LEACHING GRAVITY CONCENTRATES

Using the

ACACIA REACTOR

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The ACACIA Reactor

1 INTRODUCTION

When coarse gold is present in an ore, there are advantages in physically recovering this gold in the grinding section of the ore processing plant. This reduces the risk of the coarse gold being locked up in the grinding section equipment, reduces the quantity of activated carbon to be eluted and reduces the risk of gold passing out of the cyanide leaching circuit only partially dissolved.

The free gold may be recovered by various mechanical means utilising the significant difference between the specific gravity of the gold and waste minerals.

Frequently, sulphide minerals and ball mill attrition steel in the form of fines and chips are present in the ground ore and behave in a similar manner to the gold in the concentrating process. These materials must be removed to produce a concentrate suitable for direct smelting and several stages of cleaning, sometimes utilising different physical principles, may be required.

The removal of these materials invariably results in a loss of gold from the final concentrate. The rejected materials containing significant quantities of gold are returned to the grinding section, consequently the opportunity for a high and early recovery has been lost. The quantity of gold returned to the grinding section will vary according to the number and type of cleaning stages and the physical characteristics of the materials and the gold but surveys of the gravity concentration processes suggest that it may be as high as 50%.

To maximise the recovery of gold from the primary gravity concentrate, some operations batch cyanide leach this concentrate with or without additional reagents. The method of agitation and solution recovery vary. The most common method of agitation is by a high-speed propeller mixer and the least expensive but time-consuming method of solution recovery is by decantation after settling and by repeated decant washing. The pregnant gold solution is either introduced into the main ore leaching circuit or the gold is recovered by direct electrowinning.

After commissioning in 1994, Union Reefs Gold Mine (URGM) experienced below expected recovery of gold from the gravity concentrate generated from the Knelson Concentrators. It was shown that the recovery into the Knelson Concentrate was high but that the subsequent mechanical concentrating techniques of tabling and magnetic separation resulted in significant gold being returned to the grinding circuit.

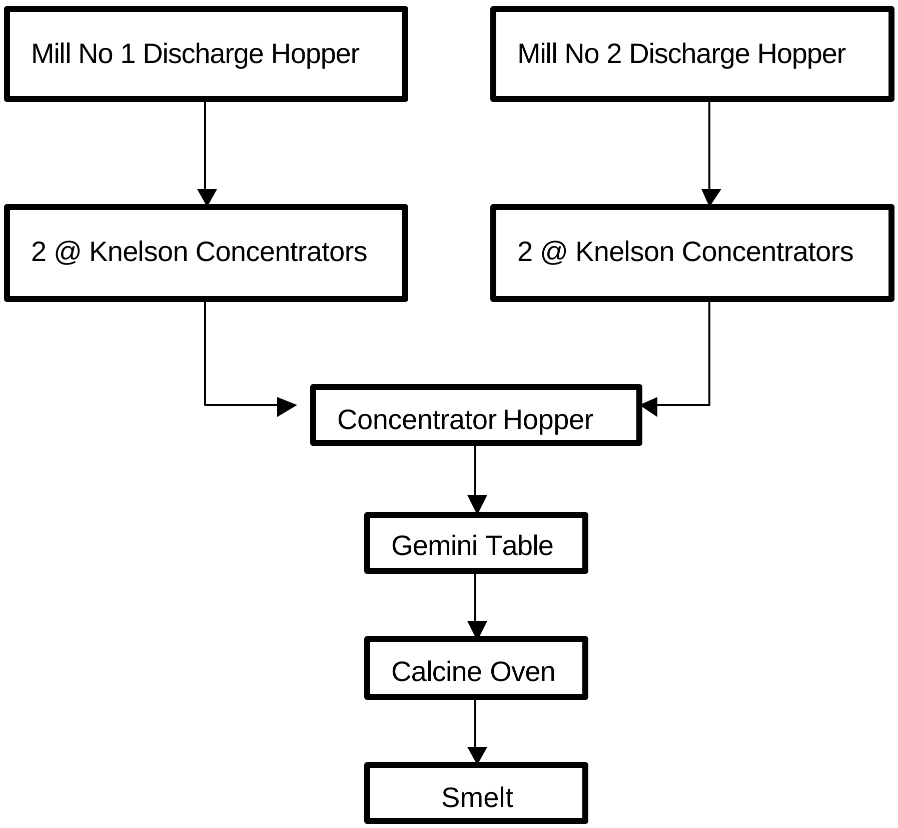
2 GRAVITY CONCENTRATION AT UNION REEFS GOLD MINE

Testwork on the Union Reefs Gold Mine (URGM) oxide and primary ore types indicated that gravity recovery averaging 40% of the gold in the feed was possible. As a consequence a gravity recovery process was designed into the comminution circuit whereby 22% of the mill discharge pulp screened at 5 mm in the trommel screen was distributed between three by 30 inch diameter automatic discharge Knelson Concentrators. Each Knelson Concentrator was protected by a static 2.0 mm aperture DSM screen. Knelson Concentrator tail was returned to the mill discharge hopper and concentrate was discharged to a concentrate storage hopper, located in the gold room, on a six-hourly cycle.

Collected concentrate was upgraded daily using a Gemini table to produce a direct smelt concentrate and the Gemini table tail returned to the mill discharge hopper.

Processing of the Gemini table concentrate involved calcining at 700^{o}C for at least 16 hours to oxidise the fine grinding steel particles as well as the iron, lead and arsenic sulphide contaminates prior to smelting and pouring into bullion bars.

URGM Gravity Concentration Flowsheet



Following commissioning, a number of issues were identified that led to investigating alternative methods for processing the Knelson Concentrator gravity concentrate. The issue drivers were:

- Improve metallurgical accounting to enable a daily instead of a weekly head grade to be calculated.
- Reduce the free gold, estimated at 10%, returned to the grinding section with the Gemini table tail.
- Improve health conditions within the Gold Room by not producing arsenic, lead and sulphur oxides during the calcine stage.
- Improve gold room security by removing the high grade concentrate handling activities from the Gold Room staff duties.
- Eliminate the environmental issue associated with disposing of arsenic oxide precipitate collected in the Gold Room dust collector bag house.

A review of the alternative process methods to that installed at URGM concluded that a chemical dissolution process was preferred to alternative physical upgrade processes.

Acacia Resources decided to pursue the low energy concept of dissolution utilising a fluid bed. The main unknown was the ability to dissolve a minus 2mm gold particle within the target 24 hour cycle period.

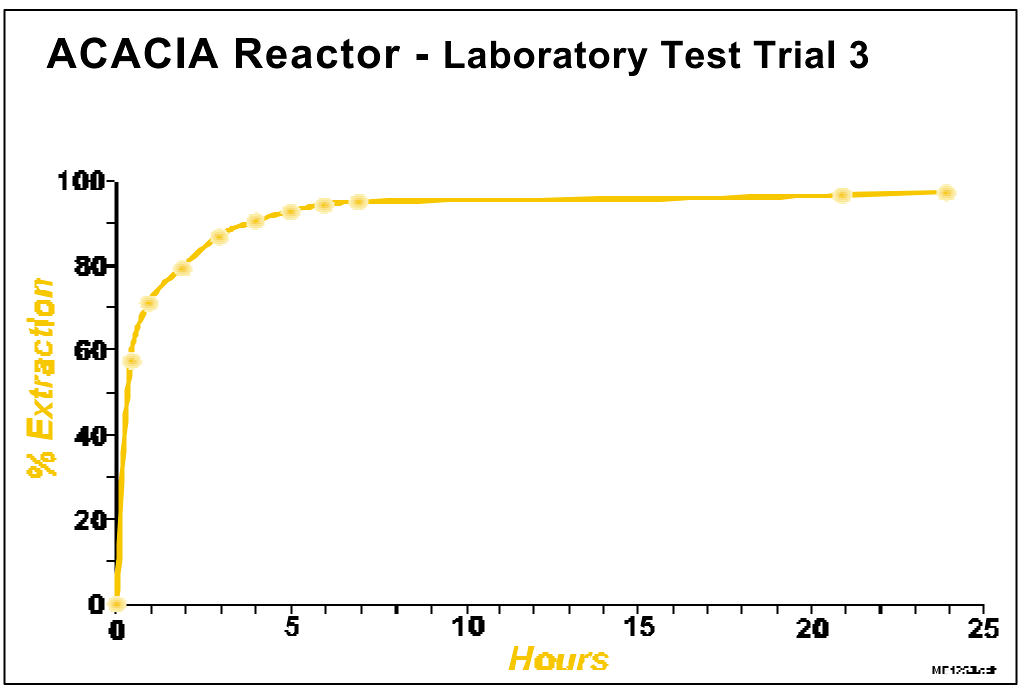
3 *PILOT SCALE ACACIA REACTOR TESTS*

During 1996, URGM developed and pilot-scale tested a batch fluidised bed leaching procedure utilising a strong caustic cyanide solution assisted by the commercially available oxidant, LeachWell KC, as a gold dissolution accelerator to maximise the recovery of gold from gravity-won concentrate without further physical concentrating operations.

The results of three pilot scale tests, simulating the fluidised bed dissolution process and the proposed reagent scheme, produced the following results:

Conditions		**Trial 1**	**Trial 2**	**Trial 3**
Dissolution Reagents				
Sodium hydroxide	gram	175	263	175
Sodium cyanide	gram	1750	2625	1750
LeachWell KC	gram	525	788	525
Concentrate				
Weight	Kg	35	35	31
Head grade	g/t	13,600	10,400	6,100
Residue grade	g/t	812	66	177
Leach time	Hrs	24	24	24

The dissolution curve for trial three shows a very rapid dissolution rate over the first hour where approximately 70% of the gold is dissolved. The 97% dissolution achieved, as shown in the rate curve below, provided sufficient encouragement to proceed with the concept to develop a commercially sized plant.



4 TRANSPORTABLE ACACIA REACTOR PLANT

4.1 DESIGN CONSIDERATIONS

In April 1998, AngloGold Australiasia commenced the design of a transportable demonstration plant to batch-treat 1.0 m^3/day of gravity-won concentrate using the fluidised bed technique developed at URGM.

The design of the transportable treatment plant was to incorporate the following:

- The concentrate was to be treated in batches with the leach cycle completed within 24 hours and the electrowinning cycle completed within the following 24 hours.
- The plant was to be self contained and fully transportable to allow for easy transportation for trials at all Acacia Resources Limited operations.
- The operation of the plant was not to interfere with normal Gold Room activities.
- All gold recovered from the gravity concentrate was to be returned as plated cathode to the Gold Room and all residue products returned to the grinding section.
- The transportable plant was to be secure and include measures to ensure full accountability.
- The equipment should be able to be re-utilised in future permanent installations.

4.2 PROCESS DESCRIPTION

The process is based on a number of batch operations as follows.

1. Transfer of concentrate from the day storage hopper.
2. Stratification of the concentrate charge to assist even solution flow.
3. Prewashing of the concentrate to remove fines.
4. Mixing of leaching reagents.
5. Leaching.
6. Recovery of the pregnant solution and washing of the residue.
7. Discharging of the leach residue.
8. Electrowinning of the gold from the pregnant solution.
9. Disposal of electrowinning tail.

Transfer of Concentrate from the Gold Room

Knelson Concentrator gravity concentrate generated over the 24 hour period is held in a storage vessel in the Gold Room for subsequent transfer to the ACACIA Reactor on day shift.

Stratification of the Concentrate

The success of fluidised bed leaching is dependent upon segregating the concentrate into layers of particles with equal minimum fluidisation velocities such that channelling of solution will not occur. This is achieved by flowing a limited volume of water through the distributor at a rate considerably higher than the fluidising flow rate. The flow is terminated before the Reaction Vessel is full to avoid the carry-over of concentrate particles in the overflow. The concentrate is allowed to settle and the supernatant water decanted

Desliming of the Concentrate

To ensure that the leach overflow solution does not carry suspended solids that will interfere with the subsequent electrowinning of the gold and that water and subsequently pregnant solution can be recovered by drainage through the settled solids, the concentrate solids are fluidised for about 30 minutes. Reaction vessel overflow solution containing fine solids estimated at minus 30 microns is discharge back to the grinding section

Mixing of Leach Solution Reagents

The leach solution is made up in the Reaction Vessel Feed Tank which is fitted with a side-mounted mixer. Potable water (3.2 m^3) is added to the tank and NaOH, NaCN and LeachWell GC are added as solids in that order and mixed.

Leaching of the Concentrate

The leach solution is pumped from the Reaction Vessel Feed Tank via the distributor through the Reaction Vessel at a rate sufficient only to fluidise the concentrate. This ensures that no fine solids are carried over in the pregnant overflow.

The leach solution is circulated through the Reaction Vessel for about 16 hours.

Recovery of Pregnant Solution and Washing of the Residue

At termination of leaching, the Reaction Vessel overflow is sampled for assay, the flow is stopped and drainage of the solution through the distributor to the Reaction Vessel Feed Tank is commenced. After about 15 minutes, when the solids in the Reaction Vessel have settled, pregnant solution is also taken off to the Reaction Vessel Feed Tank via the decant. This reduces the pregnant solution recovery time.

The wash water is applied as a spray to the surface of the residue solids. The minimum quantity of wash applied is approximately equal to the voids in the residue which are about 0.5 m^3.

Discharging of the Leach Residue

The leached residue is fluidised and then discharged to the grinding section.

The very coarse grinding ball chips fail to fluidise and are retained on the distributor screen. The grinding ball chip is physically removed from the Reaction Vessel.

Electrowinning

The pregnant solution and recovered wash solution in the Reaction Vessel Feed Tank are mixed and pumped to the Electrowinning Cell Feed Tank where it is sampled and the volume of the solution is measured.

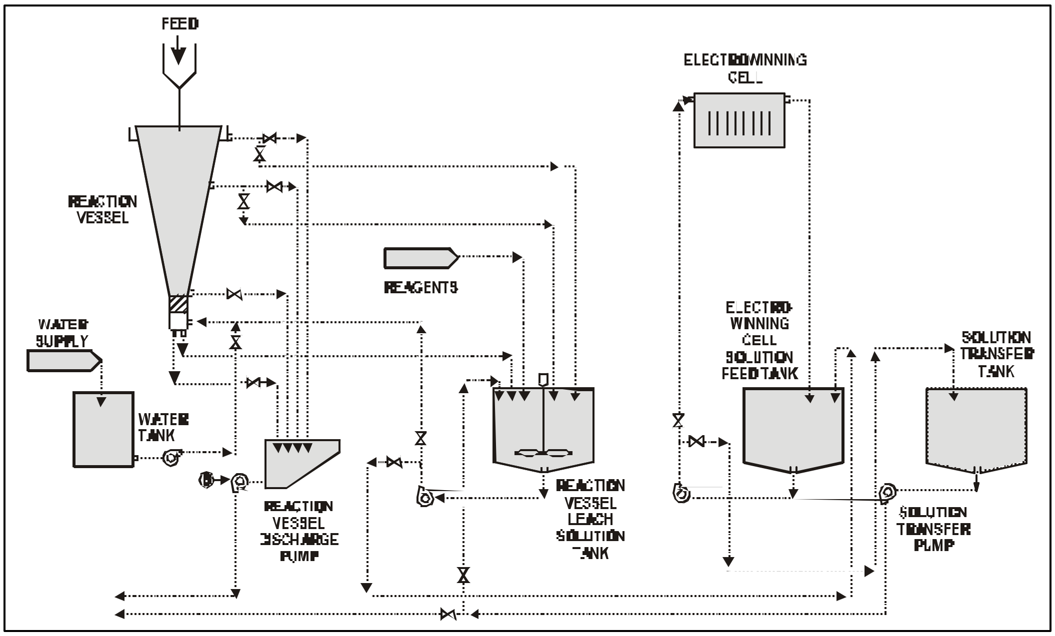
The solution in the Electrowinning Cell Feed Tank is pumped to the EW Cell at controlled flow rate. Solution is circulated on the cell for a specific period of time determined by the cell tail assay.

Disposal of Electrowinning Tail

The EW Tail is transferred in total to the CIL circuit.

4.3 FLOWSHEET

The flowsheet developed for the process is shown below



5 ENGINEERING AND CONSTRUCTION

The design concept for the transportable ACACIA Reactor was based on using modules which were sized to be easily transported to the various AngloGold Australasia sites as normal “in gauge” loads which allowed for day and night travel and eliminated the need for an escort vehicle.

The plant was based on three major items of equipment - namely, the Lower Module the Upper Module and the Raw Water Tank.

Plug in electrical connections were used to join all electrical circuits between the Lower and Upper Modules. This approach eliminated the need for an electrician on site to perform any equipment wiring other than termination of the incoming supply cable to the MCC.

Similarly, all necessary piping was pre-run on the modules with flanged connection between the Lower and Upper Modules. This approach eliminated the need for on-site piping work with the only field connection necessary being the incoming and outgoing product lines.

The Lower Module was fitted with four levelling jacks which eliminated the need for precise and level concrete foundations.

The unit was facility-assembled and wet-commissioned in the workshop. This approach ensured all the pumps were wired correctly and all the process lines were checked for leaks and correct destination.

Construction commenced in October 1998. The plant was delivered to the URGM site on 10 January 1999 for commissioning and a full month plant trial during February 1999.

6 OPERATING AT URGM

6.1 COMMISSIONING PERIOD

The ACACIA Reactor was located on the south side of the grinding section adjacent to the No. 2 Ball Mill.

Commissioning of the ACACIA Reactor was conducted using 0.94 m^3 of Gemini Table Tailing since this did not interfere with normal URGM production. Leaching of this material proceeded as expected producing a 1.7 g/t residue but an unexpected issue arose with the electrowinning process being retarded.

The initial leach solution (3.2m^3) contained 90 kg NaCN, 9 kg NaOH and 27 kg LeachWell GC based on recommendation by the LeachWell GC supplier. On the assumption that the LeachWell GC reagent was retarding the electrowinning, the reagent combination was altered mainly decreasing the amount of Leachwell GC used. The combination that was settled on that enabled complete dissolution of gold and subsequent recovery in the electrowinning cycle within the 16 hour time period for each operation, was 45 kg NaCN, 9 kg NaOH and 3 kg Leachwell equivalent to 1.25% NaCN, 0.25% NaOH and 0.08% LeachWell GC.

Trial Treatment Period Results

From 28 January to 1 March (33 days), all Knelson Concentrate available at the Gold Room was treated in the ACACIA Reactor. The production data are summarised below:

	Units	
Production days		33
Concentrate treated	m^3	11.1
Residue contents	Kg Au	1.417
Calculated Head	Kg Au	70.473
	Au g/t	3528
Leach Extraction	Au %	98.0

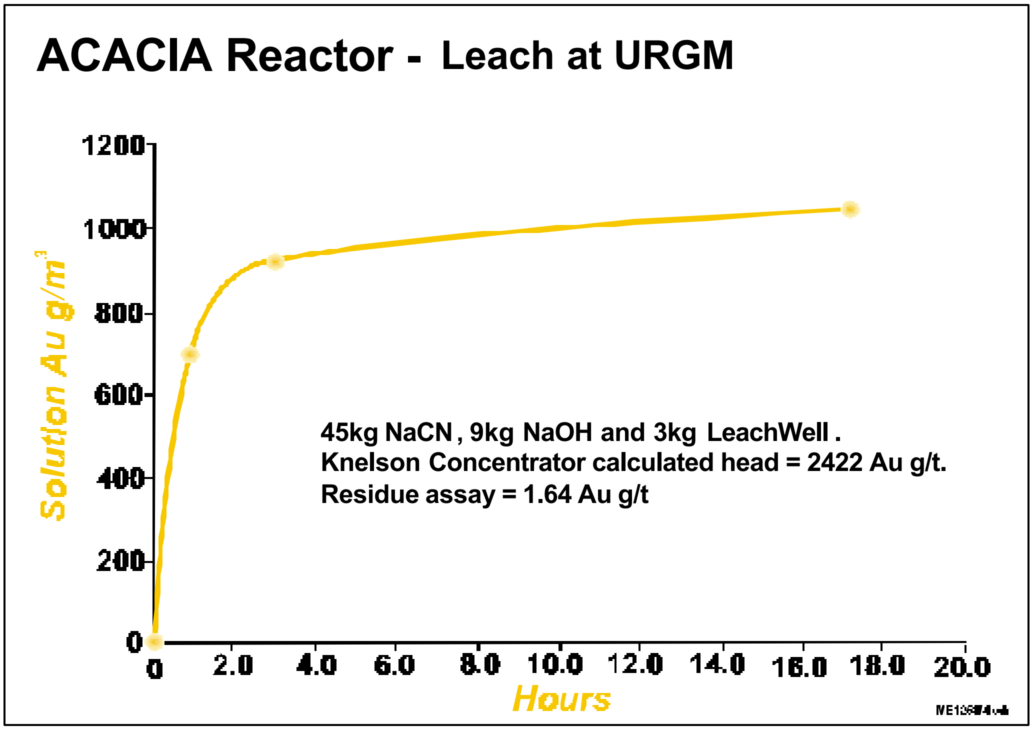
Safety

Throughout the operation of the ACACIA Reactor, pH of solutions and HCN levels in air in the Upper Module were monitored. Readings taken immediately above the solution tanks, the Reaction Vessel and the EW Cell never exceeded 2ppm HCN.

Dissolution of Gold

The gold recovered into concentrate varies daily. During the 33 day trial the range of the daily gravity concentrate gold content was from 3.2 kg to 10.7 kg per batch. There were no difficulties in operating the ACACIA Reactor with this wide variation in feed gold content.

Typical dissolution curve, as per the graph below, shows rapid initial dissolution with plus 99% dissolution achieved with in the 16 hour time frame. Solution value between 1000 ppm to 2600 ppm were generated in the 3.2 m^3 dissolution solution.



Metallurgical Accounting
A thorough sampling programme was carried out during the month long production trial to provide data to assess operating parameters and enable calculation of a detailed metallurgical account.

Operating Costs
Because of the manual operation of the Portable ACACIA Reactor treatment plant, the labour requirement was about the same as for operating the Gemini Table in the Gold Room

The sodium cyanide and caustic soda cost have been calculated from the actual usage for the 33 days of concentrate production and for a projected addition of 3 kg of LeachWell GC per batch. No credit has been allowed for the benefit of reagents provided when the EW Tail is transferred to the CIL circuit.

Electric power consumed has been based on the actual hours of operation of the individual units and an assumed power draw by each unit. The unit cost for power has been allowed at $0.10/kWh.

Actual	**Reagents**	**Power**	**Total**
$ per batch of concentrate	219	26	245
$ per day	80	13	93
$ per Oz	1.31	0.21	1.52

6.2 OPERATING PERIOD

The results for the trial month were so encouraging that URGM retained the transportable ACACIA Reactor unit on site as a production unit treating all of their Knelson Concentrator concentrate until October 1999. During this period URGM designed, built and installed an ACACIA Reactor within the gold room replacing the Gemini table and associated activities.

A summary of the gold recover distribution for the URGM operation is shown in Table A. There has been a plus 20% increase in gold recovered by gravity circuit since the installation of the ACACIA Reactor.

Table A. URGM Gold Distribution

Month	Gravity Recovery		CIL Recovery	
	kg	%	kg	%
Ist Half 95	210.99	16.20	1058.03	81.23
2nd Half 95	291.92	20.05	1121.61	77.02
Ist Half 96	352.02	24.46	1017.54	70.70
2nd Half 96	347.83	25.41	951.82	69.54
Ist Half 97	272.91	25.47	738.41	68.92
2nd Half 97	224.39	14.29	1248.09	79.51
Ist Half 98	350.85	18.73	1395.90	74.51
2nd Half 98	195.97	11.78	1346.53	80.97
ACACIA Reactor commenced				
Ist Half 99	444.84	24.41	1240.70	68.07
2nd Half 99	667.51	29.18	1453.01	63.52

The major impact within the gold room has been the eliminated the health issues due to arsenic oxide fumes generated when treating Gemini table concentrate and improvement security with respect to manually handling of high grade gold concentrates.

Other improvement has been a stabilising of the CIL recovered gold, reduc ing the overload situation developed in the CIL/Elution circuit due to the increasing tonnage throughput.

7 ACACIA REACTOR AT SDGM

The transportable ACACIA Reactor was transferred to Sunrise Dam Gold Mine and commenced operation during November 1999.

The main reason for trialing the ACACIA Reactor concept at SDGM was to prove the unit could dissolve, not only the increased quantity of gravity recoverable gold but also the coarser gold that occurred at SDGM.

The increased quantity of gold proved to be not an issue for the ACACIA Reactor as on one occasion during the trial period dissolving 38 kg of gold from a batch of gravity concentrate. The unit proved to be extremely versatile, handling individual batches containing recoverable gold between 12.5 kg to 38.4 kg of gold.

The very coarse gold flakes typically the size of an Australian 10 cent coin were not dissolved during the allocated 16 hours dissolution cycle. As these gold particles were the exception rather than the norm, no changes were made to the leach conditions because all leached residue was returned to the grinding section where any coarse gold will be returned to the ACACIA Reactor for a second and third chance for dissolution.

7.1 COMMISSIONING PERIOD

From 15th November, 1999 to 1st January (48 days), all Knelson Concentrate available at the Gold Room was treated in the ACACIA Reactor. The production data are summarised below:

	Units	
Production days		48
Concentrate treated	m^3	20.4
Estimate	Dt	44.9
Residue contents	kg Au	60.4
Calculated Head	kg Au	579.6
	Au g/t	12908
Leach Extraction	Au %	89.6

7.2 OPERATING PERIOD

At the time of writing this paper the ACACIA Reactor had only been in action for 4 months and the trends indicate improved gravity recovery, but the variations in ore types processed during this time and throughout the mine life makes it difficult to state categorically the Acacia reactor has increased gravity recovery. The gold distribution is shown in Table B below.

Table B. SDGM Gold Distribution

Year	Gravity Recovery		CIL Recovery	
	Kg	%	kg	%
2nd Half 97	1617.26	47.8	1648.66	48.7
Ist Half 98	1434.86	44.5	1653.51	51.3
2nd Half 98	1280.20	43.6	1512.62	51.5
Ist Half 99	1100.87	46.9	1097.22	46.7
2nd Half 99	1712.21	47.2	1587.15	43.7
ACACIA Reactor commenced				
3 months	915.69	48.4	739.65	39.1

8 COMMERCIAL

A patent covering the process has been granted. ConSep have been granted a licence to sell the ACACIA Reactor by AngloGold Australasia.