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THE EFFECT OF AGITATION IN THE CYANIDATION OF GOLD ORES

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EXTRACTION METALLURGY DIVISION

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THE EFFECT OF AGITATION IN THE CYANIDATION OF GOLD ORES

by

B. H. Lucas* and W. A. Gow**

ABSTRACT

The effect of agitation on the leaching rate of gold from ore of the Lamaque Mining Company Limited was investigated. Leaching-solution velocities, relative to the ore particles, of from 25 to 150 cm per minute were studied by passing the solution at various flow rates through a static bed of the ground ore. The lowest velocity investigated was that occurring in an air-lift agitator. Along with the static-bed tests, other tests were made in which the slurry was stirred vigorously with a high-speed stirrer. These stirred tests were done to simulate high-speed agitation and were presumed to result in much higher velocities of solution relative to the ore than those used in the static-bed tests.

It was concluded that the rate of cyanide leaching of gold from this ore was independent of the solution velocity relative to the ore particles in the range of velocities studied. The practical significance of this is that the gold leaching rate from ore similar to that used in this work would be independent of the type of reactor used for leaching.

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Direction des Mines

L'EFFET DE L'AGITATION DANS LA CYANURATION DES MINERAIS D'OR

par

B.H. Lucas* et W.A. Gow**

RÉSUMÉ

Les auteurs ont étudié l'effet de l'agitation sur le temps de lessivage du minerai d'or de la compagnie Lamaque Mining Limitée. Ils ont étudié des vitesses relatives solution-minerai de l'ordre de 25 à 150 cm par minute, obtenues en faisant passer la solution à des vitesses différentes à travers une couche statique de minerai broyé. La vitesse la plus faible étudiée a été celle produite dans un agitateur à injection d'air. En plus de ces essais comportant des couches statiques, on en a effectué d'autres où les boues étaient vigoureusement brassées dans un agitateur à grande vitesse. Ces essais de brassage ont été effectués pour simuler l'agitation à grande vitesse et étaient présumées produire des vitesses relatives solution-minerai beaucoup plus élevées que celles obtenues lore des essais avec couches statiques.

Les auteurs ont conclu que le temps de lessivage de ce minerai au cyanure dans la gamme des vitesses étudiées ne dépendait pas de la vitesse de la solution par rapport aux particules de minerai. Il ressort de cette étude que le temps de lessivage de minerais de cette nature ne dépend pas du genre de réacteur utilisé.

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INTRODUCTION

In 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 are then allowed to 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 low. J.J. Oldshue has reported that in a slurry of 50 per cent solids, or higher, the settling velocity of a particle through the solution was one foot per minute or less (1).

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. No reference was found in the literature to work where the dissolution rates of gold from ores in air-lift and mechanical agitators were compared quantitatively.

This paper describes work in which the dissolution rate of gold from an ore in an agitator of the air-lift type 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 25, 37.5, 75 and 150 cm per minute.

The lowest of these velocities was in the order of the settling velocity of ore particles in a 50-per-cent-solids slurry according to Oldshue (1). Finally, the gold dissolution rate that might be expected from the use of high-speed agitation was determined by conducting tests in a beaker where a 50 per cent slurry was stirred by means of a high-speed stirrer.

PROCEDURE

Gold ore from the Lamaque Mining Company, Limited was selected for this test program. This feed material was chosen because it contained a low level of impurities, such as pyrrhotite and chalcopyrite, which are known to have a deleterious effect on the dissolution rate of gold in cyanide solutions. Mineralogical study of the feed material showed that the major metallic minerals present were pyrite and iron oxides. In addition, the only observed native gold occurred as inclusions in pyrite grains. A chemical analysis of the feed is given in Table 1.

Thirty pounds of the Lamaque bulk sample was crushed to minus 10 mesh and, after mixing, riffled into 1150-gram batches. These batches were ground as required in a laboratory Abbé pebble mill to about 75 per cent minus 200 mesh (Table 2). The ground batch was filtered and dried, after which four 70-gram lots were taken as feeds for four similar leach tests and a fifth lot was taken for chemical analysis.

A diagram of the test apparatus is shown in Figure 1. A layer of 130 grams of HCl-treated, minus 48-mesh plus 65-mesh quartz particles was placed uniformly on the filter cloth of a 5 1/4-inch I.D. pressure filter. Seventy grams of the ground ore was blended with 70 grams of minus 48-mesh plus 65-mesh quartz and the mixture placed on the lower quartz layer. Both the quartz layer and the ore-quartz layer were 1/4 inch thick. 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.

The alkaline cyanide leaching solution was prepared by dissolving reagent-grade sodium cyanide and calcium hydroxide in distilled water. The concentrations, chosen to approximate current plant practice, were 0.6 lb NaCN per ton solution and 1.2 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 leaching solution to replace solution taken for analysis was supplied to the circuit from the fresh-leaching-solution container, which was under pressure from a compressed-gas source. The volume of the liquor recycle tank was such as to provide a very high solution-to-solids ratio within the circuit. This was done so that the change in concentrations of the NaCN and CaO, as these compounds were consumed in leaching, would be insignificant.

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

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

Along with the static-bed tests, beaker tests were done in which the pulp was agitated using high-speed, motor-driven stirrers. In these tests, 200-gram lots of ore were leached at 50 per cent solids in 400-ml beakers. The stirrers used in these tests were 1.75-inch, marine-type impellers rotating at 400 rpm. The temperatures and retention times used were the same as those used in the static-bed tests and, as in the static-bed tests, each set of conditions was run in quadruplicate.

The void space of the bed was determined as being 41 per cent of the total bed area, which is in agreement with the literature (10, 11). On this basis the open cross-sectional area of the 5.25-inch-diameter bed was 8.68 sq cm.

The starting time of the test was taken to be when the ore-quartz bed was first wetted with leaching liquor. At the completion of the run the cake was washed with water, wet-screened to remove the quartz, and submitted for gold analysis.

RESULTS

The results of the test work are given in Figures 2, 3 and 4. Visual inspection of these figures indicates that the extraction rate of gold from this sample is not affected either by the flow rate used in the static-bed tests or by the high-speed stirring used in the beaker tests. It is also apparent from these figures that there is considerable scatter in the data, particularly in the six- and twelve-hour tests.

The observed scatter is attributed to the usual errors encountered in the sampling of gold ores (10). A statistical analysis of the results of the fourteen feed analyses done (one for each set of replicate tests shown in Figures 2, 3 and 4) shows that the relative standard deviation in these samples was $\pm$ 8.32 per cent (Table 3). We can expect that the same sampling error would be present in the individual feeds for the replicate tests, and to a similar or lesser degree in the sampling of the residues, depending on the extractions obtained. Under these conditions the degree of scatter shown in Figures 1, 2 and 3 could be expected.

In order to derive acceptable conclusions from the data in spite of the scatter, the results were analysed by calculating (using regression methods) the equation of the straight line that fitted the data most closely, and by calculating the correlation coefficients of the gold extractions on solution flow rates (12). The results of these calculations are shown in Figures 2, 3 and 4, along with the plots of the regression linear equations. Neither the correlation coefficients nor the coefficients of X in the regression equations are significantly different from zero, thus showing that the solution velocity (X) had no significant effect on the extraction rates based on the results of this work.

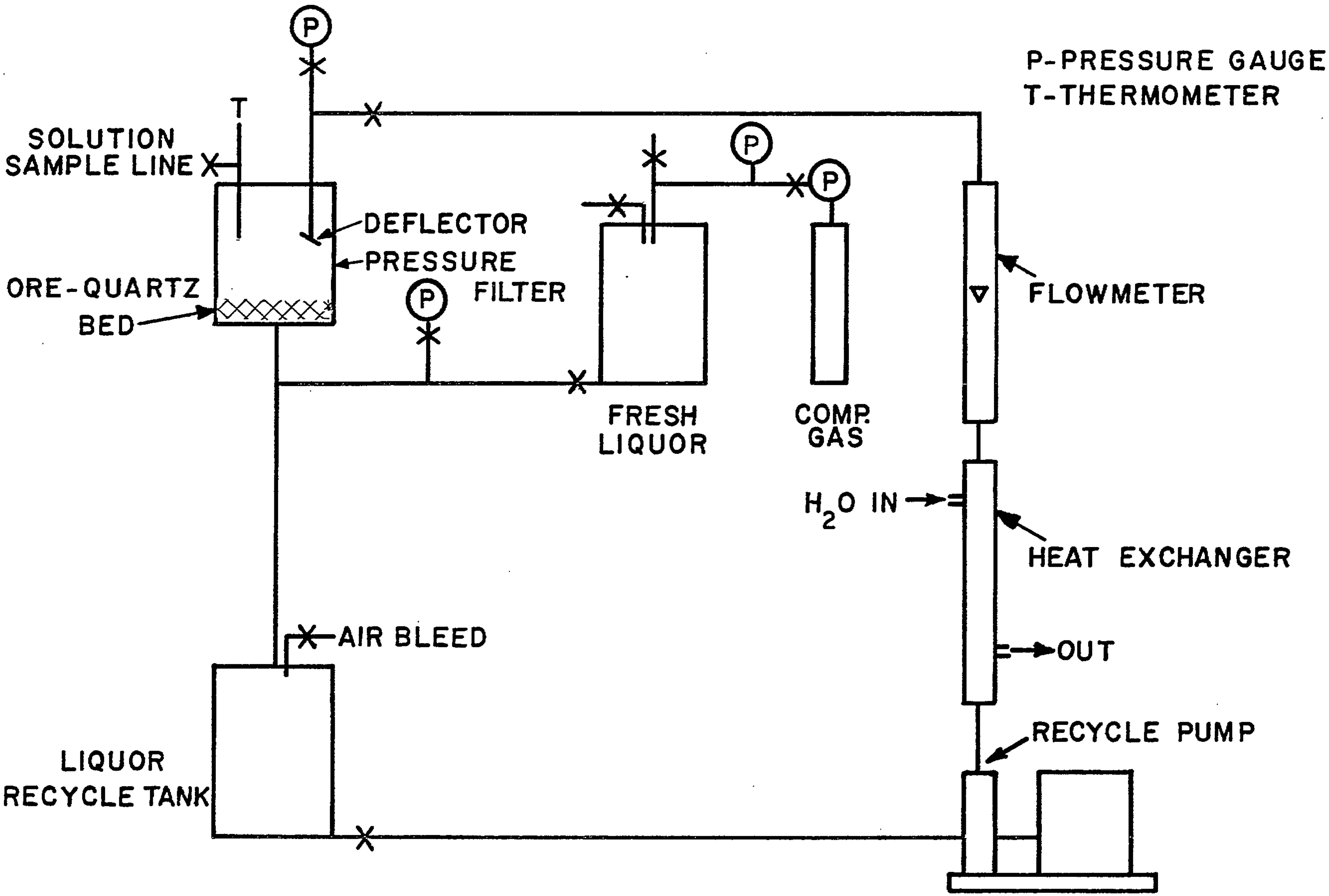

Figure I: TEST EQUIPMENT FOR STATIC - BED LEACHING OF GOLD ORE

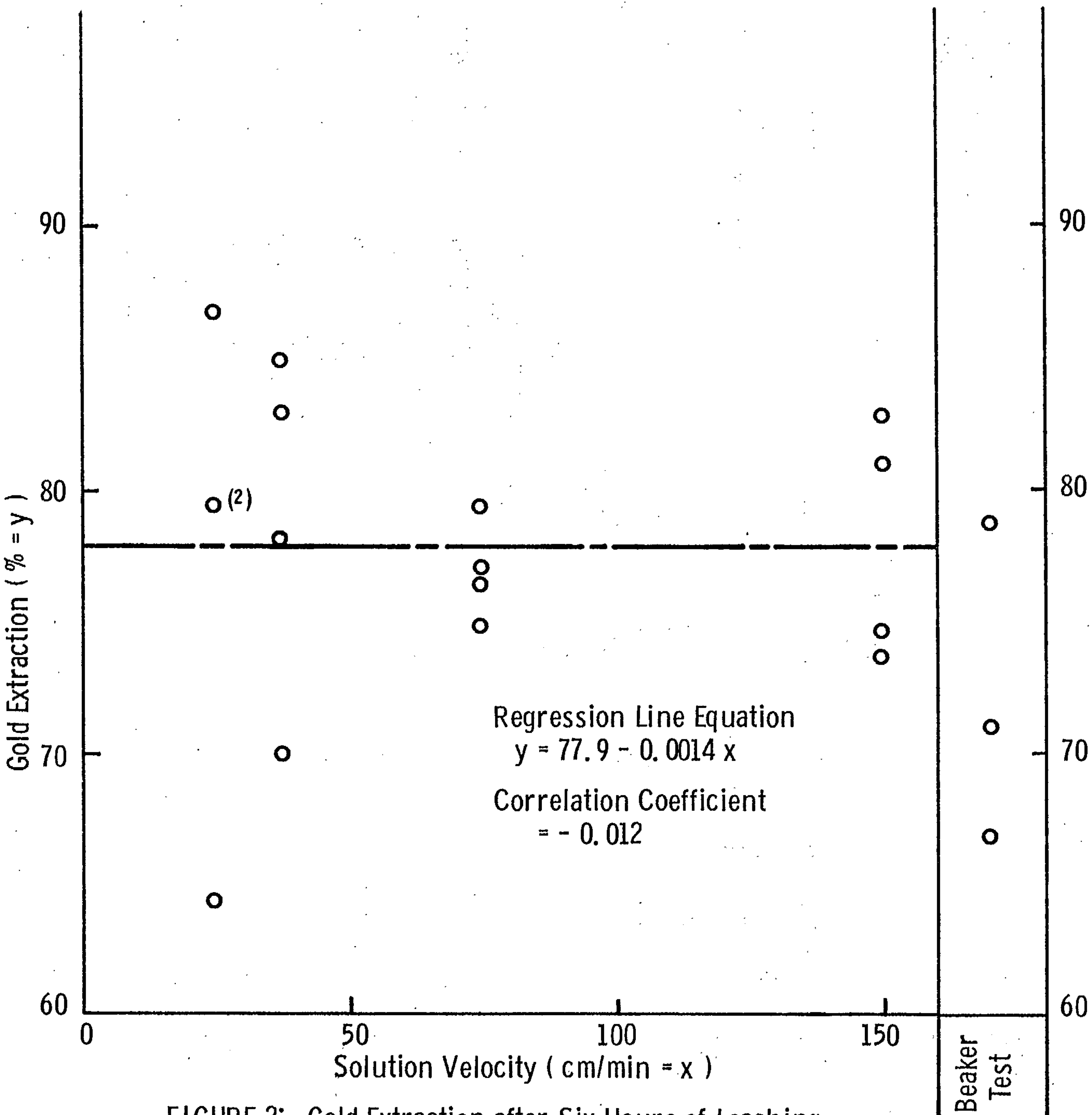

FIGURE 2: Gold Extraction after Six Hours of Leaching

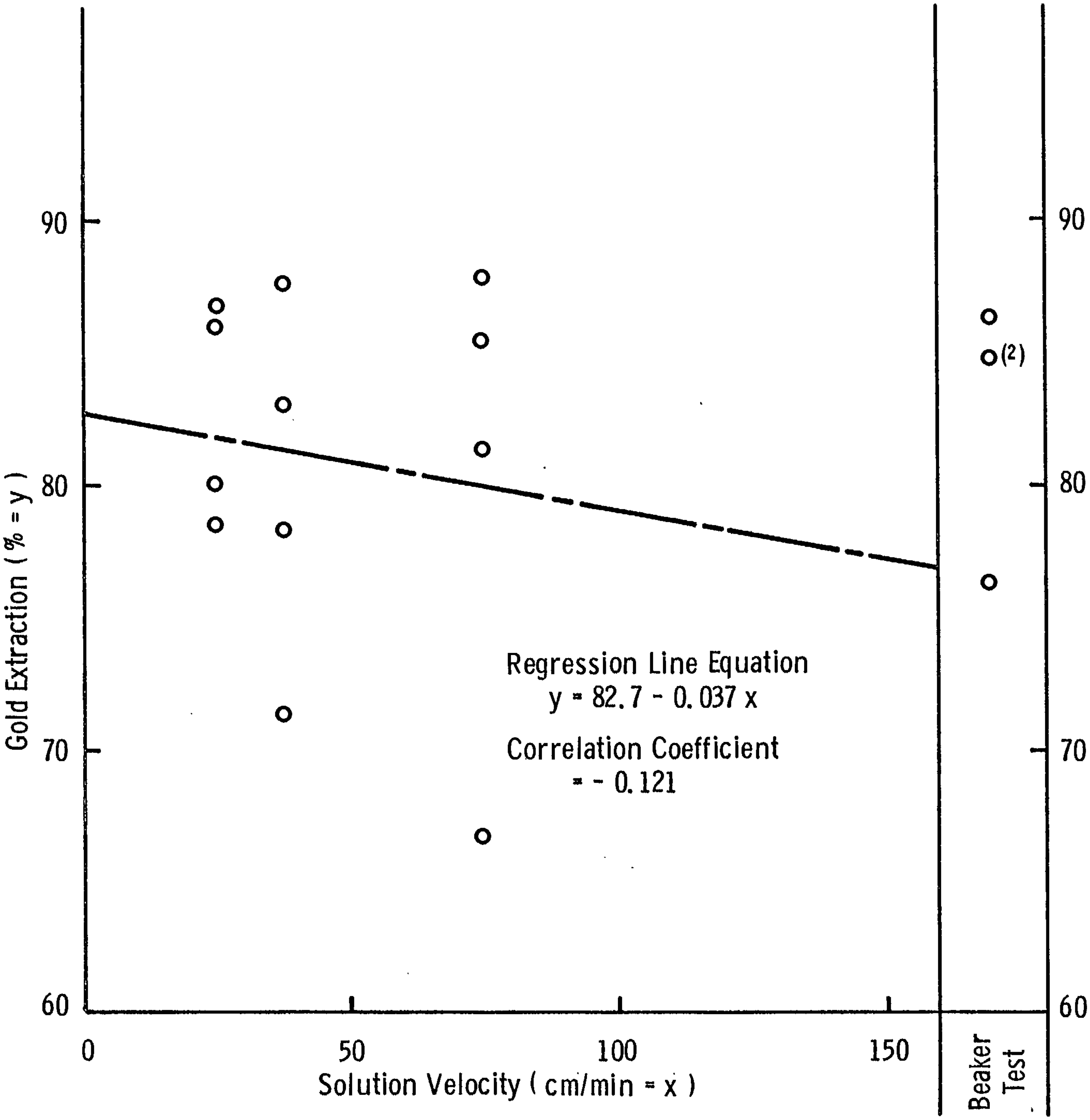

FIGURE 3: Gold Extraction after 12 Hours of Leaching

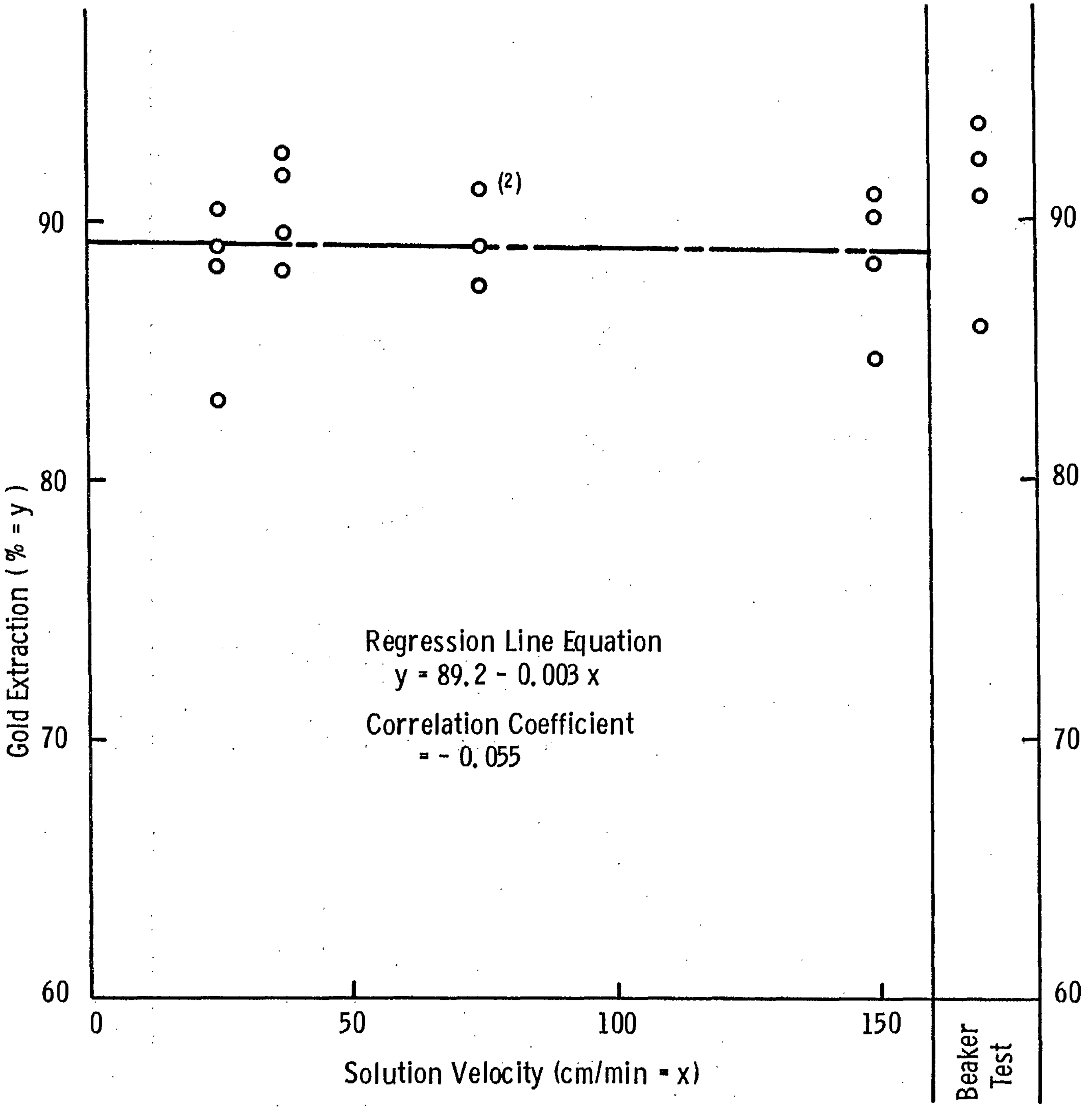

FIGURE 4: Gold Extraction after 24 Hours of Leaching

Since it has been shown that the velocity at which the leaching solution passes the ore particles had no effect on the gold extraction rate, all tests with the same retention time can be regarded as replicates, with the observed variation in the results being due to experimental error. Consequently, it was possible to calculate the statistics listed in Table 3. This table shows that the relative standard deviations of the feed samples and 6-hour residue samples are similar, while the relative standard deviations of the 12- and 24-hour residue samples decreased as the extraction obtained increased. This supports the comments made above regarding the scatter observed in the results.

TABLE 3

Statistical Data

Product	Mean	Standard Deviation	
		Actual	Relative*
Feed	0.1296 (Au oz/ton)	± 0.0108	8.32 per cent
6-hr residue	76.96 per cent	± 6.56	8.52 per cent
12-hr residue	81.52 per cent	± 6.08	7.46 per cent
24-hr residue	89.47 per cent	± 2.77	3.08 per cent

$$* \text{ Relative standard deviation} = \frac{\text{actual standard deviation}}{\text{mean}} \times 100.$$

Chemical 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 indicated that the liquor at the start of all leach tests was saturated 100 per cent with oxygen. The oxygen content at the end of each test was 96 to 100 per cent of saturation.

Chemical analyses were also carried out on the leach solutions to determine whether an appreciable amount of impurities was 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 concentration to an insignificant level; for example, the thiocyanate concentration of the leach solution reached a maximum of 2 parts per million.

DISCUSSION

The purpose of this investigation was to determine whether the rate of gold dissolution from an ore with alkaline-cyanide solutions could be affected significantly by the degree of agitation applied. The static-bed procedure used in this work approximated the type of solution-ore contact obtained in the air-lift agitators commonly used in gold-milling operations. The beaker tests, where high-speed stirring was used, approximated the type of turbulent agitation that would be obtained in a purely mechanical agitator.

These results showed that the static-bed tests gave as rapid a gold dissolution rate as was obtained with high-speed stirring. In addition, Cathro and Walkley (8) demonstrated that increasing the degree of agitation in a mechanical agitator beyond the level used here did not result in an increase in the gold dissolution rate. Our work, along with the results of Cathro and Walkley, provided a strong indication that the dissolution rate of gold from some gold ores is not controlled by the stirring rate. This is contrary to what might be expected with a diffusion-controlled reaction, such as the dissolution of gold in alkaline-cyanide solution has been shown to be (1 to 8). These results are not evidence that the reactions of interest in gold cyanidation are not diffusion-controlled; rather, the results simply show that where the gold occurs in an ore in narrow veinlets or inclusions in gangue, with only a small proportion of the surface exposed to the leaching solution, increasing the rate of stirring cannot affect the thickness of the diffusion layer, except possibly in the early stages of leaching.

CONCLUSIONS

The velocity of the leaching solution past the ore particles in the leaching of a low-grade gold ore did not affect the gold extraction rate. High-speed agitation, therefore, is of no advantage in gold cyanidation of such ores. Consequently, in choosing agitators for a gold cyanidation plant designed to treat ores similar to that used in this work, the type of agitation is not an important consideration in determining the contact times required to obtain economic overall gold extraction.

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REFERENCES

1. J.J. Oldshue, "Solid-Liquid Mixing in Hydrometallurgy", Unit Processes in Hydrometallurgy, Metallurgical Society Conferences, Vol. 24, Gordon and Breach, Science Publishers, Inc., New York, 1964, p.26.

2. V. Kudryk and H.H. Kellogg, "Mechanism and Rate-Controlling Factors in the Dissolution of Gold in Cyanide Solution", Journal of Metals, May 1954, pp. 541-548.

3. E. Beyers, "Some of the Factors Which Influence the Rates of Dissolution of Gold and Silver in Cyanide Solutions", Journal of the C.M.M. Society of South Africa, Vol. 36-37, August 1936, pp. 37-89.

4. H.A. White, "The Physics of Gold Solution", Journal of the C.M.M. Society of South Africa, Vol. 25, July 1934, pp. 1-11.

5. M. Kameda, "Fundamental Studies on Solution of Gold in Cyanide Solutions. II - On Equations of Reactions and Effects of Cyanide Strength and Other Variables on Dissolution Rate." Science Report of Research Institute, Tohoku University, Japan, Ser. A, Vol. 1 (1949), pp. 223-230.

6. K.J. Cathro, "The Effect of Oxygen in the Cyanide Process for Gold Recovery", Proceedings Austral. Inst. Min. Met., No. 207, 1963, pp. 181-205.

7. F. Habashi, "The Theory of Cyanidation", Transactions Soc. of Mining Engineers, September 1966, pp. 236-239.

8. K.J. Cathro and D.A. Walkley, "The Cyanidation of Gold", Report of Division of Chemistry, C.S.I.R.O., Melbourne, Australia, December 1961, p. 9.

9. E.L. Day, "Some Factors Influencing the Rate of Dissolution of Gold in Sodium Cyanide Solution", Proceedings of 4th Annual Meeting, Canadian Gold Metallurgists, Ottawa, January 1967.

10. A.F. Taggart, "Handbook of Mineral Dressing", Section 19, pp. 19 and 205. John Wiley and Sons, Inc., New York, 1950.

11. G.G. Brown et al., "Unit Operations", p. 214. John Wiley and Sons, Inc., New York, 1950.

12. K.A. Brownlee, "Industrial Experimentation", pp. 62 and 63. Chemical Publishing Co., Inc., New York, 1952.

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