




INLINE
LEACH REACTOR

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A continuous, intensive cyanidation process for the recovery of free or sulphide gold concentrates.

INTRODUCTION TO THE ILR

The InLine Leach Reactor (ILR) has been developed by Gekko Systems  for the purpose of optimising the recovery of gold from high grade concentrate streams. Current practice of upgrading cons using tables or other gravity devices is labour intensive, has significant security risks and very low recovery rates.

The ILR is designed to operate in conjunction with a distributed control system (DCS) or as a stand alone unit with minimal operator input. The unit is designed on a skid base with an integrated control system. As a result, on-site construction is minimal. The dimensions of the ILR are small allowing it to be placed in a convenient position close to the discharge of gravity concentrates. All solid and liquid waste products can be pumped back to the grinding circuit or removed if tramp steel or other “nasties” are present. The pregnant solution is pumped to the gold room. Spent solution from the electrowin cell is recirculated back to the Reactor feed.

The move away from inefficient multistage gravity treatment of concentrates has been slow. These systems are generally complicated with screening, secondary concentration of table tails and magnetic separation in order to achieve high recoveries. Every step in the upgrading of concentrates also increases the potential for losses (entrained gold in magnetics etc).

THEORY OF OPERATION

The concentrates from the primary recovery device report to a cone for de-watering. The feed can be either continuous or batch. The feed system will continuously feed the reactor at a rate lower than the recommended maximum feed rate. The Cone underflow reports to the reactor feed while the Cone overflow is returned to the circuit.

The InLine Leach Reactor works on the principal of the laboratory bottle roll to keep the solids in contact with the liquor. A horizontal drum rotating at low speed with a set of specially designed baffles and aeration system for maximum leach performance. Residence time is predicted in the laboratory and controlled by Reactor volume. Barren solids are washed and removed from the circuit via a dewatering cone and dewatering screen. Solids report to the reactor solids discharge sump for further washing if necessary.

Pregnant liquor is pumped to the Solids Settling Vessel (SSV), remaining slimes settle to the bottom and reticulate to the solids discharge sump. The pregnant solution is pumped to the electrowin cell for Au recovery. The spent solution from the electrowin discharge is returned to the reactor feed. This vessel has a permanent overflow which will discharge excess liquor to the solids discharge sump which will be returned to the mill circuit. The flow rate of eluate from the SSV controls the rate of recirculation of liquor in the system.



REAGENT ADDITION

Reagents are added to the Reactor feed via a dosing pump. The typical operating solution grade is recommended at around 2% cyanide at 13.5 pH. A leach accelerant (such as ProLeach) at around 0.5% may also be added if required.

High dissolved oxygen levels (+20ppm dissolved Oxygen) in the spent eluate, which reports to the reactor feed, are generated using the electrowin cell running with ambient solution. This improves leach times significantly and allows large particles to be leached with extremely low retention times.

PREDICTED COST

Including Caustic, Cyanide, Power, Wear Parts, and Leach Accelerant (such as ProLeach), predicted cost is \$10 - \$50 per kg Au poured (dependant on gold loading in concentrates).

ADVANTAGES

High Recovery:	The target recovery of free gold for the ILR is plus 95%. Very high recovery rates on complex sulphide-related gold can also be expected.
High Security:	The ILR will significantly improve gold concentrate security by replacing the tabling step and eliminating concentrate handling.
Low Operating Cost – High Automation:	The system offers fully integrated electronic control of all critical leach parameters and is fully automated. Recovery costs per ounce are attractive.
Ease of Installation:	This complete system can be retro-fitted to any grinding circuit. The ILR is modular and can sit adjacent to the plant. Controls easily integrate into existing plant distributed control system.
Bench Scale Test Work:	The performance and cost for this simple system can be effectively predicted at bench scale in a laboratory. Reactor conditions can be optimised prior to full scale installation.
Low Maintenance:	There are no high speed/high wear components in the system.
Very Simple:	Only one pump and one drum drive.
Proven Technology:	Thorough mixing of solids / solution with the rotating drum, unlike vat leaching systems.

MODELS AVAILABLE

	BATCH	MAXIMUM DRY CAPACITY*
	ILR MICRO	10 kg
	ILR 100	1140 kg
	ILR 1000	3000 kg
	ILR 2000	5700 kg
	ILR 3000	8400 kg

	CONTINUOUS	MAXIMUM DRY CAPACITY*
	ILR 100	150 kg/hr
	ILR 1000	750 kg/hr
	ILR 2000	1400 kg/hr
	ILR 3000	2100 kg/hr
	ILR 4000	2800 kg/hr
	ILR 5000	3500 kg/hr
	ILR 10000	7000 kg/hr

*All capacities are calculated for slurries with two tonnes dry solids per cubic meter. Continuous capacity was calculated on the basis of having a residence time of four to four and a half hours. Models are available in a wide range of sizes and capacities, with automatic or manual operation, to meet the varied requirements of our customers.

BATCH VERSUS CONTINUOUS MODELS

The batch models of the InLine Leach Reactor have been developed to treat higher-grade lower volume gold bearing concentrates while the continuous InLine Leach Reactors have been developed to treat lower grade higher volume gold bearing concentrate streams. This allows for flexible application of intensive cyanide leaching technology for the treatment of different primary concentration methods, different ore characteristics and types.

Areas of Application of the Continuous and Batch ILR

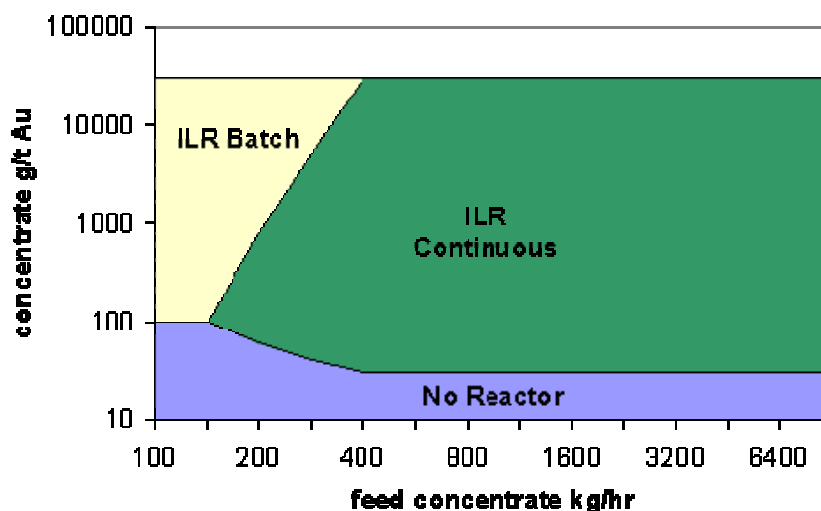


Figure above showing area of application for each type of ILR in relation to concentrate mass and Au grade.



BATCH INLINE LEACH REACTOR OPERATION

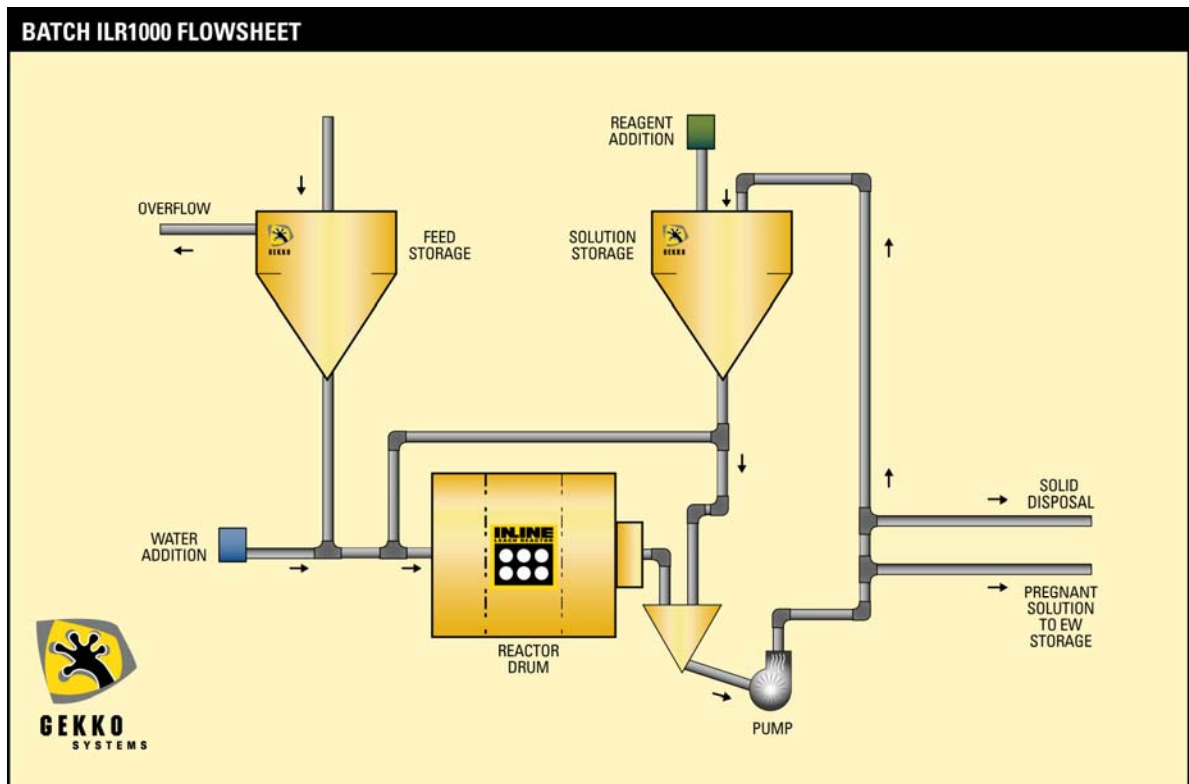
The concentrates from the primary recovery device report to the feed cone for de-watering, with the water overflowing and returning to the mill circuit. Solids are stored in the feed cone until the beginning of each leach cycle.

The Batch InLine Leach Reactor works on the principal of the laboratory bottle roll to keep the solids in contact with the liquor. A horizontal drum rotating at low speed with a set of specially designed baffles and aeration system for maximum leach performance. Residence time is predicted in the laboratory and controlled by leach cycle time. During leaching solution is continually recirculated through the solids from the solution storage tank to ensure a fresh supply of reagents, including oxygen, is always available for leaching.

At the completion of the leach cycle the pregnant solution is clarified then pumped to the electrowinning circuit. Barren solids are emptied by reversing the drum rotation and pumped to the mill circuit. Pregnant liquor is pumped to the electrowinning circuit where it can be recovered in a dedicated electrowinning cell or mixed with the main elution solution. The barren solution from electrowinning is then pumped to the CIL/CIP circuit (optionally to the ILR) to reuse the residual cyanide.

The batch ILR accomplishes this by cycling through discrete steps. These steps are:

1. Load concentrate into Reactor Drum
2. Adjust initial solution volume and add reagents
3. Leach by re-circulating solution through reactor drum
4. Drain drum and with floc clarify pregnant solution pumping into solution storage tank.
5. Wash solids with water
6. Drain and clarify wash water to solution storage tank
7. Empty solids from Reactor Drum and transfer to mill
8. Drain remaining water to mill.
9. Transfer solution to electrowinning circuit



Drawing of Gekko Systems Batch InLine Leach Reactor Flowsheet

SPECIFIC ADVANTAGES OF THE BATCH INLINE LEACH REACTOR

- Captures and leaches fine and coarse gold.
- Engineered to prevent gold precipitation on mill scats.
- Simple system with low component count; 1 drum; 1 pump; 1 sump; 2 tanks.
- Low operating costs with no requirement for expensive chemical leach agents.
- Low installed power of less than 10kW.
- Dedicated clarification step reliably produces clear electrowinning solutions.
- Pregnant solution is highly suitable for recovery by electrowinning.

CONTINUOUS INLINE LEACH REACTOR OPERATION

The continuous ILR is designed to accept dilute, high-grade gold concentrates in order to recover the solid gold into solution. The gold is recovered from the solution by means of electrowinning technology.

The feed slurry reports to the feed cone where it is de-watered. The cone holds the solids and the water overflows to the ILR tails sump. The feed cone is controlled using a load cell and pinch valve combined in a PID timer loop. The load cell measures the mass in the cone. The solids are allowed to build-up in the cone to form a bed until the bed reaches a predetermined mass when the controller allows the timer circuit to open and shut the feed valve.

The thickened feed reports to the reactor drum feed. Fresh reagents and return barren solution from the electrowinning circuit are added at the feed. The drum rotates around a horizontal axis. The drum is rotated only fast enough to ensure fresh solution is mixed through the solid. The drum inlet and outlet are set to create a low angle of repose across the drum. The solids are agitated only enough to keep the mass moving from feed to outlet. A set of internal baffles allow movement of solids through the drum but inhibit short circuiting and help to hold very coarse gold particles back. The mass of the solids retained in the drum dictate the residence time. Solution passes through at a controlled rate. The solution and solids pass through at rates independent to each other. This enables the equivalent of a low leach density to be achieved. The low-density leach allows high levels of fresh reagent to be passed through the solids.

Solid and solution pass out of the reactor drum and into the pregnant solution sump. This sump is divided into three interconnected sections. The first section allows the solids and solution from the reactor tail to report to the solids recirculation pump. This pump transfers all solids to the tails settling cone. The solids settle to the base of the cone and are thickened. This solid reports to the inclined dewatering screen. The solids are dewatered to > 83% w/w and are dropped from the end of the screen into the tailings discharge sump. Any underflow solids from the dewatering screen are returned to the first two sections of the pregnant solution sump.

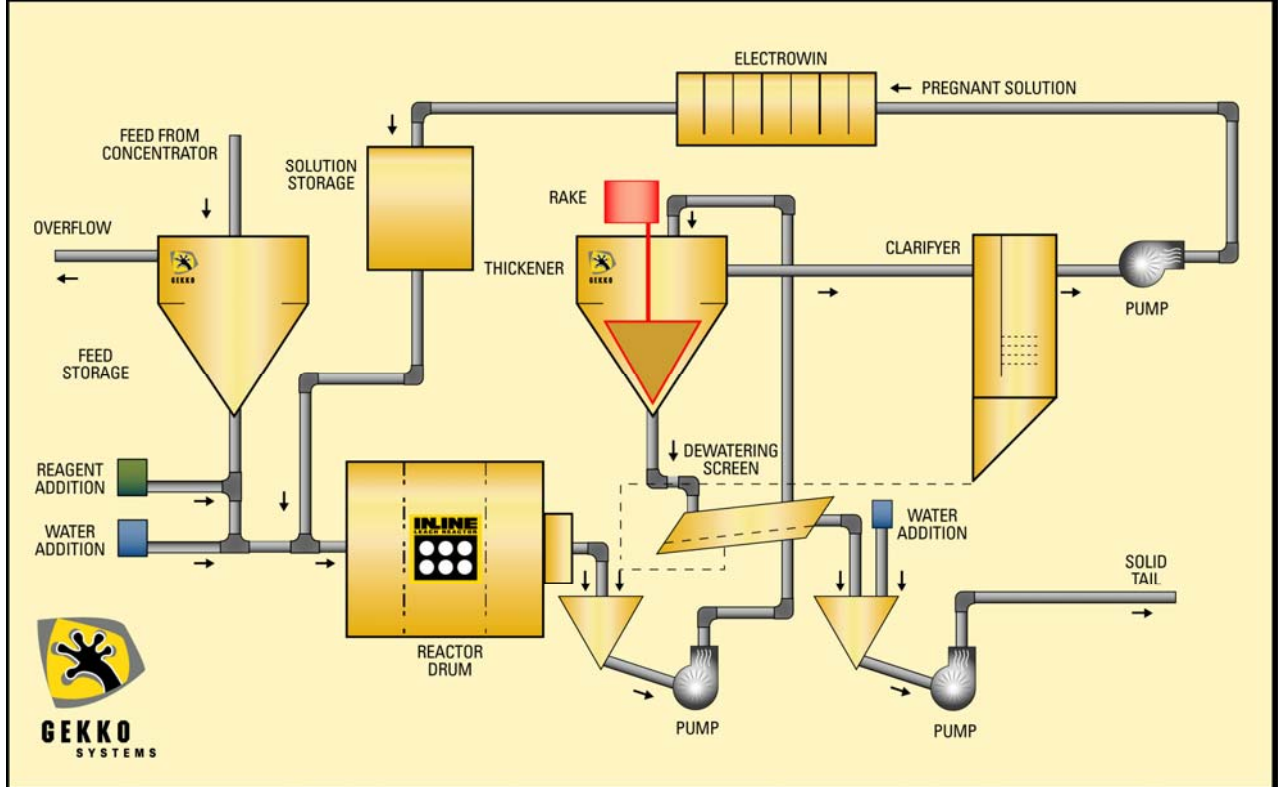
The overflow from the tailings settling cone reports to the second section of the pregnant solution sump. The third section of the pregnant solution sump incorporates a set of lamella plates, which completes the clarification of the liquor. The overflow from the lamella plates reports to the pregnant solution pump, which pump solution to the solids settling vessel. The solids settling vessel is a safety trap to ensure minimal solids reach the electrowinning cell. Flocculent is used to improve clarification performance if required.

The overflow from the solids settling vessel reports to the electrowinning cell. The barren solution overflows from the tail of the electrowinning cell and is returned back to the feed of the reactor drum. The system makes excess solution, which is released as overflow from a small tank located at the reactor feed.

If electrowinning is not metallurgically feasible, other options include Activated Carbon, Aurix resin and Merrill Crowe interfaces.

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CONTINUOUS ILR1000 FLOWSHEET



Drawing of Gekko Systems Continuous InLine Leach Reactor

SPECIFIC ADVANTAGES OF THE CONTINUOUS INLINE LEACH REACTOR

- Demonstrated ability to treat high volume sulphide streams as well as free gold.
- Significant achievements on complex ores as well as oxide ores.
- Extra chemicals added only as required, reducing reagent use and cost.
- Continuous flow allows for instant and straightforward gold accounting.
- Variety of solution recovery options including electrowinning, carbon columns, zinc precipitation and resin absorption.

INSTALLATION LIST

COMPANY	PROJECT	LOCATION	FEED	UNITS
Goldfields	St Ives Upgrade	Australia	IPJ2400 Concentrates	ILR3000BA
Gold Fields	Agnew	Western Australia	Knelson Concentrates	ILR100 BA
Gold Fields	St Ives	Western Australia	Knelson Concentrates	ILR2000 BA
Newmont	Yanacocha	Peru	Refinery Slags	ILR3000 BA
RTZ	PT Kelian Equatorial Mining	Indonesia	Knelson Concentrates	ILR2000 BA
Avgold	Target	South Africa	Knelson Concentrates	ILR100 BA
Buenaventura	Antapite	Peru	Falcon Concentrates	ILR1000 BM
Bendigo Mining NL	Bendigo New Moon	Victoria, Australia	IPJ1500/1000 Conc.	ILR2000 BM
Anglogold Ashanti	Obuasi	Ghana	Knelson Concentrates	ILR2000 CA
Anglogold Ashanti	Obuasi Biox	Ghana	Knelson Concentrates	ILR1000 BA
Anglogold Ashanti	Bibiani	Ghana	Knelson Concentrates	ILR1000 CA
Anglogold Ashanti	Freda Rebecca	Zimbabwe	Knelson Concentrates	ILR1000 BM
Anglogold Ashanti	Iduapriem	Ghana	Knelson Concentrates	ILR1000 BA
Anglogold Ashanti	Cerro Vanguardia	Argentina	Knelson Concentrates	ILR100 CA
Anglogold Ashanti*	Siguiri	Guinea	Knelson Concentrates	ILR1000 BA
Zinifex	Rosebery	Tasmania, Australia	Knelson Concentrates	ILR100 BA
Placer Dome	Henty	Tasmania Australia	IPJ2400 - Spinner Conc.	ILR100 BM
Lion Ore Australia	Thunder Box	Western Australia	IPJ2400 – Spinner Conc.	ILR100 BM

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COMPANY	PROJECT	LOCATION	FEED	UNITS
FML	Frontier	Kazakhstan	Gravity and Flotation Conc.	ILR1000 CM
Randgold / Anglogold	Morila	Mali	Knelson Concentrates	ILR1000 CA
Placer Dome – WAJV	South Deeps	South Africa	Knelson Concentrates	ILR2000 CA
St Barbara Mines Limited	Blue Bird	Western Australia	IPJ1500 – Spinner Conc.	ILR100 BM
Ranger Minerals	Abosso	Ghana	Falcon Concentrates	ILR2000 CA
Specific Resources Bhd	Penjom	Malaysia	IPJ 1500 – Sulphide Conc.	ILR1000 CA
New Hampton	Big Bell	Australia	IPJ 2400 Concentrates	ILR10,000CA
Celtic Resources*	Nezhdaninskoye	Russia	IPJ and Flotation Conc.	ILR10,000 CM
Redback	Chirano	Ghana	Knelson Concentrates	ILR150BA
Barrick	Tulawaka	Tanzania	Knelson Concentrates	ILR100 BA
SMT – Red Rock	Belguwa	Sudan	IPJ1500/InLine Spinner Conc.	ILR1000 BA
Teck Cominco	Pogo	Alaska	Table Middlings/Tails	ILR2000BA
Glamis Gold	Marlin	Guatamala	Knelson Concentrates	ILR1000BA
Griffin	Caijiaying Zink	China	IPJ2400 Concentrates	ILR2000CA
Golden Star*	Bogoso	Ghana	Spiral Concentrates	ILR5000CM
Foran	North Star Project	Canada	2 Stage IPJ Concentrates	ILR5000AC
Olympus Pacific	Ho Gan	Vietnam	2 Stage IPJ Concentrates	ILR5000AC
Newmont	Jundee	Australia	Knelson Concentrates	ILR1000BA
Newcrest	Telfer	Australia	Falcon Concentrates	2 x ILR4000BA
Newcrest*	Kencana	Indonesia	Falcon Concentrates	ILR1000BA
Peak Gold	Peak	Australia	Knelson Concentrates	ILR2000BA

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COMPANY	PROJECT	LOCATION	FEED	UNITS
Kingsgate	Chatree	Thailand	Falcon Concentrates	ILR1000BA
Aurizon*	Casa Baradi	Canada	Knelson Concentrates	ILR1000BA
Hothschilds*	Explorador	Peru	Flotation Concentrates	2 x ILR5000BM
Breakwater Resources*	El Toqui	Chile	Flotation Concentrates	ILR4000BA
Crew Gold*	LEFA	Guinea	Knelson Concentrates	ILR2000 BA
Consolidated Murchison*	Consolidated Murchison Mine	South Africa	Knelson Concentrates	ILR3000BA
Bendigo Mining NL	Bendigo	Australia	Table Tails	ILR2000CA
Ballarat Goldfields*	Ballarat East Project	Australia	IPJ2400 / InLine Spinner Conc	ILR10,000CA
Minera Santa Cruz*	San Jose	Argentina	IPJ / Falcon Conc	ILR5,000CA
Minera Santa Cruz*	San Jose	Argentina	Flotation Concentrates	ILR10,000CA

B = Batch C = Continuous M= Manual A = Automatic

*Currently in production, on trial or awaiting installation



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ILR DEVELOPMENT

Gekko Systems has led the worldwide commercialisation of intensive leaching technology with the development of the InLine Leach Reactor.

The first ILR prototype was designed and developed by Sandy Gray, Technical Director, to treat continuous gold concentrates produced by Gekko's original technology, the InLine Pressure Jig (IPJ). Whilst customers were excited by the volume of gold concentrated by the InLine Pressure Jig, there was no technology capable of treating this mineral stream to the customer's satisfaction.

STEP CHANGE IMPROVEMENT OVER TABLING TECHNOLOGY

In particular the tabling of gravity concentrates was proven to offer very low recoveries - often well below 70% and much lower than expected by the minesites operating these devices. This outcome was true for both installations running IPJ's and Knelson Concentrators.

The research indicated that tabling was clearly a "below optimum" process. It was regarded as inefficient to achieve high recoveries in a high residence unit like the IPJ or high "g" 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 and losses from the leach circuit to tails.

FIRST TRIALS AT MCCLURE

The first InLine Leach Reactor prototype was built in 1997 for a trial at Mt McClure Gold Mine, operated by Australian Resources. A key proponent in pushing for the trial was Rod Elvish, recent President of the AusIMM. Rod recognised that Mt McClure had poor recoveries, which he felt could be maximised by upgrading the gravity circuit. Mt McClure contributed to the costs of the trial, which included the installation of InLine Pressure Jigs as well as the prototype ILR. Whilst the trials were successful, Mt McClure Mine was closed within the following six months.

As a result of this test work and development of the IPJ, Technical Director Sandy Gray was nominated by Rod Elvish for the AusIMM Operating Technique Award, which he was duly awarded at a ceremony in 1998.

The prototype ILR from Mt McClure was onsold and is still being successfully operated by Aurion's Kundana Mine.

TECHNICAL RESULTS

Trials at Mt McClure Gold Mine were performed to investigate the amount of gold leached in each size fraction within the InLine Leach Reactor (ILR). The results (refer below) prove that high recoveries of coarse gold particles are achieved in the unit. Further work carried out at other ILR installations has supported these results with average recoveries of 97% and rapid leach kinetics. The trials were performed over one week intervals with a reactor residence time of approximately 10 hours. The cyanide level was high at 2%. Composite samples were taken during the week, split, screened into fractions and assayed.

SIZE	FEED	GRADE	TAIL GRADE	RECOVERY
TRIAL 1				
+ 1.00 mm	2917	ppm	1.70 ppm	99.95%
+ 0.50 mm	404.8	ppm	67.0 ppm	83.42%
+ 0.25 mm	500.5	ppm	25.05 ppm	95.00%
+75 um	310.8	ppm	14.15 ppm	95.45%
- 75 um	4155	ppm	139.1 ppm	96.65%



SIZE	FEED	GRADE	TAIL GRADE	RECOVERY
TRIAL 2				
+ 2.00 mm	1462	ppm	1.95 ppm	99.86%
+ 1.00 mm	1380	ppm	147 ppm	89.34%
+ 0.50 mm	1289	ppm	27.90 ppm	97.84%
+ 0.25 mm	191.6	ppm	15.25 ppm	92.04%
+75 um	408.9	ppm	14.50 ppm	96.45%
- 75 um	1357	ppm	127.6 ppm	90.60%

AVERAGE FEED	GRADE	RECOVERY
~ 2000 ppm		~ 95 %

In addition to the excellent recoveries, the operators of the ILR can either recirculate the solids through the grinding circuit or discharge the solids. Discharge of the solids may be advantageous in removing tramp steel and “nasty” minerals from the circuit, improving downstream processing. The attractive coarse gold recoveries reflect high oxygen levels and the addition (where appropriate) of leach accelerants such as ProLeach. The baffles within the ILR are designed to trap the coarse product and allow a longer leaching retention time, improving recovery.

OPERATING RESULTS

The results below show the average daily recoveries of the ILR operating at 80-100 kg/hr of gravity (<2mm) concentrates. These recoveries are total recoveries and do not reflect free gold recoveries. No free gold was visible in the reactor solids tailing.

DAY	FEED	TAIL	RECOVERY
	(ppm)	(ppm)	(%)
1	819.0	13.00	98.4
2	381.0	10.50	97.2
3	686.0	3.25	99.5
4	1305.5	15.65	98.8
5	773.0	19.65	97.5
6	695.0	14.35	97.9

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