



Challenges & Improvements In Milling At Omai Gold Mines

ABSTRACT

High tonnage, low grade gold mines such as Omai's afford economies of scale that are unto their own insufficient to sustain profitability at today's depressed gold price. Complimenting profitability objectives is the perpetual challenge to reduce operating costs and optimize unit operating efficiencies while being ever vigilant of issues such as environmental control.

Key to achieving these objectives at Omai are throughput and availability gains, gold recovery improvements, cost cutting, a skilled workforce and reliable power generation.

This paper attempts a cursory review of startup-to-date plant performance advances and future performance-driven objectives.

INTRODUCTION

Commercial gold production at Omai commenced in January 1993 with annual output climbing to 250,000 opy by the end of 1994. A mill expansion completed in August 1996 increased gold production to 340,000 opy by the end of 1997. Current milling capacity is 20,000 mtpd (nom.) with actual capacity exceeding 24,000 mtpd on occasion depending on ore size and competency. Mill feed consists of **hardrock** (andesite, quartz diorite and rhyolite) and **softrock** (saprolite, laterite) at a nominal ratio of 70:30, respectively. Present day average weighted grade of the feed is 1.4 g/t gold.

PROCESS DESCRIPTION

Primary crushing, ore handling and the original 12,000 mtpd hard and soft rock SABC mill, hereafter referred to as Mill 'A', remains essentially as documented by Konigsmann (1994) complete with post-startup modifications. The mill expansion, hereafter referred to as Mill 'B', features an

OMAI GOLD MINES LIMITED
Mill Flowsheet

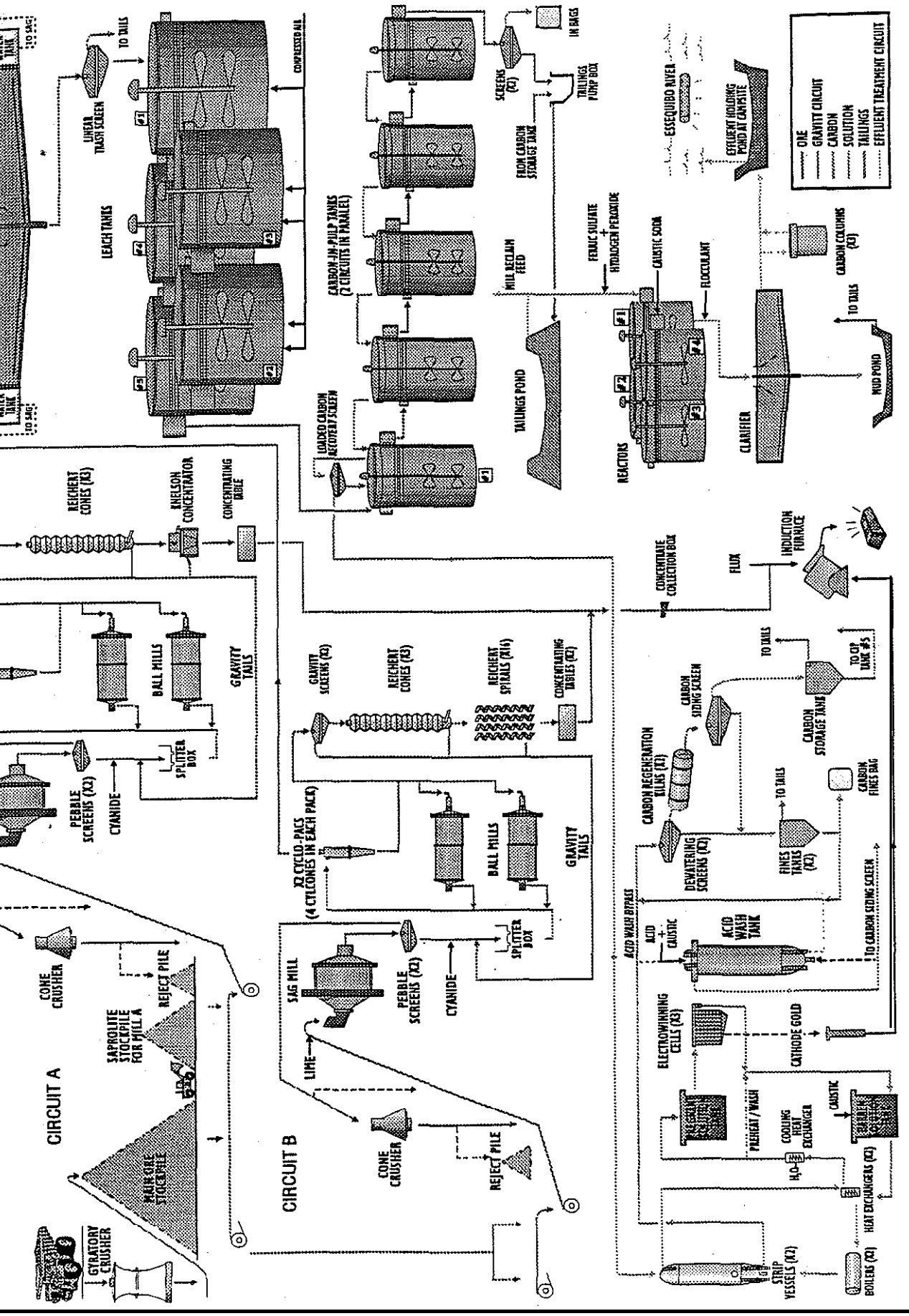


FIG. 1

8000 mtpd hard rock SABC grinding circuit similar in configuration to Mill 'A' and differing only in equipment size. Mill 'B' includes a 9000 H.P., reversible variable speed, single pinion drive, 32 ft. x 15 ft. SAG mill, a 7 ft. short head pebble crusher and two parallel 5400 H.P., 16.5 ft. x 30 ft. ball mills with dedicated cyclone packs consisting of D26 hydrocyclones.

Mills 'A' and 'B' have separate gravity circuits fed by screened cyclone underflow bleeds. However they differ in that Mill 'A' features Reichert cones and a 30 in. Knelson concentrator whereas Mill 'B' resembles the original Mill 'A' gravity configuration - Reichert cones, spirals and rougher/cleaner shaking tables.

Cyclone overflows from both mills report to a common thickener with the underflow reporting to a 5 tank leach circuit with a design throughput residency of 14 hours. Cyanidation tailings flows are split to parallel, 5 tank CIP circuits. Thereafter loaded carbons are conventionally stripped, regenerated and returned to CIP, strip eluates are electrowon and concentrates refined as per Konigsmann (1994) and Figure 1.

Approximately 30% of total gold production is gravity recovered as a 70% concentrate. The remaining gold production is recovered by cyanidation-UP-elution-electrowinning. The actual leaching process begins at SAG discharge pump boxes in both mills with approximately 50% of net leaching taking place prior to the cyanidation circuit.

Tailings are pumped to basin situated 4 km northeast of the mill complex. The tailings impoundment consists of six embankments which connect a series of knolls and will ultimately provide storage for 69 Mt of tailings. The core of each embankment is constructed from compacted saprolite and features vertical chimney drains infilled with sand, horizontal sand blanket drains and toe drains of sand, crushed rock and geotextile fabric. Tailings are spigot discharged into the 200 hectare basin from each embankment to produce a quasiplanar beach. Tailings solution is reclaimed to the mill at 80% (+) recycle and, when necessary, a portion bled to an effluent treatment facility for tailings basin water balance management.

MILLING CRITERIA

The Omai concentrator gauges its performance on a cost per tonne basis and its relative performance to mills of similar feed grade, configuration and capacity world-wide. Performance criteria of greatest concern are plant throughput and availability, gold recovery, consumable and material cost control and power generation. Other less tangible but important criteria include metallurgical and environmental control, training and safety and health.

Productivity

Fundamental to throughput and availability gains is an in-house system that tracks and records the causes and frequencies of unscheduled and scheduled downtime. The system is embodied in the form of a daily 'Mill Tonnage and Downtime' report (Figure 2). This document identifies recurrent problems such as feed chute blockages, emergency pull-cord trips, mill lube system problems etc. and it provides a convenient day-to-day measure of hard and soft rock throughputs and Mill 'A' and 'B' availabilities.

A second in-house system assists with the organization of scheduled downtime and manpower/job time efficiency during same. Each downtime event is thoroughly planned, pre-shutdown meetings help coordinate activities between and within the different mill groups. The agreed to plan of

MILL TONNAGE AND DOWNTIME

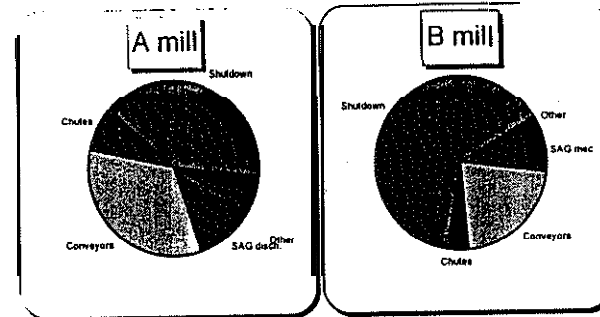
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PRODUCTION AND DOWNTIME

DATE	TONNAGE					Min.Downtime		% Availability		
	A (hard)	A (sap.)	B	TOTAL	%Hd.Roc	A	B	A	B	Avg.
1	6969	4998	10227	22194	77.48	201	1	86.04	99.93	92.99
2	6275	4352	10730	21357	79.62	273	18	81.04	98.75	89.90
3	8583	5247	11043	24873	78.90	88	22	93.89	98.47	96.18
4	8319	4330	10849	23498	81.57	8	2	99.44	99.86	99.65
5	2115	1067	9883	13065	91.83	911	32	36.74	97.78	67.26
6	7046	3045	10424	20515	85.16	99	28	93.13	98.06	95.59
7	8765	3873	9093	21731	82.18	8	21	99.44	98.54	98.99
8	7257	4844	8884	20985	76.92	9	5	99.38	99.65	99.51
9	6074	6491	6129	18694	65.28	3	348	99.79	75.83	87.81
10	5811	6021	3688	15520	61.20	123	758	91.46	47.36	69.41
11	8724	4686	5364	18774	75.04	87	446	93.96	69.03	81.49
12	8869	5242	7531	21642	75.78	5	4	99.65	99.72	99.69
13	8526	5682	8196	22404	74.64	43	214	97.01	85.14	91.08
14	8917	6234	10079	24720	78.40	15	35	98.96	97.57	98.26
15	8554	5101	9032	22687	77.52	34		97.64	100.00	98.82
16	8876	5240	8972	23088	77.30		132	100.00	90.83	95.42
17	8629	5479	7460	21568	74.60	6	299	99.58	79.24	89.41
18	7861	4430	9283	21574	79.47	191		86.74	100.00	93.37
19	8351	6152	10019	24522	74.91	19	5	98.68	99.65	99.17
20	8224	5869	9478	23571	75.10	11	93	99.24	93.54	96.39
21	8227	5482	9776	23485	76.66	7	26	99.51	98.19	98.85
22	6946	5104	9671	21721	76.50	230	6	84.03	99.58	91.81
23	7536	6694	9667	23897	71.99	19	77	98.68	94.65	96.67
24	9417	4715	10475	24607	80.84		25	100.00	98.26	99.13
25	8209	4881	7766	20856	76.60	174	380	87.92	73.61	80.76
26	5526	2664	9725	17915	85.13	528	7	93.33	99.51	81.42
27	8820	5104	9959	23883	78.63	7	9	99.51	99.38	99.44
28	9045	3679	10289	23013	84.01	55	7	96.18	99.51	97.85
29	7425	5630	11021	24076	76.62		11	100.00	99.24	99.62
30	8618	5532	385	14535	61.94	36	1380	97.50	4.17	50.83
31										
AVG.	7750.5	4695.6	6636.6	21482.6	77.21	106	146	92.62	89.64	91.23
TOTAL	232514	146868	265097	644479	77.21	3190	4391	92.62	89.84	91.23
PROJECT.	240264	151764	273934	665962	77.21	3296	4537	92.62		

CAUSES OF DOWNTIME (Hr)

	A	B	TOTAL	%
SAG electric	0.12		0.12	0.1%
SAG dis. screen+pumps	6.40	0.35	6.76	5.3%
SAG lube system				
SAG Overload + LCI	0.32	0.28	0.60	0.5%
SAG mechanic		5.75	5.75	4.6%
Conveyors	17.47	15.77	33.23	26.3%
Chutes	4.45	2.72	7.17	5.7%
Air pressure				
Power failure		0.32	0.32	0.3%
Shutdown	21.42	46.67	68.08	53.9%
PLC - Instrumentation	0.25		0.25	0.2%
Thickener, Leaching, CIP	0.50		0.50	0.4%
Tailings & tailings Pumps				
Other	2.25	1.33	3.56	2.6%
Total hours	53.17	73.18	126.35	100.0%



Number of days in month	31
Number of days left	1
Budgeted tonnage by month	651000
Budgeted tonnage by day	21000
Budgeted tonnage to date	630000
Tonnage to date	644479
Variation with budget to date	2.30% 14479
Tons to do by day	6521
Projected Monthly Tonnage	665962

FIG. 2

action and its scope is then documented and distributed to all parties and a Gantt chart prepared and likewise distributed detailing the duration and manpower assignments of the various work items,

Mill 'A' provided the bulk of productivity challenges at startup in 1993. The majority of post-startup changes was discussed by Konigsmann (1994), however, in the context of this discussion it is relevant to superficially review them and detail other Mill 'A' modifications undertaken since that time. Post-startup modifications to the crushing plant and ore handling systems included ;

- Enlarging the dump pocket and installing a rock breaker.
- Concave and mantle liner style and configuration changes
- Replacing the stacking conveyor, upgrading all conveyor belting and extensively modifying ore transfer chutes to minimize wear and impact damage.
- A dedicated saprolite feeder external from the primary crusher.
- A backhoe to feed saprolite.

Today, stockpile stacking capacity is 1800 tph and crusher 'in service' availability is 75%.

Within Mill 'A', the SAG pebble reject system was thoroughly redesigned from the complete removal of the flexwall conveyor system and its replacement by two conventional inclined conveyors to dismantling the pebble crusher feed chute bypass flopgate and replacing it with a bypass shuttle conveyor system. Other changes included additional magnet protection ahead of the pebble crusher, SAG shell and feed end liner changes and open area changes to the SAG pebble grates and SAG discharge screen.

Downstream of the SAG several concerns were resolved successfully;

- SAG discharge undersize splitter box modifications.
- Process water supply to the SAG discharge pump boxes.
- Ball mill trommel screen aperture shape change.
- Enlarging cyclone overflow collection boxes.
- Implementation of a chemical scale control program
- Replacing the cyclone underflow gravity screen oversize launders with a conventional conveyor and reconfiguring the undersize launders.

A major Mill 'A' productivity improvement occurred with a thickener retrofit commissioned in January 1995 when a thickener feed dilution / flocculating system was incorporated into its operation for flocculating saprolite fines suspended in overflow solutions. The reduction in fines recirculated to the cyclone feed pump boxes was immediate with concomitant improvements in ball mill recirculating loads, ball mill throughput, cycloning efficiency, thickener underflow densities and wear problems with valves etc..

- SAG throughput including but not limited to a change in pebble grate open area and process control investigations.
- Splitter box redesign.
- Cyclone underflow gravity screen deck structural support for vibration dampening.
- The use of launders versus pipe to convey gravity screen undersize to the gravity circuit feed pump box.

Abrasion and equipment wear rates are substantial at Mill 'B' and considerable effort and ingenious remedies have been expended to control it.

In summary the aforementioned changes to both mills have improved total throughput (Figure 3) and availability (Figure 4) to 21,000 dmtpd and 91%, respectively, at a better than planned hard / soft rock feed ratio of 2.6 : 1 (Figure 5).

Fig.3

Throughput

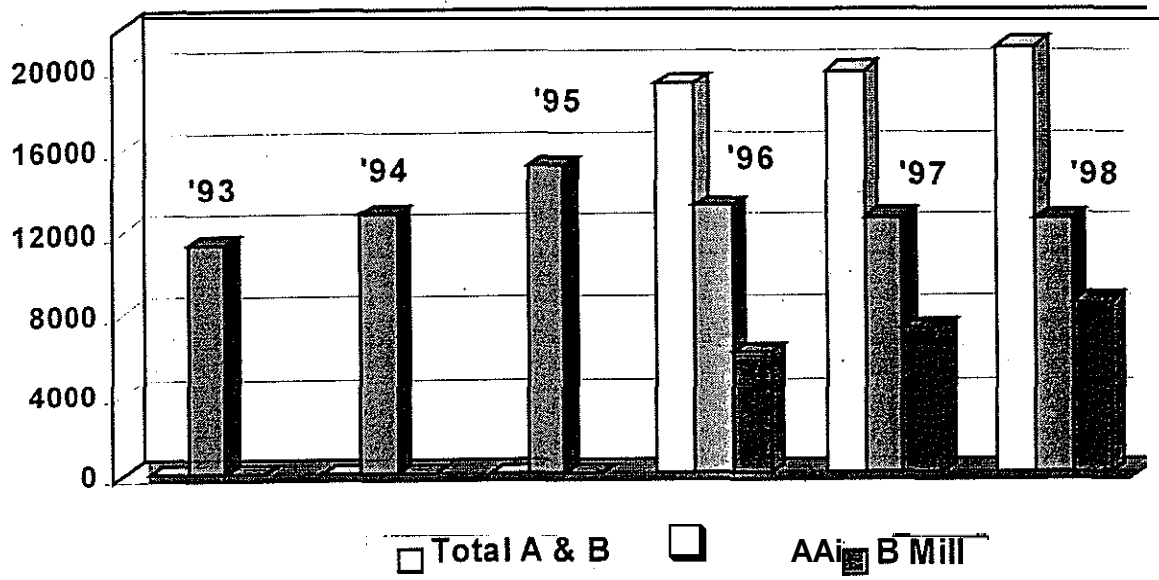


Fig. 4

Availability

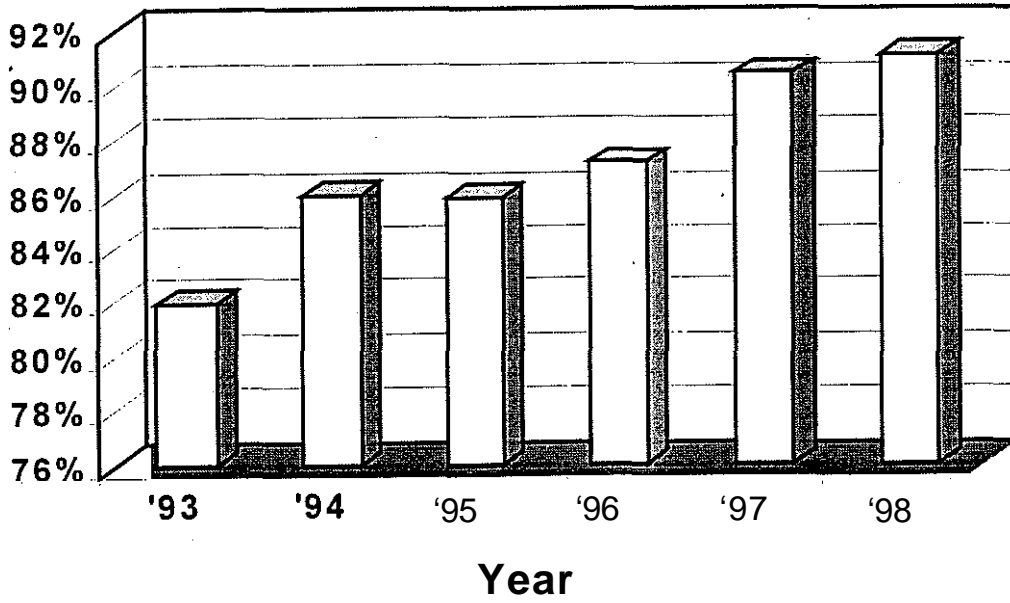
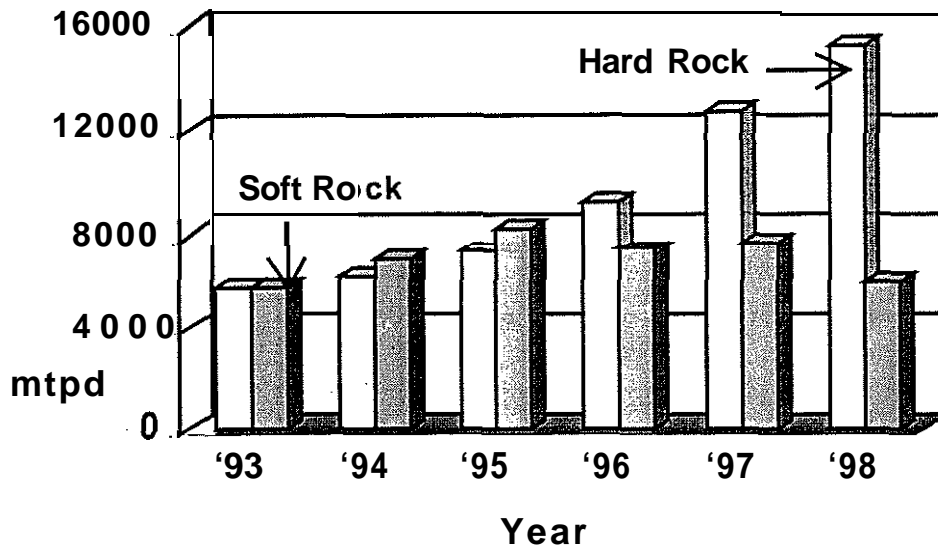


Fig.5 Hard & Soft Rock Feed



Performance

Recoveries are impacted by a multitude of factors. The major recovery accomplishments have arisen from;

- a) The thickener feed dilution / flocculating system retrofit discussed earlier. The finer size distribution of cyclone underflows and overflows (Figure 6) and the increase in gravity circuit feed density realized from this retrofit yielded a 40% improvement in Mill 'A' gravity circuit recovery.
- b) Assorted changes to the Mill 'A' gravity circuit such as increasing the cyclone underflow gravity screen deck open area, providing a more uniform and consistent pulp density in the gravity feed, Reichert cone configuration changes and scale control of cone surfaces and the installation of a Knelson concentrator as a replacement to the Reichert spirals and shaking table (Figure 8).
- c) Better pulp viscosity, leach pH, dissolved oxygen, cyanide and carbon tines control as well as diligent and frequent NKM interstage screen cleaning (Figure 7).
- d) Carbon column operation.

Figure 8 best illustrates the mill's recovery performance since startup. Last year's average recovery was in excess of 92% at a 1.4 g/t gold head grade which translates into solid and solution tenors of 0.10 and 0.015 g/t gold, respectively.

Fig. 6

Cyclone Overflow Grinds

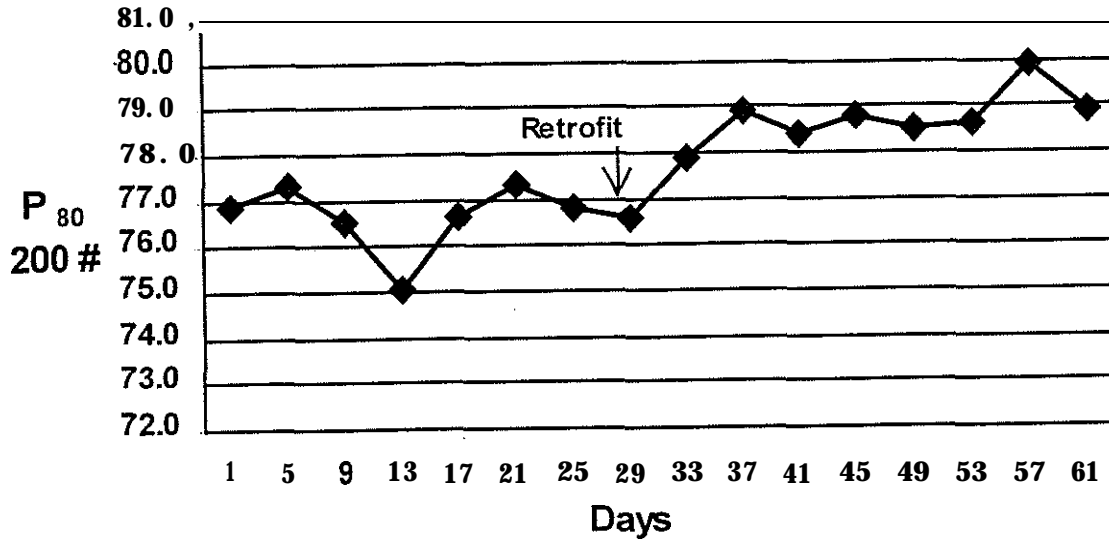


Fig. 7

Reagent Consumptions

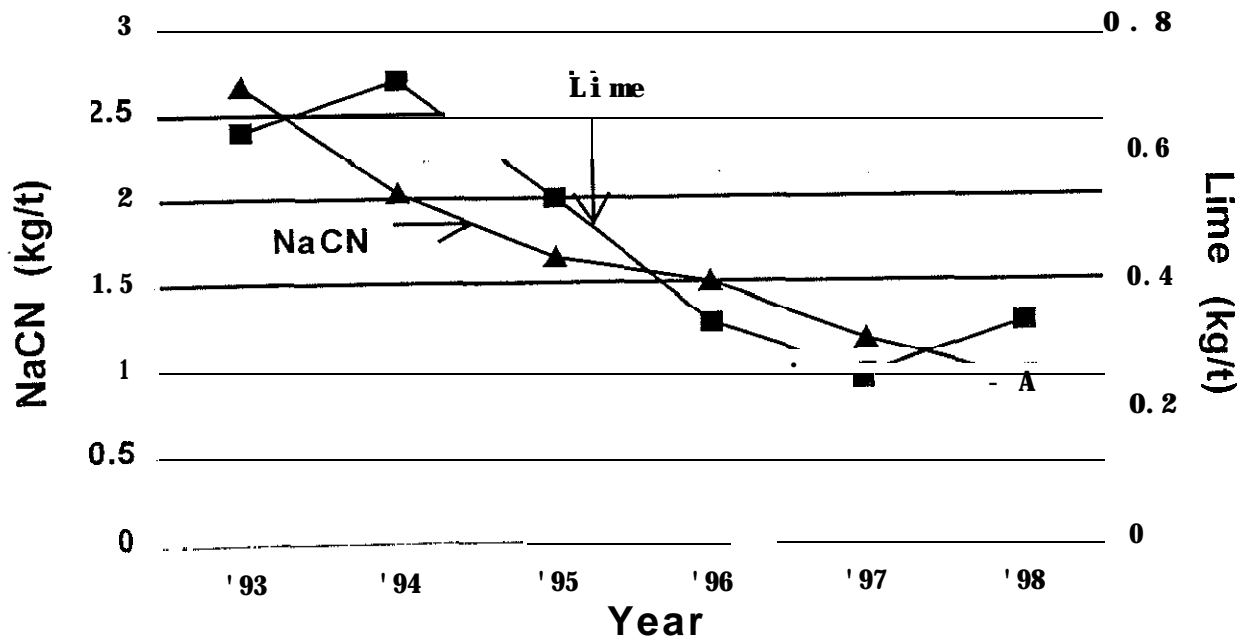
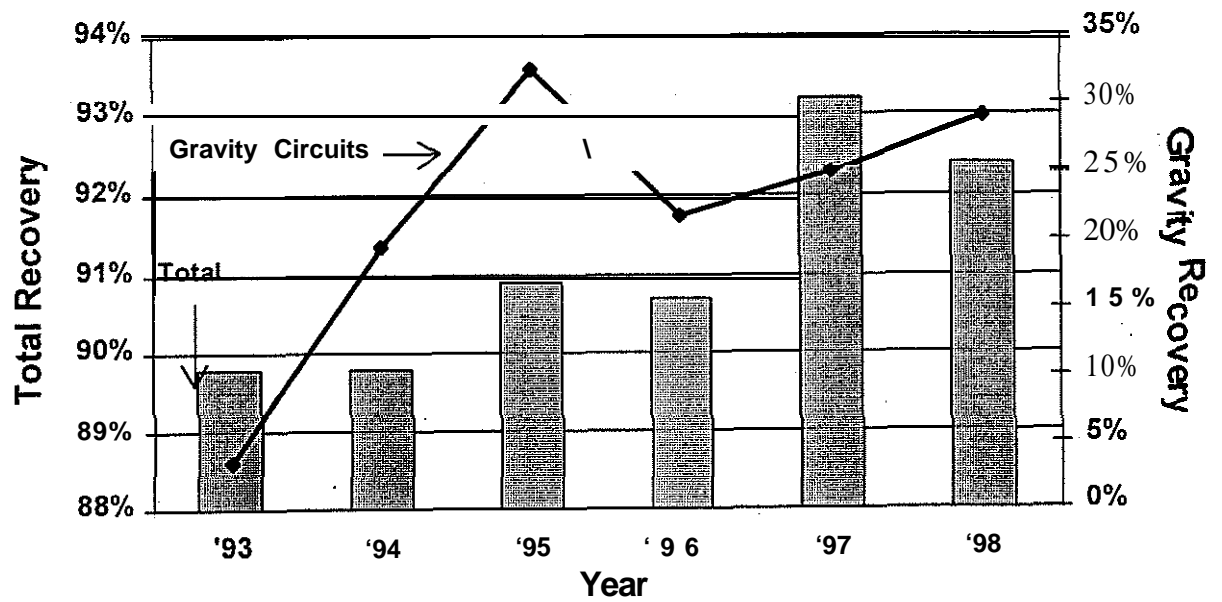


Fig. 8

Recoveries



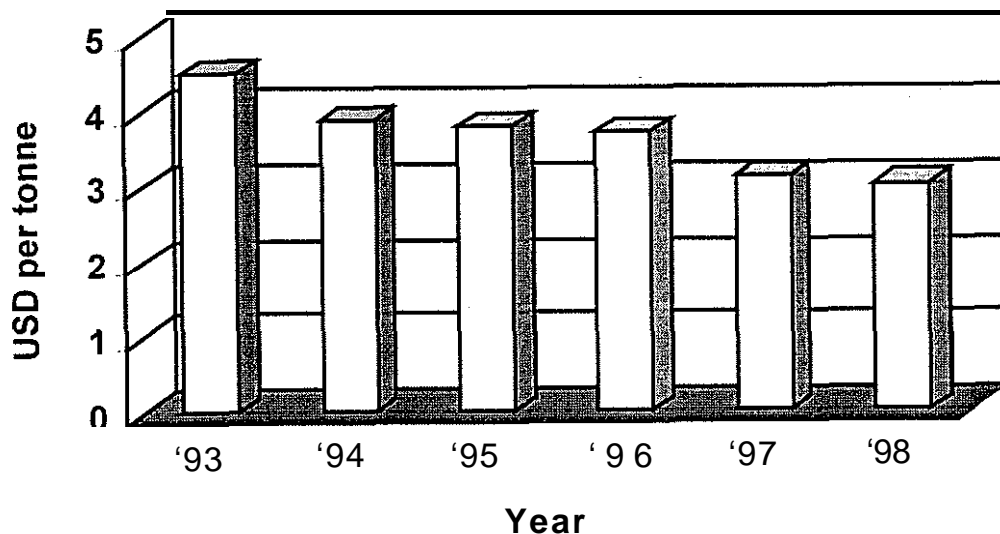
Operating Costs

Consumable and material costs have dropped since commissioning (Figure 9). The positive impact of OEM sourcing, vendor support and metallurgical control notwithstanding, the cost savings are attributed to;

- a) Reliable and accurate on-line monitoring and control of cyanide, lime and flocculant levels.
- b) Bulk deliveries of grinding media.
- c) Reduced carbon fines production

Fig. 9

Production Cost



d) Reduced cost for screening media, ball mill liners, conveyor belting etc. etc.

power Generation

The Omai power plant generated 265,000 MWh of power from 66 million liters of #2 (light) diesel fuel in 1998. Substantial economy-of-scale payback from improved generation efficiency is well worth the effort, for example, a 0.10 kWh per liter improvement in fuel economy saves the operation on the order of \$250,000 (US) per year.

The power plant consists of 8 Wartsila (3 MW cap. ea.) gensets commissioned in 1992 and 7 caterpillar (3.3 MW cap. ea.) gensets commissioned in 1996. Additional cooling water capacity, genset load sharing and other operating strategy changes translate into one less genset on-line at nominal power demand. Consequently a 99.5% (+) power plant availability is realized at a cost of 4.5-5.0 cents per kWh.

METALLURGICAL CONTROL

Metallurgical control by its simplest definition is an activity whereby productivity, performance and costs are monitored, analyzed and their interdependency optimized. A fundamental prerequisite to metallurgical control is the reliable measurement of plant metallurgical performance including, but not limited to, representative sampling, proper sample preparation, reliable and accurate instrumentation, good housekeeping, precise and accurate assaying, training and supervision.

Academic and technical considerations aside, metallurgical control takes on a whole new importance with a transitional workforce and lengthy periods of absence from the operation.

Sampling and Sample Preparation

Operators are trained in proper sampling methods which essentially constitutes the mechanics of where, when, what and how. The same holds true for operating parameter measurement such as carbon concentrations, pulp densities, thickener bed depth checks, cyanide concentrations and even pH. Supplementing this basic training process is periodic 'refresher' training that involves close interaction between the Mill Training and Metallurgy groups.

Sampling redundancy is the primary means of assuring representative sampling. This philosophy is applied to the leach feed and final tailings sample points whereat composite manual and automatic samples are collected each 12 hour shift. However this approach is premised on reliable, robust, low maintenance autosampling devices that cut representative samples based on sample theory. Extensive testing and configuring of different autosampler types has led to the development of an in-house hybrid device that meets these criteria and is user-friendly.

Sample preparation quality control impacts considerably on metallurgical monitoring accuracy. Standardization and documentation of preparation procedures helps avoid 'short cutting' and other compromising actions and it serves as an effective training tool for new hires. Of course independent and / or arbitrary changes to the standard methods are prohibited without first being tested and reviewed by a Metallurgist. Also, metallurgical technicians are routinely 'spot checked' for technique compliance and house keeping practices.

This protocol together with an assay quality control system yields reliable and accurate production run data reflecting the mill's performance.

Instrumentation

The importance of modern day instrument methods as it relates to the continuous, on-line monitoring of the mill's performance cannot be understated. Effective, real time process control is built on the instrument output interface between the milling process and the process control hardware and software, Therefore well maintained, accurate and reliable instrumentation is a vital component of metallurgical control.

At Omai instrumentation is periodically inspected, referenced and calibrated as part of a computer assisted maintenance management system with urgent repairs and calibrations being performed on an 'as needed' basis.

Formal weekly meetings complement the preventative maintenance system and serve as a venue for discussing troublesome or recurrent technical issues and for coordinating remedial work between different groups such as Mechanical or Electrical.

In the future its planned to train operators the basics of instrument troubleshooting with the objective of more efficiently utilizing instrumentation personnel and hopefully improving overall instrument availability.

With plant operating data quality assured, then and only then is it possible to exercise effective metallurgical control as plant staff is now able to identify problem areas in the mill with confidence.

Actual control at Omai begins in the form of a documented setpoint change recorded on the 'Metallurgical Operating Parameters Sheet' Prior to issuing the document to the operators in the various circuits, the proposed changes are jointly reviewed by the Metallurgy and Operations groups. Frequent parameter changes are kept to a minimum to avoid confusing the operators. It's safe to say that this protocol has been well received and accepted by the operators particularly in the Control Room. It's accepted because it provides a history of metallurgical optimization efforts, it's an effective communication continuum which is very important with a turnaround operation, it fosters discussion and encourages ideas and it introduces a pause within the hectic operations setting to stop and reflect on the parameter change(s) in question.

METALLURGICAL ACCOUNTING

Accounting is in statistical terms more accurate due to;

- More frequent reconciliations of daily production run head grade estimates against bullion / inventory grade determinations.
- Redundant sampling of CIP carbon concentrations at each inventory check.
- Back-to-back checks of inventory levels the day prior and the day of bullion pours.
- More accurate refinery inventory determinations.
- Reconciling refinery inventory changes and bullion produced against the refinery 'gold call'.

- Reliable, representative and continuous autosampling of leach feed and final tails process streams.

The cumulative effect of these changes are month-end head grade reconciliations between production-based and bullion / inventory-based grades that differ no more than 1-2 %.

ENVIRONMENTAL CONTROL

Diligent tailings water balance management, controlled tailings deposition practices, minimal reagent usage in the mill, tailings solution recycle and effluent and water quality monitoring all contribute to minimize the impact of the operation on the environment.

Cyanide and lime usage refinements in the mill (Figure 7) have reduced free cyanide and pH levels in the final tailings exiting the mill to 50 ppm and pH 10, respectively. Tailings slurry is pumped from the mill to a 200 hectare tailings basin and spigot discharged along dam embankments. This serves to reduce the phreatic contact at the upstream face of the dam and improve the dam's hydraulic integrity.

Monthly water balance determinations of the tailings pond serve to gauge its filling rate and provide a measure for effluent treatment bleed rates. The large surface area and shallow depth of the pond make it conducive to natural degradation processes to the extent that *recycle* solutions to the mill are typically less-than 1 ppm total cyanide at pH 8.

Tailings pond water is recycled via barge-mounted 3 stage, 350 H.P. vertical turbine pumps. Better than 80% of mill water use constitutes pond recycle.

An effluent treatment plant and polishing carbon columns function to treat and bleed acceptable quality solution from the tailings basin. Effluent treatment is a simple and effective undertaking whereby ferric sulphate, caustic and flocculant are contacted with a 350 cu.m. per hour portion of pond recycle in a two stage, coagulation / flocculation process prior to clarification in a reactor clarifier. Clarifier overflows are polished in 3 cascade-flow carbon columns to produce a treated effluent well within Canadian effluent quality regulations. As an added measure of safety, carbon column effluent is pumped to the Essequibo River via a pipe diffuser.

Extensive effluent and surface / subsurface water quality monitoring is the test of environmental control at Omai as it measures the operation's impact upon the aquatic environment.

MILL TRAINING

Omai's 'Mill Modular Training System' is fundamental in developing a capable workforce. Comprehensive training in the classroom and on the mill floor is crucial to a certification process that grades tested trainees according to their practical skills level and theoretical knowledge. The highest position of competency attainable under this accreditation process is Mill Operator 1.

A similar training system exists for technical and trades personnel.

The system's training standards are similar to those 'in Canada where work place safety supercedes *all* other aspects of the job, accountability is mandated, the concept of team work promoted and respect for the views and opinions of others encouraged particularly in light of the unique cultural differences between expatriate and Guyanese employees.

The Modular Training System is integral to safe, healthy and productive mill operations at Omai.

CONCLUSIONS

With the imminent depletion of soft rock reserves, the immediate and future challenge facing the mill is to increase hard rock throughput. Plant trial investigations are already planned to determine SABC circuit and cycloning efficiency limitations resulting from reductions in SAG feed F₈₀. Complementing this is a process control project to improve the regulatory control of Mill 'B' SAG and thereby increase throughput. We have thus far independently audited the current process control strategies and performed tonnage step tests to determine circuit response times and static gains for different hard rock feed types.

A more immediate challenge is pulp viscosity control and its impact on cyanidation recoveries and CIP efficiencies resulting from milling laterite and saprolite stockpiles. Several viscosity control strategies have been identified and bench/bulk tested with full-scale plant trials currently in progress.

Operations, equipment, instrumentation and metallurgical innovations have significantly contributed to the efficient operation of the mill. Technology transfer of some of these innovations such as on-line reagent monitoring and control systems and a loaded carbon grit removal device is currently in progress within the Cambior group of mines. Teamwork dynamics, an experienced expatriate manpower base and innovation and invention spawned by the remote location of the operation have yielded significant production improvement returns.

ACKNOWLEDGEMENTS

The author wishes to thank the management of Omai Gold Mines Ltd. for the opportunity of presenting this paper and the mill staff who contributed much to its research.

REFERENCES

Konigsmann, E. "Milling Operations at Omai Gold Mines", Proceedings – 26th Annual Canadian Mineral Processors 1994.