

Optimizing the Extraction Conditions of Gold in AuCN Solution

A Refinery Overview of the Gold Processing Plant of Porgera Gold Mine in Papua New Guinea

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Abstract — The refinery section of Porgera Gold Mine utilizes carbon in leach, carbon in pulp, elution, and electrowinning processes to extract gold from low-grade ores. This paper aims to discuss the optimum conditions that must be maintained to optimize gold recovery. Gold leaching is optimized at pulp density of 28 – 29 % solids, pH 10.5, 160 – 180 ppm cyanide concentration, 5 – 6 mg/L oxygen concentration, and 25 tonnes of activated carbons in a 765 m³ agitated leach tank with residence time up to 32 and 24 hours for low-grade and high-grade ores respectively. The amount of carbon in each 392 m³ carbon in pulp tank is the main determining factor for gold extraction efficiency. Each tank requires up to 12 tonnes of carbon and 5 ppm dissolved oxygen to concentrate 93 – 96 % of soluble gold at 95 % carbon activity rate, achieving up to 10,000 ppm gold-cyanide in feed and 0.001 ppm in tails solution. The gold-loaded carbon is then stripped to remove gold into an alkaline cyanide solution via two 20 m³ pressurized vessels at 400 kPa and 140 °C. The produced eluate enters 12 electrowinning cells, where electricity is passed through the cells, causing gold to deposit onto stainless steel wool cathodes. These are regularly removed, pressure filtered in a plate, and frame pressed to collect gold in the form of a solid cake. This is finally mixed with flux, and smelted to produce gold bullion containing 80 – 83 % gold and 17 – 20 % silver.

Keywords — Gold solution; leaching; adsorption; elution; electrowinning.

I. INTRODUCTION

Papua New Guinea is a gold-producing country, exporting gold since the 1930s and is ranked the 11th largest gold producer in the world over the last few years. The country is ranked 10th in the world in terms of copper production, and also has silver as a commercial by-product from most of its mines. During 2018, eight mines were operating in PNG, distributed over several provinces. Four of these mines: Porgera Gold Mine, Ok Tedi Gold Mine, Lihir Gold Mine, and Hidden Valley (Morobe) Gold mine are in advanced stages of gold production. This paper discusses the hydrometallurgical gold cyanidation technique used in extracting gold from low-grade ores in the world-class Porgera Gold Mine, the second largest mine in Papua New Guinea. Cyanidation is the most widely used gold-leaching technique in the world today [1] and involves converting the gold ore into water-soluble slurry to undergo several refinery stages to produce gold bullion [2]. Since the start of its operation in 1990, the mine has produced more than 20 million ounces of gold and almost 5 million ounces of silver, accounting for about 12 percent of Papua New Guinea's total exports.

Most of the gold mined at the Porgera Gold Mine is usually locked in sulfides, mainly pyrites (FeS). In this form, the gold cannot be easily leached out using cyanide. Because of this, froth flotation is the first stage applied to float pyrite after crushing and grinding to the required particle size. The flotation concentrates are fed to the autoclaves at 14 % sulfur grade to achieve set

target gold recovery. Low sulfur means less fuel to keep oxidation reactions going in the autoclaves, resulting in usage of more steam which means high cost for diesel fuels to run boilers. On the other hand, high sulfur will result in not all feed through the autoclaves being oxidized, resulting in reducing of oxidized tonnage, ultimately reducing gold recovery at the refinery. Oxidized slurry is better able to be treated with cyanide to dissolve the gold component of the slurry, and maintain high recoveries. The incoming sulfide material from froth flotation is treated in a high temperature, high pressure, and high oxygen environment such that maximum oxidation is achieved in the autoclaves within the set targets for density and sulfur grade.

The purpose of Porgera Gold Mine's refinery section is to (1) dissolve gold with cyanide in the finely ground oxidized slurry entering the circuit from autoclaves (leaching), (2) recover these dissolved gold from the leached slurry by applying fresh/activated carbon to adsorb gold-cyanide (AuCN) solution in slurry (carbon in pulp, CIP) and reject impurities [3], (3) elution of gold from the loaded carbon (stripping), and (4) recovery of gold from eluates (AuCN solution) through electrowinning. This work aims to describe the hydrometallurgical process overview of the mine's refinery section and outline the optimal extraction conditions that must be maintained for maximum recovery of gold in gold-cyanide (AuCN) solution.

II. REFINERY OVERVIEW OF MAJOR OPERATIONS OF PORGERA GOLD MINE

A. Gold Leaching

The primary objective of the carbon in leach (CIL) circuit is to dissolve gold in cyanide solution in the presence of oxygen. 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 [4]. Figure 1 shows the process overview of the leaching circuit. The important process parameters that must be maintained for optimal recovery are given in Table I.

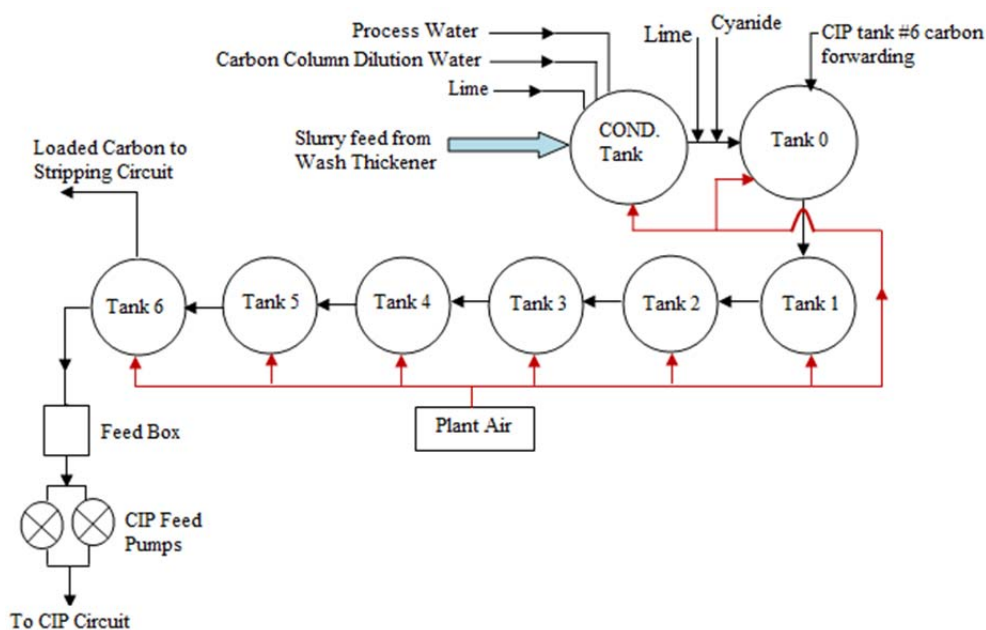
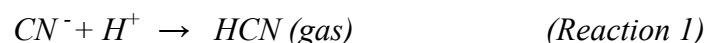


Fig. 1. Process flowsheet of leaching circuit.

TABLE I. PROCESS PARAMETERS OF CONDITIONING AND LEACH TANKS OF THE LEACHING CIRCUIT

Tank	Parameters
Conditioning tank	• Total volume capacity: 392 m³ • Leach feed density: 40% solids • Feed rate 100 – 120 tonnes per hour (tph) • Target pulp density of 28 – 29% solids • Target pH: 10.5
Leach tank 0	• Total volume capacity: 765 m³ • Target cyanide concentration: 160 – 180 ppm • Oxygen concentration: 5 – 6 mg/L • Pulp density: 28 – 29% solids • Activated carbon tonnage: 25 tonnes
Leach tanks 1 – 6	• Total volume capacity: 392 m³

The leaching circuit consists of eight (8) agitated tanks namely the conditioning tank, leach tanks 0, 1, 2, 3, 4, 5, and 6. The conditioning tank receives oxidized slurry from the autoclaves wash thickeners at 40 % solids feed density. Oxidized slurry from the autoclaves is very acidic hence lime, process water, and carbon column dilution water are made up, reducing feed density to 28 or 29 % solids and increasing pH to at least 10.5. This is because, at low pH, toxic hydrogen cyanide (HCN) gas is formed according to reaction 1 [5]. The conditioned slurry then flows through an upcomer and onto an overflow launder where it cascades and gravitates to leach tank 0. Further addition of lime and cyanide occurs at the launder as the feed cascades into tank 0.



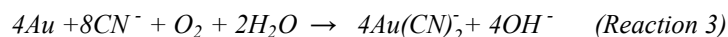
The HCN gas can also be further hydrolyzed, yielding formic acid and ammonia [1], increasing cyanide losses by hydrolysis according to reaction 2 [4], [6].



Oxidized slurry conditioning is aided by continuous agitation and air sparging from the plant air. The function of process air is to support the agitator to effectively leach gold in the slurry by dispersing activated carbons so that they do not settle and build up at the bottom. Both leach tanks 0 and 6 are mounted with NKM (North Kalgoorlie Mine) carbon intertank screens to prevent the uncontrollable flow of carbon into the next tank. NKMs are screens of 1 mm aperture so anything <1mm passes through and is collected and reported as fine carbons while those >1 mm are trapped and forwarded as loaded carbon to the stripping circuit. Once the target level of gold loading onto activated carbon granules in leach tank 0 is achieved it is sent directly to leach tank 6. The loaded carbon is then forwarded from leach tank 6 to the stripping circuit. The purpose of leach tanks 1 to 6 is basically to increase the residence time so cyanide can effectively dissolve gold. Slurry flows by gravity through each tank via the overflow launder while agitation and air sparging continue at each of the tanks until the feed reaches leach tank 6. At leach tank 6 loaded carbon is forwarded to the stripping circuit while feed slurry is pumped to the carbon in pulp (CIP) feed box and into the CIP circuit. Pulp density affects viscosity considerably, which has an impact on gold leaching [7]. The optimal pulp density of Porgera Gold Mine's leaching circuit is 28 – 29 % solids and must be maintained to avoid negative consequences. It has been found that pulp densities that are too high, as well as those which are too low, can negatively affect gold leaching performance [8]. Pulp density < 28 % solids will reduce plant throughput for the given residence time, which can result in sanding of carbon particles and coarse sands at the bottom of the tanks [9]. Pulp density > 29 % solids will decrease its ability to flow, retarding the kinetics

of gold leaching hence reducing the plant's throughput [7].

The 100 – 120 tonnes per hour (tph) feed rate commensurate sufficient residence time in the leach tanks 0 to 6. The target cyanide concentration of 160 – 180 ppm in the leach tanks optimizes the kinetics of leach reaction and is sufficiently high to dissolve gold in solution. The optimum cyanide rate is found in practice by monitoring the response of the leachable gold losses determined through daily laboratory leaches and correlated with the plant cyanide addition rate [10]. The dissolved oxygen concentration of 5 to 6 mg/L in the pulp is also important in gold cyanidation. The relationship between cyanide and dissolved oxygen is given by Elsner's equation in reaction 3 [11]. It can be seen from the reaction that a deficiency in dissolved oxygen will affect the cyanidation process, resulting in gold not dissolving readily [4]. On contrary, a high gas feed decreases the solids suspension induced by the agitator, which can decrease the effective leach tank volume and thus the residence time of coarse solid particles [9].



Gold, separated from the majority of its gangue through cyanidation gets adsorbed on the surface of the activated carbons. Hence the amount of activated carbon in leach tanks 0 and 6 are of paramount importance as it is the means by which gold is concentrated and is determined by carrying out a carbon profile test. Leach tank 0 has 25 tonnes of carbon while leach tank 6 has between 15 to 20 tonnes. Tanks 1 to 5 are primarily for increasing residence time so that the gold in slurry is effectively leached by CN solution. The procedure for conducting a 4 hourly carbon profile test is summarized in Table II below:

TABLE II. PROCEDURE FOR CONDUCTING A FOUR-HOURLY CARBON PROFILING TEST.

Aim of Test: • Determine the tonnage of carbon in each leach tank. • Determine Au loading on carbon granules. • If less tonnage is present, carbon is added.
Equipment used: • Funnel, 106 µm screen, scoop, 1000 mL cylinder, 10-gram plastic bags, and hand gloves.
Procedure: 1. Four scoops of loaded carbon (slurry) samples are taken from each leach tank and poured onto 106 µm screen. 2. These are then washed and poured into the 1000 mL measuring cylinder through the funnel. 3. Water is added and carbons are settled to the bottom of the measuring cylinder. The open end of the measuring cylinder is blocked and shaken for even settling of carbons. 4. After balancing the settled carbons, m/L* reading is noted for each of the leach tanks. Table III shows carbon level and gold adsorption rate after 16 hours of feed residence time for a high gold tonnage. 5. After noting the reading, water is poured out and carbons packed into 10 g plastic bags, labeled respectively for each leach tank, and sent to the assay laboratory for analysis. 6. The procedure for conducting tests at the CIP circuit is the same as that for the leach tanks. The last column of Table III shows the gold assay lab results for the carbon profile test conducted.

*Reading in g/L is compared against standard leach carbon tonnage table to determine tonnes of carbon present in each leach tank.

TABLE III. GOLD ADSORPTION BY ACTIVATED CARBON AND CARBON TONNAGE IN LEACH TANKS.

Leach tank	Carbon level reading (g/L)	Equivalent Carbon tonnage	Au (ppm)
0	90.38	20.54	3724
1	2.90	0.66	3727
2	0.70	0.16	3742
3	0.70	0.16	3802
4	0.70	0.16	3863
5	0.70	0.16	3904
6	72.60	16.50	3931

B. Gold Adsorption using Activated Carbon

The carbon in pulp circuit uses activated or fresh carbon for gold adsorption, with subsequent desorption, and electrowinning. Soluble gold is concentrated by carbon adsorption and separated from the process slurry. Figure 2 summarizes the process overview of Porgera Gold Mine's CIP circuit, while Table IV outlines the important process parameters that must be maintained to optimize gold adsorption onto activated carbon.

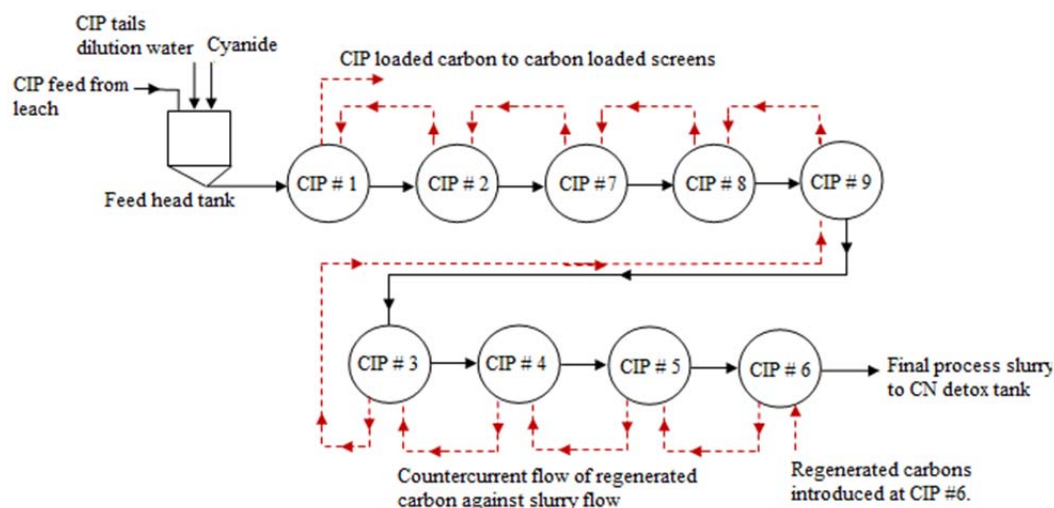


Fig. 2. Process flowsheet of CIP circuit.

TABLE IV. PROCESS PARAMETERS FOR AGITATED TANKS IN CIP CIRCUIT

Tank	Parameters
CIP tanks 1 – 9	• pH: 10.5 • Feed Density: 28 – 29% solids • Tails Density: 27% solids • Carbon Concentration: 22 g/L or 5 – 7 tonnes in tanks 2 – 9 and 12 tonnes in tank 1. • Gold cyanide: 10,000 ppm in feed and 0.001 ppm in tails solution. • Tails cyanide: 45 – 50 ppm • % Solution Recovery: 99% (normally it is between 93 – 96%) • Agitation: Suspend slurry for effective gold and carbon contact. • Carbon Activity: 90 – 95% • Oxygen: 5 ppm

CIP feed (leach tail from leach tank 6) enters the CIP circuit via the feed head tank located above CIP tank 1. Cyanide and CIP tails dilution water are made up with the feed in the head tank where it gravitates into CIP tank 1. From CIP tank 1 the feed cascades into CIP tanks 2, 7, 8, 9, and from CIP tank 9 it is collected in a feed pump box and pumped up to CIP tank 3. From CIP tank 3, feed cascades to CIP tank 4, from CIP tanks 4 to 5, and finally to CIP tank 6. All tanks are fitted with impellers that provide agitation to suspend slurry for effective gold and carbon contact. The carbons are transferred frequently to prevent equilibrium between the solution and the carbon phases, thus maintaining a fast rate of loading [12]. A carbon concentration of 22 g/L or 5 to 7 tonnes is required in CIP tanks 2 to 9 and 12 tonnes in tank 1, which is sufficiently high to recover between 93 – 96 % of the gold in slurry.

All CIP tanks (1 to 9) are mounted with NKM carbon intertank screens to prevent the uncontrolled flow of loaded carbon granules. The regenerated or fresh carbon is introduced in CIP tank 6, where it is pumped countercurrent to the flow of the feed slurry. The countercurrent method of contacting pulp and carbon ensures high adsorption efficiencies between 90 – 95 %. AuCN solution in the feed pulp is adsorbed by the activated carbon as it makes its way up to CIP tank 1. Screens are mounted in CIP tank 6 discharge end to separate the fine carbons from the final process slurry containing 0.001 ppm AuCN and 45 – 50 ppm cyanide. The fine carbons are collected and discarded while the process slurry is pumped to the CN detoxification tank where cyanide is destroyed before forwarding it to the waste treatment circuit for final treatment and disposal. The CIP-loaded carbon, concentrated to 10,000 ppm AuCN in CIP tank 1 is forwarded by pumps to the loaded carbon screens which separate the loaded carbons from the slurry and are processed at the stripping circuit. The optimum pulp residence time depends on the ore grade; up to 32 hours for low-grade ores and 24 hours for high-grade ores, determined through four-hourly carbon profile tests and subsequent gold assaying. Table V shows carbon level and gold adsorption rate after 16 hours of pulp residence time for a high gold tonnage.

TABLE V. GOLD ADSORPTION BY ACTIVATED CARBON AND CARBON TONNAGE IN CIP TANKS.

CIP tank	Carbon level reading (g/L)	Equivalent Carbon tonnage	Au (ppm)
*LT 6	72.60	16.50	3931
1	55.00	12.5	2955
2	21.12	4.80	1900
7	22.44	5.10	1393
8	23.32	5.30	902
9	21.56	4.90	766
3	21.12	4.80	660
4	22.00	5.00	395
5	22.44	5.10	112
6	23.32	5.30	51

*LT 6 is leach tank 6; CIP feed is tails from leach tank 6.

The adsorption rate of gold onto activated carbon (in parts per million, ppm) in solution, Figure 3, is governed by several interacting factors. Plant experience and mathematical modelling have shown that the amount of carbon in each CIP tank is the main determining factor for gold extraction efficiency [13]. Other factors influencing extraction rate are residence time, gold concentration, carbon activity, and temperature [14]. A carbon granule is made up of many micropores, and within these micropores are 'active sites' [12]. As carbon is introduced into the CIP circuit, it immediately adsorbs gold as well as many other substances including organic and inorganic minerals known as carbon foulants (xanthates, calcium carbonates, and so on). The longer the carbon is in the solution, the more gold it adsorbs. Initially, the adsorption is fast which relates to the availability of highly active sites in carbon but will gradually slowdown in loading the gold as the active sites become occupied [7]. How much gold the carbon can adsorb and how quickly it will adsorb depends on its activity rate. The higher the activity of the carbon, the faster it will adsorb the gold. Additionally, the adsorption rate is faster at higher temperatures, up to about 84 °C.

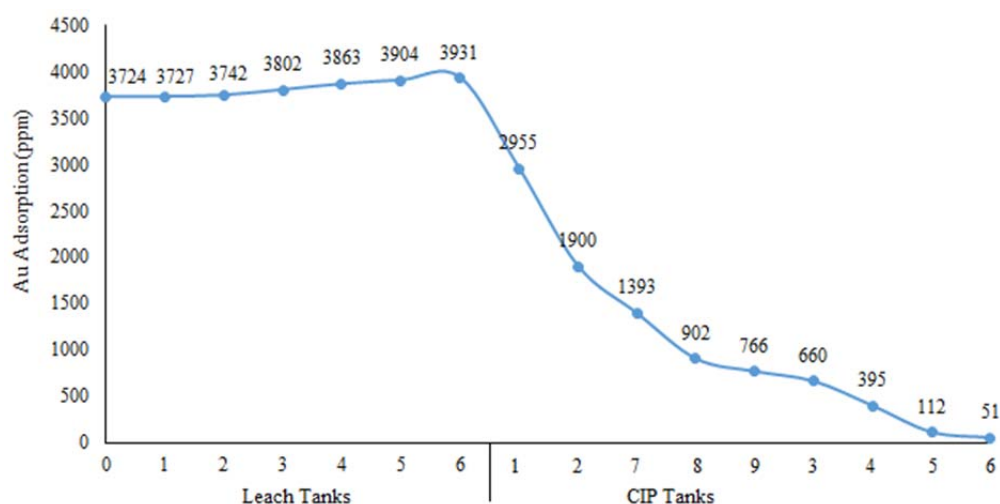


Fig. 3. Gold adsorption by activated carbons in leach and CIP tanks after 16 hours pulp residence time.

Gold is lost to tails when carbon activity level drops. For this reason, routine carbon activity tests are conducted to monitor carbon activity levels of regenerated, acid washed, stripped (barren) and loaded carbon compared to the activity level of fresh

carbon. Table VI shows typical carbon activity levels of activated carbon, while Table VII shows the results of a routine carbon activity test.

TABLE VI. ACTIVITY LEVELS OF CARBON IN GOLD ADSORPTION.

Carbon	Activity Rate
Fresh carbon	100%
Regenerated carbon	> 76%
Acid washed carbon	> 46%
Barren carbon	> 36%
Loaded carbon	> 36%

TABLE VII. STRIPPED CARBON ACTIVITY LEVELS OF BARREN, ACID WASHED, LOADED & FRESH CARBONS

Test Conditions		Residual Gold (ppm)				
Material	Amount	Time (hrs)	Fresh carbon	Barren	Regenerated	Acid washed
Start volume (ml)	2000	0.5	9.91	9.67	8.88	9.83
Carbon (g)	2	1	8.01	9.03	7.80	9.38
Aliquot volume (ml)	125	2	6.30	8.55	6.50	8.56
Solution (Au) at t = 0 (ppm)	9.95	4	4.47	7.58	4.32	7.66

The residual concentrations of gold in solution after samples were taken from 2 litres solutions containing 2 grams each of fresh, barren, and washed carbon with an initial head of 9.95 ppm gold was tested. 25 mL of solution was taken after 0.5, 1, 2 and 4 hours (Table VII). As indicated above by the gold assays, the amount of gold adsorbed from solution after 0.5 hours by fresh carbon was the highest compared to 1, 2 and 4 hours whereas barren and washed carbons had 9.67 ppm and 9.83 ppm respectively after 0.5 hours. Regenerated carbon had the lowest residual gold after 0.5 hours. Overall, after 4 hours all carbons performed slightly well. Additionally, it can be seen that thermal washing of activated carbon with hydrochloric acid promotes very high activity rate. This is because HCl-washing effectively removes all scales and contaminants that have precipitated onto the carbon during gold adsorption.

C. Gold Elution from Loaded Carbon and Acid-Wash

The objective of the stripping circuit is to remove gold from the loaded carbon into an alkaline cyanide solution by means of two 20 m³ pressurized vessels. The process overview is shown in Figure 4, while the essential process parameters of the stripping circuit are given in Table VIII.

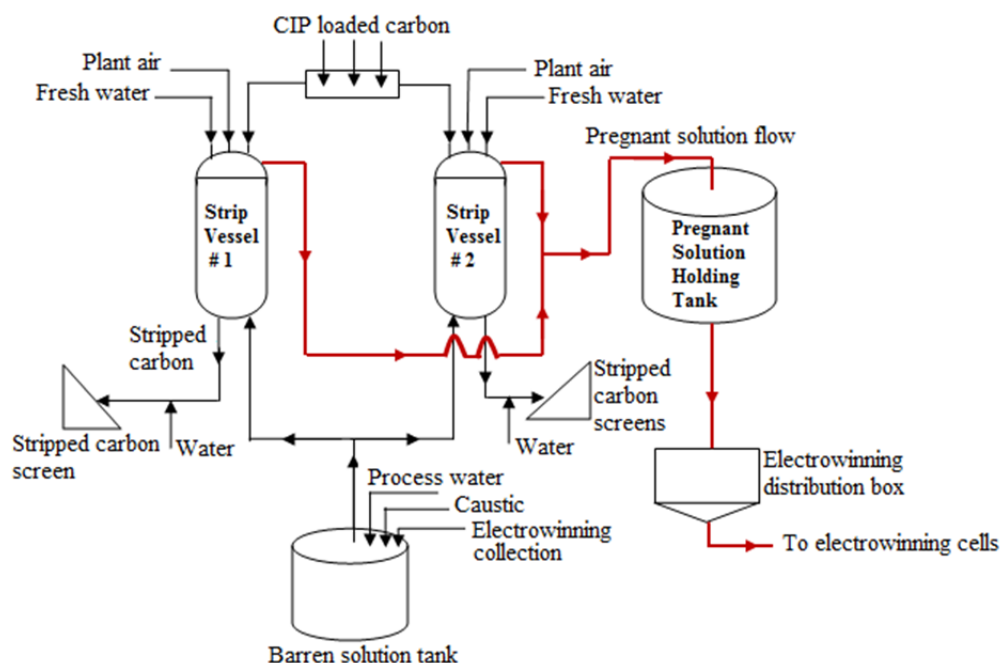


Fig. 4. Process flowsheet of the stripping circuit.

TABLE VIII. PROCESS PARAMETERS OF THE STRIPPING CIRCUIT.

Vessel pressure	400 kPa
Vessel temperature	140 °C
Barren inlet flow	30 – 40 m ³ /hr
Caustic concentration	2.5 – 3.0 ppm
Cyanide concentration	0.3 %
Electrowinning flow	18 – 24 m ³ /hr
Pregnant & barren combine tank volume	120%

During the elution process, CIP-loaded carbon enters the circuit via two strip vessels, 1 and 2; normally one strip vessel is on duty and the other on standby. The carbon particles enter the top of the vessel loaded with gold and exit barren through the bottom, while the hot pressurized barren eluate (aqueous caustic soda) enters near the bottom of the vessel and exits loaded with gold near the top. Plant and laboratory-based studies conducted on gold desorption showed that temperature is the most important factor affecting gold desorption rate [15], [16]. At 400 kPa and 140 °C gold is released from the loaded carbon into solution, termed the gold-rich pregnant solution. If the pressure and temperature drop below the set targets of 400 kPa and 140 °C stripping would take longer, and consequently the rate at which gold is stripped of the loaded carbon will decrease. Other factors affecting gold elution include high cyanide and caustic concentration, low ionic strength of solution (i.e. low level of salts in the water), optimum flow rate of solution through the carbon, and low gold concentration in the solution [17]. The function of freshwater is to cool and control the temperature of the vessels so that the duty vessel is maintained at the set target temperature. Pregnant solution from the strip vessels is pumped to the pregnant solution tank inside the gold room where it feeds twelve (12)

electrowinning cells via the electrowinning distribution box. Once the gold has been electrowon, the barren solution (electrowinning collection) is pumped to the barren solution tank. Here it is made up with process water and caustic and recycled to the strip vessels for pressure-controlling purposes.

During adsorption other inorganic species, notably calcium, and organic species like silica, alumina, and iron oxide that tend to foul carbon also adsorb on the activated carbon [8]. Leaving these contaminants to buildup will eventually lead to a reduced absorption rate hence the stripped carbon is pre-washed with process water, screened, and sent to the acid-wash section to undergo hydrochloric acid (HCl) washing. HCl-washing is highly effective in removing nearly all scales and contaminants that have precipitated onto the carbon. The refinery's carbon wash circuit, Figure 5, consists of two carbon wash tanks. After stripping, the loaded carbons are forwarded by pumps to these tanks and washed with fresh water. Both tanks are fitted with screens at their bottom (conical) end so that when process water is flushed at the bottom, fine carbons rise to the surface and overflow. The overflow is collected at the fine carbon screens. The loaded carbon is then acid-washed with caustic (NaOH) and forwarded to the washed carbon screens. The carbons collected from screen 1 are forwarded by pumps to CIP tank 6 while those collected at screen 2 are sent to the regenerating kiln where they are reactivated and recycled to the CIP circuit. New carbon is added as required.

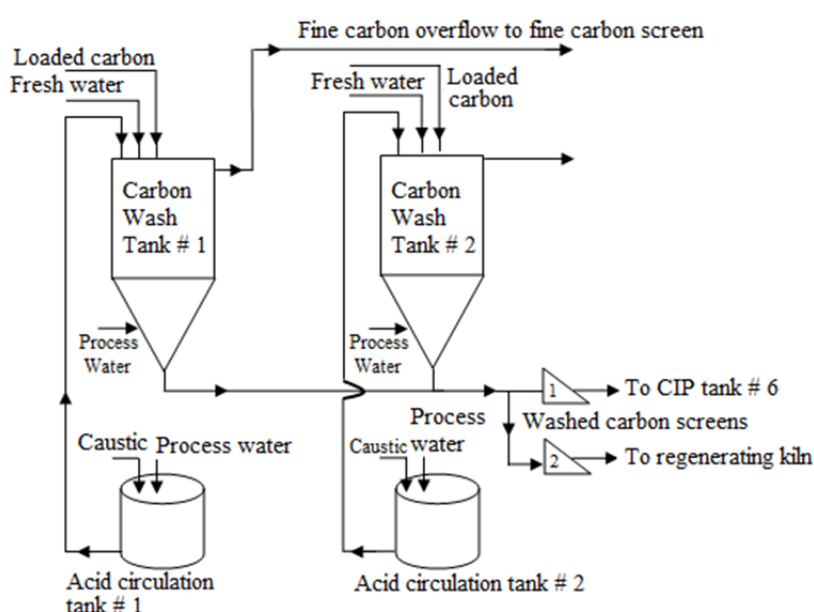
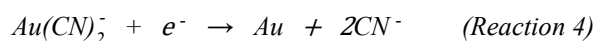


Fig. 5. Process flowsheet of the carbon wash circuit.

D. Gold Electrowinning from AuCN Solution

The gold refinery's electrowinning circuit consists of 12 electrowinning cells. There are four banks (A, B, C & D) consisting of 3 cells each in series. Inside the banks, there are stainless steel wool cathodes and stainless mesh anodes. The pregnant solution held in the pregnant solution tank is pumped into the banks via the electrowinning distribution box and electricity is passed through the cells, causing gold to deposit onto the stainless steel wool cathodes according to reaction 4 [18]. Figure 6 shows the process overview of the electrowinning circuit.



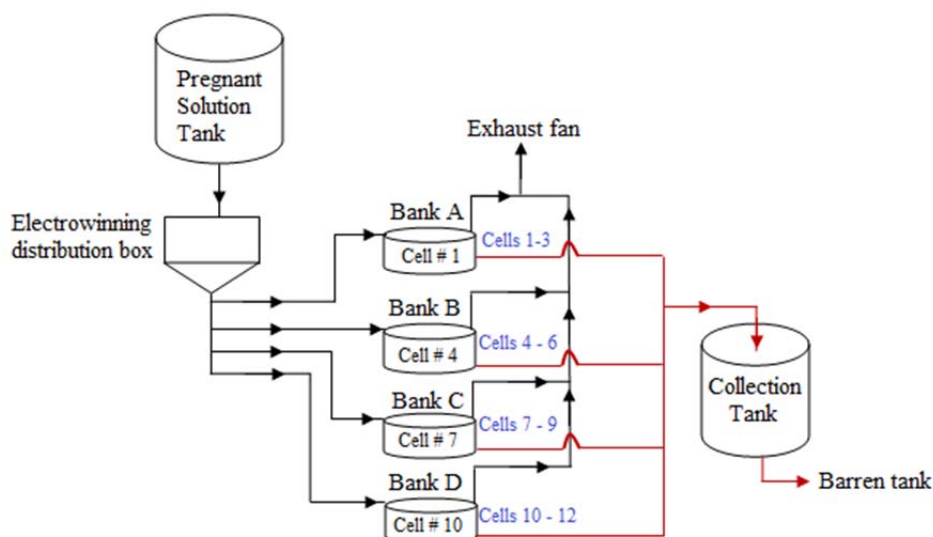


Fig. 6. Process flowsheet of the electrowinning circuit.

The gold and silver deposited at the stainless steel wool cathodes are removed at regular intervals, then pressure filtered in a plate and frame press to collect gold in the form of a solid cake. This is then heated in a retort furnace to remove any entrained mercury. Finally, the cake is dried, mixed with flux, and smelted to produce gold bullion, comprising between 80 – 83 % gold and 17 – 20 % silver. Any residuals remaining during the process are collected and held in the collection tank and forwarded to the barren solution tank for recirculation in the stripping circuit. Plant and laboratory-based studies conducted showed that AuCN solution temperature, NaOH concentration, and current density in the electrowinning cells are major influencing factors affecting the gold electrowinning process [19]. Other factors affecting cell performance include cell voltage, AuCN solution conductivity, Au concentration, and the presence of base metal ions such as silver, copper, nickel, cobalt, and iron that typically occur with gold in the electrolyte as cyanide complex ions [20].

III. CONCLUSION

The refinery section of Porgera Gold Mine in Papua New Guinea uses hydrometallurgical processes carbon in leach, carbon in pulp, elution, electrowinning, and the high pressure and temperature smelting process to produce gold bullion. Gold may be lost to tails if the operating conditions of each of these processes are not optimized. The carbon in leach circuit is optimized by ensuring a steady feed density of 28 – 29 % solids, pH 10.5, 160 – 180 ppm cyanide concentration, 5 – 6 mg/L dissolved oxygen, 25 tonnes of carbon with proper tank agitation, and sufficient residence time up to 32 and 24 hours for low-grade and high-grade ores respectively. The carbon in pulp circuit of the refinery comprises 9 agitation tanks with the primary aim of increasing residence time for effective gold-carbon contact. Carbon granules are introduced countercurrent to the slurry flow, achieving adsorption efficiencies of up to 95%, and concentrating the carbon to 10,000 ppm gold-cyanide solution. This is then stripped in the gold elution circuit whereby gold is removed from the loaded carbon into an alkaline-cyanide solution. Temperature is the most important factor affecting the gold desorption rate. Gold stripping occurs at 400 kPa and 140 °C. At these pressure and temperature, gold is released from the loaded carbon into a gold-rich pregnant solution. Anything below these setpoints, the elution process will take longer, and consequently, the rate at which gold is stripped off the loaded carbon will decrease. The pregnant solution then gets sent to the electrowinning cells, where electricity is passed through the cells, causing gold to deposit onto stainless steel wool cathodes. These are regularly removed, pressure filtered in a plate, and frame pressed to collect gold in the form of a solid cake. Finally, the filtered cake is mixed with flux, and smelted to produce gold bullion containing 80 – 83 % gold and 17 – 20 % silver while the spent carbon is acid-washed with HCl and forwarded to the carbon in pulp circuit for reuse.

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