



# ALTA 2011 NICKEL/COBALT/COPPER CONFERENCE

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#### Summary of the Anode Bag Pilot Cell Campaign

ALTA 2011 Free Paper Compared to cathode bag technology, many advantages can be gained by using bagged anodes as discussed in<sup>(4)(5)</sup>. The main observations from the pilot cell campaign are given below:

- Good and efficient tankhouse practices were learned using anode bag technology. Stable operation was possible with good current efficiency.
- By careful control of the catholyte flow through the diaphragm to the anode bags, a higher anolyte acid concentration and consequently a higher  $\Delta Ni$  can be obtained. At lower anolyte flow rates higher acid concentrations were obtained. The aim - a sulfuric acid concentration of 80 g/l in anolyte - was achieved in the pilot campaign.
- Catholyte can be circulated and higher catholyte flow rates obtained. This improved the cathode • surface finish, since the nickel concentration, pH, and temperature were easier to control.
- Very high oxygen content was measured inside the anode bag and thus it is possible to recover anodically evolved oxygen, which in turn can be re-circulated to the leaching step.
- Due to gas-impermeable anode bags above electrolyte level, acid mist control can be improved and virtually all Ni emissions can be recovered, resulting in a cleaner tankhouse environment.
- The number of torn bags can be reduced. This is due to several reasons
  - Access to the cathodes is easier, since they are not located inside the bags, and 0 consequently there are fewer damaged bags during the harvest.
  - By monitoring the cell voltage with CellSense™, prediction of short circuits was 0 possible. Removing the shorts early enough decreased the number of torn bags and increased the current efficiency.
- Bent starter sheets increased the number of shorts and torn bags. At the same time, the current efficiency was decreased. Therefore it is important to ensure that the starter sheets are straight.
- Double contact bus bars increased the current efficiency by approx. 1%.
- Lead precipitates from the deterioration of the anodes could be minimized since they were collected in the anode bags.

#### ACKNOWLEDGEMENTS

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### ALTA 2011 NICKEL/COBALT/COPPER

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## **LEACHING OF SULPHIDES**

#### RECOVERING COPPER AND GOLD IN CHLORIDE SYSTEM BY NIKKO CHLORIDE PROCESS

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#### ABSTRACT

JX Nippon Mining & Metals Corporation (NMM) has been developing a process which makes copper and gold recovery easy and effective. The process, named Nikko Chloride Process, employs sodium chloride media and is composed of copper leaching and copper recovery, gold leaching and gold recovery and silver recovery. Leaching of copper and gold is performed under ambient pressure with only aeration. Nikko Chloride Process recovers copper by solvent extraction, then produces copper cathode from sulphate solution. Some bromide helps gold leaching from gold bearing copper concentrate. Gold is recovered on activated carbon or by solvent extraction. Silver is recovered by solvent extraction.

NMM built a pilot plant for the process in Perth. The pilot plant has operated well. More than 98% of copper is leached and high quality copper cathode is produced. More than 90% of gold is leached. Applying floatation could recover 5% more of the gold from the gold leach residue. NMM is trying to apply gold recovery by solvent extraction.

#### INTRODUCTION

LTA2011 Free Paper The Nikko Chloride Process is a hydrometallurgical process to treat copper sulphide concentrate that has a low copper grade and some gold. The process can leach copper and gold into same leach solution. The process can treat high impurity concentrate and can recover minor elements like nickel and cobalt which are usually not suitable for recovery by pyrometallurgical processing. The Nikko Chloride Process treats sulphide concentrate in a chloride system, and leaching is performed under ambient pressure and at a temperature less than boiling point.

> The process is composed of copper leaching, copper solvent extraction and electrowinning, gold leaching and gold recovery and silver recovery.

#### **REVIEW OF CHEMICAL REACTIONS**

Ferric chloride and cupric chloride leach copper sulphide concentrate and release copper and iron<sup>(1)(2)(3)</sup>. Sulphur is left in the residue as elemental sulphur. Cuprous ion is unstable in aqueous solution. The leach solution of the Nikko Chloride Process contains some sodium chloride to make the cuprous ion stable.

(1) 
$$CuFeS_2 + 3FeCl_3 \rightarrow CuCl + 4FeCl_2 + 2S$$

(2) 
$$CuFeS_2 + 3CuCl_2 \rightarrow 4CuCl + FeCl_2 + 2S$$

(3) 
$$FeCl_2 + HCl + \frac{1}{4}O_2 \rightarrow FeCl_3 + \frac{1}{2}H_2O$$

When the leach solution contains proton and the pH value of the solution is high enough, ferrous ion is oxidized to ferric ion by oxygen and ferric iron is precipitated.

(4) 
$$FeCl_2 + 2H_2O \rightarrow FeO \cdot OH + 3HCl$$

Cuprous ion is also oxidized to cupric ion.

(5) 
$$4CuCl + 4HCl + O_2 \rightarrow 4CuCl_2 + 2H_2O$$

Overall reaction would be as follows.

(6) 
$$CuFeS_2 + 2HCl + \frac{5}{4}O_2 \rightarrow CuCl_2 + FeO \cdot OH + \frac{1}{2}H_2O + 2S$$

Two moles of hydrochloric acid and oxygen are needed to dissolve one mole of chalcopyrite. On the other hand, solvent extraction applied for recovering cupric copper extracts one mole of cupric ion and generates two moles of hydrochloric acid. The reaction is given below.

(7) 
$$2RH + CuCl_2 \rightarrow R_2Cu + 2HCl$$

When copper extraction raffinate is returned to the copper leaching stage, hydrochloric acid generated at the copper extraction stage can oxidize cuprous copper and ferrous iron with oxygen in air. Cupric chloride and ferric chloride are good oxidants in chloride media and can progress sulphide leaching in the pH range without adding any acid.

When some impurities like arsenic exist in the copper concentrate, they are co-precipitated with iron<sup>(4)</sup>.

Copper loaded organic extractant is stripped with sulphuric acid, then copper is converted to copper sulphate from copper chloride in the leach solution. Copper electrowinning from copper sulphate solution is a well known method to recover copper.

When copper sulphide is leached in halide solution, gold in concentrate begins to be soluble when cthe opper content is low enough<sup>(5)</sup>. Bromide ion forms a stable complex with gold and reduces the redox potential of gold oxidation compared with the chloride complex<sup>(6)(7)</sup>. Figure 1 shows the standard redox potential of gold in the aqueous halide system. The standard redox potential of each half-cell reaction is shown in V vs SHE.

The Nernst equation for the gold halide complex is,

$$E = E^{\circ} + \frac{RT}{nF} \ln \frac{[AuX_{n+1}]}{[X]^{n+1}}$$
(8)

According to equation (8), low gold concentration in a solution makes the redox potential lower. When gold concentration is low enough, ferric ion or cupric ion is suitable for leaching gold in bromide containing solution.

Leach solution is returned and leaches the concentrate many times and some minor elements in the concentrate are accumulated in the leach solution. These elements can be recovered from a part of leach solution with a combination of solvent extraction and/or ion exchange resin.



Figure 1: Standard redox potential of gold complex

#### **PROCESS EXAMINATION**

Bench scale testing was performed at the Technology Development Center in Hitachi, Japan. A concentrate sample was composed of chalcocite, chalcopyrite, silicate and pyrite. It contained 15 - 23% of copper, 21 - 24% of iron, 20 - 27% of sulphur and 54 - 84 g/t of gold. The reaction was performed in a glass beaker at 85 degree centigrade.

#### **Copper Leaching**

Figure 2 shows copper content change in leach residue. The copper concentrate was leached in chloride solution which contained 20 g/l of copper chloride and 5 g/l of iron chloride. Chloride concentration in the leach solution was 2.4, 4.0 and 5.1 mol/l. Temperature was 85 degrees centigrade. Copper content in residue was reduced to less than 0.5% in 20 hours in the solution containing over 4.0 mol/l of sodium chloride. More than 4.0 mol/l of chloride had no effect to shorten the reaction time with this sample. 2.4 mol/l of chloride had a little longer reaction time but enough to leach copper.



Figure 2: Copper content change in residue at copper leaching

#### **Copper Solvent Extraction**

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Copper recovery by solvent extraction from chloride media has been applied in a number of processes. Hydroxyoximes, ACORGA CLX-50 and amine have been used as the copper extractant<sup>(8)</sup>. Sulphuric acid or water were used to strip copper from these extractants. NMM was familiar with copper electrowinning from sulphate media and selected the hydroxyoxime, LIX series<sup>(9)</sup>.

	pН	Analysis		Calculated	
	after Ex	Cu g/l		Cu g/l	
		Raffinate	Strip	Organic	
LIX860	0.05	3.26	4.94	2.3	
∐X84-I	0.27	6.14	3.57	0.8	
LIX622	0.05	4.10	4.62	1.8	
LIX984	0.10	4.46	4.51	1.5	

Table 1: Cupric copper extraction with various extractants

There were four candidates for the extractant. These were LIX860, LIX84-I, LIX622 and LIX984. 20% of each extractant was diluted in Isoper. The copper solution contained 3 mol/l of sodium chloride, 18 g/l of sodium bromide and 10.5 g/l of copper as cupric chloride and the pH was adjusted to pH 2. The result was on Table 1.

According to the result, LIX860 has a good isothermal curve and a good effective loading capacity. LIX84-I has a good stripping behavior. NMM selected LIX984 for the process extractant because of loading capacity and low copper concentration after stripping.

#### **Copper Electrowinning**

Lead anode and stainless cathode were employed for copper electrowinning examination. Cobalt sulphate was added to minimize generating over potential of oxygen and to achieve a suitable power consumption. The sample cathode had a good shape and enough quality for LME A grade.

#### Gold Leaching

ALTA 2011 Free Pager Bromide addition to a chloride solution makes gold leaching more effective than with only chloride. Figure 3 shows the effect of adding bromide.

Chloride solution leached gold in this sample, and high concentration of chloride made the gold content lower. Bromide addition to the chloride solution reduced the gold content in residue. Figure 4 shows the effect of bromide concentration in chloride solution for gold leaching.



Figure 3: Gold content change in leach residue



Figure 4: Effect of bromide concentration for gold leaching

The concentration of gold in the solution should be 9 mg/l when 100 % of gold was leached in one leach solution. The bromide concentration examined in this testing was sufficient to leach and make a stable complex with gold, and there was not much difference among the bromide concentrations. It seemed that a solution that contained high concentration of bromide could leach more gold.

#### Silver Recovery

ALTA 2011 Free Paper Silver recovery from chloride media is possible by solvent extraction. Cyanex 471X can extract silver from chloride media<sup>(10)</sup>. Cyanex 471X has a not very large distribution ratio but a certain amount of silver should be removed from leach solution. Silver is easily dissolved into the leach solution and is stable in a high chloride solution. The pregnant leach solution from the copper leach stage is sent to the copper extraction stage to recover copper and the raffinate from copper extraction is returned to the copper leach stage to contact the leach solution. Dissolved silver is accumulated in the leach solution according to its solubility. The Nikko Chloride Process oxidizes pregnant leach solution to precipitate iron before copper solvent extraction and cuprous copper is oxidized to cupric copper. Cyanex 471X has a sufficient selectivity of silver over cupric copper.

#### PROCESS FLOW FOR THE NIKKO CHLORIDE PROCESS



Figure 5 shows the block flow diagram for the Nikko Chloride Process.

Figure 5: Flowsheet diagram of the Nikko Chloride Process

The copper leaching stage includes some steps to control copper concentration in leach solution. Copper extraction raffinate is divided in a number of parts. It is divided into four in the above case. Concentrate is added into the first copper leaching stage and agitated with one of the four portions of the leaching solution. Compressed air is sparged into the copper leaching tanks to continue oxidizing. After the first copper leaching step, the slurry flows to a thickener and is separated into overflow and spigot. The overflow solution flows to the next stage, namely the iron removal stage. The spigot is pumped to the second copper leaching step where it is mixed with another part of the leaching solution and copper leaching continues. After four stages of copper leaching, the residue is separated from the leach solution and is sent to the gold leach stage.

Dissolution of the gold in concentrate starts in the second or third copper leach step according to the copper content in residue. Gold in the pregnant leach solution is usually recovered from the overflow of the third and the fourth leach thickeners.

The thickener overflows are combined into one PLS after gold recovery and sent to the iron removal stage. Oxidation of cuprous ion and ferrous ion is performed by aeration. Copper is extracted from PLS by solvent extraction and stripped with spent electrolyte to recover copper by electrowinning. The raffinate from copper extraction is returned to the copper leaching stage as leach solution.

Copper leach residue is further processed in the gold leach stage. 80 to 85% of gold is leached in the copper leach stage. There are a number of methods for recovering the rest of gold from the copper leach residue. One is further leaching with almost the same leach solution as the copper leach stage. CIL is employed to recover gold in this case. CIL has been applied by NMM and at the pilot plant in Perth. Another method is to recover gold with a part of the elemental sulphur as froth by flotation.

#### **PROCESS FLOW EXAMINATION**

At the Hitachi Laboratory of the Technology Development Center, NMM prepared bench scale equipment for each stage and examined the circuit work of the process. A leach solution which contains 5.1 mol/l of sodium chloride, 22 g/l of sodium bromide, 7 g/l of hydrochloric acid, 20 g/l of cupric chloride and 2 g/l of ferric chloride was prepared in a 5L glass beaker. The copper concentrate sample was added into the beaker and copper leaching started at a temperature of 85 degrees centigrade with air sparging. Copper leach slurry was filtered after defined hours of agitation. The filtrated cake was added to another 5L beaker in which copper leach solution was prepared and a second copper leach started. This procedure was repeated twice more and one copper leach residue and four filtrates were produced.

The four filtrates were combined in one solution. The solution was sent to the iron removal stage. Air was sparged into the solution to oxidize iron and precipitated iron was filtered to separate it from the copper pregnant solution.

Mixer-settlers, each of which had 1L of mixing tank and 1.6L  $(0.017 \text{ m}^2)$  of settler, were prepared. Two were for copper extraction, two for chloride scrubbing, one for stripping and one for sulphate scrubbing. Aqueous phase flow was at 11 ml/min and organic phase flow at 16 ml/min. Stripping solution flow was 17 ml/min. Copper was electrowon as a 0.01 m<sup>2</sup> plate from stripping solution at the current density of 300 A/m<sup>2</sup>. Copper depleted raffinate was returned to leach more concentrate.

#### **Copper Leaching and Copper Electrowinning**

Figure 6 shows the copper content in copper leach residue and the copper extraction rate for this circuit examination. Copper content was reduced to about 0.5% and almost 99% of copper extracted.



Figure 6: Copper leaching result

Figure 7 shows the amount of copper extracted at the copper solvent extraction stage and the amount electrowon at the electrowinning stage. The amount of copper extracted fluctuated somewhat but both

copper amounts changed almost in parallel, which means copper extraction and copper electrowinning were balanced.



Figure 7: Copper transfer at extraction stage and electrowinning stage

#### **Gold Leaching**

Four 3L beakers were prepared in series. Each beaker had an agitator, a heater and an air sparging pipe. They were connected together with overflow nozzles. Copper leach residue was pulped to be fed into first gold leaching beaker. The flow rate of the copper leach residue slurry was adjusted for each beaker to retain the slurry for twelve hours. The copper leach residue was continuously added into this leach equipment. Gold leach residue was also continuously eluted from the 4th beaker. Leach solution contained 180 g/l of chloride as sodium chloride, 20 g/l of bromide as sodium bromide, 5 to 20 g/l of copper and 2 g/l of iron.

Figure 8 shows the change of gold content in gold leach residue. Some adjustments to the conditions were applied in this campaign. CIL was applied from the 43rd day. Activated carbon was replaced with new carbon from the 93rd day. Retention time was changed from 48 hours to 96 hours from the 139th day. Chloride and bromide concentration were analyzed and adjusted from the 140th day. When chloride and bromide concentrations were analyzed, they were 110 g/l and 10 g/l and were adjusted to 180 g/l and 25 g/l respectively.



#### Figure 8: Gold content change in gold leach residue

The original feed concentrate had 74 g/t of gold. The copper leaching stage leached gold down to 37 g/t, which meant that 70% of gold in concentrate was extracted. The gold leach system reduced gold

ALTA 2011 Free Paper content to 7 g/t. The gold extraction was over 90% because the amount of the feed was reduced to 60% of its weight.

The process flow examination was continued for one year to confirm the process performance below.

- Proton consumed in copper leaching and proton re-generated in solvent extraction were balanced.
- Copper extraction was sufficiently high.
- Quality of copper cathode was sufficiently high.
- Over 90% of the gold was leached.

#### **PILOT PLANT IN PERTH**

JX NMM built a pilot plant for the Nikko Chloride Process in Perth. The plant has the complete stages of the process. Bateman Engineering were EPCM consultant for building the pilot plant and JX NMM started the plant operation in October 2009 with Amdel.

Fig 9 shows the layout of the pilot plant. The pilot plant processed copper concentrate of which the copper content was adjusted from 20 to 12.5 %.



Figure 9: Layout of the pilot plant

#### **Copper Leaching and Recovery**

Fig 10 shows the copper leaching results for the pilot plant. The copper content figures for the final leach residue are shown at the bottom. They are less than 0.3%, and the copper extraction efficiency is more than 99%. The plant has four copper leaching stages. Thickeners are installed to separate copper leach solution and copper leach residue. Copper leach solution, copper extraction raffinate, was divided into four and each part of the solution contacted with feed concentrate or processing intermediate once. Thus the copper concentrate was leached four times.



Figure 10: Results of the copper leaching stage

Four copper leach solutions were combined and oxidized by sparging air to oxidize cuprous copper and ferrous iron. The oxidized solution was sent to copper solvent extraction stage after filtration. LIX984N (LIX984 was changed to LIX984N) extracted copper from the oxidized solution and spent copper electrolyte was used to strip copper. Table 2 shows average analysis values of the copper cathode produced in the pilot plant.

Table 2	: Average	assay	value	of copper	cathode
---------	-----------	-------	-------	-----------	---------

Copper Cathode	Ag	S	Fe	As	Sb	Bi	Pb
	0.2	4	1	<0.1	<0.1	<0.1	<0.1
Copper Cathode	Sn	Ni	Со	Ti	Se	Те	
	<0.1	<0.1	<0.1	<0.1	0.1	0.1	

#### **Gold Leaching**

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Gold starts to be dissolved when the copper content in leach residue reduces to a certain level. Gold is dissolved in the copper leaching stage and the gold leaching stage. A copper content less than 4% was achieved at the 3rd copper leaching step. Gold concentration of the 3rd and 4th copper leaching steps increased up to 5 mg/l as shown in Figure 11. Gold leaching in the copper leaching stage attained to 60 to 80% and around 90% of gold was extracted after the gold leaching stage. Figure 12 shows the gold extraction changes in these two leaching stages.



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Figure 11: Gold concentration changes in copper leaching stage



Figure 12: Gold leaching in copper leaching stage and gold leaching stage

Gold content in gold leach residue changed as Figure 13. The gold content change had a little variation. The poor leaching between 250 and 300 days was caused by the shortening of the leaching hours and mismatching between the amount of proton in leach solution and the amount of copper in feed. The gold content was reduced to about 10 g/t. An activated carbon column was installed after the 3rd and 4th copper leaching steps. The 2nd copper leach solution sometimes flowed through the activated carbon column. The activated carbon adsorbed 3,000 to 5,000 ppm of gold in this system. The capacity was too low to offset its operating cost. Therefore gold solvent extraction is being examined to replace activated carbon.



Figure 13: Gold content change in leach residue

#### **Minor Elements**

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Sometimes copper concentrate contains minor elements like zinc, cobalt and nickel. With pyrometallurgical processing it is difficult to recover these elements. Nikko Chloride Process re-uses leaching solution many times; therefore these elements can accumulate in the process leach solution which makes recovery possible.

Figure 14 shows the concentration changes of the minor elements in copper leach solution. The average contents of zinc, cobalt, manganese and nickel were 906 ppm, 1,655 ppm, 472 ppm and 413 ppm, respectively. Nickel and cobalt are less soluble in this system considering the relative concentration ratio of these elements. These elements can be recovered separately by applying solvent extraction.



Figure 14: Minor elements build-up

#### Improvement of Process

JTA 2011 Free Paper The Nikko Chloride Process pilot plant in Perth processed copper sulphide concentrate to prove the effectiveness of the process. The process extracted more than 99% of copper in concentrate and produced high quality copper cathode with solvent extraction and electrowinning. The process leached more than 90% of gold. It is clear that the solution composed of sodium chloride and sodium bromide is suitable for treating gold bearing copper sulphide.

> Gold solvent extraction has the potential to make the process effective for recovering gold. JX NMM has operated a hydrometallurgical process for copper anode slime treatment since 1997. Gold is extracted by DBC after wet chlorination and recovered by direct reduction of loaded DBC with oxalic acid in the plant. It is a simple and effective way to recover gold from chloride solution.

> JX NMM examined DBC and LIX7820 for the gold extraction reagent. Gold is added as  $HAuCl_{4}$ . The oxidation reduction potential of copper leaching stage was about 550 to 630 mV vs Ag / AgCl. It is close to the redox potential of  $AuCl_4$  /  $AuCl_2$  and according to Figure 1 Au(I) extraction was also examined with a solution which was prepared by adding ferrous chloride to  $HAuCl_{4}$  solution.

> Table 3 shows the gold extraction with DBC. DBC extracted gold from the solution containing auric gold as in Run No. 1. Cuprous copper had some effect on gold extraction and ferrous iron had more effect on the extraction. The mixture of DBC and octanol extracts aurous gold<sup>(12)</sup>. Comparing Run No. 4 and 5, the mixture of DBC and octanol extracts more gold than DBC alone when solution contains ferrous iron.

Run No.	Cu <sup>2+</sup> g/l	Cu⁺ g/l	Fe <sup>3+</sup> g/l	Fe <sup>2+</sup> g/l	Au mg/l	
					before SX	after SX
1	20	0	2	0	0.95	0.03
2	20	2	2	0	1.00	0.15
3	20	4	2	0	0.67	0.05
4	20	0	1	1	1.20	0.63
5	21	0	1.5	0.5	1.35	0.15

#### Table 3: Gold solvent extraction with DBC

\* Run No. 1 to 4 are extracted with DBC, Run No. 5 is with a mixture of DBC and octanol.

Table 4 shows the result of gold extraction with LIX7820. LIX7820 is a mixture of a quaternary amine and a weak acid to extract gold from cyanide solution<sup>(13)</sup>. This reagent is usually applied to alkaline solution. NMM tried gold extraction at pH 1.5 and got a result in which LIX7820 could extract gold from chloride solution with low redox potential as shown in Table 4.

#### Table 4: Gold solvent extraction with LIX7820

Run No.	Cu2⁺g/l	Cu⁺g/l	Fe3⁺g/l	Fe2⁺g/l	Au mg/l	
					before SX	after SX
1	20	0	2	1	0.66	< 0.01
2	20	2	2	0	1.83	0.19
3	20	2	2	1	1.34	< 0.01

When ferrous iron is added to the leach solution, its redox potential is reduced by 130 to 200 mV. Some gold would be as aurous in the solution and it becomes difficult to extract gold with DBC.

Gold extraction was performed in a mixer-settler with chloride solution and LIX7820. The chloride solution contained copper, iron and about 5 mg/l of gold. LIX7820 loaded gold to 290 mg/l. Sodium oxalate reduced gold directly from LIX7820 to produce gold powder which contained 0.45% of copper. Silver and iron were not detected in the gold powder.

#### CONCLUSION

JTA 2011 Free Paper Chloride processing has an ability to leach copper sulphide easily. Solvent extraction can convert chloride copper into sulphate copper and electrowinning of copper from sulphate solution can produce high quality copper plate. Various processes which combine these technologies are well known. The Nikko Chloride Process re-uses copper extraction raffinate as leach solution by dividing the raffinate in a number of parts to control copper concentration increase in the leach solution.

> The Nikko Chloride Process can leach gold with only aeration by adding bromide to the leach solution ,because the gold bromide complex has a lower standard redox potential than the chloride complex and low gold concentration makes the oxidation potential lower.

> The Nikko Chloride Process has been examined through bench scale tests. The process flow works well and a pilot plant has been built in Perth. The pilot plant achieved more than 99% of copper leaching and more than 90% gold leaching. Copper cathode electrowon in the plant was of very high quality.

> It has become clear that the Nikko Chloride Process can be applied for copper and gold recovery from low copper grade concentrate with only air sparging under ambient pressure.

Nikko Chloride Process has many benefits mentioned below:

- Leaching copper with high extraction efficiency.
- Producing high quality copper by electrowinning in sulphate media.
- Leaching gold in concentrate by air sparging without any special oxidant (e.g. chlorine gas hydrogen peroxide).
- Accepting a wide range of copper and impurities content.
- Operating under ambient pressure and at a temperature less than boiling point

The Nikko Chloride Process can process low copper and/or high impurity concentrates that are difficult to treat by pyrometallurgical processing, and also can process gold bearing copper concentrates that cause complications in other hydrometallurgical processes.

The application of solvent extraction instead of activated carbon for improvement in gold recovery is being tried in the Perth pilot plant. The silver recovery stage is going to be verified in the pilot plant.

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