GRAVITY CONCENTRATION AT CAMPBELL MINE

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Abstract. Placer Dome Canada owns and operates the Campbell Mine at Balmertown, in the Northwestern corner of the Province of Ontario, Canada. The mine operates at 1500 stpd and produces in excess of 300,000 oz of gold annually. Recent changes to the gravity concentration circuit have resulted in a 10-15 % increase in gravity recovery.The circuit changes responsible for these improvements will be the focus of this paper.

Introduction

The Campbell Mine is owned and operated by Placer Dome Canada. The mill throughput is 1,500 stpd and the mine has produced in excess of 300,000 oz annually over the past three years. The mill head grade is relatively high at an average grade of 0.54 oz/ton over the total reserve tonnage. Over the past several years the head grade has been averaging close to 0.6 oz/ton. Prior to 1994, gravity concentration was achieved by using a combination of conventional mineral jigs and tables. Jig concentrates were upgraded on shaking tables to produce a concentrate which was refined to bullion. In May 1994, the decision was made to purchase two Knelson CD 30 in. Concentrators. The objective was to replace the existing jigs and increase gravity gold recovery by up to 15%. Gravity recovery with jigs averaged between 30-35%.Gravity recovery was anticipated to increase to around the 50% mark with the installation of the Knelsons.

Knelson Concentrator Economic Justification

The economic analysis aimed at justifying the switch to Knelson Concentrators focused the following expected Znefits:

1) Increase in gravity recovery from about 35% to 50%.

2) Reduction in the amount of gold reporting to downstream processes and thus a reduction in reagent costs. It was anticipated that many fewer carbon strips would be required in the CIP.

3)Labour savings were anticipated with the addition of the Knelson Concentrators. The jig concentrate had to be dumped by the shift supervisor fairly frequently.

4)A reduction in the amount of gold in inventory in the autoclave circuit.

5)A reduction in the handling of gravity gold concentrates by employees.

6)Increase in mill throughput. It was anticipated that higher gravity recovery would allow processing higher tonnages without metallurgical impact.

Circuit Description

The gravity recovery circuit at Campbell is incorporated within a conventional rod/ball mill grinding circuit.

Prior to the installation of the Knelsons gravity gold was recovered using a combination of mineral jigs and shaking tables. The flowsheet for this circuit is illustrated ' Figure 1. The full ball mill circulating load was treated in three jigs operated in parallel. The tailing from the jig required dewatering prior to ball milling as the jig tail typically would run at a lower than acceptable density for ball mill feed. The concentrate from the jigs was upgraded on a series of two shaking tables. The table concentrate was then refined to bullion.

The gravity circuit flowsheet was modified to accommodate the installation of the Knelson Concentrators. The modified flowsheet is illustrated in Figure 2..

Two 30 inch Knelson Concentrators replaced the existing jigs. One Knelson is operating and the other is in stand-by mode. In contrast to the jigs, only a portion of the cyclone underflow is treated in the Knelson.

FIGURE 1

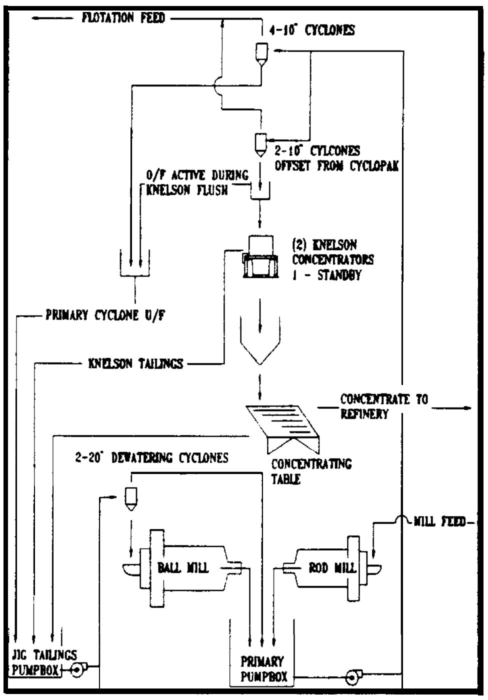

Figure 1. Gravity Circuit Configuration with Mineral Jigs and Shaking Table

This is accomplished by isolating two cyclones from the cyclopac and directing the underflow from the isolated cyclone into the Knelson feed. Each Knelson is fed by a dedicated cyclone in this manner. The cyclone overflow from the Knelson feed cyclones reports back through the normal routing for the primary cyclone overflow. Both the Knelson tails and the primary cyclone underflow report to the Jig Tails pumpbox. This pumpbox was named due to it's former service in the jig based gravity circuit. The Jig Tails pumps feed two 20 inch dewatering cyclones.

The Knelson Concentrators are controlled by an independent PLC that was purchased with each of the units. The PLC controls the sequential operation of the unit and a number of the key variables are programable. The Knelson operates as a batch unit and typical cycle times at

FIGURE 2

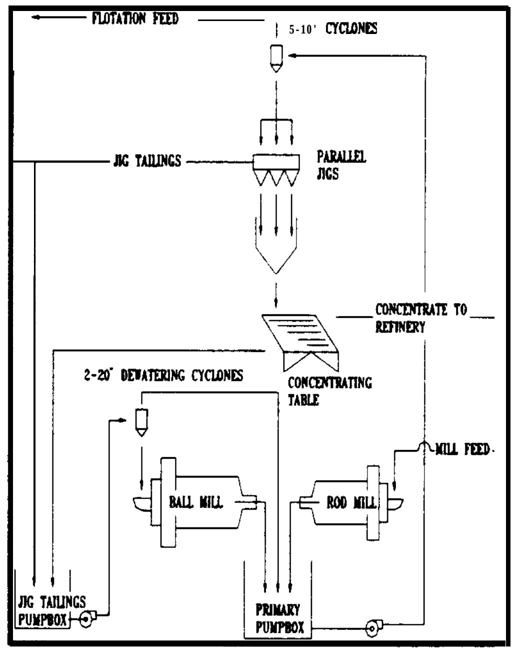

Figure 2. Current Circuit Configuration with Knelson Concentrators

Campbell are 30 minutes.

Consideration is being given to elimination of the Jig Tails pumps and secondary dewatering cyclones. The dilution water added via the Knelson Concentrators is minimal compared to the jigs and dewatering prior to ball milling is not required. The removal of the Pumps and cyclones will result in operating and maintenance cost savings.

Improvement in Gravity Recovery

Table 1 shows the comparison between gravity recovery with jigs versus the Knelson Concentrators.

The first of the two Knelsons was installed and operational in January 1995. The second unit was operational by February 1995 and the old jig circuit was completely decommissioned at that time. As can be seen from the data, gravity recovery did not improve to current levels immediately upon installation of the Knelsons. A period of trial and error was required to refine the operation of the units. The first complete year of operation with the Knelsons, after the tune-up period, has resulted in an average gravity recovery of 50.17%. This is a full 16%

TABLE1

Year	Mill Throughout		
	(tons)	(tpd)	(tph)
1993	522027	1430	60
1994	534974	1466	61
Combined	1057002	1448	60
1995	579563	1588	66
1996 *	427038	1564	65
Combined	1006601	1578	66

Year	Mill Feed Grade (oz/ton)	Gravity Recovery (%)	Flotation Grade		
			Feed (oz/ton)	Con. (oz/ton)	Tailing (oz/ton)
1993	0.63	30.98	0.44	6.22	0.071
1994	0.62	36.97	0.39	6.56	0.070
Combined	0.62	34.02	0.41	6.40	0.070
1995	0.60	39.38	0.36	3.71	0.076
1996 *	0.60	50.17	0.30	3.58	0.070
Combined	0.60	43.96	0.33	3.65	0.074

Post-Knelson data.

* - to September 30.

Table 1. Comparison of Gravity Recovery Using Mineral Jigs and Knelson Concentrators.(Campbell Plant Data 1993-96)

improvement over the two year average prior to the change from jigs to Knelsons.

Reduced Carbon Stripping

Carbon stripping frequency has not been reduced as a result of the Knelson installation. Although the flotation feed grade has been reduced significantly the flotation tails grade has remained fairly constant. This in turn means that the feed grade to the flotation tails leach and CIP circuits has also remained somewhat constant.

The flotation feed, concentrate and tails grade are illustrated in Figures 3,4 and 5 respectively.

The flotation tails grade has remained fairly constant over the past three years in spite of a sharp drop in the feed and concentrate grade.This' in turn translates into little variation in the CIP solution

FIGURE 3

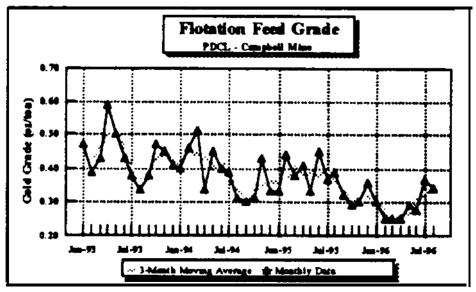

Figure 3. Flotation Feed Grade(Jan 1993-Present)

assay and hence stripping requirements.

FIGURE 4

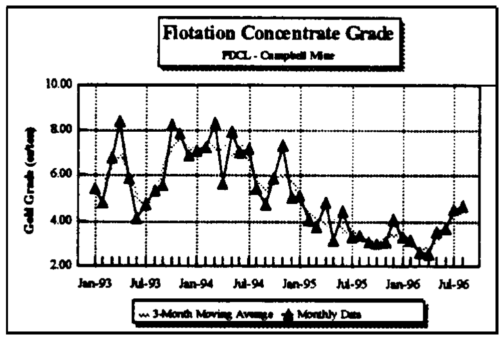

Figure 4. Flotation Concentrate Grade (January 1993-Present)

FIGURE 5

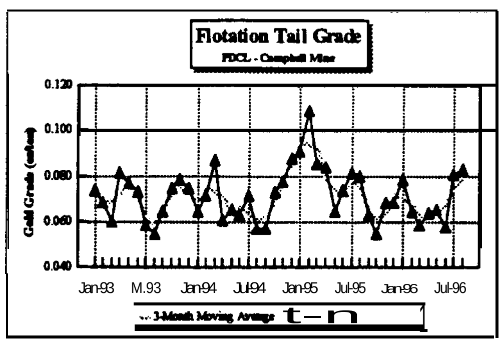

Figure 5. Flotation Tail Grade (1993-Present)

Increase in Mill Throughput

The mill throughput has increased substantially over the transition period from Jigs to Concentrators. Figure 6. illustrates the mill throughput from January 1993 to present.

As can be seen from the illustration, mill tonnage has been considerably higher than the average in the period July 95-January 1996. In spite of this gravity recovery was on the rise. It is doubtful whether or not the existing jig circuit could have handled the increased throughput without a deterioration in gravity recovery.

FIGURE 6

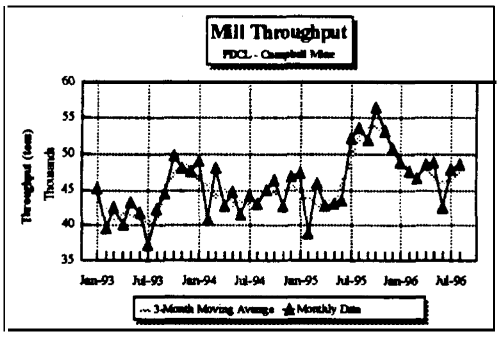

Figure 6. Mill Throughput (Short Tons per Month)

Reduced Mill Gold Inventory

Autoclave gold inventory has been measured at Campbell since the introduction of pressure autoclaving in 1992. During the period 1993-94, autoclave gold inventories ran between 1000-2100 oz of fine gold. The inventory was determined by processing material cleaned out of the autoclave after each major shutdown. Less than 500 oz have been recovered on each of the last three autoclave shutdowns.

Reduced Manpower Requirements

Although manpower levels in the mill overall have not been reduced as a result of the Concentrator installation, manpower requirements in the gravity area have been reduced significantly. The jigs required two men for several hours each morning with an extra overtime shift each weekend to table concentrates. All the gravity operations are now handled by one man on a 8 hour per day 5 day per week basis.

Security

In contrast to the jigs, the Knelson Concentrators require no manual cleaning during the normal course of operation. This reduced exposure to the concentrate reduces the chance of theft.

Conclusion

The change to Knelson Concentrators has been a very successful project for the Campbell Mill. Gravity recovery has improved by a full 16% over the previously used mineral jigs. This translates into economic value through:

1)Reduced gold inventory in the plant process. This is particularly true in the autoclave circuit.

2)Ability to maintain gravity recovery levels at higher mill throughput rates.

3)Reduction in security risk.

4)Reduction in manpower requirements in the gravity area.

5)Potential to reduce operating and maintenance costs through elimination of one stage of pumping and cycloning.

In the case of the Campbell flowsheet, reduced stripping frequency has not occurred. This is more related to the inability of the current flotation flowsheet to reduce the flotation tails below the .07 oz./ton level.

The ability to produce higher tonnage rates while increasing overall gravity recovery provides the most compelling argument for the switch.

References

Dufour, Linda,1994," 30 in. Knelson Concentrator Justification". Internal Memorandum dated May 19, 1994.

Hewitt,Brad,1996,"Gravity Concentration at Campbell Gold Mine".Presented at Rand01 Gold Conference, 1996. Squaw Creek , California, April 1996.

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INTRODUCTION

Since Campbell Mine began processing ore, there has been a gravity gold recovery circuit. From 1947 to 1982, gravity gold was concentrated through the combination of jigs and mercury amalgamation. In 1982, jigs with concentrating table upgrading commenced and was utilized until the end of 1994. As of January of 1995 to the present, Knelson Concentrators in combination with concentrating tables have been employed to achieve a refinable product. An evaluation of the justification used for the last change is the focus of this paper.

KNELSON CONCENTRATOR TEST WORK AND PURCHASE JUSTIFICATION

In the spring of 1994, approximately four weeks of test work was conducted on site using a 12" centre discharge Knelson Concentrator. The gold recovery achieved by this pilot plant ranged from 34.1% to 69.1% and the average was 48.8%[1].

The decision to go ahead with the installation of two 30" centre discharge Knelson Concentrators was made in August of 1994. One used concentrator was purchased from Les Mines Sigma in Val D'Or, Quebec and the other was purchased new from Knelson Gold Concentrators Inc. Installation of the used concentrator was completed in December of 1994 and the new concentrator was installed by February of 1995. The purchase of the Knelson Concentrators was justified based on the following points:

i. 50% gravity gold recovery (~15% increase in gravity recovery);
ii. reduced stripping frequency due to a reduced flotation tailing;
iii. reduced Au in flotation concentrate;
iv. increased mill throughput;
v. reduced mill gold inventory;
vi. reduced manpower requirements; and
vii. reduced handling of gravity concentrate by mill personnel.

CIRCUIT DESCRIPTION

Old Circuit Description

The grinding/gravity circuit at Campbell mine consists of a conventional open circuit rod mill feeding a reverse, closed-circuit ball mill. Prior to the installation of the Knelson Concentrators, the gravity circuit consisted of three jigs operated in parallel to recover gold from the entire primary cyclone underflow. The jigs tailings were dewatered by a secondary set of cyclones prior to ball mill grinding. The jigs concentrate was upgraded on a concentrating table to a refinable grade.

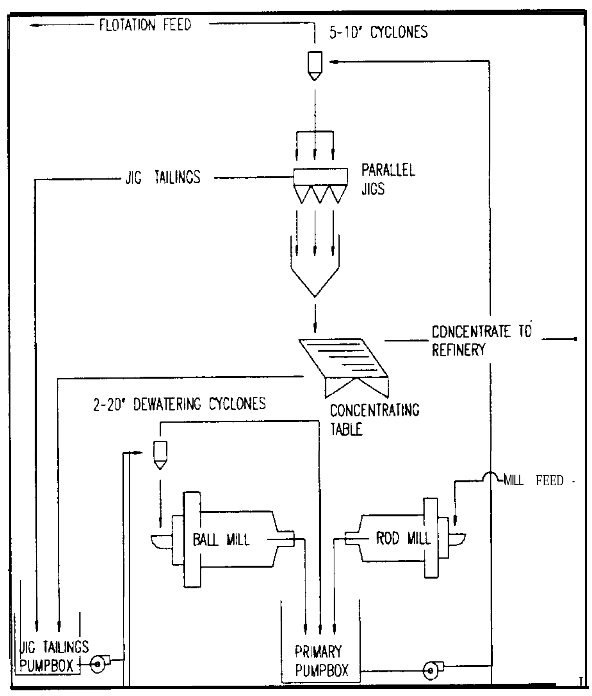

Figure 1: Gravity circuit configuration prior to the Knelson installation.

Present Circuit Configuration

The installation of two 30" centre discharge Knelson Concentrators required some alteration to the grinding circuit. The intention was to operate the concentrators one at a time to treat a single cyclone underflow. To accomplish this, two

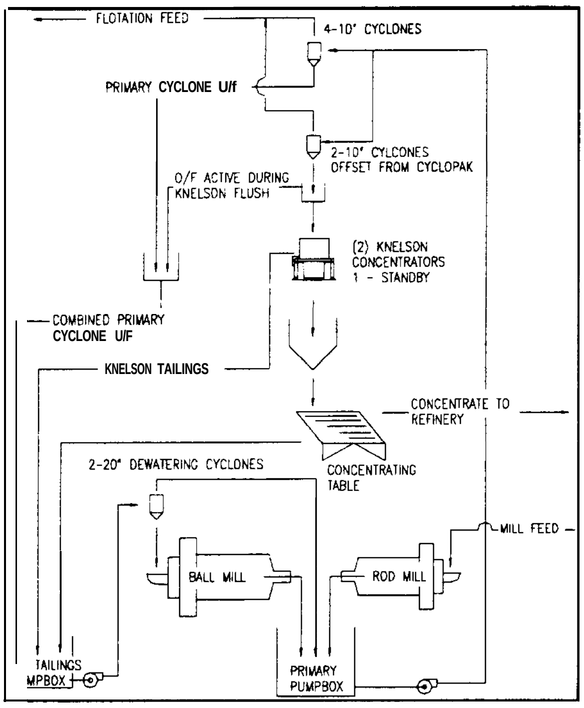

Figure 2: The present gravity circuit is a modification of the former arrangement and does not take advantage of the options available with the Knelson Concentrator.

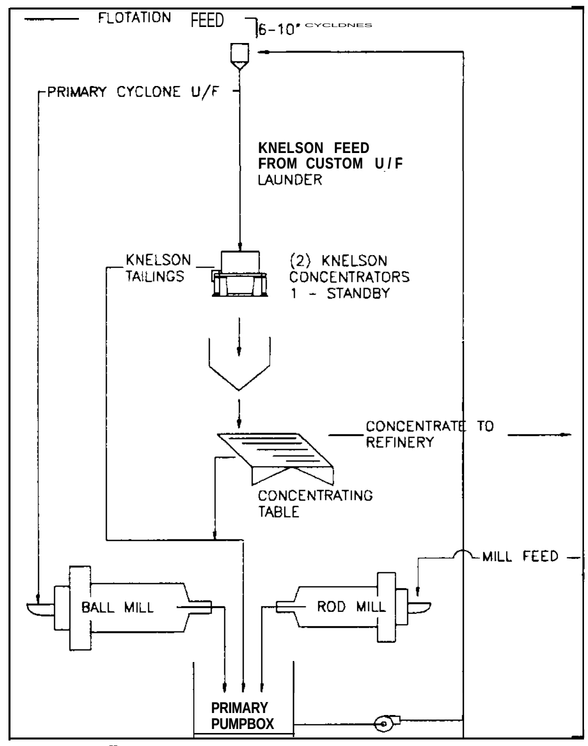

Figure 3: Proposed gravity circuit configuration.

cyclones were removed from the cyclopak and mounted on independent underflow boxes which were equipped with a concentrator feed outlet and an overflow. These cyclones are fed from the cyclopak distribution maniflod through material handling hose extensions. The feed outlet was fitted with an automatic pinch valve which is controlled by a plc (Knelson Concentrators refers to this plc as the Independent Control System, **ICS**). During the concentrating cycle, the concentrator tailing reports to the former jig tailings box where it combines with the primary cyclone underflow. However, since concentration using Knelson concentrators is a semi-continuous process, two allowance for the flush portion of concentrating cycle had to be made. First a secondary underflow box was installed to receive the primary cyclone underflow and the overflow of the two independent underflow boxes. This box drains into the jig tailings pumpbox. Second, automatic water addition based on dewatering cyclone feed density was installed at the jig tailings pumpbox. The second modification was made when it became obvious that the dewatering cyclone feed density was too high during the flush cycle (ie. plugged cyclone). The density climbs to 75% solids while the fluidizing water is off during the flush cycle. The remainder of the grinding/gravity circuit is unchanged.

Proposed Circuit Modifications

The present circuit, as it is, works well, however, several areas of improvement could be made. The first is to incorporate the automation that is currently controlled by the KS into our plant PLC/DCS system. This will allow us to better monitor, trend, and evaluate the performance of the concentrators. Second, the addition of water to only one cyclone underflow stream may allow a flow sheet change that would eliminate the secondary cyclones and the pumps that feed them. The impact of this flow sheet change has not yet been fully explored and evaluated. Finally, in the near future a need for increased primary cyclone capacity may necessitate the installation of a larger cyclopak. This change will allow a more aesthetic concentrator installation.

RESULTS COMPARISON

Year	Mill Throughput (tons)	Mill Throughput (tpd)	Mill Throughput (tph)
1993	522027	1430	60
1994	534974	1466	61
Combined	1057002	1448	60
1995	579563	1588	66
1996 *	96175	1603	67
Combined	675738	1590	66

Year	Mill Feed Grade (oz/ton)	Gravity Recovery (%)	Flotation Grade Feed (oz/ton)	Flotation Grade Con (oz/ton)	Flotation Grade Tailing (oz/ton)
1993	0 63	30 98	0 44	6 2 2	0.071
1994	0.62	36.97	0.39	6.56	0.070
Combined	0.62	34.02	0.41	6.40	0.070
1995	0.60	39.38	0.36	3.71	0.076
1996 *	0.52	47.10	0.28	3.21	0.072
Combined	0.59	40.48	0.35	3.64	0.076

Post-Knelson installation data.
* - to February 29th.

Table 1: Major statistics

Table 1 summarizes the major statistics for the period over which the Knelson Concentrator installation has been evaluated. A 6% increase in the gravity gold recovery occurred between

1993 and 1994 despite a similar feed grade and throughput, (see Figure 4 and Figure 9) and no equipment upgrades or flow sheet changes. The increase can be explained by an increase in the labour. A weekend shift was added to the gravity circuit to clean out the jigs as their recovery was decreasing during the second day of the weekend.

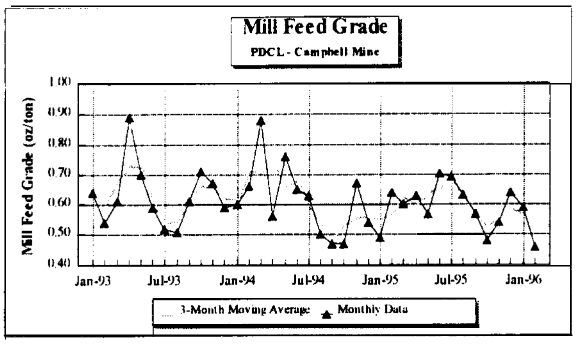

Figure 4: 1993 to present mill feed gold grade.

(i) Gravity Gold Recovery

Figure 5 illustrates the gravity gold recovery for the two years prior to and for the fourteen months after the installation of the Knelson Concentrators. In general the recovery has increased steadily over the time period. At the beginning of 1995, there was a drop in gravity recovery. This was the period in which mill personnel were learning to operate the Knelson Concentrators. The concentrating cycle was defined, the screen hopper opening size was changed twice, and the fluidizing water flow was varied. The most significant improvement in recovery can be attributed to the increase in the slot opening size of the feed screen. The Knelson recovery has steadily increased and does not appear to have levelled off yet. The average pilot plant recovery of 48.8% has been achieve only once on a monthly basis (Jan. 1996, 49.1%), but the gravity ounces in this month were aided by a ball mill reline.

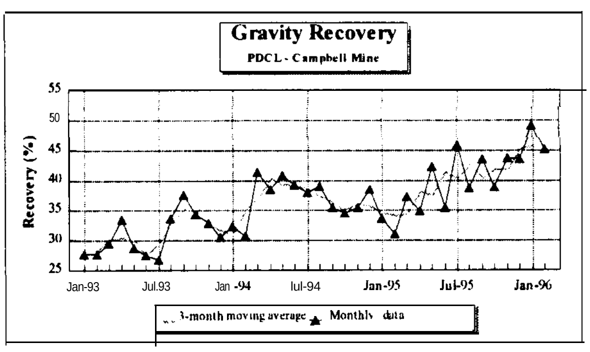

Figure 5: January **1993** to present gravity gold recovery.

(ii) Reduced Carbon Stripping Frequency

It was assumed that the increased gravity recovery would result in a decreased flotation gold tailing. As can be seen in Figure 6, the flotation tail has remained fairly flat with the exception of the period from November 1994 to March 1995 where an unusual formation of gelatinous material adversely affected the flotation circuit performance. The tailings grade is quantified in Table 1 at a very cdnsistent 0.07 oz/ton. At Campbell Mine, the

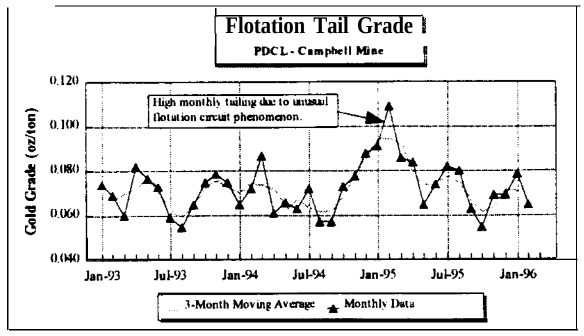

Figure 6: January 1993 to present flotation tailing grade. The anticipated reduction as a result of higher gravity recovery did not occur.

flotation tailing is leached and the solubilized gold is recovered in a CIP circuit. It was anticipated that a lower flotation tailings grade would decrease carbon loading resulting in less frequent stripping. This did not occur, consequently, the carbon stripping frequency has not decreased.

(iii) Reduced Flotation Concentrate Gold

Since the installation of the Knelson Concentrators, the flotation concentrate grade has dropped off markedly (see Figure 7). The combined concentrate grade in the post-Knelson period is less than 60% of the pre-Knelson period. The mill feed grade in the same period has decreased, but only slightly. Additionally, there has been a noticeable decrease in the flotation feed grade (see Table 1 and Figure 8).

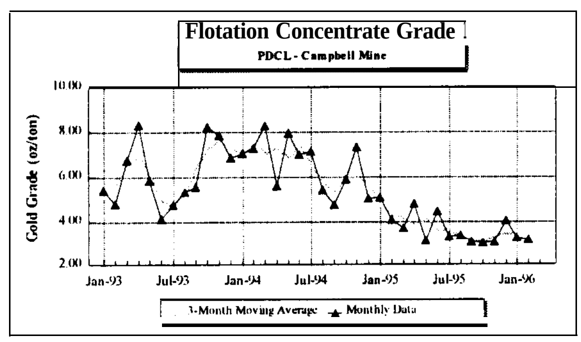

Figure 7: The Knelson Concentrator has had a marked effect on the flotation concentrate grade.

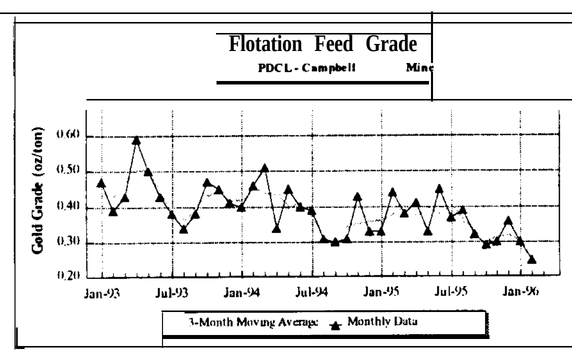

Figure 8: There is a downward trend in the flotation feed grade which has been extended since the Knelson Concentrators have come on line.

iv) Increased Mill Throughput

As can be seen in **Figure 9,** the mill throughput was considerably increased in the later part of 1995. While the concentrators facilitated this increase by not being a bottleneck in the process, the same sort of increase could have been made using the jigs, but with the requirement of additional labour. Tonnage increases are an easy way of justifying equipment changes or upgrades, but at Campbell Mine sustained throughput increases are presently dictated by what the mine can supply as opposed to what the mill can process. However, with respect to the gravity circuit, the way is clear for future throughput increases.

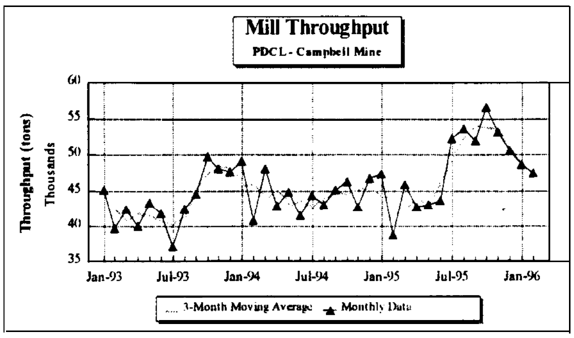

Figure 9: Despite a mill throughput increase in the latter half of 1995, justification on this basis is not presently feasible at Campbell Mine. However, future throughput increases will not be limited by the gravity circuit.

(v) Reduced Mill Gold Inventory

Until June of 1995, the mill gold inventory was not extensively measured. However, the autoclave was one area where the inventory was measured on a regular interval, and a very noticable decrease in the gold inventory has occurred. Campbell Mine operates an autoclave for the treatment of refractory sulphide concentrate. .Periodically the autoclave is taken off-line for inspection and repair of the internal refractory lining. Descaling of the interior is required for this maintenance. The scale is collected and refined as it has a high gold content. Table 2 shows the marked decrease in the autoclave gold inventory despite increased time between inspections.

Date of Inspection	Months Since Last Inspection	Fine Oz. Recovered Oz.	Rate of Deposition Oz/month
Mar-93	4	8087	2022
Jul-93	4	8723	2181
Oct-93	4	5881	1470
Jan-94	3	4372	1457
May-94	4	4434	1109
Oct-94	6	7754	1292
May-95	6	2575	429
Nov-95	7	1378	197

Table 2: Autoclave inventory before and after the Knelson installation.

Another area of likel) inventory reduction is the ball mill circulating load. Since October of 1995 when the ball mill discharge daily sample was re-instated, the discharge grade has averaged at 1.90. A reliable number from the period of jigs concentration is not available, but given the increase in gravity recovery and the decrease in flotation feed grade, it is probable that the ball mill circulating load has decreased.

(vi) Reduced Manpower Requirements

Since the installation of the Knelson Concentrators, the labour requirements in the gravity circuit have decreased significantly. In 1994, a weekend overtime shift was added to improve gavity recovery. This shift has been eliminated. Additionally, on week days, two men were required in the gravity area for two hours each morning. One man cleaned out the jigs while the other operated the concentrating table. There is no longer a requirement for the second man. Moreover, the mass of material recovered by the Knelson is a fraction of that collected by the jigs. This has decreased the amount of time needed for tabling. Gravity circuit manpower requirements have decreased as a result of the Knelson Concentrator installation.

(vii) Reduced Handling of Gravity Concentrate

Due to the way in which the Knelson Concentrators go off-line and purge themselves, there is no need for mill personnel to manually clean out the concentrator as with the jigs. This is a benefit not only in terms of the saved labour, but also, in terms of security. Campbell Mine is fortunate to have a very reliable and honest work force, but there may be operations where security is a concern.

CONCLUSION

The change to Knelson Concentrators was worthwhile. Of the seven points of justification, points iii, v, vi, and vii have, in hindsight, been achieved. While 50% gravity recovery has not been consistently obtained, it remains the target. Reduced stripping efficiency as a result of a reduced flotation gold tailing has not occurred, but it is believed that this is more a function of the flotation method than a deficiency in the performance of the Knelson Concentrator. Mill throughput has not been sustainably increased, but, with respect to the gravity circuit, the way is clear for future increases in the throughput.

REFERENCES

(1) Dufour, Linda (1994) “30” Knelson Concentrator Justification” internal memorandum dated May 19, 1994.