# OPTIMIZING GOLD CYANIDATION BY PRESSURIZING PULP AND OXYGEN

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## ABSTRACT

Upgrading of the 3000 tpd Crystallex-San Gregorio (Uruguay) pyritic gold operation has been achieved by an optimized milling circuit and the enhancement of cyanidation kinetics using the Filblast leaching technology. Forcing the auriferous pulp to the leach circuit through a continuous high-shear mixer/reactor, in which a unique regime exists of simultaneous high pressure, intensive turbulence and pure oxygen, has increased recoveries from 91,7% to 94,0%, with an average 0,054 gpt decrease in Au tailings content.

## INTRODUCTION

Based on daily averages from Monthly Operation Reports, a comparison is made between plant data collected during the five months (Sept-99 to Jan-00) prior to the Filblast installation in Feb 2000, with equivalent data obtained during the 5-month period thereafter (March-July 2000). Figure 1 is an illustration of the Minera San Gregorio operation.

Before testing the Filblast the leach circuit consisted of one leach tank Tk1, and 6 CIL tanks. During the air-sparged baseline period, head content averaged 2,31 gpt, while tails averaged 0,193 gpt, for a recovery of 91,7%. A typical [DO] profile through the circuit indicates 2-4 ppm [DO] in Tk1 and Tk2, with 6-8 ppm in subsequent tanks.

Repairs to the SAG and ball mills carried out in Feb-00 allowed stabilizing hydrocyclone performance, increasing solids content in the feed pulp from 45% in Jan-00 to about 49% in March and April. As a consequence, the residence time in the circuit increased from 24h in Jan to about 30h in April. This improvement coincided with the Filblast start-up, for which Tk2 was made a pure-leach tank, therefore the 7-tank circuit was left with 5 CIL tanks.

## CHEMICAL BASIS of the FILBLAST CYANIDATION TECHNOLOGY

The process of Au cyanidation has been represented by Elsner's equation:

$$4\,Au + 8\,CN^- + O_2 + 2H_2O \Rightarrow$$
$$\Rightarrow 4\,Au(CN)_2^- + 4\,OH^-$$

Cyanide concentration determines the rate of anodic Au dissolution, whereas the kinetics of $O_2$ reduction depends on the dissolved oxygen concentration. The ratio between [CN] and [DO] determines the global velocity of the reaction, according to the following restrictions:

$$[CN^-]D_{CN} = 8[O_2]D_O$$

where $D_{CN}$ and $D_O$ are the respective diffusion coefficients for the cyanide ion and [DO]. Based on the respective values of the diffusion coefficients, it has been determined that:

If $[CN] < 6\,[DO]$ the speed of reaction is cyanide starving, and

If $[CN] > 8\,[DO]$ the speed of reaction is limited by [DO]

This implies that, unless other cyanide consumming species exist in the mineral, for [CN] of about 250 ppm, the level of [DO] should be in the range of 30 ppm to ensure the optimum reaction kinetics. Atomaer's experience demonstrates that [DO] concentrations between 25 and 30 ppm are adequate for most cases. Beyond 30 ppm [DO], excessive oxygen losses to atmosphere at the tank's surface are commercially unjustified.the 7-tank circuit was left with 5 CIL.

### Air-based cyanidation

For over 100 years industry accepted kinetics of industrial Au cyanidation as limited by the very low 4-8 ppm dissolved oxygen in the air-sparged leach tanks. Bubbling air into gently agitated pulp means that the controlling step for the cyanidation reaction is the simultaneous mass transfer of both cyanide and oxygen across a "boundary layer" to reach the gold on the mineral surface.

This hydrodynamic "boundary layer", characteristic of diffusion-controlled reaction regimes, is a relatively stagnant film of solution, bound to the mineral surface rather than being a part of the bulk liquid. Low [DO] plus the thickness of the boundary layer are barriers to reagents diffusion to the mineral surface, thus resulting both in slow kinetics and low recoveries. Reaction kinetics is also controlled by the availability of the limiting reagent: According to the aforementioned stoichiometry of the cyanidation reaction shown below, the optimum cyanide-to-oxygen ratio is between 6 and 8.

We customarely observe in industry concentrations of 300 ppm free cyanide maintained in leach tanks with 6 ppm [DO], equivalent to a [CN]: [DO] ratio of 50.

**Pure $O_2$ / filblast cyanidation.**

Atomaer recognised the benefits of higher [DO] levels and, after years of development (Sceresini, 1997), found 25 ppm [DO] to be the optimum level for gold cyanidation. In the case of silver or gold-silver ores, up to 35 ppm [DO] is beneficial, with little effect at higher [DO]. It had been observed, in other gold operations, that sparging or lancing pure $O_2$ instead of air, has allowed attaining a maximum of 16 - 18 ppm [DO] with lower mass transfer efficiency, using twice the $O_2$ required by the Filblast to establish 25 ppm. In the abscense of intensive shear turbulence, recoveries have just mildly increased.

To overcome the stagnant "boundary layer" barrier without increasing the power (and mechanical) duty of the agitator, it became necessary to increase the turbulence of the solution next to the solid particles. The continuous Filblast Gas Shear reactor was designed to eliminate the diffusion regime and establish a highly turbulent kinetic regime.

A recirculating pump pressurizes all the fresh feed and a fraction of "high [DO]" pulp to the Filblast, where high pressure $O_2$ is injected, attaining [DO] levels as high as 35 ppm, at $O_2$ flowrates about half of that required to attain 18 ppm using either $O_2$ spargers or lances with high speed nozzles. The power supplied to the motor of to the pump is a much more effective way to use energy, without significantly penalizing the overall power requirement, since the compressed air to all the tanks in the circuit could, in most cases, be completely shut-OFF.

## COMMISSIONING AND OPTIMIZATION OF THE FILBLAST

Fig.2 schematically illustrates the Filblast installation at San Gregorio.

Implementation of the Filblast 350 using pure $O_2$ injection instead of air bubbling in the first leach tank allowed establishing a [DO] concentration of 25 - 30 ppm instead of the conventional air-based 2 - 4 ppm. The pressure at the top of the Filblast was set at 500 kPa when the $O_2$ flowmeter read 25 $Nm^3/h$. An 8/6 Warman pump driven by a 132 kW motor was installed for the purpose of driving 450 $m^3/h$ of pulp through the Filblast, of which about 200 $m^3/h$ represent all the new feed to the leach circuit while the balance is recirculated pulp from the lower section of Tk1.

While establishing 30 ppm [DO] in Tk1, a drop to about 10 ppm [DO] was measured in Tk2. In order to run Tk1 and Tk2 as "one-tank" the pipework was modified to allow the option of recirculating pulp from Tk2 instead of Tk1.

Although an increase in [DO] was observed in Tk2 at a constant $O_2$ flow, there was a drop in [DO] in Tk1 and no decrease in Au tail content was measured, so the system was returned to the initial configuration. The delta [DO] between Tk1 and Tk2 averages now about 15 ppm. The average $O_2$ flowrate was 39,0 $Nm^3/h$ $O_2$ equivalent to 29 $Nm^3O_2$/ton.

## TEST RESULTS

Table 1 is a summarised comparison of the results obtained during these periods. Table 2 lists detailed data for each month considered. Both Tables are shown at the end of the text.

**Au recovery and tail content.**

There is a net increase in Au recovery from 91,7% to 94,0%. Tail content is reduced from 0,193 gpt to 0,139 gpt. At a throughput of 3050 tpd and a gold price of US$ 270 per ounce, this equates to a benefit of US$ 43,600 per month in improved Au extraction.

Starting May, a reduction on Au head content was observed, from about 2,35 gpt to 2,14 gpt. Normally, this condition would result in a drop in recovery, which did not occur in this case, with recovery values holding at above 94% until the end of July.

**Reagent control**

On March 17-18 , there was an increase of about 40% in head Au content (3,44 and 3,58 gpt each day, whereas the monthly average was 2,45 gpt), which resulted in high tail contents during the 3 following days (averaging 0,30 and 0,32 gpt, with corresponding low recoveries) compared to an average of 0,17 gpt on the 28 remaining days. The inability of the circuit to handle an abrupt head-Au increase, suggests that an automatic control of [CN] and [DO] to treat abnormal demands, could prove profitable.

**The [CN] to [DO] ratio.**

Optimum recovery values are obtained when the [CN]:[DO] ratio is between 7 and 8, confirming the teachings of the stoichiometric coefficients of the cyanidation reaction. Values as high as 10 did not increase recovery values.

**Dissolved oxygen in Tk1.**

The optimum [DO] in Tk1 is estimated to be in the range of 26 to 30 ppm. Concentrations higher or lower than said value yields dipersed and lower Au recovery levels.

**CONCLUSIONS**

During Mar-July 2000 the Filblast operated at Crystallex, boosted Au recovery from 91,7 to 94%, cutting tail Au content by 0,054 gpt. The now adopted Filblast technology successfully achieved high-shear and micro-bubble dispersion in the feed pulp and the recirculated slurry from Tk1. This intense regime results in:

- Higher gold recovery
- Increased leaching rate
- Increased [DO] concentration

Further work will address increasing throughput while maintaining recoveries, along with reductions in cyanide and oxygen consumption and improved carbon loading.

**ACKNOWLEDGEMENTS**

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**REFERENCES:**

Sceresini, Bruno. The Filblast Cyanidation Process - A Maturing Technology

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FIG. 1: SAN GREGORIO GOLD OPERATION

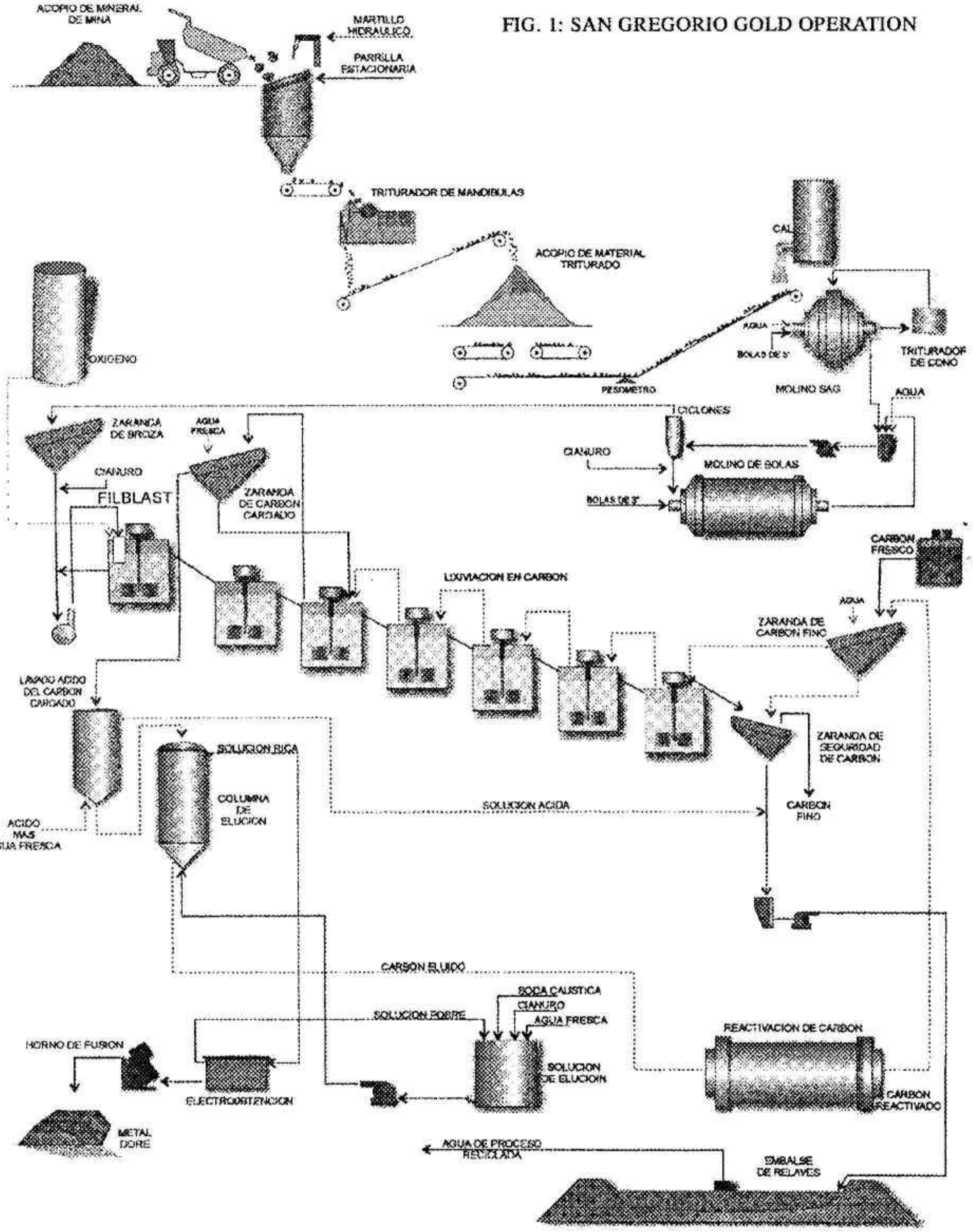

FIG Z : TYPICAL FILBLAST INSTALLATION

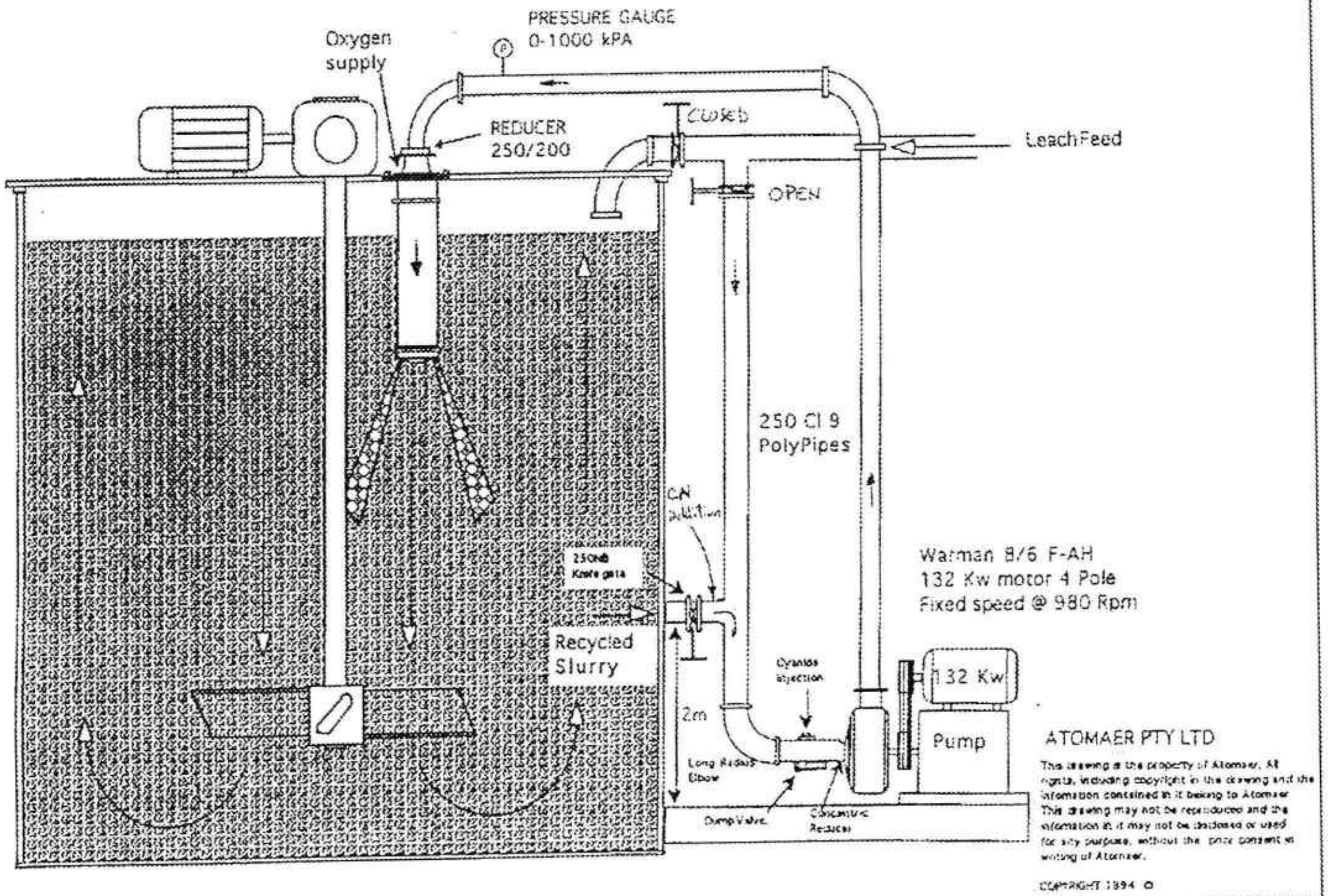

**Table 1. Summary Comparison With and Without Filblast**

| | | Sept99-Jan00 | Mar-Jul 00 | Diff. | % Change |
|---|---|---|---|---|---|
| | | Air Spargers | Filblast/O2 | | . |
| Throughput, dry | tpd | 3094 | 3047 | -47 | - 1,5% |
| Head Au | gpt | 2,31 | 2,31 | 0 | 0,0 % |
| % solids in pulp | % | 44,9 | 48,8 | +3,9 | + 8,6% |
| Au in tailings | gpt | 0,193 | 0,139 | -0,54 | - 27,9% |
| Au recovery | % | 91,7 | 94,0 | 2,3 | 2,5% |
| [CN] consumed | kg/t | 0,58 | 0,63 | 0,05 | + 8,6% |
| O2 consumed | Nm3/t | 0 | 0,29 | | |
| Carbon consumpt. | kg/t | 0,052 | 0,047 | -0,005 | -9,6% |
| Gold cast | kg/mo | 197,9 | 195,6 | | -1,16% |

**Table 2. Monthly Averages of Relevant Operating Parameters**

| AIR SPARGING - NO FILBLAST | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1999 | Tonnage mton/mo DRY | % solid in feed Pulp | Head Au aver.(gpt) | Tail Grade Aver.(gpt) | Recv. (%) | Solutn Assay (ppm) | O2 cons. $m^3/h$ | Au Recup. physic.bal. (g) | Total Au in feed (g) | CN kg/mo | Au cast (g) |
| Sep-99 | 93.392 | 46,06% | 2,53 | 0,214 | 91,5 | 0,0026 | | 216.212 | 236.230 | 54.000 | 226,083 |
| Oct-99 | 102.947 | 45,72% | 2,24 | 0,226 | 89,9 | 0,0076 | | 207.624 | 230.843 | 54.000 | 189,649 |
| Nov-99 | 92.464 | 46,39% | 2,36 | 0,208 | 91,2 | 0,0112 | | 198.747 | 217.977 | 48.000 | 201,949 |
| Dec-99 | 91.408 | 46,49% | 2,30 | 0.159 | 93,1 | 0,0089 | | 195.310 | 209.809 | 56.250 | 203,576 |
| Jan-00 | 83.891 | 44,96% | 2.14 | 0.157 | 92,7 | 0,0096 | | 166.270 | 179.194 | 55.000 | 168,054 |
| | | | | | | | | | | | |
| Averg1 | 92.820 | 45,92% | 2,31 | 0,193 | 91,7 | 0,0080 | | 196.832 | 214.811 | 53.450 | 197,862 |
| Total | 464.102 | | | | | | | 984.162 | 1.074.052 | | 989,310 |
| | | | | | | | | | | | |
| FILBLAST OPERATION | | | | | | | | | | | |
| | CARGA a lixivic. | %solid Pulpa | LEY CABEZA | LEY COLAS | Recup | SOLUC Ensayo | Oxygen Cons | Au Recup. physic.bal. | Au total en Cabeza | CN kg/mo | Au cast |
| 2000 | Ton/mes | Aliment | (g7t) | (g7t) | % | (ppm) | m3/h | (g) | (g) | kg/mo | (g) |
| Mar-00 | 94.766 | 48,83% | 2,52 | 0,188 | 92,5 | 0,0120 | 36,0 | 221.949 | 239.137 | 56000 | 202.190 |
| Apr-00 | 81.110 | 48,32% | 2.38 | 0,124 | 94,8 | 0,0102 | 41,0 | 183,314 | 193.238 | 55000 | 201.666 |
| May-00 | 88.789 | 47.26% | 2,15 | 0,125 | 94,2 | 0,0133 | 39,5 | 187.023 | 191.255 | 55300 | 204.631 |
| Jun-00 | 95.699 | 47,53% | 2.26 | 0,127 | 94,4 | 0,0111 | 40,0 | 204.313 | 216.718 | 60000 | 199.031 |
| Jul-00 | *96.602* | 47,11% | 2,20 | 0,130 | 94,1 | 0,0135 | 38,7 | 200.876 | 171.593 | 62000 | *170.472* |
| | | | | | | | | | | | |
| Averg2 | 91.393 | 47,81% | 2,31 | 0,139 | 94,0 | 0,0120 | 39,0 | 199.495 | 202.388 | 57.660 | 195.598 |
| Total | 456.966 | | | | | | | 997.475 | 1.011.941 | | 977.989 |