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METALLURGICAL INVESTIGATION ON CARBONACEOUS GOLD BEARING ORE FROM AGNICO-EAGLE MINES LTD.

by

L.E. Shaheen
Ore Treatment Section
Extraction Metallurgy Division

~~Industrial Confidential~~

CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

OTTAWA

MINES BRANCH INVESTIGATION REPORT

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- ABSTRACT -

Cyanidation with and without pre-aeration, kerosene passivation, and carbon flotation has been studied on samples of carbonaceous gold ore from Agnico-Eagle Mines Ltd. Gold extractions of 85 to 92% have been obtained by two routes. Kerosene addition to the whole ore followed by cyanidation offers the simplest metallurgical approach. However, flotation of a carbon concentrate with pre-aeration-cyanidation of the flotation tails and a kerosene-cyanide retreatment of the small volume of carbon concentrate also yields similar gold extractions. This latter procedure, although more detailed, appears to be the most satisfactory at present, because of the number of pieces of rubber-lined equipment in the circuit which would be attacked by kerosene. Either route will eliminate the adverse effect of carbon adsorption of soluble gold and thereby increase the present gold extraction to an acceptable level.

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Normal rates of settling and filtering the pulp of the finely ground ore were obtained in the laboratory tests.

- INTRODUCTION -

The object of this investigation was to solve the metallurgical problems existing in the newly erected 800 TPD straight cyanidation plant at Joutel, Quebec. Three metallurgical problems were encountered in the mill. These were: low gold extraction, high reagent consumption and poor filtration. This report summarizes the results of a metallurgical investigation, initiated at the request of Mr B. G. McDermid, of Leslie Engineering, Don Mills, Ontario, consultants for Agnico-Eagle Mines Ltd., Joutel, Quebec.

During the initial plant tune-up period, considerable "graphite" was observed in the circuit. The "graphite" occurred as a large slick on the pulp surface in the agitators. A sample of this ground "graphite" was collected and found to contain 15 oz of gold per ton. It was therefore evident that a substantial amount of the gold extracted was being adsorbed by this amorphous carbon and was ending up in the waste residues. The high reagent consumptions during this period indicated the presence of cyanicides. Milling at a rate of 500 TPD plus has been continuous with gold recoveries in the order of 40-60%. The Division was contacted for assistance on February 11th, 1974.

- HISTORICAL DEVELOPMENT -

The property has had a long period of active development and considerable metallurgical research work has been done by reputable organizations. Comprehensive metallurgical investigations(1) were conducted by Metals Research Laboratories of Don Mills, for Kilborn Engineering Ltd., in September 1966. Work was also undertaken by Cyanamid of Canada Ltd. for microscopy and feasibility testing. Other samples were tested(2) by the Extraction Metallurgy Division, Mines Branch, Ottawa; the Quebec Department of Natural Resources, and Lakefield Research Ltd.

The samples previously tested were primarily diamond drill core rejects from the 9th and 15th levels. These samples yielded satisfactory gold extractions by conventional cyanidation practices, averaging 89%. This earlier work established some of the important parameters for ore treatment, many of which are still valid.

In 1969, some "graphitic" ore * from the 12th level was tested and gave rise for concern in the treatment of this ore. Straight cyanidation of this "graphitic" ore yielded only 15% gold extraction. With the addition of 1 lb kerosene/ton to the grinding circuit to inhibit the adsorptive capacity of the amorphous carbon, 60-90% gold extractions were effected by subsequent cyanidation. Cyanidation tests by other laboratories indicated reprecipitation (adsorption) of the gold because the gold extraction decreased with increased time of contact.

* containing amorphous carbon

From a review of this earlier work, it can only be concluded that the test work was comprehensive and valid for the samples received. The present difficulties at the property are believed attributable to three facts. First, the ore now being processed is not similar to the ore tested by the research establishments. Second, the grind necessary for maximum gold extraction is not being achieved or approached in the plant. Third, no provision was made for treating the "graphitic" gold ore in the mill circuit.

Amorphous carbon is now occurring in the ore in greater concentration, because of the present mining practice. Sub-level blast hole mining of substantially wider widths is being undertaken at this time, because this practice is a low-cost efficient mining method. However, this mining method introduces considerable deleterious mineral assemblages, both from the hanging and footwall zones, as well as waste inclusions between the parallel ore zones. The consequence is that the present ore differs with the previous ore on which the metallurgical test work was conducted.

— MINERALOGY —

The detailed mineralogy of ore samples received from Eagle Gold Mines in March 1969 was reported[3] by S. Kaiman, Mineralogy Section, Extraction Metallurgy Division.

In brief, the ore consists of fine grained banded greenish-grey rock containing quartz, calcite, chlorite and amphibole. The gangue minerals include siderite, dolomite and quartz. The pyrite occurs as fine euhedral grains and crystalline aggregates. Less than 1% pyrrhotite occurs in the ore, as well as trace amounts of chalcopyrite and arsenopyrite. The gold occurs as very fine irregular grains, usually as inclusions in the pyrite. The grains of gold are mainly smaller than 5 microns and rarely measure 10 microns in size. In one of the samples submitted for study, the presence of amorphous carbon was observed.

As reported by the mine geologist, the slaty sediments contain higher percentages of this amorphous carbon. These sediments constitute the waste inclusions occurring between the parallel ore zones within the stope boundaries.

Mineralogical investigations[3,4] were carried out on some of the ore samples and carbon flotation concentrates from this investigation. The occurance of gold in the present samples is generally similar to that observed and reported above.

- SAMPLE PREPARATION -

A total of 744 lb of samples were received in the week of February 12th-15th, 1974. This was composed of six separate samples, listed below:

-No. 9-2-35, 82 lb of ore from stope development on the 9th level;

-No. 12-2-35, 82 lb of ore from stope development on the 12th level;

-No. 15-2-33, 94 lb or ore from stope development on the 15th level;

-No. 12-2-35, SEDIMENTS, 16 lb of slaty sediments which occur as inclusions within the ore mass in the 12th level stope development;

-No. 15-2-33, SEDIMENTS, 16 lb of slaty sediments which occur as inclusions within the ore mass in the 15th level stope development;

- Mill Feed, 454 lb of rod mill feed to the cyanide plant representative of the ore for part of the month of February.

From the above samples of ore and waste rock, seven separate test samples or combinations were investigated:

1) 9th level ore.

2) 12th level ore.

3) 15th level ore.

4) Mill Feed.

5) A blend of the 9th, 12th and 15th level ore in equal percentages. This is referred to as a "blend of 3".

6) A blend of the 9th, 12th and 15th level ore in equal portions, totalling 80% of the charge plus a 20% addition of 12th level sediments.

7) A blend of the 9th, 12th and 15th level ore in equal portions, totalling 80% of the charge plus a 20% addition of 15th level sediments. (No. 6 and No. 7 blends are referred to as "blends of 4".)

All samples were stage-crushed and screened to minus 10 mesh separately. The screened ore was then blended to ensure homogenity and then riffled into 1150 gram charges for test work.

Table 1

Analysis of Gold-Bearing Samples as Received from Agnico-Eagle Mines Ltd.

Sample	Au oz/ton	Fe %	S %	CO_2 evol	CO_2 comb	C %	Cu %	Ni %	Ca %	Mg %
9-2-35 ore	0.20	25.5	9.16	21.4	21.4	0.00	.004	.009		
12-2-35 ore	0.47	24.0	16.5	12.4	14.3	0.52	.007	.007		
15-2-33 ore	0.29	20.3	11.4	14.3	14.3	0.00	.009	.007		
Mill feed	0.32	30.1	12.8	16.1	18.4	0.63	.006	.007		
Blend of 3 ores	0.30	23.3	12.5	16.4	17.1	0.19	.005	.007		
Blend of 4 (12th sediments)	0.23	21.4	10.3	15.2	15.8	0.16	.006	.007		
Blend of 4 (15th sediments)	0.29	21.0	10.3	14.5	14.8	0.08	.005	.008		
12-2-35 sediments	.005	15.3	2.46	10.9	12.0	0.30	.009	.009	2.76	1.83
15-2-33 sediments	.045	13.3	2.50	7.2	8.9	0.46	.009	.009	2.46	1.76

The mill feed and the 12th level ore have the highest carbon contents of the samples tested. It is interesting to note that high carbon contents also exist in the barren slaty sediments from the 12th and 15th levels, which are waste inclusions within the stope boundaries.

Four options were considered worthy of investigation in the treatment of the ore:

1) Straight Cyanidation,

2) Pre-aeration and Cyanidation.

3) Kerosene Addition and Cyanidation, and

4) Flotation and Cyanidation.

The various tests conducted are discussed in this report in accordance with the list of options outlined. As mentioned previously, considerable test work conducted in the past established several important parameters. As a consequence, a number of the variables were not considered for further investigation. The most important problems to be resolved in this work are:

a) To effectively remove or inhibit the carbonaceous material in the ore from adsorbing the gold.

b) To prevent the cyanicides dissolving and thereby minimize the high consumption of reagents.

c) To determine the settling and filtration characteristics of the pulps.

- TEST PROCEDURES -

The basic test procedure for cyanidation was used throughout the investigation, with minor variations. 1150 grams of minus 10 mesh ore was ground to 97% minus 325 mesh in a 10" laboratory ball mill. The grind time was established at 60 minutes. The ground charge was filtered and a head sample removed. Filter cake, equivalent to 1000 grams dry weight, was placed in an open 2 litre beaker and repulped with water to 50% solids. The pH was then adjusted to 12.0 with CaO and 2.0 lb NaCN/ton solution were added initially. The reagent concentrations were maintained at regular intervals, at 1.0 lb/ton solution each of NaCN and CaO, as determined by titration. Aeration was provided by sparging low pressure air through a fritted glass tube submerged in the pulp. Gentle aeration of the pulp was practiced. The cyanidation period was 24 hours, after which the pulp was filtered and washed thoroughly.

In the straight cyanidation series of tests, the whole ore was cyanided directly for 24 hours.

When pre-aeration cyanidation series of tests were conducted, the basic procedure was followed in making the repulp charge to 50% solids. The pulp was aerated with or without lime present for specified periods of time, followed by cyanidation for 24 hours.

In the kerosene addition-cyanidation series of tests, the same basic procedure was followed. Grinding, dilution to 30 or 50% solids, agitation of the pulp by either high speed or medium speed mechanical agitation in a baffled beaker and addition of 1 lb kerosene per ton solids. Retention for passivation was kept at 1 hour, followed by cyanidation for 24 hours.

In the flotation series of tests, a 600 gram size Fagergren flotation machine was used. The ground ore was repulped and diluted in the flotation cell to either 20 or 30% solids. Conditioning was done for 4 minutes with 0.2 lb pine oil per ton of solids, followed by flotation of the carbon concentrate for 4 minutes. A second period of conditioning and flotation for the same time intervals followed. The collected concentrates were filtered and analysed. The flotation tails were allowed to settle, and then were pre-aerated, and cyanided at 50% solids for 24 hours.

- RESULTS -

I. Straight Cyanidation

Four tests were run to determine the relationship between retention time and gold extraction. The results are listed in Table 2 below.

Table 2

Gold Extraction and Reagent Consumption versus Time

Test #	Sample #	% Au Extraction at various times				Reagent Consumption in lb/ton solids							
						2 hr		4 hr		20 hr		24 hr	
		2 hr	4 hr	20 hr	24 hr	NaCN	CaO	NaCN	CaO	NaCN	CaO	NaCN	CaO
AE-5	9-2-35	<3.5	5.1	32.3	85.9	4.0	11.2	6.0	14.4	14.0	32.7	14.0	32.7
AE-27	12-2-35	1.8	14.3	89.3	89.3	4.0	4.56	5.4	6.0	5.70	8.12	5.7	9.12
AE-28	15-2-33	21.3	81.5	81.5	85.0	4.0	4.68	5.0	5.74	5.0	7.56	5.0	8.64
AE-13	Mill feed	25.1	56.4	90.2	90.2	6.0	7.4	6.5	7.4	7.0	10.5	7.0	12.2

The results in Table 2 show that the four samples tested had varying dissolution rates. The 9th level ore gave extremely high lime and cyanide consumptions. Maximum gold extraction from this ore was not effected until the 22nd to 24th hours, when the pH stabilized and the specified free cyanide and lime levels were able to be maintained constant. Satisfactory gold extractions were obtained from all samples tested. No reprecipitation of gold was indicated by the analysis of test products.

II. Pre-aeration-Cyanidation

The pre-aeration-cyanidation tests are discussed under the following headings:

a) Effect of grind on gold extraction.

b) The use of lime during pre-aeration.

c) Pre-aeration time.

a) Effect of Grind on Gold Extraction and Reagent Consumption

Six tests were performed to examine the effect of grind on gold extraction and reagent consumption. The 15th level ore was used in this series because it responded well to pre-aeration-cyanidation practice. Pre-aeration in this test series was conducted for 2½ hours at 50% solids. A ½ hour liming period and pH adjustment followed, after which cyanidation was conducted for 24 hours. The results are tabulated in Table 3 below.

Table 3

The Effect of Grind in the Pre-aeration-Cyanidation of 15th Level Ore from Agnico-Eagle Mines

Test #	Grind			% Au Extraction	Reagent Consumption lb/ton ore	
	Time in minutes	% minus 325 mesh	% minus 10 micron		NaCN	CaO
AE-31	20	57.3	19.4	77.6	2.7	6.06
AE-32	30	77.5	25.8	81.8	2.7	6.80
AE-33	40	92.5	33.9	83.3	2.7	6.56
AE-34	50	96.5	38.6	84.3	2.9	6.24
AE-35	60	98.2	44.4	84.9	3.10	10.0
AE-36	120	99.6	68.1	87.7	5.90	16.8

Table 4

Complete Screen and Cyclosizer Analysis
on the Six Grinds Reported in Table 3

Size	AE-31 20 min. grind	AE-32 30 min grind	AE-33 40 min. grind	AE-34 50 min. grind	AE-35 60 min. grind	AE-36 120 min. grind
+ 48	3.9					
+ 65	1.8					
+ 100	4.2	0.6				
+ 150	8.6	2.2	0.1	0.3	0.4	
+ 200	12.5	7.4	1.6	0.6	0.4	0.3
+ 325	11.7	12.3	5.8	2.6	1.0	0.1
+ 37 μ	9.0	10.4	8.3	5.9	3.9	0.6
+ 29 μ	8.2	11.6	12.2	9.9	7.5	1.0
+ 20 μ	7.9	11.7	14.7	14.8	13.7	4.2
+ 14 μ	8.2	11.6	15.2	17.5	18.2	13.4
+ 10 μ	4.6	6.4	8.2	9.8	10.5	12.3
- 10 μ	19.4	25.8	33.9	38.6	44.4	68.1
	100.0	100.0	100.0	100.0	100.0	100.0

The results in Table 3 show that grinding to finer than 97% minus 325 mesh is required to give gold extractions of 85%, or greater.

b) The Effect of the Presence of Lime during Pre-aeration

Only one test of a preliminary nature was conducted in which 4.0 lbs of CaO/ton ore were added to the ground pulp and pre-aerated for 20 hours prior to cyanidation.

Table 5

Effect of the Presence of Lime during Pre-aeration-Cyanidation of 15th Level Ore

Test #	Sample #	Grind %-325	Pre-aeration lb CaO/ton		24 hr Cyanidation		
			at start	at finish	Reagent Consumption lb CaO/ton	Reagent Consumption lb NaCN/ton	% Au Extraction
AE-1	15-2-33	97	4.0	0.0	13.8	2.88	86.2

The results of AE-1 indicate that all of the lime added was consumed during the pre-aeration period. Therefore, in an attempt to reduce reagent consumption, it was decided that the reagents would not be added until the apparent oxygen demand of the pulp was satisfied.

c) Pre-aeration Time

A Corning digital pH meter, model 110, was used in conjunction with a Hewlett Packard 680-M strip-chart recorder to measure and record the redox potential of the pulp when air was continuously being sparged into the pulp through a fritted glass tube.

It was evident from the graph produced that the redox potential was stabilized after about 2½ hours of aeration in the absence of lime.

A series of tests was then done to determine what advantages pre-aeration-cyanidation had over straight cyanidation. The results of these tests are shown in Table 6.

Table 6

A Comparison of Results between Pre-aeration-Cyanidation and Straight Cyanidation

Test #	Sample #	Hours pre-aeration	Hours cyanidation	% Au Extraction				Reagent Consumption lb/ton ore							
				2 hr	4 hr	20 hr	24 hr	2 hr NaCN	2 hr CaO	4 hr NaCN	4 hr CaO	20 hr NaCN	20 hr CaO	24 hr NaCN	24 hr CaO
AE-5	9-2-35	Nil	24	<3.5	5.1	32.3	85.9	4.0	11.2	6.0	14.4	14.0	32.7	14.0	32.7
AE-6	9-2-35	2½	24	78.3	78.3	78.3	87.5	2.8	8.0	3.6	9.5	3.6	14.6	3.6	15.4
AE-27	12-2-35	Nil	24	1.8	14.3	89.3	89.3	4.0	4.56	5.4	6.0	5.7	9.1	5.7	9.1
AE-30	12-2-35	2½	24	1.4	17.0	83.9	86.0	4.0	4.7	4.8	7.5	5.3	11.4	5.3	11.5
AE-28	15-2-33	Nil	24	21.3	81.5	81.5	85.0	4.0	4.7	5.0	5.7	5.0	7.6	5.0	8.64
AE-29	15-2-33	2½	24	22.2	65.6	78.1	84.3	3.6	4.8	3.9	7.5	4.1	10.0	4.1	11.4
AE-13	Mill feed	Nil	24	25.1	56.4	90.2	90.2	6.0	7.4	6.5	7.4	7.0	10.5	7.0	12.2
AE-14	Mill feed	2½	24	7.4	49.3	83.3	89.4	5.0	8.6	6.5	10.9	6.5	11.2	6.5	11.5

The results of Table 6 show that, with three of the four samples tested, pre-aeration offered little advantage. However, in tests AE-5 and AE-6 with 9th level ore, the benefit of pre-aeration was dramatic. Cyanide consumption was reduced by 74% and lime by 47% over what was consumed during straight cyanidation of this particular ore sample. The elements that exist in the 9th level ore that differentiates it from the others in being a high reagent consumer are not definitely known at this time. However, higher ratios of siderite to silica and siderite to sulphides are known to exist in the 9th level ore. The pregnant solution from test 5, done without pre-aeration, had substantially higher concentrations of ferro-cyanide than in test 6, which was pre-aerated.

III. Kerosene Addition-Cyanidation

To inhibit the adsorptive capacity of carbon for soluble gold, kerosene in the amount of 1 lb/ton ore, is generally added to the grinding circuit where the new exposed surfaces are produced. Previous test work showed that 60 to 90% of the gold was extracted by cyanidation when kerosene was added to passivate the carbon surfaces.

Six tests were conducted to note the effect of kerosene added to the pulp after grinding and cycloning. The results of this test series is shown in Table 7.

Table 7

The Effect of Kerosene Passivation on Gold Extraction of Agnico-Eagle Mines Ore

Test #	Sample #	Passivation			Cyanidation		Consumption		% Au Extraction
		Rpm of Mixer	Type of Vessel	% Solid	% Solids	Reten-tion hr	NaCN lb/ton	CaO lb/ton	
AE-2	12-2-35	1700	Fag.cell	30	30	24	3.88	12.8	90.5
AE-17	Mill feed	600	Baffled	50	50	24	3.6	9.5	91.2
AE-37	9-2-35	600	Beaker	50	50	24	4.5	12.6	89.8
AE-38	15-2-33	600	Beaker	50	50	24	4.3	10.2	89.6
AE-39	9+12+15 +12 SED	600	Beaker	50	50	24	4.4	9.8	88.4
AE-40	9+12+15 +15 SED	600	Beaker	50	50	24	5.9	11.0	85.0

Preliminary tests showed that a 1 hour passivation period was satisfactory for coating the carbonaceous particles present in the ore. It appeared that the density of the pulp had no effect on efficiency of passivation. Thorough mixing of the kerosene into the pulp and sufficient contact time appear to be the basic requirements for passivation of amorphous carbon. The tests in Table 7 show that kerosene addition to the pulp followed by cyanidation results in satisfactory gold extraction from Agnico-Eagle Gold ore.

IV. Flotation-Cyanidation

Considerable flotation-cyanidation test work was conducted on Eagle ore by various laboratories in previous years. The approach was to float the gold in a sulphide concentrate and to cyanide only the resulting concentrate. The flowsheet produced no advantage over straight cyanidation of the whole ore.

The use of flotation, at this time, by the author was for the selective separation of the amorphous carbon from the ground ore with or without depression of the sulphides and gold. The resulting flotation tails were pre-aerated and cyanided.

A series of 14 flotation pre-aeration-cyanidation tests were run. The results obtained in this test series are shown in Table 8.

Table 9 shows the distribution of gold in the resulting products.

Table 8

Results of Flotation Pre-aeration-Cyanidation on Agnico Eagle Mines Ores

Test #	Sample #	Flotation		Pre-aeration		Cyanidation				Feed oz Au per ton	Re-sidue oz Au per ton
		% Solids	CaO lb/ton	% Solids	Temp. °F	Reten-tion hr	NaCN lb/ton	CaO lb/ton	% Au Extra-cted		
AE-3	12-2-35	30	-	50	72	24	3.5	12.1	87.7	0.47	0.05
AE-4	12-2-35	30	4.0	50	72	24	4.0	15.3	87.5	0.45	0.05
AE-7	9-2-35	30	-	50	72	24	3.6	14.7	85.9	0.26	0.03
AE-8	Mill feed	30	-	50	72	24	4.2	12.2	58.9	0.35	0.03
AE-9	9+12+15	30	-	50	72	24	3.0	11.2	86.7	0.35	0.04
AE-10	9+12+15+12 SED	30	-	50	72	24	3.0	10.6	83.9	0.28	0.04
AE-11	9+12+15+15 SED	30	-	50	72	24	3.0	12.7	73.7	0.28	0.069
AE-12	9+12+15+15 SED	30	-	30	72	24	5.8	18.4	80.7	0.31	0.054
AE-15	Mill feed	20	-	62	72	24	2.8	11.3	82.8	0.36	0.029
AE-16	9+12+15	20	-	66	72	24	3.0	9.4	90.1	0.34	0.030
AE-18	Mill feed	20	-	50	41	24	2.8	7.3	81.4	0.37	0.028
AE-23	9+12+15	30	-	30	72	24	12.7	11.8	86.0	0.34	0.04
AE-25	9+12+15+15 SED	30	-	30	72	24	13.3	11.9	80.7	0.30	0.048
AE-26	9+12+15+12 SED	30	-	50	72	24	8.3	11.8	82.6	0.28	0.036

Table 9

Distribution of Gold in the Metallurgical Products of Flotation Pre-aeration-Cyanidation Tests

Test #	Sample #	Concentrate		Gold Distribution (%)		
		% of Feed	oz Au/ton	Solution	Conc.	Residue
AE-3	12-2-35	2.2	0.33	87.7	1.6	10.7
AE-4	12-2-35	2.0	0.33	87.5	1.4	11.1
AE-7	9-2-35	1.8	0.41	85.9	2.8	11.3
AE-8	Mill feed	3.8	3.03	58.9	32.6*	8.5
AE-9	9+12+15	3.0	0.21	86.7	1.8	11.5
AE-10	9+12+15+12 SED	2.8	0.17	83.9	1.7	14.4**
AE-11	9+12+15+15 SED	3.0	0.14	73.7	1.5	24.8**
AE-12	9+12+15+15 SED	3.4	0.15	80.7	1.7	17.6**
AE-15	Mill feed	3.2	1.04	82.8	9.2*	8.0
AE-16	9+12+15	2.0	0.19	90.1	1.1	8.8
AE-18	Mill feed	4.0	1.01	81.4	11.0*	7.6
AE-23	9+12+15	4.7	0.16	86.0	2.2	11.8
AE-25	9+12+15+15 SED	3.3	0.21	80.7	2.4	16.9**
AE-26	9+12+15+12 SED	3.5	0.42	82.6	5.0	12.4**

* High gold values in concentrate from mill feed sample.

** Reprecipitation of gold values, due to incomplete carbon flotation.

In five flotation tests conducted on mill feed (February ore), the carbon flotation concentrate contained a high gold content. This is in contrast to the low gold content of the carbon flotation concentrates produced from the other samples. A mineralogical investigation[3] of the mill feed, and carbon concentrates produced from flotation of mill feed, shows:

- Native gold occurs in the mill feed as inclusions in pyrite in grains of approximately 9.5 x 9.5 microns in size, this being four times the normal grain size.
- Native gold occurs in the carbon concentrates from mill feed as "free" grains of approximately 8 x 8 microns in size. It is evident that the gold occurring in the concentrate is "free", due to liberation by fine grinding, and floats with the amorphous carbon during flotation of the carbon concentrate.

In tests AE-10, AE-11, AE-12, AE-25 and AE-26, where slaty sediments containing high percentages of amorphous carbon are present, higher than normal residue values resulted. This was probably due to adsorption of soluble gold by trace amounts of amorphous carbon not floated. It is desirable to float all of the carbon at the expense of the flotation of some gold so that maximum cyanidation extraction can be achieved from the flotation tails. The small volume of carbon float with the entrained gold and auriferous sulphides can be treated separately by the addition of kerosene before cyanidation.

The carbon flotation concentrates from all of the flotation tests were combined and treated with 1 lb kerosene/ton concentrate for 1 hour. Cyanidation for 24 hours followed. Cyanide and lime strengths were maintained at 1.0 lb/ton solution. The combined flotation concentrates contained gold ranging from 0.16 to 2.63 oz Au/ton. Table 10 gives the results obtained in the retreatment of carbon flotation concentrate.

Table 10

Cyanidation Results on the Retreatment of Carbon Flotation Concentrate

Test #	Passivation			Cyanidation				Oz Au/ton		Au Extraction %
	Vessel	% Solids	Retention hr	% Solids	Retention hr	Consumption		Feed	Residue	
						NaCN lb/ton	CaO lb/ton			
AE-41	Baffled beaker	30	1	23	24	8.3	33.0	0.729	0.06	91.8

The results show that satisfactory gold extraction can be obtained from the carbon flotation concentrate, if it is pretreated with kerosene before cyanidation.

Table 11 shows the overall results which can be obtained by cyanidation of the flotation tails and re-treatment of the carbon concentrate by the addition of kerosene, followed by cyanidation.

Table 11

Distribution of Total Gold in the Feed Extracted by Cyanidation

Test #	% of Total Gold Extracted by Cyanidation of Flotation Tails (a)	% of Total Gold Extracted by Cyanidation of Carbon Concentrate (b)	% of Total Gold Extracted by Cyanidation (a + b)
AE-3	87.7	1.5	89.2
AE-4	87.5	1.3	88.8
AE-7	85.9	2.6	88.5
AE-8	58.9	30.0	88.9
AE-9	86.7	1.7	88.4
AE-10	83.9	1.6	85.5
AE-11	73.7	1.4	75.1
AE-12	80.7	1.6	82.3
AE-15	82.8	8.5	91.3
AE-16	90.1	1.0	91.1
AE-18	81.4	10.1	91.5
AE-23	86.0	2.0	88.0
AE-25	80.7	2.2	82.9
AE-26	82.6	4.6	87.2

With the exception of four tests (AE-10, AE-11, AE-12 and AE-25), where reprecipitation of the gold was indicated by analysis, overall extractions by cyanidation of flotation tails plus cyanidation of carbon concentrates yielded 87.0 to 91.5%

gold extractions. The re-treatment of carbon flotation concentrate by kerosene, followed by cyanidation, offered no problems other than excessive frothing during cyanidation, which can be controlled by small additions of anti-frothing agents.

V. Grinding in Cyanide Solution

One test was run to dètermine the effect of grinding in cyanide solution followed by flotation of carbon and pre-aeration cyanidation of flotation tails. The procedure in this test was modified by the addition of 1.0 lb of lime and cyanide/ton ore to the ball mill. The ground-cyanided pulp was sampled directly after grinding and again after 24 hours of cyanidation. Table 12 shows the results of this test.

Table 12

Effect of Grinding in Cyanide Solution on Agnico-Eagle Ore

Sample #	Hr Retention		Reagent Consumption (lb/ton ore)		Au Extracted (%)		
	In Grind	Pre-aeration Cyanid-ation	NaCN	CaO	Grinding circuit	After 24 hr Cyanid-ation of Tailings	Overall Extraction
9+12+15 level ores	1	24	8.0	12.7	67.5	18.5	86.0

As shown in Table 12, 67.5% of the gold was dissolved during grinding in the presence of cyanide. Cyanidation of the flotation tails dissolved an additional 18.5% of the total gold of the feed. The result was an overall gold extraction of 86.0%.

The flotation concentrate contained 2.2% of the total gold. Although in this test the concentrate was not cyanided, it is anticipated that about 92% of this gold would be extracted if pre-treated with kerosene and then cyanided in a separate circuit (see Table 10).

- SEDIMENTATION TESTS -

A series of static settling tests in duplicate were run to determine the settling characteristics of both ground untreated pulp and cyanided pulp. This was to simulate what might be expected in a dewatering thickener and a thickener in the cyanide circuit. The ore for these tests was a blend of four samples, ground to 97% minus 325 mesh. One-litre volumes of pulp with an initial pulp density of 30% solids were tested with and without the addition of a flocculant. The amount of flocculant necessary to reduce the settling time to about one-half was also determined. The tests followed established sedimentation test procedures reported in many papers. Settling rates were recorded and settling areas calculated. A 25% safety factor was allowed.

The results of these tests are tabulated in Table 13. These results show that about 7 1/2 sq. ft. of settling area/ton/day is necessary for both the feed pulp and the cyanided pulp. This is in agreement with known design figures for finely ground ore. Acceptable underflow densities of greater than 60% solids were also obtained.

Since the amount of flocculant required to reduce the settling time by about one-half is less than 0.005 lb/ton ore, the cost would be only 1 cent/ton ore if the cost of the reagent was $2.00/lb.

Table 13

Results of Settling Tests on Agnico-Eagle Mines Ore

Test #	Flocculant added lb/ton	Settling Rate lb/hr	Area sq ft ton/24 hr		Type of Pulp	Feed % Solids	% Solids after 16 hrs
			Actual	With 25% Safety Factor			
I	Nil	0.417	5.87	7.34	Dewatering thickener feed	30	67
II	* MGL 0.0031	0.6833	3.48	4.35	Dewatering thickener feed	30	65
III	Nil	0.378	6.01	7.51	Fresh cyanide pulp	30	61.5
IV	* MGL 0.0047	0.742	3.06	3.83	Fresh cyanide pulp	30	61.0

*) MGL synthetic polymer, manufactured by Dow Chemical Company.

- FILTRATION TESTS -

The filtration tests of pre-aerated-cyanided pulps were conducted in duplicate. The first series was on reconstituted pulps of residues from cyanidation test work with the addition of pregnant cyanide solutions retained from such work. The reconstituted pulp was made to 50% solids with residues which had a grind of 97% minus 325 mesh. The second series of tests was conducted on freshly cyanided pulps with a grind and pulp density similar to the reconstituted pulp. A filter test leaf, 0.1 sq ft in area was used. Three types of cloth of varying permeability, weave, and material were used. Vacuum was maintained at 22-23" Hg Cycle time was set at 2 minutes with 30 seconds form time, 30 seconds dry time, 30 seconds wash time and 30 seconds dry or discharge time. The results obtained on the filter test leaf were multiplied by a factor of 0.65. This is an acceptable factor for conversion of test leaf filtration rates to what can be expected in plant operation.

Table 14 contains the results obtained. These results show that all three filter cloths tested produced good filtration rates which were in the range of 48-63 lb dry solids/sq ft /hr. This is similar to the filtration rates obtained in a number of other Canadian gold mills treating a finely ground ore.

It is suggested that the problem in filtering at the mill is caused by partially blinded filter cloths. This problem might be alleviated by more frequent acid washing of the cloths, say, every two or three days. This frequency of washing is not uncommon in many gold mills treating finely ground ore.

Table 14

Filtration Test Results

Test #	Filter cloth used	Cycle time in seconds: Form	Dry	Wash	Dry or discharge	Total cycle time	% moist-ure in cake	Filter area lb dry solids/sq ft / hr	Imp. gal/sq ft of filter area per hour: Mother liquor	Wash	% solids in filtrate	Cake discharge character-istics	Type of pulp
1, 2, 3	Eimco filter cloth Polypropylene 853-F Weave 2/2 Twill Yarn-Multi-Filament	30	30	30	30	2 min	22.6	47.96	3.97	2.03	0.43	Excellent	Reconst-ituted
9	Thread count 59 x 38 Wt.-9 oz/sq yd Airflow - cfm/sq /ft - 22.00 Finish - heat set.	30	30	30	30	2 min	23.2	60.7	4.28	2.79	2.8	Excellent	Fresh
4, 5	Scyco Textile Cotton ST-19 Weave - Twill Wt.-18 oz /sq yd	30	30	30	30	2 min	22.7	50.3	4.45	2.33	0.25	Poor	Reconst-ituted
10	Air permeability - 12 cfm/sq ft	30	30	30	30	2 min	23.5	62.8	4.60	2.38	Tr	Poor	Fresh
6, 7, 8	Eimco filter cloth Nylon 529-F Weave 2/2 Twill Yarn-Multi-Filament	30	30	30	30	2 min	22.7	53.1	4.70	3.06	2.82	Excellent	Reconst-ituted
11	Thread count - 144 x 54 Wt.-8 oz /sq yd Air flow cfm/sq ft - 39.65 Finish - heat set	30	30	30	30	2 min	22.9	60.9	4.38	2.60	5.7	Excellent	Fresh

Both synthetic cloths, the nylon and polypropylene, allowed for good clean separation of cake from the cloth, but the cake adhered to the fibrous cotton cloth. The greater permeability cloths gave higher percent solids in the filtrates. This could effectively be reduced by using synthetic cloths of lower permeability.

Although freshly cyanided pulp filtered faster than reconstituted pulp, the filtrate contained a higher percentage of solids.

- CONCLUSIONS -

Gold extractions of 85% to 92% were obtained from ore samples from Agnico-Eagle Mines Ltd. by two methods:

1) Kerosene addition to the whole ore followed by cyanidation.

2) Flotation of a carbon concentrate with pre-aeration-cyanidation of the flotation tailings, along with a kerosene-cyanidation treatment of the carbon concentrate.

Fine grinding of the ore to 97% minus 325 mesh is necessary to obtain satisfactory gold extraction.

Pre-aeration of the pulp is beneficial in lowering the reagent consumption.

The pulp had good settling characteristics and small additions of flocculants reduced the settling time required to about one-half.

Filtration of the finely ground pulp presented no problem, especially when synthetic cloths were used.

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