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THE EFFECT OF AGITATION IN THE CYANIDATION OF GOLD ORES

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B. H. LUCAS AND W. A. GOW

EXTRACTION METALLURGY DIVISION

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THE EFFECT OF AGITATION IN THE CYANIDATION OF GOLD ORES

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SUMMARY

Mill feed from Lamaque Mining Company Limited was subjected to cyanide leaching by passing solution at various flow rates through a static bed of the ground ore. Standard beaker leach tests, using a laboratory mechanical stirrer, were carried out to allow a comparison to be made with the rate of leaching using conventional agitation.

The results obtained from this study indicated that there was no significant increase in the overall rate of leaching attributable to the increased rate of flow of the leach solution past the ore particles. At a contact time of 6 hours the percentage extraction of gold from the ore was 77.1% for a solution velocity of 10 cm per minute and 78.1% for a velocity of 60 cm per minute. A contact time of 24 hours yielded percentage extractions of gold which were 87.4 at 10 cm per minute solution velocity and 88.1 at 60 cm per minute. Conventional beaker leaching employing mechanical agitation gave essentially the same extraction rates as those indicated for static bed leaching.

It was concluded that the overall rate of cyanide leaching of gold from an ore was independent of solution velocity relative to the ore particles in the range of velocities studied.

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* Scientific Officer and ** Head, Hydrometallurgy Section, Extraction Metallurgy Division, Mines Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

INTRODUCTION

In the process for recovering gold from its ores by the cyanide process, the dissolution of the gold is generally effected in air-lift agitators. In these agitators the ore particles are lifted to the surface of the slurry in the agitator tank by a centrally located air-lift, and then settle by gravity to the bottom of the tank where they are once more picked up by the air-lift. It is apparent that the relative velocity between ore particles and solution in this type of agitator is very low. J.J. Oldshue has reported (1), that in a slurry of 50% solids or higher, the settling velocity of a particle through the solution was one foot per minute or less.

Since many investigators (references 2 to 9) have shown that the dissolution rate of gold in cyanide solutions is diffusion controlled, the question arises as to whether a high speed mechanical agitator might not be a more efficient reactor than the air-lift type usually used. If the dissolution rate could be increased appreciably by more vigorous agitation, total agitator capacity could be reduced with accompanying reductions in the size of the mill building and in building heating costs. No reference was found in the literature to work where the dissolution rates of gold from ores in air-lift and mechanical agitators were quantitatively compared.

This paper describes work in which the overall dissolution rate of gold from an ore in an air-lift type agitator was simulated by forcing the leaching solution through a static bed of ore at controlled flow rates. The flow rates were controlled to give solution velocities relative to the ore of 10, 15, 30 and 60 cm/min. These velocities were in the order of the settling velocities of ore particles in slurry according to Oldshue[1]. Finally a comparison was made of the overall dissolution rates observed in the static bed tests with those obtained in a high speed agitator.

EXPERIMENTAL METHODS

Feed

Gold ore from the Lamaque Mining Co. Limited was selected for the test program. The reasons for the choice of this ore were the low level of impurities such as pyrrhotite, chalcopyrite and tellurides and the fact that the way in which the gold occurred was typical of most Canadian ores.

Average chemical analyses of the original head sample will be found in Table 1.

The Mineralogy Section of the Extraction Metallurgy Division reported[10] that in the minus 100 mesh plus 150 mesh fraction of a sample of Lamaque ore, pyrite constituted over 91% of the metallic minerals present, iron oxides, approximately 8% and chalcopyrite approximately 0.5%. Native gold was observed in some pyrite grains.

TABLE 1

Chemical Analysis of Lamaque Ore
(Au = 0.14 oz/ton)

EMD Sample 5/63-10	Per cent
CO_2 (evol.)	3.86
Fe	4.42
S (total)	0.78
Cu	0.012
Te	0.0011

Feed Preparation

Thirty pounds of ore were blended and then riffled into 1150-g batches suitable for grinding in a standard laboratory pebble mill. The average screen analysis of the nine batches of Lamaque ore used in the test work is given in Table 2. The minus 200 mesh fraction ranged from 71.6% to 76.0%.

TABLE 2

Average Screen Analysis - Cyanide Leach Feed

Particle Size	Per cent
+ 48 mesh	0.2
- 48 + 65 "	0.5
- 65 + 100 "	3.7
-100 + 150 "	9.6
-150 + 200 "	11.9
-200 + 325 "	20.8
-325	53.3
	100.0

After grinding, each of the 1150 g batches was riffled into lots of a suitable quantity for the test procedure. Each set of test conditions were done in quadruplicate.

Test Procedure

A diagram of the test apparatus is shown in Figure 1. A layer of 130 g of HCl-treated, minus 48 mesh plus 65 mesh quartz particles was placed uniformly on the filter cloth of a 5 1/4 inch ID pressure filter. Seventy grams of ore, ground to minus 65 mesh and blended with 70 g of minus 48 mesh plus 65 mesh quartz, was carefully placed on the quartz layer. Each layer was 1/4 inch in depth. The quartz was added to prevent pressure build-up in the system which would result from packing of the finely-ground ore. The final ore residue was readily separated from the diluent quartz by wet screening.

Fresh leach liquor was prepared from reagent grade NaCN and $Ca(OH)_2$, dissolved in distilled water. The concentrations chosen to approximate current plant practice were 0.60 lb NaCN per ton solution and 1.20 lb CaO per ton solution. The leach solution was clarified, saturated with air, and charged to the closed leaching circuit. Care was taken not to disturb the ore-quartz bed in the filter unit. Trapped air was discharged through the air-bleed valves so that the system was completely flooded.

Additional fresh liquor was supplied from the feed liquor holding bottle to replace withdrawn sample volumes. The compressed gas source, used to transfer fresh liquor, could also provide for back-flushing of the bed to relieve pressure build-up. The volume of the liquor recycle tank was selected so as to give a large solution to solids ratio in the leaching circuit, thus keeping the change in concentration of the liquor constituents to an insignificant level.

For comparative purposes, beaker leach tests, with high speed mechanical stirring were also done. Two hundred gram lots of ore were leached at 50% solids in a 400 ml beaker. A 1 3/4 inch marine impeller was rotated at 400 rpm. Temperature and retention were the same as for the static bed tests.

The test started when the ore was first wetted with cyanide liquor. The desired flow of liquor was maintained by the flowmeter. The leach liquor temperature was controlled at 22°C by the employment of adequate heat exchange capacity. At the completion of the run, the cake was washed with water at room temperature, wet-screened to remove the quartz, and the dried residue submitted for gold assay. Both fire assay and atomic absorption spectrophotometry methods were used for gold determinations.

RESULTS

The effects of solution velocity relative to the ore particles on both the gold residue assays and the gold extraction were studied at solution flow rates of 10, 15, 30 and 60 cm/min for leaching periods of 6, 12 and 24 hours. Quadruplicate tests were done on each set of leaching conditions. The results of the work are shown in Tables 3 and Figure 2.

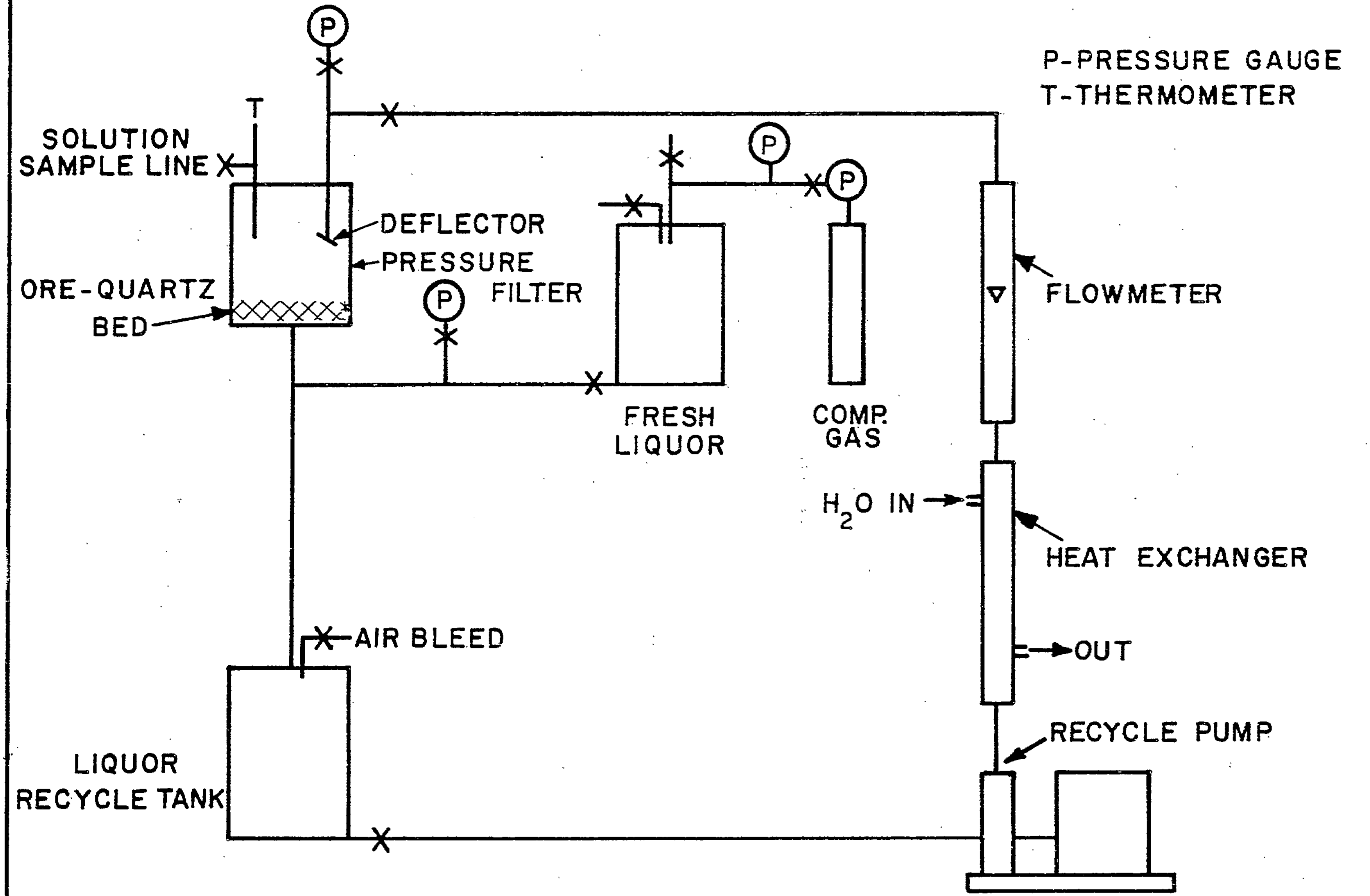

Figure 1: Test Equipment for Laminar Flow Leaching of a Static Bed of Gold Ore.

TABLE 3

Fixed Bed Cyanide Leaching - Lamaque Ore

Test Conditions and Results

Leach Conditions				Gold Assay (oz/ton			Gold Extraction
				Feed	Residue		
Contact	Velocity	Temp	Pressure		Mean	True Mean Range*	
(hour)	(cm/min)	(oc)	(psig)			±	(%)
6	10	22.7	2.2	0.135	0.031	0.021	77.1
	15	22.0	8.6	0.146	0.031	0.019	78.8
	30	22.0	6.8	0.135	0.031	0.005	77.1
	60	22.8	6.4	0.110	0.024	0.008	78.1
	Beaker	25.9	0.0	0.117	0.031	0.011	73.5
12	10	22.3	4.2	0.135	0.023	0.010	83.0
	15	22.1	5.7	0.129	0.026	0.019	79.8
	30	22.3	10.0	0.123	0.024	0.022	80.4
	Beaker	26.2	0.0	0.131	0.022	0.010	83.2
24	10	22.5	2.6	0.135	0.017	0.006	87.4
	15	23.9	4.0	0.133	0.013	0.005	90.2
	30	22.2	5.4	0.135	0.014	0.005	89.6
	60	22.3	6.2	0.110	0.013	0.005	88.1
	Beaker	26.4	0.0	0.141	0.013	0.008	90.8

* 95% confidence level

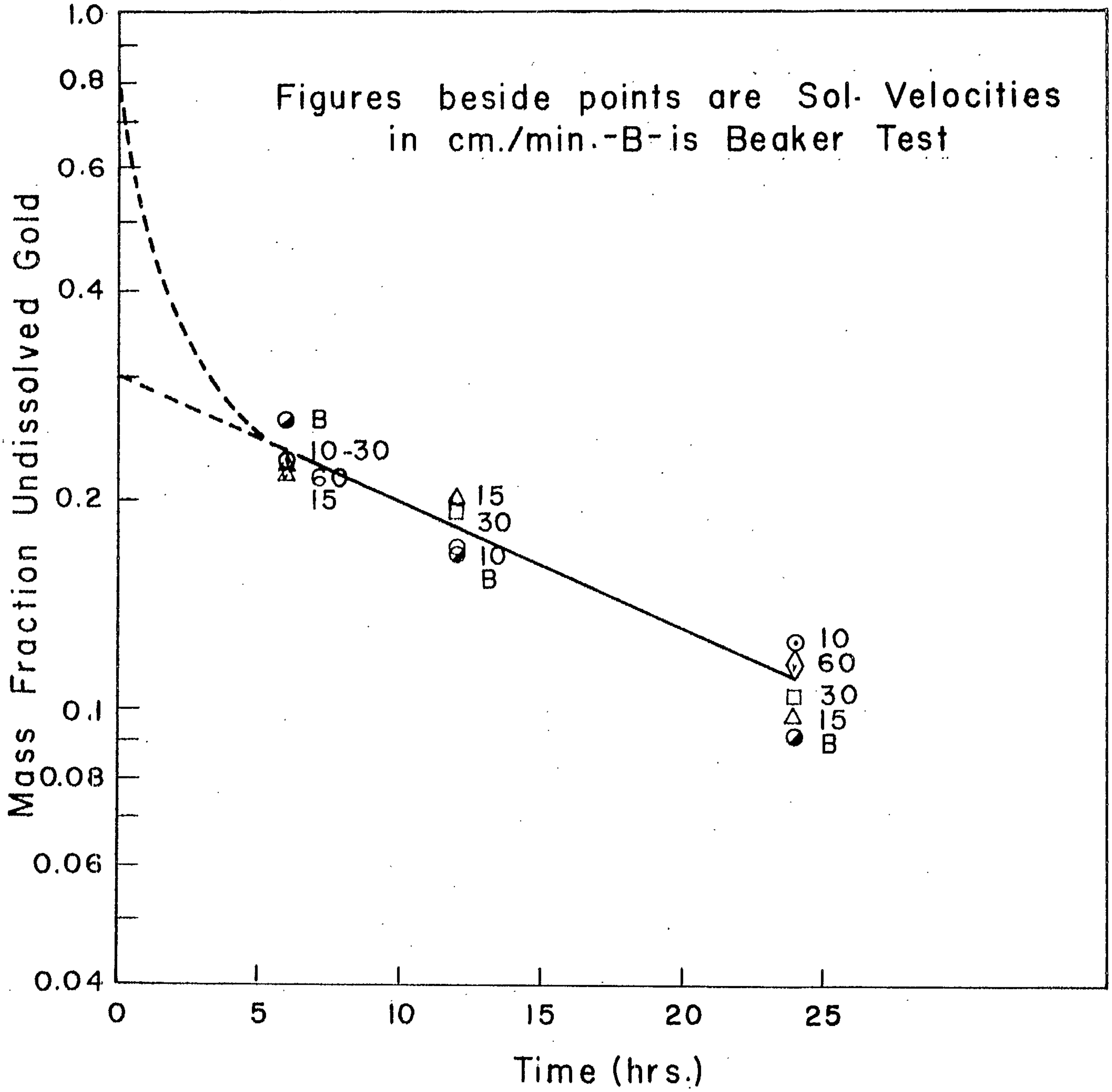

Figure 2: Comparison of Undissolved Gold Values After Leaching At Various Solution Velocities.

In Table 3 the leaching conditions, feed and residue assays and gold extractions are shown. The residue assays are shown as the mean values of the four tests done on each set of conditions with the 95% confidence level range. The range is a measure of the limits within which the true mean lies.

In the series where the leaching time was 6 hours, solution velocities of 10, 15 and 30 cm/min and the beaker test all resulted in mean residue assays of 0.031 oz Au/ton and extractions ranging from 73.5 to 78.8%. In the test when the solution velocity was 60 cm/min, the mean residue assay obtained was 0.024 oz Au/ton which was significantly lower than the 0.031 oz/ton obtained under the other leaching conditions tested. However, because of the low gold content of the feed to the tests where 60 cm/min flow rate was used the gold extraction obtained was not significantly different from those obtained with the other flow rates.

In the series where the leaching time was 12 hours, four sets of leaching conditions resulted in mean residue assays ranging from 0.022 to 0.026 oz Au/ton and extractions ranging from 79.8 to 83.2%. Again, the ranges obtained were high as compared to the mean residue values obtained. With 24 hours leaching time five sets of leaching conditions resulted in mean residue assays ranging from 0.013 to 0.017 oz/ton and extractions ranging from 87.4 to 90.8%. The ranges obtained in the 24 hour leaches were large compared to the mean values, but were not as large as those obtained in the 6 and 12 hour leaches.

The range in residue analyses obtained within each set of quadruplicate tests was wide as shown in Table 3 and Figure 2, thus indicating a low order of reproducibility in the test results. A study of the test conditions showed that the reproducibility of the test results was affected mainly by

(a) variability in the gold content of the feed material which could not be reduced in spite of the use of careful sampling techniques,

(b) variability of the solution temperature (21°C to 26°C) and the solution pressure across the static bed (2 to 20 psig),

(c) channeling in the static bed.

Further analysis of the above sources of experimental error showed that these conditions were independent of the solution velocity used and were randomly distributed throughout all the tests. Because of this it appeared that the ranges in residue analyses obtained for any set of quadruplicate tests were equally affected by the sources of experimental error, and that a statistical comparison of the distributions of the ranges by the F-test would provide a more significant comparison than a simple comparison of the mean residue analyses.

The results of this comparison are shown in Table 4. The results show that, except for two comparisons in the 6 hour leaches, the F-test could not detect a significant difference between the results obtained at different solution velocities at any given leaching time. This analysis shows that the distribution of results obtained for a given solution velocity at a

TABLE 4

Statistical Analyses by the "F" Test of Results From Fixed Bed Cyanide Leach Tests

Contact Time (hour)	Vel. cm/min	Mean of 4 Tests oz/ton	Mean Square (3 df)	Test No.	Significance of Variance Ratio at 95% Confid Level * between tests indicated									
					1:2	1:3	1:4	1:5	2:3	2:4	2:5	3:4	3:5	4:5
			$\times 10^{-6}$											
6	10	0.031	476	1	NS	S	NS	NS						
	15	0.031	287	2					S	NS	NS			
	30	0.031	19	3								NS	NS	
	60	0.024	75	4										NS
	Beaker	0.031	145	5										
12	10	0.023	93	1	NS	NS	NS							
	15	0.026	241	2					NS	NS				
	30	0.024	407	3								NS		
	Beaker	0.022	105	4										
24	10	0.017	57	1	NS	NS	NS	NS						
	15	0.013	23	2					NS	NS	NS			
	30	0.014	18	3								NS	NS	
	60	0.013	29	4										NS
	Beaker	0.013	69	5										

* Significantly different at ratio $\geq 9.28:1$

given leaching time is similar to that obtained for other solution velocities at the same leaching time. Expressed another way, the degree of reproducibility, experimental error and mean extractions obtained for sets of tests with the same leaching time were similar, and consequently on the basis of the results obtained there is no indication that solution velocity was a controlling factor in determining the overall gold extraction rate.

Analyses showed that the change in cyanide and lime concentrations of the recycle liquor as a test proceeded was not measurable. It was convenient, therefore, to use the solution repeatedly. Air was bubbled into the liquor before each test. Determinations of soluble oxygen in solution indicated that the liquor at the start of all leach tests was 100% saturated with oxygen. The oxygen content at the end of each test showed 96 to 100% saturation.

Analyses were also carried out on the leach solution to determine if there was an appreciable amount of impurities present. Impurities may result from the presence of metallic sulphides and oxides and from the use of stainless steel test equipment. However the high solution to solid ratio used in the work kept the impurity level to an insignificantly low level; for example the thiocyanate concentration of the leaching solution reached a maximum of 2 ppm.

The two methods employed for gold analysis of leach residues gave excellent agreement. It was possible, therefore, to obtain leach results, if required, on as little as 5 grams of ore. This quantity was the amount used for analysis in the atomic absorption spectrophotometry method.

DISCUSSION

The purpose of this investigation was to determine if the overall rate of gold dissolution from a gold ore using alkaline-cyanide solutions could be significantly increased by increasing the degree of agitation applied within practical and economic limits. The static bed procedure used in this work approximated the type of solution/ore contact obtained in the air-lift agitators usually used in gold milling operations. The beaker tests, on the other hand, approximated the type of turbulent agitation that would be obtained in a purely mechanical agitator.

This work showed that the static bed tests resulted in as rapid a gold dissolution rate as was obtained in a mechanical agitator where the rate of agitation was just enough to keep the ore particles in suspension in a pulp containing 50% solids by weight. In addition, Cathro and Walkley(8) demonstrated that increasing the degree of agitation in a mechanical agitator beyond the level used in this work did not result in an increase in the gold dissolution rate. This work, along with the results of Cathro and Walkley, provide a strong indication that the overall dissolution rate of gold from a typical ore is not diffusion controlled and that the less expensive air-lift agitator is as effective as more expensive mechanically agitated equipment.

Although these findings are not in agreement with the results obtained by other investigators whose data have shown that under certain conditions the rate of dissolution of gold from gold foil(1,2,3,4,5,6,7,8) is diffusion controlled, there is at least one important reason for this disagreement. Usually in an ore some of the gold occurs in very narrow veinlets in gangue so that as leaching proceeds the overall rate of dissolution will depend on the rate at which the active leaching agents are transported through the narrow fissure left by the gold already dissolved. It seems reasonable that this rate will be less than the diffusion rate as determined by gold foil experiments, and that it will not be significantly affected by the type of agitation used. There may be other reasons for the disagreement between the results obtained using gold foil and the results obtained in this work, but further conjecture here along these lines is somewhat irrelevant, since the main point here is that the overall rate of dissolution of gold from an ore apparently is not diffusion controlled and not why this should be the case. Consequently in designing agitators for a gold cyanidation plant, the type of agitation is not an important consideration in determining the contact times required to obtain economic overall gold extraction.

CONCLUSIONS

The velocity of the leach solution past the ore particles does not control the overall gold extraction rate. High speed agitation, therefore, is of no advantage in gold cyanidation. It could be considered that the velocities in conventional agitators are sufficient for maximum leaching rate which presumably is controlled by other factors.

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