THE EFFECT OF THE INSTALLATION OF A KNELSON CONCENTRATOR ON GOLD RECOVERY AT FREDA REBECCA

MARK WILLIAMS JOHNS
PETER JAMES TOUT
GRANT KELSEY LOVEDAY

Mintek

PHILEMON BUNDO
ANDREW MOYO

Cluff Resources Zimbabwe Ltd

PRESENTED AT:
SAIMM/MMMA Symposium entitled
"New Developments in the Extractive Metallurgical Industry"
Zimbabwe
February 1996

Paper for submission to the SAIMM/MMMA symposium entitled “New Developments in the Extractive Metallurgical Industry” to be held in February 1996

THE EFFECT OF THE INSTALLATION OF A KNELSON CONCENTRATOR ON GOLD RECOVERY AT FREDA REBECCA

by

Mark Williams Johns+

Peter James Tout+

Grant Kelsey Loveday+

Philemon Bundo*

and

Andrew Moyo*

ABSTRACT

The Freda Rebecca Gold Mine is situated near Bindura in Zimbabwe and processes some 100 000 tons of gold-bearing ore per month. A laboratory test programme was undertaken to quantify the deportment of the gold in the residue. The test programme included mineralogical studies, diagnostic leaching, gravity concentration and cyandiation. The results indicated that cyanide-soluble gold was present in the residue.

The mine decided to hire a 30 inch Knelson gravity concentrator to quantify the effect of the removal of coarse gold from the milling circuit. Samples were taken on the plant before and after the installation of the concentrator. The samples were used to quantify the amount of cyanide-soluble gold in the residue and the deportment of gold in the residue (gold associated with quartz,gold associated with sulphides and gold that is ‘preg-robbed’). The gold distribution in the milling circuit, the gold distribution in the various size fractions, the gold lock-up and the amount of coarse gold recovered were determined. The effect of the removal of the coarse gold on the response of the cyanidation circuit (cyanide consumption and residence time) and the CIP circuit (equilibrium isotherm and mass transfer coefficient) were measured. The programme indicated a pay-back period of months, and hence the Knelson was purchased.

+ Mintek

* Cluff Resources Zimbabwe Ltd

INTRODUCTION

The Freda Rebecca Gold Mine is in Bindura in Zimbabwe. The plant was commissioned in 1988 to process ore from the Freda and Rebecca pits. The life of the mine was to be 7 years and the plant was designed and constructed accordingly. The process flowsheet is a single-stage crushing circuit (jaw crusher) to - 150 mm, two separate milling modules consisting of a SAG mill (diameter 4,88 m by length 7,35 m) in closed circuit with a cyclone (diameter 0,375 m) to produce a product of 75% - 75um, a three-stage cyanidation circuit (3 hours per tank residence time) and a seven stage carbon-in-pulp (CIP) circuit (AARL elution and vertical kiln regeneration).

The mine decided to go underground in 1993 upon depletion of the Rebecca surface ore. Ore was still sourced from the Freda pit. A laboratory test program was undertaken to evaluate the metallurgical response of the plant to the underground ore. Lower extraction's than expected led to the quantification of the deportment of the gold in the residue. The test program included mineralogical studies, diagnostic leaching, gravity concentration and cyanidation. The results indicated that cyanide-soluble gold was present in the residue.

The mine decided to hire a 30 inch Knelson gravity concentrator in March 1995 to quantify the effect of the removal of coarse gold from the milling circuit. A 30 inch Knelson concentrator was installed on the cyclone underflow in one of the two milling modules. This paper deals with the evaluation of the installation of Knelson concentrators on the cyclone underflow.

EXPERIMENTAL PROCEDURE

Cyanidation of a sample was carried out in a rolling bottle at a liquid/solid ratio of 1: 1, except for the diagnostic leach test work (2:l). The reagent addition for the diagnostic leach test work was 5 kg/t NaCN and 10 g/l carbon. The reagent addition for the other tests was 0,5 kg/t NaCN, except for the cyanide-addition test work. The duration of the tests was 24 hours, except for the rate of dissolution test work. A pre-oxidation step was not performed.

An equilibrium test involved a number of contacts of a fixed volume of pre-leached pulp with different masses of powdered adsorbent. After the contact had reached equilibrium, the solution phase was analyzed for gold and the adsorbent loadings calculated. A kinetic test involved contacting a set volume of pulp with a predetermined mass of adsorbent in a hydrodynamically controlled mechanically agitated tank. Samples of the solution phase were removed at predetermined times and analyzed for gold. The adsorbent used was the high-capacity activated carbon ANK 11.

For the grading analysis test the samples were wet screened at 75 um to remove the fines, prior to dry screening at 150 urn.

GOLD RECOVERY

Prior to the installation of the Knelson concentrator 15 *individual samples* of the residue were taken by sampling the residue stream hourly and forming a daily sample. These samples were used to form three weekly *samples* and a single *total sample.* After the installation of the concentrator 10 *individual samples* of the residue were taken by sampling the residue stream hourly and forming a bi-daily sample. These samples were used to form five *daily samples* and a single *total sample.*

The effect of recovering free gold from the cyclone underflow, by a Knelson gravity separator, on the total gold recovery was evaluated by a laboratory test program that encompassed

* on the *individual residue samples*
    > the determination of the amount of gold in the solution phase of the residue
    > the determination of the amount of gold in the ore phase of the residue that is
        ~cyanidable
        ~not liberated from the ore matrix

* on the *before weekly residue and after daily residue samples*
    > the determination of the amount of gold in the solution phase of the residue
    > the determination of the amount of gold in the ore phase of the residue that is
        ~cyanidable
        ~'preg-robbed' by carbonaceous material
        ~not liberated from the ore matrix
* on the *total residue sample*
    > the determination of the amount of gold in the solution phase of the residue
    > the determination of the amount of gold in the ore phase of the residue that is
        ~cyanidable
        ~'preg-robbed' by carbonaceous material
        ~not liberated from the ore matrix and is
            - associated with soluble sulphides or oxide coated
            - associated with stable sulphides
            - associated with quartzite

The results are shown in Figures 1 to 3.

The amount of cyanide-soluble in the *individual residue samples* (Figure 1) decreased from 0,25g/t (standard deviation 1,12) to 0,12g/t (standard deviation 0,05) after the installation of the Knelson concentrator. The statement that the installation of the Knelson concentrator decreases the amount of cyanide-soluble gold can be made with 99,5 per cent confidence but not 99,95 per cent confidence. This represents an increase in the gold recovery of 0,13g/t of gold. Since the trial Knelson concentrator was installed on only one of the two milling modules and the residue sample was taken after the CIP circuit, it is reasonable to expect that the installation of the second Knelson will reduce this loss to close to zero. Hence, the cyanide-soluble gold that was detected in the residue is due to coarse gold. At a tonnage of 96 000 t/m and a gold price of R45 program, this increase in recovery constitutes and increase in revenue of Rl million per month.

The 'preg-rob' test indicated the presence of a 'preg-robber' in the *weekly residue samples* before and after the installation of the Knelson (Figure 2). The amount of gold that was 'preg-robbed' was 0,07g/t before the installation of the Knelson and 0,07g/t after the installation of the Knelson. The amount of cyanide-soluble gold in the *weekly residue* samples (Figure 2) decreased from 0,3Og/t to 0,05g/t after the installation of the Knelson concentrator. The test confirmed the decrease in the amount of cyanidable gold after the installation of the Knelson.

The diagnostic leach test work carried out on the total *residue sample* (Figure 3) revealed that before the installation of the Knelson concentrator the amount of gold in the residue was 0,69g/t.

The amount of cyanidable gold was 0,27g/t, the amount of 'preg-robbed' gold was 0,08g/t, the amount of gold associated with the reactive sulphides or ‘coated’ gold was 0,08g/t, the amount of gold associated with the stable sulphides was 0,14g/t and the amount of gold in the matrix was 0,12g/t. After the installation of the Knelson concentrator the amount of gold in the residue was 0,49g/t. The amount of cyanidable gold was 0,09g/t, the amount of ‘preg-robber’ gold was 0,0g/t, the amount of gold associated with the reactive sulphides was 0,21g/t and the amount of gold in the matrix was 0,13g/t. The test confirmed the decrease in the amount of cyanidable gold after the installation of the Knelson.

GOLD DISTRIBUTION

The effect of recovering gold from the cyclone underflow, by a Knelson gravity separator, on the gold distribution in the mill circuit was evaluated by a laboratory test program that encompassed quantification of the amount of gold in the various size fractions in the mill circuit before and after the installation of the Knelson.

Grading and gold distribution test work was carried out on the cyclone feed, overflow and underflow samples taken before and after the installation of the Knelson concentrator. The results are listed in Table 1. Inspection of the cyclone overflow data indicates that the bulk of the gold recovered by the Knelson concentrator comes from the -75um fraction. The gold in the +150um circulating load (cyclone underflow) remained virtually the same after the installation of the Knelson. This indicates that gold in the coarse fraction is not removed by the concentrator as it is probably incompletely liberated.

MASS BALANCE

The inert solid and solution mass balance of the mill circuit was quantified mathematically. The mass balance indicated that the recirculating load was 120 per cent.

The gold mass balance in the mill circuit was quantified mathematically. The mass balance indicated that the recirculating load of gold was 383 per cent prior to the installation of the Knelson and 300 per cent after the installation of the Knelson. The amount of gravity gold recovered by the Knelson is 37 per cent.

GOLD LOCK-UP

The effect of recovering gold from the cyclone underflow, by a Knelson gravity separator, on the gold lock-up was evaluated by a mass balance that encompassed quantification of the amount of gold in the circuit, cyanidation circuit and CIP circuit before and after the installation of the Knelson’s. The installation of the Knelson did not reduce the gold lock-up in the mill circuit. However, as the bulk of the gold lock-up is in the CIP circuit and the circuit processed a lower ore grade, the gold lock-up in the plant decreased from 21 to 15 kg.

OTHER BENEFITS

The effect of recovering gold from the cyclone underflow, by a Knelson gravity separator, on the operating parameters of the cyanidation and CIP circuits was evaluated by a laboratory test program that encompassed

* the optimum cyanide addition and cyanidation residence time
* the carbon equilibrium and kinetic parameters.

The results of the effect of leach time and cyanide addition on the cyclone overflow appear in Figures 4 and 5. The removal of coarse gold can be expected to result in an increase in the rate of gold dissolution. However, no such benefit was detected after the installation of the Knelson. This could be due to the fact that only one of the two mill modules had a Knelson concentrator in place during the trial period and therefore coarse gold was therefore still entering the cyanidation circuit. Similarly, no benefit was noted for the cyanide addition. The removal of coarse gold should not affect the cyanide addition unless the leach time is shortened.

The equilibrium isotherm test work and mass transfer coefficient test work are shown in Figures 6 and 7. Both the isotherm and the mass transfer coefficient decreased after the installation of the Knelson. If gold is removed from the mill circuit the load on the CIP circuit is decreased and hence a lower solution barren is expected at an equivalent carbon flowrate. The solution barren was 0,063 ppm prior to the installation of the Knelson and 0,056 ppm after the installation of the Knelson. The deterioration in the adsorption characteristics of the pulp after the installation of the Knelson explains why the solution barren did not decrease to the degree expected.

OPERATION OF THE KNELSON

The Knelson concentrator treats a portion of the cyclone underflow. A knife valve controls the proportion of the cyclone underflow that reports to the Knelson. The feed to the Knelson is screened to remove oversize material that would otherwise fill the concentration zone with relatively barren material, thereby reducing the capacity. The screen installed was a 3 mm wedge wire deck with the slots running across the flow so as to cut at a finer size. Some 97 per cent of the material is less than 3mm. The screen did prevent coarse material from entering and filling the concentrate rings. A 1,18 mm mesh screen was tried below the wedge wire screen, but failed as it could not handle the flow.

The effect of the Knelson operating parameters on the recovery of gold was evaluated on the plant by a test program that encompassed the effect of the water pressure, the effect of the cycle time and the effect of the feed rate.

The Knelson concentrator was started up at a pressure of 6 psi and a sample of the tailings taken. Immediately thereafter the water pressure was increased and as soon as the pressure had stabilized, a sample was taken. The results are shown in Figure 8. The test work indicated that the performance of the Knelson is sensitive to the water pressure and that the pressure should be maintained above 9 psi.

The knife valve that limits the flow to the Knelson concentrator takes approximately 18 turns from fully closed to fully open. The gate was opened in multiples of 3 turns and the tailings were sampled at each flowrate. The results are shown in Figure 9. It appears that the flowrate that corresponds to the full cyclone underflow (less the screen oversize giving a total feed mass of some 91 t/h) gives the minimum gold loss. However, the gold loss at the 50 per cent aperture is very similar. The scatter may be due to the number of sample points or to the presence of coarse gold. Hence, the Knelson is relatively insensitive to changes in the feed rate. One unusual aspect of the test is the high gold content in the tailings at the low feed rate. It is hypothesized that this is due to constant loss of gold from the bowl. When the amount of barren material, the vast majority of the feed material, is low, this gold loss becomes significant.

To test the effect of cycle time on the recovery of gold, the Knelson was run continuously for a period of seven hours without flushing and samples of the tailings were taken. The results are shown in Figure 10. The data display a high degree of scatter. However, a cycle time of four hours seems reasonable. Hence, the Knelson has the capability of recovering 37 per cent of the gold in less than 0,02 per cent of the mass.

CONCLUSIONS

The life of the Freda Rebecca Gold Mine, situated in Zimbabwe, is to be extended by processing underground ore. The process flowsheet is a jaw crusher, two closed-circuit SAG mills, cyanidation and CIP. A laboratory test program indicated that cyanide-soluble gold was present in the residue. The mine decided to hire a 30 inch Knelson gravity concentrator and install it on one of the two milling modules to quantify the effect of the removal of coarse gold from the milling circuit, Samples were taken on the plant before and after the installation of the concentrator.

The amount of cyanide-soluble gold in the residue decreased from 0,25g/t (standard deviation 0,12) to 0,12g/t (standard deviation 0,05) after the installation of the Knelson concentrator. As the trial Knelson concentrator was installed on only one of the two milling modules and the residue sample was taken after the CIP circuit, it is reasonable to expect that the installation of the second Knelson will reduce this loss to close to zero. Hence, the cyanide-soluble gold that was detected in the residue is due to coarse gold. At a tonnage of 96 000t/m and a gold price of R45 per gram, this increase in recovery constitutes an increase in revenue of Rl million per month.

The bulk of the gold recovered by the Knelson concentrator comes from the -75 µm fraction. The gold in the +150 µm circulating load (cyclone underflow) remained virtually the same after the installation of the Knelson. The recirculating load on the mill is 120 per cent. The recirculating load of gold was 383 per cent prior to the installation of the Knelson and 300 per cent after the installation of the Knelson. The amount of gravity gold recovered by the Knelson is 37 per cent. The gold lock-up in the plant decreased from 2 1 to 15 kg.

The operating window of the Knelson concentrator was evaluated. The Knelson concentrator is sensitive to the water pressure, which should be maintained above 9 psi. It appeared that the flowrate that corresponds to the full cyclone underflow (some 90t/h gives the minimum gold loss. One unusual aspect of the test was the high gold content in the tailings at the low feed rate. A cycle time of four hours seemed reasonable. The Knelson has the capability of recovering 37 per cent of the gold in less that 0,02 per cent of the mass.

ACKNOWLEDGMENTS

This paper is published with the permission of Mintek and Cluff Resources Zimbabwe Limited with special thanks to G. G. Gombe (CRZ Managing Director) and M. P. Marriot (Freda Rebecca General Manager).

Table 1

The distribution of gold in the size fractions

	Fraction			Cyclone feed	
		Mass solids %	Gold grade g/t	Mass gold	Gold fraction %
Before	150	36.9	5.19	192	31.1
	-150+75	19.7	7.35	145	23.5
	-75	43.4	6.43	279	45.3
	Total	100.0	7.22	615	100.0
After	150	37.4	5.94	222	49.4
	-150+75	17.5	4.5	79	17.5
	-75	45.1	3.30	149	33.1
	Total	100.0	3.08	450	100.0
	Fraction			Cyclone U/F	
		Mass solids %	Gold grade g/t	Mass gold	Gold fraction %
Before	150	58.6	5.02	294	47.8
	-150+75	14.7	10.33	152	24.7
	-75	26.7	6.33	169	27.5
	Total	100.0	3.94	615	100.0
After	150	63.0	4.28	270	58.5
	-150+75	13.8	5.16	71	15.5
	-75	23.2	5.16	120	26.0
	Total	100.0	4.66	461	100.0
	Fraction			Cyclone O/F	
		Mass solids %	Gold grade g/t	Mass gold	Gold fraction %
Before	150	11.7	2.41	28	11.2
	-150+75	18.4	1.94	36	14.1
	-75	69.9	2.70	189	74.1
	Total	100.0	2.31	253	100.0
After	150	7.1	1.56	11	7.8
	-150+75	20.6	1.39	29	20.1
	-75	72.3	1.42	103	72.1
	Total	100.0	1.50	142	100.

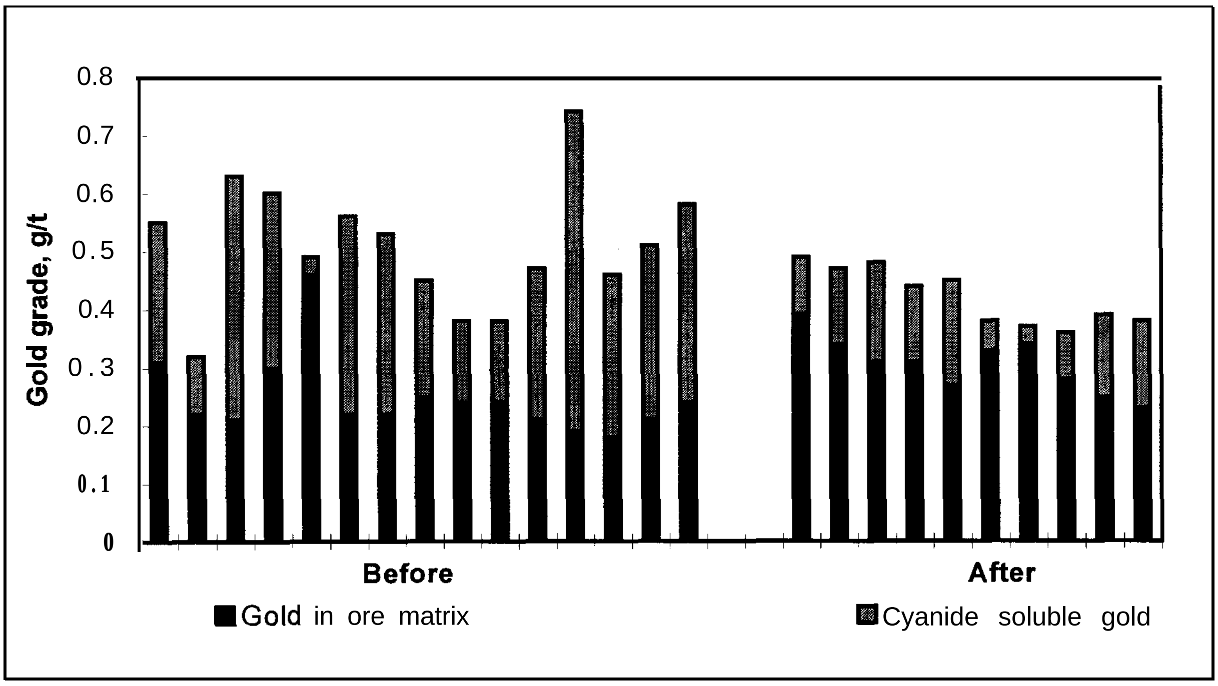

Figure I
The amount of cyanide soluble gold in the individual samples

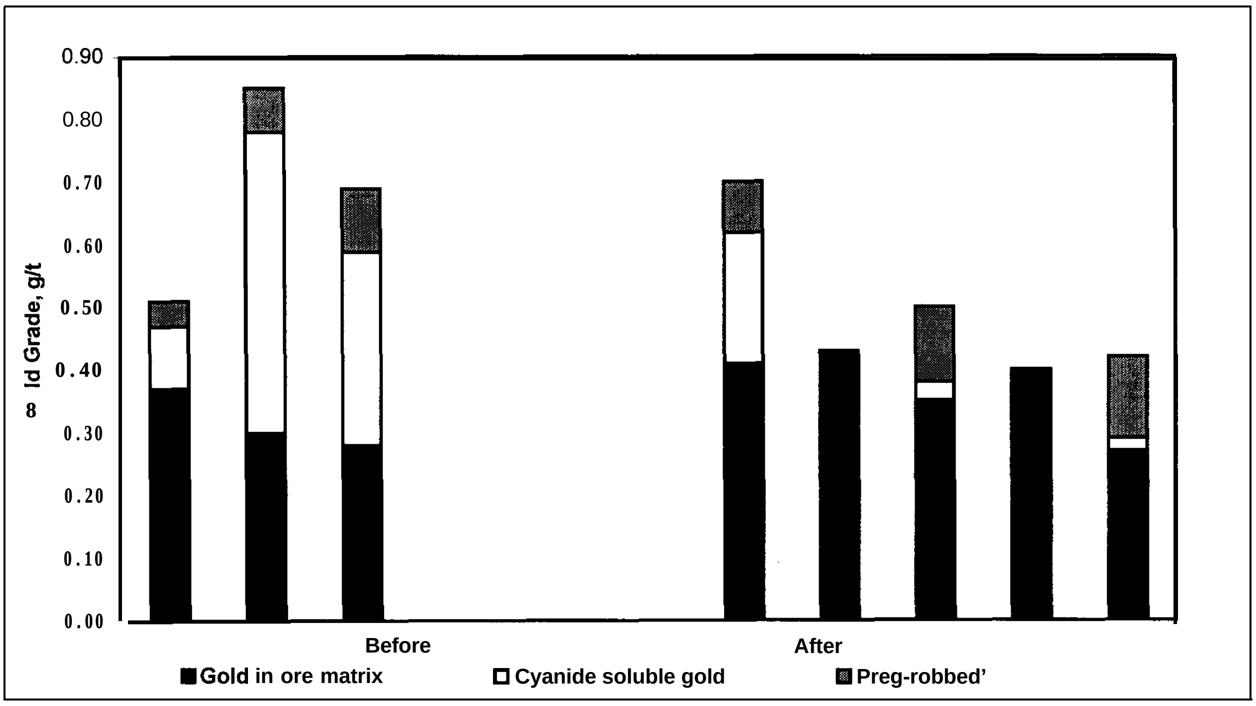

Figure 2
The amount of 'preg-robbed' gold in the composite samples

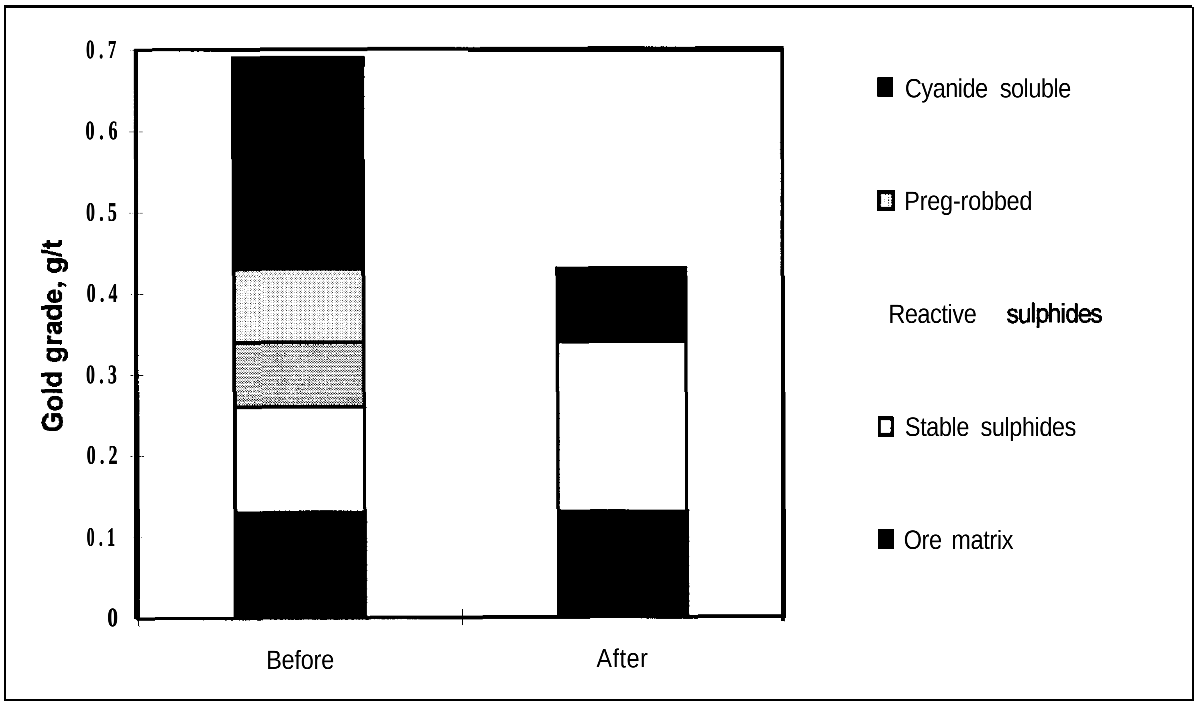

Figure 3
The diagnostic leach of the total composite samples

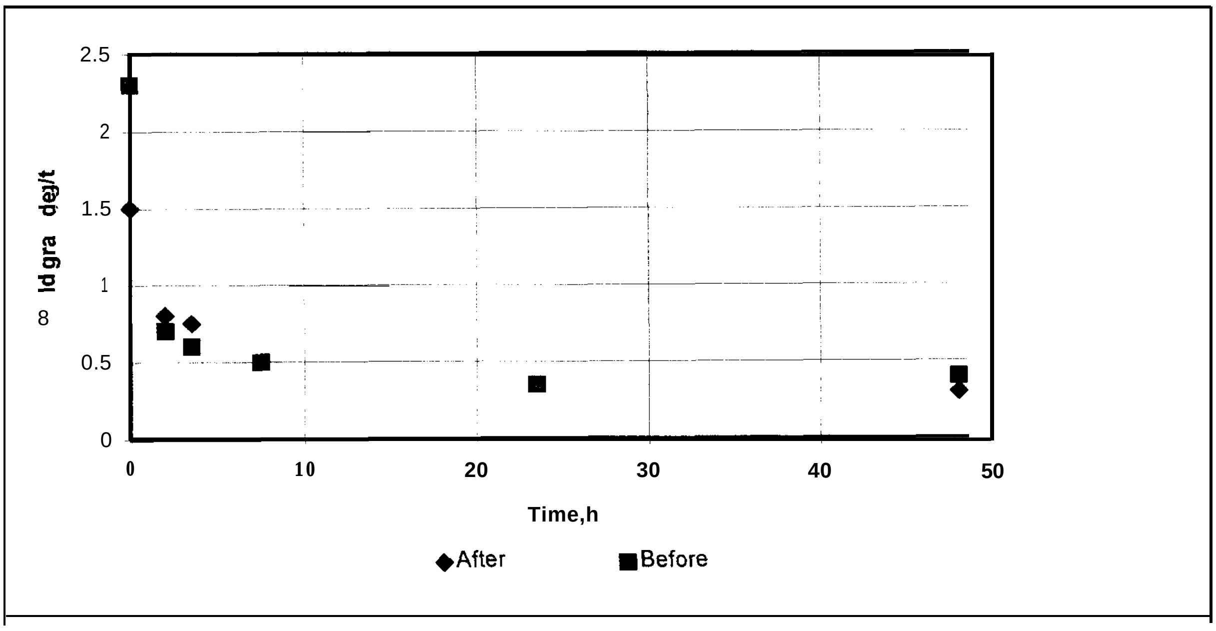

Figure 4
The rate of gold dissolution

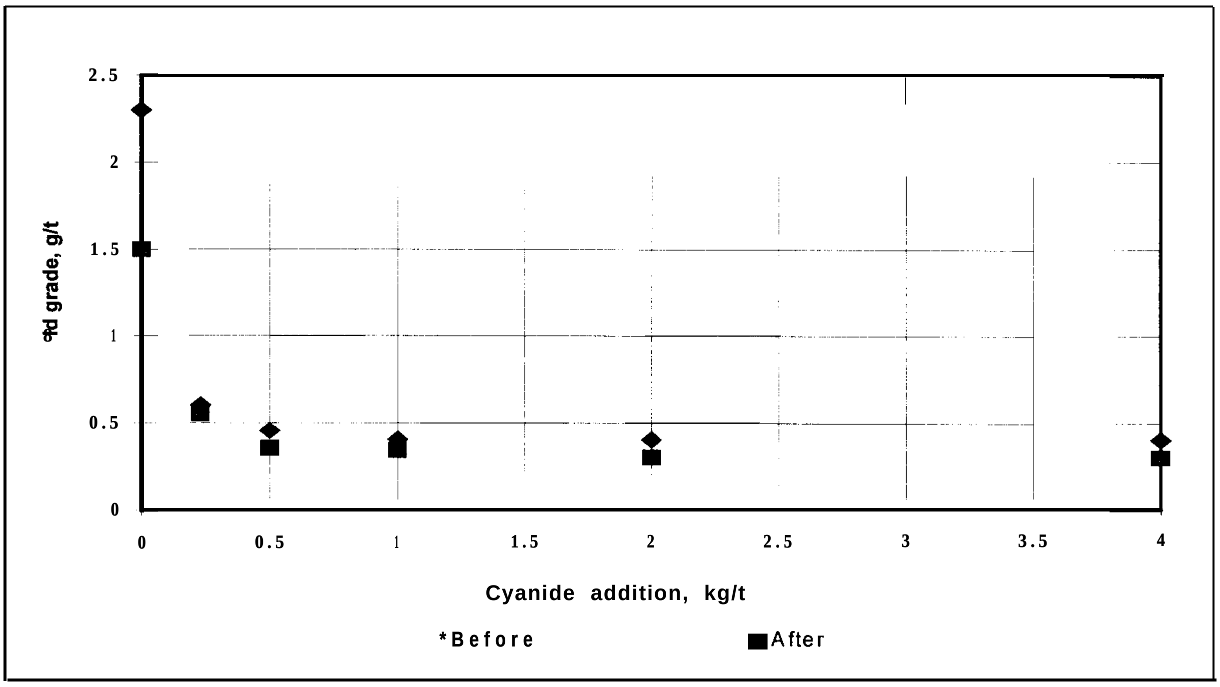

Figure 5
The effect of cyanide addition

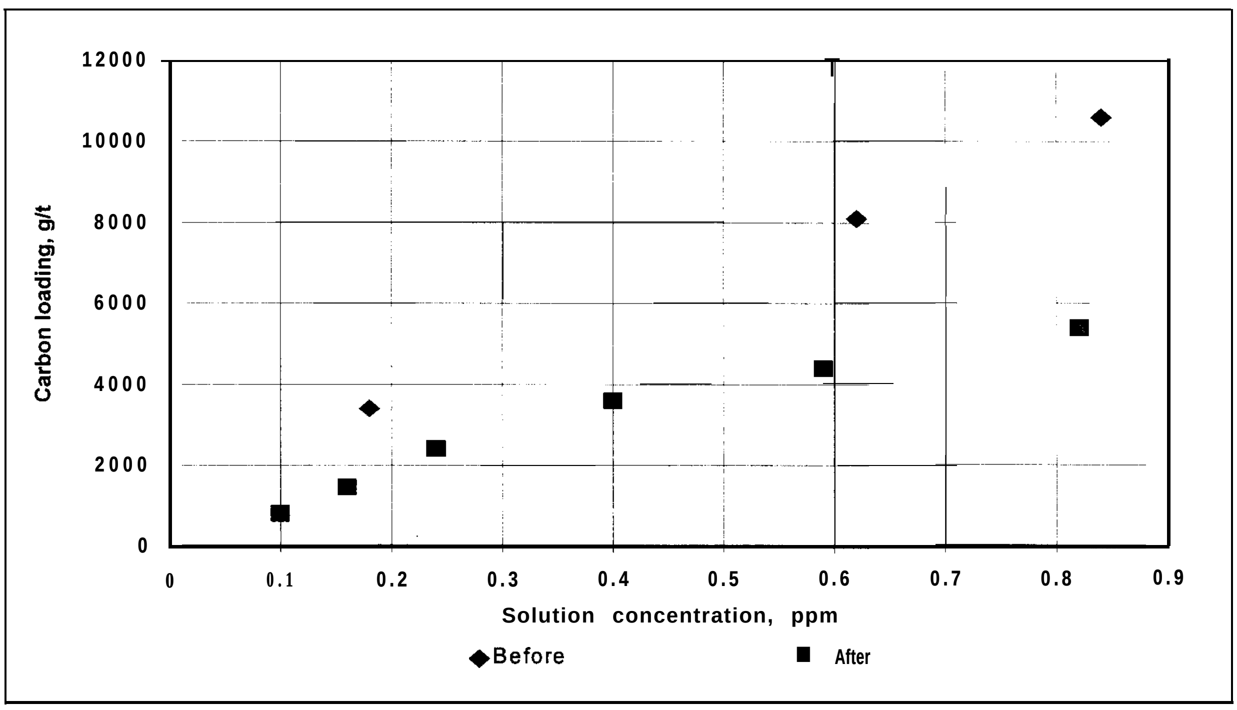

Figure 6
Th equilibrium isotherm

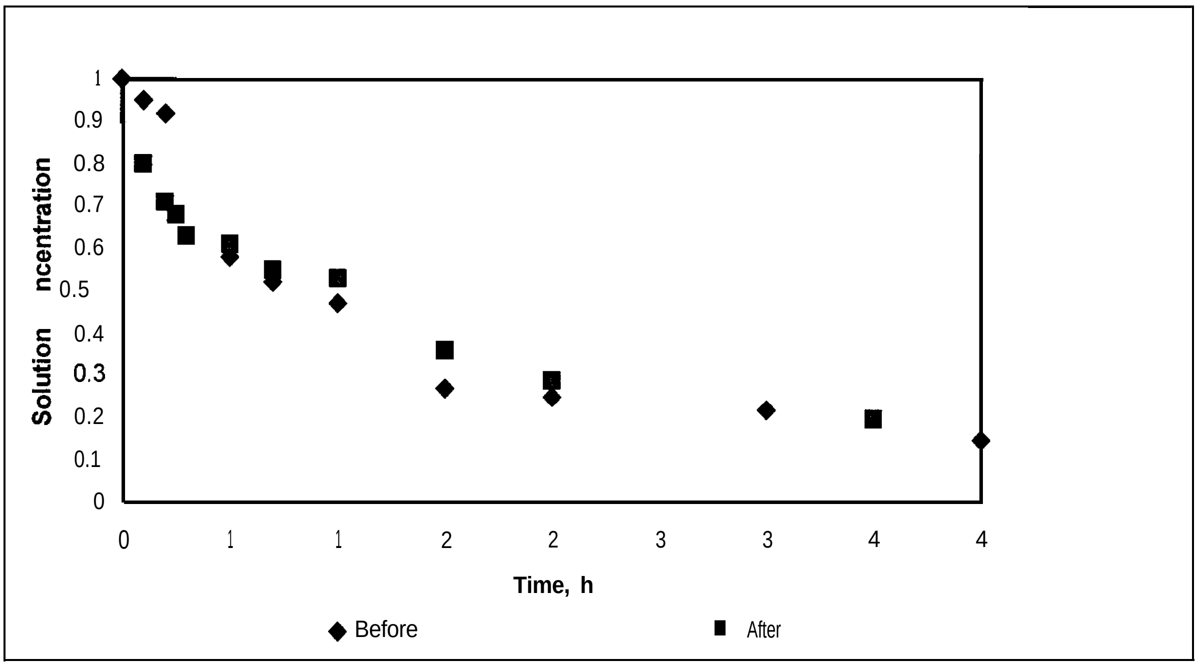

Figure 7
The rate of gold adsorption

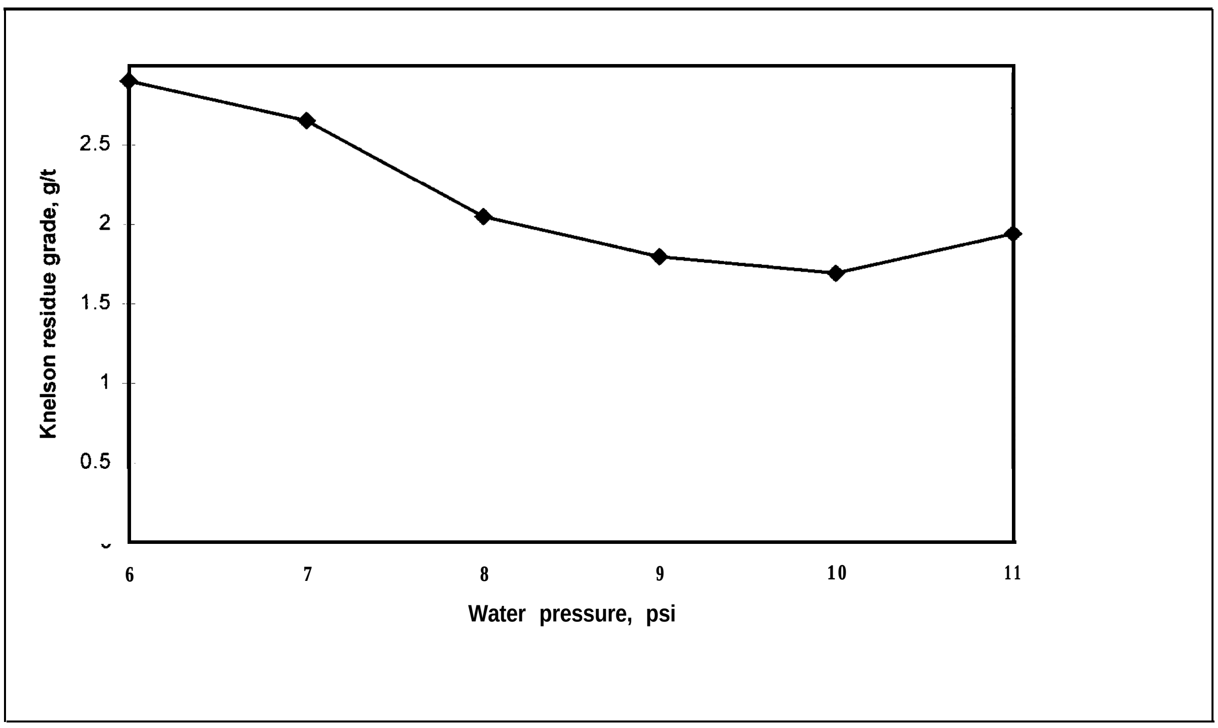

Figure 8
The effect of water pressure

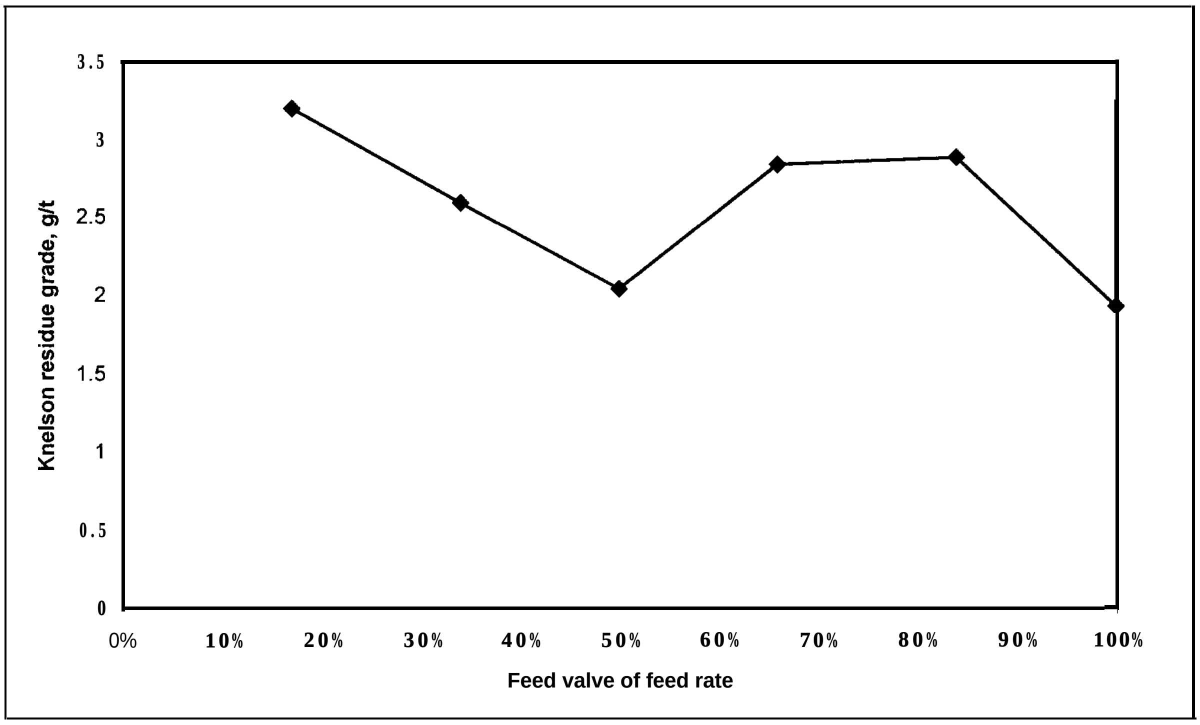

Figure 9
The effect of feed rate

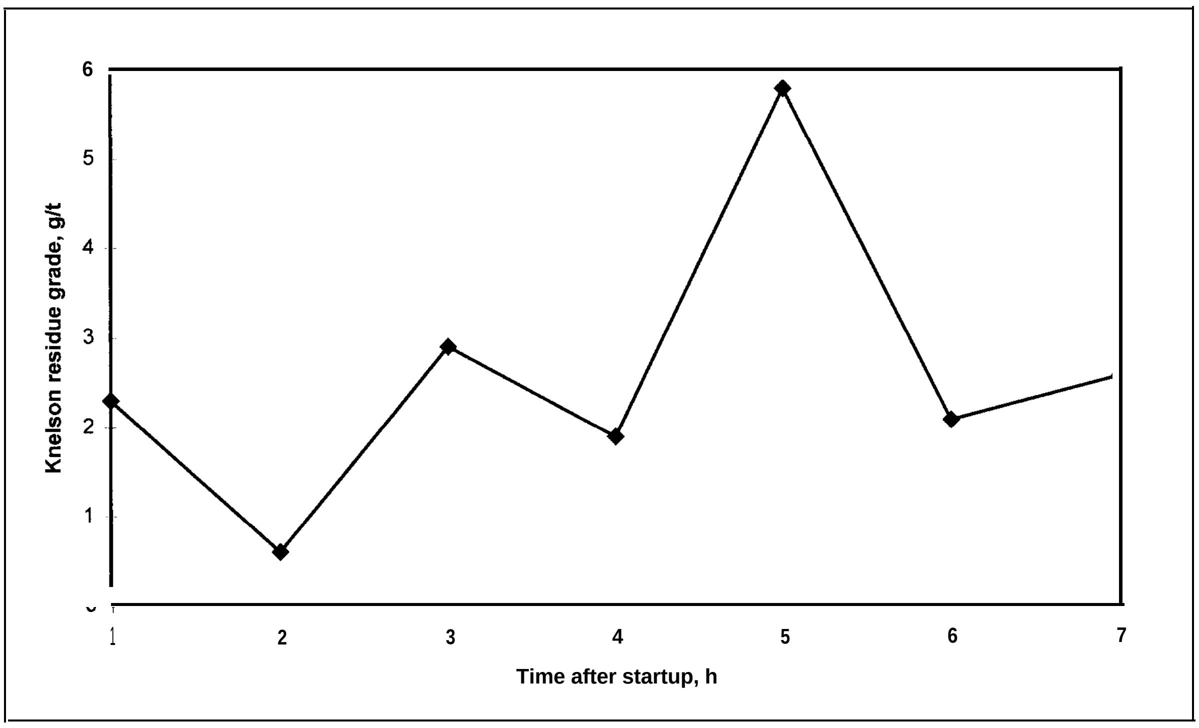

Figure IO
The effect of cycle time