 98.05%. This confirms that the ILR can achieve 98% dissolution within 10 hours. It must be mentioned that these dissolutions were achieved with 220ml of peroxide being added per minute to the reactor drum. The leach time has now become a controlled variable based on the amount of gravity recoverable gold in the circuit.

**Hydrogen peroxide additioning vs. Oxygen additioning**

As part of the optimisation program both hydrogen peroxide and gaseous oxygen were tested as oxidants in the reactor drum. The hydrogen peroxide was only added to the inlet of the reactor drum, the oxygen was added to the ILR in two places; the inlet of the reactor drum and the solution storage tank. The results are reflected figure 9. This indicates hydrogen peroxide is a far better oxidant than oxygen because where the leach reaction was completed with hydrogen peroxide after approximately 6 hours, the leach reaction was still carrying on after 24 hours with gaseous oxygen. The highest dissolution that was achieved during the optimisation phase with oxygen was 54%. As such the tails going back to the milling circuit still contained a considerable amount of gold (>17 000 ppm) and...
although this gold was not lost, because it would most likely report back to the gravity circuit, it still meant that money was wasted on reagents and energy to pump the gold around the circuit. Conversely the lowest dissolution that was achieved with hydrogen peroxide during the optimisation period was 94%.

With the hydrogen peroxide, the dissolved oxygen levels in the leach liquor ran in excess of 20 ppm whilst with the oxygen the highest level that could be obtained was 16 ppm.

The reasons why better results were obtained with hydrogen peroxide could be the following:

- Hydrogen peroxide is added as a liquid to the inlet of the reactor drum (see picture 1). This means that the peroxide is easily carried into the reactor drum and there is proper mixing between the peroxide and leach liquor because of the liquid-liquid interface. On the other hand the oxygen, which was injected at the same point, was added as a gas and unless the oxygen dispersion was very good at this point to ensure that very fine bubbles were formed, the oxygen would tend to rise due to buoyancy, not reaching the drum. Simply put the bigger the oxygen bubbles the more difficult it would be to force the oxygen bubble down the vertical pipe into the reactor drum.

- The oxygen that was added to the solution storage also did not contribute very much because it was not possible to obtain a fine enough dispersion in this storage tank and any oxygen that flashed off disappeared into the extraction system. Once again finer bubbles would have helped due to the bigger surface area for the transfer of oxygen molecules and the buoyancy forces would be smaller allowing the bubble to rise more slowly, giving the oxygen bubble more residence time in the solution.

- **Optimisation of hydrogen peroxide additioning**

The fact that the ILR was achieving such a high dissolution rate allowed a reduction in hydrogen peroxide additioning to the reactor with each batch that was leached.

This can be done in two ways.

- Firstly by reducing the period that the peroxide is added to the reactor drum during the leaching process i.e. is it added to the reactor for the whole leaching period.
- Secondly by reducing the amount that is added to the reactor per minute.
The first major change was to reduce the additioning period from 100% of the leaching period to 80% of the leaching period. This change was done based on the fact that 98% dissolution was achieved within the first 6 hours.

Secondly the amount of peroxide that was added to the reactor every minute was reduced. The actual pumping period of the pump was reduced from 7 seconds per minute to 6 seconds per minute. This was found to be the minimum as below this level the pump stalls.

With these changes the dissolutions varied between 60 to 99%. It was concluded that the peroxide must be added to the reactor drum for the whole leaching period because lower dissolutions were obtained when peroxide was added for only the first couple of hours of the leaching process.

As part of the ongoing optimisation process, a dissolved oxygen meter was also installed in the solution storage tank. This gives an indication to the operators on the plant whether or not peroxide is added to the reactor drum during the leaching step.

Currently the plant pays USD 0.33 per ounce gravity gold recovered, for the peroxide that is used in the ILR.

**POST OPTIMISATION PERFORMANCE**

**Metallurgical**

Since the commissioning and optimisation of the ILR, the reactor has been operational for 704 days and the only mechanical problem that has been experienced to date was with the gland on the ILR pump. On the other hand a number of problems were experienced with the process. These included problems with the leach process, the bullion fineness and blocking of the lines. These problems have however been dealt with and currently the ILR is operating at a recovery in excess of 98%.

The following set of graphs is an indication of the improvement in certain areas of the plant as a result of the commissioning of the ILR.
Before the commissioning of the ILR, Target gold plant had to pay on average approximately USD 20 000 per month for the toll treatment of the table tails depending on the amount of tails that was treated for the month. This did not include the treatment cost (mostly for labour and electricity) of the Target gold plant to recover the gold in the middlings and concentrate streams. With the ILR operational the plant is effectively saving USD 20 000 per month.

As figure 11 shows, the amount of gravity gold that is recovered on the plant has also increased after the commissioning of the ILR. In the period before the commissioning, the gravity gold made up 31% of the total gold smelted. This increased after the commissioning to 49%. It should be noted that the reason for the steady decrease in the amount of gravity gold produced since the commissioning of the ILR is a continuous decrease in the feed grade to the plant. The rapid decrease in the last two months is as result of a decrease in the plant feed grade and reduced gravity recovery due to a worn concentrator bowl.
Although the monthly bullion fineness has been above 90% on only two occasions, there is still a significant improvement in the fineness compared to what was measured during the commissioning period, as can be seen in figure 12. The average fineness since the commissioning problems have been sorted out runs at 89.35%.

One of the tendencies that has been picked up is that the bullion fineness on the Target gold plant is very dependent on the elution to ILR batches ratio. The higher the number of elution batches that are processed for a specific smelt the higher the resulting bullion...
fineness. This is to be expected since the eluate solution contains fewer impurities than the ILR pregnant solution as pointed out in table 1.

The most significant impact the ILR has had on the Target gold plant's performance is illustrated in Figure 13. Since the commissioning of the ILR, the plant's overall recovery has steadily increased from an average of 96.39% before the commissioning to an average of 97.74%. That is an increase of 1.35% in the plant's overall recovery, which equates to an additional 4871 ounces of gold that has been recovered to date. One can also see from figure 13 that the increase in recovery is not as a result of an increase in the plant feed grade.

![OVERALL PLANT RECOVERY](image)

**Figure 13: Overall Plant Recovery And Plant Feed Grade On Target Gold Plant**

**Costs**
The operating cost of the ILR can be divided into three components
- Reagent cost
- Maintenance cost
- Labour cost

The reagent cost can be broken down further into sodium cyanide, sodium hydroxide and hydrogen peroxide cost. When one does the operating cost calculations for the ILR you should keep in mind that there is a cyanide credit that should be deducted from the operating cost because of the cyanide that is returned to the leach circuit through the wash and the barren electrolyte solutions. This credit is approximately 40% of the total cyanide cost.

A summary of the operating cost can be seen in table 2. The reagent cost calculations in this table is based on 100% concentration.
### TABLE 2 - ILR Operating Cost

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost (USD/ounce recovered)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reagent Cost</strong></td>
<td></td>
</tr>
<tr>
<td>Sodium Cyanide</td>
<td>0.52</td>
</tr>
<tr>
<td>Sodium Hydroxide</td>
<td>0.04</td>
</tr>
<tr>
<td>Hydrogen Peroxide</td>
<td>0.33</td>
</tr>
<tr>
<td>Maintenance &amp; Labour Cost</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Total Cost (excl. credit)</strong></td>
<td>0.92</td>
</tr>
<tr>
<td>Cyanide credit</td>
<td>0.21</td>
</tr>
<tr>
<td><strong>Total Cost (incl. credit)</strong></td>
<td>0.71</td>
</tr>
</tbody>
</table>

**CONCLUSION**

The following benefits were obtained through the installation and commissioning of the ILR100BA:

- The overall plant recovery has increased from an average of 96.39% to an average of 97.74% resulting in the payback of the capital cost within approximately 6 weeks.
- The plant is saving approximately USD 20 000 per month on the toll treatment of the Gemini table tails.
- The percentage gravity gold as a function of the total gold smelted has increased from 31% to 49%.
- It has improved the security around the handling of the gravity concentrates because the ILR is mostly a hands off operation.
- It has improved the safety in the refinery because there is no longer a health risk to the operators in the refinery because of poisonous off gases (arsenic) during smelting.
- There is the possibility of milling the current smelt slag and adding it to the solids storage tank of the ILR to recover the gold in the slag and further improving cash flow as a result.

One of the disadvantages of the current unit is that it is situated within the refinery. This makes access for the plant operators to the unit very difficult in times when there is something wrong with the unit (block lines etc.). It is recommended that future units be installed outside refineries to increase accessibility to the unit.

Lastly it can be concluded that the ILR100BA enabled Target gold plant to significantly increase the amount of gold recovered from gravity concentrates, which in turn resulted in an increase in the overall plant recovery. Routine recoveries of above 98% are obtained using proven chemistry and by using reagents that the operators are already confident with and experienced in their use.

**ACKNOWLEDGEMENTS**

Target gold plant wish to thank Gekko Systems, South Africa for the metallurgist that was seconded to the plant during the optimisation phase of the project as well as all the
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