EMC FLOTATION TEST PROCEDURE 1:
THE BRYSON TEST

FLOTATION TEST PROCEDURE (developed by Mike Bryson of Mintek) AND EXPLANATION TO INCREASE RECOVERY BY TESTING THE SEPARABILITY OF VALUES AND GANGUE

SYNOPSIS

Recovery and concentrate grade increase as the degree of separability between values and gangue increases. An increase in separability is indicative of a "good" ore and one that is mineralogically clean having undergone little alteration and/or oxidation. Its metals and minerals tend to exist in a state that are readily recoverable. If the gangue component is active it is usually controllable with a suitable depressant because of the high degree of liberation between metal/mineral and gangue.

Performing a flotation rate test characterises the ore. The results of the test are used to calculate the flotation kinetics of metal or mineral and gangue under chosen test conditions. Change the test conditions and the kinetics change. The kinetics describes the behaviour of the ore and is a numerical representation of the ore's mineralogical qualities and its metal – mineral – gangue associations.

Flotation kinetics are derived from Kelsall's unmodified equation and comprise fast and slow floating fractions and rates of metal and/or mineral and gangue. Together, these variables define a flotation system, whether in the laboratory, pilot plant or production plant. The numerical values of these variables change in order to define the particular system and take into account the differences between systems under consideration – e.g. laboratory to pilot or laboratory to plant.

Recovery is a function of whatever recovery-grade relationship exists as determined by the ore's mineralogy and is thus dependant upon the concentrate grade required. Therefore how the metals and minerals float relative to gangue and knowledge of how separable they are is important. This communication note describes testwork that measures how separable mineral and gangue are and whether recovery can be improved by using a rougher-cleaner-recleaner + cleaner scavenger circuit with extended cleaner residence time and additional reagents.

This test procedure is applicable to ores which show poor upgrading, high recovery dropout between flotation stages and/or possess a particularly active gangue component.

Introduction

The aim of this communication note is to,

- Describe a set of laboratory scale flotation tests which will determine if recovery and possibly grade may be improved by testing a rougher-cleaner-recleaner + cleaner-recleaner scavenger circuit. The tests include extended cleaner residence time and supplementary reagent addition to the rougher concentrate, primary cleaner tails and cleaner scavenger concentrate and
- Explain what the tests mean.

A case study is used to introduce the procedure and explain the results. Simulation of the various laboratory tests is used to illustrate the beneficial changes that may be made by stage adding reagents. This is done by comparing the numerical values of PGM and gangue kinetics which change when a change is made to the system, in this case by adding reagents. These sets of kinetics are then used to simulate the actual tests.

The Source of Recovery

Recovery originates from three sources in the ore's mineralogical structure;

1. Its liberated, easily floatable fast floating metal/mineral fraction,
2. Its fast to medium floating metal/mineral fraction that may or may not be overwhelmed by fast floating gangue and
3. Its slow floating metal/mineral fraction that competes with slow floating gangue.

The scope of this note addresses points 1 and 2 above.

Fast floating metal/mineral fraction (IMF) is nearly always recovered – that is, excluding those specific and uncommon situations in which this does not happen (the description of these situations is outside the scope of this note). Fast floating gangue fraction (IGF) is always recovered together with IMF. If only IMF and IGF are recovered in the ratio IMF/IGF then a high to very high concentrate grade at IMF% recovery is achieved. However, this is rarely the case in a flotation system because there are also fast to medium, medium and slow floating components competing for the same concentrate bubble to be recovered to concentrate.

After IMF and IGF have been recovered, the fast to medium and medium floating metal/mineral (IMM) and gangue (IGM) components then compete to be recovered to final concentrate. If the gangue is particularly active then it will overpower the metal/mineral component and leapfrog to final concentrate. If this is the case, no further metal/mineral is recovered beyond IMF but the final concentrate will now contain IGF and IGM components and thus concentrate grade is reduced. A case study is used to show this in Figure 1. A standard laboratory rate test measured the fast floating values (PGMs) fraction, IPF, as 0.62. Test B gives results for a rougher-cleaner-recleaner test at a standard, if not low, addition of gangue depressant. Recleaner concentrate recovery is 61.6% PGMs at 62g/t. The fast floating PGM fraction has been recovered together with IGF and IGM. Project objective was a grade of 105g/t at 70% PGM recovery. Even with increasing depressant addition and extending cleaner and recleaner residence time (Test A) recovery is only raised to 64.8% for a much better grade of 140g/t. Again, only IPF is being recovered together with IGF but at least some IGM is being rejected hence concentrate grade increases.

A number of ores possess an IGM fraction which floats faster than its associated IMM fraction. As is highlighted in Figure 1 this results in recovery being limited to IMF (i.e. IPF) because the gangue fractions IGF+IGM cause the concentrate to be equal to or less than the required grade.

The Two-Concentrate Process

If a portion of IGF and the majority of IGM is selectively depressed then IMM (i.e. IPM) is freed to be recovered and can be upgraded to concentrate grade. The recovery of fast floating metal/mineral and gangue, IMF (IPF) with IGF, and medium floating metal/mineral and gangue, IMM (IPM) with IGM, are best accomplished in separate banks which can be set-up to suit the specific conditions suitable for each component. Figure 2 summarises a case study which achieved just this. Actual and simulated laboratory test results are compared.

Compared to tests A and B, depressant addition has been raised to a total of 200g/t from 40g/t in test A and 90g/t in test B. Additional reagents and depressant is added to the rougher concentrate, primary cleaner tails and cleaner scavenger concentrate. Recleaner concentrate recovers IPF together with only the very fast floating gangue (IGFF) to give 62% PGM recovery at 175g/t. Cleaner and recleaner flotation time is reduced relative to tests A and B because only the fast floating fraction is being recovered. Even though all but the very fast floating gangue has been depressed in the cleaner and recleaner stages, the rest of the gangue component in the primary cleaner tails remains active. If no additional reagents and depressant is added at this point the gangue will remain active and overwhelm the flotation of values and PGMs in the cleaner and recleaner scavenger stages. This is illustrated in Figure 3 by simulation. The end product of 63.9% PGM recovery at 109g/t is approximately an average of tests A and B. The advantage achieved by 100g/t of depressant in the roughing and cleaning stages is almost completely lost in the cleaner and recleaner scavenger stages.

As is well known, gangue has a tendency to rapidly reactivate; hence the need to stage add depressant and other reagents in order to continuously change the state (and reactivity) of the PGM and gangue components. The result in Figure 2 boosts recovery from 63.9% (as in Figure 3) to 69.5% for the same final concentrate grade – an increase of about 5.5% PGM recovery or 7.5% relative to the measured fast floating fraction IPF. In effect, the PGM fast floating fraction of 0.62 as measured by a standard rougher rate test and observed as a recovery of 61.6% in test B, Figure 1 has been increased to 0.70 as seen in Figure 2. In the process concentrate grade has been increased from 62g/t to 102g/t.

Change in Kinetics

Additional Depressant to a Rougher-Cleaner-Recleaner Circuit

The effect of gangue depressant in the cleaner/recleaner and cleaner scavenger/recleaner scavenger stages is best illustrated by comparing the flotation kinetics at each stage with and without additional reagents and depressant. Table 1 compares the rougher-cleaner-recleaner circuits of tests A and B, Figure 1.

TEST B

RO RATE TEST, BBW COMPOSITE
60%-75um (low depressant)

IPF =	0.6589	kPF =	1.4456
IPS =	0.3411	kPS =	0.0210
IGF =	0.1000	kGF =	0.2500
IGS =	0.9000	kGS =	0.0029

IPF/IGF =	6.59	kPF/kGF =	5.78
		kPS/kGS =	7.14

Final Concentrate	
3.00	% mass
62.0	g/t
61.6	% PGM Rec

TEST A

RO RATE TEST, BBW COMPOSITE
60%-75um (high depressant)

IPF =	0.6415	kPF =	1.8000
IPS =	0.3585	kPS =	0.0350
IGF =	0.0700	kGF =	0.2831
IGS =	0.9300	kGS =	0.0027

IPF/IGF =	9.16	kPF/kGF =	6.36
		kPS/kGS =	12.96

Final Concentrate	
1.34	% mass
140.0	g/t
64.5	% PGM Rec

TABLE 1

The effect of the depressant upon PGMs and gangue is clear and improves the relative flotation and separability between the two. For approximately the same PGM fast floating fraction (0.659 compared to 0.642) recovery is increased by 3% and concentrate grade is more than doubled.

Additional Depressant to a Rougher-Cleaner-Recleaner Circuit and a Cleaner-Recleaner Scavenger Circuit to Increase Recovery

The test in Figure 2 used 100g/t of Depramin 267 depressant to the rougher-cleaner-recleaner circuit, which is about double that of test A. The kinetics used to simulate this portion of the circuit is shown in Table 2. A comparison of Tables 1 and 2 shows that the PGM kinetics are broadly unaffected whereas the fast floating fraction and rate of gangue has been significantly reduced. Note that the slow floating rate of gangue has increased slightly.

The result of an increase in depressant is to capture the fast floating PGM fraction into a high-grade concentrate.

HIGH GRADE PRIMARY CONC
KINETICS TO SIMULATE LAB TEST, BBW COMPOSITE
ROUGHER-CLEANER-RECLEANER SECTION
60%-75um (high stage added depressant)

IPF =	0.6200	kPF =	1.5700
IPS =	0.3800	kPS =	0.0200

IGF =	0.0300	kGF =	0.1002
IGS =	0.9700	kGS =	0.0035

IPF/IGF =	20.67	kPF/kGF =	15.67
		kPS/kGS =	5.71

Final Primary Concentrate	
1.07	% mass
175.0	g/t
62.0	% PGM Rec

These kinetics did not simulate the cleaner scavenger-recleaner scavenger stage accurately and gave;

Recleaner Scavenger Concentrate			
Simulated		Actual	
0.75	% mass	0.90	% mass
6.0	g/t	25.0	g/t
1.5	% PGM Rec	7.5	% PGM Rec

TABLE 2

These same kinetics were not successful at simulating the cleaner and recleaner scavenger section. This is because additional reagents and depressant was added to the primary cleaner tails and cleaner scavenger concentrate which changes the state of the material and hence changes its floatability and kinetics. Table 2 illustrates (by simulation) what would happen if flotation was continued without any further reagent addition.

The kinetics and floatability of the primary cleaner tails is changed significantly by treating with additional reagents. To illustrate this change, the cleaner-recleaner scavenger section was simulated as a separate entity starting with primary cleaner tailings as feed. Two simulations are done, one with no additional reagents producing 6g/t concentrate and 1.5% recovery; the other with additional reagents producing 25g/t concentrate and 7.5% recovery. Table 3 compares these two simulations. This case is different to simulating a rougher-cleaner-recleaner circuit where the kinetics of the PGMs remains broadly constant with depressant addition whereas the gangue changed significantly. In this instance both PGM and gangue kinetics change significantly. In Table 2 the floatability of fast floating PGMs relative to gangue (IPF/IGF and kPF/kGF) is affected the most. In Table 3 the slow floating species (kPS/kGS) is affected the most. This is logical because the primary cleaner tailing carries slow floating material of which some has the potential to be captured to final concentrate.

HIGH GRADE PRIMARY CONC & INCREASED RECOVERY KINETICS TO SIMULATE LAB TEST, BBW COMPOSITE CLEANER AND RECLEANER SCAVENGER SECTION 60%-75um (NO ADDITIONAL DEPRESSANT ADDITION)

IPF =	0.2500	kPF =	0.1250
IPS =	0.7500	kPS =	0.0150
IGF =	0.2000	kGF =	0.1000
IGS =	0.8000	kGS =	0.0150
IPF/IGF =	1.25	kPF/kGF =	1.25
		kPS/kGS =	1.00

Final Primary Concentrate	
0.75	% mass
6.0	g/t
1.5	% PGM Rec

The above kinetics are specific to the cleaner and recleaner scavenger section and describe flotation if NO additional depressant was added to the primary cleaner tails. Feed to this section is the primary cleaner tails at 4.3g/t.

HIGH GRADE PRIMARY CONC & INCREASED RECOVERY KINETICS TO SIMULATE LAB TEST, BBW COMPOSITE CLEANER AND RECLEANER SCAVENGER SECTION 60%-75um (WITH ADDITIONAL DEPRESSANT)

IPF =	0.4200	kPF =	0.3700
IPS =	0.5800	kPS =	0.1490
IGF =	0.1000	kGF =	0.1000
IGS =	0.9000	kGS =	0.0030
IPF/IGF =	4.20	kPF/kGF =	3.70
		kPS/kGS =	49.67

Final Primary Concentrate	
0.90	% mass
25.0	g/t
7.5	% PGM Rec

The above kinetics are specific to the cleaner and recleaner scavenger section and describe flotation when additional depressant was added to the primary cleaner tails. Feed to this section is the primary cleaner tails at 4.3g/t.

TABLE 3

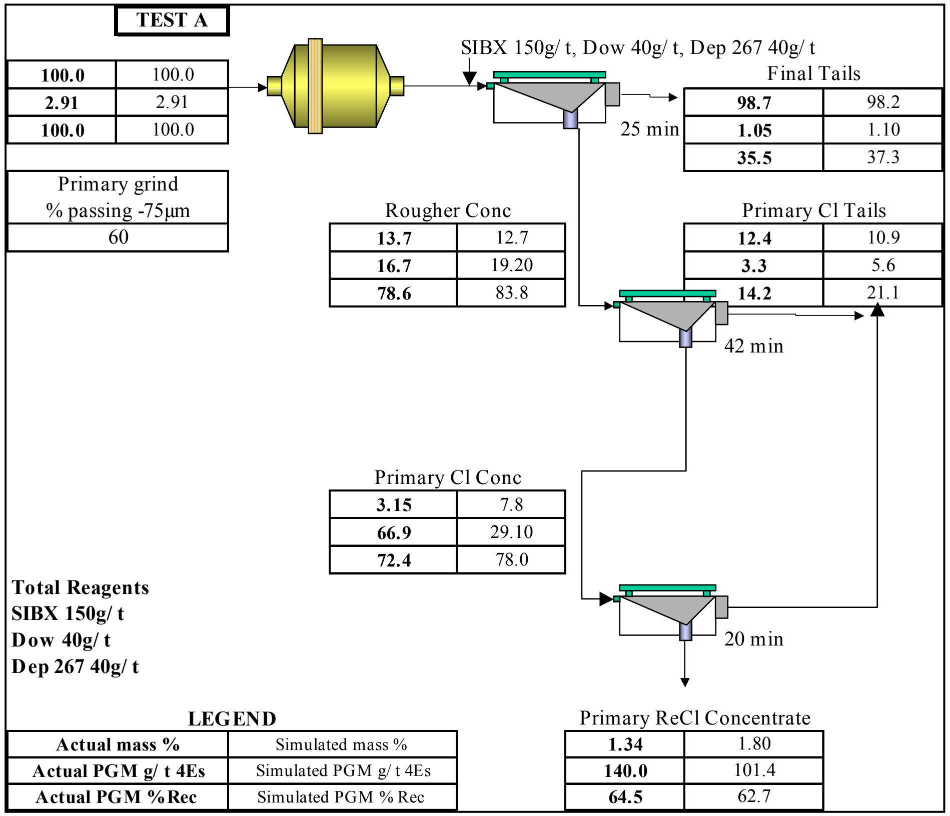
Conducting Laboratory Tests

The red dots marked with "RT" denote where a rate test should be performed. A rate test performed on,

1. Rougher feed defines rougher and cleaner kinetics for any chosen set of conditions such as grind, reagent type and addition, pH etc,
2. Rougher concentrate defines cleaner kinetics. It is done as a check on 1.0 above. However if a change is made which alters the physical and/or chemical state of the values and/or gangue (such as regrinding, reagents, pH, temperature etc) then a rate test is necessary to properly define the new system from this point on,
3. Primary cleaner tails defines the cleaner scavenger system. This point is equivalent to 1.0 above as it can be considered as an entry stream into a new float system,
4. Cleaner scavenger concentrate for the same reasons as 2.0 above,
5. Primary (MF1) tails – with or without cleaner tails – defines the flotation characteristics of a new system as per 1.0 above.

Having done a few scoping rougher rate tests the tests in Figure 2 can be conducted without doing any further rate tests as the results will enable the ores fast floating fractions to be estimated. However, if the tests are to be used to simulate and design an operating plant the internal rate tests on rougher concentrate, primary cleaner tails and cleaner scavenger concentrate (all with and without additional reagents and other selected changes) should be conducted.

FIGURE 1


TEST A
100.0 100.0
2.91 2.91
100.0 100.0
Primary grind
% passing -75µm
60
SIBX 150g/ t, Dow 40g/ t, Dep 267 40g/ t
25 min
Final Tails
98.7 98.2
1.05 1.10
35.5 37.3
Rougher Conc
13.7 12.7
16.7 19.20
78.6 83.8
Primary Cl Tails
12.4 10.9
3.3 5.6
14.2 21.1
42 min
Primary Cl Conc
3.15 7.8
66.9 29.10
72.4 78.0
20 min
Total Reagents
SIBX 150g/ t
Dow 40g/ t
Dep 267 40g/ t
LEGEND
Actual mass % Simulated mass %
Actual PGM g/ t 4Es Simulated PGM g/ t 4Es
Actual PGM %Rec Simulated PGM % Rec
Primary ReCl Concentrate
1.34 1.80
140.0 101.4
64.5 62.7

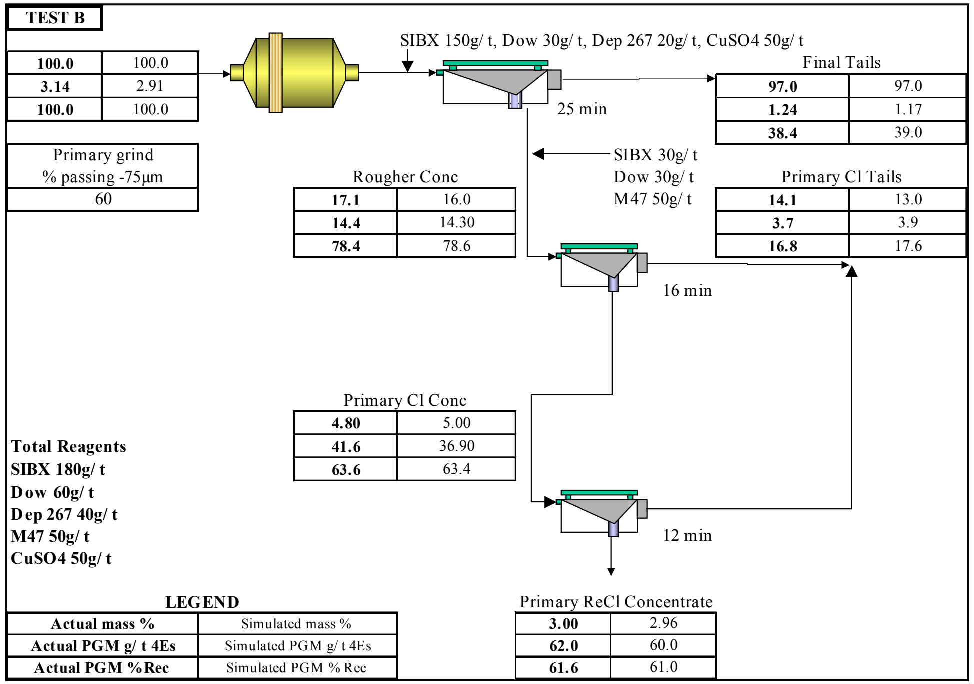

TEST B
100.0 100.0
3.14 2.91
100.0 100.0
Primary grind
% passing -75µm
60
SIBX 150g/ t, Dow 30g/ t, Dep 267 20g/ t, CuSO4 50g/ t
Final Tails
97.0 97.0
1.24 1.17
38.4 39.0
25 min
SIBX 30g/ t
Dow 30g/ t
M47 50g/ t
Rougher Conc
17.1 16.0
14.4 14.30
78.4 78.6
Primary Cl Tails
14.1 13.0
3.7 3.9
16.8 17.6
16 min
Primary Cl Conc
4.80 5.00
41.6 36.90
63.6 63.4
Total Reagents
SIBX 180g/ t
Dow 60g/ t
Dep 267 40g/ t
M47 50g/ t
CuSO4 50g/ t
12 min
LEGEND
Actual mass % Simulated mass %
Actual PGM g/ t 4Es Simulated PGM g/ t 4Es
Actual PGM %Rec Simulated PGM % Rec
Primary ReCl Concentrate
3.00 2.96
62.0 60.0
61.6 61.0

FIGURE 2

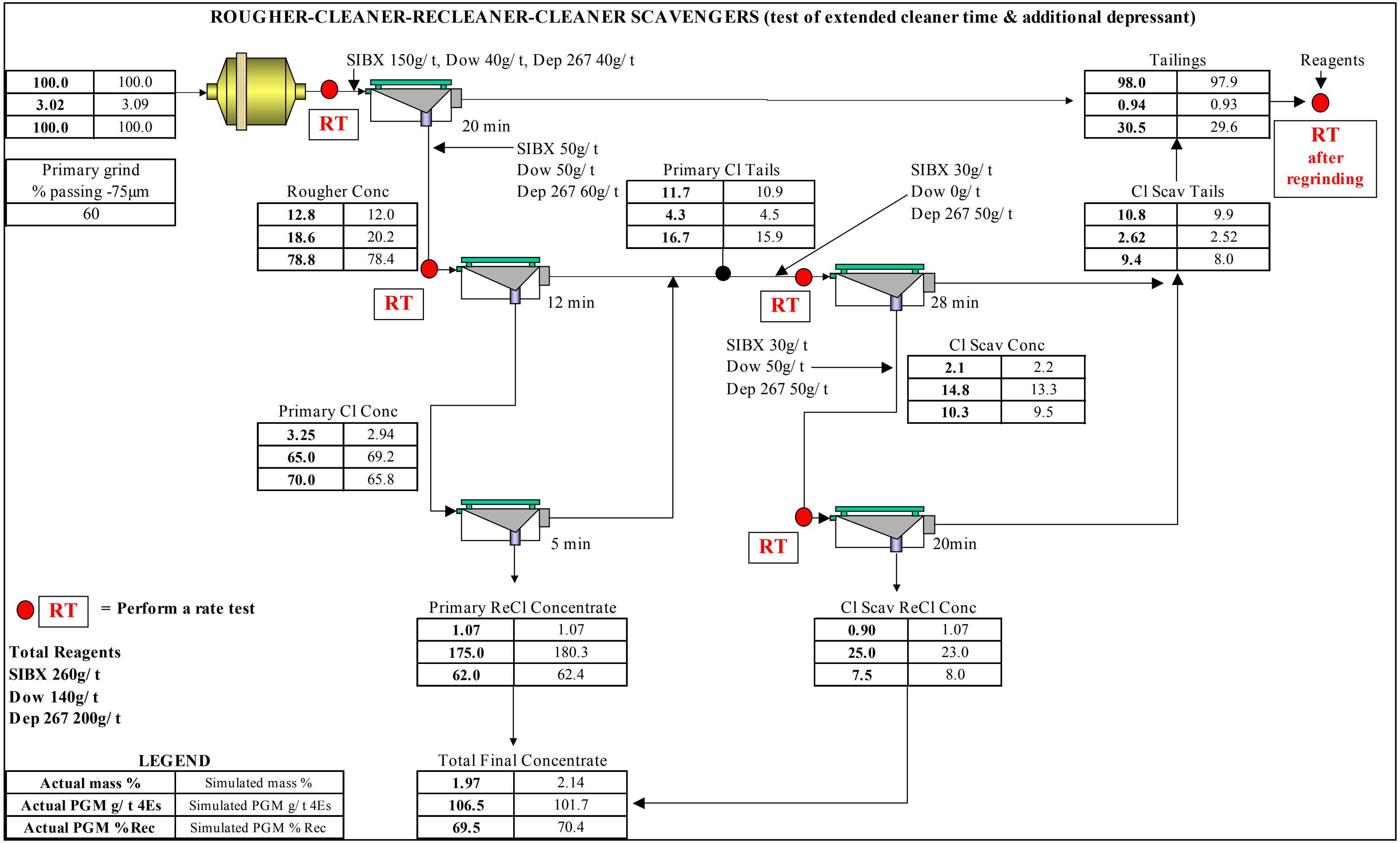
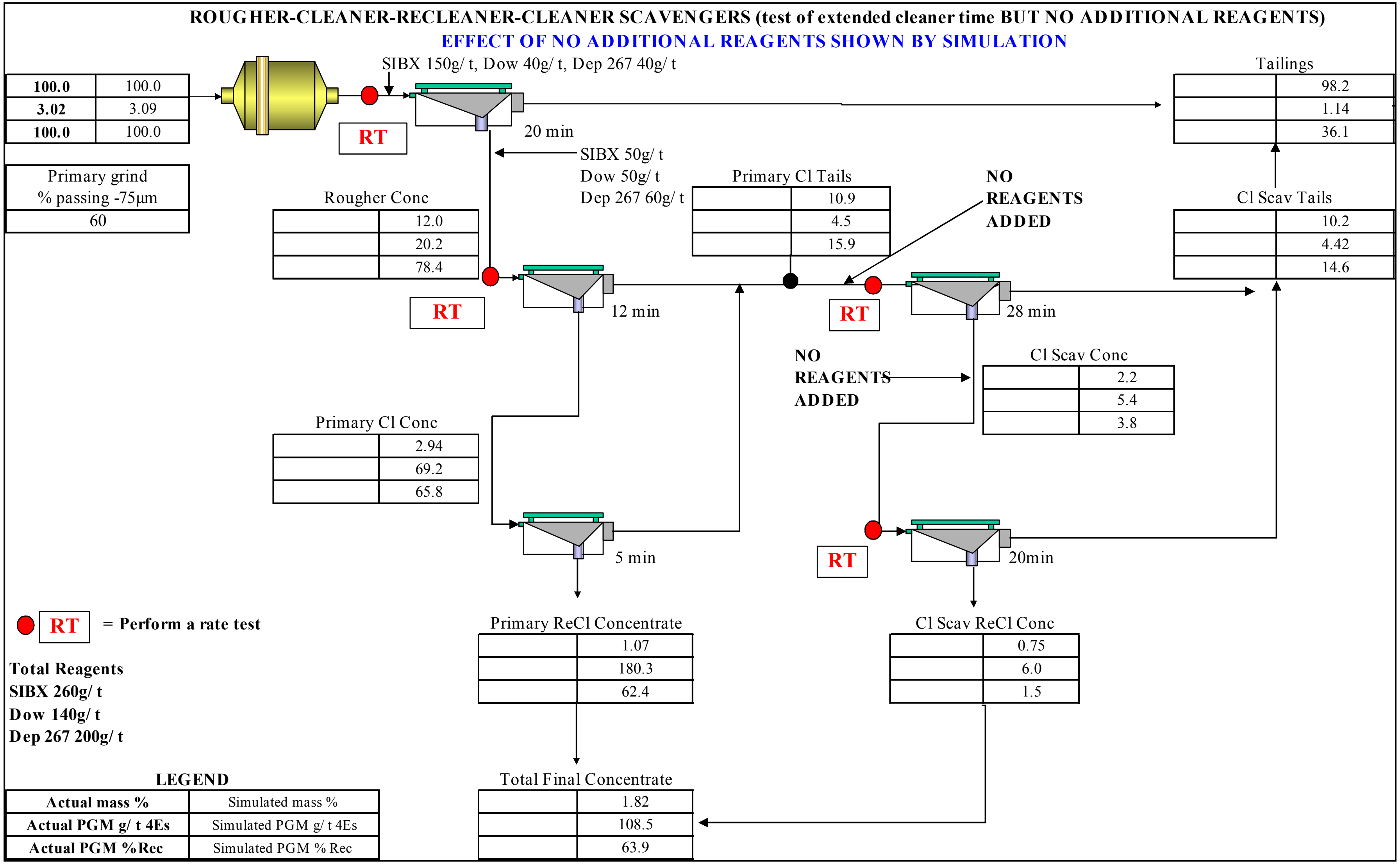

ROUGHER-CLEANER-RECLEANER-CLEANER SCAVENGERS (test of extended cleaner time & additional depressant)
100.0 | 100.0
3.02 | 3.09
100.0 | 100.0
Primary grind
% passing -75µm
60
SIBX 150g/ t, Dow 40g/ t, Dep 267 40g/ t
RT
20 min
Tailings
98.0 | 97.9
0.94 | 0.93
30.5 | 29.6
Reagents
RT
after
regrinding
SIBX 50g/ t
Dow 50g/ t
Dep 267 60g/ t
Rougher Conc
12.8 | 12.0
18.6 | 20.2
78.8 | 78.4
Primary Cl Tails
11.7 | 10.9
4.3 | 4.5
16.7 | 15.9
SIBX 30g/ t
Dow 0g/ t
Dep 267 50g/ t
Cl Scav Tails
10.8 | 9.9
2.62 | 2.52
9.4 | 8.0
RT
12 min
RT
28 min
SIBX 30g/ t
Dow 50g/ t
Dep 267 50g/ t
Cl Scav Conc
2.1 | 2.2
14.8 | 13.3
10.3 | 9.5
Primary Cl Conc
3.25 | 2.94
65.0 | 69.2
70.0 | 65.8
5 min
RT
20min
RT = Perform a rate test
Primary ReCl Concentrate
1.07 | 1.07
175.0 | 180.3
62.0 | 62.4
Cl Scav ReCl Conc
0.90 | 1.07
25.0 | 23.0
7.5 | 8.0
Total Reagents
SIBX 260g/ t
Dow 140g/ t
Dep 267 200g/ t
LEGEND
Actual mass % | Simulated mass %
Actual PGM g/ t 4Es | Simulated PGM g/ t 4Es
Actual PGM %Rec | Simulated PGM % Rec
Total Final Concentrate
1.97 | 2.14
106.5 | 101.7
69.5 | 70.4

FIGURE 3


ROUGHER-CLEANER-RECLEANER-CLEANER SCAVENGERS (test of extended cleaner time BUT NO ADDITIONAL REAGENTS)
EFFECT OF NO ADDITIONAL REAGENTS SHOWN BY SIMULATION
SIBX 150g/ t, Dow 40g/ t, Dep 267 40g/ t
100.0
100.0
3.02
3.09
100.0
100.0
Primary grind
% passing -75µm
60
RT
20 min
Tailings
98.2
1.14
36.1
SIBX 50g/ t
Dow 50g/ t
Dep 267 60g/ t
Rougher Conc
12.0
20.2
78.4
Primary Cl Tails
10.9
4.5
15.9
NO
REAGENTS
ADDED
Cl Scav Tails
10.2
4.42
14.6
RT
12 min
RT
28 min
NO
REAGENTS
ADDED
Cl Scav Conc
2.2
5.4
3.8
Primary Cl Conc
2.94
69.2
65.8
5 min
RT
20min
RT
= Perform a rate test
Primary ReCl Concentrate
1.07
180.3
62.4
Cl Scav ReCl Conc
0.75
6.0
1.5
Total Reagents
SIBX 260g/ t
Dow 140g/ t
Dep 267 200g/ t
LEGEND
Actual mass %
Simulated mass %
Actual PGM g/ t 4Es
Simulated PGM g/ t 4Es
Actual PGM %Rec
Simulated PGM % Rec
Total Final Concentrate
1.82
108.5
63.9