MgO rejection from Birchtree ore at Inco's Manitoba Division

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RESUME

Birchtree est un gisement ultrabasique, et avant 2003, représentait un tier de la production des opérations d'Inco à Thompson. La roche mère ultrabasique est riche en oxide de magnésium (MgO), qui lorsque traité par fonderie, contribu à certains problèmes aux fours et aux convertisseurs du à la haute temperature du liquide. En octobre 2003, la production de la mine Birchtree a grimpé à plus de la moitié de l'alimentation totale de l'usine. Cette dernière ne peut pas produire un concentré de fonderie approprié avec la configuration du circuit et les pratiques d'opération existantes. L'objectif de l'usine est la production d'un concentré de nickel avec moins de 3% de MgO.

Des mini cellules de flottation en continu ont été utilisées afin d'explorer les options de traitement. Deux campagnes ont été entreprises. La première visait à rejeter les minerais de silicate de magnésium à l'aide de réactifs provenants des concentrés de la dégrossisseuse et de l'épuiseuse. Les réactifs incluaient le silicate de sodium, la gomme de guar et deux types de CMC. Les résultats indiquent que la pratique courante d'usine d'addition de CMC au circuit de l'épuiseuse minimise le grade de MgO du concentré.

La seconde campagne se concentrait sur le rejet des minerais de MgO du concentré de la finisseuse par l'utilisation d'une solution diluée de CMC. Le temps de rétention de la flottation, le taux de dosage de CMC, et le temps de conditionnement, ont été variés. Les résultats indiquent que 0.1 g de CMC par kilogram de solides dans la pulpe produit un concentré avec un grade de MgO <3.0%.

ABSTRACT

MgO Rejection From Birchtree Ore at Inco's Manitoba Division

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Birchtree is an ultramafic ore body and prior to 2003, represented one third of the production for Inco's Thompson operation. The ultramafic host rocks are high in MgO which, when processed through the smelter, promotes problems in the roasters and converters due to the high liquidus temperature. In October 2003, production from Birchtree mine ramped up to more than half of the total feed to the mill. The mill cannot produce a suitable concentrate for the smelter with current circuit configuration and operating practices. The target for the mill was to produce a nickel concentrate with less than 3% MgO.

Continuous mini flotation cells were used to explore processing options. Two campaigns were carried out. The first looked at rejecting the magnesium silicate minerals with the use of reagents from the rougher and scavenger concentrates. Reagents included sodium silicate, guar gum and two types of CMC. Results indicated that current plant practice of CMC addition to the scavenger circuit favours minimizing MgO grade in concentrate.

The second campaign focused on rejecting MgO minerals from the rougher-cleaner concentrate with the use of a dilute CMC solution. Flotation retention time, CMC dosage rate, and conditioning time, were varied. Results indicate that 0.1 g CMC per kilogram of solid in slurry produced a concentrate grading <3.0% MgO.

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CONTENTS

CHAPTER 1 INTRODUCTION 1
1.1 BACKGROUND AND MOTIVATION 2
1.2 OBJECTIVE AND SCOPE 3
1.3 FORMAT OF THESIS 4

CHAPTER 2 LITERATURE REVIEW 5
2.1 GEOLOGICAL INFORMATION 5
2.1.1 Birchtree Ore Body Geology 5
2.1.2 Optical Mineralogical Analysis 7
2.2 THE EFFECT OF MAGNESIUM SILICATES ON FLOTATION 8
2.2.1 Aggregation 9
2.2.2 Depression 11
2.2.3 Combined Effects of Aggregation and Depression 12
2.3 REAGENTS 14
2.3.1 Polysaccharides 15
2.3.2 Carboxymethyl Cellulose: CMC 16
2.3.3 Guar Gum 19
2.3.4 Sodium Silicate 20
2.3.5 Other Depressants/Dispersants Not Tested 23
2.4 HISTORY OF TEST CAMPAIGNS WITH BIRCHTREE ORE 24
2.4.1 Exploratory Test Work 24
2.4.2 Initial CMC Plant Work 25
2.4.3 Froth Washing 26
2.5 FLOTATION HINDRANCES 27
2.6 OTHER BIRCHTREE RELATED PROJECTS 28

CHAPTER 3 THOMPSON MILL OPERATION 30
3.1 ORE RECEIVING 30
3.2 CRUSHING PLANT 30
3.3 MILLING CIRCUIT 31
3.4 FLOTATION CIRCUIT 33
3.5 SMELTER 34
3.6 REFINERY 36

CHAPTER 4 EXPERIMENTAL EQUIPMENT 37
4.1 MINICELLS 37
4.2 AUXILLARY EQUIPMENT 38
4.3 REAGENTS 39
4.4 PROCEDURES 40
4.4.1 Data Analysis 40

CHAPTER 5 TEST WORK: ROUGHER and SCAVENGER STAGE 41
5.1 TEST PLAN 42
5.2 RESULTS AND DISCUSSION 46
    5.2.1 Flotation Test Results 46
    5.2.2 Rougher Stage Performance 46
    5.2.3 Scavenger Stage Performance 50
    5.2.4 Reagent Evaluation 54
5.3 OVERALL ASSESSMENT 55

CHAPTER 6 TEST WORK: ROUGHER CLEANER STAGE 57
6.1 TEST PLAN 59
    6.1.1 Sample Collection and Test Procedure 60
    6.1.2 Test Matrix 63
6.2 RESULTS AND DISCUSSION 64
    6.2.1 Effect of CMC Dosage 65
    6.2.2 Effect of Conditioning Time 68
    6.2.3 Effect of Retention Time 69
    6.2.4 Dependence on Mass Recovery 73
6.3 OVERALL ASSESSMENT 74

CHAPTER 7 THOMPSON MILL PLANT PRACTICE 76
7.1 PLANT SCALE CMC ADDITION 76
7.2 COMPARISON OF MINICELL RESULTS AND PLANT BEHAVIOUR . 80

CHAPTER 8 CONCLUSIONS AND RECOMMENDATIONS 83
8.1 CONCLUSIONS 83
8.2 RECOMMENDATIONS 86

LIST OF REFERENCES 88
APPENDIX A: Data for Chapter 5.. 91
APPENDIX B: Data for Chapter 6.. 117
APPENDIX C: Data for Chapter 7.. 141
APPENDIX D: Reagent Specifications... 145

LIST OF TABLES

Table 2-1: Head Grade of Birchtree and Thompson Ore 7

Table 2-2: Chemical Formula of Major and Minor Minerals Present In Birchtree Process Streams 8

Table 5-1: Test Matrix 45

Table 5-2: Head Grade and Dates of Tests Completed 46

Table 5-3 Summary of Rougher Stage Results 47

Table 5-4 Summary of Scavenger Stage Results 51

Table 6-1: Average Grade of Rougher Concentrate for Test Work 62

Table 6-2: Test Results from Phase 2 65

LIST OF FIGURES

Figure 2-1: Photograph Illustrating BT 84 Ore Zone Brecciated Ultramafic Within a Sulphide Matrix 6

Figure 2-2 Solubility Diagram of Mg^{2+}, $MgOH^{+}$, $Mg(OH)_2$ (s).......... 10

Figure 2-3 Polymeric Reaction With the Surface of a Metal Species.......... 16

Figure 2-4 CMC Molecule 17

Figure 2-5 Carboxy Reaction (of CMC) With the Surface of a Metal Species 18

Figure 2-6 Guar Molecule 20

Figure 2-7 Sodium Silicate Molecule 21

Figure 2-8 SEM (secondary electron image) of the surface of a pentlandite particle lost to tails showing the presence of high magnesium bearing slimes.......... 28

Figure 3-1 Crushing Plant Flow Sheet 31

Figure 3-2 Grinding Flow Sheet 33

Figure 3-3 Flotation Flow Sheet 34

Figure 4-1 General Set-Up of Minicells 37

Figure 4-2 Minicell Set-Up in the Thompson Mill 38

Figure 5-1 Flotation Flow Sheet : Minicell Test Work Focuses on Circuit Within Dotted Line 43

Figure 5-2 Flow Sheet of Minicells 44

Figure 5-3 Rougher Stage Performance 48

Figure 5-4 Rougher Concentrate Ratio 50

Figure 5-5 Scavenger Stage Performance 52

Figure 5-6 Scavenger Concentrate Ratio 53

Figure 6-1 Flotation Flow Sheet : Minicell Focus Within the Dotted Line 61

Figure 6-2 Flow Sheet of Minicells 62

Figure 6-3 Test Matrix 63

Figure 6-4 Effect of CMC Dosage on Nickel Recovery and MgO Grade 66

Figure 6-5 Effect of CMC Dosage on Nickel and MgO Grade 67

Figure 6-6 Effect of Conditioning Time on MgO and Nickel Recovery 68

Figure 6-7 Effect of Conditioning and Retention Times on MgO Grade 69

Figure 6-8 Effect of Retention Time on MgO Grade and Nickel Recovery 71

Figure 6-9 MgO Recovery vs. Nickel Recovery 72

Figure 6-10 Overall Trend of Ni+MgO Recovery Against Mass Recovery 73

Figure 6-11 Nickel and MgO Recovery Against Mass Recovery Individually 74

Figure 7-1 CMC Bag and Hopper System 77

Figure 7-2 CMC Addition to Rougher Concentrate Launder 78

Figure 7-3 Plant Performance of CMC in Solution to Rougher Concentrate 79

Figure 7-4 Plant Nickel and MgO Grade in Concentrate 80

CHAPTER 1
INTRODUCTION

Inco's Thompson Operation is an integrated mine, mill, smelter and refinery complex which produces refined electrolytic nickel and cobalt oxide. Nickel sulphide ore is mined from two sources: the Thompson Mine and Birchtree Mine. In October 2003, Birchtree Mine, an ultramafic ore body doubled production. The Birchtree ore body has generally been described as a brecciated ultramafic rock within a sulphide matrix. The mineralogy of the ultramafic rocks includes serpentine, chlorite and talc, which have a high MgO content. These serpentine minerals contribute to high MgO levels in concentrate. The Thompson Concentrator batch processes the ore from the two mines and in the past, Thompson Mine concentrate diluted the effects of MgO in Birchtree concentrate to the Thompson Smelter. There are several issues associated with this that will be mentioned in the body of the thesis. With the increased Birchtree production and the mill's inability to reject MgO, there is not sufficient Thompson mine concentrate available for blending. The smelter's ability to process the concentrate becomes restricted unless the mill can consistently provide a low MgO product.

1.1 BACKGROUND AND MOTIVATION

The Birchtree Mine (BT) in Thompson Manitoba is an ultramafic associated ore body with a high serpentine mineral content. The serpentine group of minerals are phyllosilicates and contain magnesium in their crystal structure. These minerals include talc, which is hydrophobic and easily flotable, in addition to serpentine and chlorite, which enter the concentrate as slime coatings or by entrainment.

Based on past production data, the MgO in the feed to the mill does not correlate with the MgO in the nickel concentrate. The upper ore zone, from 1400 Level to 2100 Level, known as BT 83, has been exhausted. The ore below BT 83, is known as the BT 84 ore body and is open at depth. However, preliminary assays of the BT 84 ore body indicate that the MgO levels in the feed are much greater than seen in the past. Average feed grades for BT 83 were between 10-18% MgO; BT 84 has shown values in the range of 18-23% MgO. Without control of the MgO content in the final nickel concentrate, levels will increase to a point that cannot be handled by the smelter.

Prior to 2003, Manitoba Division produced Thompson Mine ore to Birchtree Mine ore at a ratio greater than 2:1. By 2004, this ratio will change to 1:1. The smelter currently blends Thompson and Birchtree concentrate but in the future the furnaces will not be able handle the high amount of MgO contained in Birchtree concentrate. As the MgO content in total concentrate increases, the energy required for smelter matte/slag separation increases due to the higher slag liquidus. The mill must find a consistent method of rejecting the MgO from concentrate.

1.2 OBJECTIVE AND SCOPE

The study aims to reduce the MgO grade in Birchtree nickel concentrate with the use of reagents.

Two sets of mini-flotation cells, assembled by the University of McGill and Noranda were shipped to Thompson. These were set up in the Mill to thief slurry from process streams. This allows for reagent alternatives to be tested while normal plant operating conditions continue without disruption. Chemical screening is conducted on actual plant streams to provide continuous and realistic data, rather than singular batch lab tests that try to replicate plant conditions. Tests can also be carried out over an extended period of time and compared to parallel plant information.

The first phase of test work explored the effectiveness of four reagents to the rougher and scavenger flotation stage. Guar gum, CMC (carboxymethyl cellulose) and sodium silicate were selected based on available literature, as possible reagents to maximize MgO rejection from concentrate.

The second phase focused on optimizing CMC addition to the rougher cleaner process stream. The objective was to determine the optimum CMC dosage rate and slurry conditioning time and to determine if flotation retention time affects CMC performance.

Plant performance data on the introduction of liquid CMC to the rougher cleaner stage is also examined and compared with minicell results. The intention was to determine if, by scaling up the system, CMC introduction was effective in rejecting the MgO minerals.

1.3 FORMAT OF THESIS

Chapter Two provides an overview of literature on the geology of Birchtree ore; the effect that the Mg-silicates have in flotation; studies performed on CMCs; reagent screening of guar gum and sodium silicate; and past Birchtree test work. Chapter Three provides brief background information about the Thompson Operation. Chapter Four describes the equipment used during the test work to evaluate the reagents. Chapter Five presents details of the first phase of the experimental test work, which included reagent screening. Details of the second phase of the test work to confirm CMC behaviour in the rougher cleaner stage are outlined in Chapter Six. Chapter Seven presents a comparison of plant scale test work against the minicell data. Finally, Chapter Eight summarizes and concludes all test work. Appendices which include the test assays and data are provided at the end of the thesis.

Note that it is the magnesium within the mineral structure which promotes problems in the smelter. In the body of this text MgO values are quoted. This is a common convention for reporting Mg assays and is used in the Thompson Operation.

CHAPTER 2
LITERATURE REVIEW

In this section, several topics are discussed: the geology of the Birchtree ore body including an analysis of the minerals in the flotation streams, the effect that magnesium silicates have on flotation, the reagents that can be used to aid sulphide recovery and silicate depression, the history of past work on Birchtree ore within Inco, and a review of external projects that were or are being carried out with Birchtree ore.

2.1 GEOLOGICAL INFORMATION

2.1.1 Birchtree Ore Body Geology

The Thompson Nickel Belt, located in North Central Manitoba, has been an exploration target for Inco since the 1940s. As a result, there have been many nickel sulphide discoveries. Thompson and Birchtree are the two mines currently in operation.

The sulphide mineralization in many parts of the Thompson Nickel Belt is closely associated with magnesium-rich ultramafic rocks that are mainly peridotites that have been altered to serpentines. (1) The Birchtree ore body has generally been described as a brecciated ultramafic rock within a sulphide matrix. The generic term used within the mine for the ultramafic rock is peridotite. There are three main classes of peridotite: core peridotite, the mining hangingwall for 50% of the BT 84 ore body with an average nickel grade of 0.20%; mineralized peridotite, located within the BT 84 ore zone: the mineralized peridotite is interspersed with sulphide inclusions and grades from 0.50 to 3.0% nickel; and barren peridotite, which constitutes the brecciated ultramafic within the BT 84 ore body and has an average grade of 0.35% Ni. The barren peridotite contributes most of the diluent in the feed and grades at 33% MgO (2). The sulphides consist predominantly of pyrrhotite with minor amounts of pentlandite, chalcopyrite and magnetite. Figure 2-1 illustrates the peridotites within a high sulphide zone.

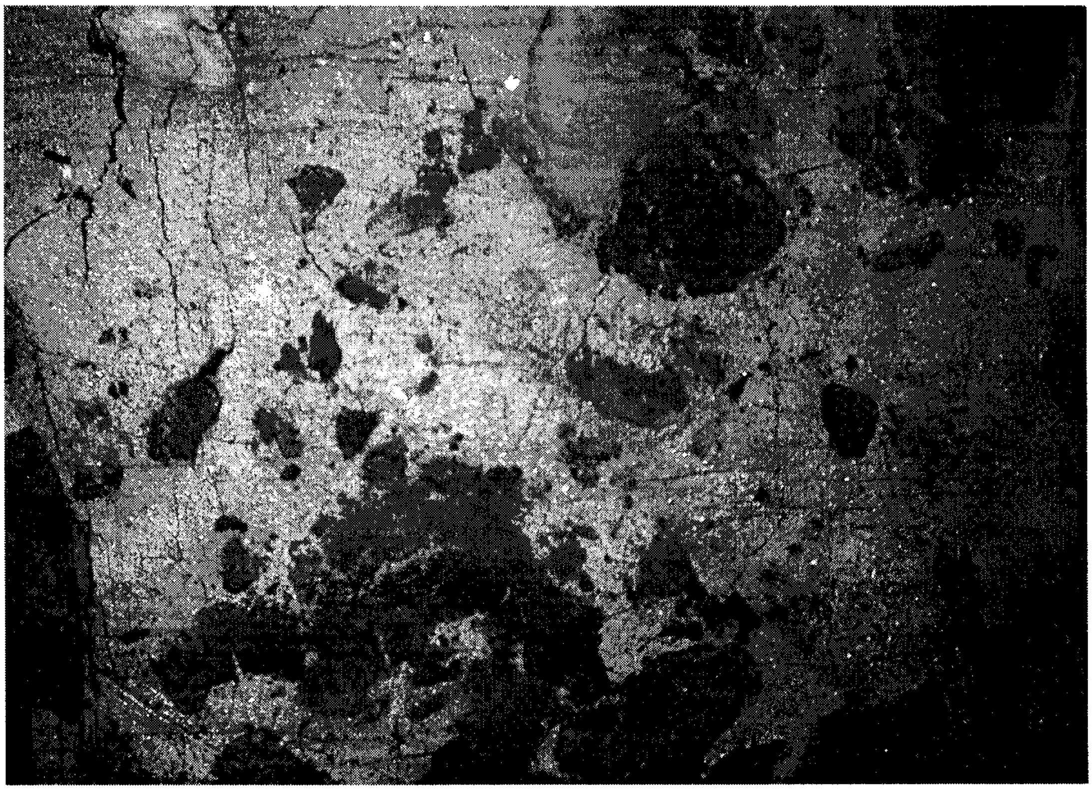

Figure 2-1: Photograph Illustrating BT 84 Ore Zone Brecciated Ultramafic Within a Sulphide Matrix (I. Blakely, 2003) (25)

The foot wall for most of the ore body is metamorphosed pelitic rock dominated by biotite, plagioclase, pyrrhotite, and quartz with minor graphite and trace amounts of talc and serpentine. The hanging wall in the lower sections of the BT 84 ore body is comprised mainly of schist (3).

For comparison, the head grades of the Thompson and Birchtree ore bodies are provided in Table 2-1. The noted differences between the two are the higher nickel grade in Thompson ore, and the much higher MgO grade in Birchtree.

Table 2-1: Head Grade of Birchtree and Thompson Ore

	Cu	**Ni**	**Fe**	**S**	**MgO**		**Cp**	**Pn**	**Po**	**Rk**
Thompson Ore	0.16	2.6	15.3	8.9	3.8		0.5	7.3	16.1	76.2
Birchtree Ore	0.10	1.7	21.1	10.2	16.5		0.3	4.9	21.7	73.1

2.1.2 Optical Mineralogical Analysis

There are at least three rock types associated with Birchtree ore: granitic, ultramafic and pelitic. Quartz, biotite and feldspar are closely associated minerals, derived from the granitic rocks. Talc, serpentine, magnetite and carbonate are derived from metamorphism and/or alteration of the ultramafic rocks. Olivine, orthopyroxene and clinopyroxene are present as relicts from the original mineral assemblage. Graphite, biotite, muscovite, quartz, feldspar and garnet are common associates in metamorphosed pelitic rocks. Chlorite is also present.(4)

Magnesium silicates, such as chlorite, serpentine and talc tend to be closely associated. These minerals will contribute to high MgO assay in nickel concentrate.

The possible ways that magnesium silicates may be recovered include being naturally hydrophobic, becoming activated, through entrainment, as locked particles with the sulphides or as slime coatings on the sulphide minerals (5).

Table 2-2 provides the chemical makeup of the minerals found in Birchtree ore.

Table 2-2: Chemical Formula of Major and Minor Minerals Present In Birchtree Process Streams

Sheet Silicates	General Formula
quartz	SiO_2
microcline	$(K,Na)AlSi_3O_8$
amphibole	$(Mg,Fe)_7Si_8O_{22}(OH)_2$-$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$-$(Na,Ka)Ca_2(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH)_2$
pyroxene	$(Fe,Mg)_2Si_2O_6$-$(Fe,Mg,Ca)_2Si_2O_6$
olivine	$(Fe,Mg)_2SiO_4$
Other Silicates	**General Formula**
biotite	$K_2(Fe,Mg)_3AlSi_3O_{10}(OH,O,F)$
talc	$Mg_3Si_4O_{10}(OH)_2$
serpentine	$Mg_3Si_2O_5(OH)_4$
muscovite	$K_2Al_2(AlSi_3O_{10})(OH)_2$
chlorite	$(Mg,Al,Fe)_3(Si,Al)_4O_{10}(OH)_2(Mg,Al,Fe)_3(OH)_6$
Sulphides	**General Formula**
pyrrhotite	$Fe_{1-x}S$
pentlandite	$(Fe,Ni)_8S_9$
pyrite-marcasite	FeS_2
chalcopyrite	$CuFeS_2$
Other Minerals	**General Formula**
carbonate	$CaCO_3$
graphite	C

2.2 THE EFFECT OF MAGNESIUM SILICATES IN FLOTATION

The valuable sulphide minerals in Birchtree ore are chalcopyrite and pentlandite. Pyrrhotite is present but has little nickel value, and no attempt at recovery is made. As illustrated in Table 2-2, many of the silicate minerals contain magnesium. In a slurry, Mg^{2+} ion can dissociate from the mineral structure. Studies by Iwasaki et al. (1980), Krishnan and Iwasaki (1986), Iwasaki (1989) and Lascelles and Finch (2003) have shown that when magnesium ions are present in a flotation system it can cause two effects: aggregation and depression. In an alkaline system, precipitates of magnesium hydroxide, $Mg(OH)_2$, form weakly bonded flocculated particles, virtually regardless of mineral type; and since the hydroxide is hydrophilic, it will promote depression of all minerals.

2.2.1 Aggregation

There are two ways magnesium hydroxide forms on the surface, through heterocoagulation and surface nucleation. Heterocoagulation occurs between particles of opposite charge. Abstraction of magnesium by heterocoagulation depends on the charge difference between $Mg(OH)_2$ precipitates and the mineral in question. $Mg(OH)_2$ particles are positive up to ca. pH 12.5, after which they become slightly negative (6). Below pH 12.5 there is ready accumulation of $Mg(OH)_2$ onto sulphide and silicate surfaces, which are predominantly negatively charged at alkaline pH, to form large flocculated particles.

Surface nucleation occurs when the $Mg(OH)_2$ forms in situ. Abstraction increases with pH, which promotes adsorption of Mg^{2+}. There is a steep rise in abstraction at or above pH 9.5 where $Mg(OH)_2$ precipitation occurs. It is these flocs and 'slime' coating of $Mg(OH)_2$ precipitates on the sulphides that hinder flotation.

The solubility diagram of Mg species as a function of pH is illustrated in Figure 2-2. As pH increases above ca 9, $Mg(OH)_2$ precipitates out of solution.

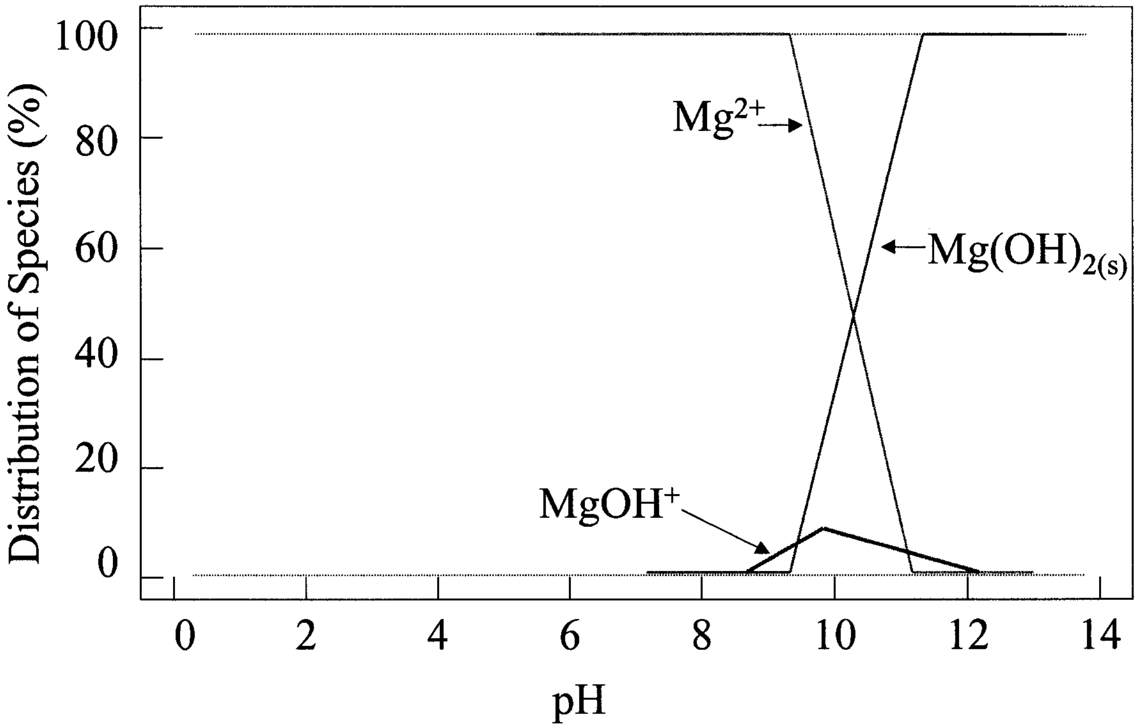

Figure 2-2: Solubility Diagram of Mg^{2+}, $MgOH^{+}$, $Mg(OH)_2$ (s) (after Fuerstenau, D. W. and Fuerstenau, M. C., 1982 (20))

Wellham et al. (1992) studied the effect of a saline solution on the flotation rate of silicate-slime coated sulphides. The electrolyte modified the hydration layer around the mineral particles and air bubbles which increased hydrophobicity and slime dispersion. The hydration layer is the field of oriented water molecules surrounding a particle and its thickness increases with an increase in zeta-potential. A thick hydration layer at an elevated pH means there is a film of water between the particle and the bubble that retards attachment to the air bubbles (5).

The study also confirmed that the extent of slime coating is related to the zeta-potential. The slime coating is densest when the hydroxides and particles have a large difference in opposite charge. The particle zeta potential will decrease with an increase in concentration of oppositely charged ions in the electrolyte. In a saline solution, large concentrations of ions such as Mg^{2+}, Na^+, and Cl^- in the solution will improve slime dispersion.(5) Reagents are also introduced to aid in slime dispersion by changing the charge on the coated surfaces.

Krishnan and Iwasaki (1986) measured the zeta potential of quartz particles in a 10^{-2} M $MgCl_2$ electrolyte solution. At pH <9.5 the zeta potential reached –70 mV. Upon increasing the pH to greater than 10, the zeta potential increased to +40 mV. This showed a change in the surface charge of the particles from "quartz-like" to "$Mg(OH)_2$-like" as the surface became coated with the precipitate. A similar response is observed for sulphide minerals. (6)

2.2.2 Depression

The depressive effects of magnesium are generally not evident until pH 9, the pH at which the hydroxide particles start to precipitate out of solution as illustrated in Figure 2-2. The hydroxides form a positively charged coating on the sulphide minerals, which imparts hydrophilic properties to the particle. This counters the hydrophobic properties of the collector and may also block possible bonding sites for collectors (i.e. xanthate). If there is a net hydrophilic property, depression will occur. The mechanism for Mg depression is the competition between hydrophilic hydroxide precipitate sites on the surface and the hydrophobic (collector) sites (7).

Edwards et al., (1980) completed a study on ore from Inco's Pipe Mine (not currently operating), an ultramafic ore body located just south of Birchtree Mine, with similar ultramafic mineralization. Tests were performed in a Hallimond tube with varying ratios of pentlandite to chrysotile and lizardite, both serpentine minerals. At pH 9, there was almost total depression of pentlandite at a ratio of 1:200 Pn:Chrysotile. Depression with lizardite also occurred but less severe, and occurred at much higher ratios. The addition of CMC (carboxymethyl cellulose) dramatically increased recovery of pentlandite in the presence of either mineral. Flotation depression caused by slime coating is controlled by the difference between the slime particle and sulphide mineral surface charge. CMC will change the particle surface charge from positive to negative (19).

Many flotation circuits have indicated problems with selectivity when magnesium-silicates are present. One remedy is to disperse the silicate mineral slimes from the surface of particles during flotation (8). This is generally achieved with the addition of dispersing agents such as CMC, guar gum and sodium silicate.

2.2.3 Combined Effect of Aggregation and Depression

Depression and aggregation are related in many cases. The formation of hydroxide precipitates on the mineral surface creates a positive surface charge and competes with the sites available for collector adsorption. As well, the oppositely charged particles, like sulphides and hydroxide, will heterocoagulate, and form large sized flocs with mixed flotation properties and often remain depressed. Slime coatings on particles will have a similar effect.

In some flotation circuits, it may be economic to implement a selective flocculation-desliming step. The pulp pH can be made highly alkaline so that the siliceous gangue particles are fully dispersed. This causes the pulp pH in the subsequent flotation steps to stay alkaline (pH 10-11) for cationic flotation (6).

Another solution is to disperse and deslime the slurry. However, the flocculation properties of hydroxide precipitates can adversely affect any selective desliming. Removal methods using high-energy conditioning or ultrasonification are two examples of mechanical dispersing systems (8). Hydrocyclones can also be used, and depending on economics and grind size, can preferentially remove the platy minerals such as talc.

Wellham et al. (1992) compared two flotation feeds: one that had been deslimed prior to flotation and one that had not. Significantly more magnesium minerals were recovered in the rougher flotation product of the non-deslimed feed and then rejected during the cleaning stage. By contrast, the deslimed material did not recover as much of the Mg-minerals in the rougher float, but rejection was poor in the cleaning stage. At this stage, locking of gangue and sulphides was an issue (5).

A solution for each ore type, and plant application must be determined depending on significance of the problem and practicality. Dispersing agents to control the magnesium are a possibility. The solution for the Thompson Mill (in

1997) was to introduce CMC, in powder form, to both the rougher and scavenger flotation stages. This worked "most" of the time to depress the MgO. However, the physical circuit operation, pH control and the operator, would determine how effectively the CMC system rejected Mg-silicates. Illustrated in Chapter 6, is test work confirming that by adding CMC to the rougher concentrate, Mg-silicates that reported to the bulk rougher stage would be dispersed and depressed by the polymer in subsequent flotation stages. Process samples collected during this stage of CMC application indicated a trend towards Mg-rejection, and is also the focus of this thesis.

2.3 REAGENTS

The polymers used in this study have proven their worth within the industry as dispersing/depressing agents. Their role is to induce a positive charge to the minerals to counter aggregation and reinforce the hydrophilic nature of the silicate minerals. The effectiveness of a given reagent depends on adsorption density and charge characteristics, which are influenced by degree of substitution of reactive head groups. There can also be a synergistic effect of two polymers. This leads to the possibility of staged addition for greatest effect.

The polymers adsorb through interactions with the metal hydroxyl species on the mineral surfaces. Polymers with a large number of hydroxyl groups are used as flotation depressants and can impart a strong charge on particle surfaces (9). Polysaccharides, such as guar gum and carboxymethyl cellulose (CMC), are natural organic polymers that are non-toxic and biodegradable. They are generally cheap and easily introduced to a flotation circuit. The slurry pH has a large influence on the effectiveness of these reagents and deviations in pH make the processes less efficient. The optimum pH for interaction between the mineral and the polysaccharide usually coincides with the iso-electric point of the metal hydroxide precipitate. This is also the point where metal hydroxylation is at a maximum (9).

2.3.1 Polysaccharides

The surface properties of the minerals in the flotation pulp will determine the effectiveness of the polysaccharide introduced to the system. The hydroxyl groups on the mineral surface can either donate or accept a proton; similarly, the hydroxyl groups in the polysaccharides give away a proton to form the 5-member polysaccharide-metal ring complex. That is, the metal surface (hydroxyl species), would behave as a Br∅nsted base during the interactions with the polysaccharide. The stronger the basicity, the stronger is the interaction with the polysaccharide (9).

The natural surface charge of the mineral will determine if the hydroxyl (OH^-) groups will be donated, thus developing a positive surface charge. However, if the solution pH is too high, the OH^- groups will be driven back to the surface. Figure 2-3 is the general reaction between the polymer and the metal surface.

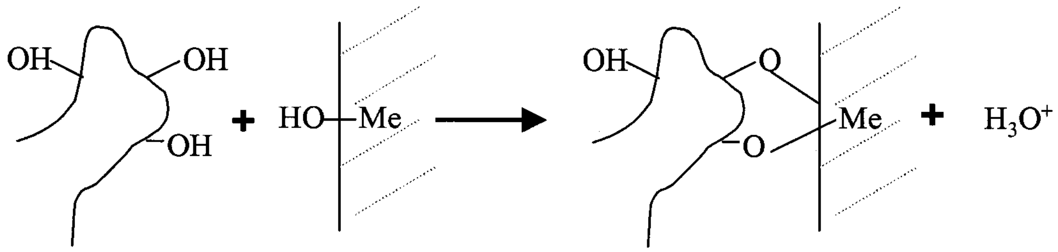

Figure 2-3: Polymeric Reaction With the Surface of a Metal Species
Lui, Q., Laskowski, J.S., 1999 (9)

The anionic polysaccharides will bind with the positive particles, like serpentines, in solution and impart a negative coating. This will promote electrostatic repulsion from the negative surfaces of the sulphides.

Selective adsorption on a mineral surface by polysaccharides may be difficult in the flotation pulp, as the slurry will contain a large variety of metal ions derived from superficial dissolution of the minerals. These can mask the surfaces of the minerals. Polymers, in combination with reagents, may be beneficial in removing the contaminating metal ions.

The success of the polysaccharide in a system will depend on the modification of its chemical structure imparted during manufacturing, the specificity of the substituted groups and the size of the polymer chain. The chain length should be such that the other non-specific forces caused by unsubstituted hydroxyl groups will not mask the effects of the substituted groups (9).

2.3.2 Carboxymethyl Cellulose: CMC

The Thompson Mill has been using the sodium salt of CMC since 1997 to disperse magnesium silicates, like serpentine, talc and chlorite from the sulphide particles. Hudson Bay Mining and Smelting in Flin Flon, Manitoba will periodically use CMC as a depressant when feed to the concentrator is being mined from a high talc zones.

CMC is the etherfication product of cellulose where protons of hydroxyl groups have been replaced by carboxymethyl groups (9). The number of these substituted functional groups per monomer is the degree of substitution (DS). A high degree of substitution for CMC can put a strong negative charge on particles and therefore promote strongly dispersed systems (10). The maximum DS for CMC is 3. A lower DS has shown to be a stronger depressant for talc minerals (9). The CMC currently used in Thompson has a DS of 0.60-0.72. The molecular structure of CMC is illustrated in Figure 2-4.

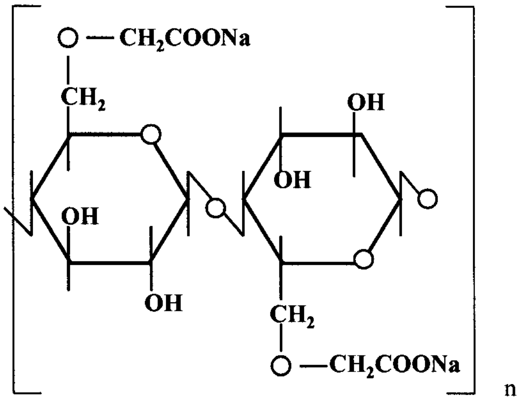

Figure 2-4: CMC Molecule
Saeki et. al. 1999 (22)

The effectiveness of CMC is pH dependent. The pH will define the mineral surface charge and degree of metal hydroxylation, which leads to selective adsorption of the CMC. The pH will also change the dissociation of the carboxyl groups and affect the interaction with the metal hydroxyl groups on the particle surface (9).

Substituted functional groups in polysaccharides can change the adsorption characteristics as well. It is suggested that the adsorption mechanism is controlled by the carboxyl group as illustrated in Figure 2-5 (11).

As mentioned in Section 2.2, the Mg^{2+} ion and the hydroxide precipitate ($Mg(OH)_2$) promote problems in flotation selectivity by heterocoagulation with the negatively charged sulphides. CMC will take magnesium out of solution, or "bind" it, either with a hydrogen bond or a dispersion interaction, where the anionic nature of the CMC induces a dipole in the MgO causing a slight change in charge distribution across the MgO molecule giving it the configuration of $^{+}Mg-O^{-}$. The result is the Mg^{+} is attracted to the O^{-} of the CMC. This reaction tends to be selective towards magnesium rather than nickel because of the size difference of the atoms (Ni>>Mg) (26). Figure 2-5 illustrates this reaction.

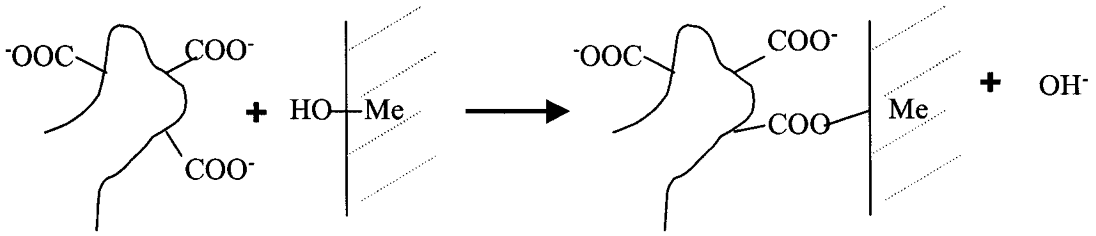

Figure 2-5: Carboxy Reaction (of CMC) With the Surface of a Metal Species
Lui, Q., Laskowski, J.S., 1999 (11)

When Na-CMC is dissolved in solution, the compound dissociates into Na^{+} and CMC^{-} where the carboxymethyl derivatives of the CMC carry the negative charge on the singly bonded oxygen on the carboxy group, hence the term “anionic dispersant”.

The negative charge of the CMC, carried on the oxygen, causes a dispersion interaction as the charge of one molecule causes a rearrangement in another molecule and an attraction occurs, forming a weak bond between the two (van der Waals forces). The negatively charged oxygen will also induce a dipole moment within the system. The oxygen will be attracted to the positive Mg^{2+} ions but will also be repelled from the negative surface charge of a sulphide mineral (26).

Another way the negatively charged oxygen can influence the dispersion is by hydrogen bonding. The hydroxyl groups of certain mineral groups will be attracted to the negative charge of the oxygen. A weak bond forms as the hydrogen atom is “shared” between the two oxygens (Figure 2-3). The hydrogen atom of the hydroxyl group has an induced positive charge as it comes into proximity of the negatively charge oxygen on the CMC. This induced charge allows the hydrogen bond to form.

2.3.3 Guar Gum

Guar gum has been used to promote the selective recovery of platinum group metals of the Bushveld Igneous Complex of South Africa, and at Falconbridge’s Kanichee open pit mine in northern Ontario (10).

Guar with a low degree of substitution adsorbs strongly onto talc and is used to reduce the negative charge on the mineral particle (10). This in turn increases the coagulation of the pulp.

The schematic of a guar molecule is illustrated in Figure 2-6. It is a nonionic compound that contains multiple hydroxyl groups throughout its structure. The hydroxyl groups will allow for the formation of hydrogen bonds with other hydroxyl groups of the minerals under appropriate circumstances.

Guar gum may not be as effective as CMC as it does not have ionic properties and thus the bonding will not be as strong.

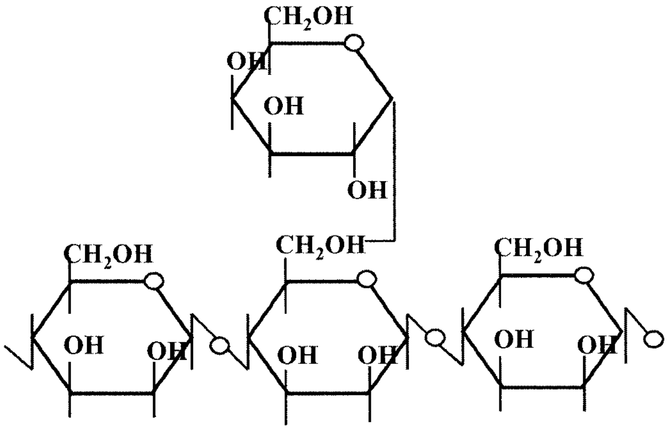

Figure 2-6: Guar Molecule
Lui, Q., Laskowski, J.S., 1999 (9)

2.3.4 Sodium Silicate

Sodium silicate is known commercially as waterglass. It is a transparent, water-soluble, viscous solution and is used as a dispersing agent in the mineral processing industry. The molecular schematic is illustrated in Figure 2-7. It also enhances the adsorption of polysaccharides on the surfaces of flotable silicate minerals and thereby allow increases selectivity and reduces depressant dosages (such as CMC) (13).

The ionic strength of the flotation slurry, due to the addition of dissociated silicate and other ions, is believed to be a critical factor affecting the adsorption of the depressant reagents. Sillwater PGM/nickel-copper mine in Montana, USA observed a 30% reduction in CMC consumption with the introduction of sodium silicate (13).

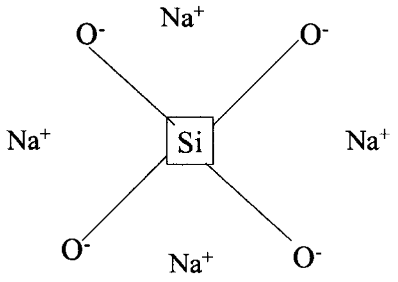

Figure 2-7: Sodium Silicate Molecule
Lempka, B., 2002 (13)

The silicate anion disperses minerals by inducing like-charges. The silicates may form complexes with multivalent metal cations (ex: Ni^{2+}, $Cu^{+,2+}$, Mg^{2+} and $Cr^{2+,3+}$), which increases the frequency of a possible problem; these complexes will settle out of solution and be lost to the flotation process. The strong negative charge of the silicate will induce a dipole moment with sulphide minerals. This will cause the sulphide portion to become more negative and the metal component more positive, which will cause an attraction between particles and weak bonds will form. Soluble silica reacts with the multivalent cationic metal ions to form the corresponding insoluble metal silicate. Silicates will precipitate these metals out of solution and render them insoluble and non-reactive. The reactant byproduct normally displays long-term stability. The bond formed can be broken only by extremely aggressive chemical action (14).

This reaction will also promote dispersion by removing the cations and restoring the negative charge to the sulphides (at alkaline pH). Dissolved silica has an anionic charge of -2. In solution, silica can donate this charge to other materials dispersed in water and cause them to be negatively charged. If all solids become negatively charged, they will repel one another. This phenomenon is the basis for the dispersive and deflocculating effects of silicates (26).

Test work by Shaw et al. reported that low levels of sodium silicate can provide very beneficial results. Plant trials on PGM and copper-molybdenum ores were carried out. Sodium silicate aids in the wetting of the silicate minerals which can enhance collector adsorption. With this wetting, defloculation of aggregated particles will occur. The hydrophilic property applied to the mineral should also improve drainage rates from the froth and reduce entrainment (14).

When the pH of liquid silicate is modified to a point below 10.7, the silica is destabilized and the system polymerizes or gels. The individual silica monomers link to form long chains of repeating SiO_2 units. The result is the precipitation of silica as a colloidal suspension or a continuous gel, depending on the silica concentration (14). This is undesirable in the flotation process.

2.3.5 Other Depressants/Dispersants (Not Tested)

The properties of polysaccharides depend on the type, source, molecular structure and modifications that would affect their adsorption and depressive functions. Inorganic reagents may be more selective than organic molecules, as they target specific ion species within the system, but can also be more expensive.

Dextrin is currently used as a graphite depressant in the copper circuit of the Thompson Mill. Figure 3-3 in the next chapter, shows that the tails from the copper circuit is one of the primary streams that make up the final nickel concentrate. It is desirable for the graphite to report to the tails, as carbon is an additional fuel source for the smelter.

Low molecular weight dextrins have been used in Brazil to depress iron and Mg-silicates, reducing the concentrate MgO grade down to 3.3% from 7.5% (15). Dextrin is derived from starch by partial thermal degradation under acidic conditions. The treatment causes the breakdown and reversion of the starch molecular chains and consequently, the resulting dextrin molecules are much smaller than starch but are more branched (9).

Dextrin adsorbs onto the mineral surface through interaction with surface metal hydroxyl species where CMC interacts with both the metal hydroxyl species and the metal cations (9).

The Jinchuan Mine in China conducted a series of tests on their copper-nickel sulphide ores. They tried CMC, tannic acid, jaguar CP-B (cationic), jaguar

CMHP (anionic) and meyprofloc (non-ionic). It was determined that CMC was superior in terms of nickel recovery compared to the other depressants (16).

Sodium pyrophosphate has been used as a selective depressant for galena in Cu-Pb bulk concentrate separation. Lui and Laskowski (1999) mention that this reagent was found to be more effective in combination with CMC than the two reagents alone (9). Edwards et al. also tried this reagent on Inco's Pipe ore. Sulphur dioxide and dextrin combinations have also been used as depressants for galena in Cu-Pb circuits at Brunswick mines and with Matabi Mines Limited (9).

2.4 HISTORY OF TEST CAMPAIGNS WITH BIRCHTREE ORE

Prior to 1994, both Thompson and Birchtree ore were blended in the crushing plant and milled together as bulk feed. During periods of high Birchtree throughput, significant nickel recovery losses were observed. The solution chosen was to batch process Thompson and Birchtree ore separately through the milling and flotation circuit.

2.4.1 Exploratory Test Work

In 1995, M. Xu and the Mineral Processing Group at Inco Technical Services Laboratory (then J. Roy Gordan Reseach Lab), conducted a test campaign using column flotation (6.35 cm diameter; 76 cm high column) on Birchtree ore. The ore used in this test work was obtained from the BT 83 ore body. These tests determined that sulphide recovery increased in Birchtree ore with the use of shallow froth depths and a short column height.

Liberation studies were carried out on BT 83 ore. It was determined that the optimum grind size for maximum nickel liberation was at 4% +100 mesh (150 μm). This is much finer than Thompson ore, which targets 37% +100 mesh and current milling configurations and equipment can only achieve 12% +100 mesh.

Dispersant evaluation was carried out with MAK Chemical CMC, Finnfix 300 CMC and Hercules Sulfoethylcellulose, Carbose D65 CMC. Finnfix 300 and MAK CMC produced the best pentlandite recovery and rock rejection. Use of the cheaper product, MAK CMC, was implemented at the Thompson Mill in 1999.

Current and future production is from the deeper BT 84 ore body. Optimum flotation operating conditions may have changed with the slight change in geology between the two ore bodies. The 84 zone, has illustrated a slightly higher nickel head grade and higher serpentine content in the ore. This translates to a higher MgO head grade than was historically observed with the Birchtree 83 ore body.

2.4.2 Initial CMC Plant Work in Thompson

CMC was used as a dispersant to reduce MgO in concentrate to the Thompson smelter during operation of the Shebandowan mine in northern Ontario during the late 1980's (17).

From 1999 through to 2001, plant test work with CMC addition to roughers and scavengers, coupled with tonnage variables and grind size targets were carried out. Birchtree is batch processed 8-10 hours during the day. Test conditions were set for one-week duration. Results were compiled based on the weekly average. It was determined, that fine grind (target: <18% +100 mesh) and CMC to the scavengers produced the most consistent increase in recovery. At the time, rock (MgO) rejection was not part of the focus.

In 2001, mineralogical analysis was completed to identify the silicates that were in the rougher and scavenger cleaner circuits. At this time, it was determined that talc was a major constituent with minor quartz and biotite. However, serpentines are the more abundant magnesium silicate in Birchtree ore, though talc is also present. Slurry samples were obtained and sent to the research lab. It was determined that CMC added prior to rougher concentrate cleaning was very effective at talc depression (18). Chapter 6 of this report explores this application further.

2.4.3 Froth Washing

In 2002, a testing campaign was carried out with focus on the rougher cleaner and scavenger cleaner circuits. Froth washing was detrimental to nickel recovery. It is possible that the froth washing bars were placed too high above the froth, and placing them within the froth layer may have been more effective. During the time of the test work, there was also a significant amount of floatable rock present.

A one-percent CMC solution was also applied to the rougher cleaner stage and scavenger cleaners. No significant trends were observed at this time.

2.5 FLOTATION HINDERENCES

Brenda Process Technology, part of Svedala Industries, Canada (now Metso Minerals), completed a feasibility study for fine grinding Birchtree 83 ore in 1997. Optimum liberation of pentlandite in Birchtree is 4% +100 mesh (150 µm). With the current mills and equipment in the Thompson Mill, the finest possible grind size is 12% +100 mesh. With a fine grind, the serpentine minerals will also be amenable to producing slime coatings on the pentlandite particles.(23)

Visual analysis of the feed at a fine grind showed that 40% of the rock is in the slime fraction (-10 µm). (19) Figure 2.4 shows a slime coated pentlandite particle. The use of CMC (or dispersing agent) is required to aid in slimes removal.

The effect of the slime coating is to prevent the successful attachment of bubbles to an otherwise hydrophobic surface. The slime coating mechanically prevents the bubble-particle attachment, presenting the colliding bubble with a hydrophilic surface (1). Figure 2-8 is an SEM surface picture of a pentlandite particle coated with slimes. The observable features on the surface contain both magnesium and silicon.

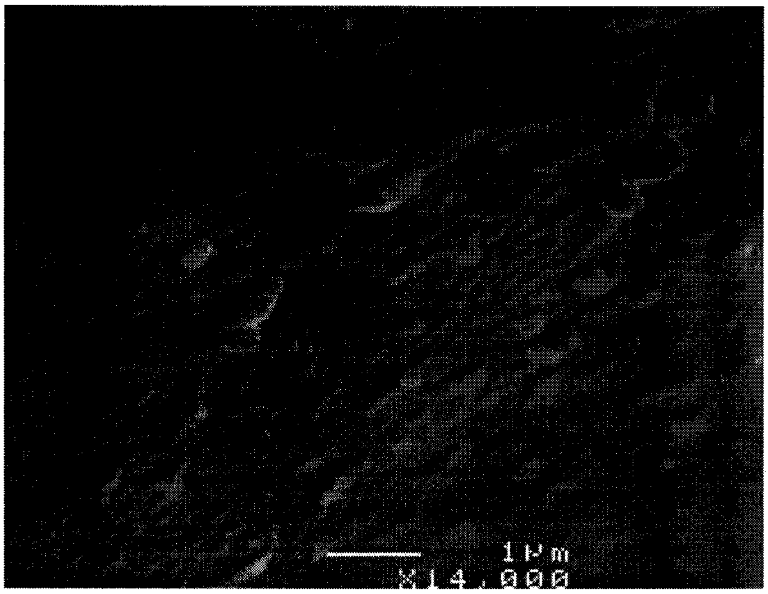

Figure 2-8 SEM (secondary electron image) of the surface of a pentlandite particle lost to tails, showing the presence of high magnesium bearing slimes. Mani et al. (1)

Another potential area for improving MgO rejection is the concentrate froth itself. There can be a large proportion of silicates entrained in the froth structure. Further exploration of froth washing may be beneficial.

2.6 OTHER BIRCHTREE RELATED PROJECTS

AMIRA, a joint project with University of South Australia, the Ian Wark Research Institute and corporate sponsors, which include Inco, is currently involved in Birchtree rock rejection. MgO depression is one aspect of this project.

In 2002, there was an initiative designed to identify and eliminate the ultramafic ores underground with a conductivity sorter. The advantage of this method was that it operated on run of mine ore, before any further processing.

The disadvantage, however, was that it could not sufficiently sort the fine material (less than one inch). The costs/benefits of this project were not positive (24).

Dense media separation was also explored. The intent was to sort gangue and sulphides in slurry form. This was effective down to particles of 850 µm (20 mesh). However, the entire feed would still have to be crushed and this process would have to come into effect before any conventional processing. A redesign of the mill operations would be required. Mining methods also were not amenable to producing the size fractions necessary for efficient separation. Rock recovery is directly related to nickel recovery. The high cost and low efficiency of fines sorting observed during pilot testing made this project uneconomical. (24)

This paper focuses on the use of reagents for magnesium-silicate rejection. The use of the McGill minicells allowed controlled continuous test work to be carried out without interrupting normal plant operation continued. Results from this test work would be then tested in the plant. The advantage of the minicells is that more tests could be completed over a shorter time period, without the large costs that may be associated with failed plant trials.

CHAPTER 3
INCO'S MANITOBA DIVISION

Thompson is located approximately 753 km north of Winnipeg Manitoba. The integrated Mine, Mill, Smelter and Refinery complex has been in operation since 1960.

In the mill, Thompson and Birchtree ores are batch processed separately through the grinding and flotation circuit. In the past, production from Thompson mine doubled Birchtree, such that, in a 24-hour period, 16 hours were dedicated to Thompson and 8 hours for Birchtree ore. However, increasing production from Birchtree, evens out these batched runs to 12 hour shifts each.

3.1 ORE RECEIVING

Birchtree Mine is located approximately 7 km south of the concentrator. The ore is delivered to the mill by 40 ton-capacity trucks through an outside receiving system. At this point, the ore can be stockpiled, or dumped onto a series of conveyors which transfers it to an 800 tonne bin inside the Mill.

3.2 CRUSHING PLANT

The Thompson Mill has three identical crushing lines. Figure 3-3 illustrates one line, which consists of a rod deck screen, a 7-ft standard crusher, tyrock screen and a 6-ft shorthead crusher. This allows some flexibility as one line can be down for maintenance without interrupting production. The target crush size for the ore is 30% + ½ inch (13 mm). The crushing system is monitored twice weekly for size control by the operators. Crushed ore is conveyed to a tripper conveyor where it is distributed between three fine ore bins. Thompson and Birchtree ores are kept separate; the #1 and #3 fine ore bins are dedicated to Birchtree ore.

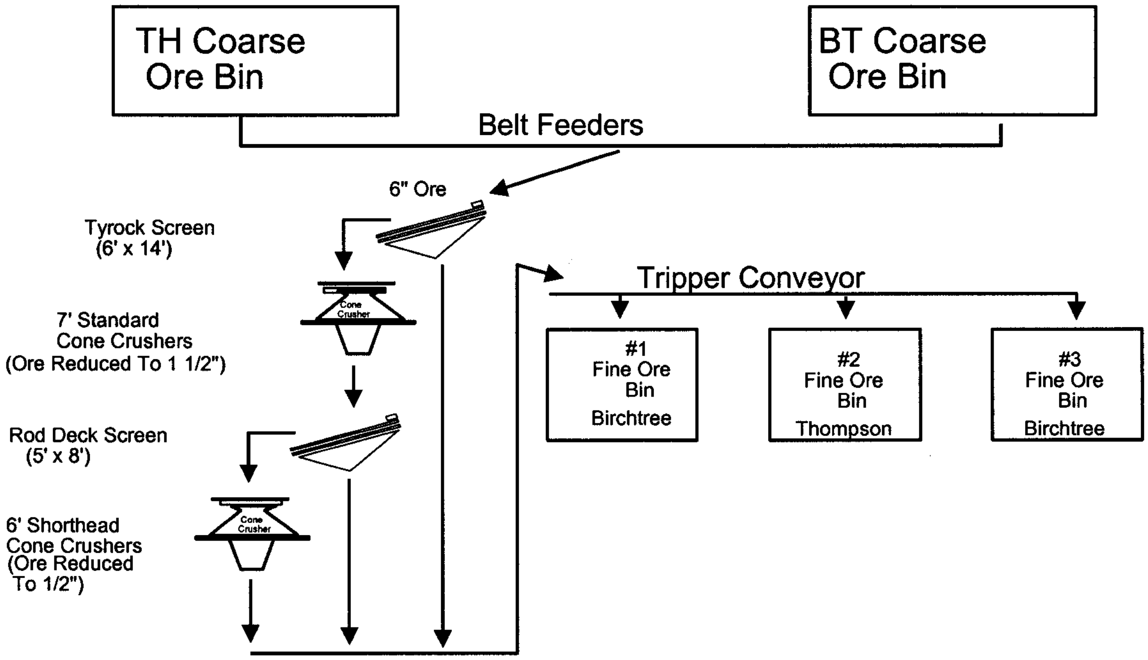

Figure 3-1: Crushing Plant Flow Sheet

3.3 MILLING CIRCUIT

The fine ore bins each hold 8000 tons (7250 tonnes). Feeders at the bottom of the bins regulate ore to the conveying system that feeds the rod mills. There are a total of nine tumbling mills consisting of three rod mills and six ball mills, all 4.5 m long and 2.7 meters in diameter. The #6 ball mill is used for regrind of rougher tails. The number of mills provides flexibility as they can be started or stopped as required for maintenance without disrupting throughput.

Figure 3-2 illustrates the grinding circuit layout. The fine ore bins are at the head of each rod mill feed conveyor.

A variety of cyclone configurations are used in the mill. On the east circuit are 30" (76 cm) cyclones, 3 of 5 are normally on. On the west circuit, there are two cyclopacs, each with five 24" (61 cm) cyclones. Slurry is pumped from the ball mill discharges, to head tanks, which gravity feed the cyclones.

Milling configurations used for Birchtree ore are:

- 240 metric tph; #3 Rod Mill; #3, #4, #5 Ball Mill; Target grind size 12-17% +100 mesh (+150 μm); 35% solids
- 400 metric tph; East Side with #1 Rod Mill, #1, # 2 Ball Mill for 200 metric tph and West Side with #3 Rod Mill, #3, #4 Ball Mill, 200 metric tph; Target grind size 15-18% +100 mesh (+150 μm), 35% solids

The tonnage rates are dependent on ore availability and the smelter's available concentrate capacity.

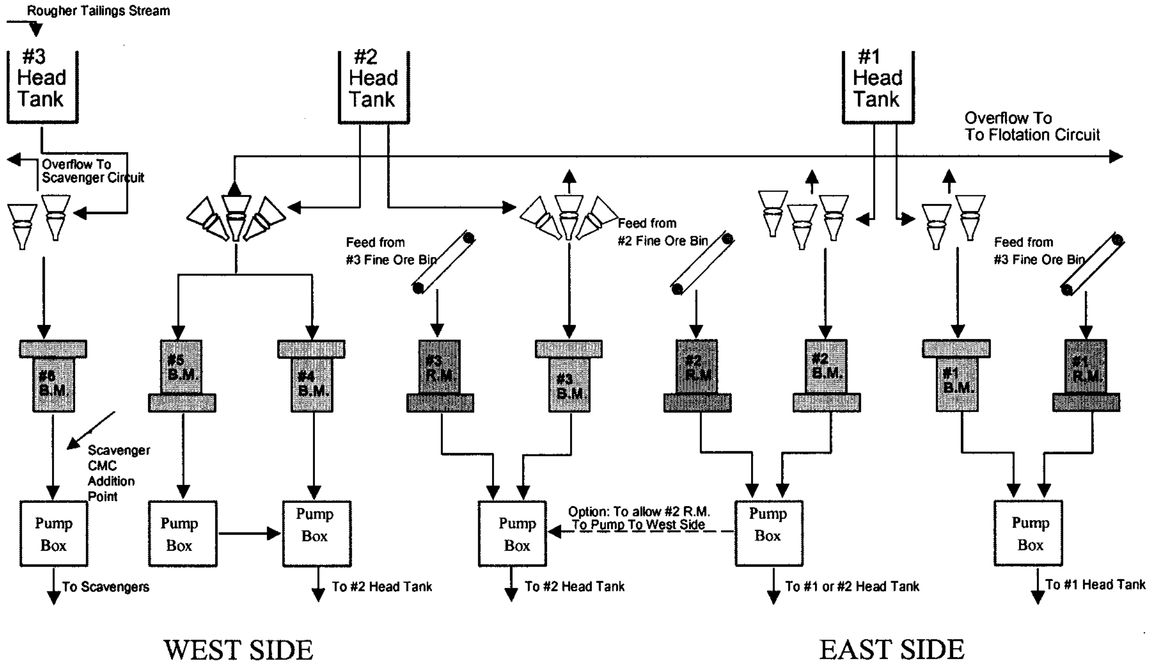

Figure 3-2: Grinding Flow Sheet

3.4 FLOTATION CIRCUIT

Cyclone overflow feeds the flotation circuit, which is illustrated in Figure 3-3. All the flotation cells are Denver 100s. Soda ash is added to the rod mill feed and is regulated by a pH probe in the rougher flotation banks. Target pH for Birchtree ore is 10.2. The collector used is a 30% solution of potassium amyl xanthate (PAX) and is added to a ball mill discharge sump at a rate of 0.65 kg xanthate per tonne of nickel in ore. Methyl isobutyl carbinol (MIBC) is the frother in use; it is added to the cyclone overflow sump at a rate of 20 g/ tonne. PAX and MIBC are also added to the rougher tails sump at a rate of 20 g/tonne and 22 g/tonne respectively. Lime is used in the copper/nickel separation stage.

Dextrin is added to the first copper cleaner, and is used for graphite depression. However, Birchtree has a lower copper content than Thompson ore, and dextrin use is minimal in this circuit.

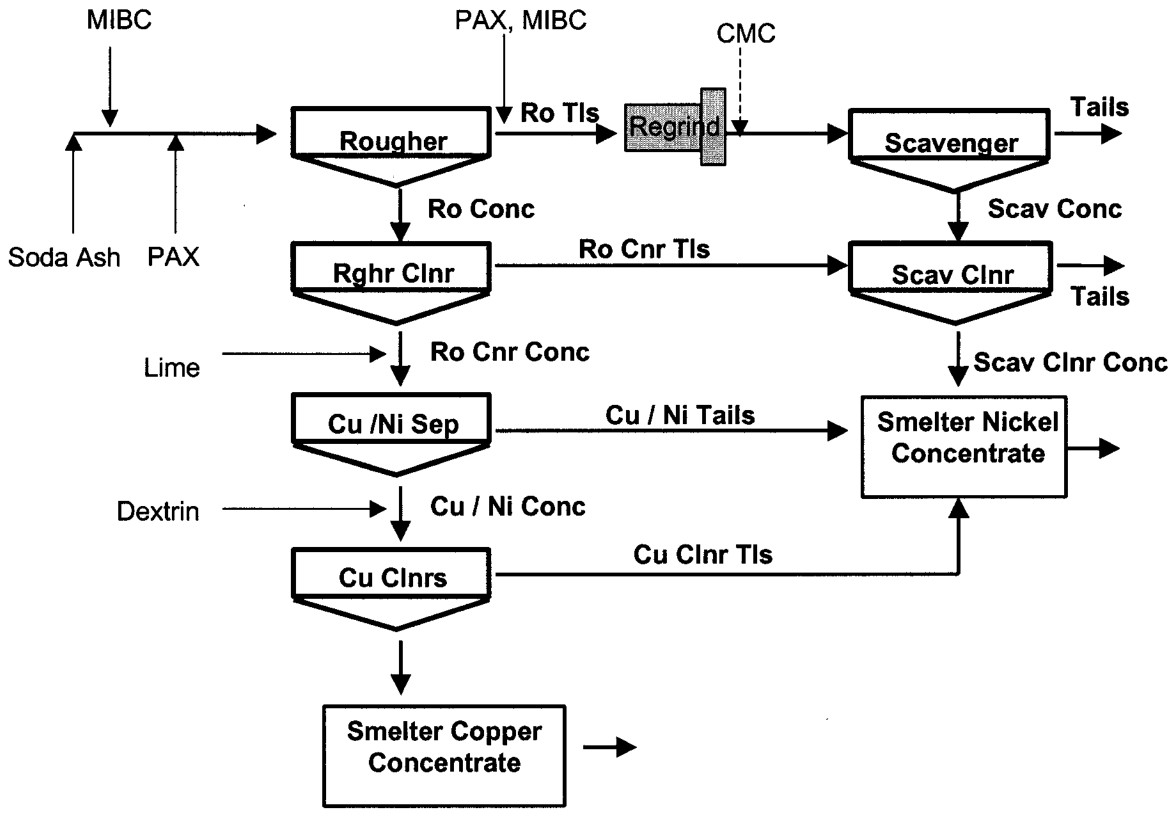

Figure 3-3: Flotation Flow Sheet

3.5 SMELTER

The nickel concentrate is pumped from the mill directly into thickeners housed at the smelter. It is then filtered, roasted and charged to an electric furnace producing nickel anodes (76% Ni) and slag (0.35% Ni). The copper concentrate is thickened and roasted to produce a copper calcine, which is shipped to Inco's Copper Cliff Smelter in Sudbury.

The impact of Birchtree concentrate on the smelter operation includes low filterability and loss of fluidization as well as problems associated with high MgO content.

When filtering Birchtree concentrate with a high level of ultramafic minerals, the moisture content increases to 22%, compared to Thompson which can be maintained at 12%. This decreases filterability and as a consequence the filtering rate drops from 32 metric tonnes per hour on Thompson concentrate to 18 metric tph for Birchtree. To improve efficiency of this process, a pressure filter was installed in the summer of 2003.

Elevated MgO grades create a sticky concentrate that promotes a loss of fluidization in the roaster, loss of temperature control which may sinter the roaster bed and plugged dump valves. With the loss of temperature control or fluidization, the air rate must be raised which leads to an increase in stack losses. The plugged dump valves decrease production.

The MgO content affects furnace operation. High MgO produces a matte with a higher liquidus temperature which reduces capacity and separation between matte and slag. The slag viscosity increases with increased MgO making skimming off the furnaces more difficult and potentially dangerous. The high temperatures also result in greater wear on the furnace wall due to prolonged temperature increases, and higher energy operating costs.

3.6 REFINERY

The nickel anodes are transported to the refinery where they are placed in bags. The bagged anodes are submersed in electrolytic cells for an approximate 17 day dissolution cycle. Anolyte from the tanks is purified through a series of oxidation and reduction processes that remove Cu, As, Fe, Co Pb in addition to trace elements. The purified electrolyte is then returned to the electrolytic tankhouse for nickel plating.

The refinery produces electrolytic nickel suitable for market, cobalt hydrate which is trucked to Port Colborne Refinery, and cobalt oxide, which is shipped to Clydach, Wales for further refining.

CHAPTER 4
EXPERIMENTAL EQUIPMENT

4.1 MINICELLS

For this research, McGill donated the use of their two continuous miniaturized flotation cells, each complete with an agitated conditioning tank. The cells were built as a joint effort between McGill University and Noranda. They are relatively small, with a nominal capacity of 5 litres and were designed to fit compactly in a crate to be shipped to a plant site. They can be placed almost anywhere in the Concentrator's flow sheet.

The plant slurry is pumped into a 48 litre conditioning tank at the head of the mini-circuit. The concentrate or tails from the first cell can then be pumped to the next agitated conditioning tank. The general equipment flow sheet is illustrated in Figure 4-1.

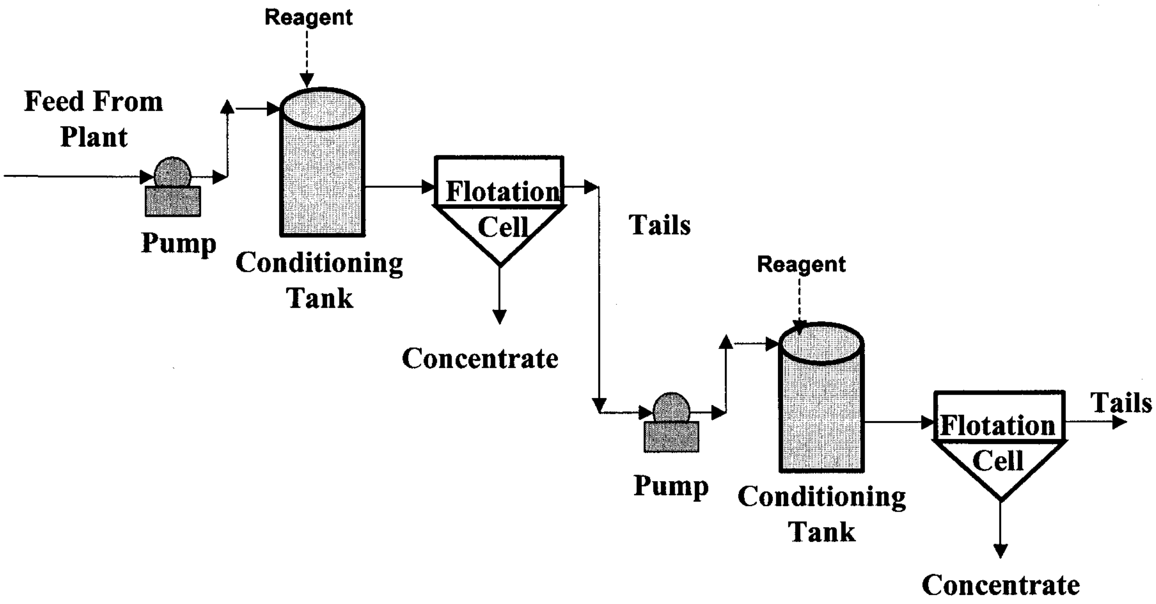

Figure 4-1: General Set-up of Minicells

Figure 4-2 shows the placement of the two minicells in the Thompson Mill. The feed pipe for the rougher distributor is in the background. The process pulp for the first conditioning tank of the cells was pumped from a still well, placed in the distributor pot prior to distribution to the mill rougher flotation banks.

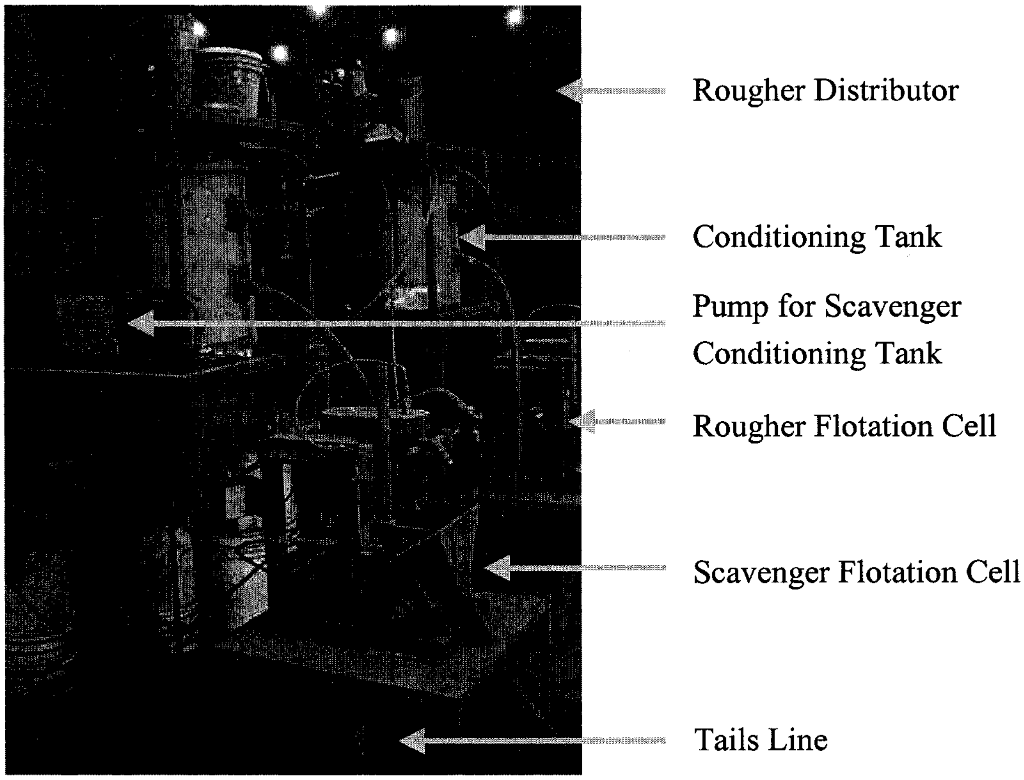

Figure 4-2: Minicell set up in the Thompson Mill

4.2 AUXILLARY EQUIPMENT

The slurry was pumped from the process stream with a Watson Marlow 701 S/R head and 701/R motor to the minicell conditioning tank. From the conditioning tank, the slurry was gravity fed to the flotation cell where concentrate and tails were collected. The tails was pumped to the minicell scavenger conditioning tank with a Masterflex Easy Load 7529-00 head and 7549-50 motor where it was gravity fed to the next flotation cell.

Reagent addition was carried out with one (or two) LMI pumps. Two pumps were used when reagents were added to both conditioning tanks.

A TPS-FL-MV Digital Multimeter was used to monitor pH, redox, and conductivity of the slurry.

4.3 REAGENTS

Manufacturer specifications sheets are provided in the appendix. A brief description of the reagents used in the process is provided below.

Soda Ash: pH modifier for the mill operating target of 10.2. Soda ash is added to the rod mill feed and is controlled by pH probes at the head of the flotation circuit.

MIBC: Methyl Isobutyl Carbinol: Frother added to the rougher circuit at a rate of 22 g MIBC/tonne ore.

PAX: Potassium Amyl Xanthate: Collector added to the rougher circuit at rate of 0.65 kg PAX per tonne nickel in ore.

MAK Chemical CMC: Currently used in the Thompson Mill and added dry to the regrind discharge, which feeds the scavenger circuit. Used as the baseline reagent in this study.

Penn Carbose CMC: Selected as a CMC comparison. Penn Carbose produces a 30% CMC solution for industrial applications. Batch laboratory tests, indicated equivalent performance to the MAK CMC.

Guar Gum (LVG II): Previously not screened for use with Birchtree ore. The literature suggests that guar gum can be effective for MgO depression.

Sodium Silicate: Screened for use with Birchtree ore, but not tested in large scale.

4.4 PROCEDURES

4.4.1 Data Analysis

Samples were collected of feed, concentrate and tails for each of the tests. Specific experimental details are discussed in Chapters 5 and 6.

The Thompson Laboratory performed metallurgical assays. These were completed by ICP. Material balances were performed using Matbal 97.

CHAPTER 5
TEST WORK: ROUGHER AND SCAVENGER STAGE

The minicell test work had two phases; reagent screening followed by detailed testing of the selected reagents. Reagent screening was conducted on plant slurry during regular daily operation. Fourteen tests were performed with four different reagents under different operating conditions. The reagents were Penn Carbose 30% CMC solution, National Silicates – N Sodium Silicate, Economy Polymers and Chemicals LVG II (Guar Gum) and MAK Chemical CMC. The purpose of this experimentation was to explore rejection of MgO bearing minerals from the in-process streams using slurry with properties identical to those in the plant.

The scavenger recovers 20-30% of the ore feed mass to concentrate. This stream contains 1-2% nickel and 8-15% MgO, and along with the rougher cleaner tails, feeds the scavenger cleaning stage. The scavenger cleaner concentrate makes up one third of the final nickel concentrate volume to the smelter, and grades 5-8% Ni, 6-10% MgO. By rejecting the MgO from the scavengers, the MgO in final nickel concentrate would be reduced.

A complete factorial design and further investigation was not completed for this stage of experimentation, the reagent screening, as metallurgical operating conditions in the mill were changed and a different approach was taken for MgO rejection during the course of this test work.

5.1 TEST PLAN

The layout of the Thompson Mill presented limited options for acquiring a flotation feed stream. The easiest location, requiring the least piping modification, was to place the minicells beside the rougher distributor. The feed to the minicells was pumped from the rougher distributor into the cell. Due to the length of the tests (2 hours) they were conducted on different days, such that the slurry was never identical from test to test. However, the purpose of this phase in the test work was to determine the best likely reagent, among the ones tested, for MgO rejection from Birchtree concentrate. Soda ash, collector and frother were added to the slurry prior to the minicells.

The dotted line in Figure 5-1 illustrates the placement of the minicells and their position in the flowsheet. They were placed ahead of rougher flotation, but after reagent addition in the milling circuit. This was unavoidable, as normal plant operation was required to continue and there was no logical placement of the cells prior to reagent addition.

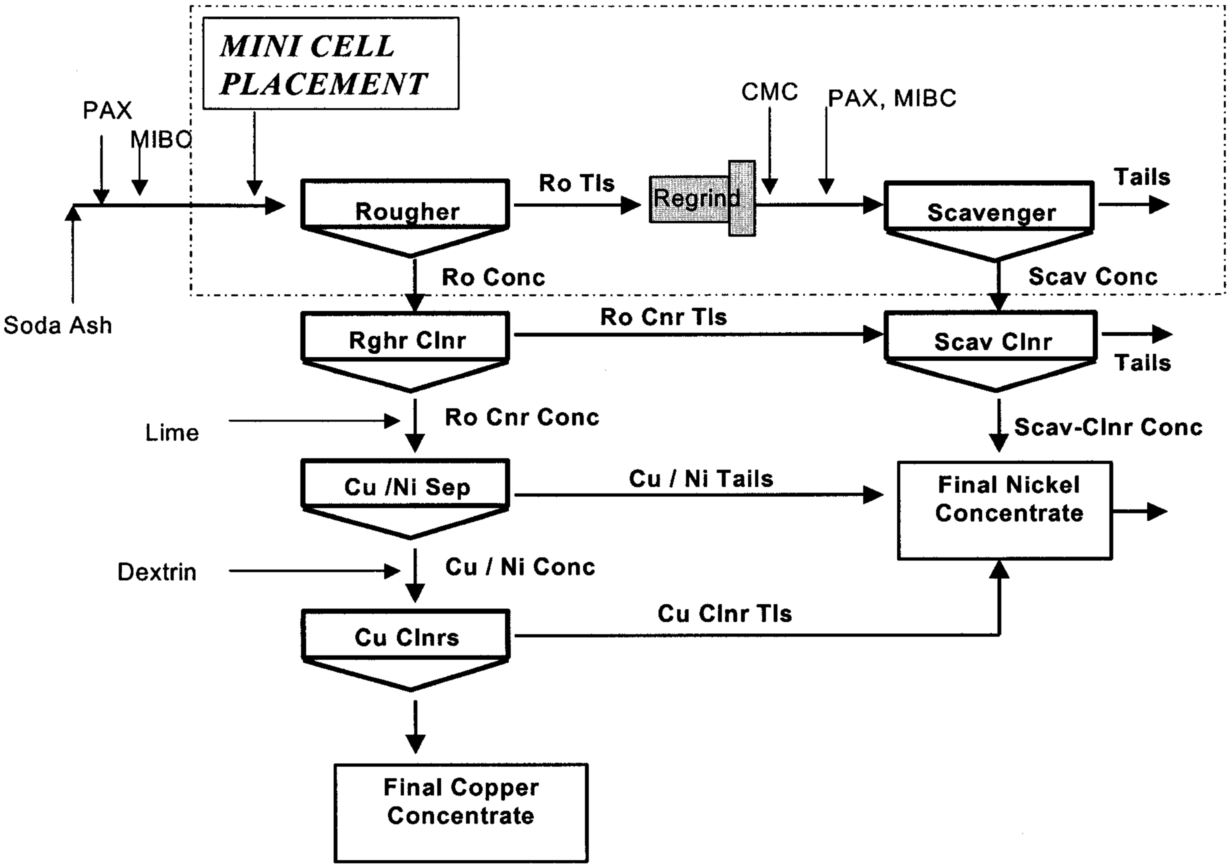

Figure 5-1: Flotation Flow Sheet: Minicell Test Work Focuses on Circuit Within Dotted Line

Slurry was pumped from the plant rougher flotation distributor to the minicell rougher conditioning tank. The tails from the first flotation cell was collected in a bucket and pumped to the second tank and cell, which acted as a scavenger.

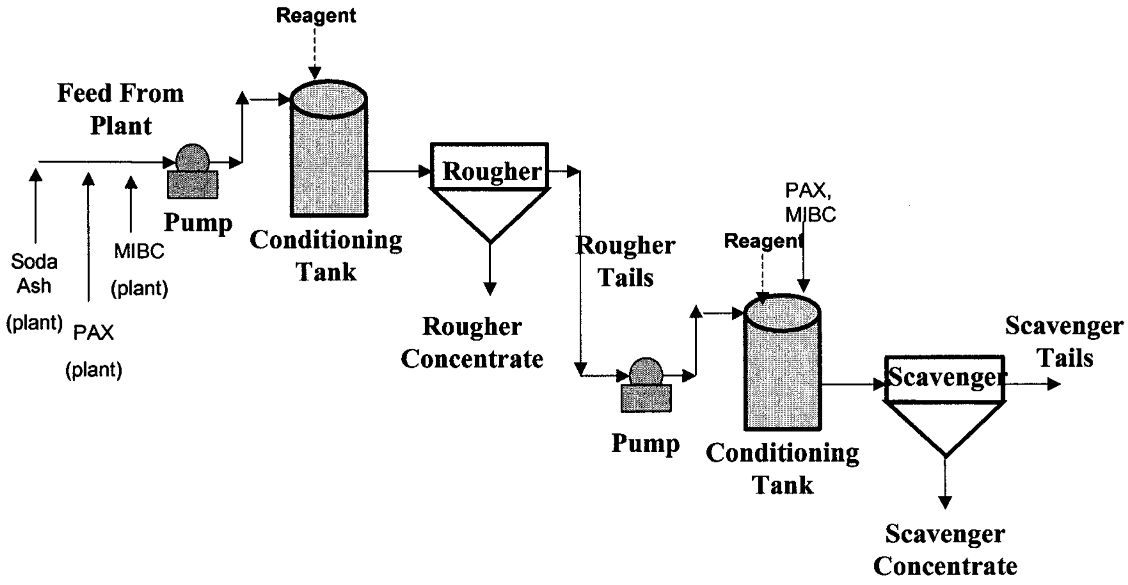

Figure 5-2: Flow Sheet of Minicells

Assays were obtained for feed, rougher concentrate, rougher tails, scavenger concentrate and scavenger tails. One cut was taken from each stream every 5 minutes. After 4 cuts (twenty minutes) a new sample batch was started. Six samples completed a 120-minute test. To ensure a suitable and representative amount of solids were collected from each stream, the feed was cut for 5 seconds, rougher and scavenger concentrates were cut for 60 seconds and the tails was cut for 15 seconds. A 10 ml dose of MIBC and 5ml shot of PAX was added to the mini cell scavenger conditioning tank at the start of every 20 minute sample cycle. The test conditions are listed in Table 5-1.

Table 5-1: Test Matrix

Test #	**Reagent/Conditions**	**Dose** (g/kg)	**Rate** (ml/min)	**Reagent Conc'n** (%)
2	Blank			
3	Penn Carbose CMC to Rougher	0.5	1	30
4	Penn Carbose CMC to Scavenger	0.5	1	30
5	Sodium Silicate to Rougher	0.5	1	25
6	Sodium Silicate to Scavenger	0.5	1	25
7	Guar Gum to Rougher	0.05	100	0.1
8	Guar Gum to Scavenger	0.05	100	0.1
9	MAK CMC to Rougher	0.5	100	1
10	MAK CMC to Scavenger	0.5	100	1
11	MAK CMC to Rougher / Guar Gum to Scavenger	0.5 / 0.05	100	1 / 0.5
12	Blank			
13	Coarse Plant Grind; Plant MAK CMC to Ball Mill Discharge / Guar Gum to Scavenger	0.5 / 0.05	100 / 100	1 / 0.5
14	Guar Gum to Rougher / MAK CMC to Scavenger	0.05 / 0.5	100 / 100	0.5 / 1

The conditions listed for Test #13 indicate that the mill was producing a coarse flotation feed. The size distribution of the slurry that day was 26% +100 mesh compared to normal grinding target of 12-17% +100 mesh. CMC was also used in the flotation circuit and the stream used for the test work had pre-conditioned CMC already added. These variables were unavoidable during this test.

Test #4 has been omitted from the result analysis, as it did not reach steady state. The condition for this test was Penn Carbose CMC addition to the scavenger stage and a repeat of these conditions was not performed.

5.2 RESULTS AND DISCUSSION

5.2.1 Flotation Test Results

The tests were spread over a period of four months between May and September 2002 with a four week maintenance shutdown in July. Changes in ore characteristics, as an additional variable over the time period, were unavoidable. Test results found favourable towards MgO rejection would be subject to further investigation and replication to ensure consistency. In this case, no tests were repeated.

Table 5-2: Head Grade and Dates of Tests Completed

Test #	Reagent/Conditions	% Ni	% MgO	2002
2	Blank	1.8	18.2	17-May
3	Penn Carbose CMC to Rougher	1.5	16.6	30-May
5	Sodium Silicate to Rougher	1.4	14.7	12-Jun
6	Sodium Silicate to Scavenger	1.5	14.8	12-Jun
7	Guar Gum to Rougher	1.6	15.3	18-Jun
8	Guar Gum to Scavenger	1.7	14.6	18-Jun
9	MAK CMC to Rougher	1.6	16.6	19-Jun
10	MAK CMC to Scavenger	1.5	16.8	19-Jun
11	MAK CMC to Rougher / Guar Gum to Scavenger	1.9	13.2	19-Sep
12	Blank	1.9	13.7	19-Sep
13	Coarse Plant Grind; Plant MAK CMC to Ball Mill Discharge / Guar Gum to Scavenger	1.4	15.2	20-Sep
14	Guar Gum to Rougher / MAK CMC to Scavenger	1.9	12.4	20-Sep

5.2.2 Rougher Stage Performance

The performance of the rougher stage will affect the performance of the scavenger stage. The operating conditions such as feed rate, pump speed, froth depth and air rate were duplicated as closely as possible. Table 5-3 provides a summary of the rougher stage performance. Representative plant data are also provided as a comparison. The last two columns are the concentrate ratio which is the concentrate grade divided by the feed grade, and can aid in evaluating the data. An MgO ratio of 1.0 indicates that there was no MgO rejection in that stage (concentrate grade = feed grade); a small number is desirable. The reverse is true for the nickel ratio (i.e. a high ratio is desired).

Table 5-3: Summary of Rougher Stage Results

		Flow (% of Total)	Ni Stage Rec	Ni Conc Gr	MgO Stage Rec	MgO Conc Gr	Ni Conc Ratio	MgO Conc Ratio
	PLANT DATA →	**10-15**	**70-85**	**8-15**	**5-9**	**8-15**		
# 2	Blank	11.0	57.7	9.4	5.3	8.8	5.26	0.48
# 3	Penn Carbose CMC to Ro	3.6	32.8	14.3	1.4	6.9	9.25	0.41
# 5	Sodium Silicate to Ro	5.6	53.6	14.3	2.1	5.4	10.25	0.36
# 6	Sodium Silicate to Scav	5.0	51.2	14.9	1.9	5.5	10.22	0.38
# 7	Guar Gum to Ro	4.6	40.5	14.7	1.5	5.0	9.01	0.33
# 8	Guar Gum to Scav	7.6	48.3	11.2	3.9	7.5	6.42	0.52
# 9	MAK CMC to Ro	9.0	36.8	6.5	6.7	12.2	4.01	0.73
# 10	MAK CMC to Scav	3.3	35.2	16.0	6.0	1.2	10.40	0.07
# 11	MAK CMC to Ro; Guar Gum to Scav	17.6	62.9	6.6	13.1	9.8	3.57	0.74
# 12	Blank	12.0	66.6	10.6	7.1	6.3	5.54	0.46
# 13	Crs Grnd; Plnt CMC to Ro; Guar Gum to Scav	4.4	53.4	16.6	1.1	3.9	12.18	0.26
# 14	Guar Gum to Ro; MAK CMC to Scav	8.5	61.3	13.6	2.9	4.5	7.25	0.36

Figure 5-4 shows nickel recovery as a function of MgO grade. The highlighted tests (with circles), indicate what could be considered “blank rougher tests”, as reagent was not added until the scavenger stage.

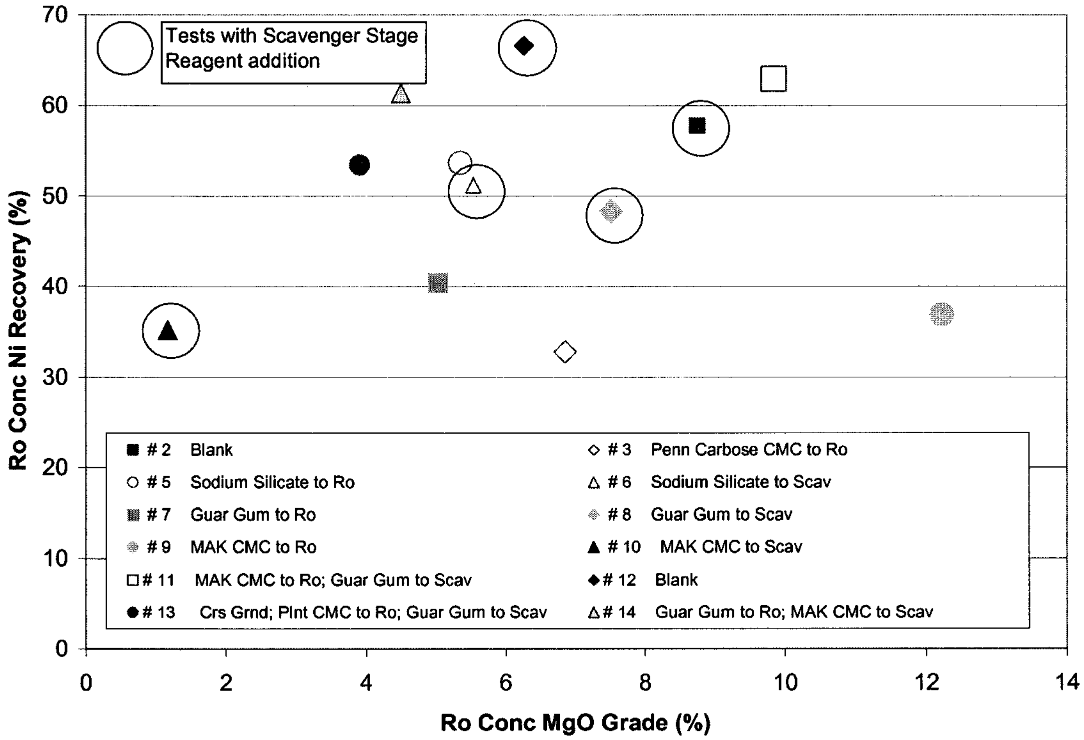

Figure 5-4: Rougher Stage Performance

There is a high degree of variability in the results. No test reached a plant stage nickel recovery of 70%. None of the reagents produced a low MgO grade in concentrate, though assays were lower than typical plant range of 8-15%. The operational nature of the minicells may not have allowed enough retention time to promote sufficient recovery to concentrate. Most tests fall below the 10-15% range observed in the plant for mass recovery. As such, the plant data are mentioned but the tests are compared against each other and not the plant.

The lowest MgO grade of 1.2% in concentrate was one of the blank tests (Test # 10) with MAK CMC added after the rougher stage. The nickel grade of the concentrate was 16%, higher than the targeted level of 8-15%. Other blank rougher tests measured MgO grades from 5.5-8.8%. One possible explanation of this is the time period between tests. Changes in ore characteristics will affect behaviour.

A coarse grind from the plant milling circuit and CMC added at the ball mill discharge (Test #13) demonstrated the next lowest MgO grade of 3.9% with a 53% stage nickel recovery. These results could indicate a reduced level of serpentine slimes present. The coarse grind will not produce the fine particles and though locking may be an issue for nickel recovery, the performance was possibly enhanced from the measured surface area of non-slimed pentlandite. CMC was also present and aided in dispersing any slimes that may have been present.

Guar gum addition to the rougher (Test #14) produced an MgO grade of 4.5% with a nickel stage recovery of 61%. However, this test is a stage duplicate of Test #7, which achieved only 40% nickel stage recovery, but a MgO grade of 5%.

Tests #9 and #11, stage duplicates of MAK CMC addition to the roughers measured the highest MgO grade of 12.2 and 9.8% respectively. The difference between these tests and #13 indicate a conditioning time may be required with CMC.

The nickel and magnesium concentrate ratios are compared in Figure 5-5. Results with a high Ni and low MgO ratio are desirable. The coarse plant grind (Test #13 and Test #10) in this aspect showed promising results. The remainder of the tests are clustered and repeated tests would be necessary to confirm behaviour.

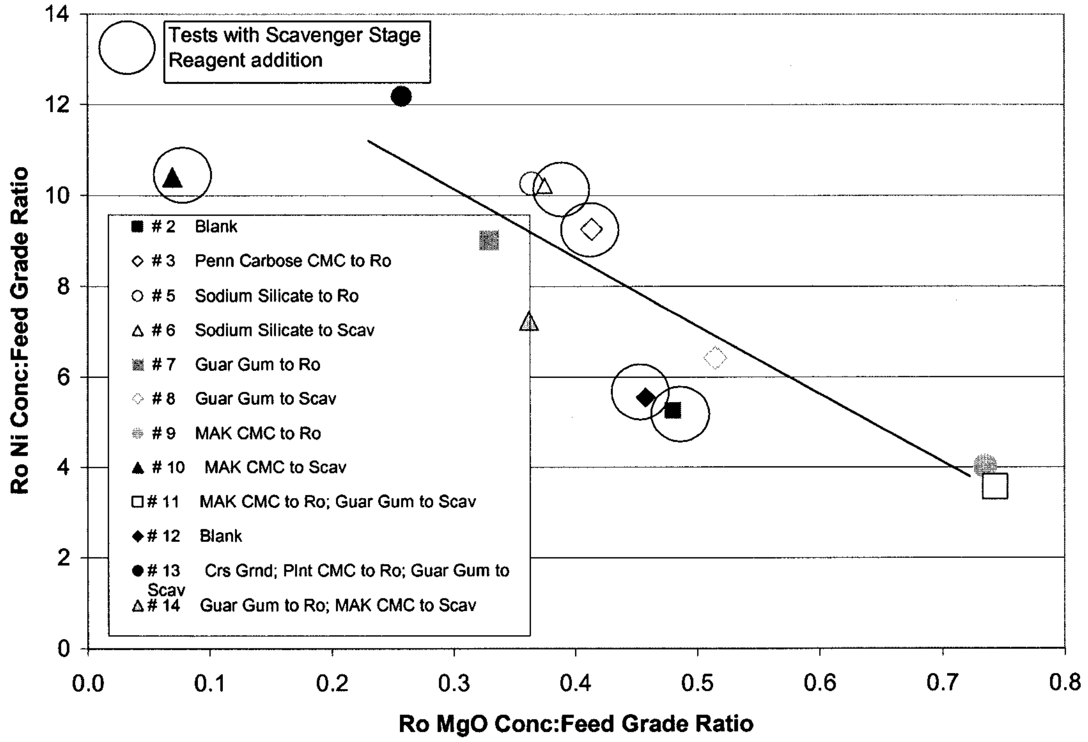

Figure 5-4: Rougher Concentrate Ratio

5.2.3 Scavenger Stage Performance

The rougher tailings provided the feed for the scavenger stage and were pumped from a collection pail to the next minicell conditioning tank. Table 5-4 provides a summary of the minicell performance and compares it to the plant data.

Table 5-4: Summary of Scavenger Stage Results

		Ro Tls Ni Grade	Ro Tls MgO Grade	Flow (% of Total)	Ni Stage Rec	Ni Conc Gr	MgO Stage Rec	MgO Conc Gr	Ni Conc Ratio	MgO Conc Ratio
	PLANT DATA →	**0.35-0.5**	**16-22**	**5-25**	**45-70**	**0.8-1.5**	**15-30**	**14-18**		
#2	Blank	0.8	19.4	7.9	17.9	4.0	6.7	15.3	4.82	0.79
#3	Penn Carbose CMC to Ro	1.1	17.5	8.8	42.1	7.5	2.5	4.9	6.85	0.28
#5	Sodium Silicate to Ro	0.7	15.2	7.4	21.5	4.3	5.2	10.1	5.85	0.67
#6	Sodium Silicate to Scav	0.8	15.2	7.2	28.6	5.8	4.0	8.2	7.75	0.54
#7	Guar Gum to Ro	1.1	15.8	6.9	28.3	6.8	3.8	8.4	6.38	0.53
#8	Guar Gum to Scav	1.0	15.2	15.7	27.4	3.1	12.6	11.8	3.12	0.78
#9	MAK CMC to Ro	1.1	16.8	7.2	37.1	8.2	3.4	7.8	7.42	0.46
#10	MAK CMC to Scav	1.0	17.2	6.9	36.3	7.9	2.7	6.5	7.79	0.38
#11	MAK CMC to Ro; Guar Gum to Scav	0.8	14.0	8.9	21.3	4.4	4.8	7.1	5.35	0.51
#12	Blank	0.7	14.6	6.0	14.6	4.6	3.7	8.4	6.34	0.58
#13	Crs Grnd; Plnt CMC to Ro; Guar Gum to Scav	0.7	15.7	8.2	22.0	3.7	4.8	8.9	5.58	0.56
#14	Guar Gum to Ro; MAK CMC to Scav	0.8	13.2	17.0	24.0	2.6	12.6	9.2	3.34	0.70

The rougher tails grade shows all the tests commenced with higher nickel in feed to scavengers than is typically observed in the mill as recovery in the minicell rougher was not as efficient. This again illustrates that tests are not representative of the plant data. The stage nickel recovery in the minicells also fell short of what is observed in the plant. Typical plant stage recovery is 45-70 % at 0.8-1.5 % Ni grade and 14-18% MgO grade.

Most of the concentrate MgO grades were clustered between 8-10%. Figure 5-6 illustrates the stage results from the scavenger minicell. Penn Carbose CMC (Test #3), produced the lowest MgO grade at 4.9%, with a high nickel recovery of 42%. The low nickel recovery from the rougher stage probably contributed to this. This also showed the lowest MgO concentrate:feed ratio. The

CMC was added to the rougher stage for this test, and the results could be a function of conditioning time.

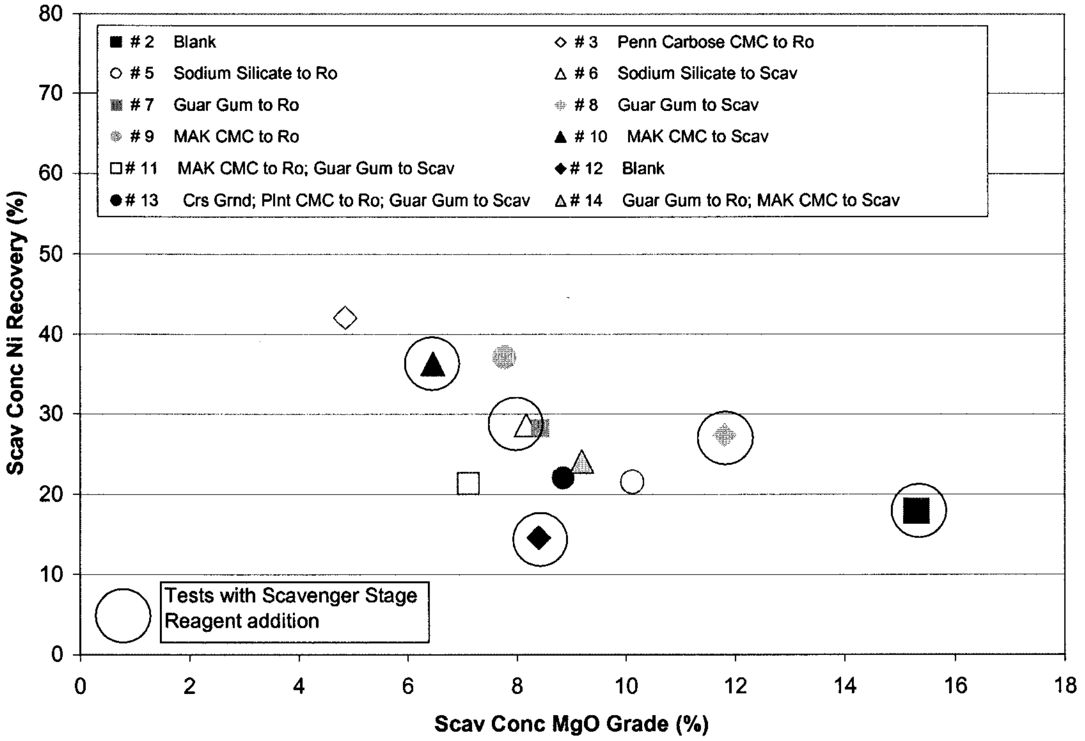

Figure 5-5: Scavenger Stage Performance

Canada Colors CMC added to the scavenger (Test #10) gave a low MgO concentrate:feed ratio with favourable Ni recovery at 36%.

Guar Gum addition to the scavengers (Test #8) produced an MgO grade of 11%; the concentrate ratio of 0.78 indicates very little rejection to tails. Guar gum to the rougher (Test #14) was also not effective with an MgO grade of 9.2%, and a concentrate ratio of 0.70.

Both blank tests (Test #2 & #12) showed low Ni recovery.

Reagents added in the rougher stage, may have been consumed by the serpentine minerals and additional dosage to the scavenger stage may have been necessary. At an optimum consumption, there should be no detrimental slimes on the pentlandite surfaces and the system should be fully dispersed.

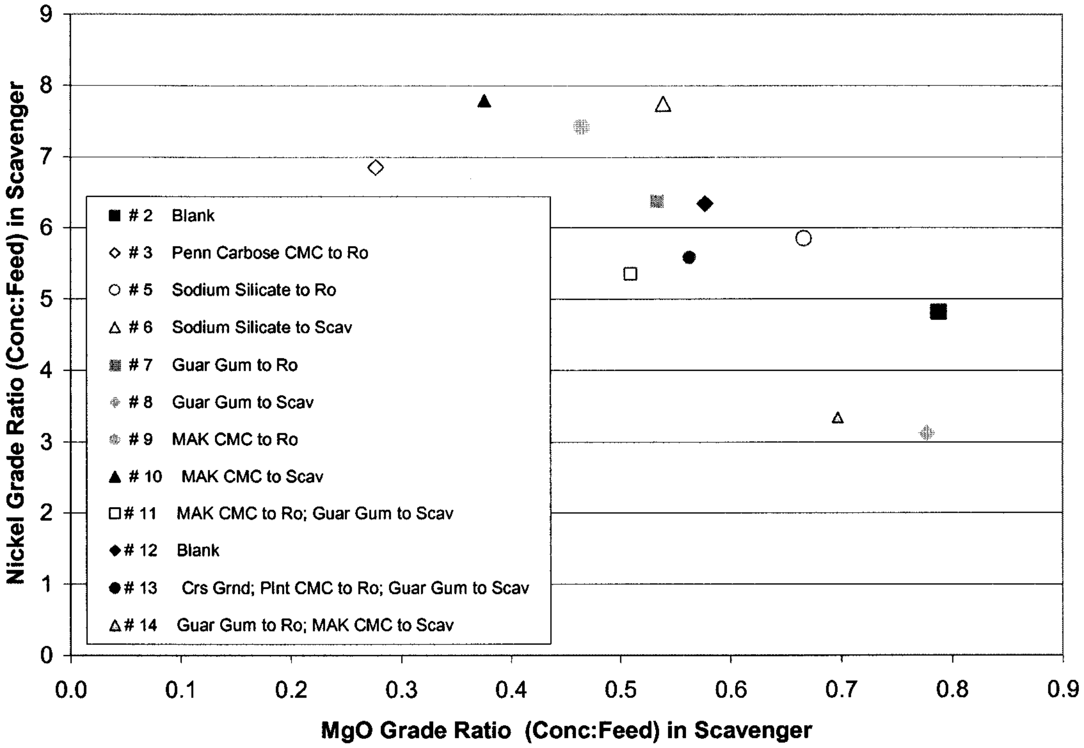

Figure 5-6: Scavenger Concentrate Ratio

The different feed grade and characteristics from the rougher flotation stage makes using the concentrate ratio a useful tool. A trend line was superimposed onto Figure 5-7. It appears that there is a relationship between the nickel and MgO concentrate ratios in the scavenger stage. The Penn Carbose CMC to the rougher and the MAK CMC to the scavenger have the best upgrading results to concentrate.

5.2.4 Reagent Evaluation

Initial dosage rates were based on recommendations from the reagent suppliers. Guar gum was added at 1/10th the dosage of CMC and sodium silicate.

Guar gum in the roughers may be a future possibility to explore. Guar gum (Tests #7 & #14), showed MgO in rougher concentrate of 5.0 and 4.5% respectively. Dosage optimization would be required for further test work. Performance of this reagent in the scavenger stage did not show a significant reduction in the MgO to concentrate. However, a synergistic relationship with CMC would be worth exploring.

The two sodium silicate tests showed similar performance whether added to the rougher (Test #5) or to the scavenger (Test #6). Test #5 graded a higher MgO to rougher concentrate than #6, which had no additional reagent. Further investigation with sodium silicate would be necessary to optimize dosage and conditioning time. The lack of selectivity observed in these tests suggests that possibly the dosage rate was too high. If the sodium silicate was overdosed in these tests the silica monomers will form long chains of SiO_2 and increase slurry viscosity, which can hinder flotation.

CMC is currently used in the Thompson Mill. Based on this limited test work, there is no reason to change it for another reagent. CMC combinations with other polymeric depressants may be beneficial.

Prior to shutdown, all Birchtree ore receipts were direct from the mine (Tests #2-10); after shutdown (Tests #11-14), ore was received fresh and from a three-week-old stockpile. Birchtree ore is easily oxidized; if a 'slug' of oxidized ore is processed during the two-hour tests it will lower the pH of the slurry. The plant operating pH for all tests was 10.2. Because of this changing ore characteristic, there were fluctuations of pH during the test work in the range of 9.8-10.3. The pH control loop is designed with a master-control pH probe in the rougher flotation bank; when it registers a pH below the set point, it sends a signal to the soda ash control valve to open. This valve is located at the rod mill feed chute. It may take up to 20 minutes to compensate for the pH due to the retention time in the grinding circuit and the PLC settings. By taking a four sample cut for each sample and collecting six samples over the two hour test, the affect of pH fluctuations should be minimized.

5.3 OVERALL ASSESSMENT

This test work did not reveal any significant solution to rock rejection of Birchtree ore, despite the fact that repeat tests were not performed and dosages and conditioning times were not optimised. The minicells remain a valuable tool for reagent screening, under realistic conditions. However, it is a significant undertaking that requires a minimum of two people and a large time commitment.

Reagent conditioning time may have also been a factor in this test work, which was not explored. Chapter 6 focuses on conditioning time of CMC, flotation retention time and dosage rates.

It may have been beneficial to move the cells to the scavenger stage in the mill, to properly evaluate this stream. However, many other variables, notably, plant rougher performance, would be introduced. Testing on this stream may be considered in the future.

The reagent evaluation is incomplete. The effectiveness of the type of reagent used will depend on the mineral species in the process. The original intent was to perform a semi-factorial experimental design to determine the best reagent and operating conditions for Birchtree ore, with plant slurry. Only limited testing was explored before the focus of evaluation was changed to CMC optimization.

The variability of the feed and rougher performance made it difficult to compare one test to another. Further investigation into the interaction of reagents and conditioning time might have proved illuminating. However, in October 2002, a different approach was taken in the design of the Birchtree ore flow sheet. From October to December, ITSL[1] set up a complete Mini-Plant for use on Birchtree ore. It was determined that the addition of CMC to the rougher concentrate gave a significant reduction in MgO to final concentrate. The addition of CMC dispersed the MgO bearing minerals where they reported to the scavenger cleaner stage and further MgO rejection and concentrate upgrading occurred. (Refer to Figure 5-1, the flotation flow sheet). Chapter 6 explores this approach to MgO rejection.

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[1] Inco Technical Services Limited

CHAPTER 6
TEST WORK: ROUGHER CLEANER STAGE

The second phase of test work focused on the application of a dilute CMC solution to the rougher cleaning stage. Currently, Thompson Mill uses MAK Chemical's CMC dry at the regrind mill discharge for the scavenger circuit.

Prior to November 2002, there was the option of also adding CMC at the primary mill discharge prior to the rougher stage. Plant test work did not support that this stage of addition provided any benefit to rock rejection. The hopper and distribution system was moved to create a 1% CMC solution that is pumped to the rougher cleaner concentrate stage. This is described in Chapter 7.

The time between the test work described in Chapter 5 and the test work detailed in this chapter was four months. Within that period, two months (October and November 2002) were spent at ITSL in Mississauga, operating a full circuit Mini-Plant to determine complete process improvements on Birchtree ore. The Mini-Plant consisted of a rod mill feeding 5 L and 10 L flotation cells and was designed to replicate the Birchtree circuit. This had an advantage over the minicells, as it simulated the complete circuit from grind size to final product. It was very easy to implement circuit changes and re-route process streams that would otherwise require significant piping changes in the mill. Ten-hour tests were completed, with steady state being achieved within two hours of start up. Two process conclusions derived from this test work: one, the addition of a scavenger cleaner re-cleaning stage is beneficial to rejecting the MgO minerals from the concentrate; and two, the addition of CMC to the rougher cleaner stage contributed to significant MgO rejection from the concentrate. The focus of the test work discussed in this chapter is CMC application in the rougher cleaner.

A full-scale temporary liquid CMC dispensing system was designed to add a dilute (1%) CMC solution to the plant rougher cleaner launders. The Thompson Mill experienced the benefit immediately. As this was a temporary system, and personnel were required on other projects, a complete test matrix was carried out on the McGill minicells to determine the optimum dosage and conditioning time for CMC in the rougher cleaner stage. The rougher cleaner concentrate (RCC) feeds the copper circuit whose tails effectively contribute about 70% of the final nickel concentrate. Lowering the MgO grade in this stream will significantly contribute to a lower MgO grade in the final nickel concentrate.

As part of the Birchtree rock rejection initiative, many plant slurry samples were sent by Thompson personnel to ITSL for visual analysis to help identify the individual minerals and their association. The flotation flow sheet is described in Chapter 3 and is illustrated again in Figure 6-1. The stream descriptions were generated by Andy Lee, a mineralogist at ITSL.

The rougher concentrate stream consists of 70% sulphides, 25% silicates, 2-4% graphite. The silicates are generally 80% liberated and most of the pentlandite is liberated in this stream. The rougher concentrate reports to a cleaning stage, which upgrades to 85% sulphides and 15% rock, mainly serpentines. Rejecting the MgO-bearing minerals from this cleaner concentrate can effectively eliminate MgO from 70% of the final concentrate. (Lee, 2001) This formed the focus for the test work.

The rougher cleaner tails combines with scavenger concentrate as feed to the scavenger cleaning circuit. The tails are typically 40% sulphides and 60% rock. Ninety percent of the sulphides were locked with rock, which consisted of serpentine and chlorite.

6.1 TEST PLAN

Rougher concentrate from the operating Birchtree circuit was obtained. Taking advantage of an accessible sampling point for this stream, five-gallon pails of slurry were collected and transported to the minicells. (The minicell set-up is outlined in Section 4.1.) The slurry was resuspended before use, and all tests, 21 in total, were completed within five hours of obtaining the samples to minimize any effects of aging or reagent decomposition. For this stage of test work, some differences in operation from Chapter 5 were applied to the equipment operation. Only one flotation cell was used (not two in series) to remain consistent with the methods from the first stage of testing. MAK CMC was the only reagent used (no auxiliary reagents were tested or used for flotation). PAX, MIBC and soda ash were present in the flotation circuit from upstream addition points.

6.1.1 Sample Collection and Test Procedure

The dotted border in Figure 6-1 outlines the minicell test stage of focus. The overall flow sheet illustrates that any MgO in concentrate from the rougher cleaner will either report to the nickel concentrate or the copper concentrate. Due to the nature of Birchtree ore, and high MgO grade, recovery of Mg-minerals to the copper concentrate is not desirable. The copper concentrate handling system in the smelter is not designed for increased volume capacity. Studies have also shown that flotation of Mg-minerals can not be promoted with increased collector dosages. (Wellham et al., 1992)

Effectively, the Mg-silicates would report to the tails of the copper circuit and ultimately to the nickel concentrate. By establishing a reliable process solution to depress the MgO minerals to the rougher cleaner tailings, the scavenger cleaning stage can then be optimized and MgO rejected to the final tailings.

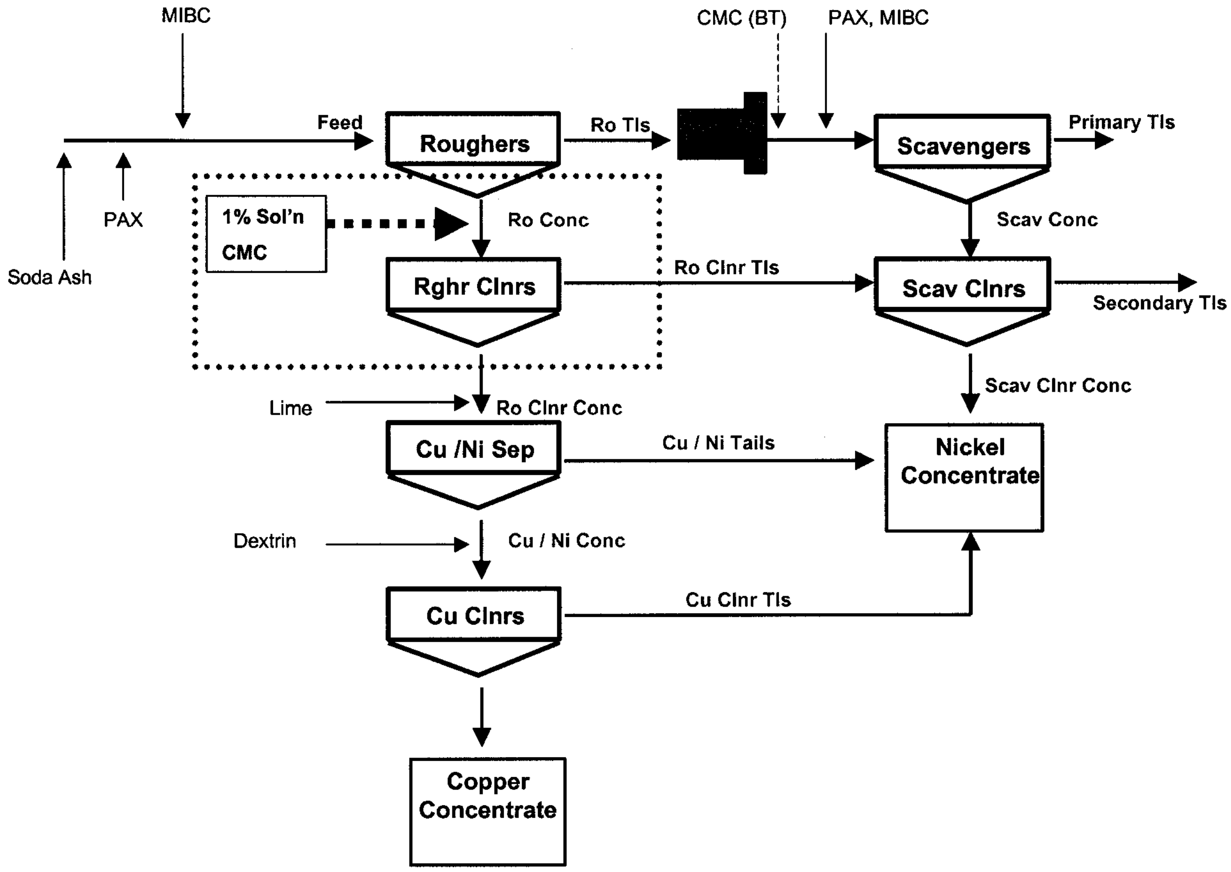

Figure 6-1: Flotation Flow Sheet: Minicell Focus Within the Dotted Line

Rougher concentrate slurry was collected in pails from the rougher cleaner feed distributor and transported to the mini flotation cells. The slurry was pumped to the agitated conditioning tank (48 L capacity). The slurry density (percent solids) was measured, and a measured amount of 0.5 % CMC solution was introduced. The slurry was agitated for the set conditioning time as defined by the test matrix. The rougher concentrate was then pumped to the flotation cell where the pump speed defined the retention time in the cell. This is illustrated in Figure 6-2.

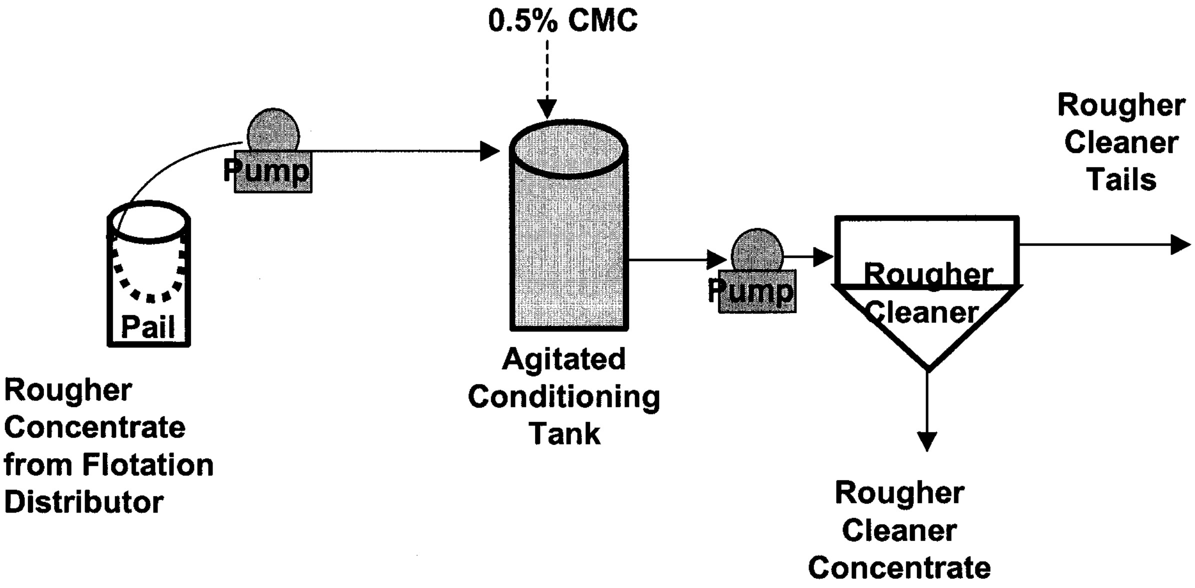

Figure 6-2: Flow Sheet of the Minicells

The single stage use of one of the minicells allowed for a continuous batch process where conditioning time commenced with CMC addition. Samples of feed, concentrate and tails were collected for data analysis. The grade of the rougher concentrate (feed to the flotation cells) for all tests is provided in Table 6-1. By using the same slurry in each of the tests, operating variables were minimized and the direct effects of CMC could be observed.

Table 6-1: Average Grade of Rougher Concentrate for Test work

Cu (%)	Ni (%)	Fe (%)	S (%)	MgO (%)	Cp (%)	Pn (%)	Po (%)	Rk (%)
0.30	4.90	27.30	16.3	13.9	0.87	14.4	28.7	28.3

The results from this stage of test work were the baseline for designing the full-scale CMC solutioning system in the Thompson Mill.

6.1.2 Test Matrix

Three variables were tested: CMC dosage rate, conditioning time and retention time in the flotation cell. For each dosage rate and conditioning time, two different retention times were examined. The test matrix is illustrated in Figure 6-3. Matrix A and B are divided by pump speed (retention time in flotation cell). The pump from the conditioning tank was set at 4.0 l/min to provide a retention time of 50 seconds for Matrix A. A steady state was visually reached after approximately six minutes and feed, concentrate and tails samples were obtained. The pump was then slowed down to 1.3 l/min for a retention time of four minutes (Matrix B), the system allowed to reach steady state (approximately five minutes) and feed, concentrate and tails samples were obtained.

A	Pump Rate: 4.0 l/min	CMC Dosage (g/kg Ro Conc)				
		0	0.05	0.1	0.2	
Conditioning Time (min)	0	30	23	21	20	Test Number
	10		29	28	27	
	20		26	25	24	

B	Pump Rate: 1.3 l/min	CMC Dosage (g/kg Ro Conc)				
		0	0.05	0.1	0.2	
Conditioning Time (min)	0	30	23	21	20	Test Number
	10		29	28	27	
	20		26	25	24	

C	Pump Rate: 5.5 l/min	CMC Dosage (g/kg Ro Conc)	
		0.5	
Conditioning Time (min)	0	22	Test Number

Figure 6-3: Test Matrix

Test #22, as listed in Matrix C was completed to determine the maximum practical dosage rate of CMC to the concentrate stream. At 0.5 g/kg the system was overdosed and flotation kinetics were very slow and the pump speed was increased to 5.5 l/min to obtain some froth overflow. Flotation was very difficult in this test, resulting in low nickel recovery and high MgO grade in concentrate. For the purposes of this report Test #22 results are not included in the data analysis.

6.2 RESULTS AND DISCUSSION

The dosage rate and retention time in the flotation cell have the greatest impact on nickel recovery and MgO rejection. All tests achieved concentrate grades greater than 17% Ni (equivalent to the plant rougher cleaner concentrate target with the use of the CMC solution). The MgO target grade for the concentrate is less than 3%.

The effect of the individual variables will be discussed, followed by how they inter-relate. The numerical results from the tests are listed in Table 6-2. Nickel and MgO are the species of prime interest. Pentlandite (Pn), pyrrhotite (Po) and rock (Rk) content are also included. (Pentlandite recovery is close to overall nickel recovery; additional nickel recovery is generated from the recovered Po which contains approximately 0.25% Ni.)

Table 6-2: Test Results from Phase 2

					Rougher Cleaner Concentrate										
		Dosage (g/kg)	Cond'n Time (min)	Pump Rate (L/min)	%Ni	%MgO	%Pn	%Po	%Rk	Ni Rec	MgO Rec	Pn Rec	Po Rec	Rk Rec	Weight Split (%)
20	A	0.2	0	4	20.9	3.1	62.3	18.7	13.9	47.5	2.8	48.3	7.9	3.1	12.1
20	B	0.2	0	1.3	21.3	2.0	63.7	17.2	13.4	56.9	2.3	57.8	8.8	3.7	14.7
21	A	0.1	0	4	17.8	4.3	53.1	23.6	19.9	56.1	4.6	57.1	12.0	5.3	14.9
21	B	0.1	0	1.3	19.5	2.2	58.0	26.3	12.1	77.4	3.2	78.6	18.3	4.4	20.2
22	A	0.5	0	5.5	17.5	5.5	52.3	16.5	23.2	17.1	1.9	17.4	2.7	2.0	4.8
23	A	0.05	0	4	19.3	3.4	57.4	23.5	15.7	45.5	2.8	46.3	8.5	3.2	11.1
23	B	0.05	0	1.3	17.8	3.1	53.0	28.4	15.9	75.6	4.5	77.0	17.8	5.4	19.1
24	A	0.2	20	4	20.2	2.7	60.3	21.3	14.5	53.4	2.6	54.4	9.2	3.1	12.3
24	B	0.2	20	1.3	20.5	1.6	61.2	24.1	10.9	67.4	1.9	68.6	12.4	2.9	15.1
25	A	0.1	20	4	19.2	3.0	57.2	21.9	17.1	59.6	3.6	60.5	12.1	5.0	16.0
25	B	0.1	20	1.3	18.7	2.1	55.7	26.9	14.0	78.4	3.5	79.5	20.4	5.7	22.2
26	A	0.05	20	4	17.4	4.2	51.9	26.6	18.5	65.0	5.4	66.1	16.1	5.8	17.7
26	B	0.05	20	1.3	17.5	2.5	52.1	27.4	17.7	76.0	4.0	77.2	19.2	7.1	21.6
27	A	0.2	10	4	21.1	2.8	62.9	22.5	10.6	53.4	2.3	54.4	8.9	2.3	12.0
27	B	0.2	10	1.3	21.1	2.0	62.9	27.3	6.2	66.8	2.0	68.0	13.5	1.6	14.5
28	A	0.1	10	4	17.5	3.2	52.1	23.7	21.1	63.7	4.3	64.7	15.3	6.5	17.7
28	B	0.1	10	1.3	18.7	2.1	55.7	28.6	12.2	73.7	2.9	74.9	19.1	4.2	19.3
29	A	0.05	10	4	19.0	4.2	56.7	26.7	13.2	68.0	6.0	68.9	18.3	5.2	20.6
29	B	0.05	10	1.3	18.0	2.4	53.7	27.5	15.3	79.8	4.1	80.9	23.2	6.5	23.6
30	A	0	0	4	18.4	4.4	54.8	21.7	19.9	67.8	5.6	68.8	14.1	6.2	17.8
30	B	0	0	1.3	17.1	2.5	51.0	30.8	15.4	72.7	2.9	74.6	13.8	4.3	15.4

6.2.1 Effect of CMC Dosage

CMC dosage rates were established by measuring the percent solids of the slurry and calculating the mass of solids. The dosage rate in the plant is based on the feed tonnage, and equals approximately 0.05 g/kg of feed or 0.5 g/kg of rougher concentrate solids.

Figure 6-4 shows trends of CMC dosage with respect to MgO grade in concentrate. Without CMC, there is no correlation with the concentrate grade and recovery, showing a low R^2 value of 0.217.

Addition of 0.05 g/kg CMC, the low dosage, decreases the MgO grade in concentrate. By removing the data point from Test 23 (square point at 3.4% MgO, 45% Ni Rec) the R^2 value for this trend line increases from 0.239 to 0.908, i.e. a good correlation.

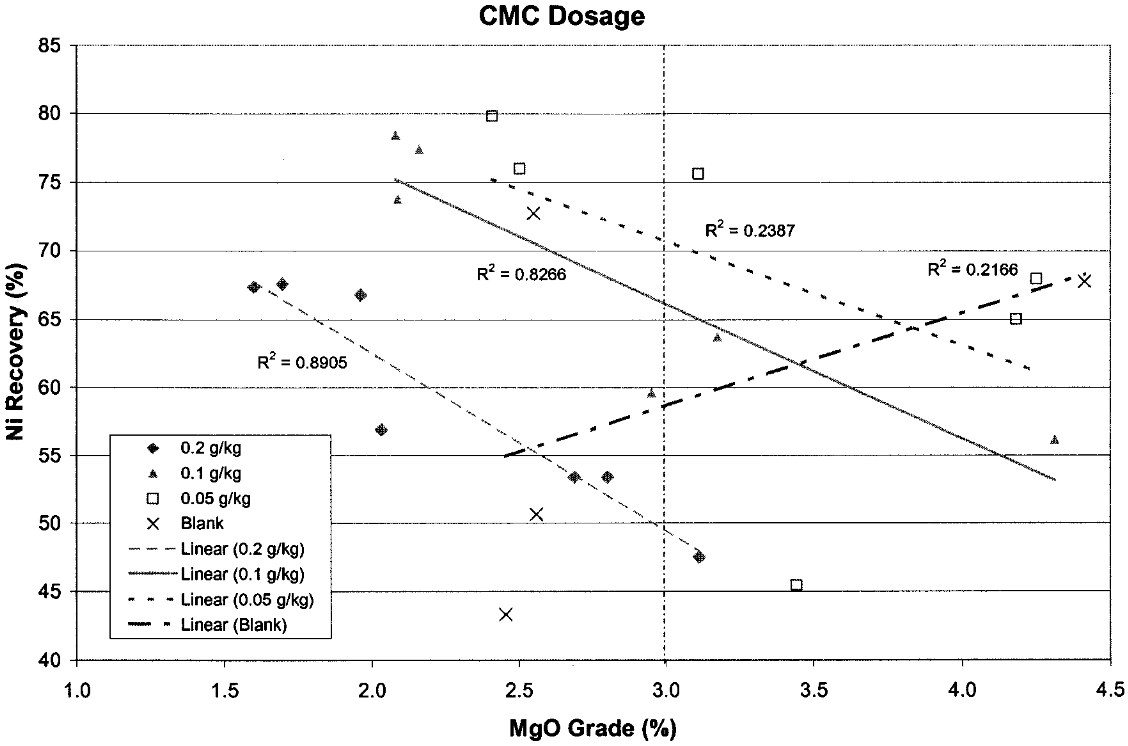

Figure 6-4: Effect of CMC Dosage on Nickel Recovery and MgO Grade.

The trend lines move down and to the left on the MgO-grade/Ni-recovery plot with increasing CMC dosage. The blank tests do not follow any trend; CMC may offer a stabilizing effect on the flotation circuit, enabling grades and recovery to be better managed.

Figure 6-5 shows the effect of dosage on nickel grade. By moving down the nickel recovery curve (Figure 6-4), the 0.2 g/kg tests produced consistently greater than 20% Ni and less than 3% MgO concentrates. The remainder of the tests showed a high scatter in MgO grades, which reached as high as 4.4%.

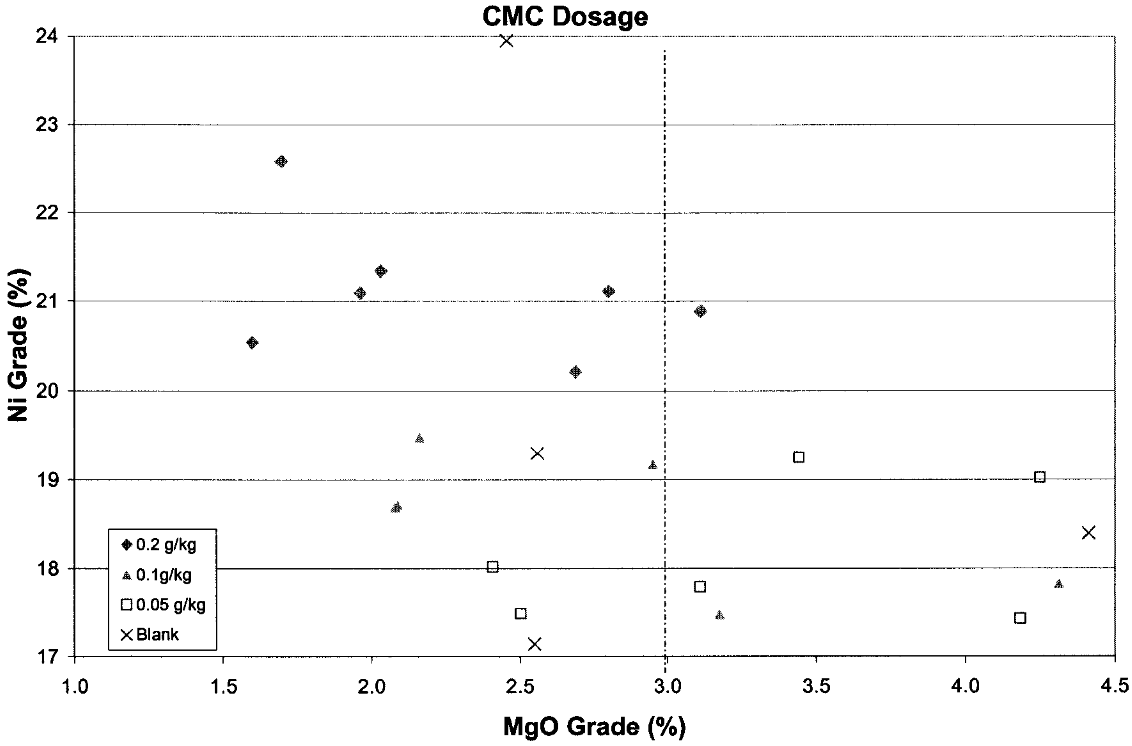

Figure 6-5: Effect of CMC Dosage on Nickel and MgO Grade

Determination of optimum dosage is essential to the operation of this stage. Over dosage can depress all minerals: Test 22, as mentioned in Section 6.1.2, observed almost no flotation due to over-dosage of CMC. Lower nickel recovery is observed with higher CMC dosages (Figure 6-4).

A high grade nickel concentrate results in a lower volume of concentrate to the smelter. The lower gangue content promotes higher throughput rates and greater utilisation of smelter capacity. The 0.2 g/kg dosage rate can achieve this condition.

6.2.2 Effect of Conditioning Time

The conditioning time of CMC in the process stream was explored as a factor that may affect the application requirements of CMC in the mill. It is possible that CMC needs a certain amount of contact time with the slurry to be effective. It may be necessary to increase the duration that the CMC is exposed to the slimes in the circuit to have a significant impact on dispersion.

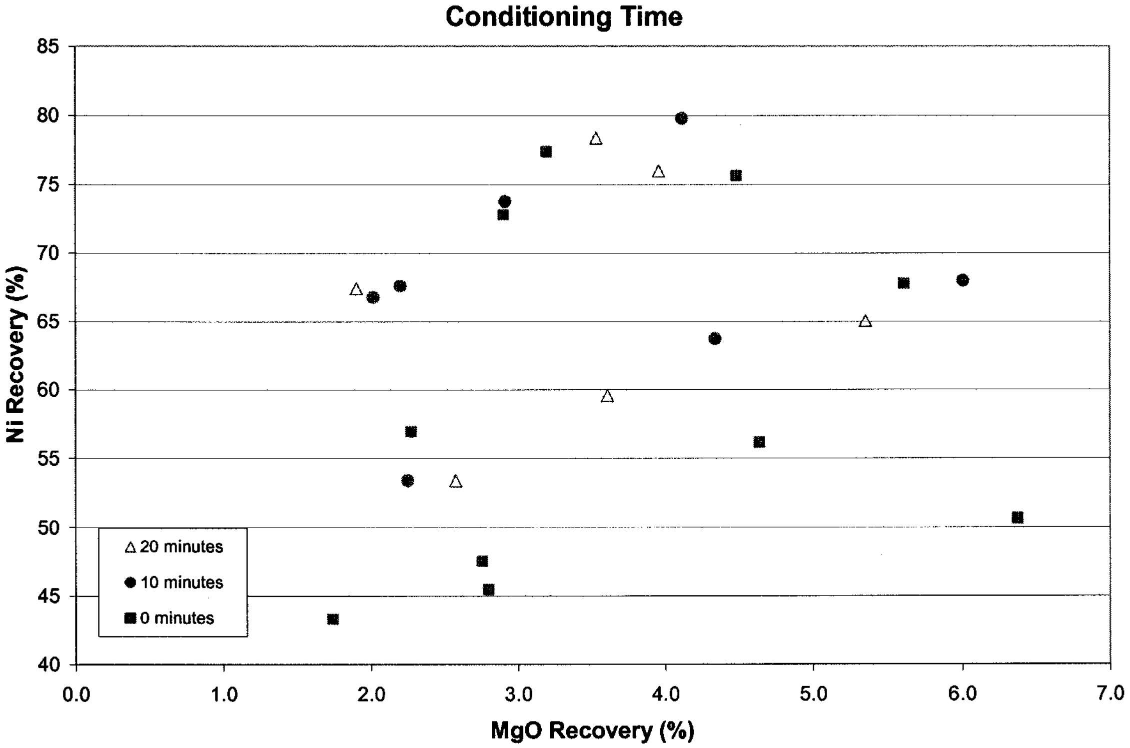

Figure 6-6: Effect of Conditioning Time on MgO and Nickel Recovery

Figure 6-6 shows a high degree of scatter between the nickel and MgO recovery. Conditioning time does not appear to have an effect on nickel recovery or MgO grade.

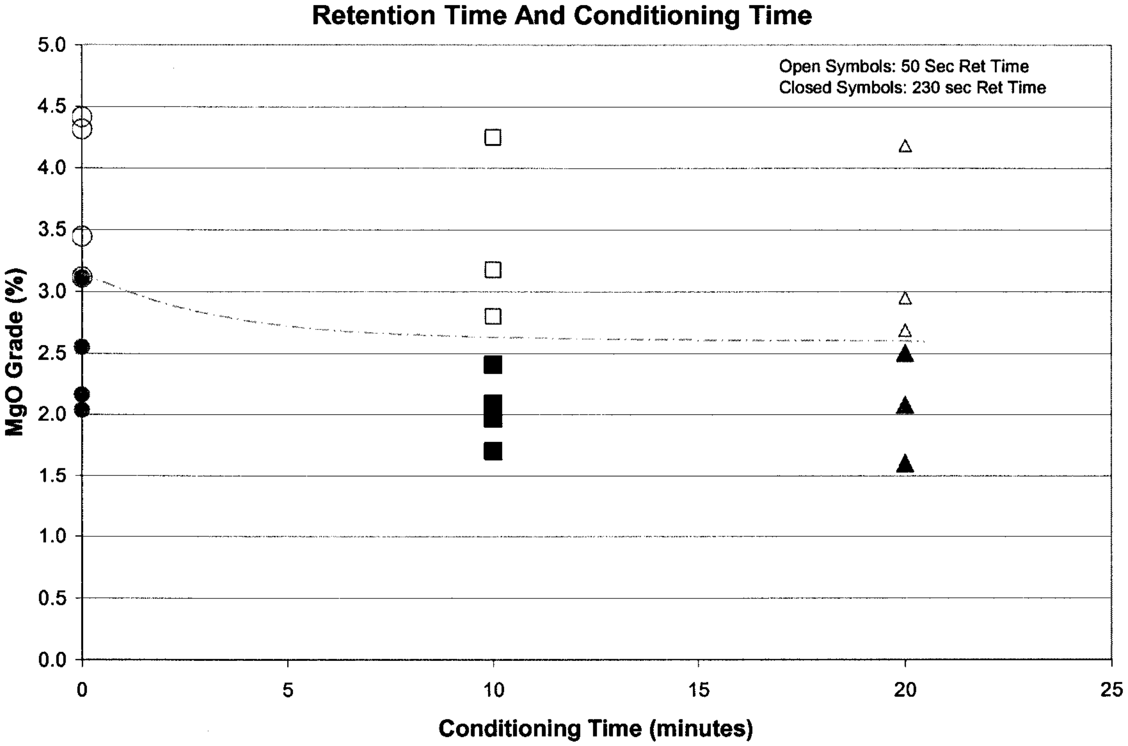

Figure 6-7: Effect of Conditioning and Retention Times on MgO Grade

Figure 6-7 shows the test data also separated out with respect to retention time in the flotation cell. Tests with longer retention time produced results with less than 3% MgO. This is examined in more detail in the next section.

In plant scale, at the solution strength of 0.5% CMC, if used to treat a full volume flotation stream, will require a high volume of water addition. Proper mixing and homogenisation of the slurry with the reagent solution is required and a minimum conditioning time will be necessary. The minicell system had a small agitated conditioning tank compared to a flotation pump box and once the CMC was added to the suspended slurry, it became fully mixed in solution. However, this is not the case in the Mill, if the CMC addition point is in the concentrate sump there is almost no mixing, and solids build-up in the sump promotes channelling for the slurry. There is only a small opportunity of mixing in the pump, which feeds the distributor, or in the distributor itself, which should equally divide the stream (and CMC solution) to each of the flotation banks.

6.2.3 Effect of Flotation Retention Time

Adjusting the pump speed at the conditioning tank discharge varied the retention time in the flotation cell. The retention times tested were 50 and 230 s. A longer retention time in the flotation cell produced consistently lower MgO concentrate grades and greater nickel recoveries.

Two distinct regions are evident in Figure 6-8. The longer retention time produced a greater nickel recovery at equivalent MgO grades. This suggests that the Mg-minerals may be entrained in the froth, and there was not sufficient time to drop out of the froth with the short retention time.

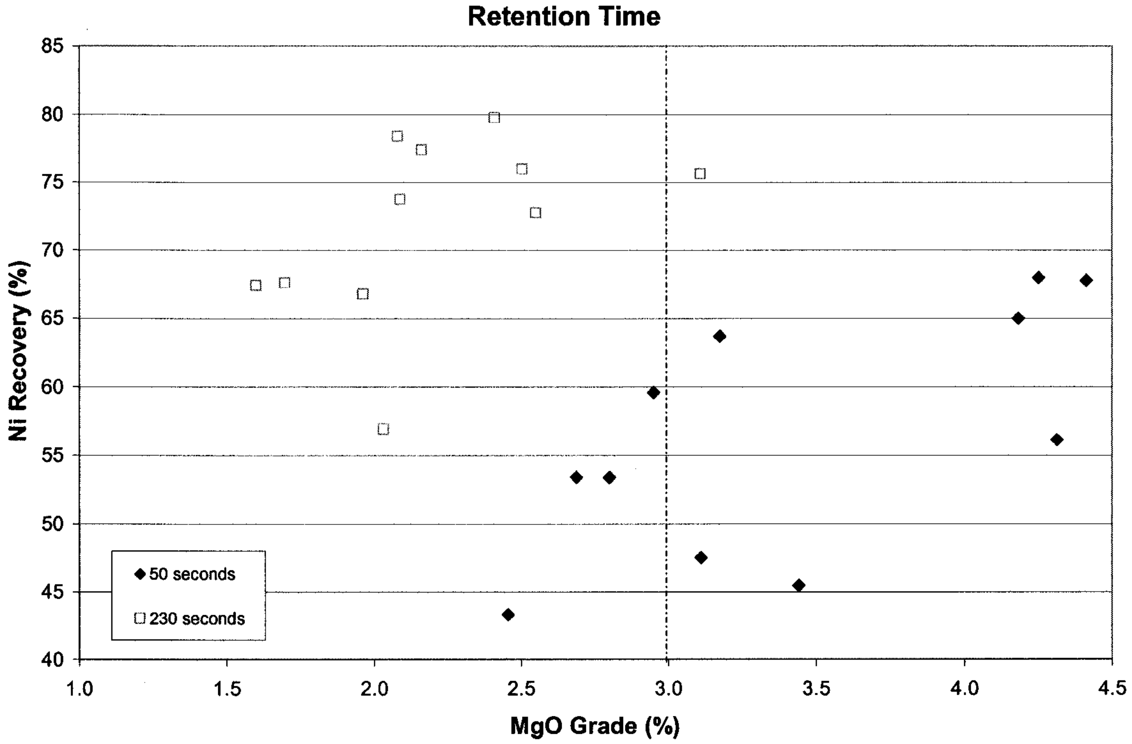

Figure 6-8: Effect of Retention Time on MgO Grade and Nickel Recovery

In the Thompson Mill, the effect of retention time in the rougher cleaning stage is maximized. Maximum copper recovery must be maintained, for the copper circuit, and very deep froth depths are used to slow the rougher cleaner banks down and increase retention time (in the froth). The slope of the trend lines in Figure 6-9 are 5.1 and 5.8 are greater than 1, indicating that nickel rate of nickel recovery is higher than for MgO recovery. The longer retention time allows for greater separation between gangue and sulphides. The parallel lines also indicate that by increasing the retention time, the recovery curve is consistently increased. The longer retention time may allow for the slurry to be more fully dispersed while flotation takes place.

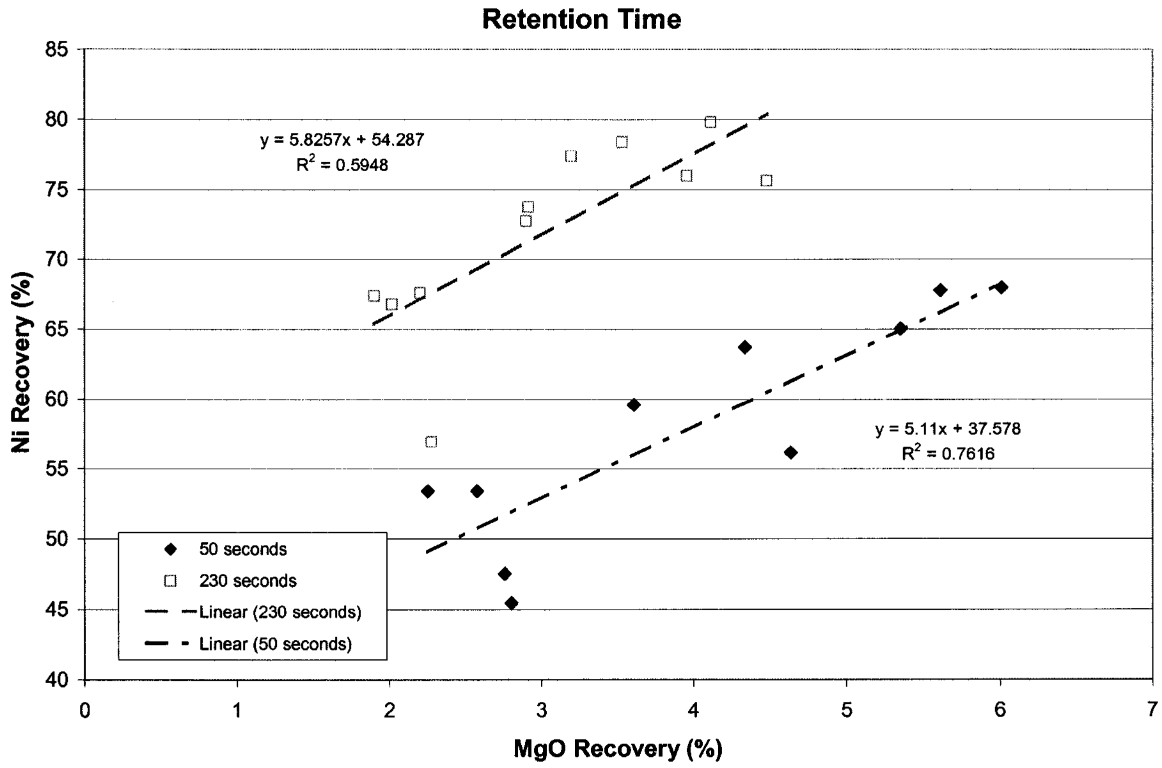

Figure 6-9 MgO Recovery vs. Nickel Recovery

6.2.4 DEPENDENCE ON MASS RECOVERY

Figure 6-10 shows there is a relationship between mass recovery and total Ni + MgO recovery. When both nickel and MgO are split in Figure 6-11 to show individual trends against mass recovery, the nickel trend follows the same slope and scatter as Figure 6-10. The nickel recovery is more dependent than MgO on concentrate mass recovery.

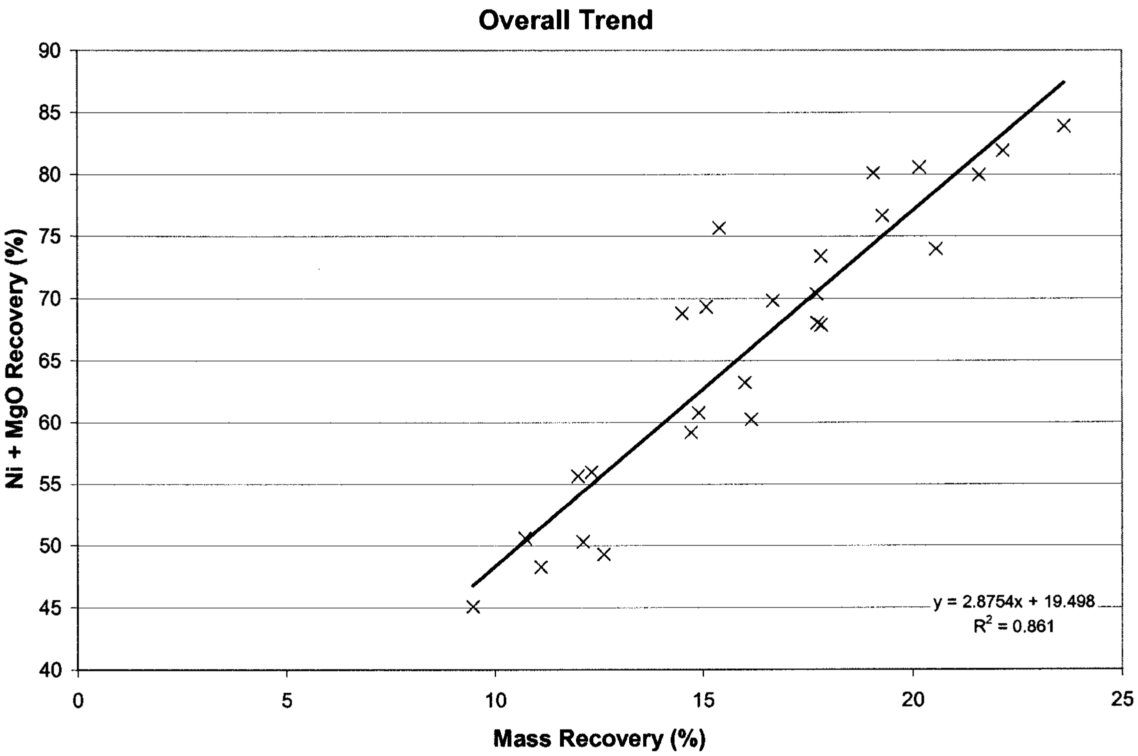

Figure 6-10: Overall Trend of Ni+MgO Recovery Against Mass Recovery

The MgO minerals show a large degree of scatter in Figure 6-11. This could be related to the varying test operating conditions. High recovery of MgO is observed with no CMC addition and low retention time in the flotation cell.

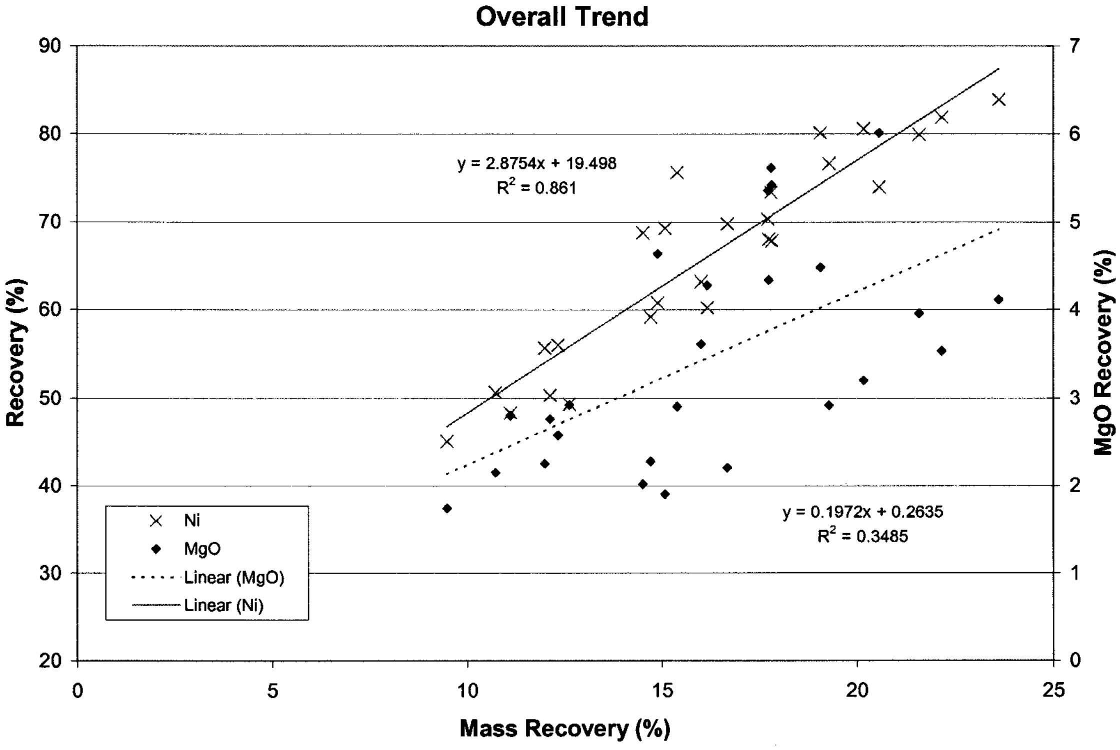

Figure 6-11: Nickel and MgO Recovery Against Mass Recovery Individually

6.3 OVERALL ASSESSMENT

Selective adsorption of CMC on the target mineral surface may be difficult to achieve in the flotation pulp. The dissolution of minerals in solution will promote the presence of many soluble species. These may have altered the surface of the minerals and promoted similarity in surface properties. The success of CMC for a specific pulp will depend on its degree of substitution and specificity of the substituted groups. MAK CMC has a DS of 0.6-0.7 and appears to be sufficient for Birchtree ore.

While there may be a need for conditioning time with the larger volume stream in the plant; this test work does not show it as a significant variable. A dosage rate of 0.2 g/kg produced the lowest MgO concentrate grade (1.5-3.0%) at 50-70% stage nickel recovery. Higher nickel stage recoveries (65-80%) and MgO grades (2.0-3.2%) were achieved with 0.1 and 0.05 g/kg CMC. Longer retention time in the flotation cell showed improved recoveries and separation.

Nickel recovery shows a relatively strong correlation with mass recovery to concentrate. MgO minerals seem to be influenced by other factors. Pentlandite is mainly recovered by true flotation while the MgO minerals may be recovered by several routes, true flotation, entrainment and thus be more sensitive to factors such as froth depth, solids density and feed rate.

Increased residence time and increased dosage (0.2 g/kg) showed that high nickel grade to concentrate is achievable. The operation of downstream stages (the copper circuit) will be more efficient with a consistent, high grade rougher cleaner concentrate. Copper-nickel separation will not be hindered by excess gangue and a clean separation can be achieved. This will reflect in the final copper concentrate and the two final nickel streams: copper cleaner tails and copper-nickel separation tails. Once gangue or MgO minerals are floated to the rougher cleaner concentrate, there is no exit to tails; they will inevitably end up in a concentrate stream. Rejection at the rougher cleaner stage is essential, and CMC is beneficial to consistent MgO depression.

CHAPTER 7
THOMPSON MILL PLANT PRACTICE

7.1 PLANT SCALE CMC ADDITION

In the Thompson mill, addition of a CMC solution has been implemented in the Birchtree flow sheet. At the time of writing, commissioning of a permanent mixing tank and distribution system had not been completed, and a temporary set up was in place. Preliminary data on the effectiveness of this crude system is illustrated in Figure 7-3.

The target dosage rate is 0.5 kg/t of solids in the rougher concentrate stream, equal to almost 0.05 kg/t of bulk flotation feed.

The temporary system consists of a 45 000 L mixing tank with an agitator. The distribution hopper for CMC was moved from the primary mill discharge and placed at the top of this tank as illustrated in Figure 7-1. Water is added to the tank and when full, CMC is added. An approximate 1% batch of CMC is made using about a quarter (225 kg) of a 1 ton (907 kg) super-sack. The solution is mixed for a minimum of two hours to ensure maximum wetting of the CMC polymer. It is then pumped to the rougher concentrate launders.

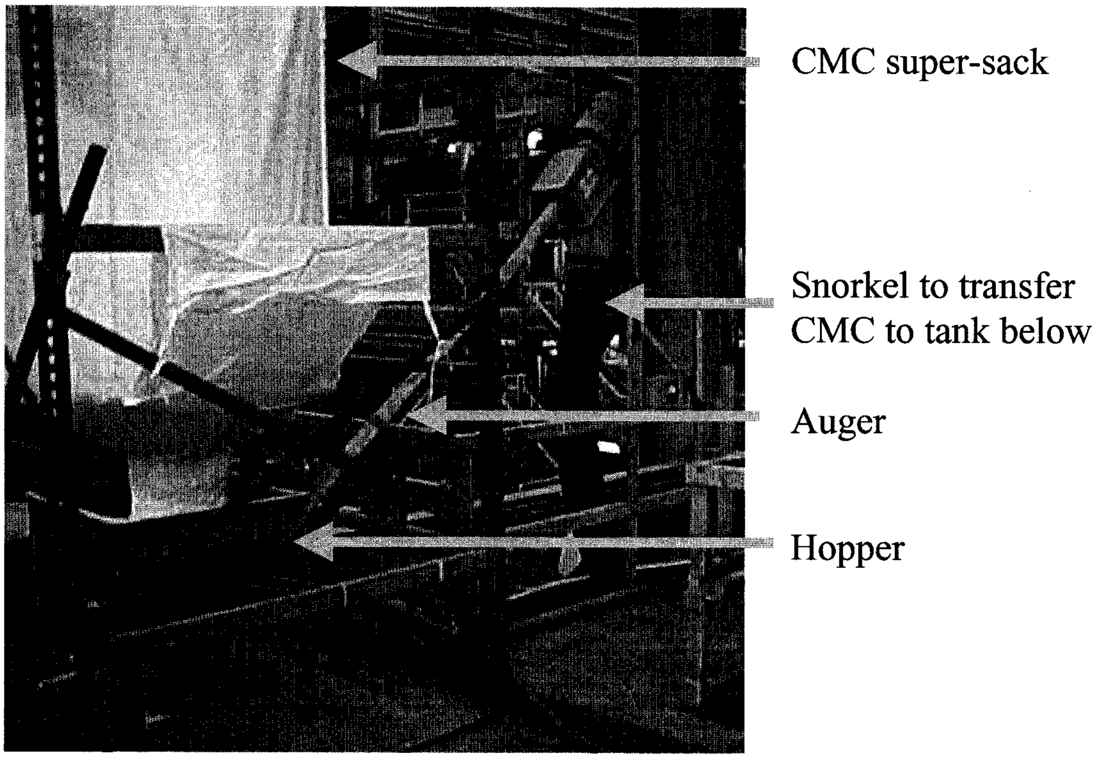

Figure 7-1: CMC Bag and Hopper System

The launder distribution system is similar to that of spray bars; the dilute CMC is added here to maximize mixing and conditioning time in that stream. Six of the eight rougher launders were equipped for CMC addition as shown in Figure 7-2. This addition point also maximized mixing and conditioning time, as the slurry flows down the launders, to the sump, before it is pumped to the rougher cleaner distributor.

Rougher Flotation Bank

CMC Distribution
into Launder

Figure 7-2: CMC Addition to Rougher Concentrate Launder

The addition of CMC in this stream was effective at decreasing MgO grade from baseline values, as illustrated in Figure 7-3. Nickel recovery in this stage was not affected by CMC. As illustrated in Chapter 6, nickel recovery is dependent on mass recovery. Circuit operation from day to day (individual data points) is dependent on the operator.

In the Thompson Mill, the effect of retention time in the rougher cleaning stage is maximized. Maximum copper recovery must be maintained, for the copper circuit, and deep froth depths (up to 36 cm) are used to slow the rougher cleaner banks down and increase froth retention time.

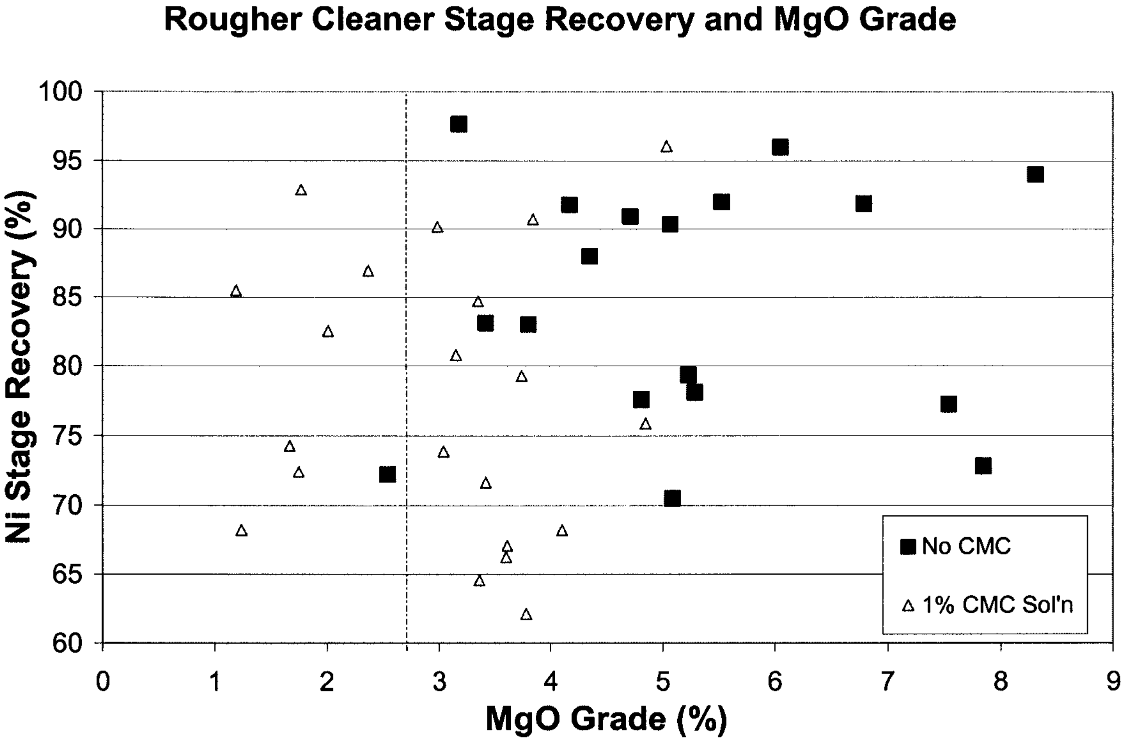

Figure 7-3: Plant Performance of CMC in Solution to Rougher Concentrate

The rougher concentrate recovers 20% of the total mill feed. Plant operating conditions such as number of flotation banks available and feed tonnage will influence the assays observed in this stream. The low concentration of CMC solution also infers that there is a lot more water being added to the stream, which will affect the solids density in all the down stream processes. Lowering the slurry density will increase the required mixing and contact time of the CMC solution in the pulp. There is also the added benefit of that lower pulp densities will favour the rejection of entrained material.

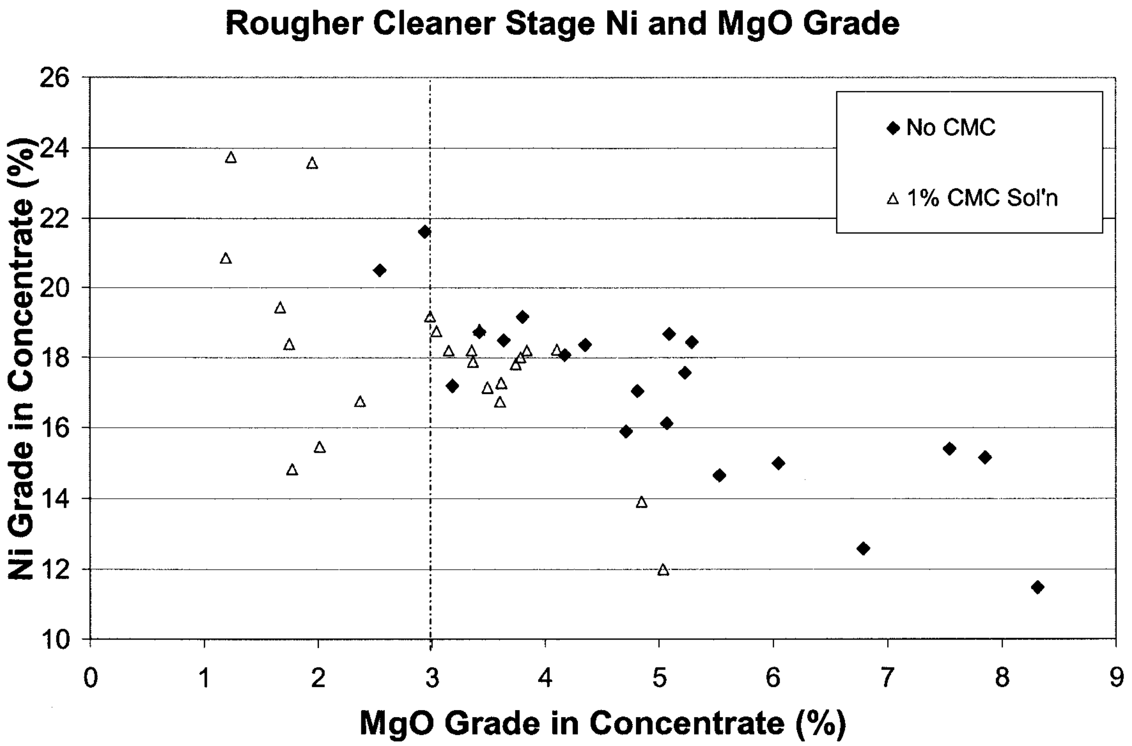

Figure 7-4: Plant Nickel and MgO Grade in Concentrate

Nickel and MgO grade comparison is illustrated in Figure 7-4, with and without CMC in the rougher cleaner. Though not consistently below the 3.0% MgO target, there is a clear shift to a lower MgO grade in concentrate. These samples were obtained during the first three weeks after the temporary system was operating.

7.2 COMPARISON OF MINICELL RESULTS AND PLANT BEHAVIOUR

The trends as described in Section 6.3 (Overall Trend) compared to the trends in Section 7.1 (Plant Scale CMC Addition) are not the same. In plant scale, the solution strength of 0.5% CMC, (if used to treat a full volume flotation stream), will require a high volume of water addition. Proper mixing and homogenisation of the slurry with the reagent solution is required and a minimum conditioning time will be necessary. The minicell system had a small agitated conditioning tank compared to a flotation pump box and once the CMC was added to the suspended slurry, it became fully mixed in solution. However, this is not the case in the mill, if the CMC addition point is in the concentrate sump there is almost no mixing, and solids build-up in the sump promotes channelling for the slurry. There is only a small opportunity of mixing in the pump, which feeds the distributor, or in the distributor itself, which should equally divide the stream (and CMC solution) to each of the flotation banks.

The addition of CMC in large scale has a significant impact on the MgO grade in the rougher cleaner stage. Conditioning time in the plant is required to allow for proper mixing of CMC with the slurry. This is dependent on the method of application of the liquid CMC solution. Direct application to the flotation pump boxes did not impact MgO grade when tested in plant scale, however, based on the data in Figures 7-3 and 7-4, CMC applied to the rougher concentrate launder was effective.

Along with the other variables present, in a plant situation the dispersive action of CMC can be mistaken for one of gangue depression. If dispersion is inadequate and the slime coatings on nickel sulphide depress the flotation rate and recovery, the operators usually respond by increasing the "pulling rate" or collector addition. This would result in an increase in the gangue entrainment and flotation of composites and hence increase the overall magnesium grade of the final concentrate. By increasing the CMC addition, for increased dispersive action, nickel flotation would improve and the "pulling rate" and collector dosage can be reduced resulting in a decrease in Mg content in concentrate (5).

Alternatively, as mentioned in Section 6.1.2, where CMC was overdosed, the flotation cell was pulled harder with the result of high MgO grade and low nickel recovery. Dosages beyond 0.2 g/kg of slurry is an overdosed amount. The mill has three rotating shifts, each with a flotation operator who has his own method of operating the flotation circuit. The rougher concentrate and rougher cleaner concentrate streams have been added to the on-stream analyser to aid the operators in achieving a target rougher cleaner concentrate grade of 18% Ni. The target of 18% Ni in concentrate has been established as it balances the nickel recovery in the rougher cleaners and the MgO recovery due to entrainment. Future work in plant includes optimizing the CMC addition rate with a permanent and automated system and correlating it with on-line measurements of rougher concentrate grade.

CHAPTER 8
CONCLUSIONS and RECOMENDATIONS

8.1 Conclusions

There was a high degree of scatter with both sets of test work as outlined in Chapters 5 and 6. One of the biggest factors in drawing conclusions on this test work is the lack of duplicate tests. In Chapter 5, optimum conditions were not established and, before further exploration could continue, the direction of work was changed.

The 5L minicells were set-up to test reagent options. The initial test work trying to simulate rougher/scavenger showed significant scatter, and trends were not identified. A coarse grind showed some potential, as the available pentlandite surface area and lack of slimes present in the system contributed to low MgO grades. However, plant testing has established that losses in nickel recovery due to insufficient pentlandite liberation are unacceptable.

Guar gum addition to the flotation circuit should be explored further, as a possible reagent in a synergistic role with CMC. The nonionic nature of guar and anionic nature of CMC would increase the possibility of depressing most Mg-minerals in the slurry. This mixture could be beneficial in both the scavenger and rougher cleaner stage.

The two sodium silicate tests showed similar performance. Further investigation with sodium silicate would be necessary to optimize dosage and conditioning time. The lack of selectivity observed in these tests suggests the possibility that the dosage rate was too high. If the sodium silicate was overdosed in these tests the silica monomers tend to form long chains and increase slurry viscosity, which would hinder flotation.

MAK Chemical's CMC is currently used in the Thompson Mill. Based on this limited test work, there is no reason to change it for another reagent. Exploration of CMC combinations with other polymeric depressants may be beneficial.

The original intent was to perform a semi-factorial experimental design to determine the best reagent and operating conditions for Birchtree ore, with plant slurry. This would have offered an advantage over a batch laboratory testing which may or may not replicate the plant conditions. Despite the fact that repeat tests were not performed and dosages and conditioning times were not optimized, this test work did not reveal any significant solution to rock rejection for Birchtree ore.

The minicell test work simulating the rougher cleaner showed the effect of CMC dosage and flotation retention time on rejecting MgO. Plant test work largely confirmed the impact of CMC on this stage but indicated that conditioning time was also an important factor. An inherent difference in the contact of reagent and slurry for the two systems is likely the reason.

In the minicells, nickel recovery showed a correlation with mass recovery to concentrate. Mg-minerals seem to be influenced by other factors and may be more sensitive to froth depth, solids density and feed rate.

The rougher stage is a bulk flotation and aims at maximizing sulphide recovery. The intense mass recovery targeted in this stage, promotes entrainment of the Mg-silicate minerals and slime coated sulphide particles. The CMC addition prior to the cleaning stage promotes dispersion of the slimed particles and the long froth retention time decreases entrainment.

Increased residence time and increased dosage (0.2 g/kg) showed that high nickel grade to concentrate is achievable. A consistent, high grade rougher cleaner concentrate increases operational efficiency of the downstream stages (the copper circuit). Copper-nickel separation will not be hindered by excess gangue and a clean separation can be achieved. This will reflect in the final copper concentrate and the two final nickel streams: copper cleaner tails and copper-nickel separation tails. With the current flow sheet, once gangue or MgO minerals are floated to the rougher cleaner concentrate, there is no exit to tails; they will inevitably end up in a concentrate stream. Rejection at the rougher cleaner stage is essential and CMC aids in reaching this objective.

The addition of CMC in large scale had a significant impact on the MgO grade in the rougher cleaner stage. Conditioning time in the plant is a factor, to allow for proper mixing of CMC with the slurry. This is dependent on the method of application of the liquid CMC solution. Direct application to the flotation pump boxes did not impact MgO grade when tested in the plant, however, CMC applied to the concentrate launder was effective.

8.1 Recommendations

Future work based on the results of rougher and scavenger reagent screening in Chapter 5 are:

- CMC in the rougher stage resulted in high MgO grades in concentrate. Addition at this stage was not beneficial. However, CMC addition in the scavenger stage, did show low MgO grades, compared to the other reagents screened.
- Sodium silicate should not be tested any further in the rougher or scavenger stage. Dosage screening would need to be performed, if this reagent were to be considered for another stream in the Thompson Mill circuit. There was no indication of selectivity between Mg-minerals and sulphides in the streams tested.
- A guar gum/CMC mix should be explored. The benefits of both reagents may have a compound effect on rejecting Mg-minerals. The nonionic nature of guar and anionic nature of CMC should increase the possibility of depressing all Mg-minerals in the slurry. The mixture would be beneficial in both the scavenger and rougher cleaner stage.

Future studies for the CMC optimization in the plant based on the results in Chapters 6 and 7 include:

- Mineralogical studies on concentrate and tails to determine if the magnesium silicates are floating, or are entrained in the froth. If it is an entrainment issue, froth washing strategies could be explored. If the minerals are floating, CMC dosage rate is not optimized.

- A proper handle on air flow rates to the individual cells may also allow for froth retention optimisation.
- Establish correlation between rougher cleaner concentrate nickel grade and MgO in concentrate. The operators will then be able to target a nickel grade and be confident that their MgO grade is within specified limits. A more in-depth plant sampling campaign to collect the necessary data points needs to be completed when the permanent system is in place.
- The Thompson mine has areas of ultramafic ore, which are currently in production. An additional benefit of this CMC addition system, will be its application on Thompson feed. However, it is unknown how beneficial CMC will be on this ore and studies will be required.

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Appendix A
Data for Chapter 5

Test # 2 **Blank Test**
May 17 2002

				ASSAYS										
	TIME		% Sol	Wt (g)	kg/min	kg/20 min	Cu	Ni	Fe	S	SiO2	MgO	Al2O3	Ca
A1B	20	1		1364.2	2.05	40.93	0.08	1.76	21.83	11.07	28.21	18.58	3.69	0.55
	40	2		663.0	1.99	39.78	0.08	1.89	23.47	11.95	27.98	18.29	3.66	0.53
	60	3		622.2	1.87	37.33	0.07	1.68	21.14	10.50	27.81	17.97	3.72	0.49
	80	4		604.5	1.81	36.27	0.08	1.79	21.78	10.97	27.20	17.67	3.61	0.48
	100	5		578.6	1.74	34.72	0.08	1.70	20.56	10.26	27.26	17.82	3.62	0.47
	120	6		665.7	2.00	39.94	0.08	1.83	21.99	11.17	28.28	18.41	3.75	0.52
				4498.2		**228.97**	0.08	1.78	21.83	11.02	27.87	18.21	3.68	0.51
		AV		**642.6**	**1.91**									
AR	0-20	1		458.2	0.11	2.29	0.42	8.95	31.54	21.99	14.56	9.50	1.87	0.33
	20-40	2		440.0	0.11	2.20	0.43	9.33	31.17	22.14	12.16	7.90	1.57	0.26
	40-60	3		405.4	0.10	2.03	0.27	6.11	27.19	17.08	19.53	12.57	2.64	0.39
	60-80	4		353.6	0.09	1.77	0.53	11.37	34.06	24.79	11.91	7.48	1.51	0.36
	80-100	5		475.3	0.12	2.38	0.44	9.27	29.82	21.05	12.41	7.97	1.64	0.26
	100-120	6		323.2	0.08	1.62	0.58	11.80	33.75	24.96	10.48	6.58	1.32	0.28
				2455.7			0.44	9.33	31.08	21.82	13.61	8.75	1.77	0.31
		AV		**409.3**	**0.10**	**2.05**								
RT	0-20	1		1033.3	1.03	20.67	0.04	0.86	20.28	9.21	30.63	20.39	3.99	0.51
	20-40	2		863.9	0.86	17.28	0.04	0.79	18.98	8.62	28.86	19.08	3.82	0.48
	40-60	3		1110.0	1.11	22.20	0.04	0.79	18.74	8.60	28.58	18.45	3.88	0.48
	60-80	4		1077.3	1.08	21.55	0.04	0.78	19.33	8.74	29.98	19.50	4.00	0.50
	80-100	5		976.7	0.98	19.53	0.04	0.76	19.48	8.68	30.09	19.68	4.04	0.50
	100-120	6		983.4	0.98	19.67	0.04	0.76	19.70	8.92	29.95	19.60	4.01	0.52
				6044.6			0.04	0.79	19.42	8.80	29.69	19.44	3.96	0.50
		AV		**1007.4**	**1.01**	**20.15**								
AS2	0-20	1		266.6	0.07	1.33	0.16	3.29	23.76	13.49	23.96	16.08	3.32	0.47
	20-40	2		204.4	0.05	1.02	0.18	3.65	22.81	13.18	21.23	14.11	2.95	0.39
	40-60	3		152.1	0.04	0.76	0.26	5.03	25.64	15.72	21.15	13.86	2.93	0.42
	60-80	4		239.3	0.06	1.20	0.19	3.82	24.07	13.73	24.74	16.18	3.49	0.52
	80-100	5		107.5	0.03	0.54	0.37	6.89	27.72	18.22	19.30	12.57	2.61	0.44
	100-120	6		269.2	0.07	1.35	0.19	3.86	24.65	13.94	25.17	16.56	3.55	0.52
				1239.1			0.21	4.10	24.43	14.27	23.17	15.30	3.23	0.47
		AV		**206.5**	**0.05**	**1.03**								
AS4	0-20	1		673.5	0.67	13.47	0.03	0.52	19.54	8.51	31.81	21.14	4.12	0.55
	20-40	2		700.3	0.70	14.01	0.02	0.53	19.84	8.74	31.05	20.52	4.06	0.54
	40-60	3		746.4	0.75	14.93	0.02	0.55	19.98	9.01	30.90	20.04	4.15	0.54
	60-80	4		793.4	0.79	15.87	0.02	0.55	19.99	8.93	30.16	19.59	4.05	0.54
	80-100	5		809.3	0.81	16.19	0.02	0.56	19.75	8.77	30.28	19.77	4.06	0.51
	100-120	6		792.3	0.79	15.85	0.02	0.51	18.09	8.06	27.68	18.28	3.73	0.45
				4515.2			0.02	0.54	19.52	8.67	30.25	19.84	4.02	0.52
		AV		**752.5**	**0.75**	**15.05**								

Bichtree Ore MiniCell Test # 2

Blank; pH 10.2

AB-1 (Flotation Feed)

kg/20min	38	100.00			
%Cu	0.08	100.00			
%Ni	1.78	100.00			
%Fe	21.83	100.00		22.25	Ni:Cu
%S	11.02	100.00		12.26	Fe:Ni
%SiO2	27.87	100.00		6.19	S:Ni
%MgO	18.21	100.00		39.94	Rk:Ni
%Al2O3	3.68	100.00			
%Ca	0.51	100.00			
%Cp	0.23	100.00			
%Pn	5.06	100.00			
%Po	23.62	100.00			
%Rk	71.10	100.00			

AR (Rougher Concentrate)

kg/20min	4.2	10.98			
%Cu	0.44	59.69			
%Ni	9.36	57.73			
%Fe	31.23	15.70		21.52	Ni:Cu
%S	22.03	21.94		3.34	Fe:Ni
%SiO2	13.61	5.36		2.35	S:Ni
%MgO	8.75	5.27		4.24	Rk:Ni
%Al2O3	1.77	5.28			
%Ca	0.31	6.67			
%Cp	1.25	59.69			
%Pn	27.71	60.18			
%Po	31.36	14.58			
%Rk	39.67	6.13			

RT (Rougher Tails)

kg/20min	33.8	89.02			
%Cu	0.04	44.51			
%Ni	0.83	41.66			
%Fe	19.92	81.23		20.83	Ni:Cu
%S	9.12	73.67		23.91	Fe:Ni
%SiO2	29.64	94.68		10.95	S:Ni
%MgO	19.42	94.94		91.67	Rk:Ni
%Al2O3	3.94	95.31			
%Ca	0.51	89.02			
%Cp	0.12	44.51			
%Pn	2.23	39.33			
%Po	21.29	80.25			
%Rk	76.36	95.61			

AS2 (Scavenger Concentrate)

kg/20min	3.0	7.94	8.9		
%Cu	0.21	21.32	47.9		
%Ni	4.00	17.85	42.8		
%Fe	24.43	8.89	10.9	18.63	Ni:Cu
%S	14.26	10.28	14.0	6.11	Fe:Ni
%SiO2	23.17	6.60	7.0	3.57	S:Ni
%MgO	15.30	6.67	7.0	15.46	Rk:Ni
%Al2O3	3.23	6.97	7.3		
%Ca	0.47	7.32	8.2		
%Cp	0.62	21.32	47.9		
%Pn	11.69	18.37	46.7		
%Po	25.85	8.69	10.8		
%Rk	61.85	6.91	7.2		

Summary:

Rec'y To Bulk Conc

kg/20min	18.9
%Cu	81.0
%Ni	75.6
%Fe	24.6
%S	32.2
%SiO2	12.0
%MgO	11.9
%Al2O3	12.2
%Ca	14.0
%Cp	81.0
%Pn	78.5
%Po	23.3
%Rk	13.0

Rec'y To Bulk Tails

kg/20min	81.08
%Cu	20.68
%Ni	23.78
%Fe	72.35
%S	63.50
%SiO2	88.09
%MgO	88.25
%Al2O3	88.35
%Ca	82.67
%Cp	20.68
%Pn	20.92
%Po	71.71
%Rk	88.67

AS4 (Scavenger Tails)

kg/20min	30.8	81.08	91.1		
%Cu	0.02	20.68	46.4		
%Ni	0.52	23.78	57.1		
%Fe	19.48	72.35	89.1	25.59	Ni:Cu
%S	8.63	63.50	86.2	37.32	Fe:Ni
%SiO2	30.28	88.09	93.0	16.53	S:Ni
%MgO	19.82	88.25	93.0	148.95	Rk:Ni
%Al2O3	4.01	88.35	92.7		
%Ca	0.52	82.67	92.9		
%Cp	0.06	20.68	46.4		
%Pn	1.30	20.92	53.2		
%Po	20.89	71.71	89.4		
%Rk	77.75	88.67	92.7		

Legend

Dry kg/20 min interval	% Of AB1	Recovery	% Previous Stage	
%Cu	%Cu	Cu Dis A1B	Cu Dis Prev Stg	
%Ni	%Ni	Ni Distribution	Ni	
%Fe	%Fe	Fe	Fe	Ni:Cu
%S	%S	S	S	Fe:Ni
%C	%C	C	C	S:Ni
%Al2O3	%Al2O3	Al2O3	Al2O3	Rk:Ni
%Ca	%Ca	Ca	Ca	
%MgO	%MgO	MgO	MgO	
%SiO2	%SiO2	SiO2	SiO2	
%Cp	%Cp	Cp	Cp	
%Pn	%Pn	Pn	Pn	
%Po	%Po	Po	Po	
%Rk	%Rk	Rk	Rk	

6/14/2004

Test # 3
May 30 2002

Penn Carbose CMC to Roughers

	TIME		Wt (g)	kg/min	kg/20 min	Cu	Ni	Fe	S	SiO2	MgO	Al2O3	Ca	% Sol
A1B	**20**	1	420.4	1.26	25.22	0.09	1.22	19.88	9.42	38.95	4.36	10.21	3.20	33.61
	40	2	968.1	2.90	58.09	0.08	1.62	23.22	12.07	30.09	17.09	4.42	0.64	36.60
	60	3	912.4	2.74	54.74	0.07	1.54	22.63	11.74	30.67	17.73	4.47	0.65	34.98
	80	4	1083.1	3.25	64.99	0.07	1.55	22.20	11.29	30.54	17.77	4.40	0.63	36.58
	100	5	918.7	2.76	55.12	0.07	1.56	22.42	11.47	30.87	18.00	4.43	0.66	36.77
	120	6	808.7	2.43	48.52	0.10	1.58	21.60	13.81	27.87	17.75	4.42	0.67	36.45
			5111.4			0.08	1.54	22.22	11.80	30.81	16.57	4.90	0.86	
		AV	**730.2**	**2.56**	**51.11**									**35.83**
AR	**0-20**	1	230.0	0.06	1.15	1.47	16.98	31.46	27.03	11.00	6.29	1.86	0.24	
	20-40	2	237.8	0.06	1.19	0.82	11.15	29.39	22.49	15.28	8.80	2.38	0.31	
	40-60	3	389.0	0.10	1.95	1.49	17.44	33.54	28.88	8.32	4.82	1.30	0.17	
	60-80	4	102.5	0.03	0.51	0.62	9.05	27.83	19.84	19.70	11.36	2.96	0.43	
	80-100	5	231.0	0.06	1.16	0.89	12.54	33.27	25.76	12.56	7.35	1.82	0.28	
	100-120	6	163.2	0.04	0.82	1.23	13.46	30.63	25.22	10.37	6.07	1.61	0.20	
			1353.5			1.17	14.31	31.63	25.78	11.83	6.85	1.84	0.25	
		AV	**225.6**	**0.06**	**1.13**									
RT	**0-20**	1	1433.4	1.43	28.67	0.04	1.14	21.23	10.92	29.80	16.72	4.44	0.58	
	20-40	2	1862.6	1.86	37.25	0.04	1.05	21.97	11.12	31.49	17.75	4.63	0.64	
	40-60	3	1689.9	1.69	33.80	0.04	1.02	21.98	10.82	31.96	18.49	4.70	0.64	
	60-80	4	1503.1	1.50	30.06	0.04	1.08	21.30	10.56	32.52	18.97	4.75	0.65	
	80-100	5	2279.5	2.28	45.59	0.04	0.94	19.22	9.49	29.60	17.32	4.26	0.56	
	100-120	6	1938.2	1.94	38.76	0.04	1.08	20.87	10.41	32.42	18.70	4.72	0.66	
			10706.7			0.04	1.04	20.99	10.49	31.25	17.98	4.57	0.62	
		AV	**1784.5**	**1.78**	**35.69**									
AS2	**0-20**	1	282.0	0.07	1.41	0.25	6.25	40.43	27.58	9.54	5.16	1.59	0.18	
	20-40	2	265.4	0.07	1.33	0.38	8.97	42.77	30.57	8.70	4.98	1.36	0.19	
	40-60	3	285.3	0.07	1.43	0.31	7.68	42.49	29.15	8.99	4.97	1.44	0.20	
	60-80	4	130.2	0.03	0.65	0.44	10.69	38.32	28.12	6.58	3.24	1.11	0.09	
	80-100	5	269.4	0.07	1.35	0.31	7.68	42.28	29.29	8.07	4.63	1.25	0.15	
	100-120	6	344.4	0.09	1.72	0.27	7.09	42.56	29.16	9.00	5.18	1.41	0.18	
			1576.7			0.31	7.76	41.80	29.05	8.69	4.85	1.39	0.17	
		AV	**262.8**	**0.07**	**1.31**									
AS4	**0-20**	1	798.8	0.80	15.98	0.01	0.38	17.49	7.82	32.66	18.66	4.85	0.63	
	20-40	2	910.5	0.91	18.21	0.02	0.54	18.78	8.66	32.18	18.19	4.82	0.64	
	40-60	3	854.2	0.85	17.08	0.01	0.41	18.78	8.41	34.52	19.82	5.11	0.71	
	60-80	4	902.9	0.90	18.06	0.02	0.56	20.23	9.56	32.75	19.12	4.79	0.67	
	80-100	5	857.3	0.86	17.15	0.01	0.43	18.07	8.10	32.25	18.90	4.70	0.65	
	100-120	6	916.2	0.92	18.32	0.02	0.41	17.53	7.66	33.06	19.38	4.83	0.68	
			5239.9			0.01	0.46	18.50	8.38	32.90	19.01	4.85	0.66	
		AV	**873.3**	**0.87**	**17.47**									

Bichtree Ore MiniCell Test # 3

Penn Carbose CMC to Rougher

AB-1 (Flotation Feed)

kg/20min	51	100.00			
%Cu	0.08	100.00			
%Ni	1.56	100.00			
%Fe	21.43	100.00		19.50	Ni:Cu
%S	11.10	100.00		13.74	Fe:Ni
%SiO2	30.44	100.00		7.12	S:Ni
%MgO	17.15	100.00		45.50	Rk:Ni
%Al2O3	4.58	100.00			
%Ca	0.65	100.00			
%Cp	0.23	100.00			
%Pn	4.39	100.00			
%Po	24.39	100.00			
%Rk	70.99	100.00			

AR (Rougher Concentrate)

kg/20min	1.8	3.59			
%Cu	1.18	52.93			
%Ni	14.25	32.78			
%Fe	31.69	5.31		12.08	Ni:Cu
%S	25.90	8.37		2.22	Fe:Ni
%SiO2	11.83	1.39		1.82	S:Ni
%MgO	6.85	1.43		1.93	Rk:Ni
%Al2O3	1.84	1.44			
%Ca	0.25	1.38			
%Cp	3.39	52.93			
%Pn	42.38	34.63			
%Po	26.72	3.93			
%Rk	27.50	1.39			

RT (Rougher Tails)

kg/20min	49.3	96.67			
%Cu	0.04	45.92			
%Ni	1.09	67.54			
%Fe	21.04	94.91		28.68	Ni:Cu
%S	10.55	91.88		19.30	Fe:Ni
%SiO2	31.13	98.86		9.68	S:Ni
%MgO	17.53	98.81		66.61	Rk:Ni
%Al2O3	4.68	98.78			
%Ca	0.67	99.64			
%Cp	0.11	45.92			
%Pn	2.98	65.70			
%Po	24.30	96.32			
%Rk	72.60	98.87			

AS2 (Scavenger Concentrate)

kg/20min	4.5	8.78	9.1		
%Cu	0.32	35.14	76.5		
%Ni	7.47	42.06	62.3		
%Fe	42.03	17.23	18.2	23.34	Ni:Cu
%S	29.39	23.26	25.3	5.63	Fe:Ni
%SiO2	8.69	2.51	2.5	3.93	S:Ni
%MgO	4.85	2.48	2.5	2.91	Rk:Ni
%Al2O3	1.40	2.69	2.7		
%Ca	0.17	2.30	2.3		
%Cp	0.92	35.14	76.5		
%Pn	21.90	43.81	66.7		
%Po	55.47	19.98	20.7		
%Rk	21.71	2.69	2.7		

Summary:

Rec'y To Bulk Conc

kg/20min	12.4
%Cu	88.1
%Ni	74.8
%Fe	22.5
%S	31.6
%SiO2	3.9
%MgO	3.9
%Al2O3	4.1
%Ca	3.7
%Cp	88.1
%Pn	78.4
%Po	23.9
%Rk	4.1

Rec'y To Bulk Tails

kg/20min	87.80
%Cu	10.98
%Ni	25.33
%Fe	77.60
%S	68.50
%SiO2	96.28
%MgO	96.25
%Al2O3	96.05
%Ca	97.26
%Cp	10.98
%Pn	21.73
%Po	76.23
%Rk	96.12

AS4 (Scavenger Tails)

kg/20min	44.8	87.80	90.8		
%Cu	0.01	10.98	23.9		
%Ni	0.45	25.33	37.5		
%Fe	18.94	77.60	81.8	45.00	Ni:Cu
%S	8.66	68.50	74.6	42.09	Fe:Ni
%SiO2	33.38	96.28	97.4	19.24	S:Ni
%MgO	18.80	96.25	97.4	172.68	Rk:Ni
%Al2O3	5.01	96.05	97.2		
%Ca	0.72	97.26	97.6		
%Cp	0.03	10.98	23.9		
%Pn	1.09	21.73	33.1		
%Po	21.18	76.23	79.1		
%Rk	77.71	96.12	97.2		

Legend

Dry kg/20 min interval	% Of AB1	Recovery	% Previous Stage	
%Cu	%Cu	Cu Dis A1B	Cu Dis Prev Stg	
%Ni	%Ni	Ni Distribution	Ni	
%Fe	%Fe	Fe	Fe	Ni:Cu
%S	%S	S	S	Fe:Ni
%C	%C	C	C	S:Ni
%Al2O3	%Al2O3	Al2O3	Al2O3	Rk:Ni
%Ca	%Ca	Ca	Ca	
%MgO	%MgO	MgO	MgO	
%SiO2	%SiO2	SiO2	SiO2	
%Cp	%Cp	Cp	Cp	
%Pn	%Pn	Pn	Pn	
%Po	%Po	Po	Po	
%Rk	%Rk	Rk	Rk	

6/14/2004

Test # 4 Penn Carbose CMC to Scavengers
May 31 02

	TIME		Wt (g)	kg/min	kg/20 min	Cu	Ni	Fe	S	SiO2	MgO	Al2O3	Ca	% Sol
A1B	**20**	1	923.5	2.77	55.41	0.10	1.65	22.55	11.47	31.08	17.85	4.59	0.65	35.85
	40	2	962.0	2.89	57.72	0.09	1.66	28.86	11.73	31.00	17.74	4.59	0.66	35.47
	60	3	819.7	2.46	49.18	0.08	1.61	22.48	11.61	30.34	17.51	4.49	0.65	35.03
	80	4	867.0	2.60	52.02	0.06	1.32	18.83	9.58	25.08	14.49	3.73	0.45	34.67
	100	5	662.0	1.99	39.72	0.08	1.59	22.57	11.87	30.09	17.24	4.54	0.63	34.25
	120	6	916.5	2.75	54.99	0.08	1.52	21.83	11.34	29.79	17.35	4.42	0.60	34.68
			5150.7			0.08	1.56	22.96	11.25	29.58	17.04	4.39	0.61	
		AV	**735.8**	**2.58**	**51.51**									**34.99**
AR	**0-20**	1	1194.6	0.30	5.97	0.27	4.95	25.13	15.26	24.45	14.26	3.73	0.51	
	20-40	2	436.6	0.11	2.18	0.54	9.43	29.30	20.93	16.45	9.46	2.53	0.35	
	40-60	3	294.0	0.07	1.47	0.78	13.58	34.03	26.82	10.69	6.09	1.65	0.25	
	60-80	4	913.0	0.23	4.57	0.32	5.70	27.26	17.20	22.81	13.25	3.54	0.50	
	80-100	5	1387.5	0.35	6.94	0.23	4.28	26.46	16.02	24.20	14.01	3.75	0.59	
	100-120	6	1846.0	0.46	9.23	0.18	3.38	24.88	14.23	26.62	15.69	4.08	0.58	
			6071.7			0.28	5.17	26.41	16.38	23.56	13.75	3.63	0.53	
		AV	**1012.0**	**0.25**	**5.06**									
RT	**0-20**	1	1715.0	1.72	34.30	0.04	0.91	21.88	10.79	31.93	18.57	4.83	0.66	
	20-40	2	1385.0	1.39	27.70	0.04	0.88	21.63	10.73	31.19	17.97	4.77	0.64	
	40-60	3	1430.9	1.43	28.62	0.04	0.92	22.11	11.05	31.50	18.26	4.83	0.64	
	60-80	4	1645.6	1.65	32.91	0.04	0.89	22.02	10.92	31.35	18.16	4.78	0.67	
	80-100	5	1507.0	1.51	30.14	0.05	0.81	21.54	11.14	31.62	18.72	4.94	0.68	
	100-120	6	1423.0	1.42	28.46	0.04	0.84	22.59	10.88	32.26	19.19	4.92	0.67	
			9106.5			0.04	0.88	21.96	10.92	31.65	18.48	4.84	0.66	
		AV	**1517.8**	**1.52**	**30.36**									
AS2	**0-20**	1	154.2	0.04	0.77	0.01	0.32	17.13	7.41	34.58	19.79	5.24	0.68	
	20-40	2	460.7	0.12	2.30	0.02	0.36	17.88	8.04	33.02	18.85	4.90	0.69	
	40-60	3	483.5	0.12	2.42	0.21	4.09	37.43	23.55	14.69	8.29	2.37	0.32	
	60-80	4	621.2	0.16	3.11	0.01	0.31	15.81	6.95	29.83	17.24	4.48	0.57	
	80-100	5	485.4	0.12	2.43	0.18	3.89	37.46	23.51	16.24	9.55	2.61		
	100-120	6	581.7	0.15	2.91	0.18	4.12	38.85	24.24	14.96	8.71	2.43		
			2786.7			0.03	0.73	8.74	5.06	6.89	3.97	1.06	0.10	
		AV	**464.5**	**0.12**	**2.32**									
AS4	**0-20**	1	900.0	0.90	18.00	0.29	6.42	39.73	26.89	11.48	6.39	1.99	0.24	
	20-40	2	1062.1	1.06	21.24	0.18	4.11	36.11	23.14	13.78	7.85	2.38	0.29	
	40-60	3	877.8	0.88	17.56	0.19	4.12	37.22	23.88	14.56	8.47	2.53	0.32	
	60-80	4	902.1	0.90	18.04	0.16	3.73	36.05	22.73	15.61	9.22	2.64	0.32	
	80-100	5	849.7	0.85	16.99	0.02	0.38	18.07	8.09	34.69	20.01	5.28	0.70	
	100-120	6	887.3	0.89	17.75	0.02	0.40	19.28	8.59	33.72	19.34	5.00	0.70	
			5479.0			0.15	3.25	31.35	19.12	20.30	11.68	3.26	0.42	
		AV	**913.2**	**0.91**	**18.26**									

Test # 5 Sodium Silicate to Roughers
June 12 2002

	TIME		Wt (g)	kg/min	kg/20 min	Cu	Ni	Fe	S	SiO2	MgO	Al2O3	Ca
A1B	**20**	1	692.7	2.08	41.56	0.07	1.50	23.15	11.90	32.57	14.73	5.51	0.87
	40	2	737.6	2.21	44.26	0.07	1.55	24.00	12.60	32.46	14.59	5.54	0.88
	60	3	883.7	2.65	53.02	0.07	1.56	23.91	12.44	32.32	14.51	5.52	0.84
	80	4	518.3	1.55	31.10	0.07	1.46	22.78	11.62	33.70	14.97	5.72	0.90
	100	5	789.2	2.37	47.35	0.07	1.49	22.82	11.89	33.07	14.79	5.63	0.89
	120	6	885.8	2.66	53.15	0.07	1.50	23.22	11.97	32.46	14.68	5.51	0.85
			4507.3			0.07	1.51	23.35	12.10	32.70	14.69	5.56	0.87
		AV	**643.9**	**2.25**	**45.07**								
AR	**0-20**	1	500.1	0.13	2.50	0.61	12.20	32.65	24.10	15.42	6.67	2.73	0.41
	20-40	2	447.3	0.11	2.24	0.65	12.99	33.77	25.16	13.91	5.86	2.45	0.39
	40-60	3	303.2	0.08	1.52	0.83	16.13	35.12	27.15	9.84	4.25	1.63	0.28
	60-80	4	365.5	0.09	1.83	0.69	13.68	33.05	25.17	13.21	5.62	2.33	0.38
	80-100	5	318.7	0.08	1.59	0.82	16.00	34.41	27.24	10.31	4.18	1.84	0.28
	100-120	6	230.8	0.06	1.15	0.84	16.74	35.14	28.03	10.11	4.11	1.81	0.24
			2165.6			0.72	14.20	33.82	25.81	12.64	5.35	2.22	0.35
		AV	**360.9**	**0.09**	**1.80**								
RT	**0-20**	1	1932.0	1.93	38.64	0.03	0.73	23.36	11.69	33.28	14.98	5.61	0.87
	20-40	2	1566.5	1.57	31.33	0.03	0.75	23.43	11.97	33.13	15.07	5.59	0.87
	40-60	3	1854.8	1.85	37.10	0.04	0.86	24.39	12.36	32.73	14.72	5.60	0.87
	60-80	4	1729.9	1.73	34.60	0.03	0.72	22.84	11.39	33.72	15.01	5.72	0.90
	80-100	5	1975.5	1.98	39.51	0.03	0.76	22.46	11.22	33.22	14.82	5.64	0.92
	100-120	6	1700.5	1.70	34.01	0.03	0.81	23.39	11.58	32.88	14.77	5.55	0.90
			10759.2			0.03	0.77	23.30	11.69	33.16	14.89	5.62	0.89
		AV	**1793.2**	**1.79**	**35.86**								
AS2	**0-20**	1	196.4	0.05	0.98	0.41	9.03	34.08	23.47	16.23	7.43	2.79	0.45
	20-40	2	403.8	0.10	2.02	0.16	3.85	32.33	19.56	22.08	10.33	3.94	0.69
	40-60	3	359.5	0.09	1.80	0.18	4.35	32.34	19.48	21.00	9.96	3.75	0.64
	60-80	4	491.4	0.12	2.46	0.16	3.53	32.24	18.82	22.73	10.71	4.08	0.69
	80-100	5	508.5	0.13	2.54	0.14	3.48	33.00	19.53	22.10	10.56	3.95	0.65
	100-120	6	391.8	0.10	1.96	0.17	4.02	33.19	20.11	21.38	10.15	3.81	0.61
			2351.4			0.18	4.24	32.75	19.81	21.45	10.13	3.82	0.64
		AV	**391.9**	**0.10**	**1.96**								
AS4	**0-20**	1	1108.4	1.11	22.17	0.02	0.46	21.26	10.15	35.51	16.32	6.03	0.92
	20-40	2	1124.6	1.12	22.49	0.02	0.36	21.66	10.52	35.22	16.09	6.00	0.89
	40-60	3	1097.7	1.10	21.95	0.02	0.44	21.87	10.44	34.11	15.40	5.86	0.87
	60-80	4	1197.8	1.20	23.96	0.02	0.43	22.33	10.80	34.79	15.53	5.94	0.91
	80-100	5	1248.1	1.25	24.96	0.02	0.38	20.71	9.66	36.22	16.07	6.14	0.96
	100-120	6	1042.2	1.04	20.84	0.02	0.42	21.43	9.65	35.45	15.85	6.01	0.92
			6818.8			0.02	0.42	21.54	10.21	35.23	15.88	6.00	0.91
		AV	**1136.5**	**1.14**	**22.73**								

Bichtree Ore MiniCell Test # 5

Sodium Silicate to Roughers

AB-1 (Flotation Feed)

kg/20min	45	100.00			
%Cu	0.07	100.00			
%Ni	1.50	100.00			
%Fe	23.40	100.00		21.43	Ni:Cu
%S	12.08	100.00		15.60	Fe:Ni
%SiO2	32.54	100.00		8.05	S:Ni
%MgO	14.63	100.00		45.67	Rk:Ni
%Al2O3	5.54	100.00			
%Ca	0.86	100.00			
%Cp	0.20	100.00			
%Pn	4.20	100.00			
%Po	27.09	100.00			
%Rk	68.51	100.00			

AR (Rougher Concentrate)

kg/20min	2.5	5.64			
%Cu	0.72	58.06			
%Ni	14.25	53.62			
%Fe	33.81	8.16		19.79	Ni:Cu
%S	25.81	12.06		2.37	Fe:Ni
%SiO2	12.64	2.19		1.81	S:Ni
%MgO	5.35	2.06		1.96	Rk:Ni
%Al2O3	2.22	2.26			
%Ca	0.35	2.30			
%Cp	2.07	58.06			
%Pn	42.37	57.00			
%Po	27.68	5.77			
%Rk	27.87	2.30			

RT (Rougher Tails)

kg/20min	42.5	94.36			
%Cu	0.03	41.79			
%Ni	0.74	46.55			
%Fe	22.78	91.86		23.87	Ni:Cu
%S	11.26	87.95		30.78	Fe:Ni
%SiO2	33.73	97.81		15.22	S:Ni
%MgO	15.19	97.97		95.86	Rk:Ni
%Al2O3	5.74	97.76			
%Ca	0.89	97.65			
%Cp	0.09	41.79			
%Pn	1.92	43.18			
%Po	27.05	94.22			
%Rk	70.94	97.70			

AS2 (Scavenger Concentrate)

kg/20min	3.4	7.44	7.9		
%Cu	0.18	18.61	44.5		
%Ni	4.33	21.49	46.2		
%Fe	32.82	10.44	11.4	24.74	Ni:Cu
%S	19.90	12.26	13.9	7.58	Fe:Ni
%SiO2	21.43	4.90	5.0	4.60	S:Ni
%MgO	10.12	5.15	5.3	10.93	Rk:Ni
%Al2O3	3.82	5.13	5.3		
%Ca	0.64	5.54	5.7		
%Cp	0.50	18.61	44.5		
%Pn	12.60	22.35	51.8		
%Po	39.59	10.88	11.5		
%Rk	47.31	5.14	5.3		

Summary:

Rec'y To Bulk Conc

kg/20min	13.1
%Cu	76.7
%Ni	75.1
%Fe	18.6
%S	24.3
%SiO2	7.1
%MgO	7.2
%Al2O3	7.4
%Ca	7.8
%Cp	76.7
%Pn	79.4
%Po	16.6
%Rk	7.4

Rec'y To Bulk Tails

kg/20min	86.89
%Cu	23.58
%Ni	24.91
%Fe	81.32
%S	75.67
%SiO2	92.90
%MgO	92.77
%Al2O3	92.54
%Ca	91.94
%Cp	23.58
%Pn	20.67
%Po	83.34
%Rk	92.53

AS4 (Scavenger Tails)

kg/20min	39.1	86.89	92.1		
%Cu	0.02	23.58	56.4		
%Ni	0.43	24.91	53.5		
%Fe	21.90	81.32	88.5	22.63	Ni:Cu
%S	10.52	75.67	86.0	50.93	Fe:Ni
%SiO2	34.79	92.90	95.0	24.47	S:Ni
%MgO	15.62	92.77	94.7	169.68	Rk:Ni
%Al2O3	5.90	92.54	94.7		
%Ca	0.91	91.94	94.2		
%Cp	0.05	23.58	56.4		
%Pn	1.00	20.67	47.9		
%Po	25.98	83.34	88.5		
%Rk	72.96	92.53	94.7		

Legend

Dry kg/20 min interval	% Of AB1	Recovery	% Previous Stage	
%Cu	%Cu	Cu Dis A1B	Cu Dis Prev Stg	
%Ni	%Ni	Ni Distribution	Ni	
%Fe	%Fe	Fe	Fe	Ni:Cu
%S	%S	S	S	Fe:Ni
%C	%C	C	C	S:Ni
%Al2O3	%Al2O3	Al2O3	Al2O3	Rk:Ni
%Ca	%Ca	Ca	Ca	
%MgO	%MgO	MgO	MgO	
%SiO2	%SiO2	SiO2	SiO2	
%Cp	%Cp	Cp	Cp	
%Pn	%Pn	Pn	Pn	
%Po	%Po	Po	Po	
%Rk	%Rk	Rk	Rk	

6/14/2004

Test # 6
June 12 2002

	TIME		Wt (g)	kg/min	kg/20 min	Cu	Ni	Fe	S	SiO2	MgO	Al2O3	Ca	% Sol
A1B	**20**	1	515.2	1.55	30.91	0.07	1.37	21.82	10.99	34.29	15.24	5.79	0.87	
	40	2	671.9	2.02	40.31	0.07	1.40	22.05	10.82	34.44	15.24	5.93	0.90	
	60	3	752.4	2.26	45.14	0.07	1.48	22.67	11.49	33.03	14.71	5.70	0.86	
	80	4	787.6	2.36	47.26	0.07	1.49	22.72	11.48	32.88	14.56	5.67	0.87	
	100	5	686.1	2.06	41.17	0.07	1.52	23.12	12.10	32.14	14.36	5.54	0.84	
	120	6	799.5	2.40	47.97	0.07	1.49	23.04	11.84	32.88	14.67	5.58	0.86	
			4212.7			0.07	1.46	22.62	11.49	33.21	14.77	5.69	0.86	
		AV	**601.8**	**2.11**	**42.13**									**#DIV/0!**
AR	**0-20**	1	239.7	0.060	1.20	0.98	18.28	33.79	27.45	9.36	4.02	1.45	0.25	
	20-40	2	222.3	0.056	1.11	0.94	18.19	33.58	27.59	9.30	3.92	1.46	0.27	
	40-60	3	570.3	0.143	2.85	0.53	10.15	30.91	21.53	18.30	8.24	3.11	0.51	
	60-80	4	297.9	0.074	1.49	0.77	14.47	32.74	25.52	13.30	5.81	2.19	0.36	
	80-100	5	254.6	0.064	1.27	0.91	17.31	35.35	28.38	8.92	3.90	1.40	0.24	
	100-120	6	247.5	0.062	1.24	0.94	17.88	34.41	28.03	8.37	3.58	1.28	0.22	
			1832.3			0.78	14.93	33.00	25.52	12.58	5.54	2.06	0.34	
		AV	**305.4**	**0.08**	**1.53**									
RT	**0-20**	1	1993.0	1.99	39.86	0.03	0.75	21.83	10.79	34.13	15.24	5.78	0.89	
	20-40	2	1896.0	1.90	37.92	0.03	0.75	21.49	10.52	34.52	15.32	5.85	0.90	
	40-60	3	1595.0	1.60	31.90	0.03	0.79	22.26	10.87	33.42	14.84	5.70	0.85	
	60-80	4	1967.0	1.97	39.34	0.03	0.82	22.40	11.12	33.28	14.72	5.71	0.86	
	80-100	5	1854.0	1.85	37.08	0.03	0.86	23.09	11.37	32.22	14.33	5.46	0.83	
	100-120	6	1807.0	1.81	36.14	0.03	0.84	22.34	11.18	32.36	14.48	5.55	0.83	
			11112.0			0.03	0.80	22.23	10.97	33.34	14.83	5.68	0.86	
		AV	**1852.0**	**1.85**	**37.04**									
AS2	**0-20**	1	110.6	0.028	0.55	0.47	11.26	36.94	26.51	11.54	4.97	2.01	0.36	
	20-40	2	314.2	0.079	1.57	0.22	5.39	36.00	22.89	17.34	7.94	3.13	0.52	
	40-60	3	293.5	0.073	1.47	0.24	5.78	35.71	22.98	16.98	7.74	3.09	0.51	
	60-80	4	452.2	0.113	2.26	0.17	4.13	33.42	20.45	20.43	9.43	3.74	0.59	
	80-100	5	503.1	0.126	2.52	0.18	4.44	34.68	21.22	19.01	8.77	3.48	0.56	
	100-120	6	99.5	0.025	0.50	0.58	13.04	34.29	25.48	12.72	5.05	2.39	0.31	
			1773.1			0.24	5.66	34.88	22.18	17.92	8.17	3.27	0.52	
		AV	**295.5**	**0.07**	**1.48**									
AS4	**0-20**	1	1156.3	1.16	23.13	0.02	0.40	20.69	9.66	35.60	16.09	6.15	0.94	
	20-40	2	1104.1	1.10	22.08	0.02	0.39	20.31	9.49	36.15	16.11	6.12	0.93	
	40-60	3	1160.0	1.16	23.20	0.02	0.40	21.15	9.91	36.23	16.10	6.14	0.93	
	60-80	4	1061.7	1.06	21.23	0.02	0.39	21.15	10.00	36.02	15.90	6.15	0.94	
	80-100	5	1152.0	1.15	23.04	0.02	0.41	21.65	10.34	35.15	15.59	6.02	0.91	
	100-120	6	1099.3	1.10	21.99	0.02	0.50	22.03	10.65	34.38	15.36	5.89	0.88	
			6733.4			0.02	0.41	21.16	10.01	35.59	15.86	6.08	0.92	
		AV	**1122.2**	**1.12**	**22.44**									

Bichtree Ore MiniCell Test # 6

Sodium Silicate to Scavengers

AB-1 (Flotation Feed)

kg/20min	42	100.00			
%Cu	0.07	100.00			
%Ni	1.46	100.00			
%Fe	22.64	100.00		20.86	Ni:Cu
%S	11.56	100.00		15.51	Fe:Ni
%SiO2	32.97	100.00		7.92	S:Ni
%MgO	14.67	100.00		47.85	Rk:Ni
%Al2O3	5.63	100.00			
%Ca	0.85	100.00			
%Cp	0.20	100.00			
%Pn	4.08	100.00			
%Po	25.86	100.00			
%Rk	69.86	100.00			

AR (Rougher Concentrate)

kg/20min	2.1	5.01			
%Cu	0.78	55.81			
%Ni	14.92	51.18			
%Fe	33.00	7.30		19.13	Ni:Cu
%S	25.50	11.05		2.21	Fe:Ni
%SiO2	12.58	1.91		1.71	S:Ni
%MgO	5.54	1.89		1.90	Rk:Ni
%Al2O3	2.06	1.83			
%Ca	0.34	2.00			
%Cp	2.24	55.81			
%Pn	44.40	54.45			
%Po	25.00	4.84			
%Rk	28.36	2.03			

RT (Rougher Tails)

kg/20min	39.9	94.66			
%Cu	0.03	40.57			
%Ni	0.75	48.63			
%Fe	22.09	92.36		25.00	Ni:Cu
%S	10.82	88.60		29.45	Fe:Ni
%SiO2	34.05	97.76		14.43	S:Ni
%MgO	15.16	97.82		96.08	Rk:Ni
%Al2O3	5.82	97.85			
%Ca	0.88	98.00			
%Cp	0.09	40.57			
%Pn	1.96	45.37			
%Po	25.90	94.81			
%Rk	72.06	97.64			

AS2 (Scavenger Concentrate)

kg/20min	2.4	5.72	6.0		
%Cu	0.23	18.80	46.3		
%Ni	5.81	22.76	46.8		
%Fe	34.90	8.82	9.5	25.26	Ni:Cu
%S	22.20	10.99	12.4	6.01	Fe:Ni
%SiO2	17.91	3.11	3.2	3.82	S:Ni
%MgO	8.17	3.19	3.3	7.02	Rk:Ni
%Al2O3	3.27	3.32	3.4		
%Ca	0.52	3.50	3.6		
%Cp	0.66	18.80	46.3		
%Pn	17.02	23.84	52.5		
%Po	41.52	9.19	9.7		
%Rk	40.80	3.34	3.4		

Summary:

Rec'y To Bulk Conc

kg/20min	10.7
%Cu	74.6
%Ni	73.9
%Fe	16.1
%S	22.0
%SiO2	5.0
%MgO	5.1
%Al2O3	5.2
%Ca	5.5
%Cp	74.6
%Pn	78.3
%Po	14.0
%Rk	5.4

Rec'y To Bulk Tails

kg/20min	88.96
%Cu	21.61
%Ni	25.59
%Fe	83.58
%S	77.57
%SiO2	94.66
%MgO	94.66
%Al2O3	94.65
%Ca	94.20
%Cp	21.61
%Pn	21.24
%Po	85.61
%Rk	94.36

AS4 (Scavenger Tails)

kg/20min	37.5	88.96	94.0		
%Cu	0.02	21.61	53.3		
%Ni	0.42	25.59	52.6		
%Fe	21.27	83.58	90.5	24.71	
%S	10.08	77.57	87.6	50.64	Fe:Ni
%SiO2	35.08	94.66	96.8	24.00	S:Ni
%MgO	15.61	94.66	96.8	176.41	Rk:Ni
%Al2O3	5.99	94.65	96.7		
%Ca	0.90	94.20	96.1		
%Cp	0.05	21.61	53.3		
%Pn	0.97	21.24	46.8		
%Po	24.89	85.61	90.3		
%Rk	74.09	94.36	96.6		

Legend

Dry kg/20 min interval	% Of AB1	Recovery	% Previous Stage	
%Cu	%Cu	Cu Dis A1B	Cu Dis Prev Stg	
%Ni	%Ni	Ni Distribution	Ni	
%Fe	%Fe	Fe	Fe	Ni:Cu
%S	%S	S	S	Fe:Ni
%C	%C	C	C	S:Ni
%Al2O3	%Al2O3	Al2O3	Al2O3	Rk:Ni
%Ca	%Ca	Ca	Ca	
%MgO	%MgO	MgO	MgO	
%SiO2	%SiO2	SiO2	SiO2	
%Cp	%Cp	Cp	Cp	
%Pn	%Pn	Pn	Pn	
%Po	%Po	Po	Po	
%Rk	%Rk	Rk	Rk	

6/14/2004

Test # 7 Guar Gum to Roughers
June 18 02

	TIME		Wt (g)	kg/min	kg/20 min	Cu	Ni	Fe	S	SiO2	MgO	Al2O3	Ca	% Sol
A1B	**20**	1	554.4	1.66	33.26	0.09	1.71	21.64	10.89	33.47	15.15	5.84	0.93	30.90
	40	2	530.6	1.59	31.84	0.09	1.64	21.25	10.71	33.48	15.24	5.80	0.92	32.16
	60	3	582.1	1.75	34.93	0.09	1.57	20.73	10.61	33.44	15.30	5.73	0.91	32.09
	80	4	590.2	1.77	35.41	0.09	1.65	21.18	10.51	33.64	15.46	5.75	0.92	33.82
	100	5	542.8	1.63	32.57	0.09	1.58	20.43	10.20	32.74	15.14	5.64	0.89	32.60
	120	6	582.2	1.75	34.93	0.09	1.63	21.21	10.41	33.56	15.45	5.73	0.92	32.01
			3382.3			0.09	1.63	21.07	10.55	33.39	15.29	5.75	0.91	
		AV	**483.2**	**1.69**	**33.82**									**32.26**
AR	**0-20**	1	208.2	0.05	1.04	1.02	14.90	33.63	25.74	11.58	5.40	1.93	0.33	
	20-40	2	280.4	0.07	1.40	0.90	14.96	36.06	27.14	10.63	5.00	1.78	0.31	
	40-60	3	299.2	0.07	1.50	0.85	13.98	35.98	27.05	11.72	5.58	2.00	0.34	
	60-80	4	286.0	0.07	1.43	0.93	15.18	36.67	28.37	9.81	4.65	1.61	0.29	
	80-100	5	274.2	0.07	1.37	0.94	14.99	37.21	28.19	9.44	4.50	1.55	0.27	
	100-120	6	302.7	0.08	1.51	0.86	14.73	36.03	27.55	10.88	5.12	1.84	0.32	
			1650.7			0.91	14.78	36.03	27.41	10.65	5.03	1.78	0.31	
		AV	**275.1**	**0.07**	**1.38**									
RT	**0-20**	1	1893.2	1.89	37.86	0.05	1.18	21.68	10.54	34.15	15.25	5.92	0.93	
	20-40	2	1701	1.70	34.02	0.05	1.07	21.44	10.61	33.96	15.51	5.87	0.94	
	40-60	3	1837.7	1.84	36.75	0.05	1.01	21.08	9.99	34.79	15.85	5.97	0.98	
	60-80	4	1939.3	1.94	38.79	0.05	1.08	21.23	10.46	33.99	15.62	5.82	0.94	
	80-100	5	1891.6	1.89	37.83	0.05	1.07	20.73	10.26	34.54	15.80	5.86	0.95	
	100-120	6	1763.6	1.76	35.27	0.05	0.99	20.69	9.91	34.28	15.67	5.83	0.95	
			11026.4			0.05	1.07	21.14	10.30	34.29	15.62	5.88	0.95	
		AV	**1837.7**	**1.84**	**36.75**									
AS2	**0-20**	1	188.4	0.05	0.94	0.43	9.26	34.97	24.12	15.29	7.01	2.71	0.48	
	20-40	2	268	0.07	1.34	0.34	7.19	33.51	21.79	18.43	8.59	3.35	0.57	
	40-60	3	212.1	0.05	1.06	0.37	7.62	36.51	24.31	15.04	6.97	2.69	0.50	
	60-80	4	348.2	0.09	1.74	0.29	6.13	34.73	21.95	18.47	8.71	3.35	0.58	
	80-100	5	314.6	0.08	1.57	0.29	5.96	34.64	21.92	18.13	8.56	3.28	0.57	
	100-120	6	300.9	0.08	1.50	0.28	5.78	31.64	20.09	20.34	9.69	3.66	0.65	
			1632.2			0.32	6.76	34.20	22.13	17.93	8.42	3.23	0.57	
		AV	**272.0**	**0.07**	**1.36**									
AS4	**0-20**	1	984.1	0.98	19.68	0.03	0.63	19.72	9.07	36.26	16.33	6.29	1.00	
	20-40	2	968.8	0.97	19.38	0.03	0.64	20.39	9.50	36.97	16.64	6.38	1.03	
	40-60	3	1041.5	1.04	20.83	0.03	0.60	19.59	8.70	36.75	16.68	6.28	1.00	
	60-80	4	1096.5	1.10	21.93	0.03	0.59	19.26	8.64	35.85	16.45	6.16	1.00	
	80-100	5	1117.8	1.12	22.36	0.03	0.61	19.42	8.53	36.51	16.66	6.21	1.00	
	100-120	6	988.4	0.99	19.77	0.03	0.58	19.45	8.53	36.65	16.82	6.21	1.01	
			6197.1			0.03	0.61	19.62	8.82	36.49	16.60	6.25	1.01	
		AV	**1032.9**	**1.03**	**20.66**									

Bichtree Ore MiniCell Test # 7

Guar Gum to Roughers

AB-1 (Flotation Feed)

kg/20min	34	100.00		32.36	%Solids
%Cu	0.09	100.00			
%Ni	1.65	100.00			
%Fe	21.41	100.00		18.66	Ni:Cu
%S	10.70	100.00		12.94	Fe:Ni
%SiO2	33.58	100.00		6.47	S:Ni
%MgO	15.33	100.00		43.49	Rk:Ni
%Al2O3	5.77	100.00			
%Ca	0.93	100.00			
%Cp	0.26	100.00			
%Pn	4.68	100.00			
%Po	23.10	100.00			
%Rk	71.96	100.00			

AR (Rougher Concentrate)

kg/20min	1.5	4.56			
%Cu	0.92	47.05			
%Ni	14.69	40.45			
%Fe	35.99	7.66		16.04	Ni:Cu
%S	27.37	11.65		2.45	Fe:Ni
%SiO2	10.65	1.45		1.86	S:Ni
%MgO	5.03	1.50		1.61	Rk:Ni
%Al2O3	1.78	1.41			
%Ca	0.31	1.52			
%Cp	2.63	47.05			
%Pn	43.68	42.50			
%Po	30.03	5.92			
%Rk	23.65	1.50			

RT (Rougher Tails)

kg/20min	32.3	95.56			
%Cu	0.05	54.84			
%Ni	1.06	61.21			
%Fe	20.74	92.59		20.82	Ni:Cu
%S	9.94	88.77		19.57	Fe:Ni
%SiO2	34.62	98.54		9.38	S:Ni
%MgO	15.80	98.49		69.98	Rk:Ni
%Al2O3	5.95	98.58			
%Ca	0.96	98.47			
%Cp	0.15	54.84			
%Pn	2.90	59.25			
%Po	22.78	94.25			
%Rk	74.17	98.49			

AS2 (Scavenger Concentrate)

kg/20min	2.3	6.92	7.2		
%Cu	0.32	24.85	45.3		
%Ni	6.76	28.28	46.2		
%Fe	34.21	11.06	11.9	21.23	Ni:Cu
%S	22.21	14.37	16.2	5.06	Fe:Ni
%SiO2	17.92	3.69	3.7	3.28	S:Ni
%MgO	8.42	3.80	3.9	5.97	Rk:Ni
%Al2O3	3.23	3.88	3.9		
%Ca	0.57	4.25	4.3		
%Cp	0.92	24.85	45.3		
%Pn	19.88	29.38	49.6		
%Po	38.85	11.64	12.4		
%Rk	40.36	3.88	3.9		

Summary:

Rec'y To Bulk Conc

kg/20min	11.5
%Cu	71.9
%Ni	68.7
%Fe	18.7
%S	26.0
%SiO2	5.1
%MgO	5.3
%Al2O3	5.3
%Ca	5.8
%Cp	71.9
%Pn	71.9
%Po	17.6
%Rk	5.4

Rec'y To Bulk Tails

kg/20min	88.64
%Cu	29.78
%Ni	32.67
%Fe	81.48
%S	74.32
%SiO2	94.88
%MgO	94.73
%Al2O3	94.73
%Ca	94.25
%Cp	29.78
%Pn	29.60
%Po	82.56
%Rk	94.64

AS4 (Scavenger Tails)

kg/20min	30.0	88.64	92.8		
%Cu	0.03	29.78	54.3		
%Ni	0.61	32.67	53.4		
%Fe	19.68	81.48	88.0	20.47	Ni:Cu
%S	8.97	74.32	83.7	32.26	Fe:Ni
%SiO2	35.94	94.88	96.3	14.71	S:Ni
%MgO	16.38	94.73	96.2	125.96	Rk:Ni
%Al2O3	6.16	94.73	96.1		
%Ca	0.99	94.25	95.7		
%Cp	0.09	29.78	54.3		
%Pn	1.56	29.60	50.0		
%Po	21.51	82.56	87.6		
%Rk	76.84	94.64	96.1		

Legend

Dry kg/20 min interval	% Of AB1	Recovery	% Previous Stage	
%Cu	%Cu	Cu Dis A1B	Cu Dis Prev Stg	
%Ni	%Ni	Ni Distribution	Ni	
%Fe	%Fe	Fe	Fe	Ni:Cu
%S	%S	S	S	Fe:Ni
%C	%C	C	C	S:Ni
%Al2O3	%Al2O3	Al2O3	Al2O3	Rk:Ni
%Ca	%Ca	Ca	Ca	
%MgO	%MgO	MgO	MgO	
%SiO2	%SiO2	SiO2	SiO2	
%Cp	%Cp	Cp	Cp	
%Pn	%Pn	Pn	Pn	
%Po	%Po	Po	Po	
%Rk	%Rk	Rk	Rk	

6/14/2004

Test # 8
June 18 02

	TIME		Wt (g)	kg/min	kg/20 min	**Cu**	**Ni**	**Fe**	**S**	**SiO2**	**MgO**	**Al2O3**	**Ca**	**% Sol**
A1B	**20**	1	655.4	1.97	39.32	0.09	1.69	21.05	10.92	33.32	14.69	5.80	0.91	34.19
	40	2	476.9	1.43	28.61	0.10	1.75	21.25	10.81	33.57	14.48	5.91	0.91	34.06
	60	3	676.7	2.03	40.60	0.10	1.77	21.00	10.58	33.91	14.45	5.99	0.92	36.44
	80	4	604.6	1.81	36.28	0.10	1.80	21.29	10.90	33.10	14.46	5.80	0.90	36.25
	100	5	821.0	2.46	49.26	0.10	1.77	21.17	10.97	32.98	14.69	5.78	0.88	37.18
	120	6	928.8	2.79	55.73	0.09	1.69	20.85	10.43	32.57	14.62	5.63	0.90	37.62
			4163.4			0.10	1.74	21.08	10.75	33.18	14.58	5.80	0.90	
		AV	**594.8**	**2.08**	**41.63**									**35.96**
AR	**0-20**	1	330.4	0.08	1.65	1.00	16.39	34.33	27.04	10.36	4.67	1.75	0.31	
	20-40	2	391.7	0.10	1.96	0.91	14.54	32.76	25.85	12.62	5.64	2.23	0.38	
	40-60	3	448.6	0.11	2.24	0.83	13.10	32.44	24.16	14.48	6.49	2.61	0.43	
	60-80	4	827.1	0.21	4.14	0.58	9.23	29.47	20.16	20.07	9.16	3.61	0.60	
	80-100	5	757.4	0.19	3.79	0.52	8.47	29.30	19.71	19.71	9.05	3.50	0.63	
	100-120	6	527.0	0.13	2.64	0.65	10.98	33.12	23.86	14.21	6.73	2.49	0.41	
			3282.2			0.69	11.22	31.30	22.57	16.41	7.51	2.92	0.50	
		AV	**547.0**	**0.14**	**2.74**									
RT	**0-20**	1	1762.3	1.76	35.25	0.04	0.89	20.99	9.94	34.28	15.07	5.92	0.93	
	20-40	2	1858.5	1.86	37.17	0.05	0.97	21.27	10.47	34.39	14.67	6.00	0.95	
	40-60	3	1868.7	1.87	37.37	0.04	0.96	21.15	10.60	35.37	14.94	6.22	0.94	
	60-80	4	2505.2	2.51	50.10	0.05	1.02	20.73	9.93	34.36	14.81	6.03	0.93	
	80-100	5	2198	2.20	43.96	0.05	1.04	20.83	9.93	34.39	15.07	5.97	0.93	
	100-120	6	2140.8	2.14	42.82	0.05	0.98	20.84	10.18	34.50	15.35	5.92	0.92	
			12333.5			0.05	0.98	20.95	10.16	34.53	14.99	6.01	0.93	
		AV	**2055.6**	**2.06**	**41.11**									
AS2	**0-20**	1	544.7	0.14	2.72	0.16	3.41	29.26	16.71	24.84	11.68	4.51	0.73	
	20-40	2	865.3	0.22	4.33	0.12	2.49	27.19	14.86	27.55	12.37	4.99	0.80	
	40-60	3	724.8	0.18	3.62	0.14	2.98	25.61	14.40	28.53	12.66	5.19	0.81	
	60-80	4	1106.3	0.28	5.53	0.11	2.29	26.90	14.71	28.22	12.44	5.13	0.79	
	80-100	5	433.8	0.11	2.17	0.22	4.58	29.99	17.96	23.38	10.67	4.27	0.68	
	100-120	6	359.1	0.09	1.80	0.22	4.68	34.95	21.35	18.86	8.70	3.42	0.56	
			4034.0			0.15	3.07	28.10	15.90	26.32	11.84	4.78	0.76	
		AV	**672.3**	**0.17**	**3.36**									
AS4	**0-20**	1	1071.1	1.07	21.42	0.03	0.55	20.05	8.98	36.99	16.62	6.31	1.00	
	20-40	2	939.7	0.94	18.79	0.03	0.50	18.76	8.27	38.24	16.57	6.65	1.03	
	40-60	3	1546.6	1.55	30.93	0.03	0.59	20.17	9.18	36.80	15.58	6.42	0.99	
	60-80	4	872.2	0.87	17.44	0.03	0.52	18.95	8.33	37.73	15.97	6.59	1.03	
	80-100	5	1117.3	1.12	22.35	0.03	0.59	19.76	8.81	36.87	15.95	6.42	0.98	
	100-120	6	932.4	0.93	18.65	0.03	0.56	18.86	8.30	36.94	16.46	6.43	1.00	
			6479.3			0.03	0.56	19.52	8.71	37.20	16.14	6.46	1.00	
		AV	**1079.9**	**1.08**	**21.60**									

Bichtree Ore MiniCell Test # 8

Guar Gum to Scavengers

AB-1 (Flotation Feed)

kg/20min	42	100.00		35.96	%Solids
%Cu	0.10	100.00			
%Ni	1.75	100.00			
%Fe	21.58	100.00		17.50	Ni:Cu
%S	10.91	100.00		12.33	Fe:Ni
%SiO2	33.46	100.00		6.23	S:Ni
%MgO	14.62	100.00		40.79	Rk:Ni
%Al2O3	5.84	100.00			
%Ca	0.91	100.00			
%Cp	0.29	100.00			
%Pn	4.97	100.00			
%Po	23.36	100.00			
%Rk	71.39	100.00			

AR (Rougher Concentrate)

kg/20min	3.2	7.57			
%Cu	0.69	52.25			
%Ni	11.17	48.33			
%Fe	31.22	10.95		16.19	Ni:Cu
%S	22.52	15.63		2.79	Fe:Ni
%SiO2	16.40	3.71		2.02	S:Ni
%MgO	7.51	3.89		3.36	Rk:Ni
%Al2O3	2.92	3.79			
%Ca	0.50	4.16			
%Cp	1.98	52.25			
%Pn	33.15	50.54			
%Po	27.28	8.84			
%Rk	37.58	3.99			

RT (Rougher Tails)

kg/20min	38.4	92.40			
%Cu	0.05	46.20			
%Ni	0.98	51.75			
%Fe	20.78	88.98		19.60	Ni:Cu
%S	9.96	84.36		21.20	Fe:Ni
%SiO2	34.86	96.27		10.16	S:Ni
%MgO	15.20	96.07		75.66	Rk:Ni
%Al2O3	6.08	96.20			
%Ca	0.94	95.45			
%Cp	0.14	46.20			
%Pn	2.66	49.54			
%Po	23.04	91.15			
%Rk	74.15	95.98			

AS2 (Scavenger Concentrate)

kg/20min	6.5	15.65	16.9		
%Cu	0.15	23.47	50.8		
%Ni	3.06	27.36	52.9		
%Fe	28.01	20.31	22.8	20.40	Ni:Cu
%S	15.93	22.85	27.1	9.15	Fe:Ni
%SiO2	26.26	12.28	12.8	5.21	S:Ni
%MgO	11.81	12.64	13.2	18.95	Rk:Ni
%Al2O3	4.77	12.78	13.3		
%Ca	0.76	13.07	13.7		
%Cp	0.43	23.47	50.8		
%Pn	8.83	27.83	56.2		
%Po	32.74	21.93	24.1		
%Rk	58.00	12.71	13.2		

Summary:

Rec'y To Bulk Conc

kg/20min	23.2
%Cu	75.7
%Ni	75.7
%Fe	31.3
%S	38.5
%SiO2	16.0
%MgO	16.5
%Al2O3	16.6
%Ca	17.2
%Cp	75.7
%Pn	78.4
%Po	30.8
%Rk	16.7

Rec'y To Bulk Tails

kg/20min	76.68
%Cu	23.00
%Ni	24.45
%Fe	68.62
%S	61.50
%SiO2	83.90
%MgO	83.34
%Al2O3	83.38
%Ca	82.58
%Cp	23.00
%Pn	21.78
%Po	69.19
%Rk	83.17

AS4 (Scavenger Tails)

kg/20min	31.9	76.68	83.0		
%Cu	0.03	23.00	49.8		
%Ni	0.56	24.45	47.3		
%Fe	19.31	68.62	77.1	18.60	Ni:Cu
%S	8.75	61.50	72.9	34.61	Fe:Ni
%SiO2	36.61	83.90	87.2	15.68	S:Ni
%MgO	15.89	83.34	86.8	138.76	Rk:Ni
%Al2O3	6.35	83.38	86.7		
%Ca	0.98	82.58	86.5		
%Cp	0.09	23.00	49.8		
%Pn	1.41	21.78	44.0		
%Po	21.08	69.19	75.9		
%Rk	77.43	83.17	86.7		

Legend

Dry kg/20 min interval	% Of AB1	Recovery	% Previous Stage	
%Cu	%Cu	Cu Dis A1B	Cu Dis Prev Stg	
%Ni	%Ni	Ni Distribution	Ni	
%Fe	%Fe	Fe	Fe	Ni:Cu
%S	%S	S	S	Fe:Ni
%C	%C	C	C	S:Ni
%Al2O3	%Al2O3	Al2O3	Al2O3	Rk:Ni
%Ca	%Ca	Ca	Ca	
%MgO	%MgO	MgO	MgO	
%SiO2	%SiO2	SiO2	SiO2	
%Cp	%Cp	Cp	Cp	
%Pn	%Pn	Pn	Pn	
%Po	%Po	Po	Po	
%Rk	%Rk	Rk	Rk	

6/14/2004

Test # 9
June 19 02

	TIME		Wt (g)	kg/min	kg/20 min	Cu	Ni	Fe	S	SiO2	MgO	Al2O3	Ca	% Sol
A1B	**20**	1	505.20	1.52	30.31	0.09	1.82	20.85	11.15	34.33	15.53	5.93	0.89	35.21
	40	2	824.50	2.47	49.47	0.08	1.65	20.89	10.44	33.67	16.40	5.50	0.83	38.38
	60	3	838.20	2.51	50.29	0.08	1.59	20.70	10.31	32.67	16.76	5.20	0.83	37.64
	80	4	758.20	2.27	45.49	0.08	1.59	21.32	10.70	32.59	16.99	5.10	0.83	39.10
	100	5	744.40	2.23	44.66	0.08	1.54	21.03	10.82	32.21	16.77	5.05	0.78	35.81
	120	6	741.20	2.22	44.47	0.08	1.57	21.75	11.12	32.82	17.05	5.15	0.80	35.19
			4411.7			0.08	1.62	21.09	10.72	32.98	16.64	5.29	0.82	
		AV	**630.2**	**2.21**	**44.12**									**36.89**
AR	**0-20**	1	409.6	0.10	2.05	0.87	14.77	33.59	26.87	11.77	5.58	2.14	0.28	
	20-40	2	377.5	0.09	1.89	0.74	13.34	33.32	25.97	12.43	6.23	2.15	0.31	
	40-60	3	710.5	0.18	3.55	0.44	7.88	28.00	19.95	20.23	10.67	3.29	0.50	
	60-80	4	954.3	0.24	4.77	0.36	6.03	27.02	17.11	23.65	12.61	3.78	0.61	
	80-100	5	2209.1	0.55	11.05	0.19	3.24	23.35	12.77	28.67	15.06	4.49	0.71	
	100-120	6	583	0.15	2.92	0.48	7.37	28.60	19.15	21.22	11.23	3.38	0.52	
			5244.0			0.38	6.46	26.75	17.29	23.29	12.22	3.72	0.58	
		AV	**874.0**	**0.22**	**4.37**									
RT	**0-20**	1	2238.7	2.24	44.77	0.05	1.18	21.10	10.74	34.34	15.08	5.90	0.89	
	20-40	2	2186.2	2.19	43.72	0.04	1.05	21.05	10.21	34.78	16.49	5.69	0.88	
	40-60	3	2511	2.51	50.22	0.05	1.07	21.86	10.46	33.40	16.77	5.24	0.85	
	60-80	4	2338.7	2.34	46.77	0.05	1.09	21.86	10.97	33.25	17.20	5.16	0.82	
	80-100	5	1924.1	1.92	38.48	0.05	1.08	21.57	10.74	32.63	16.93	5.05	0.82	
	100-120	6	2201	2.20	44.02	0.05	1.19	22.39	11.04	32.51	16.98	5.12	0.79	
			13399.7			0.05	1.11	21.65	10.69	33.50	16.57	5.36	0.84	
		AV	**2233.3**	**2.23**	**44.67**									
AS2	**0-20**	1	2701	0.68	13.51	0.40	10.24	34.19	25.02	14.72	6.66	2.75	0.39	
	20-40	2	607.1	0.15	3.04	0.17	4.53	31.55	19.44	20.70	9.95	3.79	0.56	
	40-60	3	399.3	0.10	2.00	0.23	5.70	33.58	21.77	18.15	9.18	3.19	0.47	
	60-80	4	364.2	0.09	1.82	0.20	4.95	35.74	23.55	16.85	8.88	2.87	0.44	
	80-100	5	463.1	0.12	2.32	0.24	5.72	35.11	23.77	17.64	9.39	2.94	0.47	
	100-120	6	318.8	0.08	1.59	0.26	6.59	37.10	24.82	14.81	7.85	2.45	0.41	
			4853.5			0.32	8.08	34.21	23.81	16.19	7.78	2.92	0.43	
		AV	**808.9**	**0.20**	**4.04**									
AS4	**0-20**	1	1053.3	1.05	21.07	0.03	0.53	18.97	8.77	37.96	15.53	6.71	0.97	
	20-40	2	1126	1.13	22.52	0.02	0.46	18.12	8.14	37.95	17.40	6.36	0.96	
	40-60	3	1169.6	1.17	23.39	0.03	0.47	18.86	8.13	36.11	17.80	5.79	0.90	
	60-80	4	878.5	0.88	17.57	0.03	0.46	19.19	8.30	35.88	18.07	5.52	0.89	
	80-100	5	1168.2	1.17	23.36	0.03	0.49	18.82	8.58	34.39	17.89	5.33	0.85	
	100-120	6	1141.5	1.14	22.83	0.03	0.52	19.70	9.07	34.80	17.99	5.38	0.86	
			6537.1			0.03	0.49	18.93	8.50	36.16	17.45	5.85	0.91	
		AV	**1089.5**	**1.09**	**21.79**									

Bichtree Ore MiniCell Test # 9

Canada Colors CMC to Roughers

AB-1 (Flotation Feed)

kg/20min	44	100.00		35.80	%Solids
%Cu	0.08	100.00			
%Ni	1.59	100.00			
%Fe	21.24	100.00		19.58	Ni:Cu
%S	10.72	100.00		13.35	Fe:Ni
%SiO2	33.04	100.00		6.74	S:Ni
%MgO	16.35	100.00		45.24	Rk:Ni
%Al2O3	5.32	100.00			
%Ca	0.83	100.00			
%Cp	0.23	100.00			
%Pn	4.49	100.00			
%Po	23.34	100.00			
%Rk	71.94	100.00			

AR (Rougher Concentrate)

kg/20min	4.0	9.00			
%Cu	0.38	41.86			
%Ni	6.50	36.81			
%Fe	26.73	11.33		17.22	Ni:Cu
%S	17.29	14.52		4.11	Fe:Ni
%SiO2	23.29	6.34		2.66	S:Ni
%MgO	12.23	6.74		8.15	Rk:Ni
%Al2O3	3.72	6.30			
%Ca	0.58	6.30			
%Cp	1.09	41.86			
%Pn	19.18	38.46			
%Po	26.73	10.31			
%Rk	53.00	6.63			

RT (Rougher Tails)

kg/20min	40.1	91.00			
%Cu	0.05	58.05			
%Ni	1.10	63.19			
%Fe	20.69	88.67		21.32	Ni:Cu
%S	10.07	85.48		18.74	Fe:Ni
%SiO2	34.01	93.66		9.12	S:Ni
%MgO	16.75	93.26		66.84	Rk:Ni
%Al2O3	5.47	93.70			
%Ca	0.85	93.69			
%Cp	0.15	58.05			
%Pn	3.04	61.53			
%Po	23.00	89.69			
%Rk	73.81	93.37			

AS2 (Scavenger Concentrate)

kg/20min	3.2	7.23	7.9		
%Cu	0.31	27.85	48.0		
%Ni	8.16	37.11	58.7		
%Fe	34.37	11.71	13.2	26.10	Ni:Cu
%S	24.05	16.23	19.0	4.21	Fe:Ni
%SiO2	16.18	3.54	3.8	2.95	S:Ni
%MgO	7.78	3.44	3.7	4.30	Rk:Ni
%Al2O3	2.92	3.97	4.2		
%Ca	0.43	3.75	4.0		
%Cp	0.90	27.85	48.0		
%Pn	24.06	38.77	63.0		
%Po	40.00	12.40	13.8		
%Rk	35.05	3.52	3.8		

Summary:

Rec'y To Bulk Conc

kg/20min	16.2
%Cu	69.7
%Ni	73.9
%Fe	23.0
%S	30.7
%SiO2	9.9
%MgO	10.2
%Al2O3	10.3
%Ca	10.1
%Cp	69.7
%Pn	77.2
%Po	22.7
%Rk	10.2

Rec'y To Bulk Tails

kg/20min	83.74
%Cu	30.22
%Ni	25.98
%Fe	76.92
%S	69.20
%SiO2	90.10
%MgO	89.81
%Al2O3	89.72
%Ca	89.92
%Cp	30.22
%Pn	22.66
%Po	77.25
%Rk	89.83

AS4 (Scavenger Tails)

kg/20min	36.9	83.74	92.0		
%Cu	0.03	30.22	52.1		
%Ni	0.49	25.98	41.1		
%Fe	19.51	76.92	86.8	16.84	Ni:Cu
%S	8.86	69.20	81.0	39.54	Fe:Ni
%SiO2	35.55	90.10	96.2	17.96	S:Ni
%MgO	17.53	89.81	96.3	156.44	Rk:Ni
%Al2O3	5.70	89.72	95.8		
%Ca	0.89	89.92	96.0		
%Cp	0.08	30.22	52.1		
%Pn	1.21	22.66	36.8		
%Po	21.53	77.25	86.1		
%Rk	77.17	89.83	96.2		

Legend

Dry kg/20 min interval	% Of AB1	Recovery	% Previous Stage	
%Cu	%Cu	Cu Dis A1B	Cu Dis Prev Stg	
%Ni	%Ni	Ni Distribution	Ni	
%Fe	%Fe	Fe	Fe	Ni:Cu
%S	%S	S	S	Fe:Ni
%C	%C	C	C	S:Ni
%Al2O3	%Al2O3	Al2O3	Al2O3	Rk:Ni
%Ca	%Ca	Ca	Ca	
%MgO	%MgO	MgO	MgO	
%SiO2	%SiO2	SiO2	SiO2	
%Cp	%Cp	Cp	Cp	
%Pn	%Pn	Pn	Pn	
%Po	%Po	Po	Po	
%Rk	%Rk	Rk	Rk	

6/14/2004

Test # 10
June 19 02

	TIME		Wt (g)	kg/min	kg/20 min	Cu	Ni	Fe	S	SiO2	MgO	Al2O3	Ca	% Sol
A1B	**20**	1	694.3	2.08	41.66	0.08	1.50	20.77	10.77	32.23	17.05	4.96	0.77	36.29
	40	2	622.2	1.87	37.33	0.08	1.51	20.99	10.23	33.20	17.38	5.12	0.79	36.32
	60	3	677.2	2.03	40.63	0.08	1.46	20.48	9.89	32.93	17.20	5.18	0.77	36.53
	80	4	629.4	1.89	37.76	0.08	1.48	20.62	10.12	33.59	16.92	5.32	0.78	36.68
	100	5	697.9	2.09	41.87	0.08	1.55	21.39	11.02	32.99	16.82	5.16	0.79	38.03
	120	6	984.9	2.95	59.09	0.08	1.65	21.99	11.67	30.86	16.03	4.83	0.81	38.53
			4305.9			0.08	1.54	21.11	10.70	32.49	16.83	5.07	0.78	
		AV	**615.1**	**2.15**	**43.06**									**37.06**
AR	**0-20**	1	337.4	0.08	1.69	0.79	12.60	29.74	23.80	15.80	8.32	2.37	0.36	
	20-40	2	208.8	0.05	1.04	1.25	19.11	32.06	28.57	8.75	4.40	1.16	0.21	
	40-60	3	243.4	0.06	1.22	1.05	17.27	31.84	26.59	9.92	5.06	1.43	0.20	
	60-80	4	264.8	0.07	1.32	1.01	16.63	31.12	26.07	11.11	5.54	1.71	0.24	
	80-100	5	276.2	0.07	1.38	1.03	16.74	32.28	28.14	10.66	5.33	1.61	0.25	
	100-120	6	296.9	0.07	1.48	0.91	14.80	33.38	27.01	11.58	6.05	1.76	0.26	
			1627.5			0.99	15.89	31.67	26.52	11.61	5.96	1.73	0.26	
		AV	**271.3**	**0.07**	**1.36**									
RT	**0-20**	1	2252	2.25	45.04	0.05	1.08	21.80	10.52	33.06	17.38	5.10	0.79	
	20-40	2	1805.1	1.81	36.10	0.05	1.06	21.55	10.73	33.30	17.40	5.11	0.81	
	40-60	3	2004.5	2.00	40.09	0.04	0.94	21.03	10.16	33.39	17.27	5.17	0.78	
	60-80	4	1939.5	1.94	38.79	0.04	0.88	20.47	9.64	33.90	17.13	5.32	0.81	
	80-100	5	2261.3	2.26	45.23	0.05	1.03	21.70	10.79	33.06	16.73	5.18	0.78	
	100-120	6	1951	1.95	39.02	0.05	1.09	21.95	11.25	32.17	16.70	5.03	0.75	
			12213.4			0.05	1.01	21.43	10.52	33.14	17.10	5.15	0.79	
		AV	**2035.6**	**2.04**	**40.71**									
AS2	**0-20**	1	179.9	0.04	0.90	0.42	10.56	40.39	28.80	8.51	4.50	1.41	0.22	
	20-40	2	363.2	0.09	1.82	0.27	6.86	37.61	25.15	14.30	7.78	2.39	0.37	
	40-60	3	188.3	0.05	0.94	0.41	9.77	39.73	28.97	9.35	5.00	1.58	0.24	
	60-80	4	246.7	0.06	1.23	0.31	7.12	39.64	26.36	11.96	6.46	2.03	0.30	
	80-100	5	204.3	0.05	1.02	0.36	8.30	39.49	27.37	11.62	5.99	1.98	0.28	
	100-120	6	366.4	0.09	1.83	0.27	6.58	38.77	26.55	13.37	7.11	2.27	0.32	
			1548.8			0.33	7.81	39.04	26.85	12.08	6.46	2.04	0.30	
		AV	**258.1**	**0.06**	**1.29**									
AS4	**0-20**	1	1280.5	1.28	25.61	0.03	0.56	20.20	9.15	34.29	17.73	5.31	0.82	
	20-40	2	1175.7	1.18	23.51	0.03	0.46	18.75	8.06	35.34	18.42	5.42	0.91	
	40-60	3	1310.5	1.31	26.21	0.03	0.49	19.88	8.87	34.80	18.18	5.37	0.83	
	60-80	4	1073.8	1.07	21.48	0.03	0.44	18.94	8.68	35.26	18.14	5.49	0.82	
	80-100	5	1019.3	1.02	20.39	0.03	0.46	19.52	8.81	34.82	17.58	5.52	0.81	
	100-120	6	1221.0	1.22	24.42	0.03	0.47	19.29	9.10	35.28	18.41	5.57	0.82	
			7080.8			0.03	0.48	19.45	8.79	34.95	18.09	5.44	0.84	
		AV	**1180.1**	**1.18**	**23.60**									

Bichtree Ore MiniCell Test # 10

Canada Colors CMC to Scavenger

AB-1 (Flotation Feed)

kg/20min	43	100.00		37.06	%Solids
%Cu	0.08	100.00			
%Ni	1.50	100.00			
%Fe	21.35	100.00		18.75	Ni:Cu
%S	10.76	100.00		14.23	Fe:Ni
%SiO2	32.51	100.00		7.17	S:Ni
%MgO	16.82	100.00		47.92	Rk:Ni
%Al2O3	5.06	100.00			
%Ca	0.78	100.00			
%Cp	0.23	100.00			
%Pn	4.22	100.00			
%Po	23.67	100.00			
%Rk	71.88	100.00			

AR (Rougher Concentrate)

kg/20min	1.4	3.30			
%Cu	0.98	40.40			
%Ni	16.01	35.20			
%Fe	31.65	4.89		16.34	Ni:Cu
%S	26.51	8.12		1.98	Fe:Ni
%SiO2	11.61	1.18		1.66	S:Ni
%MgO	5.96	1.17		1.58	Rk:Ni
%Al2O3	1.73	1.13			
%Ca	0.26	1.10			
%Cp	2.82	40.40			
%Pn	47.67	37.28			
%Po	24.25	3.38			
%Rk	25.26	1.16			

RT (Rougher Tails)

kg/20min	41.6	96.70			
%Cu	0.05	60.44			
%Ni	1.01	65.11			
%Fe	21.00	95.12		20.20	Ni:Cu
%S	10.23	91.94		20.79	Fe:Ni
%SiO2	33.22	98.81		10.13	S:Ni
%MgO	17.19	98.83		72.72	Rk:Ni
%Al2O3	5.18	99.00			
%Ca	0.80	99.18			
%Cp	0.14	60.44			
%Pn	2.75	63.05			
%Po	23.66	96.64			
%Rk	73.45	98.81			

AS2 (Scavenger Concentrate)

kg/20min	3.0	6.92	7.2		
%Cu	0.33	28.55	47.2		
%Ni	7.87	36.31	55.8		
%Fe	39.09	12.67	13.3	23.85	Ni:Cu
%S	26.96	17.34	18.9	4.97	Fe:Ni
%SiO2	12.08	2.57	2.6	3.43	S:Ni
%MgO	6.46	2.66	2.7	3.53	Rk:Ni
%Al2O3	2.04	2.79	2.8		
%Ca	0.30	2.66	2.7		
%Cp	0.95	28.55	47.2		
%Pn	23.15	37.99	60.3		
%Po	48.16	14.08	14.6		
%Rk	27.74	2.67	2.7		

Summary:

Rec'y To Bulk Conc

kg/20min	10.2
%Cu	68.9
%Ni	71.5
%Fe	17.6
%S	25.5
%SiO2	3.7
%MgO	3.8
%Al2O3	3.9
%Ca	3.8
%Cp	68.9
%Pn	75.3
%Po	17.5
%Rk	3.8

Rec'y To Bulk Tails

kg/20min	89.78
%Cu	33.67
%Ni	28.73
%Fe	82.42
%S	74.60
%SiO2	96.24
%MgO	96.13
%Al2O3	96.17
%Ca	95.54
%Cp	33.67
%Pn	24.98
%Po	82.55
%Rk	96.14

AS4 (Scavenger Tails)

kg/20min	38.7	89.78	92.8		
%Cu	0.03	33.67	55.7		
%Ni	0.48	28.73	44.1		
%Fe	19.60	82.42	86.7	16.00	Ni:Cu
%S	8.94	74.60	81.1	40.83	Fe:Ni
%SiO2	34.85	96.24	97.4	18.63	S:Ni
%MgO	18.01	96.13	97.3	160.36	Rk:Ni
%Al2O3	5.42	96.17	97.1		
%Ca	0.83	95.54	96.3		
%Cp	0.09	33.67	55.7		
%Pn	1.17	24.98	39.6		
%Po	21.77	82.55	85.4		
%Rk	76.97	96.14	97.3		

Legend

Dry kg/20 min interval	% Of AB1	Recovery	% Previous Stage	
%Cu	%Cu	Cu Dis A1B	Cu Dis Prev Stg	
%Ni	%Ni	Ni Distribution	Ni	
%Fe	%Fe	Fe	Fe	Ni:Cu
%S	%S	S	S	Fe:Ni
%C	%C	C	C	S:Ni
%Al2O3	%Al2O3	Al2O3	Al2O3	Rk:Ni
%Ca	%Ca	Ca	Ca	
%MgO	%MgO	MgO	MgO	
%SiO2	%SiO2	SiO2	SiO2	
%Cp	%Cp	Cp	Cp	
%Pn	%Pn	Pn	Pn	
%Po	%Po	Po	Po	
%Rk	%Rk	Rk	Rk	

6/14/2004

Test 11
Sept 19 02

	TIME		Wt (g)	kg/min	kg/20 min	Cu	Ni	Fe	S	SiO2	MgO	Al2O3	Ca	% Sol
A1B	**20**	1	972.60	2.92	58.36	0.10	1.80	20.02	10.61	30.37	12.76	5.44	0.84	36.08
	40	2	1056.50	3.17	63.39	0.10	1.88	20.96	11.00	31.39	13.24	5.62	0.86	35.55
	60	3	913.80	2.74	54.83	0.10	1.92	21.80	11.42	32.16	14.01	5.60	0.89	36.55
	80	4	636.70	1.91	38.20	0.10	1.92	21.32	11.37	30.99	13.74	5.38	0.86	34.55
	100	5	547.80	1.64	32.87	0.09	1.71	19.68	10.12	29.66	13.35	5.12	0.79	31.32
	120	6	469.00	1.41	28.14	0.09	1.73	20.37	10.52	31.76	14.43	5.48	0.89	31.37
			4596.4			0.10	1.84	20.77	10.90	31.10	13.50	5.47	0.86	
		AV	**656.6**	**2.30**	**45.96**									**34.24**
AR	**0-20**	1	972.9	0.24	4.86	0.29	6.15	26.72	17.24	23.66	10.31	4.34	0.72	
	20-40	2	947.8	0.24	4.74	0.31	6.14	26.67	17.02	23.37	10.23	4.32	0.70	
	40-60	3	834.2	0.21	4.17	0.31	5.99	26.36	16.91	22.32	10.00	4.05	0.64	
	60-80	4	614.1	0.15	3.07	0.31	6.12	25.11	16.29	20.26	9.46	3.71	0.58	
	80-100	5	610.2	0.15	3.05	0.38	7.68	27.36	18.77	20.33	9.45	3.64	0.60	
	100-120	6	579.6	0.14	2.90	0.40	8.40	28.29	19.62	18.82	8.80	3.36	0.57	
			4558.8			0.33	6.61	26.71	17.51	21.83	9.82	3.98	0.65	
		AV	**759.8**	**0.19**	**3.80**									
RT	**0-20**	1	1175.2	1.18	23.50	0.05	0.78	19.63	9.52	34.07	13.90	6.13	0.93	
	20-40	2	1245.9	1.25	24.92	0.05	0.87	20.93	10.27	33.50	13.81	5.97	0.93	
	40-60	3	1074.4	1.07	21.49	0.04	0.76	19.43	9.45	32.57	13.89	5.71	0.87	
	60-80	4	1624.2	1.62	32.48	0.05	0.85	18.42	9.01	30.16	13.15	5.24	0.78	
	80-100	5	1195.5	1.20	23.91	0.05	0.84	19.74	9.69	30.88	13.73	5.31	0.84	
	100-120	6	1204.2	1.20	24.08	0.05	0.83	19.99	9.67	33.79	15.06	5.81	0.95	
			7519.4			0.05	0.82	19.63	9.57	32.36	13.88	5.67	0.88	
		AV	**1253.2**	**1.25**	**25.06**									
AS2	**0-20**	1	307	0.08	1.54	0.25	5.25	32.91	21.52	19.10	8.00	3.77	0.56	
	20-40	2	373.6	0.09	1.87	0.22	4.77	33.42	21.81	15.77	6.97	3.16	0.45	
	40-60	3	327.6	0.08	1.64	0.19	4.04	29.30	18.57	15.58	6.84	3.06	0.43	
	60-80	4	297	0.07	1.49	0.21	4.51	33.37	21.93	13.61	6.18	2.69	0.40	
	80-100	5	226.1	0.06	1.13	0.23	4.85	31.90	20.67	15.78	7.36	3.06	0.46	
	100-120	6	338.2	0.08	1.69	0.17	3.62	29.19	18.50	15.31	7.38	2.93	0.42	
			1869.5			0.21	4.48	31.66	20.48	15.86	7.11	3.11	0.45	
		AV	**311.6**	**0.08**	**1.56**									
AS4	**0-20**	1	853.9	0.85	17.08	0.03	0.42	17.41	7.99	35.51	14.01	6.44	0.94	
	20-40	2	973.8	0.97	19.48	0.03	0.43	18.77	8.57	35.59	14.47	6.38	0.97	
	40-60	3	867.9	0.87	17.36	0.03	0.40	18.03	8.07	35.21	14.68	6.23	0.98	
	60-80	4	813.3	0.81	16.27	0.03	0.37	17.84	7.90	34.92	14.99	6.10	0.93	
	80-100	5	674	0.67	13.48	0.03	0.36	17.17	7.51	33.52	14.78	5.80	0.92	
	100-120	6	706.8	0.71	14.14	0.03	0.38	18.08	7.70	33.79	15.09	5.78	0.95	
			4889.7			0.03	0.40	17.93	8.00	34.85	14.65	6.15	0.95	
		AV	**815.0**	**0.81**	**16.30**									

Bichtree Ore MiniCell Test # 11

CMC to Rougher; Guar Gum To Scavenger

AB-1 (Flotation Feed)

kg/20min	46	100.00		34.24	%Solids
%Cu	0.10	100.00			
%Ni	1.85	100.00			
%Fe	20.77	100.00		18.61	Ni:Cu
%S	10.86	100.00		11.25	Fe:Ni
%SiO2	30.81	100.00		5.88	S:Ni
%MgO	13.24	100.00		38.71	Rk:Ni
%Al2O3	5.45	100.00			
%Ca	0.85	100.00			
%Cp	0.29	100.00			
%Pn	5.26	100.00			
%Po	22.99	100.00			
%Rk	71.47	100.00			

AR (Rougher Concentrate)

kg/20min	8.1	17.61			
%Cu	0.33	58.84			
%Ni	6.60	62.91			
%Fe	26.71	22.65		19.90	Ni:Cu
%S	17.53	28.42		4.05	Fe:Ni
%SiO2	21.86	12.49		2.66	S:Ni
%MgO	9.84	13.09		7.94	Rk:Ni
%Al2O3	3.98	12.87			
%Ca	0.65	13.48			
%Cp	0.95	58.84			
%Pn	19.45	65.16			
%Po	27.22	20.85			
%Rk	52.37	12.90			

RT (Rougher Tails)

kg/20min	37.9	82.39			
%Cu	0.05	41.20			
%Ni	0.83	37.09			
%Fe	19.50	77.35		16.76	Ni:Cu
%S	9.44	71.58		23.46	Fe:Ni
%SiO2	32.72	87.51		11.35	S:Ni
%MgO	13.97	86.91		90.91	Rk:Ni
%Al2O3	5.76	87.13			
%Ca	0.89	86.51			
%Cp	0.14	41.20			
%Pn	2.22	34.83			
%Po	22.08	79.15			
%Rk	75.55	87.10			

AS2 (Scavenger Concentrate)

kg/20min	4.1	8.85	10.7		
%Cu	0.21	18.83	45.7		
%Ni	4.44	21.28	57.4		
%Fe	31.70	13.50	17.5	21.04	Ni:Cu
%S	20.56	16.75	23.4	7.14	Fe:Ni
%SiO2	15.86	4.55	5.2	4.63	S:Ni
%MgO	7.11	4.75	5.5	10.26	Rk:Ni
%Al2O3	3.11	5.05	5.8		
%Ca	0.45	4.68	5.4		
%Cp	0.61	18.83	45.7		
%Pn	12.92	21.74	62.4		
%Po	40.90	15.74	19.9		
%Rk	45.57	5.64	6.5		

Summary:

Rec'y To Bulk Conc

kg/20min	26.5
%Cu	77.7
%Ni	84.2
%Fe	36.2
%S	45.2
%SiO2	17.0
%MgO	17.8
%Al2O3	17.9
%Ca	18.2
%Cp	77.7
%Pn	86.9
%Po	36.6
%Rk	18.5

Rec'y To Bulk Tails

kg/20min	73.54
%Cu	22.39
%Ni	15.83
%Fe	63.85
%S	54.85
%SiO2	82.95
%MgO	82.15
%Al2O3	82.07
%Ca	81.82
%Cp	22.39
%Pn	13.12
%Po	63.41
%Rk	81.45

AS4 (Scavenger Tails)

kg/20min	33.8	73.54	89.3		
%Cu	0.03	22.39	54.3		
%Ni	0.40	15.83	42.7		
%Fe	18.03	63.85	82.6	13.16	Ni:Cu
%S	8.10	54.85	76.6	45.37	Fe:Ni
%SiO2	34.75	82.95	94.8	20.38	S:Ni
%MgO	14.79	82.15	94.5	199.18	Rk:Ni
%Al2O3	6.08	82.07	94.2		
%Ca	0.95	81.82	94.6		
%Cp	0.09	22.39	54.3		
%Pn	0.94	13.12	37.7		
%Po	19.82	63.41	80.1		
%Rk	79.15	81.45	93.5		

Legend

Dry kg/20 min interval	% Of AB1	Recovery	% Previous Stage	
%Cu	%Cu	Cu Dis A1B	Cu Dis Prev Stg	
%Ni	%Ni	Ni Distribution	Ni	
%Fe	%Fe	Fe	Fe	Ni:Cu
%S	%S	S	S	Fe:Ni
%C	%C	C	C	S:Ni
%Al2O3	%Al2O3	Al2O3	Al2O3	Rk:Ni
%Ca	%Ca	Ca	Ca	
%MgO	%MgO	MgO	MgO	
%SiO2	%SiO2	SiO2	SiO2	
%Cp	%Cp	Cp	Cp	
%Pn	%Pn	Pn	Pn	
%Po	%Po	Po	Po	
%Rk	%Rk	Rk	Rk	

6/14/2004

Test 12
Sept 19 02

	TIME		Wt (g)	kg/min	kg/20 min	Cu	Ni	Fe	S	SiO2	MgO	Al2O3	Ca	% Sol
A1B	20	1	594.7	1.78	35.68	0.09	1.80	21.21	11.07	31.62	13.99	5.52	0.87	33.92
	40	2	646.7	1.94	38.80	0.10	1.89	22.15	11.51	32.79	14.49	5.70	0.89	34.75
	60	3	602.0	1.81	36.12	0.10	1.87	21.92	11.53	32.29	14.74	5.53	0.87	33.56
	80	4	562.4	1.69	33.74	0.09	1.83	21.84	11.27	32.77	14.86	5.62	0.89	33.06
	100	5	795.0	2.39	47.70	0.09	1.84	21.82	11.40	30.74	13.71	5.23	0.87	36.20
	120	6	925.0	2.78	55.50	0.09	2.02	22.43	12.03	28.97	13.07	4.98	0.79	36.96
			4125.8			0.09	1.88	21.94	11.51	31.29	14.04	5.39	0.86	
		AV	589.4	2.06	41.26									34.74
AR	0-20	1	620.1	0.16	3.10	0.51	11.14	28.96	21.69	14.93	6.83	2.67	0.42	
	20-40	2	750.1	0.19	3.75	0.45	9.71	28.52	20.58	18.21	8.32	3.26	0.53	
	40-60	3	644.7	0.16	3.22	0.54	11.15	30.24	22.41	16.49	7.72	2.91	0.49	
	60-80	4	573.2	0.14	2.87	0.51	10.88	27.62	20.99	13.98	6.54	2.47	0.38	
	80-100	5	463.5	0.12	2.32	0.49	10.54	26.44	20.03	12.86	5.88	2.28	0.35	
	100-120	6	537.4	0.13	2.69	0.49	10.98	28.53	21.38	14.54	6.70	2.57	0.41	
			3589.0			0.50	10.70	28.50	21.22	15.42	7.11	2.74	0.44	
		AV	598.2	0.15	2.99									
RT	0-20	1	1667.1	1.67	33.34	0.05	0.83	21.33	10.46	32.56	14.34	5.60	0.87	
	20-40	2	1769.4	1.77	35.39	0.03	0.78	19.95	9.80	31.28	13.80	5.38	0.82	
	40-60	3	1838.5	1.84	36.77	0.02	0.58	15.61	7.54	24.75	11.19	4.19	0.57	
	60-80	4	1903	1.90	38.06	0.04	0.79	20.74	10.06	33.58	15.16	5.70	0.90	
	80-100	5	1746	1.75	34.92	0.03	0.71	19.03	9.13	30.02	13.48	5.11	0.77	
	100-120	6	1281.1	1.28	25.62	0.04	0.84	20.98	10.08	34.51	15.73	5.86	0.99	
			10205.1			0.03	0.75	19.51	9.47	30.93	13.86	5.28	0.81	
		AV	1700.9	1.70	34.02									
AS2	0-20	1	126	0.03	0.63	0.39	10.30	36.46	26.57	11.49	5.15	2.06	0.38	
	20-40	2	283.4	0.07	1.42	0.22	5.46	35.41	23.05	16.81	7.75	3.10	0.57	
	40-60	3	445	0.11	2.23	0.16	3.95	32.62	20.26	19.51	8.97	3.63	0.61	
	60-80	4	359	0.09	1.80	0.18	4.36	33.83	21.45	17.71	8.29	3.24	0.56	
	80-100	5	459	0.11	2.30	0.15	3.59	32.15	19.73	20.02	9.35	3.71	0.65	
	100-120	6	314	0.08	1.57	0.17	4.05	33.41	21.01	17.81	8.29	3.29	0.59	
			1986.4			0.19	4.58	33.50	21.27	18.14	8.41	3.35	0.59	
		AV	331.1	0.08	1.66									
AS4	0-20	1	1110.0	1.11	22.20	0.02	0.46	20.62	9.65	34.62	15.39	5.96	0.97	
	20-40	2	1066.5	1.07	21.33	0.02	0.45	20.55	9.58	35.41	15.55	6.09	0.96	
	40-60	3	1056.9	1.06	21.14	0.02	0.44	20.51	9.59	33.77	14.88	5.78	0.91	
	60-80	4	1143.0	1.14	22.86	0.02	0.42	19.26	8.98	33.59	15.09	5.70	0.88	
	80-100	5	830.0	0.83	16.60	0.02	0.44	19.61	8.95	35.93	16.12	6.13	1.03	
	100-120	6	936.8	0.94	18.74	0.02	0.42	20.44	9.39	35.55	15.91	6.08	0.97	
			6143.2			0.02	0.44	20.17	9.37	34.74	15.45	5.94	0.95	
		AV	1023.9	1.02	20.48									

Bichtree Ore MiniCell Test # 12

Blank Test

AB-1 (Flotation Feed)

kg/20min	41	100.00		34.74	%Solids
%Cu	0.09	100.00			
%Ni	1.91	100.00			
%Fe	21.45	100.00		21.67	Ni:Cu
%S	11.28	100.00		11.24	Fe:Ni
%SiO2	30.52	100.00		5.91	S:Ni
%MgO	13.67	100.00		36.88	Rk:Ni
%Al2O3	5.24	100.00			
%Ca	0.83	100.00			
%Cp	0.25	100.00			
%Pn	5.44	100.00			
%Po	23.92	100.00			
%Rk	70.39	100.00			

AR (Rougher Concentrate)

kg/20min	5.0	12.01			
%Cu	0.51	69.14			
%Ni	10.59	66.62			
%Fe	28.60	16.01		20.88	Ni:Cu
%S	21.32	22.70		2.70	Fe:Ni
%SiO2	15.44	6.08		2.01	S:Ni
%MgO	7.12	6.26		3.87	Rk:Ni
%Al2O3	2.74	6.29			
%Ca	0.44	6.42			
%Cp	1.46	69.14			
%Pn	31.42	69.37			
%Po	26.16	13.14			
%Rk	40.96	6.99			

RT (Rougher Tails)

kg/20min	36.3	87.89			
%Cu	0.03	30.93			
%Ni	0.73	33.46			
%Fe	20.48	83.90		23.44	Ni:Cu
%S	9.91	77.23		28.18	Fe:Ni
%SiO2	32.57	93.81		13.64	S:Ni
%MgO	14.56	93.63		102.39	Rk:Ni
%Al2O3	5.58	93.59			
%Ca	0.88	93.46			
%Cp	0.09	30.93			
%Pn	1.90	30.71			
%Po	23.61	86.77			
%Rk	74.40	92.90			

AS2 (Scavenger Concentrate)

kg/20min	2.5	6.00	6.8		
%Cu	0.19	12.81	41.4		
%Ni	4.63	14.56	43.5		
%Fe	33.38	9.34	11.1	24.63	Ni:Cu
%S	21.17	11.27	14.6	7.21	Fe:Ni
%SiO2	18.39	3.62	3.9	4.57	S:Ni
%MgO	8.40	3.69	3.9	9.49	Rk:Ni
%Al2O3	3.35	3.83	4.1		
%Ca	0.59	4.28	4.6		
%Cp	0.54	12.81	41.4		
%Pn	13.47	14.88	48.4		
%Po	42.04	10.56	12.2		
%Rk	43.94	3.75	4.0		

Summary:

Rec'y To Bulk Conc

kg/20min	18.0
%Cu	81.9
%Ni	81.2
%Fe	25.4
%S	34.0
%SiO2	9.7
%MgO	9.9
%Al2O3	10.1
%Ca	10.7
%Cp	81.9
%Pn	84.2
%Po	23.7
%Rk	10.7

Rec'y To Bulk Tails

kg/20min	82.08
%Cu	18.35
%Ni	19.19
%Fe	74.81
%S	66.24
%SiO2	90.35
%MgO	90.10
%Al2O3	89.92
%Ca	89.35
%Cp	18.35
%Pn	16.13
%Po	76.49
%Rk	89.31

AS4 (Scavenger Tails)

kg/20min	33.9	82.08	93.4		
%Cu	0.02	18.35	59.3		
%Ni	0.45	19.19	57.3		
%Fe	19.55	74.81	89.2	22.65	Ni:Cu
%S	9.10	66.24	85.8	43.81	Fe:Ni
%SiO2	33.59	90.35	96.3	20.39	S:Ni
%MgO	15.00	90.10	96.2	171.64	Rk:Ni
%Al2O3	5.74	89.92	96.1		
%Ca	0.90	89.35	95.6		
%Cp	0.06	18.35	59.3		
%Pn	1.07	16.13	52.5		
%Po	22.29	76.49	88.2		
%Rk	76.59	89.31	96.1		

Legend

Dry kg/20 min interval	% Of AB1	Recovery	% Previous Stage	
%Cu	%Cu	Cu Dis A1B	Cu Dis Prev Stg	
%Ni	%Ni	Ni Distribution	Ni	
%Fe	%Fe	Fe	Fe	Ni:Cu
%S	%S	S	S	Fe:Ni
%C	%C	C	C	S:Ni
%Al2O3	%Al2O3	Al2O3	Al2O3	Rk:Ni
%Ca	%Ca	Ca	Ca	
%MgO	%MgO	MgO	MgO	
%SiO2	%SiO2	SiO2	SiO2	
%Cp	%Cp	Cp	Cp	
%Pn	%Pn	Pn	Pn	
%Po	%Po	Po	Po	
%Rk	%Rk	Rk	Rk	

6/14/2004

Test # 13
Sept 20 2002

	TIME		Wt (g)	kg/min	kg/20 min	Cu	Ni	Fe	S	SiO_2	MgO	Al_2O_3	Ca	% Sol
A1B	**20**	1	582.7	1.75	34.96	0.07	1.43	18.81	9.18	35.73	15.50	6.12	1.00	36.53
	40	2	632.7	1.90	37.96	0.08	1.41	18.46	8.95	35.38	15.30	6.07	1.00	34.59
	60	3	737.3	2.21	44.24	0.07	1.36	18.45	8.94	35.98	15.40	6.28	1.01	33.73
	80	4	783.6	2.35	47.02	0.07	1.41	18.89	9.16	35.94	14.87	6.35	1.00	34.04
	100	5	764.4	2.29	45.86	0.07	1.43	19.33	9.42	36.05	14.56	6.47	1.02	34.54
	120	6	1085.3	3.26	65.12	0.07	1.44	19.35	9.60	36.40	14.33	6.56	1.06	34.93
			4586.0			0.07	1.41	18.93	9.24	35.97	14.92	6.34	1.02	
		AV	**655.1**	**2.29**	**45.86**									**34.73**
AR	**0-20**	1	355.2	0.09	1.78	0.72	16.06	33.98	27.98	9.02	4.13	1.44	0.26	
	20-40	2	271.8	0.07	1.36	0.93	17.83	34.98	29.62	7.54	3.20	1.34	0.21	
	40-60	3	195.6	0.05	0.98	0.91	18.86	35.13	30.46	6.40	2.58	1.18	0.16	
	60-80	4	185.2	0.05	0.93	0.93	19.15	35.67	31.27	5.91	2.28	1.08	0.15	
	80-100	5	199.4	0.05	1.00	0.89	18.51	36.95	31.24	6.21	2.33	1.11	0.15	
	100-120	6	350.1	0.09	1.75	0.56	11.13	30.22	22.75	17.36	6.76	3.10	0.48	
			1557.3			0.79	16.29	34.03	28.21	9.58	3.91	1.68	0.26	
		AV	**259.6**	**0.06**	**1.30**									
RT	**0-20**	1	1692	1.69	33.84	0.04	0.70	18.72	8.73	35.88	16.46	6.00	0.97	39.25
	20-40	2	1372.6	1.37	27.45	0.04	0.67	18.06	8.32	36.04	16.29	6.41	1.03	37.64
	40-60	3	1731.7	1.73	34.63	0.04	0.69	17.75	8.22	37.51	16.08	6.49	1.06	36.16
	60-80	4	1592	1.59	31.84	0.04	0.65	18.03	8.16	37.50	15.41	6.61	1.05	37.25
	80-100	5	1580	1.58	31.60	0.03	0.63	18.86	8.62	37.81	15.19	6.74	1.05	37.87
	100-120	6	1435	1.44	28.70	0.03	0.60	18.28	8.25	38.05	15.15	6.91	1.05	36.49
			9403.3			0.04	0.66	18.28	8.39	37.13	15.77	6.52	1.03	
		AV	**1567.2**	**1.57**	**31.34**									**37.44**
AS2	**0-20**	1	215.7	0.05	1.08	0.17	4.18	36.60	23.62	16.56	7.78	3.11	0.48	
	20-40	2	264.8	0.07	1.32	0.18	3.98	33.47	21.05	19.53	9.10	3.71	0.59	
	40-60	3	265.4	0.07	1.33	0.19	4.73	35.51	23.28	16.94	7.43	3.30	0.50	
	60-80	4	276.2	0.07	1.38	0.19	4.65	33.46	21.76	19.42	8.46	3.81	0.58	
	80-100	5	390.6	0.10	1.95	0.13	3.11	31.00	19.18	22.18	9.56	4.38	0.65	
	100-120	6	478.8	0.12	2.39	0.11	2.52	30.38	18.41	22.98	9.68	4.58	0.68	
			1891.5			0.15	3.66	32.82	20.70	20.23	8.86	3.96	0.60	
		AV	**315.3**	**0.08**	**1.58**									
AS4	**0-20**	1	578.1	0.58	11.56	0.03	0.44	17.27	7.47	37.19	17.51	6.20	1.02	29.88
	20-40	2	881.0	0.88	17.62	0.03	0.40	17.23	7.53	38.01	17.21	6.50	1.06	34.54
	40-60	3	1027.7	1.03	20.55	0.03	0.37	16.84	7.27	38.49	16.90	6.63	1.08	36.17
	60-80	4	789.0	0.79	15.78	0.02	0.38	16.81	7.25	38.34	16.33	6.71	1.08	34.61
	80-100	5	825.0	0.83	16.50	0.03	0.37	16.82	7.05	38.43	15.91	6.84	1.08	35.11
	100-120	6	801.8	0.80	16.04	0.03	0.35	16.31	6.64	39.49	15.90	7.08	1.08	35.32
			4902.6			0.03	0.38	16.87	7.20	38.38	16.61	6.68	1.07	
		AV	**817.1**	**0.82**	**16.34**									**34.27**

Bichtree Ore MiniCell Test # 13

Coarse Grind; Plant CMC to Rougher; Guar Gum to Scavenger

AB-1 (Flotation Feed)

kg/20min	46	100.00	34.73	%Solids
%Cu	0.07	100.00		
%Ni	1.36	100.00		
%Fe	18.94	100.00	18.84	Ni:Cu
%S	9.24	100.00	13.89	Fe:Ni
%SiO2	35.83	100.00	6.77	S:Ni
%MgO	15.20	100.00	55.57	Rk:Ni
%Al2O3	6.29	100.00		
%Ca	1.00	100.00		
%Cp	0.21	100.00		
%Pn	3.83	100.00		
%Po	20.15	100.00		
%Rk	75.82	100.00		

AR (Rougher Concentrate)

kg/20min	2.0	4.40			
%Cu	0.78	47.21			
%Ni	16.56	53.41			
%Fe	34.03	7.91		21.32	Ni:Cu
%S	28.21	13.43		2.05	Fe:Ni
%SiO2	9.58	1.18		1.70	S:Ni
%MgO	3.91	1.13		1.25	Rk:Ni
%Al2O3	1.68	1.18			
%Ca	0.26	1.14			
%Cp	2.23	47.21			
%Pn	49.29	56.62			
%Po	27.72	6.06			
%Rk	20.75	1.20			

RT (Rougher Tails)

kg/20min	43.9	95.64		37.44	%Solids
%Cu	0.04	52.71			
%Ni	0.66	46.51			
%Fe	18.25	92.13		16.63	Ni:Cu
%S	8.37	86.59		27.51	Fe:Ni
%SiO2	37.04	98.87		12.61	S:Ni
%MgO	15.72	98.92		118.11	Rk:Ni
%Al2O3	6.50	98.88			
%Ca	1.04	98.91			
%Cp	0.11	52.71			
%Pn	1.73	43.30			
%Po	19.80	93.98			
%Rk	78.36	98.85			

AS2 (Scavenger Concentrate)

kg/20min	3.8	8.17	8.5		
%Cu	0.15	16.84	31.9		
%Ni	3.68	22.01	47.3		
%Fe	32.83	14.16	15.4	24.64	Ni:Cu
%S	20.71	18.31	21.1	8.93	Fe:Ni
%SiO2	20.24	4.61	4.7	5.63	S:Ni
%MgO	8.85	4.76	4.8	12.38	Rk:Ni
%Al2O3	3.96	5.14	5.2		
%Ca	0.60	4.89	4.9		
%Cp	0.43	16.84	31.9		
%Pn	10.61	22.64	52.3		
%Po	43.43	17.61	18.7		
%Rk	45.53	4.91	5.0		

Summary:

Rec'y To Bulk Conc

kg/20min	12.6
%Cu	64.0
%Ni	75.4
%Fe	22.1
%S	31.7
%SiO2	5.8
%MgO	5.9
%Al2O3	6.3
%Ca	6.0
%Cp	64.0
%Pn	79.3
%Po	23.7
%Rk	6.1

Rec'y To Bulk Tails

kg/20min	87.41
%Cu	35.86
%Ni	24.47
%Fe	77.91
%S	68.22
%SiO2	94.19
%MgO	94.09
%Al2O3	93.66
%Ca	93.96
%Cp	35.86
%Pn	20.64
%Po	76.31
%Rk	93.87

AS4 (Scavenger Tails)

kg/20min	40.1	87.41	91.4	34.27	%Solids
%Cu	0.03	35.86	68.0		
%Ni	0.38	24.47	52.6		
%Fe	16.89	77.91	84.6	12.86	Ni:Cu
%S	7.21	68.22	78.8	44.21	Fe:Ni
%SiO2	38.61	94.19	95.3	18.89	S:Ni
%MgO	16.36	94.09	95.1	213.21	Rk:Ni
%Al2O3	6.74	93.66	94.7		
%Ca	1.08	93.96	95.0		
%Cp	0.09	35.86	68.0		
%Pn	0.90	20.64	47.7		
%Po	17.59	76.31	81.2		
%Rk	81.42	93.87	95.0		

Legend

Dry kg/20 min interval	% Of AB1	Recovery	% Previous Stage	
%Cu	%Cu	Cu Dis A1B	Cu Dis Prev Stg	
%Ni	%Ni	Ni Distribution	Ni	
%Fe	%Fe	Fe	Fe	Ni:Cu
%S	%S	S	S	Fe:Ni
%C	%C	C	C	S:Ni
%Al2O3	%Al2O3	Al2O3	Al2O3	Rk:Ni
%Ca	%Ca	Ca	Ca	
%MgO	%MgO	MgO	MgO	
%SiO2	%SiO2	SiO2	SiO2	
%Cp	%Cp	Cp	Cp	
%Pn	%Pn	Pn	Pn	
%Po	%Po	Po	Po	
%Rk	%Rk	Rk	Rk	

6/14/2004

Test # 14
Sept 20 2002

	TIME		Wt (g)	kg/min	kg/20 min	**Cu**	**Ni**	**Fe**	**S**	**SiO2**	**MgO**	**Al2O3**	**Ca**	**% Sol**
A1B	**20**	1	709.2	2.13	42.55	0.09	1.61	18.70	9.05	34.52	12.86	6.41	0.90	33.06
	40	2	589.2	1.77	35.35	0.11	1.94	19.26	9.30	37.00	12.05	7.16	0.93	35.16
	60	3	1030.0	3.09	61.80	0.10	1.89	19.10	9.41	35.08	12.31	6.68	0.91	35.29
	80	4	755.0	2.27	45.30	0.11	1.97	19.83	9.86	35.47	12.96	6.67	0.92	34.68
	100	5	839.0	2.52	50.34	0.09	1.77	17.72	8.76	30.30	11.46	5.65	0.73	35.22
	120	6	879.0	2.64	52.74	0.09	1.79	18.17	9.09	31.55	11.92	5.89	0.75	35.24
			4801.4			0.10	1.83	18.76	9.24	33.81	12.24	6.37	0.85	
		AV	**685.9**	**2.40**	**48.01**									**34.78**
AR	**0-20**	1	264.6	0.07	1.32	0.71	14.37	35.28	27.57	9.23	3.51	1.87	0.28	
	20-40	2	320.5	0.08	1.60	0.74	14.77	33.19	26.82	9.68	3.36	2.04	0.32	
	40-60	3	270.4	0.07	1.35	0.78	16.02	34.73	28.55	7.79	2.79	1.67	0.23	
	60-80	4	334.6	0.08	1.67	0.80	15.09	32.53	26.55	10.50	4.09	2.20	0.31	
	80-100	5	274.8	0.07	1.37	0.86	16.46	34.25	28.10	7.73	2.99	1.66	0.24	
	100-120	6	561.1	0.14	2.81	0.51	9.71	27.26	19.65	17.16	6.52	3.39	0.50	
			2026.0			0.70	13.76	32.06	25.29	11.31	4.25	2.32	0.34	
		AV	**337.7**	**0.08**	**1.69**									
RT	**0-20**	1	1037	1.04	20.74	0.04	0.65	17.77	7.75	37.67	14.06	6.93	0.99	35.28
	20-40	2	1316	1.32	26.32	0.04	0.72	17.19	7.70	38.90	12.65	7.43	0.95	38.28
	40-60	3	1158	1.16	23.16	0.04	0.77	18.41	8.24	38.82	13.23	7.42	0.97	38.23
	60-80	4	1237	1.24	24.74	0.04	0.78	18.57	8.31	37.32	13.53	6.95	0.95	35.18
	80-100	5	1097	1.10	21.94	0.04	0.89	19.50	8.98	36.57	13.71	6.81	0.87	38.17
	100-120	6	1412	1.41	28.24	0.04	0.91	20.08	9.35	37.40	14.15	6.99	0.90	38.27
			7257.0			0.04	0.79	18.62	8.41	37.80	13.55	7.10	0.94	
		AV	**1209.5**	**1.21**	**24.19**									**37.24**
AS2	**0-20**	1	406.6	0.10	2.03	0.13	2.82	28.80	16.95	22.82	9.20	4.60	0.66	
	20-40	2	524.1	0.13	2.62	0.10	2.23	26.40	14.61	23.66	9.19	4.92	0.58	
	40-60	3	437.8	0.11	2.19	0.13	3.06	30.09	17.63	24.59	8.91	5.29	0.63	
	60-80	4	475.2	0.12	2.38	0.13	3.13	28.74	16.71	23.69	8.74	5.03	0.61	
	80-100	5	488.6	0.12	2.44	0.12	2.91	26.16	15.45	21.83	8.47	4.56	0.52	
	100-120	6	759.8	0.19	3.80	0.09	2.20	23.54	13.06	25.27	10.04	5.13	0.63	
			3092.1			0.12	2.66	26.86	15.42	23.79	9.18	4.94	0.60	
		AV	**515.4**	**0.13**	**2.58**									
AS4	**0-20**	1	880.5	0.88	17.61	0.02	0.33	15.45	6.35	36.02	14.09	6.54	1.00	36.66
	20-40	2	744.3	0.74	14.89	0.02	0.34	15.37	6.28	36.75	13.49	6.80	0.87	36.45
	40-60	3	664.5	0.66	13.29	0.02	0.39	16.04	6.51	41.16	14.08	7.80	0.99	35.18
	60-80	4	758.8	0.76	15.18	0.02	0.36	15.55	6.43	37.58	13.20	7.10	0.85	38.81
	80-100	5	772.3	0.77	15.45	0.03	0.42	16.95	7.17	40.28	14.85	7.54	0.97	37.69
	100-120	6	875.2	0.88	17.50	0.02	0.40	16.30	6.88	37.17	14.05	6.89	0.88	38.17
			4695.6			0.02	0.37	15.94	6.61	38.03	13.97	7.08	0.93	
		AV	**782.6**	**0.78**	**15.65**									**37.16**

Bichtree Ore MiniCell Test # 14

Guar Gum to Rougher; CMC to Scavenger

AB-1 (Flotation Feed)

kg/20min	48	100.00		34.78	%Solids
%Cu	0.10	100.00			
%Ni	1.87	100.00			
%Fe	19.23	100.00		19.42	Ni:Cu
%S	9.63	100.00		10.26	Fe:Ni
%SiO2	34.11	100.00		5.14	S:Ni
%MgO	12.43	100.00		39.82	Rk:Ni
%Al2O3	6.44	100.00			
%Ca	0.85	100.00			
%Cp	0.28	100.00			
%Pn	5.36	100.00			
%Po	19.76	100.00			
%Rk	74.60	100.00			

AR (Rougher Concentrate)

kg/20min	4.1	8.48			
%Cu	0.71	62.78			
%Ni	13.55	61.33			
%Fe	31.94	14.09		18.97	Ni:Cu
%S	25.04	22.05		2.36	Fe:Ni
%SiO2	11.31	2.81		1.85	S:Ni
%MgO	4.25	2.90		2.22	Rk:Ni
%Al2O3	2.32	3.05			
%Ca	0.34	3.39			
%Cp	2.06	62.78			
%Pn	40.28	63.74			
%Po	27.53	11.81			
%Rk	30.13	3.42			

RT (Rougher Tails)

kg/20min	43.9	91.50		37.24	%Solids
%Cu	0.04	37.17			
%Ni	0.79	38.64			
%Fe	18.05	85.90		20.19	Ni:Cu
%S	8.20	77.93		22.81	Fe:Ni
%SiO2	36.23	97.17		10.37	S:Ni
%MgO	13.19	97.09		99.48	Rk:Ni
%Al2O3	6.82	96.93			
%Ca	0.90	96.59			
%Cp	0.11	37.17			
%Pn	2.12	36.23			
%Po	19.04	88.17			
%Rk	78.72	96.55			

AS2 (Scavenger Concentrate)

kg/20min	8.2	17.02	18.6		
%Cu	0.12	21.55	58.0		
%Ni	2.64	24.00	62.1		
%Fe	26.92	23.82	27.7	21.62	Ni:Cu
%S	15.36	27.16	34.8	10.19	Fe:Ni
%SiO2	23.88	11.92	12.3	5.82	S:Ni
%MgO	9.19	12.59	13.0	22.57	Rk:Ni
%Al2O3	4.96	13.11	13.5		
%Ca	0.60	12.08	12.5		
%Cp	0.35	21.55	58.0		
%Pn	7.58	24.08	66.5		
%Po	32.44	27.94	31.7		
%Rk	59.63	13.60	14.1		

Summary:

Rec'y To Bulk Conc

kg/20min	25.5
%Cu	84.3
%Ni	85.3
%Fe	37.9
%S	49.2
%SiO2	14.7
%MgO	15.5
%Al2O3	16.2
%Ca	15.5
%Cp	84.3
%Pn	87.8
%Po	39.8
%Rk	17.0

Rec'y To Bulk Tails

kg/20min	74.50
%Cu	15.67
%Ni	14.65
%Fe	62.09
%S	50.79
%SiO2	85.28
%MgO	84.52
%Al2O3	83.84
%Ca	84.53
%Cp	15.67
%Pn	12.15
%Po	60.24
%Rk	82.97

AS4 (Scavenger Tails)

kg/20min	35.8	74.50	81.4	37.16	%Solids
%Cu	0.02	15.67	42.2		
%Ni	0.37	14.65	37.9		
%Fe	16.03	62.09	72.3	18.15	Ni:Cu
%S	6.57	50.79	65.2	43.50	Fe:Ni
%SiO2	39.04	85.28	87.8	17.82	S:Ni
%MgO	14.10	84.52	87.1	225.54	Rk:Ni
%Al2O3	7.24	83.84	86.5		
%Ca	0.96	84.53	87.5		
%Cp	0.06	15.67	42.2		
%Pn	0.87	12.15	33.5		
%Po	15.98	60.24	68.3		
%Rk	83.09	82.97	85.9		

Legend

Dry kg/20 min interval	% Of AB1	Recovery	% Previous Stage	
%Cu	%Cu	Cu Dis A1B	Cu Dis Prev Stg	
%Ni	%Ni	Ni Distribution	Ni	
%Fe	%Fe	Fe	Fe	Ni:Cu
%S	%S	S	S	Fe:Ni
%C	%C	C	C	S:Ni
%Al2O3	%Al2O3	Al2O3	Al2O3	Rk:Ni
%Ca	%Ca	Ca	Ca	
%MgO	%MgO	MgO	MgO	
%SiO2	%SiO2	SiO2	SiO2	
%Cp	%Cp	Cp	Cp	
%Pn	%Pn	Pn	Pn	
%Po	%Po	Po	Po	
%Rk	%Rk	Rk	Rk	

6/14/2004

Appendix B
Data for Chapter 6

		Cu	Ni	Co	Fe	S	SiO_2	MgO	Al_2O_3	Ca
20A	**Rougher Conc**	0.35	5.21	0.19	27.45	16.38	23.13	14.03	3.32	0.59
	Ro Clnr Conc	1.71	21.12	0.75	34.81	30.24	5.12	3.11	0.80	0.15
	Ro Clnr Tls	0.14	3.22	0.11	27.49	15.38	24.56	14.81	3.47	0.60
20B	**Rougher Conc**	0.44	5.37	0.19	27.17	16.57	22.71	13.67	3.25	0.55
	Ro Clnr Conc	1.89	21.69	0.78	34.61	30.45	3.48	2.03	0.55	0.07
	Ro Clnr Tls	0.12	2.82	0.10	27.53	15.34	24.26	14.56	3.43	0.59
21A	**Rougher Conc**	0.29	4.72	0.17	27.27	16.17	23.53	14.02	3.38	0.59
	Ro Clnr Conc	1.17	17.84	0.64	34.43	28.40	7.25	4.31	1.08	0.19
	Ro Clnr Tls	0.12	2.44	0.09	26.71	14.51	25.39	15.36	3.61	0.62
21B	**Rougher Conc**	0.31	5.08	0.18	28.13	17.03	23.03	13.88	3.29	0.57
	Ro Clnr Conc	1.21	19.47	0.70	36.41	30.79	3.90	2.16	0.57	0.09
	Ro Clnr Tls	0.07	1.44	0.05	24.83	12.81	26.88	16.28	3.83	0.64
22	**Rougher Conc**	0.31	4.88	0.17	26.66	16.10	23.27	13.95	3.38	0.58
	Ro Clnr Conc	2.76	17.57	0.62	30.73	26.90	8.99	5.46	1.36	0.23
	Ro Clnr Tls	0.18	4.34	0.15	27.60	16.46	23.46	14.00	3.39	0.58
23A	**Rougher Conc**	0.27	4.58	0.16	27.43	16.35	23.51	13.99	3.42	0.59
	Ro Clnr Conc	1.13	19.50	0.69	34.91	29.86	6.20	3.44	0.91	0.17
	Ro Clnr Tls	0.13	2.93	0.10	28.04	15.62	24.33	14.60	3.55	0.61
23B	**Rougher Conc**	0.24	4.52	0.16	26.58	16.00	22.16	13.19	3.22	0.54
	Ro Clnr Conc	0.96	17.69	0.63	37.15	30.27	5.82	3.11	0.79	0.17
	Ro Clnr Tls	0.07	1.35	0.05	26.35	13.78	26.60	15.66	3.83	0.65
24A	**Rougher Conc**	0.28	4.67	0.16	25.69	14.98	21.25	12.57	3.12	0.51
	Ro Clnr Conc	1.35	20.20	0.71	35.73	30.51	4.63	2.69	0.75	0.13
	Ro Clnr Tls	0.12	2.48	0.09	27.61	15.04	24.82	14.68	3.61	0.62
24B	**Rougher Conc**	0.27	4.65	0.16	25.24	15.20	20.91	12.38	3.05	0.49
	Ro Clnr Conc	1.35	20.39	0.72	37.70	32.08	2.93	1.60	0.50	0.06
	Ro Clnr Tls	0.09	1.76	0.06	26.95	14.43	25.89	15.07	3.74	0.65
25A	**Rougher Conc**	0.33	5.15	0.18	26.82	16.22	22.04	13.10	3.20	0.54
	Ro Clnr Conc	1.31	19.18	0.68	35.20	29.46	5.11	2.95	0.79	0.16
	Ro Clnr Tls	0.13	2.48	0.09	27.29	14.88	25.36	15.01	3.65	0.64
25B	**Rougher Conc**	0.31	5.42	0.19	27.49	16.88	21.75	12.92	3.16	0.55
	Ro Clnr Conc	1.24	18.34	0.66	37.08	30.51	3.93	2.08	0.60	0.10
	Ro Clnr Tls	0.08	1.46	0.05	25.23	13.15	27.46	16.32	4.00	0.69

		Cu	Ni	Co	Fe	S	SiO2	MgO	Al2O3	Ca
26A	**Rougher Conc**	0.28	4.76	0.17	27.46	16.46	23.79	13.95	3.50	0.61
	Ro Clnr Conc	1.07	17.41	0.62	35.64	28.91	7.27	4.18	1.08	0.21
	Ro Clnr Tls	0.11	2.02	0.07	25.64	13.72	26.89	15.81	3.93	0.67
26B	**Rougher Conc**	0.27	5.13	0.18	28.39	17.05	23.51	14.07	3.46	0.64
	Ro Clnr Conc	1.01	17.10	0.60	36.00	29.32	4.44	2.50	0.65	0.11
	Ro Clnr Tls	0.08	1.51	0.05	26.54	13.95	27.29	16.28	3.94	0.72
27A	**Rougher Conc**	0.27	4.75	0.17	27.39	16.43	24.23	15.00	3.51	0.64
	Ro Clnr Conc	1.35	21.09	0.75	36.89	31.53	4.52	2.80	0.74	0.15
	Ro Clnr Tls	0.12	2.51	0.09	27.46	15.19	26.63	16.49	3.84	0.71
27B	**Rougher Conc**	0.25	4.68	0.17	27.05	16.17	23.86	14.81	3.44	0.64
	Ro Clnr Conc	1.30	20.81	0.75	38.84	33.15	3.27	1.96	0.57	0.12
	Ro Clnr Tls	0.08	1.77	0.06	25.70	13.41	26.21	15.54	3.71	0.64
28A	**Rougher Conc**	0.29	4.93	0.17	27.12	16.17	22.84	13.51	3.29	0.58
	Ro Clnr Conc	1.07	17.34	0.62	34.26	27.74	5.47	3.17	0.82	0.14
	Ro Clnr Tls	0.11	2.14	0.07	24.69	13.13	24.59	14.60	3.53	0.59
28B	**Rougher Conc**	0.29	4.92	0.17	26.71	15.94	22.66	13.44	3.29	0.57
	Ro Clnr Conc	1.22	18.64	0.67	38.91	31.51	3.87	2.09	0.56	0.12
	Ro Clnr Tls	0.08	1.59	0.05	25.95	13.20	27.95	17.13	4.03	0.75
29A	**Rougher Conc**	0.34	5.77	0.20	28.75	17.75	23.21	14.50	3.36	0.65
	Ro Clnr Conc	1.18	18.99	0.68	36.40	30.69	6.96	4.25	1.05	0.28
	Ro Clnr Tls	0.12	2.32	0.08	26.69	14.40	27.68	17.24	3.99	0.75
29B	**Rougher Conc**	0.34	5.37	0.19	27.35	16.65	22.70	13.73	3.27	0.59
	Ro Clnr Conc	1.23	17.92	0.64	36.62	29.99	4.37	2.41	0.61	0.11
	Ro Clnr Tls	0.08	1.41	0.05	24.44	12.38	29.02	17.47	4.17	0.74
30A	**Rougher Conc**	0.30	4.82	0.17	26.62	15.76	23.74	14.10	3.48	0.61
	Ro Clnr Conc	1.23	18.44	0.65	33.61	28.18	7.59	4.41	1.04	0.22
	Ro Clnr Tls	0.10	1.90	0.06	24.92	13.10	26.71	15.98	3.86	0.67
30B	**Rougher Conc**	0.20	3.62	0.13	29.51	17.16	20.10	13.46	27.49	0.31
	Ro Clnr Conc	0.99	17.17	0.61	36.96	30.20	4.34	2.55	6.50	0.48
	Ro Clnr Tls	0.06	1.17	0.04	27.92	14.82	24.11	15.63	3.46	0.41

Material Balance Results

20A

Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	100	100.0583	100
RCC	N-O	12.13	12.1229
RCT	N-O	87.9283	87.8771

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.35	0.3367	100	0.3369
Ni	5.21	5.327	100	5.3301
Co	0.19	0.1884	100	0.1885
Fe	27.45	27.9648	100	27.9811
S	16.38	16.8422	100	16.852
SiO2	23.13	22.6357	100	22.6489
MgO	14.03	13.6876	100	13.6956
Al2O3	3.32	3.226	100	3.2279
Ca	0.59	0.5653	100	0.5656

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	1.71	1.7485	62.9583	0.2121
Ni	21.12	20.8873	47.5345	2.5336
Co	0.75	0.7531	48.4615	0.0913
Fe	34.81	34.7097	15.0469	4.2103
S	30.24	30.0492	21.6292	3.645
SiO2	5.12	5.1229	2.7437	0.6214
MgO	3.11	3.112	2.7563	0.3775
Al2O3	0.8	0.8007	3.0088	0.0971
Ca	0.15	0.1502	3.221	0.0182

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.14	0.1419	37.0301	0.1247
Ni	3.22	3.1807	52.4716	2.7968
Co	0.11	0.1105	51.5359	0.0971
Fe	27.49	27.0362	84.9589	23.7725
S	15.38	15.0219	78.3791	13.2085
SiO2	24.56	25.0498	97.2493	22.0259
MgO	14.81	15.1453	97.2357	13.317
Al2O3	3.47	3.5602	96.9819	3.1305
Ca	0.6	0.6225	96.7653	0.5473

Material Balance Results

20B

Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	100	99.9996	100
RCC	N-O	14.7148	14.7149
RCT	N-O	85.2848	85.2851

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.44	0.399	100	0.399
Ni	5.37	5.5159	100	5.5159
Co	0.19	0.1964	100	0.1964
Fe	27.17	27.9567	100	27.9566
S	16.57	17.1556	100	17.1555
SiO2	22.71	21.8864	100	21.8863
MgO	13.67	13.1476	100	13.1475
Al2O3	3.25	3.1154	100	3.1154
Ca	0.55	0.5301	100	0.5301

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	1.89	2.0012	73.7967	0.2945
Ni	21.69	21.3399	56.9288	3.1401
Co	0.78	0.7641	57.2401	0.1124
Fe	34.61	34.4223	18.118	5.0652
S	30.45	30.1592	25.8685	4.4379
SiO2	3.48	3.4828	2.3416	0.5125
MgO	2.03	2.0317	2.2739	0.299
Al2O3	0.55	0.5506	2.6005	0.081
Ca	0.07	0.07	1.9443	0.0103

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.12	0.1226	26.2032	0.1046
Ni	2.82	2.7857	43.0712	2.3758
Co	0.1	0.0985	42.7599	0.084
Fe	27.53	26.8411	81.882	22.8914
S	15.34	14.912	74.1315	12.7176
SiO2	24.26	25.0617	97.6584	21.3738
MgO	14.56	15.0655	97.7261	12.8486
Al2O3	3.43	3.5579	97.3995	3.0343
Ca	0.59	0.6095	98.0557	0.5198

Material Balance Results

21A
Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	100	100.0017	100
RCC	N-O	14.9041	14.9038
RCT	N-O	85.0977	85.0962

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.29	0.2809	100	0.2809
Ni	4.72	4.7301	100	4.7301
Co	0.17	0.1713	100	0.1713
Fe	27.27	27.6113	100	27.6118
S	16.17	16.4183	100	16.4186
SiO2	23.53	23.0729	100	23.0733
MgO	14.02	13.856	100	13.8563
Al2O3	3.38	3.2996	100	3.2996
Ca	0.59	0.5711	100	0.5711

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	1.17	1.1921	63.2462	0.1777
Ni	17.84	17.8186	56.1442	2.6557
Co	0.64	0.6373	55.4445	0.095
Fe	34.43	34.3489	18.5405	5.1194
S	28.4	28.2858	25.6766	4.2157
SiO2	7.25	7.2565	4.6873	1.0815
MgO	4.31	4.3123	4.6384	0.6427
Al2O3	1.08	1.0812	4.8838	0.1611
Ca	0.19	0.1903	4.9661	0.0284

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.12	0.1213	36.7537	0.1032
Ni	2.44	2.4377	43.8558	2.0744
Co	0.09	0.0897	44.5555	0.0763
Fe	26.71	26.4313	81.4595	22.4925
S	14.51	14.3398	74.3234	12.2029
SiO2	25.39	25.8429	95.3127	21.9917
MgO	15.36	15.5275	95.3616	13.2135
Al2O3	3.61	3.6881	95.1161	3.1385
Ca	0.62	0.6378	95.0338	0.5427

Material Balance Results

21B
Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	100	99.999	100
RCC	N-O	20.1678	20.168
RCT	N-O	79.8312	79.832

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.31	0.3039	100	0.3039
Ni	5.08	5.0778	100	5.0777
Co	0.18	0.1807	100	0.1807
Fe	28.13	27.5136	100	27.5133
S	17.03	16.6324	100	16.6323
SiO2	23.03	22.6103	100	22.6101
MgO	13.88	13.6416	100	13.6414
Al2O3	3.29	3.227	100	3.227
Ca	0.57	0.5473	100	0.5473

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	1.21	1.2288	81.5461	0.2478
Ni	19.47	19.4767	77.3582	3.928
Co	0.7	0.698	77.9229	0.1408
Fe	36.41	36.6183	26.842	7.3851
S	30.79	31.0521	37.6529	6.2625
SiO2	3.9	3.9024	3.4809	0.787
MgO	2.16	2.1612	3.1951	0.4359
Al2O3	0.57	0.5704	3.5647	0.115
Ca	0.09	0.0901	3.3206	0.0182

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.07	0.0702	18.4539	0.0561
Ni	1.44	1.4401	22.6418	1.1497
Co	0.05	0.05	22.0771	0.0399
Fe	24.83	25.2134	73.158	20.1282
S	12.81	12.9896	62.3471	10.3697
SiO2	26.88	27.3365	96.5191	21.823
MgO	16.28	16.5419	96.8049	13.2056
Al2O3	3.83	3.8982	96.4352	3.1119
Ca	0.64	0.6628	96.6794	0.5291

Material Balance Results

22

Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	100	100.0491	100
RCC	N-O	4.8068	4.8044
RCT	N-O	95.2424	95.1956

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.31	0.306	100	0.3061
Ni	4.88	4.9345	100	4.937
Co	0.17	0.1715	100	0.1716
Fe	26.66	27.2103	100	27.2237
S	16.1	16.5394	100	16.5476
SiO2	23.27	23.008	100	23.0193
MgO	13.95	13.7623	100	13.7691
Al2O3	3.38	3.3344	100	3.336
Ca	0.58	0.5712	100	0.5715

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	2.76	2.7755	43.5836	0.1334
Ni	17.57	17.5359	17.0734	0.8429
Co	0.62	0.6191	17.344	0.0298
Fe	30.73	30.6947	5.4196	1.4754
S	26.9	26.8409	7.7968	1.2902
SiO2	8.99	8.9919	1.8776	0.4322
MgO	5.46	5.4614	1.9066	0.2625
Al2O3	1.36	1.3604	1.9601	0.0654
Ca	0.23	0.2301	1.9351	0.0111

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.18	0.1813	56.4105	0.1727
Ni	4.34	4.2989	82.9338	4.0944
Co	0.15	0.1489	82.6617	0.1418
Fe	27.6	27.0386	94.5949	25.7522
S	16.46	16.0228	92.2222	15.2605
SiO2	23.46	23.7134	98.1143	22.5852
MgO	14	14.1799	98.0839	13.5053
Al2O3	3.39	3.4337	98.0303	3.2703
Ca	0.58	0.5884	98.0542	0.5604

Material Balance Results

23A

Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	100	99.999	100
RCC	N-O	11.1052	11.1053
RCT	N-O	88.8938	88.8947

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.27	0.2493	100	0.2493
Ni	4.58	4.7029	100	4.7029
Co	0.16	0.1636	100	0.1636
Fe	27.43	28.1739	100	28.1736
S	16.35	16.8331	100	16.8329
SiO2	23.51	22.8639	100	22.8637
MgO	13.99	13.6519	100	13.6517
Al2O3	3.42	3.3319	100	3.3319
Ca	0.59	0.5744	100	0.5744

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	1.13	1.1703	52.1274	0.13
Ni	19.5	19.2525	45.4623	2.138
Co	0.69	0.6826	46.3374	0.0758
Fe	34.91	34.7762	13.7078	3.862
S	29.86	29.681	19.5815	3.2961
SiO2	6.2	6.205	3.0139	0.6891
MgO	3.44	3.4423	2.8002	0.3823
Al2O3	0.91	0.9107	3.0354	0.1011
Ca	0.17	0.1701	3.2898	0.0189

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.13	0.1343	47.8725	0.1194
Ni	2.93	2.8853	54.5377	2.5648
Co	0.1	0.0988	53.6626	0.0878
Fe	28.04	27.349	86.2922	24.3116
S	15.62	15.2281	80.4185	13.5368
SiO2	24.33	24.9451	96.9861	22.1746
MgO	14.6	14.9273	97.1998	13.2695
Al2O3	3.55	3.6344	96.9646	3.2307
Ca	0.61	0.6249	96.7102	0.5555

Material Balance Results

23B

Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	100	99.9567	100
RCC	N-O	19.0635	19.0718
RCT	N-O	80.8931	80.9282

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.24	0.2398	100	0.2397
Ni	4.52	4.4868	100	4.4849
Co	0.16	0.1604	100	0.1603
Fe	26.58	27.6465	100	27.6345
S	16	16.572	100	16.5648
SiO2	22.16	22.4049	100	22.3952
MgO	13.19	13.2297	100	13.224
Al2O3	3.22	3.2357	100	3.2343
Ca	0.54	0.5494	100	0.5492

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.96	0.9605	76.3765	0.1831
Ni	17.69	17.787	75.6062	3.3908
Co	0.63	0.6289	74.785	0.1199
Fe	37.15	36.7527	25.3537	7.0064
S	30.27	29.8796	34.3867	5.6961
SiO2	5.82	5.8168	4.9514	1.1089
MgO	3.11	3.1096	4.4827	0.5928
Al2O3	0.79	0.7898	4.6554	0.1506
Ca	0.17	0.1698	5.8947	0.0324

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.07	0.07	23.6234	0.0566
Ni	1.35	1.3524	24.3931	1.094
Co	0.05	0.05	25.2153	0.0404
Fe	26.35	25.5018	74.6502	20.6292
S	13.78	13.4366	65.6166	10.8693
SiO2	26.6	26.3144	95.0498	21.2866
MgO	15.66	15.6147	95.5176	12.6312
Al2O3	3.83	3.8121	95.3451	3.0837
Ca	0.65	0.6389	94.1073	0.5168

Material Balance Results

24A
Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	50	49.9993	100
RCC	N-O	6.1655	12.3312
RCT	N-O	43.8338	87.6688

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.28	0.2744	100	0.1372
Ni	4.67	4.6667	100	2.3333
Co	0.16	0.1642	100	0.0821
Fe	25.69	27.2137	100	13.6067
S	14.98	16.0506	100	8.0252
SiO2	21.25	21.7772	100	10.8884
MgO	12.57	12.8782	100	6.439
Al2O3	3.12	3.1877	100	1.5938
Ca	0.51	0.5332	100	0.2666

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	1.35	1.366	61.3783	0.0842
Ni	20.2	20.2076	53.3957	1.2459
Co	0.71	0.6998	52.5625	0.0431
Fe	35.73	35.3666	16.0254	2.1805
S	30.51	29.9624	23.0191	1.8473
SiO2	4.63	4.6269	2.62	0.2853
MgO	2.69	2.6883	2.5741	0.1657
Al2O3	0.75	0.7495	2.8994	0.0462
Ca	0.13	0.1298	3.0022	0.008

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.12	0.1209	38.6217	0.053
Ni	2.48	2.4808	46.6043	1.0874
Co	0.09	0.0888	47.4376	0.0389
Fe	27.61	26.067	83.9746	11.4262
S	15.04	14.0939	76.9809	6.1779
SiO2	24.82	24.1895	97.3801	10.6032
MgO	14.68	14.3115	97.4259	6.2733
Al2O3	3.61	3.5306	97.1006	1.5476
Ca	0.62	0.5899	96.9978	0.2586

Material Balance Results

24B
Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	50	49.8913	100
RCC	N-O	7.5284	15.0895
RCT	N-O	42.3629	84.9105

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.27	0.2761	100	0.1378
Ni	4.65	4.5989	100	2.2945
Co	0.16	0.1597	100	0.0797
Fe	25.24	27.016	100	13.4786
S	15.2	16.2792	100	8.1219
SiO2	20.91	21.6284	100	10.7907
MgO	12.38	12.6972	100	6.3348
Al2O3	3.05	3.1463	100	1.5697
Ca	0.49	0.5212	100	0.26

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	1.35	1.3269	72.5095	0.0999
Ni	20.39	20.5381	67.3878	1.5462
Co	0.72	0.7208	68.0899	0.0543
Fe	37.7	37.1025	20.7232	2.7932
S	32.08	31.3551	29.0637	2.3605
SiO2	2.93	2.9279	2.0427	0.2204
MgO	1.6	1.5992	1.9005	0.1204
Al2O3	0.5	0.4996	2.3961	0.0376
Ca	0.06	0.0599	1.735	0.0045

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.09	0.0894	27.4972	0.0379
Ni	1.76	1.7662	32.6099	0.7482
Co	0.06	0.06	31.9103	0.0254
Fe	26.95	25.2305	79.2987	10.6884
S	14.43	13.604	70.9569	5.7631
SiO2	25.89	24.9548	97.9697	10.5716
MgO	15.07	14.6708	98.1086	6.215
Al2O3	3.74	3.617	97.6151	1.5323
Ca	0.65	0.6033	98.2892	0.2556

Material Balance Results

25A
Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	100	99.9658	100
RCC	N-O	16.0068	16.0123
RCT	N-O	83.959	83.9877

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.33	0.3227	100	0.3226
Ni	5.15	5.1527	100	5.1509
Co	0.18	0.1829	100	0.1828
Fe	26.82	27.7981	100	27.7885
S	16.22	16.8123	100	16.8065
SiO2	22.04	22.08	100	22.0725
MgO	13.1	13.0891	100	13.0846
Al2O3	3.2	3.1959	100	3.1948
Ca	0.54	0.5516	100	0.5514

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	1.31	1.3284	65.9157	0.2126
Ni	19.18	19.1741	59.5848	3.0692
Co	0.68	0.6734	58.9525	0.1078
Fe	35.2	34.9302	20.1205	5.5912
S	29.46	29.1472	27.7601	4.6655
SiO2	5.11	5.1097	3.7055	0.8179
MgO	2.95	2.9501	3.6089	0.4722
Al2O3	0.79	0.79	3.9583	0.1265
Ca	0.16	0.1598	4.6398	0.0256

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.13	0.131	34.0822	0.1099
Ni	2.48	2.4795	40.4152	2.0817
Co	0.09	0.0894	41.049	0.0751
Fe	27.29	26.4395	79.8831	22.1983
S	14.88	14.4613	72.2433	12.1416
SiO2	25.36	25.3155	96.2947	21.2546
MgO	15.01	15.0221	96.391	12.6124
Al2O3	3.65	3.6545	96.0415	3.0683
Ca	0.64	0.6263	95.3626	0.5258

Material Balance Results

25B
Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	100	100.0015	100
RCC	N-O	22.1517	22.1514
RCT	N-O	77.8498	77.8486

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.31	0.3248	100	0.3248
Ni	5.42	5.2824	100	5.2825
Co	0.19	0.187	100	0.187
Fe	27.49	27.7181	100	27.7185
S	16.88	16.9556	100	16.9558
SiO2	21.75	22.0029	100	22.0033
MgO	12.92	13.0448	100	13.045
Al2O3	3.16	3.204	100	3.2041
Ca	0.55	0.5548	100	0.5548

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	1.24	1.1877	81.0078	0.2631
Ni	18.34	18.6884	78.3684	4.1398
Co	0.66	0.668	79.119	0.148
Fe	37.08	36.9882	29.5598	8.1935
S	30.51	30.4554	39.788	6.7464
SiO2	3.93	3.9282	3.9547	0.8702
MgO	2.08	2.0793	3.5308	0.4606
Al2O3	0.6	0.5996	4.1458	0.1328
Ca	0.1	0.1	3.9916	0.0221

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.08	0.0792	18.9921	0.0617
Ni	1.46	1.4678	21.6312	1.1427
Co	0.05	0.0502	20.8806	0.0391
Fe	25.23	25.0803	70.4402	19.525
S	13.15	13.1143	60.2119	10.2094
SiO2	27.46	27.146	96.0454	21.1331
MgO	16.32	16.1649	96.4692	12.5844
Al2O3	4	3.9451	95.8543	3.0712
Ca	0.69	0.6842	96.0085	0.5326

Material Balance Results

26A
Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	100	99.99	100
RCC	N-O	17.7215	17.7232
RCT	N-O	82.2686	82.2768

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.28	0.2801	100	0.2801
Ni	4.76	4.752	100	4.7515
Co	0.17	0.1684	100	0.1683
Fe	27.46	27.431	100	27.4283
S	16.46	16.4295	100	16.4278
SiO2	23.79	23.588	100	23.5857
MgO	13.95	13.8425	100	13.8412
Al2O3	3.5	3.4595	100	3.4592
Ca	0.61	0.5982	100	0.5981

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	1.07	1.0698	67.691	0.1896
Ni	17.41	17.4291	65.0045	3.0887
Co	0.62	0.6239	65.6778	0.1106
Fe	35.64	35.6487	23.0327	6.3175
S	28.91	28.9267	31.2045	5.1262
SiO2	7.27	7.2733	5.4649	1.2889
MgO	4.18	4.1817	5.354	0.7411
Al2O3	1.08	1.0807	5.5363	0.1915
Ca	0.21	0.2102	6.2294	0.0373

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.11	0.11	32.3091	0.0905
Ni	2.02	2.0212	34.9954	1.6628
Co	0.07	0.0702	34.322	0.0578
Fe	25.64	25.6608	76.9673	21.1108
S	13.72	13.7374	68.7954	11.3016
SiO2	26.89	27.1023	94.5349	22.2967
MgO	15.81	15.9236	94.6458	13.1001
Al2O3	3.93	3.972	94.4634	3.2677
Ca	0.67	0.6817	93.7702	0.5609

Material Balance Results

26B
Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	100	100.1112	100
RCC	N-O	21.6061	21.5821
RCT	N-O	78.5051	78.4179

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.27	0.2763	100	0.2766
Ni	5.13	4.9681	100	4.9736
Co	0.18	0.1728	100	0.173
Fe	28.39	28.5084	100	28.5401
S	17.05	17.1896	100	17.2088
SiO2	23.51	22.8834	100	22.9089
MgO	14.07	13.653	100	13.6682
Al2O3	3.46	3.3326	100	3.3364
Ca	0.64	0.6111	100	0.6118

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	1.01	0.9911	77.4301	0.2141
Ni	17.1	17.4874	75.9677	3.7783
Co	0.6	0.6172	77.0827	0.1334
Fe	36	35.959	27.2225	7.7693
S	29.32	29.2311	36.7005	6.3157
SiO2	4.44	4.4448	4.1921	0.9604
MgO	2.5	2.5028	3.9564	0.5408
Al2O3	0.65	0.651	4.2156	0.1406
Ca	0.11	0.1102	3.8914	0.0238

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.08	0.0796	22.586	0.0625
Ni	1.51	1.521	24.008	1.1941
Co	0.05	0.0504	22.8867	0.0396
Fe	26.54	26.4588	72.78	20.7715
S	13.95	13.8767	63.3042	10.8939
SiO2	27.29	27.9525	95.7888	21.9441
MgO	16.28	16.718	96.0223	13.1245
Al2O3	3.94	4.0696	95.7579	3.1948
Ca	0.72	0.7487	96.0762	0.5878

Material Balance Results

27A
Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	100	100.0225	100
RCC	N-O	11.9941	11.9914
RCT	N-O	88.0285	88.0086

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.27	0.2683	100	0.2684
Ni	4.75	4.742	100	4.7431
Co	0.17	0.1694	100	0.1695
Fe	27.39	28.0543	100	28.0606
S	16.43	16.8488	100	16.8526
SiO2	24.23	24.1004	100	24.1059
MgO	15	14.9218	100	14.9252
Al2O3	3.51	3.4884	100	3.4892
Ca	0.64	0.6415	100	0.6416

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	1.35	1.355	60.5483	0.1625
Ni	21.09	21.1089	53.3793	2.5318
Co	0.75	0.7513	53.1761	0.0901
Fe	36.89	36.7453	15.7062	4.4073
S	31.53	31.3449	22.3083	3.7595
SiO2	4.52	4.5205	2.2492	0.5422
MgO	2.8	2.8003	2.2504	0.3359
Al2O3	0.74	0.7401	2.5442	0.0888
Ca	0.15	0.15	2.8039	0.018

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.12	0.1203	39.4504	0.1059
Ni	2.51	2.512	46.6205	2.2112
Co	0.09	0.0901	46.8233	0.0793
Fe	27.46	26.8724	84.301	23.6554
S	15.19	14.875	77.6988	13.0943
SiO2	26.63	26.7677	97.749	23.5632
MgO	16.49	16.5731	97.7479	14.5891
Al2O3	3.84	3.8628	97.4538	3.4003
Ca	0.71	0.7084	97.1968	0.6236

Material Balance Results

27B
Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	100	99.999	100
RCC	N-O	14.5118	14.5119
RCT	N-O	85.4872	85.4881

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.25	0.2543	100	0.2543
Ni	4.68	4.5834	100	4.5833
Co	0.17	0.1634	100	0.1634
Fe	27.05	27.377	100	27.3767
S	16.17	16.2358	100	16.2356
SiO2	23.86	23.3399	100	23.3396
MgO	14.81	14.1226	100	14.1225
Al2O3	3.44	3.3397	100	3.3396
Ca	0.64	0.5964	100	0.5964

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	1.3	1.2832	73.2309	0.1862
Ni	20.81	21.0872	66.7662	3.0601
Co	0.75	0.7686	68.2477	0.1115
Fe	38.84	38.7422	20.5364	5.6222
S	33.15	33.1099	29.5944	4.8048
SiO2	3.27	3.2714	2.0341	0.4747
MgO	1.96	1.9617	2.0158	0.2847
Al2O3	0.57	0.5704	2.4786	0.0828
Ca	0.12	0.1202	2.9252	0.0174

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.08	0.0796	26.7691	0.0681
Ni	1.77	1.7818	33.2338	1.5232
Co	0.06	0.0607	31.7523	0.0519
Fe	25.7	25.4477	79.4636	21.7545
S	13.41	13.3713	70.4056	11.4308
SiO2	26.21	26.7466	97.9659	22.8649
MgO	15.54	16.187	97.9842	13.8378
Al2O3	3.71	3.8098	97.5214	3.2569
Ca	0.64	0.6773	97.0748	0.579

Material Balance Results

28A

Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	100	99.9997	100
RCC	N-O	17.7442	17.7442
RCT	N-O	82.2555	82.2558

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.29	0.2837	100	0.2837
Ni	4.93	4.8688	100	4.8688
Co	0.17	0.1684	100	0.1684
Fe	27.12	26.6657	100	26.6656
S	16.17	15.8791	100	15.8791
SiO2	22.84	21.9202	100	21.9202
MgO	13.51	12.9864	100	12.9864
Al2O3	3.29	3.1547	100	3.1547
Ca	0.58	0.539	100	0.539

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	1.07	1.0853	67.8865	0.1926
Ni	17.34	17.4744	63.6854	3.1007
Co	0.62	0.6237	65.7075	0.1107
Fe	34.26	34.3887	22.8833	6.102
S	27.74	27.8919	31.168	4.9492
SiO2	5.47	5.4794	4.4355	0.9723
MgO	3.17	3.1751	4.3384	0.5634
Al2O3	0.82	0.8215	4.6206	0.1458
Ca	0.14	0.1404	4.6232	0.0249

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.11	0.1107	32.1135	0.0911
Ni	2.14	2.1495	36.3146	1.7681
Co	0.07	0.0702	34.2925	0.0578
Fe	24.69	24.9997	77.1167	20.5636
S	13.13	13.2877	68.832	10.9299
SiO2	24.59	25.4669	95.5645	20.9479
MgO	14.6	15.1029	95.6616	12.423
Al2O3	3.53	3.6581	95.3794	3.009
Ca	0.59	0.6249	95.3768	0.514

Material Balance Results

28B
Stream Flowrates

Stream	Measured	Adjusted V	Recovery
AR	100	100.0001	100
RCC	N-O	19.2842	19.2842
RCT	N-O	80.7159	80.7158

Component Assays by Streams

Rougher Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.29	0.2958	100	0.2958
Ni	4.92	4.8937	100	4.8938
Co	0.17	0.1697	100	0.1697
Fe	26.71	27.7368	100	27.7368
S	15.94	16.4368	100	16.4368
SiO2	22.66	22.9844	100	22.9845
MgO	13.44	13.8235	100	13.8235
Al2O3	3.29	3.3258	100	3.3258
Ca	0.57	0.5975	100	0.5975

Rougher Cleaner Concentrate

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	1.22	1.2003	78.2639	0.2315
Ni	18.64	18.7127	73.7386	3.6086
Co	0.67	0.6708	76.2137	0.1294
Fe	38.91	38.4897	26.7602	7.4224
S	31.51	31.1356	36.5292	6.0042
SiO2	3.87	3.8682	3.2454	0.7459
MgO	2.09	2.0882	2.9131	0.4027
Al2O3	0.56	0.5598	3.2459	0.108
Ca	0.12	0.1198	3.8655	0.0231

Rougher Cleaner Tails

Assay	Measured	Adjusted V	Recovery	Flowrate
Cu	0.08	0.0796	21.7361	0.0643
Ni	1.59	1.5922	26.2614	1.2852
Co	0.05	0.05	23.7864	0.0404
Fe	25.95	25.1678	73.2398	20.3144
S	13.2	12.925	63.4708	10.4326
SiO2	27.95	27.5516	96.7546	22.2385
MgO	17.13	16.6272	97.0869	13.4208
Al2O3	4.03	3.9866	96.7541	3.2179
Ca	0.75	0.7116	96.1345	0.5744

Material Balance Results

29A

Stream Flowrates

Stream	Measured Value	Adjusted Value	Recovery
AR	100	100.0021	100
RCC	N-O	20.5621	20.5617
RCT	N-O	79.44	79.4383

Component Assays by Streams

Rougher Concentrate

Assay	Measured Value	Adjusted Value	Recovery	Flowrate
Cu	0.34	0.3387	100	0.3387
Ni	5.77	5.7557	100	5.7558
Co	0.2	0.2021	100	0.2021
Fe	28.75	28.7106	100	28.7112
S	17.75	17.7497	100	17.75
SiO2	23.21	23.3202	100	23.3207
MgO	14.5	14.5364	100	14.5367
Al2O3	3.36	3.3735	100	3.3735
Ca	0.65	0.6518	100	0.6518

Rougher Cleaner Concentrate

Assay	Measured Value	Adjusted Value	Recovery	Flowrate
Cu	1.18	1.1832	71.8263	0.2433
Ni	18.99	19.0219	67.9544	3.9113
Co	0.68	0.675	68.6642	0.1388
Fe	36.4	36.413	26.0779	7.4873
S	30.69	30.6902	35.5523	6.3106
SiO2	6.96	6.958	6.1349	1.4307
MgO	4.25	4.2494	6.0107	0.8738
Al2O3	1.05	1.0497	6.3983	0.2158
Ca	0.28	0.2799	8.8304	0.0576

Rougher Cleaner Tails

Assay	Measured Value	Adjusted Value	Recovery	Flowrate
Cu	0.12	0.1201	28.1737	0.0954
Ni	2.32	2.3218	32.0456	1.8445
Co	0.08	0.0797	31.336	0.0633
Fe	26.69	26.717	73.9221	21.2239
S	14.4	14.4002	64.4477	11.4395
SiO2	27.68	27.5554	93.8651	21.89
MgO	17.24	17.1991	93.9893	13.663
Al2O3	3.99	3.9749	93.6017	3.1577
Ca	0.75	0.7481	91.1696	0.5943

Material Balance Results

29B
Stream Flowrates

Stream	Measured Value	Adjusted Value	Recovery
AR	100	99.9961	100
RCC	N-O	23.6104	23.6113
RCT	N-O	76.3857	76.3887

Component Assays by Streams

Rougher Concentrate

Assay	Measured Value	Adjusted Value	Recovery	Flowrate
Cu	0.34	0.3465	100	0.3465
Ni	5.37	5.3328	100	5.3326
Co	0.19	0.1896	100	0.1896
Fe	27.35	27.3282	100	27.3271
S	16.65	16.5755	100	16.5748
SiO2	22.7	22.9555	100	22.9547
MgO	13.73	13.8246	100	13.8241
Al2O3	3.27	3.3005	100	3.3003
Ca	0.59	0.5907	100	0.5906

Rougher Cleaner Concentrate

Assay	Measured Value	Adjusted Value	Recovery	Flowrate
Cu	1.23	1.2098	82.4267	0.2856
Ni	17.92	18.0178	79.7747	4.2541
Co	0.64	0.6411	79.8449	0.1514
Fe	36.62	36.6292	31.6473	8.6483
S	29.99	30.0471	42.8013	7.0942
SiO2	4.37	4.3678	4.4925	1.0312
MgO	2.41	2.4093	4.1149	0.5688
Al2O3	0.61	0.6097	4.3621	0.144
Ca	0.11	0.11	4.397	0.026

Rougher Cleaner Tails

Assay	Measured Value	Adjusted Value	Recovery	Flowrate
Cu	0.08	0.0797	17.5734	0.0609
Ni	1.41	1.412	20.2253	1.0785
Co	0.05	0.05	20.1551	0.0382
Fe	24.44	24.4533	68.3527	18.6788
S	12.38	12.4115	57.1987	9.4806
SiO2	29.02	28.701	95.5075	21.9234
MgO	17.47	17.353	95.8851	13.2552
Al2O3	4.17	4.1322	95.638	3.1564
Ca	0.74	0.7392	95.603	0.5647

Material Balance Results

30A
Stream Flowrates

Stream	Measured Value	Adjusted Value	Recovery
AR	100	99.9744	100
RCC	N-O	17.8097	17.8142
RCT	N-O	82.1647	82.1858

Component Assays by Streams

Rougher Concentrate

Assay	Measured Value	Adjusted Value	Recovery	Flowrate
Cu	0.3	0.3008	100	0.3007
Ni	4.82	4.8369	100	4.8356
Co	0.17	0.1668	100	0.1668
Fe	26.62	26.5275	100	26.5207
S	15.76	15.7768	100	15.7728
SiO2	23.74	23.5054	100	23.4994
MgO	14.1	14.0032	100	13.9996
Al2O3	3.48	3.4133	100	3.4124
Ca	0.61	0.5989	100	0.5988

Rougher Cleaner Concentrate

Assay	Measured Value	Adjusted Value	Recovery	Flowrate
Cu	1.23	1.2276	72.6987	0.2186
Ni	18.44	18.396	67.7528	3.2763
Co	0.65	0.6582	70.2832	0.1172
Fe	33.61	33.6363	22.588	5.9905
S	28.18	28.1704	31.8083	5.0171
SiO2	7.59	7.5943	5.7555	1.3525
MgO	4.41	4.4117	5.6123	0.7857
Al2O3	1.04	1.0411	5.4334	0.1854
Ca	0.22	0.2203	6.5513	0.0392

Rougher Cleaner Tails

Assay	Measured Value	Adjusted Value	Recovery	Flowrate
Cu	0.1	0.0999	27.3015	0.0821
Ni	1.9	1.8978	32.2474	1.5594
Co	0.06	0.0603	29.7158	0.0496
Fe	24.92	24.9866	77.4118	20.5302
S	13.1	13.0904	68.1917	10.7557
SiO2	26.71	26.9541	94.2439	22.1467
MgO	15.98	16.0822	94.3873	13.2139
Al2O3	3.86	3.9274	94.5656	3.227
Ca	0.67	0.681	93.4477	0.5595

Material Balance Results

30B
Stream Flowrates

Stream	Measured Value	Adjusted Value	Recovery
AR	100	99.9968	100
RCC	N-O	15.4018	15.4022
RCT	N-O	84.5951	84.5978

Component Assays by Streams

Rougher Concentrate

Assay	Measured Value	Adjusted Value	Recovery	Flowrate
Cu	0.2	0.202	100	0.202
Ni	3.62	3.6289	100	3.6288
Co	0.13	0.1286	100	0.1286
Fe	29.51	29.667	100	29.6661
S	17.16	17.178	100	17.1774
SiO2	20.1	20.5752	100	20.5746
MgO	13.46	13.5391	100	13.5386
Al2O3	27.49	28.7931	100	28.7922
Ca	0.31	0.358	100	0.358

Rougher Cleaner Concentrate

Assay	Measured Value	Adjusted Value	Recovery	Flowrate
Cu	0.99	0.9826	74.931	0.1513
Ni	17.17	17.1391	72.7434	2.6397
Co	0.61	0.6147	73.6161	0.0947
Fe	39.96	39.9156	20.723	6.1477
S	30.2	30.1914	27.0705	4.65
SiO2	4.34	4.3366	3.2463	0.6679
MgO	2.55	2.5496	2.9004	0.3927
Al2O3	6.5	6.4888	3.471	0.9994
Ca	0.48	0.4623	19.8887	0.0712

Rougher Cleaner Tails

Assay	Measured Value	Adjusted Value	Recovery	Flowrate
Cu	0.06	0.0599	25.0692	0.0506
Ni	1.17	1.1692	27.2568	0.9891
Co	0.04	0.0401	26.3841	0.0339
Fe	27.92	27.8011	79.277	23.5184
S	14.82	14.8087	72.9296	12.5274
SiO2	24.11	23.5317	96.7536	19.9066
MgO	15.63	15.5398	97.0995	13.1459
Al2O3	34.6	32.8539	96.5289	27.7928
Ca	0.41	0.339	80.1112	0.2868

Appendix C
Data for Chapter 7

Rougher Concentrate

NO CMC	% Solids	% Ni	% MgO	%Pn	%Po	%Rk
4	23.3	9.73	8.99	28.8	33.95	35.91
5	22.3	9.17	10.52	27.14	32.99	38.63
6	24.7	3.03	16.67	8.77	26.8	63.97
7	23.4	3.62	16.34	10.54	26.18	62.73
8	21.4	10.7	8.85	31.74	32.1	34.68
9	20.0	11.27	8.5	33.44	30.22	34.8
10	19.6	12.92	8.56	38.4	27.2	32.6
11	22.4	12.2	7.86	36.24	28.92	33.12
12	23.0	9.08	9.17	26.85	32.35	39.56
13	25.3	14.97	4.33	44.48	34.13	19.5
14	27.5	11.11	7.85	32.94	31.41	34
15	24.4	11	8.4	32.61	29.71	36.21
16	23.1	8.72	17.4	25.79	30.92	42.12
17	24.8	4.55	13.71	13.34	16.01	59.98
18	24.9	5.02	13.72	14.73	27.52	57.12
19	-	4.23	15.12	12.34	32.98	54.15
Aug 13 2001	18.9	9.5	12.9	53.31	25.31	18.33
Dec 11 2001	24.0	10.83	10.26	32.15	15.89	49.82
Dec 7 2001	27.7	7.56	5.06	22.32	29.53	46.84
Jan 22 2002	22.4	15.16	6.84	45.11	23.75	28.97
June 13 2002	22.4	11.08	7.49	32.89	27.44	37.92
Mar 26 2002	22.4	8.81	8.75	26.06	30.88	41.71
MAK CMC						
Dec 6 2002	-	4.6	13.1	13.5	27.3	58.5
Dec 12 2002-am	-	3.9	15.8	11.5	25.5	62.2
Dec 12 2002-pm	27.9	3.7	15.7	10.7	25.5	63.3
Dec 13 2002	30.8	3.9	13.3	11.4	26.2	61.9
Dec 17 2002	27.3	6.6	11.4	19.4	27.5	52.0
Dec 18 2002	22.3	6.1	11.6	18.0	30.4	50.8
Dec 19 2002	-	6.3	12.6	18.5	31.4	49.2
Jan 7 2003	-	4.0	14.2	11.7	28.5	59.2
Jan 8 2003	-	3.2	15.7	9.3	27.5	62.7
Jan 9 2003	-	1.8	18.6	5.1	22.1	72.5
Jan 10 2003	-	3.8	15.3	11.0	27.5	61.0
Jan 14 2003	-	3.7	16.7	11.0	27.9	60.6
Jan 21 2003-am	-	6.4	9.3	18.7	39.4	41.1
Jan 21 2003-pm	-	10.1	5.7	29.9	39.1	29.7
Jan 24 2003	-	9.6	7.9	28.5	34.5	35.6
Jan 28 2003-am	-	7.6	8.2	22.4	39.7	36.8
Jan 28 2003-pm	-	9.7	6.3	28.6	38.9	31.1
Jan 29 2003	-	6.8	10.3	20.0	31.9	47.1
Feb 5 2003	-	5.5	10.5	16.3	31.3	51.6
Feb 6 2003	-	7.2	9.0	21.2	30.3	47.4
Feb 20 2003	-	5.5	13.0	16.2	33.3	49.8
Feb 21 2003	-	5.2	4.7	15.4	25.9	57.9
Feb 26 2003	-	10.3	10.0	30.5	26.8	41.2

Rougher Cleaner Concentrate

NO CMC	% Solids	% Ni	% MgO	%Pn	%Po	%Rk	Ni Rec	MgO Rec	Pn Rec	Po Rec	Rk Rec	SPLIT
4	22.5	12.58	6.79	37.34	33.79	27.07	91.82	53.64	92.07	70.67	53.5	71.0
5	22.8	11.47	8.31	34	33.48	30.91	94	59.38	94.22	76.32	60.2	75.2
6	21.2	15.16	7.85	45.12	23.19	29.39	72.79	6.84	74.78	12.58	6.7	14.5
7	19.1	15.4	7.54	45.79	22.01	29.78	77.23	8.38	78.9	15.27	8.6	18.2
8	24.4	17.56	5.23	52.31	25.48	19.4	79.34	28.57	79.72	38.39	27.1	48.4
9	24.3	15.89	4.71	47.28	29.22	21.19	90.88	35.75	91.14	62.33	39.2	64.5
10	22.9	18.73	3.42	55.8	27.7	13.5	83.08	22.88	83.3	58.4	23.8	57.3
11	25.1	14.99	6.05	44.58	26.95	26.3	95.96	60.17	96.13	72.81	62.1	25.1
12	23.7	16.12	5.07	47.96	27.55	22.25	90.31	28.11	90.85	43.3	28.6	50.9
13	29.6	17.2	3.18	51.21	31.96	14.73	97.62	62.32	97.74	79.5	63.9	84.9
14	28.9	18.36	4.35	54.71	23.51	18.83	87.96	29.47	88.38	39.83	29.5	53.2
15	30.3	18.07	4.17	53.82	26.64	17.04	91.73	27.74	92.1	50.04	26.3	55.8
16	28.9	19.16	3.8	57.1	22.65	17.51	82.98	14.93	83.61	27.66	15.7	37.8
17	26.3	18.44	5.29	54.98	17.8	24.41	78.07	7.44	79.43	13.19	7.8	19.3
18	26.2	18.67	5.09	55.67	18.35	23.5	70.49	7.03	71.61	12.64	7.8	19.0
19	-	20.5	2.54	61.1	24.43	11.87	72.21	2.51	73.82	11.05	3.3	14.9
Aug 13 2001	20.6	5.9	16.63	54.24	24.96	17.7	99.88	95.57	99.89	96.81	94.8	55.2
Dec 11 2001	26.5	14.34	8.81	42.69	13.29	40.96	90.88	58.93	91.12	57.4	56.4	68.6
Dec 7 2001	31.0	14.3	2.65	42.58	30.94	23.85	87.45	24.18	88.01	48.35	23.5	46.1
Jan 22 2002	24.9	16.43	5.92	48.93	22.7	26	98.41	78.57	98.47	86.77	81.5	90.8
June 13 2002	24.9	15.98	4.47	47.57	25.79	24.08	94.4	39.06	94.68	61.53	41.6	65.5
Mar 26 2002	24.9	16.65	3.08	49.53	31.57	16.32	93.46	17.42	94	50.56	19.4	21.3
MAK CMC												
Dec 6 2002	-	17.8	3.7	53.1	28.3	15.4	79.2	5.8	80.5	21.2	5.4	20.4
Dec 12 2002-am	-	16.7	3.6	49.8	22.5	24.3	66.2	3.5	67.5	13.7	6.1	15.2
Dec 12 2002-pm	28.4	18.2	4.1	54.3	22.2	24.3	68.2	3.6	69.7	12.0	4.5	13.8
Dec 13 2002	29.5	13.9	4.9	41.3	27.7	28.9	75.9	7.7	77.3	22.5	9.9	21.2
Dec 17 2002	32.4	18.2	3.4	54.2	28.3	14.2	84.7	9.0	85.5	31.5	8.3	30.6
Dec 18 2002	32.4	18.8	3.0	55.9	25.1	15.9	73.8	6.3	74.8	19.9	7.5	24.0
Dec 19 2002	-	18.2	3.2	54.2	30.1	12.6	80.8	7.0	81.7	26.7	7.1	27.8
Jan 7 2003	-	18.8	3.4	56.0	26.0	15.0	71.6	3.7	73.1	13.9	3.9	15.3
Jan 8 2003	-	17.9	3.4	53.3	23.9	19.8	64.6	2.5	66.3	10.0	3.6	11.5
Jan 9 2003	-	17.2	3.5	51.1	23.8	21.6	41.8	0.8	43.8	4.7	1.3	4.4
Jan 10 2003	-	17.3	3.6	51.4	29.9	15.9	67.1	3.5	68.5	16.0	3.8	14.6
Jan 14 2003	-	18.0	3.8	53.6	28.2	15.1	62.1	2.9	63.4	13.1	3.2	13.0
Jan 21 2003-am	-	19.4	1.7	57.9	29.7	9.5	74.2	4.4	75.3	18.3	5.6	24.3
Jan 21 2003-pm	-	20.9	1.2	62.1	29.6	5.4	85.5	8.7	86.1	31.4	7.6	41.4
Jan 24 2003	-	23.7	1.2	70.9	29.6	8.5	68.2	4.4	68.8	13.1	6.6	27.6
Jan 28 2003-am	-	15.5	2.0	45.9	38.1	10.3	82.5	9.9	83.2	42.4	11.3	40.6
Jan 28 2003-pm	-	14.8	1.8	44.1	38.1	15.5	92.8	17.0	93.3	59.3	30.2	60.5
Jan 29 2003	-	18.4	1.7	54.7	30.1	12.1	72.4	4.5	73.2	25.2	6.9	26.7
Feb 5 2003	-	16.8	2.4	49.9	31.5	16.1	86.9	6.5	88.1	29.0	9.0	28.8
Feb 6 2003	-	19.2	3.0	57.2	22.8	17.1	90.1	11.2	91.0	25.4	12.2	33.8
Feb 20 2003		23.6	1.9	70.4	19.4	6.2	55.8	2.0	56.8	7.6	1.6	13.0
Feb 21 2003		12.0	5.0	35.5	49.5	13.4	96.0	44.6	96.7	80.1	9.7	42.0
Feb 26 2003		18.2	3.8	54.2	26.4	16.7	90.7	19.6	91.1	50.3	20.8	51.2

Rougher Cleaner Tails

NO CMC	% Solids	% Ni	% MgO	%Pn	%Po	%Rk	Ni Rec	MgO Rec	Pn Rec	Po Rec	Rk Rec	SPLIT
4	25.3	2.75	14.38	7.88	34.36	57.64	8.18	46.36	7.93	29.33	46.5	29.0
5	20.9	2.22	17.22	6.32	31.49	62.04	6	40.62	5.78	23.68	39.84	24.8
6	25.5	0.96	18.17	2.59	27.41	69.85	27.21	93.16	25.22	87.42	93.32	85.5
7	24.6	1.01	18.3	2.72	27.11	70.04	22.77	91.62	21.1	84.73	91.38	81.8
8	19.2	4.28	12.25	12.46	38.31	48.99	20.66	71.43	20.28	61.61	72.94	51.6
9	15.1	2.89	15.36	8.33	32.03	59.49	9.12	64.25	8.86	37.67	60.786	35.5
10	16.5	5.12	15.46	15.04	26.51	58.3	16.92	77.12	16.7	41.6	76.24	42.7
11	16.4	2.26	14.32	6.41	35.97	57.47	4.04	39.83	3.87	27.19	37.94	74.9
12	22.3	1.79	13.42	5	37.32	57.48	9.69	71.89	9.15	56.7	71.4	49.1
13	14.0	2.36	10.8	6.65	46.32	46.81	2.38	37.68	2.26	20.5	36.12	15.1
14	26.1	2.86	11.83	8.18	40.38	51.25	12.04	70.53	11.62	60.17	70.53	46.8
15	19.6	2.06	13.73	5.83	33.58	60.41	8.27	72.26	7.9	49.96	73.74	44.2
16	20.6	2.39	13.13	6.79	35.94	57.06	17.02	85.07	16.39	72.34	84.3	62.2
17	24.2	1.24	15.72	3.4	27.97	68.47	21.93	92.56	20.57	86.81	92.16	80.7
18	19.2	1.83	15.74	5.16	29.67	64.98	29.51	92.97	28.39	87.36	92.2	81.1
19	-	1.38	17.32	3.8	34.45	61.55	27.79	97.49	26.18	88.95	96.73	85.1
Aug 13 2001	16.9	13.93	8.32	3.11	44.29	52.52	0.12	4.43	0.11	3.19	5.22	44.8
Dec 11 2001	19.9	3.13	13.43	9.04	21.57	69.24	9.12	41.07	8.88	42.6	43.57	31.4
Dec 7 2001	25.3	1.76	7.13	4.97	28.32	66.54	12.55	75.82	11.99	51.65	76.5	53.9
Jan 22 2002	11.3	2.62	15.92	7.49	34.11	58.25	1.59	21.43	1.53	13.23	18.52	9.2
June 13 2002	11.3	1.8	13.23	5.06	30.57	64.18	5.6	60.94	5.32	38.47	58.44	34.5
Mar 26 2002	11.3	1.14	14.3	3.1	30.21	66.56	6.54	82.58	6	49.44	80.65	78.7
MAK CMC												
Dec 6 2002	-	1.2	15.5	3.3	27.0	69.6	20.8	94.2	19.5	78.8	94.6	79.6
Dec 12 2002-am	-	1.6	18.1	4.4	26.1	69.3	33.8	96.5	32.5	86.3	93.9	84.8
Dec 12 2002-pm	23.8	1.4	17.6	3.8	26.0	70.1	31.8	96.4	30.3	88.0	95.5	86.3
Dec 13 2002	28.8	1.2	15.7	3.3	25.8	70.8	24.1	92.3	22.7	77.5	90.1	78.8
Dec 17 2002	20.9	1.4	14.9	4.0	27.2	68.7	15.3	91.0	14.5	68.5	91.7	69.4
Dec 18 2002	18.5	2.1	14.3	6.0	32.0	61.8	26.2	93.7	25.2	80.1	92.5	76.0
Dec 19 2002	-	1.7	16.2	4.7	31.8	63.3	19.2	93.0	18.3	80.1	92.9	72.2
Jan 7 2003	-	1.3	16.1	3.7	29.0	67.2	28.4	96.3	26.9	86.1	96.1	84.7
Jan 8 2003	-	1.3	17.3	3.5	28.0	68.3	35.4	97.5	33.7	90.0	96.4	88.5
Jan 9 2003	-	1.1	19.2	3.0	22.0	74.8	58.2	99.2	56.2	95.3	98.7	95.7
Jan 10 2003	-	1.5	17.3	4.1	27.0	68.7	32.9	96.5	31.5	84.0	96.2	85.4
Jan 14 2003	-	1.6	18.7	4.6	27.8	67.4	37.9	97.1	36.6	86.9	96.8	87.0
Jan 21 2003-am	-	2.2	11.7	6.1	42.5	51.2	25.8	95.6	24.7	81.7	94.4	75.7
Jan 21 2003-pm	-	2.5	8.9	7.1	45.8	46.9	14.5	91.3	13.9	68.6	92.4	58.6
Jan 24 2003	-	4.2	10.4	12.3	41.4	45.9	31.8	95.6	31.2	86.9	93.4	72.4
Jan 28 2003-am	-	2.2	12.5	6.3	38.5	54.9	17.5	90.1	16.8	57.6	88.7	59.4
Jan 28 2003-pm	-	1.7	13.3	4.9	40.1	54.9	7.2	83.0	6.7	40.7	69.8	39.5
Jan 29 2003	-	2.5	13.4	7.3	32.6	59.9	27.6	95.5	26.8	74.8	93.1	73.3
Feb 5 2003	-	1.0	13.8	2.7	31.2	66.0	13.1	93.5	11.9	71.0	91.0	71.2
Feb 6 2003	-	1.1	12.1	2.9	34.1	62.9	9.9	88.8	9.0	74.6	87.8	66.2
Feb 20 2003		2.8	14.6	8.0	35.4	56.3	44.2	98.0	43.2	92.4	98.4	87.0
Feb 21 2003		0.4	4.5	0.9	8.9	90.2	4.0	55.4	3.3	19.9	90.3	58.0
Feb 26 2003		2.0	16.6	5.6	27.3	66.9	9.3	80.4	8.9	49.7	79.2	48.8

APPENDIX D
Reagent Specifications

Sodium Carboxymethyl Cellulose solution
Penn Carbose LT-30 CMC

Product	Carbose LT-30 CMC
Lot Number	1187
Activity (% CMC)	30.4%
Total Solids (wt%)	30.9%
Viscosity of solution (Brookfield @ 25 C)	700 cps
pH (of solution)	5.6
Degree of Substitution	0.80
Density (lbs/gal)	8.8-9.2

Sodium Carboxymethyl Cellulose
MAK Chemical

Product	Technical Grade CMC
Lot Number	139-03
Moisture	6.4%
Activity (% CMC)	67.5%
pH (of 1% solution)	8.1
Degree of Substitution	0.74
Density (lbs/cu ft)	24
Particle Size through 18 mesh	100%

Guar Gum
Economy Polymers and Chemicals

Product	ECOPOL-LVG-II
Moisture, wt%	6.0-10.0
Ash, wt %	1.0-5.0
Viscosity of 1% solution (Brookfield @ 25 C)	2000-2500 cps
pH (of 1% solution)	6.0-7.5

Sodium Silicate
National Silicates

Product	N Sodium Silicate
Na_2O %	8.9 %
SiO_2	28.66 %
Weight Ratio %SiO_2:Na_2O	3.22
Specific Gravity @ 20 C	1.39
Total Solids (wt%)	37.6%
Viscosity of solution (@ 20 C)	177
pH (of solution)	11.3

Potassium Amyl Xanthate
Prospec Chemicals

Product	KAX 51 Liquid
% Xanthate By Weight	32%

Soda Ash
General Chemical

Product	Soda Ash
Na_2CO_3 Wt%	99.5
Bulk Density lb/ft^3	65.4
Particle Size through 18 Mesh	99%