

Metalliferous Mining - Processing
LEACHING & ADSORPTION
Resource Book

Table of Contents

TABLE OF CONTENTS	2
INTRODUCTION TO LEACHING & ADSORPTION.....	3
<i>What is this module about?</i>	3
<i>What will you learn in this module?</i>	3
<i>What do you have to do to complete this unit?</i>	3
<i>What resources can you use to help?</i>	3
INTRODUCTION.....	4
CYANIDATION THEORY.....	5
FACTORS AFFECTING THE RATE OF THE CYANIDATION REACTION.....	6
Size of Gold Particles.....	6
Free Cyanide Concentration.....	6
Dissolved Oxygen.....	6
Slurry pH.....	6
Residence Time.....	7
Agitation.....	9
Temperature.....	9
Cyanocides and Oxygen Consumers.....	9
Lead Nitrate.....	9
Slurry Density.....	9
CARBON ADSORPTION THEORY.....	10
FACTORS AFFECTING ADSORPTION EFFICIENCY AND RATE.....	10
Time.....	10
Foulants.....	10
Gold Concentration.....	11
Slurry Density.....	11
Temperature.....	11
CIL CIRCUIT COMPONENTS AND PROCESS FLOW.....	12
<i>Trash Screens</i>	12
<i>Leach Feed Thickener</i>	12
<i>CIL Tanks</i>	12
<i>Intertank Screens</i>	13
<i>Carbon Forwarding Pumps</i>	14
<i>Carbon Safety Screens</i>	14
<i>Automatic Sampling Mechanisms</i>	15
<i>TAC Cyanide Analyser</i>	15
Debex Carbon Meter.....	15
Leach Feed Slurry Autosampler.....	15
Tailings Slurry Autosampler.....	15
CIRCUIT FLOW DIAGRAMS.....	16
BASIC CIL CIRCUIT TROUBLESHOOTING.....	18
<i>Notes</i>	<i>Error! Bookmark not defined.</i>

Introduction to Leaching & Adsorption

What is this module about?

This unit is about how we manage and conduct leaching and adsorption within the processing plant

What will you learn in this module?

When you have completed this module, you will be able to:

- Demonstrate an understanding of cyanidation theory
- Demonstrate an understanding the factors that affect leaching
- Demonstrate an understanding of carbon adsorption theory
- Demonstrate an understanding the components and equipment used in a leaching and adsorption circuit

What do you have to do to complete this unit?

You will need to complete all the training tasks in your workbook, the review exercise and the assessment given to you by your supervisor.

Discuss the competency standards for this unit with the Training Coordinator or your supervisor.

What resources can you use to help?

If you need more information about topics in this unit, then you should approach:

- Your work mates and supervisor
- The training coordinator
- Metallurgists

Introduction

The CIL (Carbon in Leach) circuit is an intermediate stage in the production of gold. The process involves dissolving the solid gold particles into solution using a process known as cyanidation.

The dissolved gold in solution is adsorbed onto activated carbon. When the carbon is loaded with enough gold it is removed from the circuit and sent to elution where the adsorption process is reversed and the gold is stripped off the carbon back into solution, electrowon and smelted into bars.

The remaining 'barren' slurry reports to the tails thickener and is pumped to the tails dam.

The CIL circuit consists of two separate trains of tanks, with seven tanks in each train. In conventional CIL circuits, leaching takes place in the presence of carbon and therefore leaching and adsorption occur simultaneously. The CIL circuit at SDGM can be considered a hybrid circuit as the first tank of each train are purely leaching tanks (no carbon addition).



CIL Tank Train No. 1

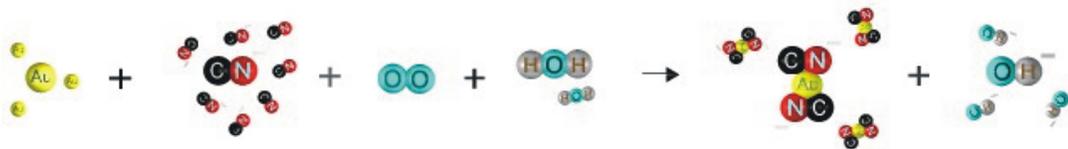
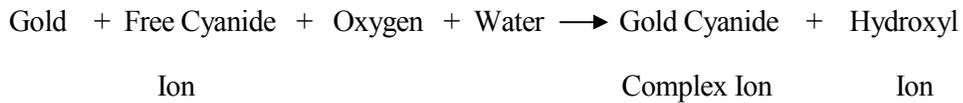
Cyanidation Theory

The Cyanidation Reaction

CIL technology is based on the fact that the gold dissolves readily in cyanide solutions in the presence of oxygen, and the resultant gold cyanide complex ion (molecule) is readily adsorbed onto activated carbon.

The dissolution of gold takes place via the following reaction:

REACTANTS \longrightarrow PRODUCTS



The goal of leaching is to ‘push the reaction to the right’ ie; consume the reactants to produce the gold complex in solution.

Therefore to leach the gold out of the ore and into solution, cyanide, and oxygen must be added to the slurry. Lime is added to the grinding circuit to modify the pH of the slurry to prevent the formation of deadly hydrogen cyanide gas. Cyanide is added in liquid form to the tanks and lime is added to the ore prior to milling. Oxygen is added in pure form, injected down the agitator shafts.

Factors Affecting the Rate of the Cyanidation Reaction

Size of Gold Particles

The gold must be in a fine particulate form (from the grinding circuit). The feed slurry must have an 80% passing size of 75µm to achieve suitable gold recovery (refer to cyclone and grinding modules). If the particles are too large they may not be totally leached during their residence time in the tanks and hence will report to tailings.

Free Cyanide Concentration

Increasing cyanide concentration drives the cyanidation reaction to the right. There must be sufficient free cyanide ions in solution to dissolve all the gold, otherwise it will be lost to tailings. The more gold which has to be leached, the more cyanide required. In practice, a balance is sought so that there is sufficient cyanide to leach the gold, but not so much that excess cyanide is left at the end of the adsorption process to be lost to tailings. This would not only increase the production cost, but also pose greater environmental problems.

Dissolved Oxygen

There must be sufficient entrained oxygen in the slurry. Increasing the oxygen concentration drives the reaction to the right. The flow of oxygen should be such that the bubbles get broken up and become finely dispersed in the slurry. If the flow rate is too high then the bubbles will not be broken up but rather burst on the surface. This is ineffective as the oxygen is released to the atmosphere rather than dissolving and hence reacting in the slurry. The flow rate should be adjusted so the surface of the tank is covered with a lot of small bubbles breaking gently as opposed to a lesser amount of large bubbles breaking violently.

The picture opposite shows some of the rotameters that are used to measure oxygen flowrate to the agitator shafts. Flow is regulated manually by means of ball valves.



Slurry pH

pH modification is achieved by adding lime to the ore prior to milling which makes the slurry alkaline (high pH). The pH level in the tanks is monitored regularly by the process technician responsible for the CIL circuit.

The term pH is the unit of measurement of a solutions' alkalinity or acidity. It is calculated in terms of hydrogen ion concentration.

$$\text{pH} = -\log(\text{hydrogen ion concentration})$$

The pH scale ranges from 0 to 14, the lower the pH the more acidic, the higher the more alkaline and a pH of seven means a neutral solution.

When Sodium Cyanide (NaCN) is added to water the cyanide portion of the molecule disassociates from the Sodium part.



Sodium Cyanide → **Sodium Ion** + **Cyanide Ion**

Depending on the pH of the slurry the cyanide can react with the hydrogen in the water to form deadly hydrogen cyanide gas.



Free Cyanide Ion + **Water** ↔ **Hydrogen Cyanide Gas** + **Hydroxyl Ion**

If the pH of the slurry is low then the reaction will proceed to the right forming hydrogen cyanide gas. On the other hand, if the pH is high then the reaction will move to the left and the free cyanide ion will be the stable species.

The formation of hydrogen cyanide gas reduces the amount of cyanide available to leach the gold and is also potentially fatal if inhaled at certain concentrations. Therefore it is important that high pH levels are maintained to prevent HCN gas formation and excess cyanide consumption.



Residence Time

Residence time in the CIL circuit is the time taken for the slurry to flow through the tanks, and is an important operational consideration. The longer the gold particles are in contact with the cyanide in the slurry the more gold that will be leached.

Residence time is determined by the volume of the tanks (which is fixed), the slurry flowrate and the slurry density.

Effect of Changes in Pulp Density and Tonnage Rate on Residence Time

150 tph @ 50 % solids

150 tph @ 45 % solids

165 tph @ 50 % solids

$$\text{Solids Volumetric Flowrate} = \text{Solids Mass Flowrate (tph)} / \text{Solids S.G (3.05)}$$

$$= 49\text{m}^3/\text{hr}$$

$$= 49\text{m}^3/\text{hr}$$

$$= 54\text{m}^3/\text{hr}$$

$$\text{Water Mass Flowrate (tph)} = \text{Solids Mass Flowrate (tph)} \times (\% \text{Water} / \% \text{Solids})$$

$$= 150 \text{ tph}$$

$$= 183 \text{ tph}$$

$$= 165 \text{ tph}$$

$$\text{Water Volumetric Flowrate (m}^3/\text{hr)} = \text{Water Mass Flowrate (tph)} / \text{Water S.G (1.12)}$$

$$= 134 \text{ m}^3/\text{hr}$$

$$= 164 \text{ m}^3/\text{hr}$$

$$= 147 \text{ m}^3/\text{hr}$$

$$\text{Pulp Volumetric Flowrate (m}^3/\text{hr)} = \text{Solids Volumetric Flowrate (m}^3/\text{hr)}$$

+

$$\text{Water Volumetric Flowrate (m}^3/\text{hr)}$$

$$= 183 \text{ m}^3/\text{hr}$$

$$= 213 \text{ m}^3/\text{hr}$$

$$= 201 \text{ m}^3/\text{hr}$$

$$\therefore \text{Residence Time per Tank} = \text{Tank Volume (679m}^3) / \text{Pulp Volumetric Flowrate (m}^3/\text{hr)}$$

$$= 3.7 \text{ hrs}$$

$$= 3.2 \text{ hrs}$$

$$= 3.4 \text{ hrs}$$

Agitation

Effective agitation allows the reactants to intimately mix and prevents the solids from settling out, bogging the tanks. Agitation also ensures that the gold cyanide complex ions forming on the surface of a gold particle are removed into the wider solution to allow 'access' on the gold particles' surface for more unreacted cyanide ions to leach more gold from the particle.

Temperature

Higher temperatures will increase the rate of gold dissolution, however it is not economical to heat the slurry. High temperatures also reduce the capacity of carbon to adsorb gold and lower the solubility of oxygen in the slurry. Therefore leaching and adsorption is conducted at ambient temperatures.



CIL Tank Agitator

Cyanocides and Oxygen Consumers

Many other metals and minerals besides gold also dissolve in alkaline cyanide solution. Some of these metals and minerals have the potential to consume cyanide and oxygen, as well as producing substances which can reduce the efficiency of gold leaching.

Minerals that cause excessive consumption of cyanide are called cyanocides. Examples include copper, nickel, iron and sulphide minerals. If they are present in the ore, extra cyanide must be added which can add considerably to the cost of leaching the gold.

Other minerals, such as arsenic can react with the oxygen and slow the rate of gold dissolution.

Lead Nitrate

Lead nitrate is added to the leach circuit and has the effect of accelerating the gold dissolution rate.

Slurry Density

Reagent consumption is minimised by maximising slurry density, since optimal concentrations can be achieved at lower dosages, due to the smaller volume of solution per unit mass of material.

Carbon Adsorption Theory

After the leaching process is complete, the soluble gold must be concentrated and separated from the process slurry. The method of recovery of gold from the process slurry is by carbon adsorption.

Adsorption is a term used to describe the attraction of a mineral compound to the surface of another material. Activated carbon is used to adsorb the gold out of solution. Because the cyanide ion forms very strong complexes with gold, it is the gold cyanide complex that is loaded onto the carbon rather than being deposited as metallic gold.

Activated carbon, or charcoal as it is now less commonly known, is made from organic material such as peat, fruit pips or coconut shell. The activated carbon used at SDGM is a special extruded granular carbon which has a high attrition resistance. Each particle has an extremely large surface area due to millions of internal pores.



‘Norit’ Extruded Carbon

Factors Affecting Adsorption Efficiency and Rate

Time

The longer the carbon is in contact with the slurry the more gold it adsorbs. However, although at first the gold cyanide adsorption takes place very quickly, it will slow down as more gold is loaded onto the carbon.

Foulants

Activated carbon is subject to ‘fouling’ with inorganic and organic matter. Fouling means that material other than the valuable metal is adsorbed or absorbed onto the carbon, decreasing the number of ‘active sites’ available for adsorption of the valuable metal. This reduces the carbon’s ‘activity’ (the ability to adsorb gold).

It is not possible to prevent fouling altogether. Salts, other metals and organic matter are invariably present in the ore and water supplies. It is possible however, to minimise the degree of fouling by ensuring no foulants are added to the process unnecessarily (eg oils, grease etc).

Foulants are removed from the carbon during elution and carbon reactivation. Inorganic foulants such as calcium, salt, other metals and reagents, are removed by acid washing, whilst organic foulants such as oils, grease and fats, are removed by high temperature thermal reactivation. (Refer to the Elution and Carbon Reactivation module).

Gold Concentration

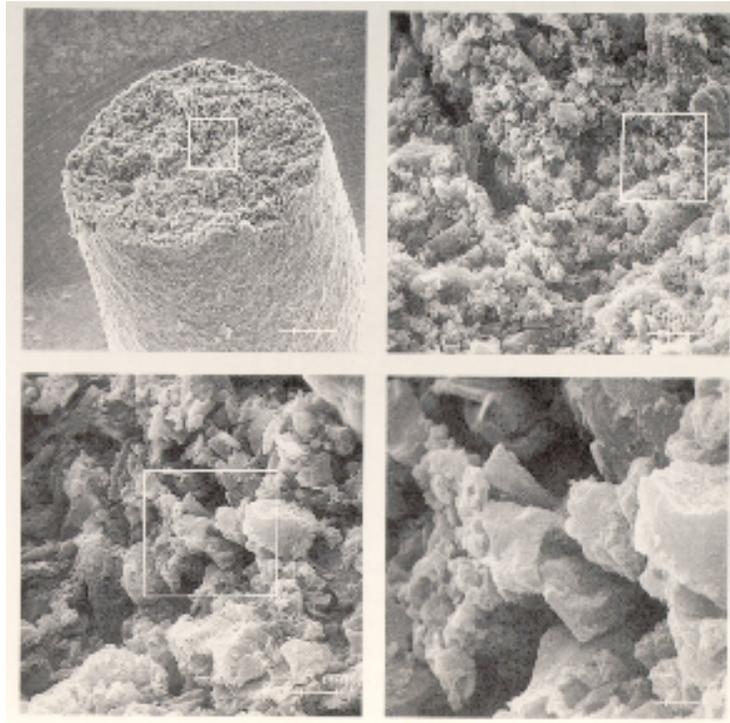
The rate of gold adsorption and the loading capacity of the carbon increases with increasing gold concentration in solution.

Slurry Density

The rate of gold cyanide adsorption decreases with increasing slurry density. However, if the slurry density gets too low then the carbon particles may not stay in suspension, and sink to the bottom of the tanks.

Temperature

The adsorption rate increases slightly with increasing temperature, however the loading capacity is reduced. Leach and adsorption is conducted at ambient temperature.



Pictures taken with a microscope showing the porous internal structure of carbon.

CIL Circuit Components and Process Flow

Trash Screens

The overflow slurry stream from the cyclone nest feeds the CIL circuit via the leach feed thickener. Before entering the leaching circuit, all the wood fibre, cloth, plastic, rocks from cyclone blowouts and other trash material must be removed from the slurry. If trash is not removed it may block the CIL interstage screens causing tank overflows and also cause problems in the elution and carbon reactivation circuit.

The cyclone overflow is fed to three trash screens, the undersize reports to the leach feed thickener feed hopper and the oversize trash material is collected and discarded.

Leach Feed Thickener

Slurry from the trash screens flows into the thickener feed hopper. The slurry is pumped from the hopper to the thickener where the slurry is flocculated and thickened to a density of 50% solids. The thickener underflow reports to a hopper from which the slurry is then pumped to the leach feed splitter box.



CIL Tanks



The major component of the CIL circuit are the two, seven tank leaching trains. The eastern, first train of tanks (train no.1, tanks 1 to 7) were part of the original plant. The western, second train of tanks (train no.2, tanks 101 to 107) was commissioned as part of the stage three plant expansion, and is very similar in design and operation as the original train apart for a few minor differences. The first tank of each train is purely a leach tank (no carbon), the remaining six are leach and adsorption (CIL) tanks. Each tank has an effective volume of 761m³ each, and operate at a leach density of 50% solids, giving a residence time of approximately 4 hrs leach (first tank) and 22 hours CIL. Tanks 1 and 101 (the leach only tanks) are the slurry feed end of trains 1 and 2 respectively, and tanks 7 and 107 the tail end.

The tanks are positioned in two staggered rows. In train 1 the tanks are interconnected with open launders and gate valves, in train 2 flow between tanks involves a system of pipes and dart valves. The flow through the tanks is such that any tank in the system may be bypassed, while the circuit continues to operate with reduced volume and residence time.

The slurry from the thickener underflow is pumped to a splitter box, which distributes the feed evenly between each train. Cyanide solution is added to the leach feed (thickener underflow) hopper, distribution box and also to the first three CIL tanks of each train (tanks 2, 3, 4, 102, 103 & 104). The tanks are agitated by twin impellers, with oxygen injected through lances down the hollow agitator shafts.

Tank 1 also incorporates a ‘multi-mix’ unit and recirculation pump as another means of adding oxygen to the slurry. Slurry is pumped from the base of the tank and is discharged below the slurry line at the top of the tank. Within the pipe, immediately after the pump is the multimix unit which injects oxygen into the passing slurry stream. The oxygen is injected as a fine jet of bubbles which are sheared by the slurry flow, giving good oxygen dissolution within the slurry.

Slurry flows by gravity through each train, with the overflow launder from each tank being preceded by an intertank screen that prevents the advance of carbon with the slurry. Barren slurry from the final tank of each train flows to a carbon safety screen, which prevents the loss of carbon in the instance that the final intertank carbon screen is holed. The barren slurry underflow from the safety screen reports to the tails thickener feed hopper.

Reactivated carbon is added to the final tank (tanks 7/107) of each train and is moved counter currently to the flow of slurry by centrifugal carbon transfer pumps, finally being removed for stripping from the second tank (tanks 2/102) of each train.

Intertank Screens

Screens are fitted in each of the CIL tanks to retain the carbon in the tank, as the circuit operates with carbon being moved counter-current to slurry flow.

The screens are cylindrical and are fitted just prior to the slurry exit launder. Wiper blades with a dedicated drive motor system are installed to keep the screen surfaces free from carbon build-up. If the wiper blades fail, then carbon is carried/forced onto the screen surface by the slurry flow. This impedes the flow of slurry and may cause the tank to overflow.

The screens may also become holed due to damage or deterioration. To check whether the screens are passing carbon, a sieve is dipped into the discharge launder and inspected.



The screens will also become pegged with near sized carbon and other material such as small rocks and need to be removed and cleaned/replaced regularly to prevent tank overflows.

Carbon Forwarding Pumps

To facilitate the counter current movement of carbon, each CIL tank has a carbon-forwarding pump.

The pumps are run on a batch schedule as required to maintain the desired carbon concentrations in the tanks. The forwarding pump from tanks 2 and 102 pumps to the loaded carbon screen where the carbon is screened from the slurry and sent to the elution column. The slurry underflow from the loaded carbon screen is returned to either tank 2, 102, 4 or 104.



Carbon Safety Screens

Both of the CIL trains each have a carbon safety screen over which the tail slurry from tanks 7/107 is passed.

Carbon may be present in the tailings slurry due to either:

The carbon has abraded over time and is fine enough to pass the intertank screen.

The intertank screen is holed.

The seal between the launder and the screen has deteriorated or is not seated properly, allowing carbon to pass.

If the screen wasn't present this carbon would end up in the tailings dam resulting in gold and carbon losses. Generally the carbon on the safety screen is due to the screen being holed or the launder seal not sealing properly. This carbon is collected and put back into the circuit.

The slurry underflow from each of the carbon safety screens flows into separate tails thickener feed hoppers, from which the slurry is pumped to the tailings thickener feed box.

Automatic Sampling Mechanisms

TAC Cyanide Analyser

The TAC analyser is an automatic titration unit that measures the cyanide concentration and pH of the slurry. A slurry sample from the splitter box is taken through a filtration sock and is sent by a peristaltic pump to the analyser unit. The filtered sample is titrated with silver nitrate to determine the free cyanide concentration. A probe measures the pH of the solution.

The cyanide concentration result as determined by the TAC is used in a control loop to automatically adjust the cyanide addition rate to the circuit.

Debex Carbon Meter

Each CIL tank is fitted with a Debex carbon meter. The meter measures the carbon concentration in the slurry. It works by sending an ultrasonic signal through the slurry, and from the loss of signal energy over the detection gap, determines the carbon concentration. The Debex system also incorporates a densimeter to account for variations in pulp density, which will alter the amount of energy absorbed from the ultrasonic pulse.



TAC Titration Unit

Leach Feed Slurry Autosampler

An autosampler intermittently takes a cut of the feed to the trash screens. The sample collects in a bucket that is removed daily by the laboratory technician.

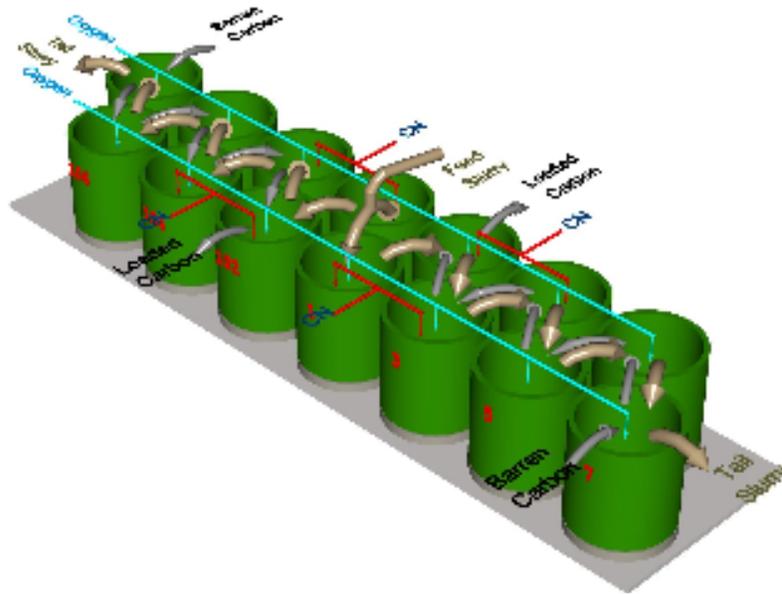
Tailings Slurry Autosampler

An autosampler placed prior to each carbon safety screen takes a periodic cut of the tailings slurry from each train.

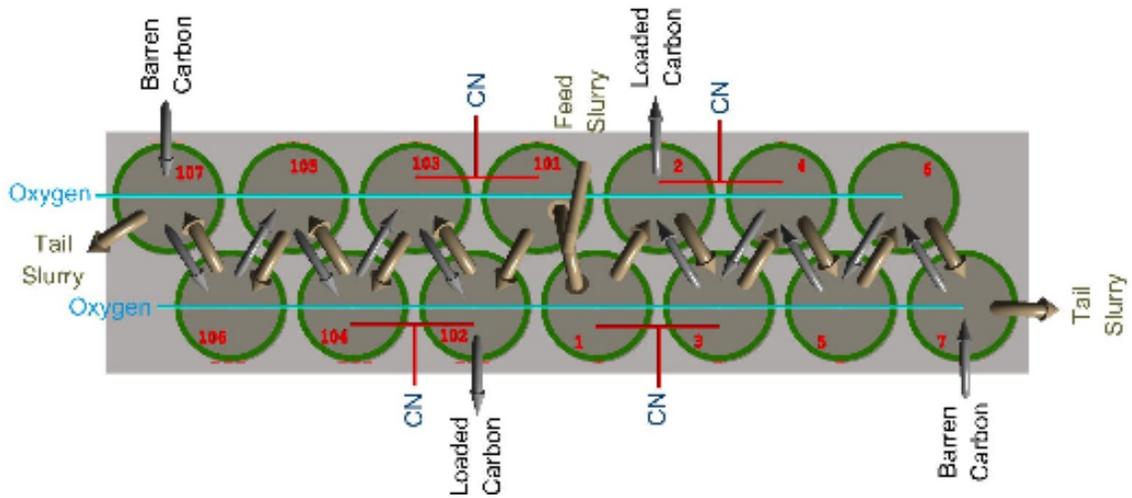


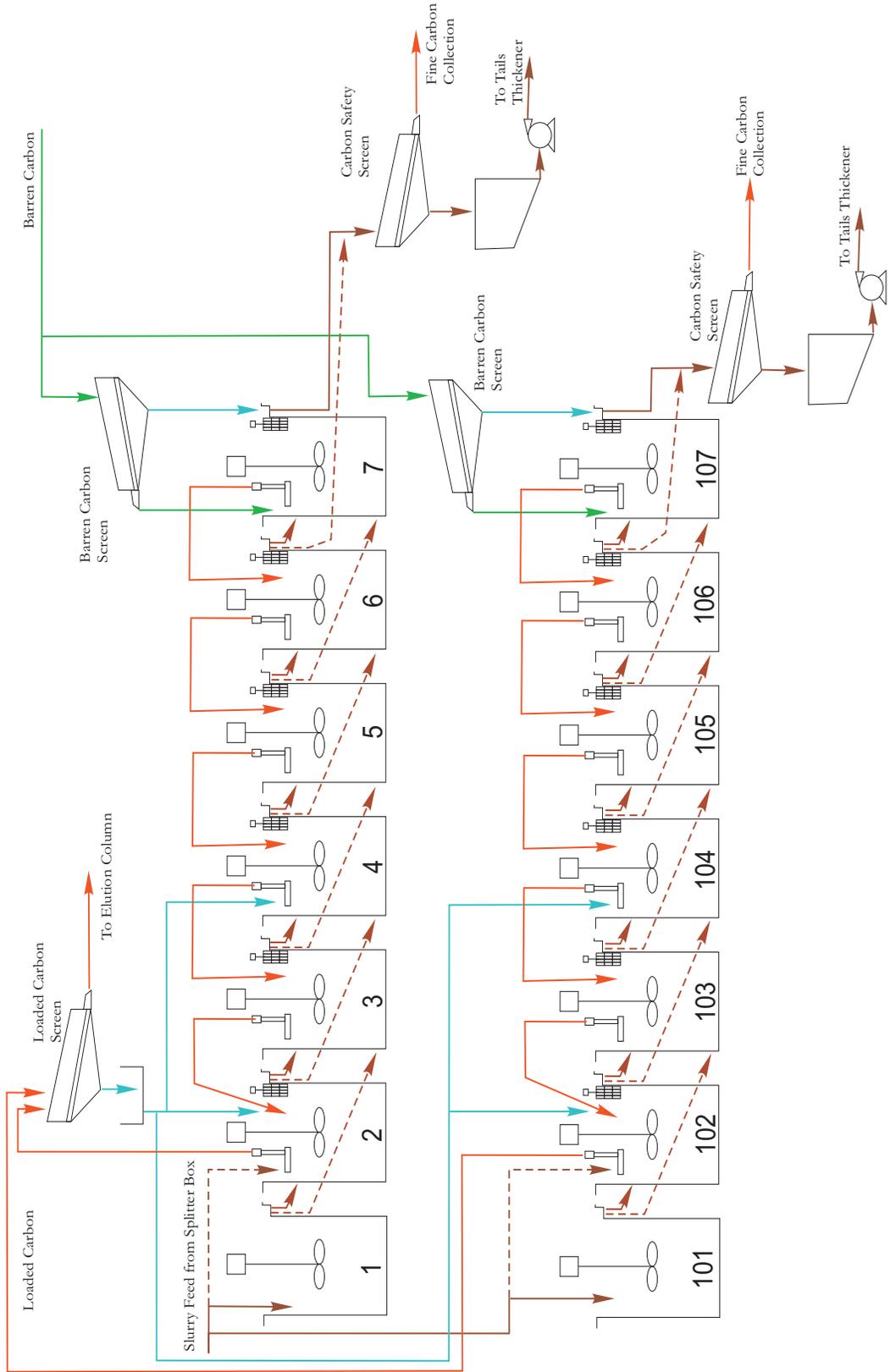
Leach Feed Autosampler

Circuit Flow Diagrams



CIL Circuit showing material flows.





Basic CIL Circuit Troubleshooting

OBSERVATION	POSSIBLE CAUSES	CORRECTIVE ACTIONS
Carbon levels lowering	Hole in intertank screen.	Bypass tank, remove screen to check/repair
Tanks filling up/ Overflowing	Interstage screens blinding	Bypass tank, check screen
	Rapid decrease in feed % solids	Correct thickener underflow density
	Valves between tanks closed	Open valves
Low pH/High HCN levels	Lime silo empty/blocked. Lime feeder faulted.	Restart feeder, clear blockages. If no lime for >15min shut down plant.
Low CN levels in slurry	Blockage or pump failure/fault in CN dosing system.	Restart pump/Change to standby pump. Clear blockage (P.P.E!)
	CN setpoint too low	Increase setpoint after consultation with metallurgist.
Low Dissolved Oxygen Readings	Blocked agitator shaft.	Increase flow of O ₂ / Use high pressure air to clear blockage.
	Insufficient oxygen flow	Increase O ₂ flow (open valve)
	Leak in pipes/Problem at oxygen plant/Multimix unit faulty	Inspect pipes/O ₂ plant/Multimix unit