

# The InLine Leach Reactor – The New Art in Intensive Cyanidation of High Grade Centrifugal Gold Concentrates.

“RANDOL GOLD AND SILVER FORUM, DENVER, MAY 1999”

**A H (Sandy) Gray**  
Technical Director

**Nick Katsikaros**  
Senior Process Engineer

Gekko Systems Pty Ltd.  
321 Learmonth Road, Ballarat, Victoria, 3350, Australia.  
Phone: +61 3 5339 5859; Fax +61 3 5339 5803  
Website: www.gekkos.com Email: gekkos@gekkos.com

## ABSTRACT

Gold concentrates are produced at many mines by a variety of centrifugal and gravity machines, such as Knelson and Falcon concentrators, however the subsequent recovery of gold is relatively inefficient and subject to security problems. The InLine Leach Reactor (ILR) offers a new method to recover over 95% of gold in concentrates using a simple, secure leaching process. The InLine Leach Reactor is of particular benefit in treating slow or difficult leaching sulphide concentrates and its performance can be reliably predicted from simple laboratory tests. The InLine Leach Reactor is now successfully operating in two gold mines providing benefits of high gold recovery, low operating costs, high security and ease of operation.

## INTRODUCTION

Centrifugal machines, such as Knelson and Falcon concentrators, are widely used in the gold industry to recover free gold concentrates prior to leaching. This has the benefit of reducing gold held in the system, reducing carbon handling costs and reducing losses due to misadventure or insufficient leaching time for slow leaching coarse gold.

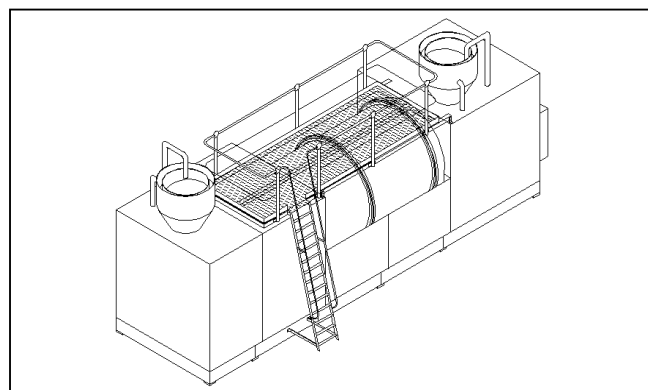
The concentrates from centrifugal machines are normally upgraded by tabling with the table concentrates going directly to smelt and the table tailings being returned to the mill circuit for leaching with the bulk of the ore. Gold recovery on the tables is relatively low and is typically in the range 20 to 70% depending on the nature of the concentrate being treated.

The InLine Leach Reactor (ILR) was developed by Gekko Systems (formerly Ground Developments) and is an effective, efficient, secure way to recover over 95% of gold from these concentrates. The ILR is designed to recover gold by intensive cyanidation from coarse concentrates under low shear conditions. The innovative design overcomes problems associated with intensive cyanidation in a stirred tank.

## DESCRIPTION OF THE INLINE LEACH REACTOR.

The ILR is a continuous intensive cyanidation reactor. It is a multi compartment, horizontal rolling vessel, in principal resembling a laboratory rolling bottle. Figure 1 shows the general view of an ILR5000. The reactor is a rotating drum supported on rollers. Feed is introduced into one end and tails removed at the other through axial ports.

The InLine Leach Reactor is available in a number of models depending on required throughput and leach kinetics. The ILR100 has a nominal throughput of 100 kg/hr, the ILR1000 has a nominal throughput of 1000 kg/hr and the ILR5000 has a nominal throughput of 5000 kg/hr. Actual throughput is determined by experimental work. Due to its flexible, modular design the ILR1000 can be easily expanded up to an ILR5000 by the addition of extra compartments. This allows cost effective plant expansions.



**FIGURE 1**  
**General View of an ILR5000**

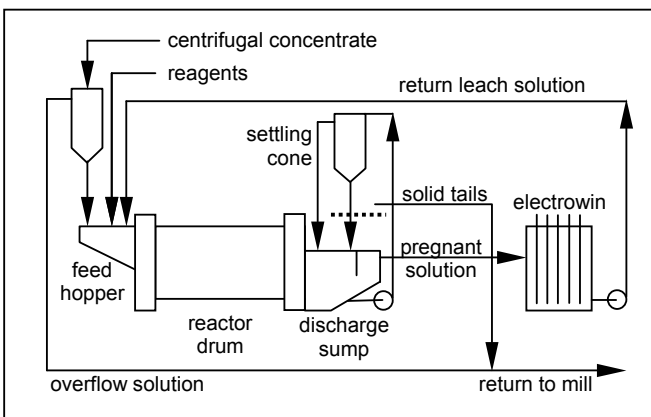
The ILR is designed to operate in conjunction with a distributed control system or as a stand alone unit with minimal operator input. The unit is compact and designed on a skid base with an integrated control system allowing it to be placed close to the discharge of gravity concentrates. All waste products can be easily returned to the mill and the pregnant solution pumped to the gold room. As a result on-site construction and installation costs are minimal.

Figure 2 shows a typical leach circuit. The concentrate slurry is de-watered to about 70% solids in a de-watering cone and fed to the leach reactor feed hopper. Leach solution and make up reagents are also metered into the leach reactor feed hopper.

The slurry is agitated by peripheral lifters and the flow of slurry through the reactor is controlled by specially designed internal baffles. The leached slurry and pregnant solution overflow from the last compartment into the discharge sump.

Solids are removed from the circuit by pumping slurry from the discharge sump to a settling cone. The cone underflow feeds a vibrating screen that returns leached solids to the milling circuit while screened solution and cone overflow return to the discharge sump. Clarified solution is withdrawn from a specially baffled section of the discharge sump.

The clarified pregnant solution transfers to the electrowinning circuit where the gold is recovered and the solution is returned to the leaching circuit. If required the pregnant solution can be recycled through the leach circuit to build up gold in solution before being transferred to electrowinning on either a batch or, preferably, a continuous basis.



**FIGURE 2**  
**Typical ILR Leach Circuit**

The leached solids can be returned to the leach circuit or removed if tramp steel or other “nasties” are present. Any solutions leaving the ILR circuit are returned to the leach stream where the contained reagents reduce required additions into the circuit.

**DESIGN FEATURES**

**High security**

The system is very secure since operators do not handle the high grade concentrates. The pregnant solutions are pumped directly to the gold room for electrowinning.

**Low Labour Input**

The system is fully automated and requires very little labour input. Labour is only required for sampling, making up stock reagent solutions and stripping the electrowinning cells.

**High gold leaching rates.**

Gold leaching rates are maintained by a combination of high cyanide and high oxidant levels. Cyanide levels are generally maintained above 2% in solution at a pH 13.5 Dissolved oxygen levels are at least 8 ppm and usually between 20 and 30 ppm in solution.

Oxygen is efficiently absorbed from the air in the ILR due to the action of the drum, providing a large turbulent solution

surface. The upper surface of the rotating drum is similar to a thin film absorber. This is sufficient oxygen in the absence of high oxygen consumers in the concentrate.

Additional oxygen is introduced into solution either by the electrowinning process, where it is generated at the anode, or it may be sparged into the solution. Continuous electrowinning of leach solution is preferred since oxygen for leaching is supplied at between 20 and 30 ppm, at no additional cost. The higher oxygen is beneficial in all cases.

Other leach accelerators have also been used to maintain rates where necessary. LeachWELL addition has been effective in a number of applications. The use of relatively expensive chemical reagents is cost effective in the ILR due to the high grade of the concentrates being treated.

**Independent solid and solution residence times.**

The residence time of solids and solution are largely independent allowing the optimum ratio of solids to dissolved reagents, such as cyanide and oxygen, to be maintained while still operating at a high solids levels in the reactor. Together with high gold leaching rates this keeps the reactor size low.

Solids residence time is controlled by internal baffles while solution residence time is determined by solution flow and reactor volume. In particular, coarse heavy gold particles are held back by the baffles. By maintaining a longer residence time for solids than for solution the same chemical effect is obtained as operating at low solids levels.

**Ability to handle coarse heavy particles.**

Due to the horizontal drum design suspension and movement of coarse heavy particles is easily maintained with low power inputs.

This overcomes agitation problems encountered when carrying out intensive cyanidation in conventional stirred tanks. The difficulty in suspending coarse heavy particles in these systems leads to high power consumption and sanding out of coarse solids. This may be addressed by re-grinding the concentrate, but at considerable cost both in capital and operating cost. Furthermore, re-grinding often results in markedly increased reagent and oxygen consumption due to increased surface area of sulphide minerals. In extreme cases re-grinding actually leads to a reduction in gold recoveries.

**Coarse gold leaching**

In the ILR coarse gold particles are retained and do not escape until they are leached, giving higher gold recovery. In a conventional stirred tank coarse gold may settle out and not be leached or, if suspended, may exit the tank before being fully leached. Re-grinding is not effective in this situation since coarse gold is not easily ground.

**Simple solid liquid separation**

The concentrates treated are generally coarse and easily settled, simplifying solid liquid separation and allowing direct electrowinning of the resulting solutions.

For situations where slimes enter the system with the concentrate and may build up, Gekko has designed a new

electrowinning cell which is tolerant of solids and removes the requirement for flocculants.

**Reliable prediction of leaching performance.**

ILR leach performance can be reliably predicted and optimised at bench scale from bottle roll tests. Tests have shown close correlation between laboratory predictions and plant performance.

The laboratory test used is a bottle roll with chemical conditions established and maintained by suitable reagent additions. Samples are taken at regular time intervals to establish leach kinetics and specify reactor size. The effect of different reagents is also established using these tests

**INSTALLATIONS**

The ILR has had three full scale installations, all of which have been effective in achieving high gold recoveries in the reactor and in increasing gravity gold recovery for the mine. The installations involve treating various products from Knelson concentrators, tables, spirals and jigs. The conditions and results are summarised in the table below and each installation is then discussed in more detail.

		Pilot	Kundana	Penjom
Feed	kg/h	54	120	500
	Au g/t	800	2129	300-1500
Tail	Au g/t	43	113	20-100
	%solid	80	85	85
Au recovery	%	94.5	94.7	90
Solids hold up	h	30	12	3
Soln flow	m <sup>3</sup> /h	0.3	3	3
Au in soln	ppm	360	250-300	40-120
NaCN use	kg/t	3.0	10	10
LeachWELL	kg/t	0	10	0

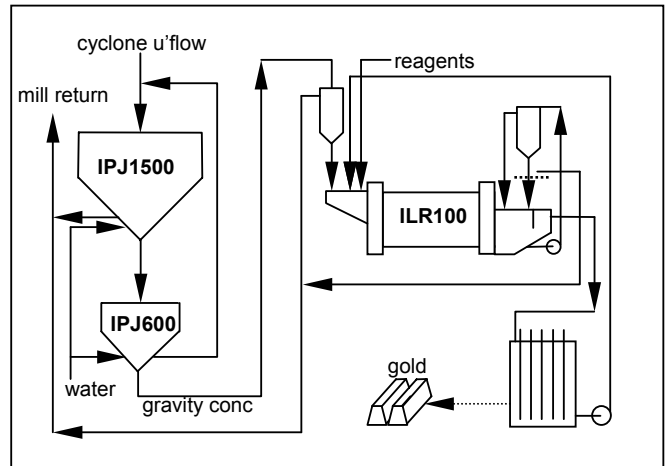
**Pilot Plant Trial**

The ILR1000 was initially piloted at a West Australian gold mine in mid 1997. The pilot plant trial involved installation of a complete gravity gold system by Gekko Systems, comprising two InLine Pressure Jigs and an InLine Leach Reactor. The InLine Pressure Jig (IPJ) is an advanced gravity separation device developed by Gekko Systems and described in detail by Gray<sup>12</sup>.

The general arrangement of this gravity circuit is shown in figure 3. A bleed stream of cyclone underflow was fed to an IPJ2400 to produce a rougher concentrate which was cleaned using an IPJ600. This cleaned jig concentrate was leached in the ILR100. The pregnant ILR solution was transferred to a dedicated electrowinning cell on a continuous basis where the gold was recovered before smelting to produce doré. The jig and ILR tails were returned to the mill feed.

The jigs produced 54 kg/hr of sulphide rich concentrate containing 800 g/t gold from an average mill feed of 2.4 g/t. This represented a recovery of approximately 13.5% of the gold fed to the mill.

The ILR100 recovered 94.5% of the gold in this concentrate. Dissolved oxygen was maintained between 20 and 30 ppm by the electrowinning cell. No leach accelerant was required to maintain gold recovery.



**FIGURE 3  
ILR Pilot Plant Flowsheet**

**Kundana**

Kundana is a gold mine located near Kalgoorlie in Western Australia, producing gold from a complex sulphide ore body. Kundana had a gravity gold circuit consisting of one 20 inch Knelson concentrator followed by a Wilfley table. The Knelson and table tails were originally returned to the ball mill feed. The gravity circuit recovered about 60% of gold in ore, significantly less than its GRG (gravity recoverable gold) value of 89%.

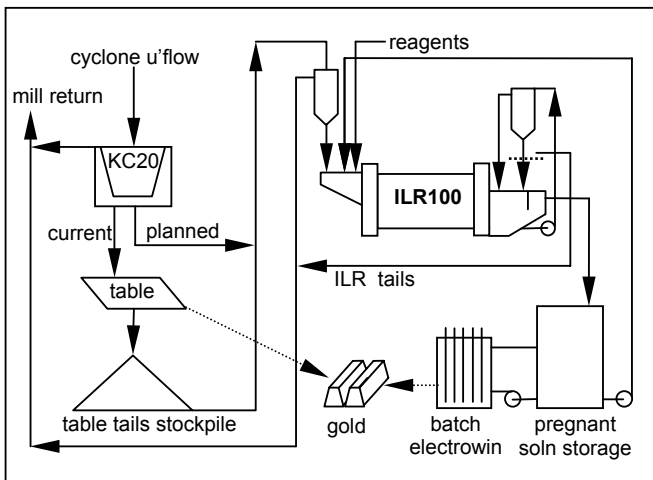
High gold spikes in the leach tails were observed by Chris Hillman, the Mill Superintendent, and it was thought that this could be due to the recycling of high grade table tails to the main leach circuit. Consequently the tails were stockpiled and no further spikes were observed.

In tests on the table tails, containing 2500 g/t gold and high levels of sulphides, intensive cyanidation gave 95 - 98% recovery, while normal cyanidation gave only 80% recovery.

In January 1999 Gekko Systems installed an ILR100 to treat this stockpile. The basic flowsheet is shown in figure 4. The concentrate is fed at 100 kg/hr with the solution recirculated and stored. LeachWELL as well as cyanide is used to maintain high gold leaching rates. The pregnant solution is stored in a tank before being batch treated in the plant electrowinning section.

Despite the ILR tails being returned to the main plant the total plant tail grade profile is now much flatter with the spikes removed. This means the ILR is effective in recovering the slow leaching gold associated with sulphides in the table tails.

After the stockpile is treated the ILR100 will be used to treat the Knelson concentrates directly. This will eliminate the tabling process which is beset by low recoveries, high labour costs, and significant security concerns.



**FIGURE 4**  
**Kundana Gravity Gold Flowsheet**

To increase the overall gravity recovery it is desirable to reduce the Knelson dump cycle time. At present this is restricted by the time required to table the concentrate and a typical dump cycle time of 90 minutes is used. The ILR, due to its capacity, allows the Knelson to be dumped as often as required. Tests using intensive cyanidation and LeachWELL accelerant predict 99% recoveries from the Knelson concentrates.

With this added flexibility it is expected gravity recovery will be increased significantly.

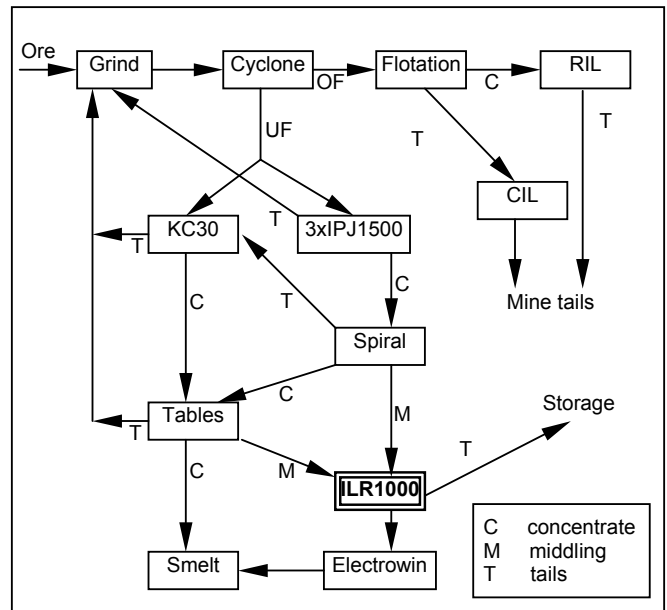
**Penjom**

The Penjom Gold Mine in Malaysia, operated by Specific Resources Sdn Bhd, produces about 80,000 oz/yr from a highly preg-robbing carbonaceous ore body, containing complex sulphides. The plant has a gravity circuit, ILR, flotation, resin in pulp (RIP) and CIL. This operation and the benefits brought to the process by the ILR are further described by Lewis<sup>3</sup>.

The flowsheet is shown in figure 5. The gravity circuit consists of three IPJ1500 InLine Pressure Jigs, one Knelson concentrator, three tables, spirals and an ILR1000 InLine Leach Reactor. The ILR is fed middling streams from the spirals and table. The gravity circuit, not including the ILR, recovers 15% of gold in new mill feed.

The ILR1000 accounts for 35% of gold recovery from mill feed, out of a total gold recovery of 70%. If the ILR was removed from the circuit, total plant recovery would drop to about 55%. This is because the ILR has the highest unit gold recovery on site at over 90%, whereas only 30% of gold entering the flotation, RIP, CIL circuit is recovered, due to preg-robbing.

At Penjom the gold in solution is recovered into a carbon column for subsequent stripping and recovery in the main electrowinning cells. Subsequently Gekko Systems has successfully designed, manufactured and installed a dedicated electrowinning cell for the ILR.



**FIGURE 5**  
**Simplified Penjom Flowsheet**

**PROCESS BENEFITS**

**Increased Gravity Gold Recovery.**

The incorporation of an ILR in the gravity circuit allows increased recovery in the gravity circuit for a number of reasons. Firstly, it allows greater recoveries from the gravity concentrate; typically greater than 95% recovery as opposed to a table which is typically 20 to 70%. This can be done by leaching either the entire concentrate stream or the table tails.

Secondly, the ILR allows higher recoveries to be obtained from the centrifugal concentrator. This is because the ILR does not restrict the operation of the centrifugal concentrator.

In practise many operations lengthen the dump cycle times of Knelson concentrators to suit their downstream tabling operation, leading to a reduction in recovery. Installation of an ILR means the Knelson concentrator dump cycle times can be reduced to maximise gold recovery. The concentrator can be run to produce a higher volume of lower grade concentrate because the increased gold recovered reports to electrowinning rather than table tails.

Thirdly the performance of the centrifugal concentrator is likely to improve due to the reduction or removal of recirculating loads due to recycling table middlings to the concentrator, and table tails to the grinding circuit.

Increasing overall gravity gold recovery maximises the benefits of an effective gravity gold circuit. These include:

- Reduced gold inventory - gold in hand
- Reduced gold spikes in mill tails
- Reduced carbon stripping
- Lower carbon movement
- Reduced cyanide soluble gold in leach tails.

**Increased recovery from slow leaching minerals**

The ILR offers particular benefits in treating slow leaching gold, associated with difficult sulphide minerals often recovered in the gravity concentrate. This is due both to the aggressive leaching conditions - high cyanide and oxidant - and to the larger particle size of the sulphide minerals in the concentrate.

The larger particle size means there is much lower active sulphide surface area to react. This is particularly relevant when the sulphides are significantly softer than the host rock, which can lead to over-grinding and sliming in the mill, which in turn leads to high oxygen demand and reagent consumption in the main leach circuit.

The low shear environment in the ILR does not produce slimes in-situ even when treating soft sulphides, minimising reagent consumption due to the presence of sulphides.

This effect is important if considering a stirred tank intensive cyanidation system since a gravity concentrate is likely to require re-grinding to obtain acceptable suspension.

**High security and accountability**

The ILR increases security by reducing or eliminating the presence of gold concentrates in the gold room. Once the centrifugal concentrate is fed to the ILR all gold is in solution until recovered in the electrowinning cells.

The reduction in gold handling and gold room personnel helps meet company probity obligations by improving the accountability of gold and minimising the temptation for theft. This has direct advantages in better metallurgical accounting and reduced insurance and security enforcement costs as well as indirect, but significant, benefits in improving relations between management and operators.

**OPERATING COSTS**

Operating costs are very modest for the InLine Leach Reactors. A typical operating cost breakdown based on treating 1000 g/t concentrate at 100 kg/hr in an ILR100 is shown below. Reagent usage in this example is typical of difficult, slow leaching, sulphide rich concentrates. With many concentrates the costs will be much lower. Power costs for an ILR5000 will also be considerably lower (~3 kW/t).

<b><u>Op Costs to leach a 1000 g/t conc in an ILR100</u></b>		
Leach Reagents		
Sodium cyanide	10 kg/t	A\$20 /t
Caustic	2 kg/t	A\$2 /t
LeachWELL	10 kg/t	A\$35 /t
Power	30 kWh/t	A\$6 /t
Electrowinning and strip		
Power	0.4 kWh/t	A\$0.1 /t
Consumables		A\$4 /t
Strip and smelt labour		A\$30 /t
<b>Total Operating Costs</b>		<b><u>A\$97 /t conc</u></b> <b><u>A\$3 /oz gold</u></b>

**Reagents** used are cyanide, caustic and LeachWELL or oxygen if required. Consumption varies with the concentrate treated however it should be noted that reagents entrained with ILR tails are not lost since they reduce reagent consumption in the plant leach circuit.

**Power** used for drum movement is low; less than 1 kW for an ILR100 and less than 11 kW for an ILR5000. The only other power is for the three pumps in the circuit. Total power usage, excluding electrowinning, for an ILR5000 is less than 15 kW.

**Electrowinning and stripping costs.** Electrowinning power is proportional to gold recovered at about 0.4 kWh/kg gold. Treating a 1000 g/t concentrate requires about 40 W in an ILR100 or 2 kW in an ILR5000. Consumables for stripping and smelting such as steel wool, acid, flux, account for about A\$4.0 /t conc. Labour costs are the highest input at about A\$30 /t conc.

**Low personnel requirements.** The ILR requires little or no labour input for routine operation. Where the ILR replaces the tables this also reduces personnel levels in the gold room.

**SUMMARY**

The InLine Leach Reactor is the new state of the art in gold recovery from centrifugal and gravity concentrates. Products from Knelson concentrators, Falcon concentrators, tables, jigs and spirals can be effectively and efficiently treated to give gold recoveries in the high nineties.

The InLine Leach Reactor brings substantial advantages by increasing recovery, reducing labour, increasing security and adding flexibility to gravity gold circuits. In many cases the leach reactor allows higher recoveries in the upstream concentrator by removing throughput restrictions imposed by the tables.

The InLine Leach Reactor is an automated, modular, effective design that makes intensive cyanidation of coarse gold concentrates a practical and effective reality.

<sup>1</sup> Gray, A H (1997) "InLine Pressure Jig – An Exciting Low Cost Technology with Significant Operational Benefits in Gravity Separation of Minerals" Proceedings of The AusIMM Annual Conference, Ballarat, March 1997.

<sup>2</sup> Moony, N and Gray, S (1998) "Enhanced Gravity Separation of Gold using the InLine Pressure Jig: Experiences from a Number of Australian Grinding Circuits" Proceeding SME Annual Meeting at Orlando, March 1998.

<sup>3</sup> Lewis, G (1999) "The InLine Leach Reactor – Increased Recovery From Preg Robbing Gold Ore at Penjom Gold Mine" Proceedings, Randol Gold at Denver '99, May 1999.