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Beneficiation of Gold Ore by Flotation Column: A Pilot Scale Study

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ABSTRACT

During the first phase of the study, laboratory size flotation column was installed within the premises of flotation plant of M/s BGML to study the amenability of column technology for the beneficiation of gold. Encouraged by the results, a semi-commercial flotation column designed and developed by NML Madras Centre was installed in the flotation circuit to evaluate its performance and also to instil confidence. The results obtained both by laboratory and semi-commercial size flotation columns clearly indicated that the columns can perform better than the conventional cells. It was observed that high quality concentrates assaying 40 to 50 ppm of gold could be achieved by flotation column, whereas conventional cells could produce hardly 10 to 15 ppm of gold concentrates.

INTRODUCTION

Kolar Gold Fields owned by M/s. Bharat Gold Mines Ltd. (BGML) is well known for its gold reserves for the past 100 years. Since its inception, gravity methods were followed to enrich gold. As the characteristics of the gold ore changed over the time, the losses of gold were found to be severe by gravity methods. During 1983 detailed mineralogical analysis was conducted in order to understand the mineralogy and nature of gold losses in tailing. It was established that very fine grained gold particles locked with gangue minerals as well as the unliberated gold particles in arsenopyrite are the main reasons for gold loss into tailings. It was also found that the gold values in cyanide residue were due to incomplete cyanidation of gold locked up in arsenopyrite. These gold inclusions along with fine specs of gold locked in sulphides were estimated to be around 20%. It is known that gravity methods are inadequate to recover micron size gold particles. Hence M/s. BGML decided to introduce flotation circuit during 1990. The flowsheet of present operation consists of usual crushing, grinding, classification, gravity concentration, flotation in addition to leaching, elution, electrowinning, smelting and bullion. Tailings generated from flotation and leaching are subjected to classification. The cyclone overflow is dumped in tailing dam whilst underflow is utilised for mine filling.

In order to sustain the impact of globalisation, M/s. BGML have identified various options. Replacement or total elimination of ineffective and age old equipments with latest technologies, simplification of flowsheet with better control strategy and steep increase in milling capacity are a few among various measures aimed to cut down the production costs. In order to meet the increased tonnage of milling, it was decided to expand the existing flotation circuit by column technology.

Since part of the gold is distributed in sulphides, incorporating flotation column in the existing flotation circuit was considered to be the best choice to derive better metallurgical results. The technology of column flotation is rapidly gaining attention due to its distinct advantages over conventional flotation technology. Increase in concentrate grade, product recovery, decrease in number of flotation stages required to achieve product grade or a combination of these effects have been reported on many ores [1-4]. Column flotation was adopted to process sulphidic gold ore at the Harbour Lights mine in Leonora, Western Australia to produce a final gold bearing sulphide concentrate in a single stage [5]. The Three Mile Hill gold deposit of Goldfan Ltd. located near Coolgardie also adopted column as rougher for the beneficiation of gold mostly associated with sulphides. Column cells have been installed in gold recovery circuits at the Austin Gold Venture in Nevada, Asamera's Cannon Mine in Washington and Echo Bay's McCoy Mine in Nivada. In all the cases, column cells were used for cleaning rougher flotation concentrate [6]. The column technology was proved to be superior over conventinal cells in many operations through out the world.

Detailed column flotation tests were conducted by 0.074 metres dia. laboratory flotation column to establish the amenability of flotation column for the beneficiation of gold ores at M/s. BGML [7]. Encouraged by the results, semi-commercial size (0.5 metre dia.) flotation column was installed to confirm the reproducibility of results obtained by laboratory size. In the present paper, results obtained by the semi-commercial size column are discussed and compared to that of laboratory size column.

MINEROLOGY

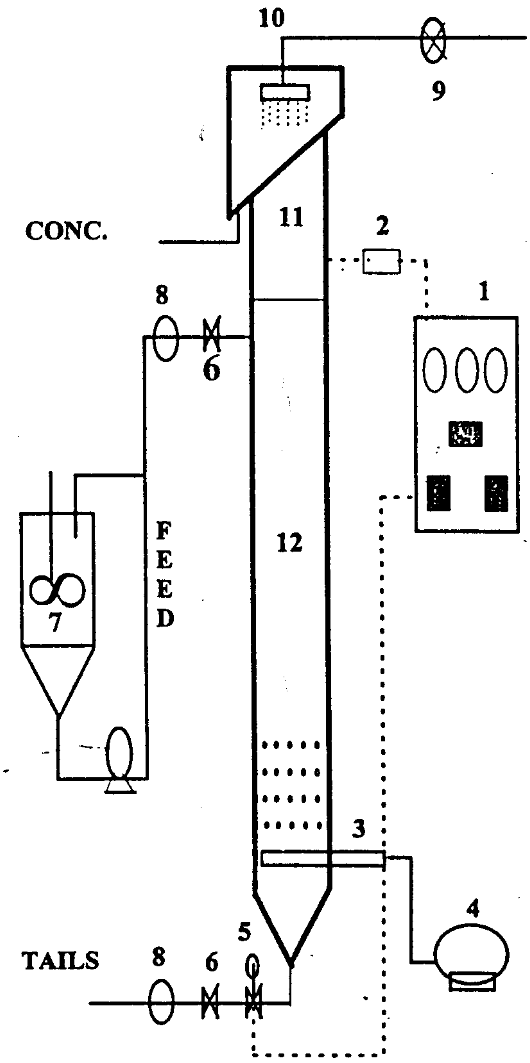
Detailed mineralogical assay of Nundydroog ore of KGF reported by Mineral Exploration Corporation, Nagpur revealed that the ore is semi-refractory containing both free and refractory gold approximately in the ratio of 80:20. In the refractory ore, about 85-90% of gold was observed to be locked in arsenopyrite and loellingite grains. Though the grain size of gold particles ranges from one micron to hundred microns, most of the particles were found to be in the range of 2 to 20 microns. The free gold occuring in the gangue is coarser i.e. 10-100 microns. Based on their modal abundances,different ore minerals were grouped as:

Major Minerals (> 5% by volume)	Pyrrhotite, Ilmenite, Sphene and Arsenopyrite
Minor Minerals (1-5% by volume)	Magnetite, Loellingite and Chalcopyrite
Accessory minerals (0.01-1.0% by volume)	Sphalerite, Pyrite and Marcasite
Trace Minerals (< 0.01 % by volume)	Gold, native Bismuth, Petlandite, Graphite and Platinoid minerals

EXPERIMENTAL

The column shell with an ID of 0.5 metre is fabricated out of mild steel. It comprises several flanged sections with suitable fixtures for feed injection, air sparging, launder and housing for level controller. The feed injection point is located at a height of 5 metres from the bottom of the column. The height of the column is further extended to 3.5 metres for cleaning froth zones measuring 3 meters and 0.5 meters respectively. The top section is connected to a launder with sufficient slope so that the froth falling from the column is effectively drained through a pipe.

Air spargers/bubble generators with different porosities designed at NML Madras Centre were used. The gas hold up of the column was found to vary from 10-15% depending on the air rate, frother dosage and solids. A single loop controller connecting differential pressure transmitter (DPT) and the tailing discharge valve is adopted to maintain the interface between froth and slurry. The discharge valve is actuated by a signal 4-20 mA generated by DPT. Under steady state conditions, the interface level could be maintained within ± 50 mm. Magnetic flow meters are used to measure slurry flow rates. Digital display meters were incorporated to measure flowrates and total volume of air and water. Online electro-pneumatic valves with timer are also installed for automatic sample collection. The schematic diagram of flotation column installed in the circuit is shown in Fig.1. The column was installed as rougher cum cleaner. Conventional cells were utilised for scavenging.



1.Control Panel
2 DPT
3.Sparger
4.Compressor
5.Control Valve
6.Auto Sampler
7. Conditioner
8. Mag. Flow meter
9. Wash water flow meter
10. Wash Water Distributor
11. Cleaning zone
12. Collection zone

Fig.1: Schematic diagram of Semi-commercial flotation column

The column was run on a continuous basis for a period of 3 months. The standard test procedure established by Finch etal. [8] was adopted through out the work.

RESULTS AND DISCUSSION

During the first phase, 0.074 metre dia laboratory size flotation column was installed within the plant premises and the amenability of the flotation column as a rougher cum cleaner was studied. Entire amenability test work was conducted on a sample collected directly from mill cyclone overflow which is free from reagents and recirculation loads.

Batch type experiments related to optimisation of various reagents and column parameters were conducted by the laboratory size flotation column. The optimum conditions thus obtained are tabulated below:

Soda ash:	1.00 kg/t
Sodium Silicate	0.50 kg/t
Copper Sulphate	0.40 kg/t
Amyl xanthate	0.04 kg/t
Pine oil	0.015 kg/t
pH	8.0
Air velocity	1.16 cm/s
Wash water velocity	0.078 cm/s
Feed velocity	1.1 cm/s
Froth depth	40 cm
Residence time	400 sec
d_{80}	75 μ

$CuSO_4$ is used as an activator to enhance the flotability of arsenopyrite. Generally the flotability of iron containing sulphides like pyrrhotite and arsenopyrite is sluggish and needs an activator like $CuSO_4$ to obtain better recoveries using xanthates as collectors. It is known that metal xanthates of arsenic and iron are less stable and more soluble compared to copper xanthates.

Typically a froth depth of 1 metre is preferred in most of the operations. Froth depth has practical advantage of dampening down the entrainment. However, in this particular case due to very high density of concentrate and low mineral content, froth depth was deliberately maintained to a maximum of 0.5 metres to obtain better recoveries. While floating heavy gold minerals, froth zone density may exceed the density of slurry due to the pressure exerted by coarse and high density solids. Consequently the froth may sink through lower density regions below. This phenomena would adversely affects the recoveries. Hence low froth depths ranging from 0.3 - 0.5 metres are preferred to achieve better recoveries.

Slurry feed rate and % solids are important variables to establish the residence time and column throughput. By increasing the feed rate, the particle residence time is reduced and there by the recovery. Effect of feed flowrate/slurry residence time on grade and recovery of gold is shown in Table 1.

prevailing in flotation column. Due to counter current flow of particles and air bubbles, the collision efficiency is high in flotation columns and inturn the recovery. Column throughput can be increased simply by increasing the feed solids upto a point where sufficient bubbles are available to lift the particles. Generally 20% solids is preferred in cleaning operations. In this particular case, since the valuable material which is to be floated is very less, thorough separation can be achieved even at 40% solids.

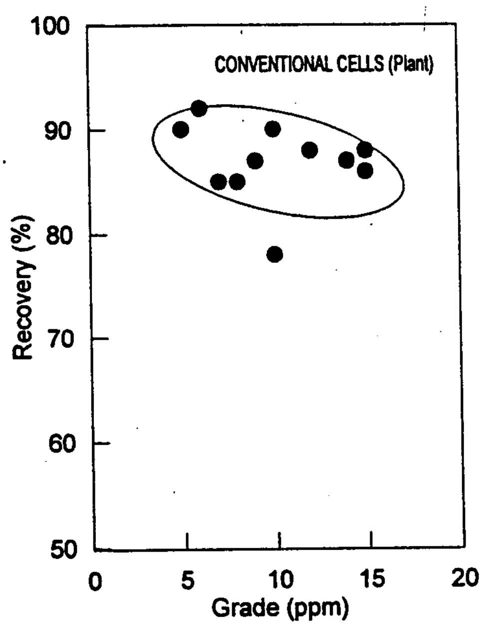
After optimising all the parameters a few runs were carried out for a longer duration ranging from 6 to 8 hours and the samples were collected from the column and the plant simultaneously. The results of the same are shown in Fig.2. High grade concentrates assaying 30-50 ppm of gold

Table 1 Effect of slurry residence time on grade and recovery

Sl. No.	Slurry residence time (Sec.)	Conc. Wt (%)	Gold Assay (ppm)			Recovery (%)
			Feed	Conc.	Tails	
1	1458	6.7	2.15	23	0.42	80.7
2	1068	7.5	2.15	30	0.40	82.5
3	1008	5.5	2.10	23	0.40	82.4
4	858	7.4	2.20	30	0.40	82.9
5	714	8.8	2.15	30	0.40	82.5
6	432	4.7	2.20	60	0.50	80.0
7	324	3.7	2.15	65	0.55	75.1

It is apparent that slurry residence time of 8 minutes is found to be sufficient to achieve the target recovery. The residence time to achieve equivalent recovery by conventional flotation cells is observed to be 15 minutes. The results clearly indicate that the kinetics of flotation of gold bearing minerals in column are superior compared to conventional cells. The better flotation kinetics are attributed to better hydrodynamic conditions

was obtained by flotation column whereas conventional cells have yielded hardly 5-10 ppm of gold concentrates. The recoveries were found to be more or less same in both the cases. It may be noted that plant recoveries mentioned are inclusive of scavenging operation whereas column recoveries reported are without scavenging. Also, it is apparent that around 40 % of the solids report to concentrate in conventional



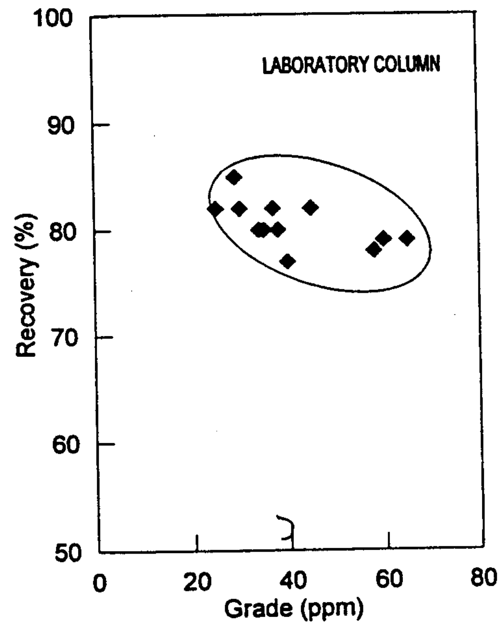


Fig. 2: Comparison of metallurgical preformance between Conventional cells and Column

flotation, resulting in poor grades, whereas weight of the float is below 10% in flotation column. Apparently, the cost of down stream operations could be minimised by rejecting most of the gangue during the flotation stage.

Encouraged by the performance of the laboratory column over the conventional flotation it was decided to confirm the same on a large scale operation. Accordingly a semi-commercial column was installed in the flotation circuit and allowed to run at the optimum conditions already established by laboratory size flotation column. The column was operated simultaneously with the flotation plant by drawing a separate stream from the conditioner. The results obtained by semi-commercial column (Figs. 3 & 4) are compared to that of the laboratory flotation column and conventional cells. Fig.3 shows the comparison of the grade-recovery profile in both laboratory and semi - commercial scale columns. Slightly better recoveries observed in the semi-commercial column were due to close circuit operation where in scavenging concentrate is recirculated. A good agreement of the results is seen from the contours drawn for the set of tests. In both the cases, gold concentrates ranging from 35-60 ppm of gold with a recovery of 70-90% is achieved. A similar agreement of results could be seen from Fig. 4 where concentrate weight is compared with gold recovery. The weight of the concentrates obtained by column flotation is 2 - 10% which is very less compared to conventional flotation where the concentrate weight was observed to fluctuate between 40-50%. Flotation columns were found to yield better concentrates with minimum gangue. The wash water introduced from the top of the column could effectively displace the entrained hydrophilic gangue particles from the froth phase. This reduction in concentrate weight will benefit the downstream operations particularly in the

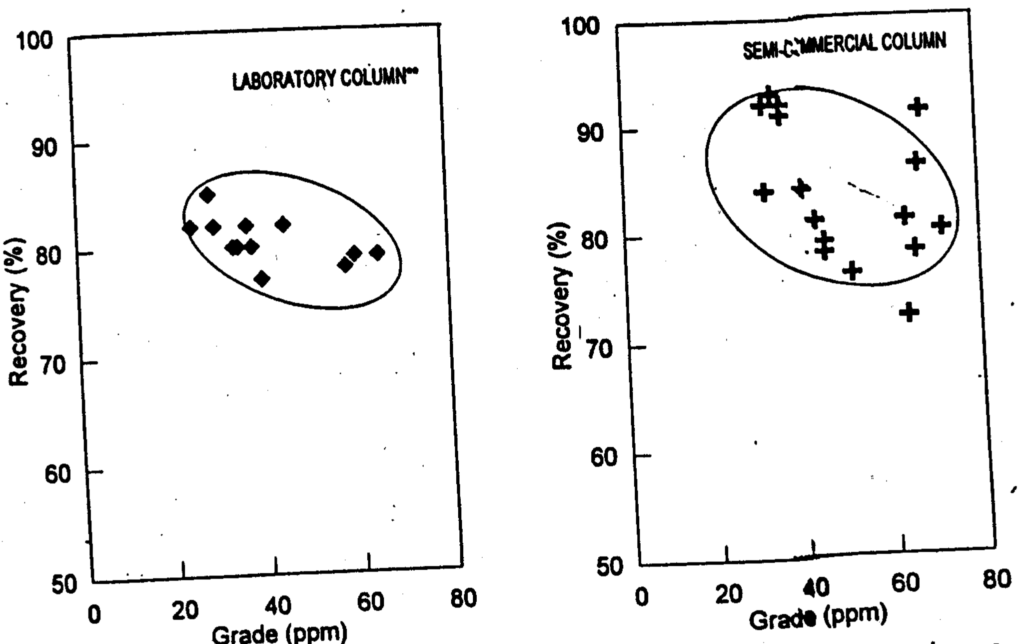


Fig. 3: Comparison between Laboratory and Semi-commercial flotation columns

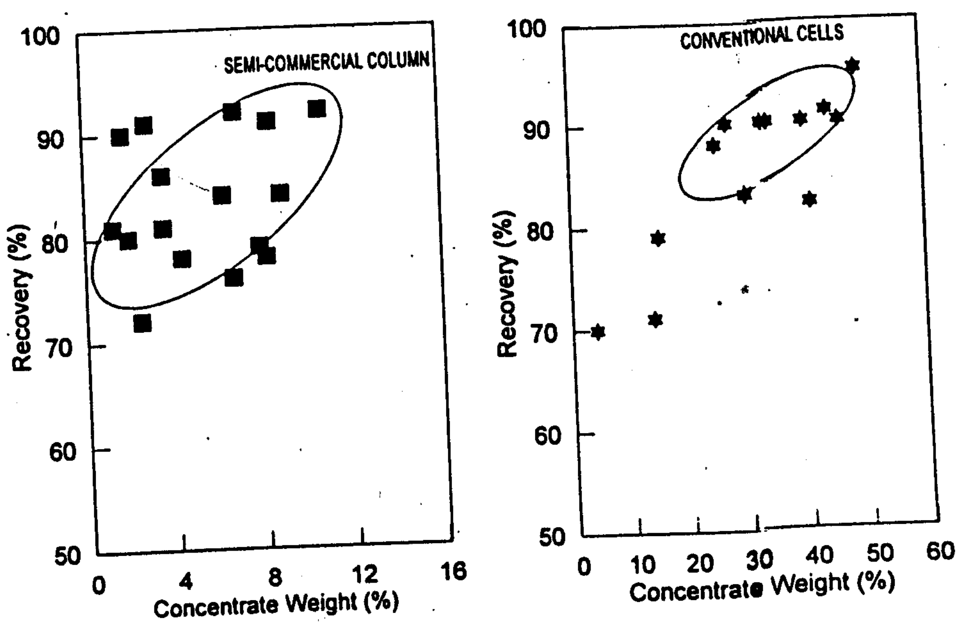


Fig. 4: Concentrate Weight vs Recovery - Comparison between Semi-commercial column and Conventional cells

reduction of cynaide consumption which inturn will reflect on the overall economics of the plant.

CONCLUSIONS

The results obtained both by laboratory and semi-commercial flotation columns clearly indicate that the flotation columns are amenable for beneficiation of gold ores of BGML. Grade-recovery profiles are almost identical in both the instances. The quality of concentrate generated by flotation column is superior compared to conventional cells. Nearly 90% of the gangue is eliminated by flotation column whereas hardly 50% is rejected by the existing conventional cells. High grade concentrates with less gangue generated by flotation column is expected to consume less cyanide during cyanidation stage. The significant reduction is cyanide consumption along with usual benefits of flotation column can certainly improve the overall economics of the plant.

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