VIII NATIONAL METALLURGICAL CONVENTION

GOLD GRAVITY RECOVERY IN COPPER CIRCUITS BHP TINTAYA

Puno-Perú

By
Valentín Choquenaira Bombilla

BIENVENIDOS / WELCOME

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Superintendente de Metalurgia BHP Tintaya

1. INTRODUCTION

The BHP-Tintaya Concentration plant is located between the cities of Arequipa and Cusco, 260 Km from the city of Arequipa. It is accessible mainly by road. The actual plant capacity is 17,500 metric tonnes/day containing copper sulphides with a basic mineralization of chalcopyrite and in lower proportion bornite and native copper. The gangues are formed as a result of a strong mineralogical variation dominated by magnetite, limestone, pyroxene, monzonite, limonite, pyrite, quartz, etc. The process consists of conventional crushing, grinding, and flotation.

The mineral fed to the concentration plant has a head grade of 1.60% Cu. and 0.35 gr./ Ton gold. The plant achieves around 90% copper and 60% gold recovery in the flotation circuit.

Gold represents 15% of the company’s net income, therefore, much effort has been made to increase the gold recovery, first by flotation and second by gravity. Research on gravity recovery as a complementary process, with special emphasis on metallurgical performance and overall economical benefits has been the priority due to potential recoveries un-attainable with flotation.

2. SUMMARY

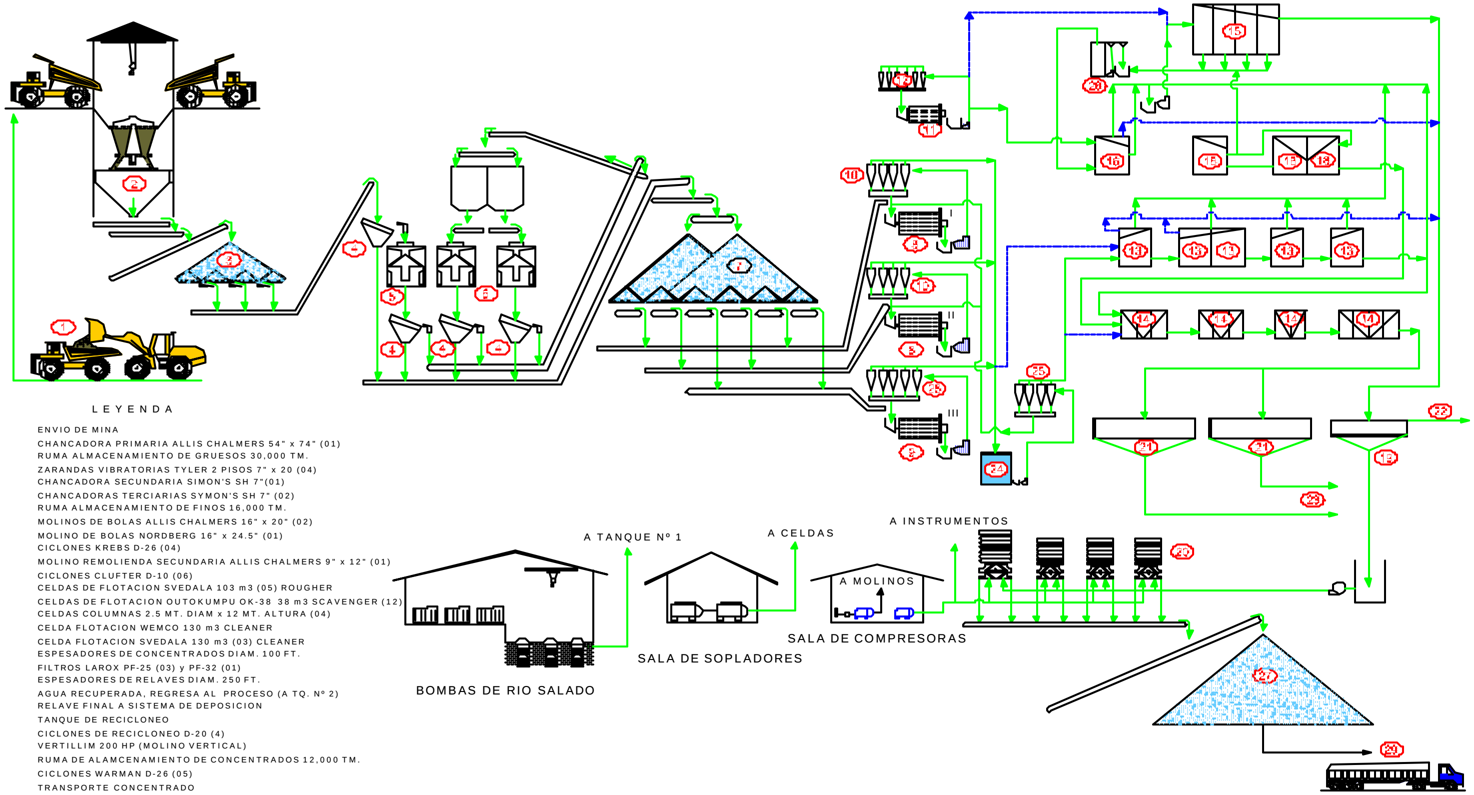
Tintaya´s main product line is copper concentrate, which has an important gold content. The process used is flotation; and the objective of the metallurgic department is to obtain the best results in copper recovery without neglecting the gold, using very specific reagents. Our copper recoveries are considered high, nevertheless much effort is made to increase those recoveries. With respect to gold, we could not achieve optimum recoveries with flotation; and had to implement a gravity circuit.

According to microscopy studies, the coarse and very fine grains of gold in native form are lost to tails. The native gold, due to its high specific gravity, is concentrated at the underflow of the cyclone, staying in the circulating load of the circuit. It reaches three times the grade of the feed entering the ball mills. This re-circulation generates very fine and laminated gold particles inside the ball mill, passing to the classification stage and making a short circuit at the overflow of the cyclone.

The very coarse gold particles, as well as the thick flakes of gold, do not react favorably to the conventional flotation process. This is why we have conducted studies to increase the recovery by including gravity. Part of the research included concentrating tables, jigs, and Knelson Concentrators. The Knelson Concentrator proved to be the best equipment in terms of metallurgical performance and recoveries considering the throughput and operating conditions of the Tintaya Plant.

The gravity concentration circuit with the Knelson Concentrator was commissioned at BHP Tintaya in October 1998, as per the flowsheet shown later on. Presently the global gold production surpasses any expectations.

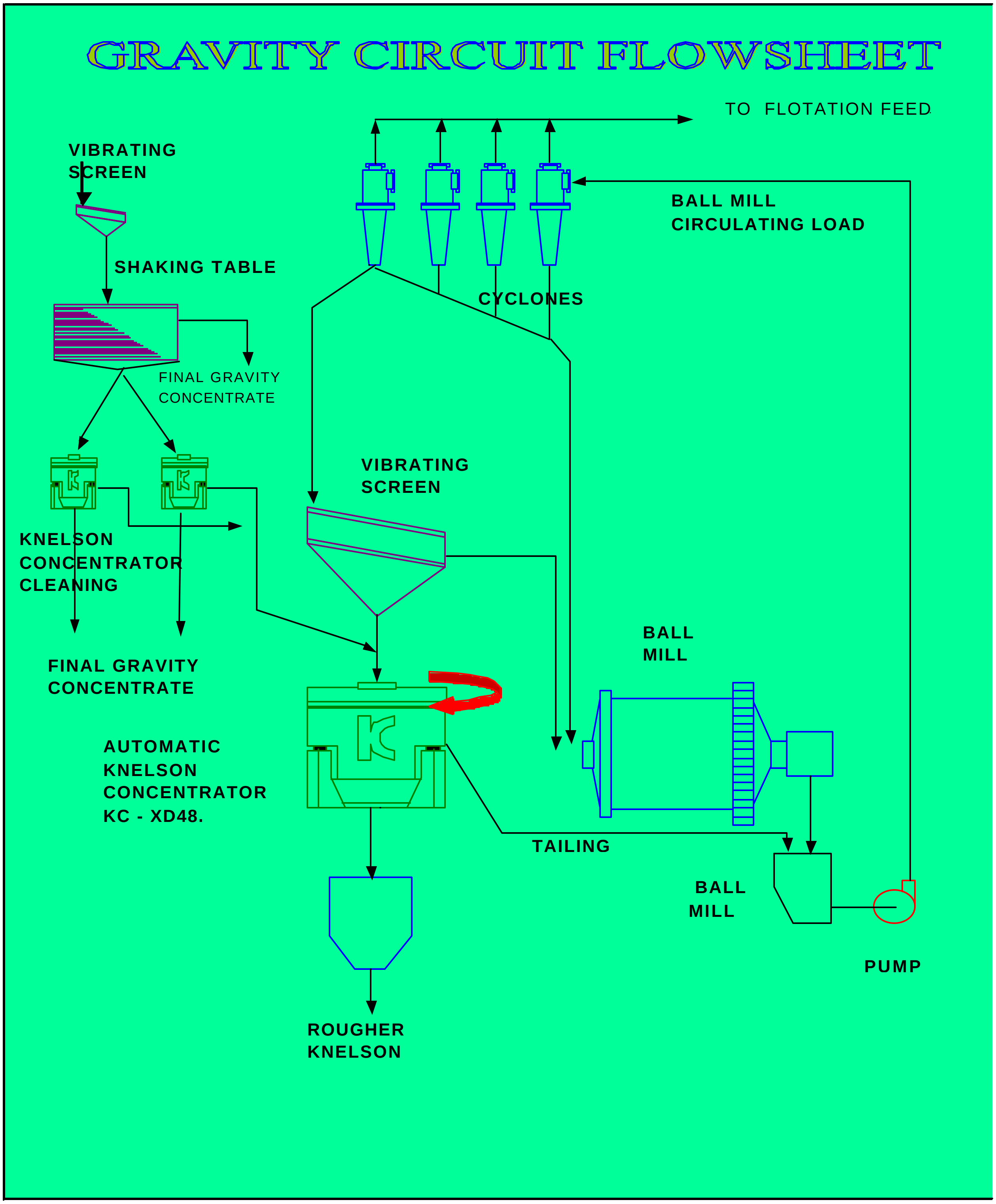
In the first year of operation we have produced 200 tons of gold concentrate with an average head grade of 320 gr./ton, having paid back in full the cost of the automated KC-XD48 Knelson Concentrator, the peripheral equipment and the cost of the installation.



LEYENDA

1. ENVIO DE MINA
2. CHANCADORA PRIMARIA ALLIS CHALMERS 54" x 74" (01)
3. RUMA ALMACENAMIENTO DE GRUESOS 30,000 TM.
4. ZARANDAS VIBRATORIAS TYLER 2 PISOS 7" x 20 (04)
5. CHANCADORA SECUNDARIA SIMON'S SH 7"(01)
6. CHANCADORAS TERCIARIAS SYMON'S SH 7" (02)
7. RUMA ALMACENAMIENTO DE FINOS 16,000 TM.
8. MOLINOS DE BOLAS ALLIS CHALMERS 16" x 20" (02)
9. MOLINO DE BOLAS NORDBERG 16" x 24.5" (01)
10. CICLONES KREBS D-26 (04)
11. MOLINO REMOLIENDA SECUNDARIA ALLIS CHALMERS 9" x 12" (01)
12. CICLONES CLUFTER D-10 (06)
13. CELDAS DE FLOTACION SVEDALA 103 m3 (05) ROUGHER
14. CELDAS DE FLOTACION OUTOKUMPU OK-38 38 m3 SCAVENGER (12)
15. CELDAS COLUMNAS 2.5 MT. DIAM x 12 MT. ALTURA (04)
16. CELDA FLOTACION WEMCO 130 m3 CLEANER
17. CELDA FLOTACION SVEDALA 130 m3 (03) CLEANER
18. ESPESADORES DE CONCENTRADOS DIAM. 100 FT.
19. FILTROS LAROX PF-25 (03) y PF-32 (01)
20. ESPESADORES DE RELAVES DIAM. 250 FT.
21. AGUA RECUPERADA, REGRESA AL PROCESO (A TQ. Nº 2)
22. RELAVE FINAL A SISTEMA DE DEPOSICION
23. TANQUE DE RECICLONEO
24. CICLONES DE RECICLONEO D-20 (4)
25. VERTILLIM 200 HP (MOLINO VERTICAL)
26. RUMA DE ALAMCENAMIENTO DE CONCENTRADOS 12,000 TM.
27. CICLONES WARMAN D-26 (05)
28. TRANSPORTE CONCENTRADO

RECORD PROCESOS	FIRMA	FECHA	BHP TINTAYA S.A. SUPERINTENDENCIA DE PROCESOS	PROYECTO: PLANTA CONCENTRADORA BHP TINTAYA S.A. TRATAMIENTO 15,000 TM. S/D	PAGINA: 1/1	REV: 24/03/00
	E. DIAZ A.	24 / 03 / 2000				
	E. DIAZ A.	24 / 03 / 2000			FECHA: 24/03/2000	
	V. CHOQUENAIRA	24 / 03 / 2000		PLANO: DIAGRAMA DE FLUJOS	CROQUIS Nº:	
	A. HERRERA	24 / 03 / 2000				
	S/E					


GRAVITY CIRCUIT FLOWSHEET
TO FLOTATION FEED
VIBRATING SCREEN
BALL MILL CIRCULATING LOAD
SHAKING TABLE
CYCLONES
FINAL GRAVITY CONCENTRATE
VIBRATING SCREEN
KNELSON CONCENTRATOR CLEANING
FINAL GRAVITY CONCENTRATE
BALL MILL
AUTOMATIC KNELSON CONCENTRATOR KC - XD48.
TAILING
BALL MILL
PUMP
ROUGHER KNELSON

3 DESCRIPTION OF THE KNELSON CONCENTRATOR

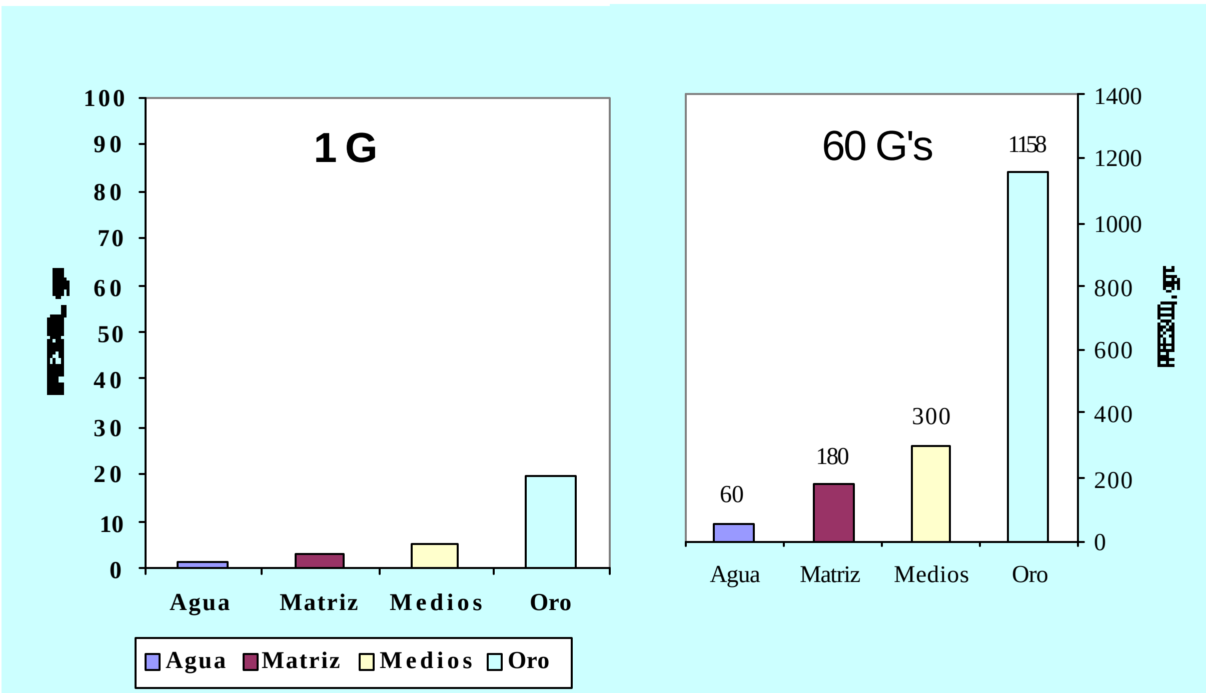
The Knelson Concentrator is a high-speed centrifugal concentrator that uses the centrifugal force with a patented fluidization process. It uses a polyurethane concentration cone that is highly resistant to wear and tear. This cone has a series of rings that increase in diameter from bottom to top. On the circumference of each ring there are a series of fluidization holes that allow water injection into the cone. The size, number and location of these rings were determined from extensive studies and continuous product development. The main variables of the operation are:

- Flow of the fluidization water.
- Concentration cycle duration.
- Flow of pulp feed.

The flow of the fluidization water enters through the rotor shaft to a water jacket. Once this jacket is full to capacity, the pressure forces water through the fluidization holes and towards the concentration rings. The holes are inclined and almost tangential forcing water in a counter-clockwise direction. During this operation the rotor assembly turns clockwise at a speed of 320 RPM. The feed enters the unit through a stationary pipe; from the pipe the flow is discharged on to a rotating deflector plate, where the centrifugal force conveys it to the tails discharge up the wall of the cone on a spiral trajectory. As the solids reach the walls, they fill up each ring starting from the lower part. Once each ring reaches its capacity, a concentration bed is established. Simultaneously the water is injected from the cavity to this concentrating bed. The optimum fluidization occurs when the water flow through the concentrating bed balances the centrifugal force applied to solids. This allows the interchange of light particles for heavy ones in an interface where concentration occurs. As long as the water fluidization flow is maintained, the selection and concentration of particles of high specific gravity will continue. The duration of the concentration cycle is determined through testing and experiments, and will depend on the grade of mineral occurrence. After cycle completion, the concentrate can be discharged manually or automatically. As the cone rotation slows down, the concentrate is discharged by gravity and a quick flush of fluidization water washes the remains of each ring of the cone through a central multi-port device.

The rotation creates a centrifugal gravity force of 60 Gs. The effects are evident in the following graphic.

THE EFFECT OF CENTRIFUGAL FORCE



4. GRAVITY CIRCUIT IN THE CONCENTRATION PLANT

In the concentration plant there is a Knelson Concentrator KC-XD48 with a processing capacity of approx. 150 tph. The feed, a percentage of the circulating load of Ball Mill Nº 2, (cyclone Nº 2 underflow), is conveyed to a Deister vibrating screen. The oversize is dumped to the feed Box of the mill. The undersize product is fed directly to the Knelson Concentrator. Knelson tails are returned to the discharge box of the ball mill, from where are pumped again to the cyclones D-26. The final KC rougher concentrate is obtained intermittently as a result of pre-determined concentration cycles. A primary storing tank receives the concentrate; later, it is discharged into polyethylene bags with the purpose of de-watering. (The additional flushing water used for discharge). Concentrates are transported to a general concentrate storage area; wet weights are determined, and using the method of “reduction by increments”, samples are taken for chemical analysis of the precious metal. There is a cleaning circuit for the Knelson rougher concentrate, but it is on stand by at the moment. It was implemented for the purpose of increasing the grade of the final gravimetric concentrate.

5. MINERALOGY

Gold content is mainly of native form and the head grade varies according to the mineralized zone of the trench. As the level of trench diminishes, the grade of the gold increases; this gives us a clear indication the gold occurs in copper sulphide. It has been clearly noticed as well that the zone of CHABUCA SUR has very little gold content in comparison to CHABUCA ESTE.

6. TESTS CONDUCTED WITH THE CONCENTRATOR KC-XD48

FACTORS THAT AFFECT THE PERFORMANCE OF THE KNELSON CONCENTRATOR

There are three main factors that affect the performance of the concentrator:

1. Flow of fluidization water.
2. Flow of feed.
3. Duration of the concentration cycle.

The variables that affect the range of the fluidization water flow are:

- The particle size distribution.
- The global gangue density or specific gravity.
- The percentage of solids in the feed.

The variables that affect the feed:

- Grinding degree, if it is coarse or fine.
- The installed capacity of the peripheral equipment, such as vibrating screen and others.

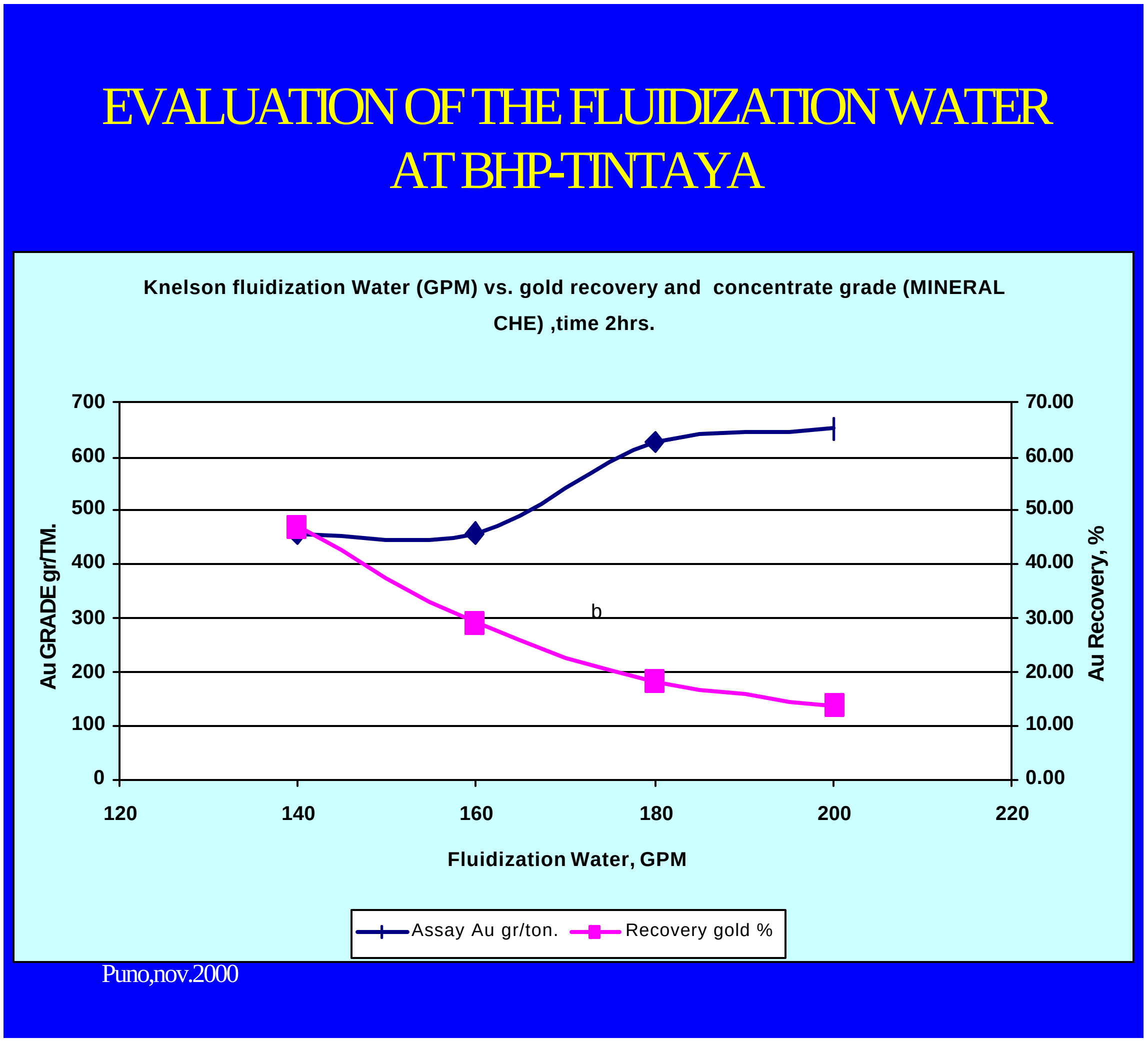
The variables that affect the concentration cycle duration:

- Saturation of the concentrating bed in the cone due to:
  - Degree of gold liberation
  - Proportion of heavy/not heavy materials
  - Amount of steel ball pieces (iron content)

6.1 EVALUATION TESTS TO DETERMINE OPTIMUM FLUIDIZATION WATER FLOW:

Tests were conducted with different fluidization water flows at 180, 200, 220, and 240 GPM, combined with different concentration times. The results clearly indicate that higher recoveries are obtained with the lower fluidization water flows (based on the grade of concentrates obtained).

On an exercise with different fluidization water flows to optimize recoveries and concentrate grades, it was determined that the optimum flow of fluidization water is 180GPM.



It should be noted that one must be very careful with the low range of fluidization water since it can cause a fast material compaction in the cone. This compaction takes place when the centrifugal forces break the balance established between the pressure of fluidization water entering the cone and the specific gravity of solids affected by centrifugal force.

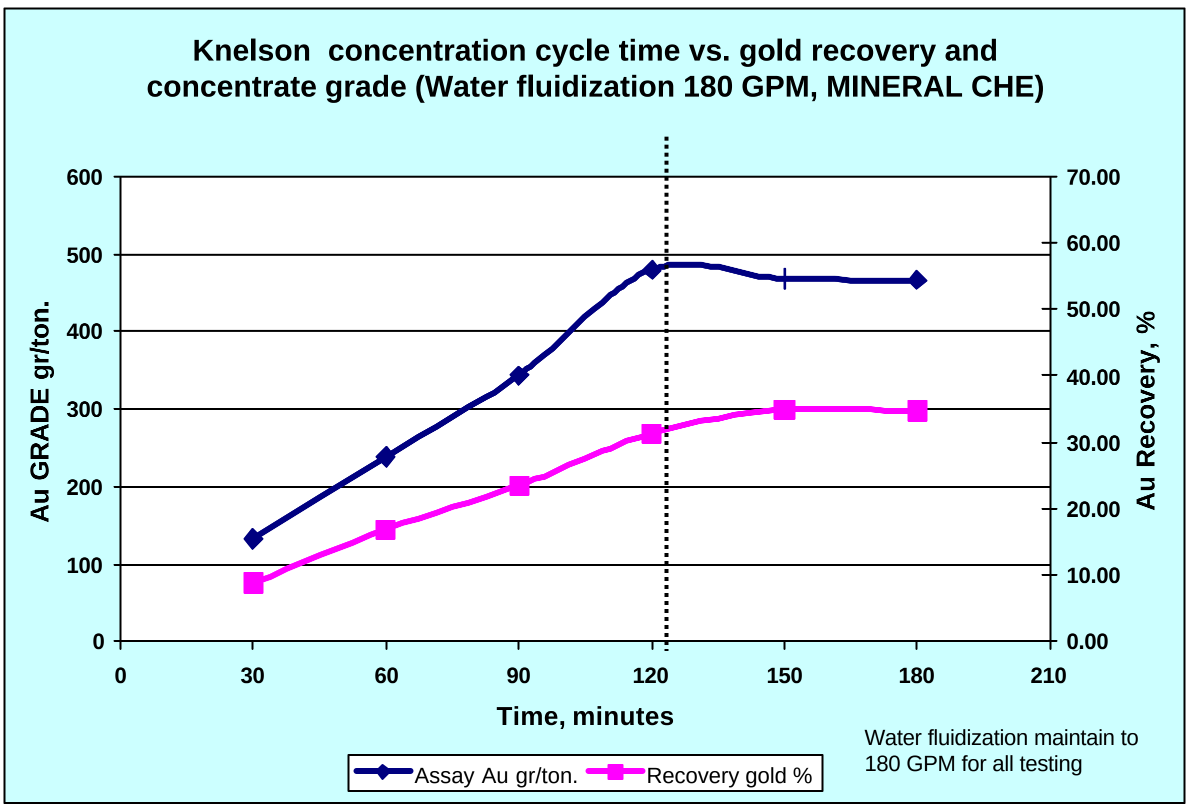
The grade of the KC concentrate keeps a close relation with the head grade.
An additional step was taken to increase the grade of the Knelson concentrate. As the concentrate is automatically discharged into the concentrate tank, we screen this concentrate to No 6 mesh. This reduces the volume of concentrate and increases the grade.

6.2 TESTS TO DETERMINE THE FEED RATE THAT ENTERS THE CONCENTRATOR

These tests were conducted by-passing the Knelson feed, to the cone concentrate discharge pipe (with machine controls in manual mod). The results obtained clearly show the effect of hardness of the mineral in the grinding process. Since the mineral of the sector of Chabuca Sur is of low hardness, it allows us to process approximately 140 TPH (Opening of the mesh approx. 3mm x 18mm at the Deister) with the existing mesh. Processing minerals of the sector Chabuca Este the average tonnage we can process with the Deister is 60 TPH. Coarse rejected material exceeds the capacity of the Deister and clogs the discharge to the feed box of the ball mill.

6.3 DETERMINATION OF THE BEST CONCENTRATION CYCLE.

These tests showed clearly that additional recoveries are minimal if any beyond 2 hours of concentration in a cycle.

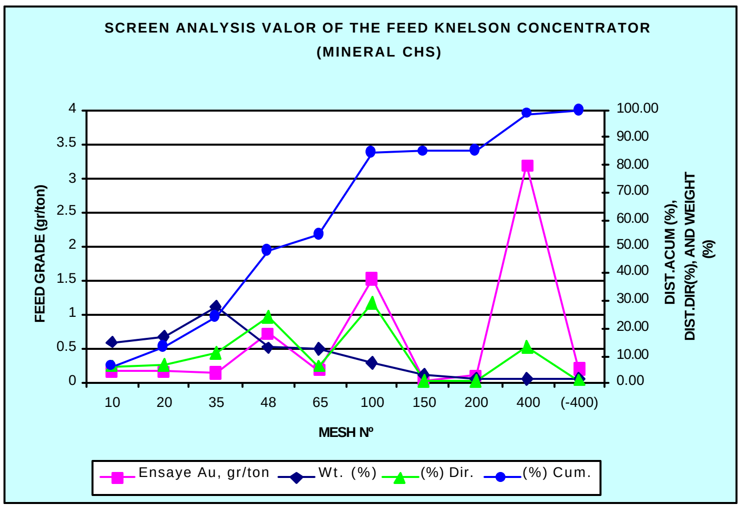


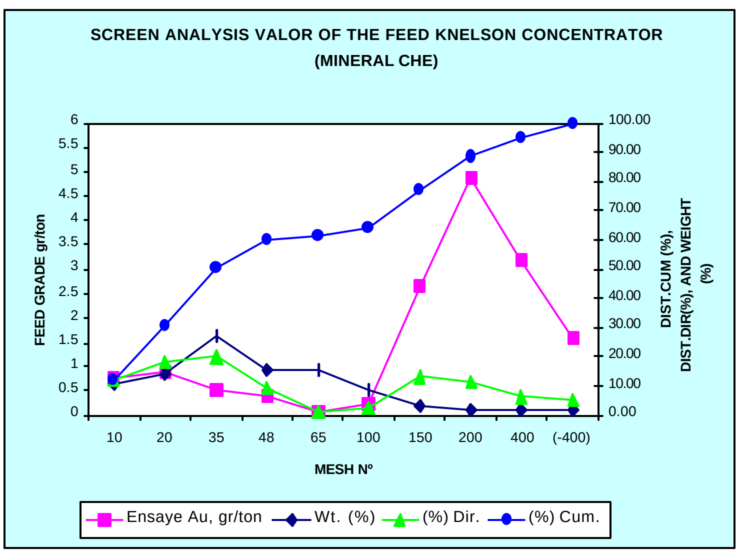
7. PARTICLE SIZE ANALYSIS OF THE HEAD AND KNELSON CONCENTRATE

In the particle size analysis of the head (minerals from Chabuca Sur and Chabuca Este), approx. 50% of the fine gold is smaller than mesh # 48 (fines). The concentrates obtained show that recoveries are higher with presence of fine gold compared to those with coarse gold.

More than 30% of the gold content is found between mesh #48 and #150, where the gold recovery by flotation process is very poor. Only 15% of the gold content is found between mesh #150 and #+400, the size range where recovery through the flotation process is very good.

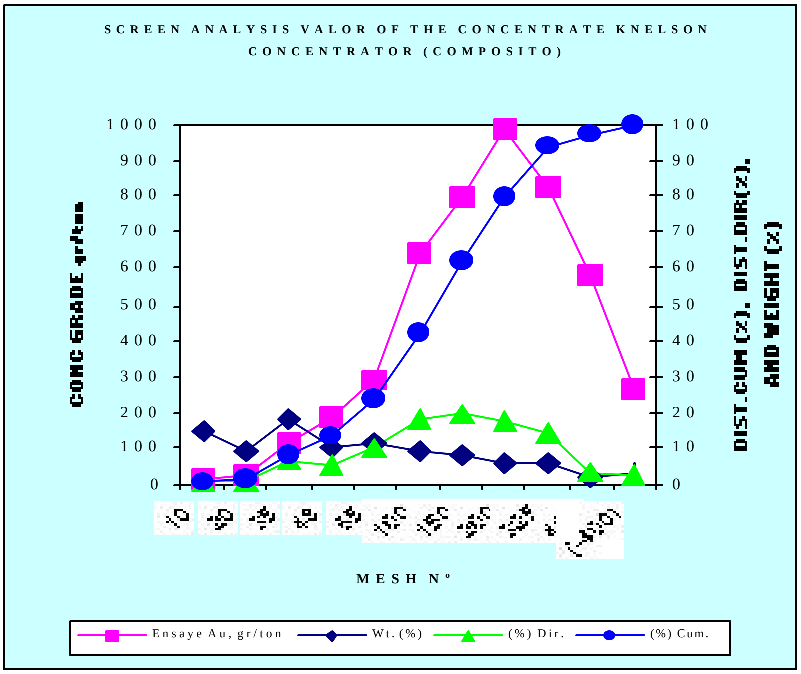
In the fine fraction (#-400 mesh) there is little gold content, therefore the metal recovery by flotation is relatively poor.

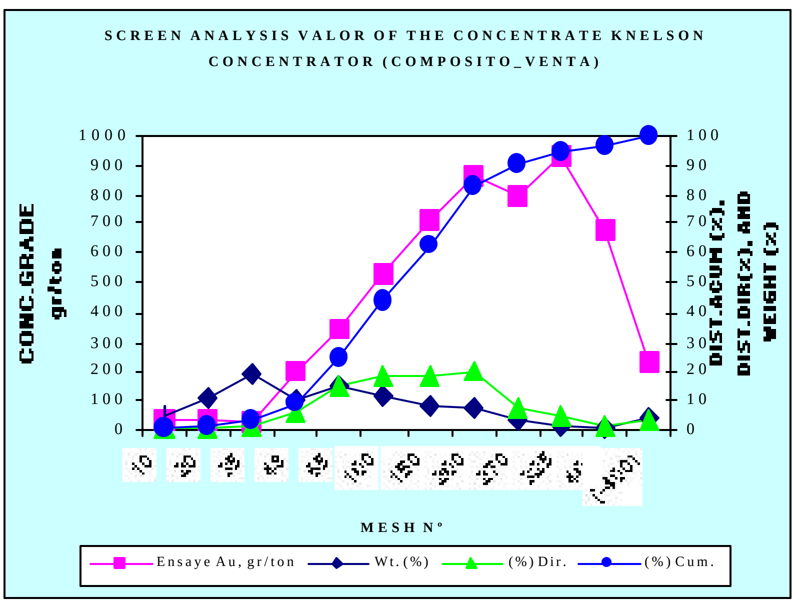




80% by weight of Knelson concentrate is over 150 mesh, and it contains up to 62% of the gold distribution.

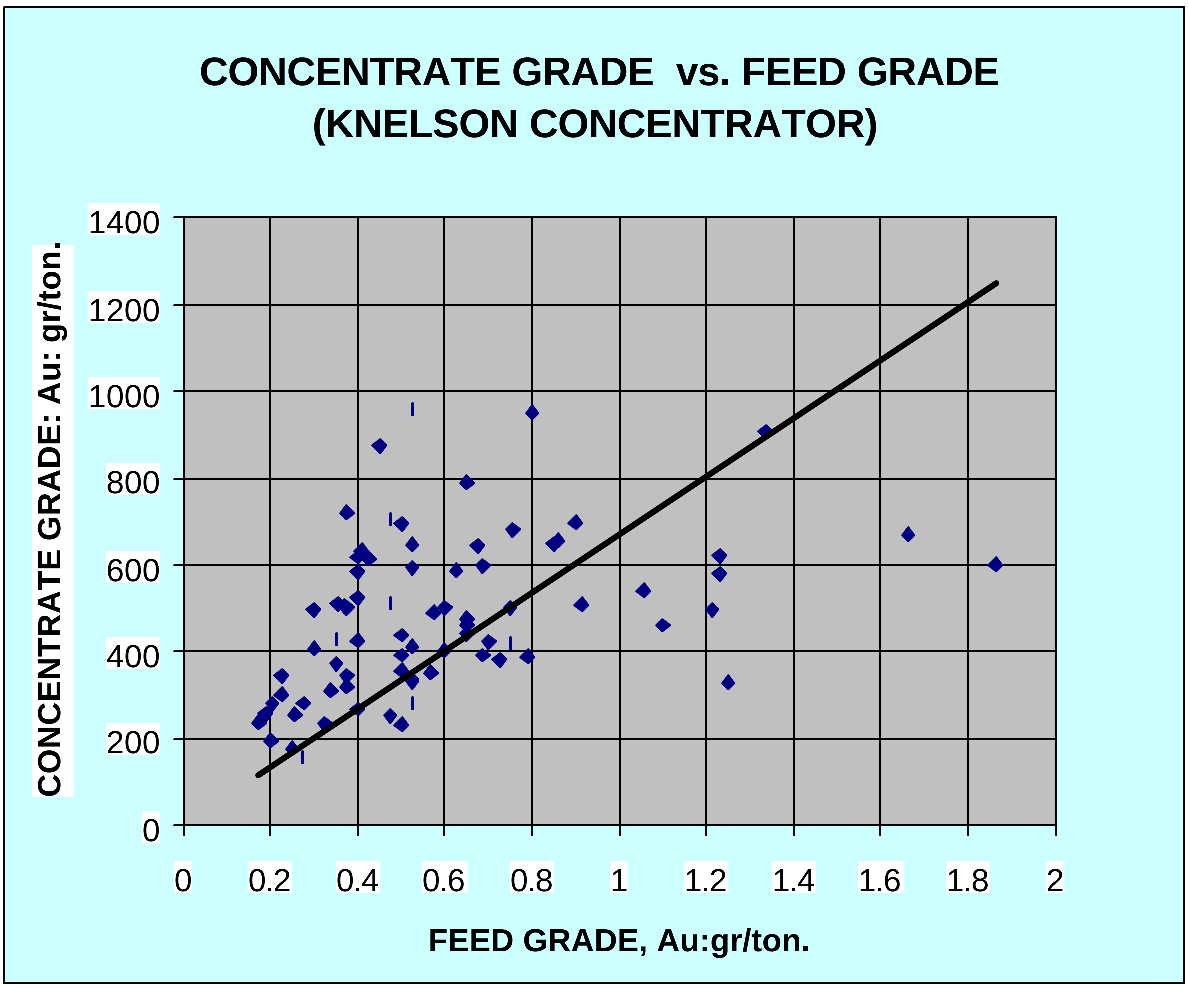
We can summarize that the Knelson Concentrate recovers particles of coarse gold without any difficulty. Also we can affirm that the Knelson concentrator performed well with the fine sizes. One of the important conclusions is that the centrifugal concentrator obtains a good recovery in the particle size range where the flotation process is not effective (either very coarse or very fine particles).





8. EFFECT OF THE HEAD GRADE IN REGARDS TO THE GRADE OF THE CONCENTRATE OBTAINED.

It is clearly noticed the effect of the head grade to the grade of the KC concentrate and recoveries. This graphic is obtained after all parameters were optimized. Higher head grades result on higher concentrate grades and good recoveries.



9. GOLD CONCENTRATE TREATMENT TESTS PERFORMED

To determine if a final high-grade concentrate for re-sale could be produced, we performed a series of tests. The results are shown herewith:

9.1 **Amalgamation Tests**: The maximum recovery obtained as a result of this grinding-amalgamation test was 84.08% Au. The cost of reagents US$75/ton in addition to the costs due to environment issues.

9.2 **Preliminary Acid Leaching Tests With Thiourea**: The purpose of this test was the selection of the proper reagent, as the rougher concentrate of the Knelson contains considerable amount of copper that affect dramatically the cost in a cyanide process. Recoveries bordered 89.24% Au. The cost of the reagents was US$ 431/ton.

9.3 **Leaching Test with Cyanide:** These tests were performed at Alex Stewart labs. Cyanide consumption was in the order of 115 Kg/ton and a treatment cost of US$ 513/ton.

9.4 TECHNICAL-ECONOMICAL EVALUATION OF THESE PROCESSES

The Knelson Concentrate obtained by gravity has a Copper content of 4%. Cut, basically native copper. The effect of copper on cyanide and the costs involved either with cyanide or Thiourea make these processes unfeasible. Regarding recoveries obtained with amalgamation, the costs involved and the environmental issues hinder this option.

Presently, we sell the Gold Concentrate to smelters abroad getting 97% of the value of Gold. None of the tests described before achieved similar values. In addition, the costs for transportation of the concentrate to the customer is lower than US$60/ton, cheaper than the cost of any of the procedures described before.

Another issue is Security during the process of production and trading. We consider that handling <u>Gold</u> during and after the process presents much more security complications than handling the <u>Gold Concentrate</u> with a lower unitary value.

As a result of this analysis, our gold production is sold as Gold Concentrate to smelters and refineries.

CONCLUSIONS & RECOMMENDATIONS

- **The total gold recovery of the concentrating plant increased 5% with the installation and operation of only one Knelson concentrator in only one grinding circuit.**

- **In the actual gravity circuit, just 8% of the cyclone under flow is processed through the Knelson. With a new bigger vibrating screen with higher capacity, it is foreseeable to reach up to 12% of the circulating load. It is recommended in the future to try two Knelson Concentrators in order to reach up to 25% of the circulating load of each ball mill.**

- **The best flow of fluidization water is of 180 GPM, obtaining efficiencies on the range of 50% recovery.**

- **The best duration of concentration is 1.5 hours, but due to the variations in the head grade, densities, and others, the cycle has been set to 2 hours to be on the practical side.**

- **It has been established that with the Knelson Concentrator in the gravity circuit is possible to recover free gold in very coarse and very fine particles. <u>In these sizes the gold recovery by flotation is very poor.</u>**

- **The grade of the gravimetric concentrate obtained per cycle with set parameters will always depend to a large extent to the head grade; the higher the head grade, the higher will be the grade of the concentrate.**

- **The installation of a screen (mesh #6) to treat Knelson concentrate and separate the oversized material has improved the concentrate grade. As a result, smaller amounts of concentrate with higher grades are obtained.**

- **It is recommended to change the existing vibrating screen for a bigger one, as the current screen limits the feed to the Knelson, which has a larger capacity.**

- **It is recommended to install another Knelson Concentrator KC-XD48 in the grinding circuit of ball mill N^{o} 3; following the recommendation made the Knelson Concentrator installed in the grinding circuit of ball mill N^{o} 2.**

Thanks for your visit