Dr. L. Cunningham

[redacted]

CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

OTTAWA

[redacted]

Mines Branch

COPY NO. 8

CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

OTTAWA

MINES BRANCH INVESTIGATION REPORT

IR 74-47 September 1974

INVESTIGATION TO DETERMINE CAUSES FOR THE POOR NICKEL RECOVERIES IN FLOTATION OF OLD ASBESTOS TAILINGS OF CAREY-CANADIAN MINES LIMITED, EAST BROUGHTON, QUEBEC

by

I. B. Klymowsky

Mineral Processing Division

Mines Branch Investigation Report IR 74-47

INVESTIGATION TO DETERMINE CAUSES FOR THE POOR NICKEL RECOVERIES IN FLOTATION OF OLD ASBESTOS TAILINGS OF CAREY-CANADIAN MINES LIMITED, EAST BROUGHTON, QUEBEC

by

I. B. Klymowsky*

- - -

SUMMARY

The nickel sulphides were found to be more finely disseminated in the old tailings. Those nickel sulphides in the free state were not only tarnished, but also were fewer in number than in the fresh tailings. These factors, together with the greater tendency of the gangue minerals in the old tailings to float, made it difficult to produce a satisfactory nickel concentrate. To overcome this problem, cleaning of the mineral surfaces was necessary, either by grinding or by acid treatment.

* Engineer, Ferrous Ores Section, Mineral Processing Division, Mines Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

Direction des Mines
Rapport d'investigation IR 74-47

ENQUETE SUR LA DETERMINATION DES CAUSES D'UNE FAIBLE RECUPERATION DE NICKEL PAR FLOTTATION DE VIEUX RESIDUS D'AMIANTE DES MINES CAREY-CANADIAN LIMITED, EAST BROUGHTON, QUEBEC

par
I. B. Kiymowsky*

RESUME

On a trouvé que les sulfures de nickel étaient plus finement répartis dans les vieux résidus. Ces sulfures de nickel, à l'état libre, n'étaient pas seulement ternis, mais étaient moins nombreux que dans les résidus plus récents. A cause de ces facteurs et aussi à cause d'une plus grande tendance des gangues minérales des vieux résidus à flotter, il a été difficile de produire un concentré de nickel satisfaisant. Afin de surmonter ce problème, il a fallu nettoyer les surfaces des minéraux, soit par broyage ou par traitement à l'acide.

---

*Ingénieur, Section des matières ferreuses, Division du traitement des minéraux, Direction des Mines, Ministère de l'Energie, des Mines et des Ressources, Ottawa, Canada.

TABLE OF CONTENTS

TABLES

FIGURES

INTRODUCTION

In 1971, Carey-Canadian Mines Limited commissioned Lakefield Research to investigate the flotation of nickel sulphides from their asbestos tailings. The testwork showed that the nickel was more difficult to recover from old tailings than from fresh tailings.

Purpose of Investigation

The Mines Branch was asked to determine causes for the poor nickel recoveries obtained from the old tailings.

Ore Shipments

On June 1, 1972, a 500-lb sample of old tailings (OS-4224), and a 100-lb sample of fresh tailings (OS-4223), were received at the Mines Branch from J. Sztuke, Manager, Research and Quality Control, Carey-Canadian Mines Limited, East Broughton, Quebec. The material arrived in 100-lb bags. The old tailings were wet; the fresh tailings were dry.

Sampling and Analysis

The top size of the material in the samples was approximately 1/2-inch; however only the minus 10-mesh fractions of the samples were used for the purpose of this investigation.

Twenty-pound samples were taken out of each of the 100-lb bags marked "Old Tailings"; these were combined and laid out to dry. The dried material was screened on 10 mesh to remove the oversize (which amounted to 36% of the total dry weight), and the undersize was split into 5000-gram samples for testing.

Similarly, the fresh tailings were screened on 10 mesh, and the undersize split into 5000-gram samples for testing. The oversize, in the case of the fresh tailings, amounted to 30% of the total weight.

Page No.

Samples were also taken of the 10-mesh screen undersize for analysis. The results are given in Table 1. All chemical analyses in connection with this investigation were done by the Analytical Chemistry Subdivision, Mineral Sciences Division.

TABLE 1

Chemical Analysis of the Minus 10-Mesh Fractions

Sample	Sample No.	Analysis, % Ni
Old Tailings	OS-4224	0.26
Fresh Tailings	OS-4223	0.30

OUTLINE OF INVESTIGATION

The Lakefield test procedure consisted of tabling the minus 10-mesh material to remove a portion of the fibre, followed by wet magnetic separation; screening of the non-magnetic fraction, which contained most of the nickel sulphides, on 48 mesh; and grinding of the screen oversize to minus 48 mesh before combining the separate screen fractions for flotation. Previous investigations had indicated that most of the nickel sulphides were liberated at minus 48 mesh. Because magnetic separation was done at minus 10 mesh, some of the nickel sulphides had reported to the magnetic concentrate and, to recover these sulphides, flotation was done separately on the magnetic fraction. In each case, flotation was carried out in the presence of large amounts of fibre and at very low pulp densities. In tests with fresh tailings, the fibre did not appear to interfere with flotation; however, in tests with old tailings large amounts of fibre floated along with the nickel sulphides, and very little

upgrading was achieved.

This procedure was modified at the Mines Branch to facilitate handling of the material, more specifically, to facilitate wet feeding of the material to magnetic separation and to tabling. The Mines Branch test procedure differed as follows:

(1) the material was divided into two size fractions, a plus 48-mesh fraction and a minus 48-mesh fraction, and each size fraction was treated separately;

(2) magnetic separation was done at minus 48 mesh on each size fraction;

(3) most of the fibre was removed from the feed by tabling before flotation.

Poor recoveries in the old tailings were found to be associated with the minus 48-mesh fraction, which passed to flotation without any grinding, and research was directed to determine:

(1) whether grinding of the minus 48-mesh fraction would be warranted;

(2) if acetic acid could be used as a dispersant in tabling to make a better separation between the fibre and nickel sulphides;

(3) if SO_2 could be used in flotation to enhance selectivity.

A mineralogical examination was made of the flotation tailings and, to determine the nickel content of the gangue minerals, electron microprobe studies were made of the fibre and serpentine.

DETAILS OF INVESTIGATION

The flowsheet used in this investigation is shown in Figure 1, and the standard test procedure is described below. A table was incorporated at the head of the circuit to remove most of the fibre, thus facilitating screening. Screen tests on the fibre showed that it would pass a 48-mesh screen if screened long enough. Therefore, the fibre was combined with the minus 48-mesh fraction. The plus 48-mesh fraction was ground for 30 minutes in a laboratory rod mill at 40% solids. Each fraction was then passed separately over a Sala wet magnetic separator. The non-magnetic products from each fraction were tabled to remove the fibre before flotation. However, in flotation, the serpentine rock particles tended to break up and form fibre, even at low impeller speeds (600 rpm), making the pulp viscous. To overcome the effects of viscosity, flotation was carried out in Agitair cells at between 7 and 10% solids. Different sizes of cells were used to maintain this range of pulp densities.

The flotation reagents used were xanthate Z-6 and Dowfroth 250. Dowfroth 250 was found to be more beneficial to the flotation of the nickel sulphides than pine oil. Steps were taken to maintain the same xanthate concentration, 25 mg/l, in each flotation test. After conditioning with xanthate for 10 minutes, flotation was carried out for 20 minutes. The Dowfroth was added in stages at 5 minute intervals. Total reagent consumption was in the order of 0.2 to 0.3 lb of Z-6 per ton of ore, and 0.1 to 0.15 lb of Dowfroth 250 per ton of ore. Relatively large amounts of reagents were used because of the low pulp densities involved.

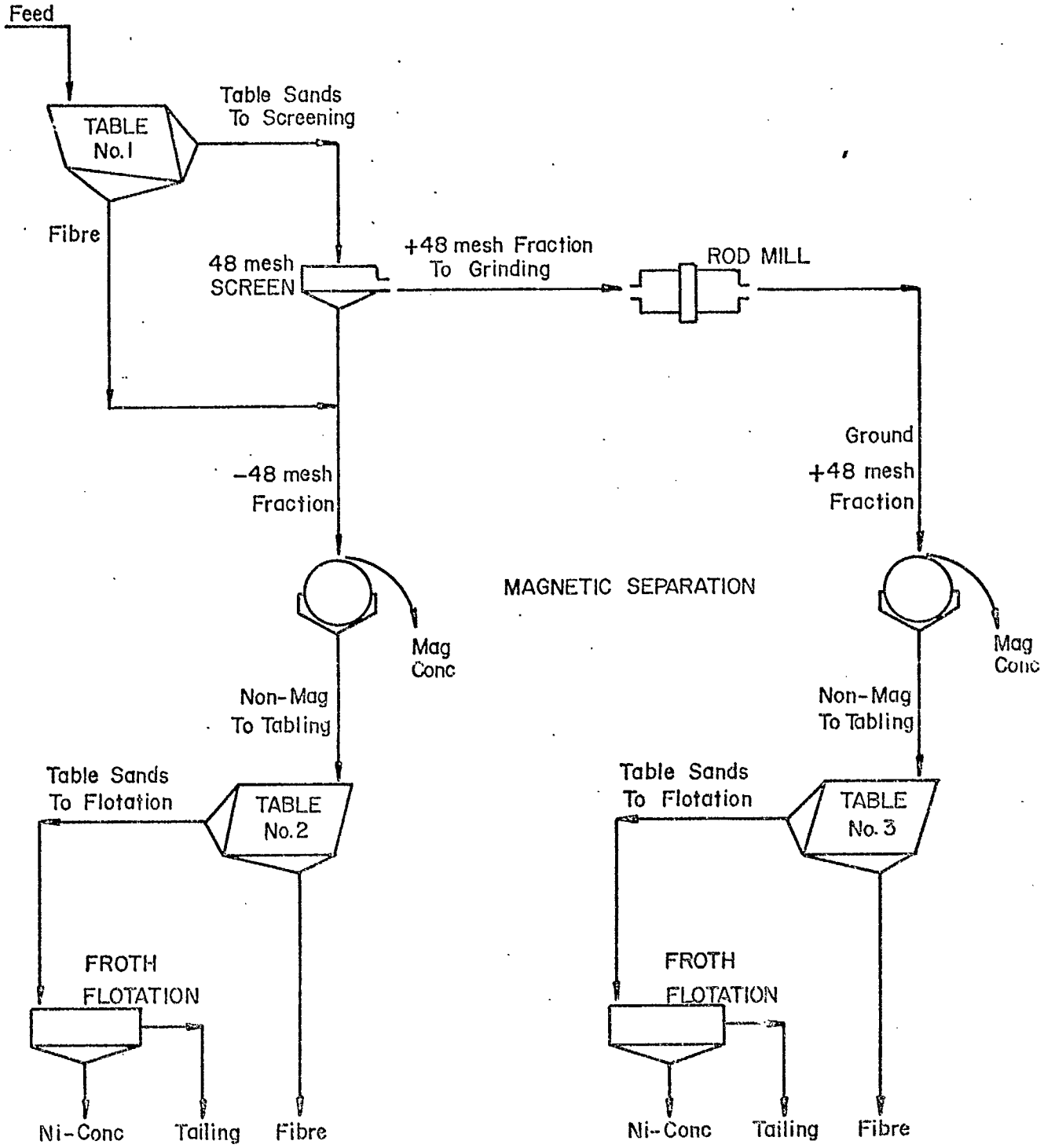

Figure I. STANDARD FLOWSHEET

RESULTS

The results of tests on samples of old tailings and fresh tailings, using the standard test procedure described above, are given in Tables 2 and 3. A high-grade nickel concentrate, assaying 10% Ni, was made from the plus 48-mesh fraction of the old tailings with a flotation tailing of 0.14% Ni. However, difficulties were encountered in making a satisfactory nickel concentrate from the minus 48-mesh fraction, and the flotation tailings assayed 0.16% Ni. In each case flotation was carried out at a pH of approximately 9.0. The overall recovery of nickel was 17.2%, and the combined grade of the concentrates was 2.95% Ni.

TABLE 2

Test 1, on Old Tailings, Using Standard Test Procedure

Product	% Wt	% Ni	Units	% Distn
-48 mesh fraction				
Flotation Conc	1.19	0.88	1.05	4.0
Flotation Tail	13.29	0.16	2.13	8.1
Feed to Flotation*	14.48	0.22	3.18	12.1
Table #2 Fibre	34.60	0.17	5.88	22.3
Feed to Tabling*	49.08	0.18	9.06	34.4
Magnetics	5.59	0.74	4.14	15.7
Total -48 mesh*	54.67	0.24	13.20	50.1
+48 mesh fraction				
Flotation Conc	0.35	10.00	3.50	13.2
Flotation Tail	19.45	0.14	2.72	10.3
Feed to Flotation*	19.80	0.31	6.22	23.5
Table #3 Fibre	21.53	0.19	4.09	15.5
Feed to Tabling*	41.33	0.25	10.31	39.0
Magnetics	4.00	0.72	2.88	10.9
Total +48 mesh*	45.33	0.29	13.19	49.9
Total Feed*	100.00	0.26	26.39	100.0

* Calculated

TABLE 3

Test 2, on Fresh Tailings, Using Standard Test Procedure

Product	% Wt	% Ni	Units	% Distn
-48 mesh fraction				
Flotation Conc	1.29	1.83	2.36	7.6
Flotation Tail	8.78	0.14	1.23	4.0
Feed to Flotation*	10.07	0.36	3.59	11.6
Table #2 Fibre	32.57	0.18	5.86	18.9
Feed to Tabling*	42.64	0.22	9.45	30.5
Magnetics	4.40	0.94	4.14	13.3
Total -48 mesh*	47.04	0.29	13.59	43.8
+48 mesh fraction				
Flotation Conc	1.36	3.77	5.13	16.5
Flotation Tail	20.18	0.14	2.83	9.1
Feed to Flotation*	21.54	0.37	7.96	25.6
Table #3 Fibre	26.18	0.19	4.97	16.0
Feed to Tabling*	47.72	0.27	12.93	41.6
Magnetics	5.24	0.86	4.51	14.6
Total +48 mesh*	52.96	0.33	17.44	56.2
Total Feed*	100.00	0.31	31.03	100.0

* Calculated

Much better results were obtained with the fresh tailings. The overall recovery of nickel was 24.1%. (This compared well with recoveries obtained by Lakefield on the non-magnetic portion of the fresh tailings). The concentrates assayed 3.77% Ni in the case of the plus 48-mesh fraction, and 1.83% Ni in the case of the minus 48-mesh fraction. The flotation tailings assayed 0.14% Ni in each case. (This appeared to be the lower limit for tailings in this investigation.)

A higher grade concentrate could be made from the plus 48-mesh fraction of the fresh tailings, with no significant loss in recovery, by conditioning the material with acetic acid before tabling. A test was re-

peated on the plus 48-mesh fraction of the fresh tailings, using acetic acid, and a concentrate was made assaying 16.57% Ni, with a recovery of 16.1% of the nickel (as compared to a recovery of 16.5% for the plus 48-mesh fraction in Test 2). The pH in flotation was approximately the same as in Test 2, (pH 9.0). The improved selectivity in flotation appeared to have been brought about by the acid treatment.

Comparison of the flotation concentrates in Tables 2 and 3 indicated that there were more nickel sulphides in the fresh tailings than in the old tailings. Consequently, higher recoveries could be expected from the fresh tailings. However, it also appeared that some improvement could be made in the recovery of nickel from the old tailings:

(1) by obtaining a lower nickel tailing from the minus 48-mesh fraction, and obtaining a higher grade concentrate;

(2) by reducing the nickel losses that were incurred in tabling.

It was found that, in tabling, the material formed three separate bands: a concentrate band, which consisted of nickel sulphides; a middling band, which consisted of granular particles of serpentine; and a tailing band, which consisted of fibre. A gravity concentration test was done on the old tailings to determine how much nickel was associated with each band. The standard test procedure was followed in screening the material and in magnetic separation. However, in tabling, cuts were made of the three separate bands. The results are given in Table 4. The concentrates assayed 2.95% Ni in the case of the plus 48-mesh fraction, and 1.54% Ni in the case of the minus 48-mesh fraction. The overall recovery of nickel was only 14.5%. The table middlings assayed 0.16% Ni, and the fibre between 0.17 and 0.18% Ni. Comparison of the results in Table 4 with the results in Table 2 showed that higher nickel losses were incurred in

TABLE 4

Test 3, on Old Tailings, Using Gravity Concentration

Product	% Wt	% Ni	Units	% Distn
-48 mesh fraction				
Table #2 Conc	0.7	1.54	1.08	4.2
Table #2 Midds	15.5	0.16	2.48	9.6
Table #2 Fibre	30.9	0.17	5.25	20.3
Feed to Tabling*	47.1	0.19	8.81	34.1
Magnetics	5.2	0.82	4.26	16.5
Total -48 mesh*	52.3	0.25	13.07	50.6
+48 mesh fraction				
Table #3 Conc	0.9	2.95	2.66	10.3
Table #3 Midds	21.8	0.16	3.49	13.5
Table #3 Fibre	21.0	0.18	3.78	14.6
Feed to Tabling*	43.7	0.23	9.93	38.4
Magnetics	4.0	0.71	2.84	11.0
Total +48 mesh*	47.7	0.27	12.77	49.4
Total Feed*	100.0	0.26	25.84	100.0

* Calculated

gravity concentration than in flotation. Polished sections were made of the table middlings produced in Test 3 for comparison with the flotation tailings produced in Test 1. Examination of these polished sections showed that there were no free nickel sulphides in these products and that all the nickel sulphides were either completely or partially enclosed in serpentine gangue. The low tailing (0.14% Ni) obtained in Test 1 for the plus 48-mesh fraction indicated that some of these middling particles could be recovered by flotation. In the case of the minus 48-mesh fraction, the assays of the flotation tailing and gravity concentration middling were similar. To improve the recovery of nickel, grinding of the minus 48-mesh fraction was investigated.

The procedure used in investigating grinding of the minus 48-mesh fraction was similar to the standard test procedure, with the following exception: the first table fibre was not combined with the 48-mesh screen undersize, which was given a 30-minute grind before magnetic separation. The results of this test are given in Table 5. A flotation concentrate was made assaying 2.24% Ni, and a tailing was made assaying 0.14% Ni. The grades of these products were satisfactory. However, there was no significant improvement in recovery when the results were compared with the results in Test 1 because of the nickel losses in the fibre that was produced by grinding.

Another point was brought out by the results shown in Table 5. The first table fibre assayed 0.20% Ni, which represented a loss in recovery of 24.1% of the nickel. The loss could be reduced to 20%, as in Test 3, by employing magnetic separation to recover the nickeliferous magnetite in the fibre. In the standard test procedure, the first table fibre was combined with the 48-mesh screen undersize for magnetic separation.

TABLE 5

Test 4, on Old Tailings, Effect of Regrinding the Minus 48-Mesh Sands

Product	% Wt	% Ni	Units	% Distn
-48 mesh fraction				
Flotation Conc	0.51	2.24	1.14	4.3
Flotation Tail	6.47	0.14	0.91	3.5
Feed to Flotation*	6.98	0.29	2.05	7.8
Table #2 Fibre	13.25	0.18	2.38	9.1
Feed to Tabling*	20.23	0.22	4.43	16.9
Magnetics	3.68	0.89	3.27	12.5
Total -48 mesh*	23.91	0.32	7.70	29.4
Table #1 Fibre	30.87	0.20	6.31	24.1
Total +48 mesh	45.22	0.27	12.21	46.5
Total Feed*	100.00	0.26	26.22	100.0

* Calculated

Nickel losses in the fibre could be reduced further by employing a dispersant in tabling. Acetic acid proved to be a good dispersant for asbestos fibre, as long as the pH was kept below 6.0. This required approximately 2 cc of acid per litre of pulp containing 5 to 10% solids. In all subsequent tests, after magnetic separation the minus 48-mesh fraction was conditioned with acetic acid before tabling.

Tests 5 and 6 were done in duplicate. The results in Tables 6 and 7 show the effect of acetic acid on the recovery of nickel from the minus 48-mesh fraction. Nickel losses in the fibre were reduced from above 20% to 17.5 - 18.7%, and the concentrate grade was improved from 0.88% Ni in Test 1 to over 1.5% Ni in Tests 5 and 6. Lower nickel losses in the fibre were reflected in higher nickel recoveries in the concentrates. Although there was no significant change in nickel content of the flotation tailings (which indicated that a fairly large proportion of the nickel sulphides were locked in non-recoverable middling particles), treating the material with acetic acid appeared to improve selectivity in flotation. The pH in these flotation tests was approximately 9.0.

In Test 7, SO_2 was added to flotation, and the test was done at a pH of 5.5. The results of this test are given in Table 8. A concentrate was made assaying 4.5% Ni, with a tailing assaying 0.16% Ni. The addition of SO_2 significantly improved selectivity in flotation.

In Test 8, a 2000-gram sample of old tailings was ground to minus 48 mesh, separated magnetically, treated with acetic acid before tabling, then tabled to remove the fibre, and floated. This test was done to determine how much nickel could be recovered from the old tailings, using those conditions that were found to be most favorable in the previous tests. A concentrate was made assaying 4% Ni, with a recovery of approximately 20% of the nickel. The tailings assayed 0.15% Ni.

TABLE 6

Test 5, on Old Tailings, Effect of Acetic Acid in Tabling

Product	% Wt	% Ni	Units	% Distn
-48 mesh fraction				
Flotation Conc	1.13	1.56	1.76	6.7
Flotation Tail	16.68	0.17	2.84	10.8
Feed to Flotation*	17.81	0.26	4.60	17.5
Table #2 Fibre	30.71	0.15	4.61	17.5
Feed to Tabling*	48.52	0.19	9.21	35.0
Magnetics	5.75	0.83	4.77	18.1
Total -48 mesh*	54.27	0.26	13.98	53.1
Total +48 mesh	45.73	0.27	12.35	46.9
Total Feed*	100.00	0.26	26.33	100.0

* Calculated

TABLE 7

Test 6, on Old Tailings, Effect of Acetic Acid in Tabling

Product	% Wt	% Ni	Units	% Distn
-48 mesh fraction				
Flotation Conc	1.05	1.52	1.60	6.1
Flotation Tail	16.16	0.16	2.58	9.9
Feed to Flotation*	17.21	0.22	4.18	16.0
Table #2 Fibre	30.59	0.16	4.89	18.7
Feed to Tabling*	47.80	0.19	9.07	34.7
Magnetics	5.37	0.82	4.40	16.9
Total -48 mesh*	53.17	0.25	13.47	51.6
Total +48 mesh	46.83	0.27	12.64	48.4
Total Feed*	100.00	0.26	26.11	100.0

* Calculated

TABLE 8

Test 7, on Old Tailings, Effect of SO_2 in Flotation

Product	% Wt	% Ni	Units	% Distn
-48 mesh fraction				
Flotation Conc	0.33	4.48	1.48	5.5
Flotation Tail	13.63	0.16	2.18	8.2
Feed to Flotation*	13.96	0.26	3.66	13.7
Table #2 Fibre	37.58	0.18	6.76	25.3
Feed to Tabling*	51.54	0.20	10.42	39.0
Magnetics	5.98	0.81	4.84	18.1
Total -48 mesh*	57.52	0.27	15.26	57.1
Total +48 mesh	42.48	0.27	11.47	42.9
Total Feed*	100.00	0.27	26.73	100.0

* Calculated

TABLE 9

Test 8, on Old Tailings, Effect of Grinding All of Sample to Minus 48-Mesh

Product	% Wt	% Ni	Units	% Distn
Flotation Conc	1.27	4.08	5.18	19.5
Flotation Tail	40.45	0.15	6.07	22.8
Feed to Flotation*	41.72	0.27	11.25	42.3
Fibre	49.80	0.17	8.47	31.9
Feed to Tabling*	91.52	0.21	19.72	74.2
Magnetics	8.48	0.81	6.87	25.8
Total Feed*	100.00	0.27	26.59	100.0

* Calculated

A comparison of the results obtained in this investigation is given in Table 10. The recoveries shown are calculated for a concentrate assaying 1% Ni, except in the case of Test 1, where the recoveries shown are calculated for a concentrate assaying 0.88% Ni. In each case, the flotation tailings were added to the concentrates. In Tests 4 to 7, the nickel recoveries for the plus 48-mesh fraction were estimated from Test 1. (Estimates were based on a concentrate assaying 1% Ni.)

TABLE 10

Table of Comparison of Recoveries

Test No.	Sample	Test Procedure	Concentrate Grade, % Ni	Ni-Recovery, %*		
				Size Fraction		Total
				-48 mesh	+48 mesh	
1	Old Tailings	Standard	0.88	4.0	15.5	19.5
2	Fresh Tailings	Standard	1.0	8.2	18.5	26.7
3	Old Tailings	Gravity Concentration	1.0	4.5	11.6	16.1
4	Old "	Regrinding the -48 mesh fraction	1.0	4.7	(15.2)	19.9
5	Old "	Modified standard procedure to include conditioning with acetic acid	1.0	7.2	(15.2)	22.4
6	Old "	(Repeat of Test 5)	1.0	6.5	(15.2)	21.7
7	Old "	Addition of SO_2 to flotation	1.0	6.4	(15.2)	21.6
8	Old "	Grinding to -48 mesh, and conditioning with acetic acid	1.0			22.1

* Calculated

DISCUSSION

Comparison of the results in Table 10 shows that some improvement in the recovery of nickel from the old tailings could be made by treating the minus 48-mesh fraction with acetic acid before tabling. The acetic acid, when used in the proper proportions, proved to be a good dispersant for the material, and helped to make a better separation between the fibre and nickel sulphides in tabling. The acid also appeared to improve the flotation response of the nickel sulphides. This indicated that the sulphide surfaces were tarnished. Further evidence to support this view was found in Test 4, in which a better flotation response was obtained after the material was ground and fresh surfaces were generated. There was no difficulty in floating nickel sulphides from the plus 48-mesh fraction, which was freshly ground before flotation.

In the case of the minus 48-mesh fraction, under standard conditions, the fibre (produced by the action of the impeller in the flotation cell) and the serpentine rock particles exhibited a tendency to float along with the nickel sulphides, making it difficult to produce a satisfactory grade of nickel concentrate. It appears that aging of the stockpiled tailings has activated the surfaces of the gangue minerals. This may have been brought about by oxidation of the metallic minerals in the stockpiled tailings and adsorption of the heavy metal ions on the surfaces of the gangue minerals, and possibly by chemical spraying to impound the tailings. The chemical spraying may also have contributed to the tarnishing of the sulphide surfaces. Washing the material with acetic acid prior to flotation appeared to improve selectivity in flotation. A stronger acid, such as a solution of SO_2, was found to be even more effective in depressing the gangue.

Only limited improvements could be made in the recovery of nickel from the old tailings by modifying the test procedure. There were mineralogical differences between the samples that contributed to poorer recoveries from the old tailings. Comparison of the head samples showed that there was 20% more nickel in the fresh tailings than in the old tailings. Comparison of the units of nickel in the concentrates (Tables 2 and 3) showed that there were more nickel sulphides in the fresh tailings than in the old tailings. A mineralogical examination of the concentrates showed that the nickel was essentially in the form of heazelwoodite (Ni_3S_2), and the majority of this nickel mineral was liberated. The nickel found in the flotation tailings was not liberated. Electron microprobe studies of the fibre and serpentine showed that the fibre contained an average of 0.11% Ni, and the serpentine contained an average of 0.12% Ni. Nickel sulphide inclusions in the serpentine particles accounted for tailing assays of 0.14 to 0.16% Ni. There appeared to be more inclusions in the old tailings than in the fresh tailings, because usually higher tailing assays were obtained from flotation when treating the old tailings.

CONCLUSIONS

There appeared to be at least four major causes for the poor nickel recoveries obtained from the old stockpiled tailings.

(1) Tarnishing of the sulphide surfaces in the stockpiled tailings due to weathering, or chemical spraying to impound these tailings, caused the nickel sulphides to respond poorly to flotation.

(2) Activation of the surfaces of the gangue minerals caused problems in selectivity, and resulted in poor concentrate

grades. Cleaning of these low-grade concentrates resulted in greater nickel losses in the flotation tailings.

(3) The higher proportion of nickel-sulphide inclusions in the serpentine gangue found in the old tailings also resulted in higher nickel losses in the flotation tailings, and

(4) the fact that there were fewer free nickel-sulphide particles in the old tailings than in the fresh tailings resulted in poorer recoveries.

The problems caused by the surface characteristics of the minerals in the old tailings could be overcome by grinding to produce fresh surfaces or by acid treatment with SO_2 or acetic acid.

ACKNOWLEDGEMENTS

Electron microprobe studies of the fibre and serpentine phases in the samples were done by Dr. D. C. Harris and Mr. D. R. Owens of the Mineralogical Section, Mineral Sciences Division.

IBK/am