

TR4-157-164

R.352

BEN LOMOND MINING COMPANY

LEACHING TESTS ON A NICKEL ORE SAMPLE FROM
BEACONSFIELD

As requested by Messrs. Webber and Pitulej, the following preliminary leaching tests with sulphuric acid at normal temperatures and pressures have been carried out, the quantities of sulphurous acid being as requested.

Sample

The sample of oxidised nickeliferous material was supplied by Mr. Pitulej and was stated to be from near Beaconsfield. The sample was screened to minus 10 mesh and used in the wet state for the tests, the moisture amounting to 18.9%.

No responsibility is accepted for the results shown in this report except in so far as they apply to the sample tested.

Analysis

The following analysis on a dry basis shows the composition of the ore:

Ni	1.14
Co	0.36
SiO ₂	5.31
Al ₂ O ₃	8.48
Fe ₂ O ₃	68.01
FeO	1.71
MnO	3.06
Cr ₂ O ₃	2.95
TiO ₂	Nil
CaO	Nil
MgO	0.87
Ignition Loss	8.16

Summary

The amount of nickel extracted under the conditions of six leaching tests is shown in Table I. The final column shows the amount of the sulphurous acid initially added to the test in terms of sulphur dioxide.

TABLE I

Test	Nickel Extracted		Sulphur Dioxide added lb. per short ton of Ore
	lb. per short ton	Percent	
1. ..	7.2	31.6	100
2. ..	10.4	45.6	200
3. ..	10.8	47.4	500
4. ..	11.0	48.2	1,000
5. ..	11.6	50.9	2,000
6. ..	11.2	49.1	500

It will be seen that in Tests 3, 4 and 5, although greatly increased amounts of sulphurous acid were used, there was only a relatively small increase in nickel extraction.

The agitation time for the tests was 44 hours, except Test 6 which was continued for six days.

In this preliminary investigation the amount of free sulphur dioxide in the finished leach solution was not determined, but it was noted that in Test 1 there was no free sulphur dioxide, in Test 2 there was some free sulphur dioxide, while in Tests 3, 4, 5 and 6 there were considerable amounts present.

The amount of other constituents dissolved during leaching is shown in Table 2.

Details of the individual tests on a short ton basis for treatment of minus 10 mesh wet ore containing 18.9% moisture are shown below.

Tests

Commercially available sulphurous acid was used, and analysis showed this to contain 4.83 grams of sulphur dioxide per 100 c.c. In the tests that follow the weight of sulphur dioxide in the acid added is quoted.

Test 1.

Ore	.....	equivalent to 1 short ton dry weight
Sulphur Dioxide	.....	100 lbs.
Agitated	.....	44 hours

No free sulphur dioxide at finish.

Analysis of the filtered leach liquor gave an extraction of 7.2 lbs. of nickel per short ton, equivalent to 31.6% of the nickel in the ore.

Test 2.

Ore	.....	equivalent to 1 short ton dry weight
Sulphur Dioxide	.....	200 lbs.
Agitated	.....	44 hours

Some free sulphur dioxide at finish.

Analysis of the filtered leach liquor gave an extraction of 10.4 lbs. of nickel per short ton, equivalent to 45.6% of the nickel in the ore.

Test 3.

Ore	.....	equivalent to 1 short ton dry weight
Sulphur Dioxide	.....	500 lbs.
Agitated	.....	44 hours

Considerable free sulphur dioxide at finish.

Analysis of the filtered leach liquor gave an extraction of 10.8 lbs. of nickel per short ton, equivalent to 47.4% of the nickel in the ore.

Test 4.

Ore	.....	equivalent to 1 short ton dry weight
Sulphur Dioxide	.....	1000 lbs.
Agitated	.....	44 hours

Considerable free sulphur dioxide present at finish.

Analysis of the filtered leach liquor gave an extraction of 11.0 lbs. of nickel per short ton, equivalent to 48.2% of the nickel in the ore.

Test 5.

Ore equivalent to 1 short ton dry weight
 Sulphur Dioxide 2000 lbs. (1 short ton)
 Agitated 44 hours

Considerable free sulphur dioxide at finish.

Analysis of the filtered leach liquor gave an extraction of 11.6 lbs. of nickel per short ton, equivalent to 50.9% of the nickel in the ore.

Test 6.

Ore equivalent to 1 short ton dry weight
 Sulphur Dioxide 500 lbs.
 Agitated 6 days

Analysis of the filtered leach liquor gave an extraction of 11.2 lbs. of nickel per short ton, equivalent to 49.1% of the nickel in the ore.

Solution of other Ore Constituents

The weight of other ore constituents dissolved in the above tests is shown in Table 2, and apart from silica is expressed as lbs. of metal dissolved from one ton of ore. Nickel extracted is shown for comparison.

Test	Lb. of constituents dissolved per short ton of Ore						
	Co	SiO ₂	Fe	Al	Mn	Mg	Ni
1.	2.2	0.1	0.1	2.1	30.9	0.2	7.2
2.	2.8	1.4	9.7	7.0	42.5	0.4	10.4
3.	3.2	2.7	38.4	10.1	42.2	0.5	10.8
4.	3.5	3.4	48.9	7.8	44.6	0.5	11.0
5.	3.8	4.1	57.4	7.5	46.6	0.5	11.6

The extractions of cobalt are also of interest. The extractions given in Table 2 amount to 30.6, 38.9, 44.4, 48.6 and 52.8% respectively of the cobalt in the ore sample supplied.

Sizing analysis of ore and residue from Test 6 showing nickel contents of fractions.

Size B.S.	Ore Percent		Leach Residue Percent	
	Weight	Ni	Weight	Ni
+30 ..	7.7	1.39	3.9	0.12
+60 ..	9.4	1.02	6.9	0.30
+100 ..	9.9	1.15	7.5	0.48
+150 ..	11.8	1.20	0.9	0.63
+200 ..	5.9	1.15	10.8	
-200 ..	55.3	1.00	70.0	0.75

R.352**APPENDIX 1****BEN LOMOND MINING COMPANY**

Following a request by the Ben Lomond Mining Co., successive batch leaches with sulphurous acid were performed on a single charge of oxidised nickeliferous ore stated to be from Beaconsfield.

The Company thought that by using a series of leaches for one charge of ore, using minimal amounts of sulphurous acid, nickel would continue to dissolve while contamination of the solution with iron, manganese, &c., would be reduced to a minimum.

Sample

The sample was screened to minus 10 mesh for the leaching test. It then contained 18.9% moisture and was used for the test in that condition.

No responsibility is accepted for the results shown in this report, except in so far as they apply to the sample tested.

Summary

The following Table 1 shows the amount of nickel and other constituents in the leach filtrates in terms of lbs. per short ton of ore, which resulted from a series of three leaches on one charge of ore, except cobalt which has not been determined in these tests.

Test 8

TABLE 1

	Lb. per short ton		
	Leach 1	Leach 2	Leach 3
Ni	7.65	3.02	0.11
Fe	0.03	12.5	13.8
Mn	34.1	10.1	0.5
Al	2.4	4.7	0.9
Mg	0.3	0.1	0.1
SiO ₂	0.2	1.1	1.0

Table 2 summarises the results of series leaching on the extract of nickel:

TABLE 2

	Ni Extraction		
	Lb. per short ton Ore	Recovery Percent	Cumulative Recovery Percent
Leach 1 ..	7.65	33.6	33.6
Leach 2 ..	3.02	13.2	46.8
Leach 3 ..	0.11	0.5	47.3
	10.78	47.3	

It is obvious from the above tables that:

1. The third leach is ineffective and that under the conditions of leaching (see later) an extraction of about 46% of the nickel in the ore is obtained.
2. Nearly all the manganese is dissolved in two series leaches, while after leach 1 iron is also dissolved.

A brief test by the process used at Nicaro consisting of a reducing roast and ammonia extraction showed encouraging results, with a 67% extraction of the nickel and complete separation from manganese and iron.

Tests

Commercially available sulphurous acid was used, and analysis showed this to contain 4.61 grams sulphur dioxide per 100 cc. of solution. In the tests that follow the weight of sulphur dioxide in the acid solution added to the ore is quoted, since there has been variation in the strength of sulphurous acid obtained.

All leaching tests were performed at atmospheric temperatures and pressures and in closed vessels to prevent loss of sulphur dioxide, and this procedure was adopted in the tests already reported.

Test 8

Leach 1:

Ore 1 short ton equivalent dry weight.
Sulphur dioxide 100 lbs.
Agitation time 44 hours.
No free sulphurous acid at finish of test.
Pulp filtered and washed.
The extraction is shown in Table 1, summary.

Leach 2:

Ore-residue from leach 1.
Sulphur dioxide 100 lbs.
Agitation time 44 hours.
Sulphurous acid present at finish of test.
Pulp filtered and washed.
The extraction is shown in Table 1, summary.

Leach 3:

Ore-residue from leach 2.
Sulphur dioxide 100 lbs.
Agitation time 44 hours.
Sulphurous acid present at finish of test.
Pulp filtered and washed.
The extraction is shown in Table 1, summary.

Recovery of Nickel from the Leach Solutions

Following a further request to attempt the recovery of nickel from the leach solutions by caustic soda precipitation, as was previously used in recovering nickel from the leaching of serpentine ore, two tests were made.

For these tests filtrates from leach 1 and 2 were combined. Owing to the very low nickel content of leach 3 filtrate this was discarded.

The combined filtrates contained the following amounts of constituents.

TABLE 3

			Lb. per short ton of Ore
Ni	..	..	10.67
Fe	..	..	12.53
Mn	..	..	44.2
Al	..	..	7.1
Mg	..	..	0.4
SiO ₂	..	..	1.3

Test A: Oxidation of Iron only

The solution was boiled to remove free sulphur dioxide, and while hot the solution was carefully treated with chloride of lime until the iron was oxidised, without oxidising more than a small amount of manganese to the tetravalent state. Caustic soda solution was then added to raise the pH of the solution from 2.3 to 3.6. The precipitated ferric hydrate was then filtered and washed. Analysis showed the precipitate to be free from nickel.

Caustic soda solution was then added to the filtrate until a pH of 8.0 was attained. As the solution was added manganous hydroxide progressively precipitated and finally at pH 8.0 all the nickel and most of the manganese were co-precipitated as hydrates.

There is no point of separation of nickel and manganese, and all that is usefully accomplished is the separation of iron from the solution.

The amounts of chemicals used in the test were as follows:

			Lb. per short ton of Ore	
			Chloride of lime	Caustic Soda
Iron removal	..	..	10	10
Mn, Ni precipitation	..	..	..	30
Total	..	..	10	40

Test B: Oxidation of Iron and Manganese

The solution was boiled to remove all free sulphur dioxide, and then to the hot solution chloride of lime was added to oxidise both iron and manganese. Caustic soda solution was then added to raise the pH to 4.7 and the hydrates of iron and manganese filtered off and washed.

To the filtrate caustic soda solution was added to bring the pH to 8.2, and the nickel hydrate filtered off and washed.

The amounts of chemicals used were as follows:—

			Lb. per short ton of Ore	
			Chloride of lime	Caustic Soda
Fe, Mn precipitation	..	..	150	15
Ni precipitation	..	..	..	2.5
Total	..	..	150	17.5

The precipitates obtained were then ignited and analysed for nickel. All the nickel was recovered but it was distributed as follows:—

	Per cent Distribution
Fe Mn hydrates	34.3
Ni hydrate	65.7

The ignited nickel precipitate contained 83.6% of nickel oxide.

The loss of 34.3% of nickel by retention in the combined iron-manganese precipitate renders the separation ineffective.

Test C: Recovery of Nickel in Solution by Ammonia Extraction

Since the foregoing requested tests A and B were ineffective, a preliminary ammonia extraction was considered since this would remove iron and manganese, whilst most of the ammonia is recoverable.

Combined solutions from leaches 1 and 2 were neutralised with ammonia and excess added, together with some ammonium sulphate, and the solution stirred mechanically for some hours. In the strongly alkaline solution manganese oxidises readily. Two extractions with an intervening filtration gave a recovery of 92% of the nickel in the solution. No attempt was made to determine the most economic conditions for this separation.

Test D: Extraction of Nickel from the Ore by the Nicaro Process

This is the process used at Nicaro and consists of a reducing roast of finely ground ore followed by leaching with ammonia-ammonium carbonate solution with agitation and aeration to dissolve nickel and cobalt.

Reduction of the ore with producer gas under controlled conditions of temperature, &c., is practised at Nicaro. For a quick laboratory test, dried and ground ore was mixed with carbonaceous matter and heated for 35 minutes at approximately 700°C. The reduced ore was cooled and then leached with ammonia-ammonium carbonate solution while being mechanically stirred.

Two leaches with intervening filtration resulted in 67.7% of the nickel in the ore being extracted. Separation of manganese and iron was virtually complete.

It should be pointed out that in this process nickel is recovered by distilling off and recovering the ammonia during which process the nickel is precipitated as the basic carbonate which is filtered off and calcined to nickel oxide.

Reduction under carefully controlled conditions could be expected to give a better extraction than that shown above.

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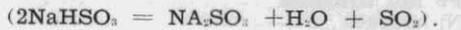
APPENDIX 2

BEN LOMOND MINING COMPANY

Test 9: Sodium Bisulphate Leaching

On receipt of a letter from Mr. Webber saying that sodium bisulphate leaching could give improved results, particularly in that little manganese would be dissolved while presumably nickel would dissolve as in previous sulphurous acid leaches, the following test was performed.

To obtain a comparison with Test 8—leach 1 (see p. 161), the sodium bisulphate strength used was such that it amounted to 100 lbs. per ton of sulphur dioxide above the amount of normal sulphite (Na_2SO_3) which would be formed by decomposition of the bisulphate.



The conditions of the test were as follows:—

Ore—1 short ton.

Sodium bisulphate—325 lbs.

Agitation time—44 hours, closed vessel.

No smell of SO_2 on completion of test.

The pulp was filtered and washed and the filtrate made up to volume for analysis which disclosed the presence of the following constituents dissolved per short ton of ore:—

	Lb. per short ton	Per cent Extraction
Nickel	1.26	5.53
Iron	0.034	
Manganese	1.45	
Aluminium	0.22	
Magnesium	0.16	
Silica	0.08	

The bisulphate leach has certainly resulted in greatly lessening the amount of manganese dissolved (compare Test 8—leach 1), but the nickel extraction is so low as to render such a process ineffective.