

SOLUBLE METAL RECOVERY IMPROVEMENT USING HIGH DENSITY THICKENERS IN A CCD CIRCUIT: RUASHI II A CASE STUDY

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Abstract

Counter Current Decantation (CCD) thickener circuits are used to recover soluble metal as pregnant liquor solution from ore leach residue. The basis of CCD operation is to concentrate suspended solids thereby minimizing liquor content in underflow slurry that flow in one direction. Then the underflow slurry liquor is diluted with wash liquor that flows in the opposite direction and the suspended solids are concentrated again and again.

The amount of liquor in the thickener underflow contributes to determining the number of CCD stages required to recover the desired amount of soluble metal. Furthermore, similar results could be achieved at lower wash ratios, reducing the size of downstream equipment. High Density Thickeners (HDT) are designed to use gravity and compression, and minimize the amount of liquor in the underflow thus minimizing the number of CCD stages. This paper reviews the process used to select HDT's rather than High Rate Thickeners (HRT) for the Ruashi II Copper-Cobalt hydrometallurgical process in the Democratic Republic of Congo (DRC), using laboratory HDT simulations, to CCD simulations and thickener design details.

1 Introduction

Copper at the Ruashi II plant is leached into solution in Stirred tanks. Leach solution (pregnant liquor) is then recovered in a counter-current-decantation (CCD) circuit. Cu is extracted from the pregnant liquor using solvent extraction (SX). The loaded strip liquor from the SX plant is fed to the electrowinning circuit to produce Cu cathodes. The washing efficiency in the CCD circuit is important to the recovery and hence, the overall copper production. The basis of CCD operation is to concentrate suspended solids thereby minimizing liquor content in underflow slurry. The underflow slurry liquor is diluted with wash liquor from the thickener upstream to achieve counter-current washing.

The amount of liquor in the thickener underflow is a parameter in determining the number of CCD stages required to recover the desired amount of soluble metal. Minimizing liquor in the thickener underflow leads to a higher recovery of soluble metal. This paper reviews the process used to select the best thickener technology for the Ruashi II Copper-Cobalt hydrometallurgical process in the Democratic Republic of Congo (DRC), ie. laboratory simulations, CCD simulations and thickener design details.

2 Laboratory Simulations

Mintek performed process simulations for milling and leaching of the ore. Various leached samples were supplied to FLSmidth Minerals for thickening testwork. Thickening testwork was done directly after leaching in order to prevent "ageing" of the samples.

2.1 Thickening Testwork

The thickener simulations used a combination of bench scale batch tests and continuous fill tests to measure the physical characteristics to be used in the size selection and design of the thickeners.

2.1.1 Settling and Flocculant Flux Curves

A summary of the measured suspended solids settling flux (kg/h/m^2) versus feed slurry suspended solids concentrations, at different flocculant dosage levels, is shown in Figure 1. A maximum settling flux is identified at a suspended solids concentration of between 7 and 8 wt%. The thickener feed slurry must be diluted to this concentration to optimize flocculation and suspended solids settling flux.

Figure 2 exhibits a summary of the measured suspended solids settling versus flocculant dose at different feed slurry suspended solids concentrations. The optimal flocculant dosage is identified by a small change in settling flux at between 50g/t and 60g/t. A flocculant dosage higher than this has an adverse effect on Opex costs.

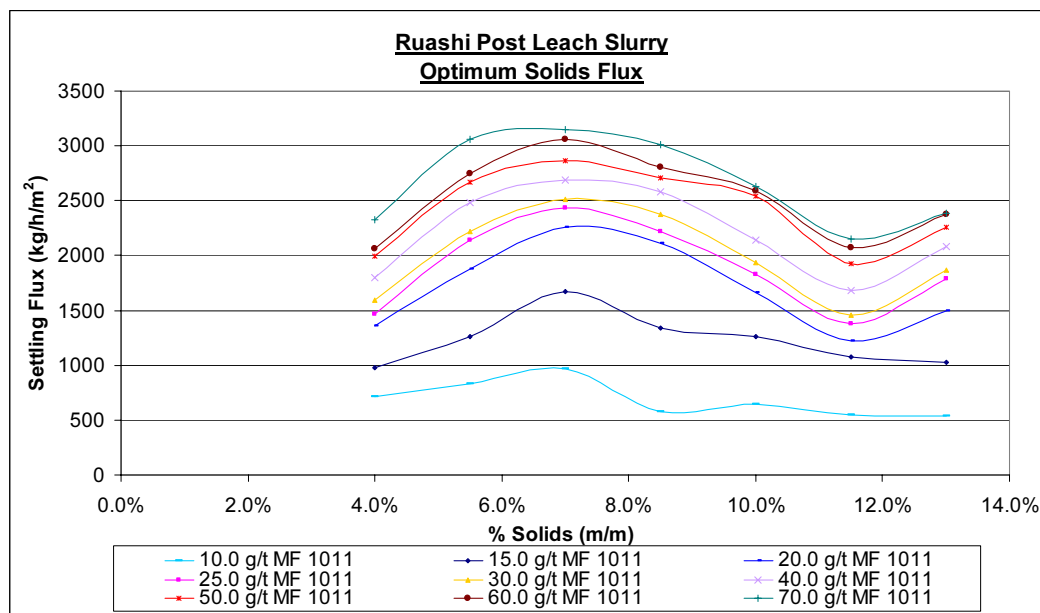


Figure 1: Settling flux versus solids content (varying settling dosage)

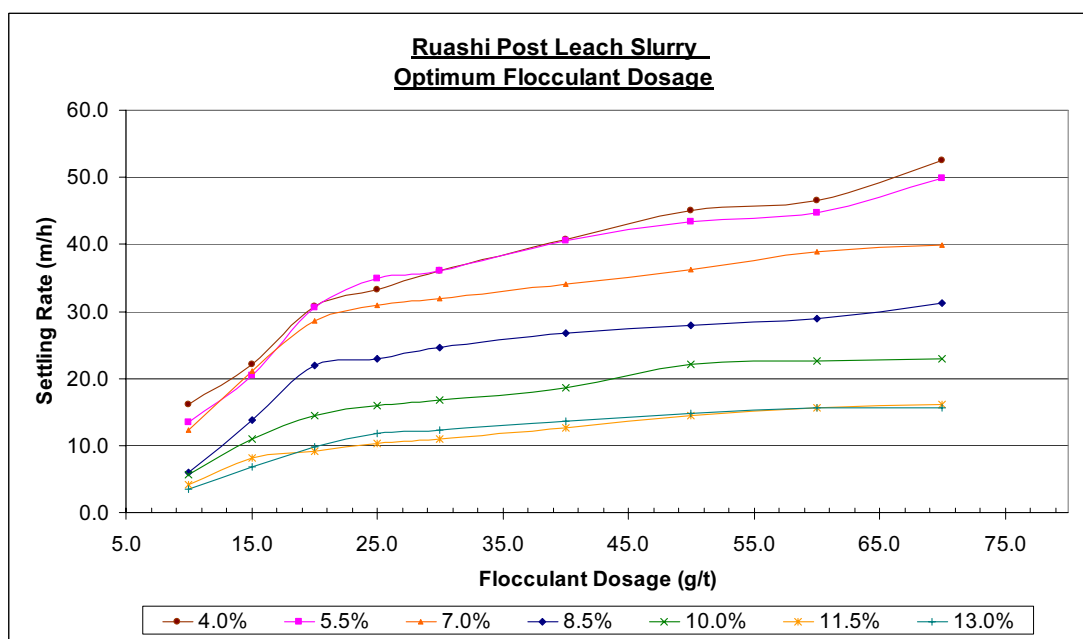


Figure 2: Settling rate versus flocculant dosage (varying solids content)

2.1.2 Batch and Continuous Thickener Simulations

Various batch simulations were done at the optimal feed solids percent and optimal flocculant dosage conditions. The average underflow density achieved in the batch tests was 55% solids (w/w).

Various continuous simulations with rakes were done to check the effect of residence time on underflow suspended solids concentration. Figure 3 below exhibits the residence time required to concentrate the slurry. These simulations are used to determine the suitability of using a High Density Thickener rather than a High Rate Thickener. As one can see in Figure 3, the continuous simulation achieved an underflow suspended solids concentration of 59 wt% when the mud residence time is between 4 and 6 hours. This residence time is normally associated with High Density thickeners (High Rate thickeners have residence times less than this).

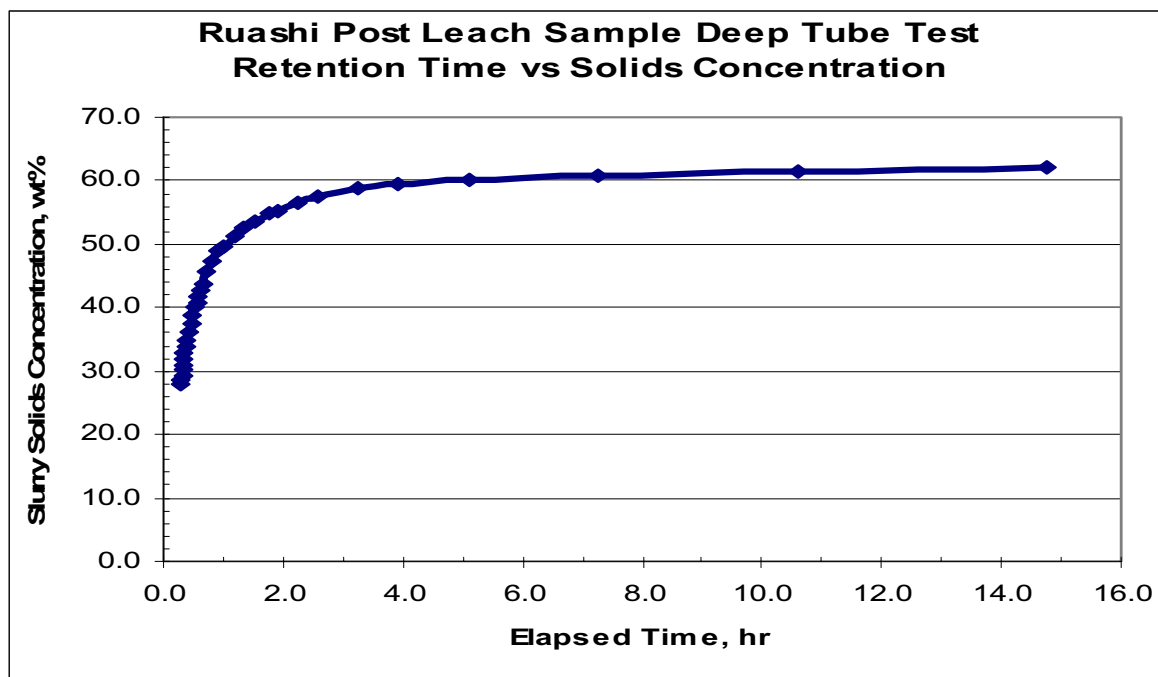


Figure 3: Continuous Test Showing Mud Residence Time vs Solids %

2.1.3 Rheology for Thickener

Rheology measurements were made with a Haake VT550 vane viscometer using FLSmidth Minerals procedures. The slurry yield stress, ie. the force required to produce movement from a stationary bed, is measured at various underflow suspended solids concentrations. The yield stress is a function of physical properties of the suspended solids (including chemical composition, particle size distribution and concentration), flocculant type, flocculant dosage, and temperature.

The yield stress results are used to define the following:

- The limit of underflow density each thickener type can achieve based on its ability to discharge.
- The torque required to rotate the rakes during normal and abnormal operation. The thickener rakes must be able to restart in unshered slurry after an unscheduled shutdown. FLSmidth Minerals thickener rake design and drive torque are designed to overcome the most severe condition.

Figure 4 below identifies a general relationship between thickener type and yield stress or underflow suspended solids concentration. Typically conventional thickeners (CT) and HRT are designed to consistently discharge underflow slurries exhibiting a yield stress of less than 25 Pa. FLSmidth Minerals HDT is designed to consistently create and discharge underflow slurries exhibiting a yield stress of around 100 Pa. FLSmidth Minerals deep cone paste thickeners (DCPT) are designed to consistently create and discharge underflow slurries at around 500 Pa.

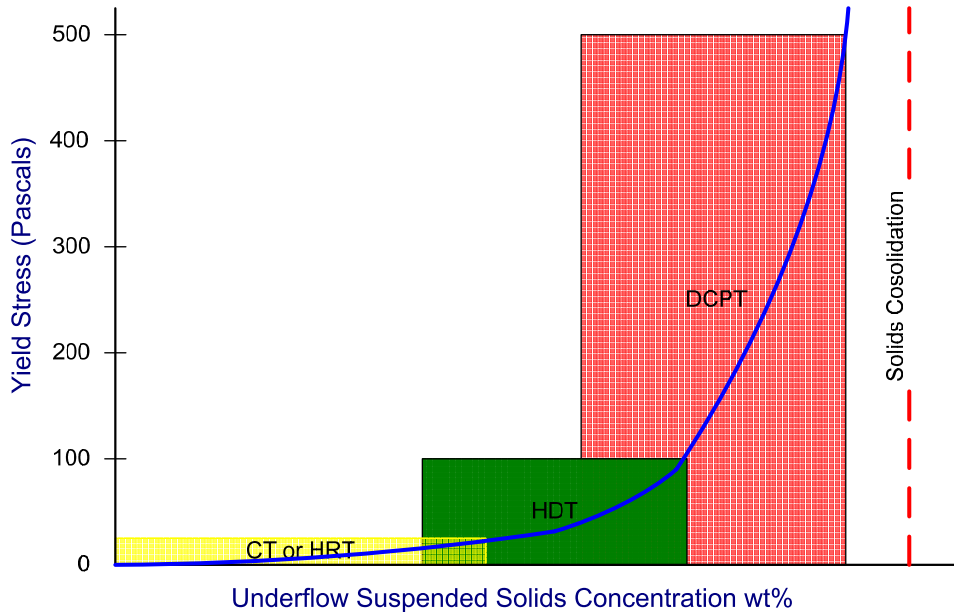


Figure 4: Generic relationship of Yield Stress versus Underflow Solids Concentration %

The yield stresses measured at various slurry suspended solids concentrations for the Ruashi post-leach sample is shown in Figure 5. Results showed yield stresses of 20 Pa and 60 Pa at underflow densities of 55% and 59% respectively. At 60 Pa yield stress, a FLSmidth Minerals HDT should be used. The residence time to achieve 59 wt% underflow suspended solids, was between 4 and 6 hours (see Section 2.1.2).

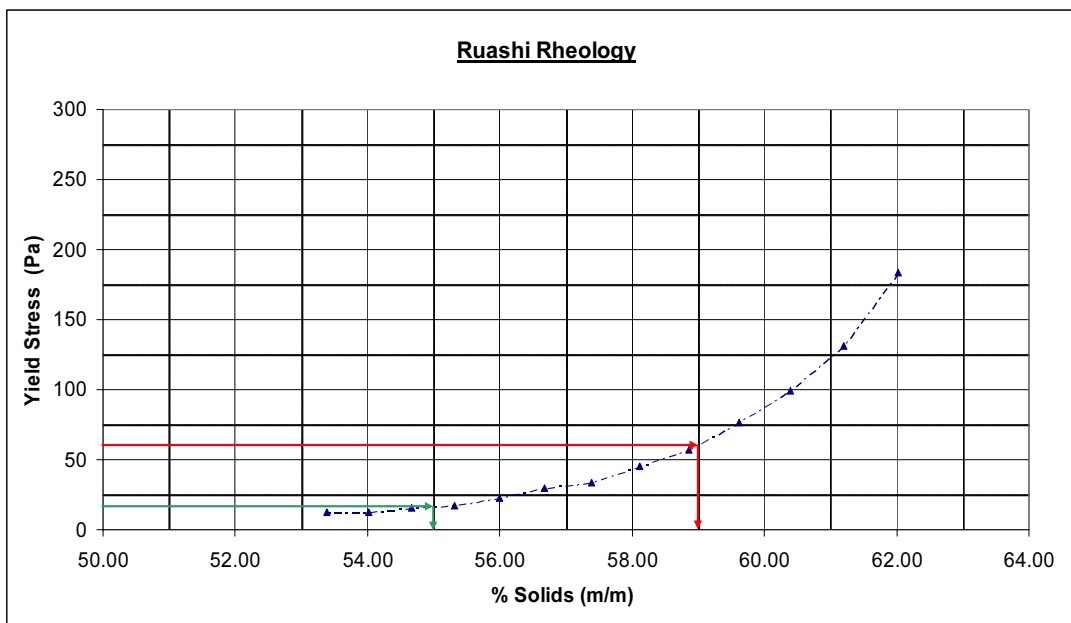


Figure 5: Underflow Mud Rheology

3 Counter Current Decantation (CCD) Simulations

Data from laboratory thickener simulations was used to simulate various CCD design options. The CCD circuit design for Ruashi is shown in Figure 6 below. The CCD simulations calculate soluble metal recoveries for changes in the most important variables affecting CCD wash recovery which include:

- suspended solids concentration in underflow slurry,
- soluble metal content in wash liquor,
- suspended solids concentration in leach residue of CCD feed,
- wash ratio (mass wash liquor/mass suspended solids),
- Interstage mixing efficiency.

Soluble metal recovery formed the basis for a sensitivity analysis around the CCD circuit.

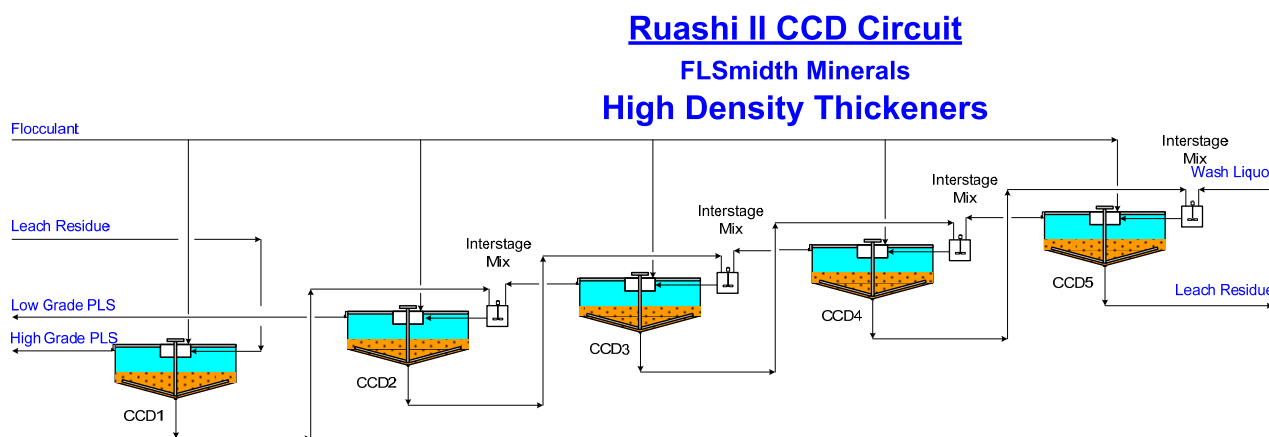


Figure 6: Schematic of Ruashi CCD circuit

3.1 CCD Wash Recovery

Metorex Ltd. required recoveries of 99% of the soluble copper in the CCD circuit. The feasibility study used a High Rate Thickener performance scenario. The underflow suspended solids concentration was 55 wt%. The initial CCD circuit design variables are shown in Table 1 below.

Table 1: Variables Used in CCD Wash Recovery Calculations

Wash Ratio	U/F Suspended Solids Concentration (wt%)	Interstage Mixing Efficiency (%)	Soluble Cu in Wash Liquor (g/l)	Feed Suspended Solids Concentration (wt%)	Soluble Cu Recovery (%)
1.6	55	95	0.0	30	+99

Results showed that 6 stages would be required to achieve more than 99% soluble metal recovery using HRT thickeners (Figure 7).

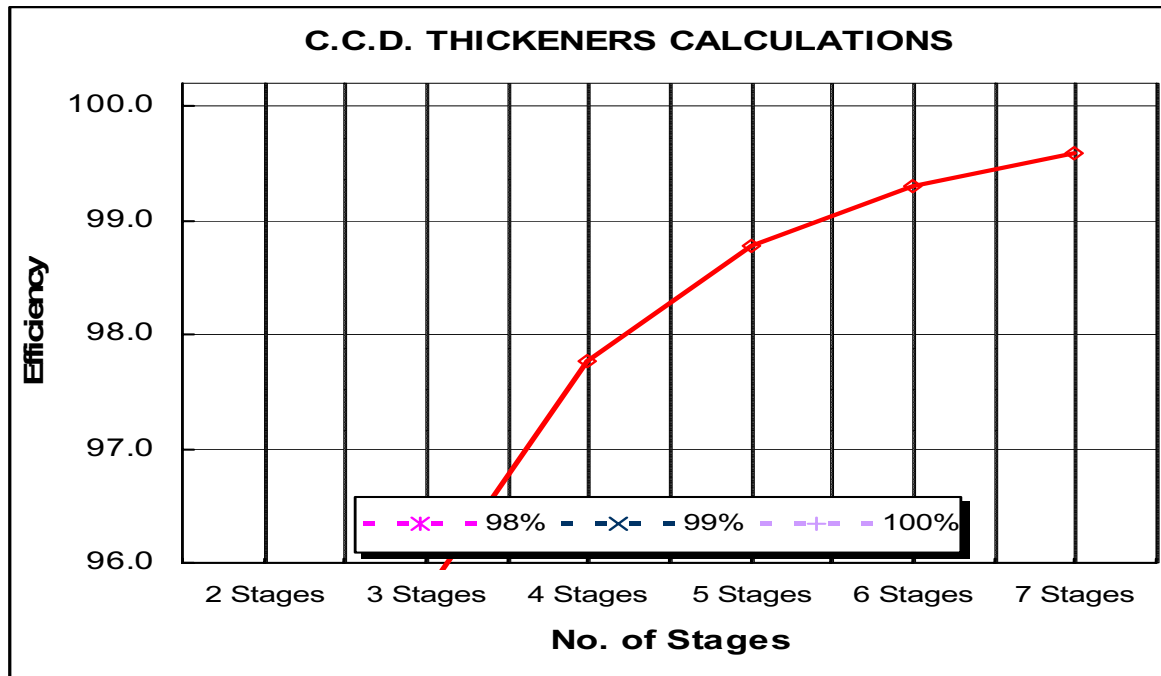


Figure 7: CCD High Rate Thickeners Wash Recovery

3.2 Variables Influencing Wash Recovery

The sensitivity of soluble metal recovery to wash ratio and underflow suspended solids, is shown in Figures 8 and 9 respectively.

Results showed that increasing the wash ratio from 1.6 to 2.1 does not offer significant benefits at 5 stages of CCD and more. However, at the higher wash ratio of 2.1, 99% wash recovery can be achieved in 5 stages compared to 6 stages at a wash ratio of 1.6. The recommended wash ratio will be between 1.6 and 2.1.

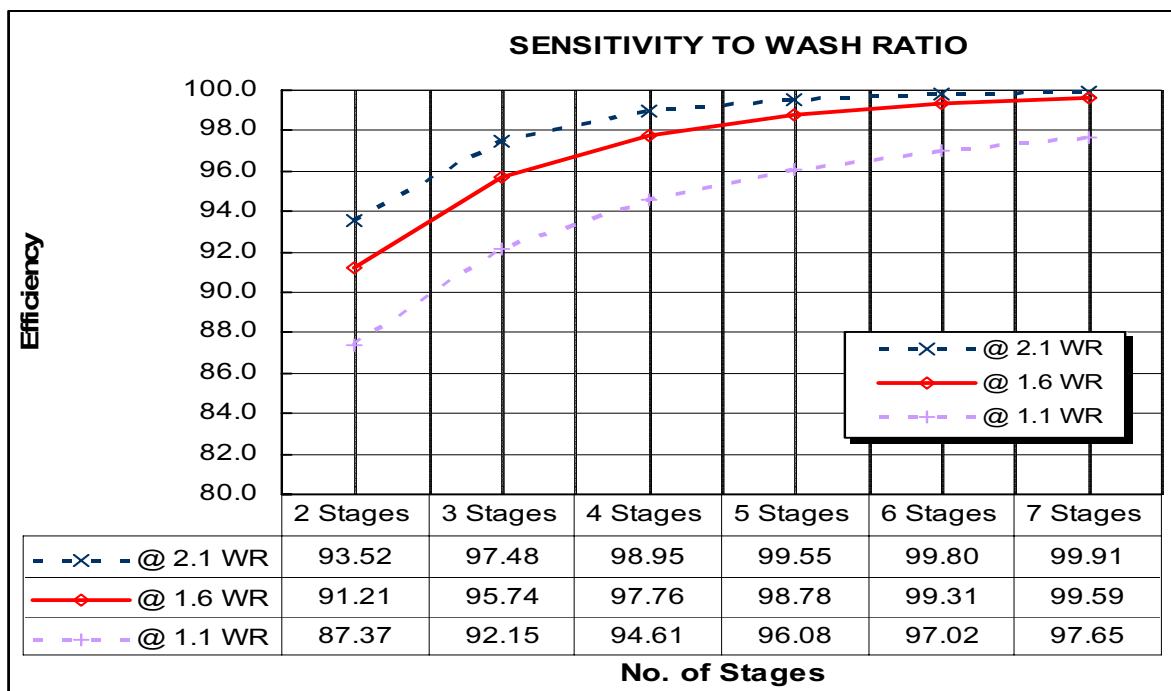


Figure 8: Sensitivity of soluble metal recovery to wash ratio

Results in Figure 9 below shows a significant effect of the underflow suspended solids concentration on the number of stages required. At 59% (w/w) solids, 99% recovery can be achieved in 5 stages, compared to 6 stages at underflow densities of 55 wt%. However, this operation would require the installation of High Density Thickeners, rather than High Rate thickeners, which would be adequate at the lower solids content and hence, lower yield stress.

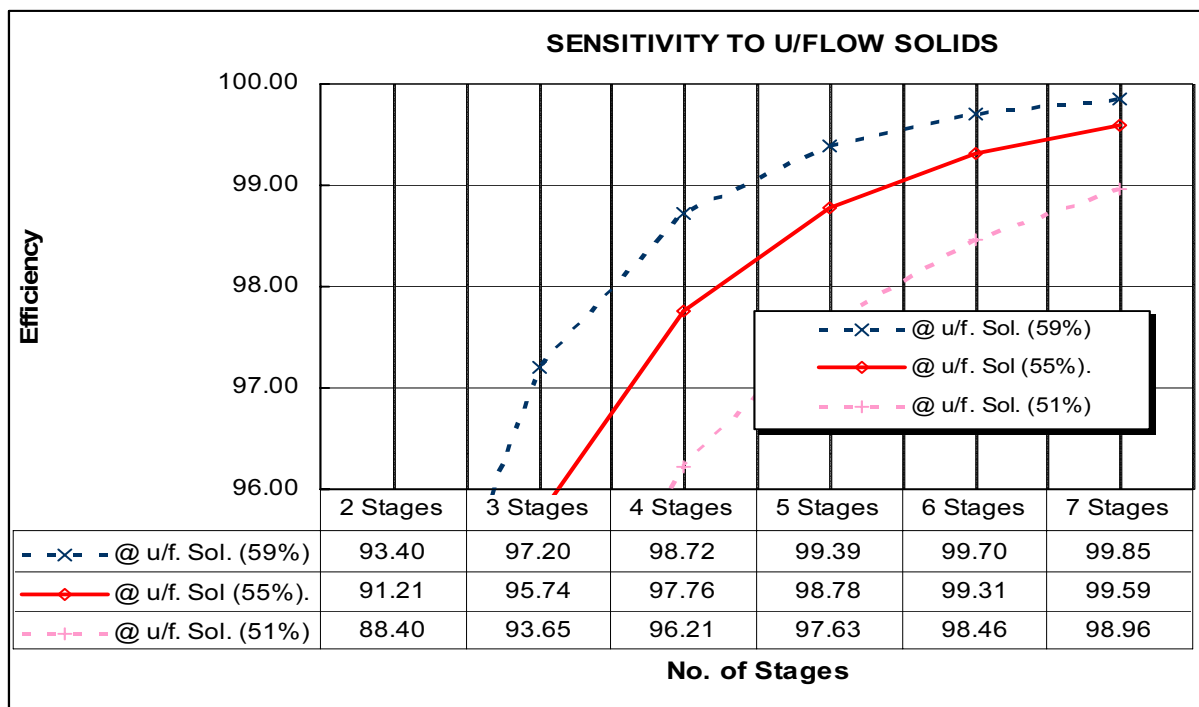


Figure 9: Sensitivity to Underflow Suspended Solids Concentration

It can be seen in the above analysis, selecting High Density thickeners rather than High Rate thickeners, means that 5 stages can be used instead of 6 stages to achieve the required wash recovery. This means that the wash ratio of 1.6 can be used. By keeping the wash ratio at 1.6, the soluble copper concentration reporting downstream to the solvent extraction plant is greater and the plant does not need to be increased in size (ie. if the wash ratio was 2.1 the solvent extraction plant would need to increase in size to handle the additional solution volume).

4 High-Rate vs. High-Density Thickeners

4.1 CCD Wash Recovery

The higher underflow suspended solids concentration means a greater wash recovery of soluble copper. This thus means that with all other variables the same, High Density thickeners will always produce greater underflow suspended solids concentration because of a combination of gravity, compression and altering of permeability of the solids in the thickener. For Ruashi II this also means that with High Density thickeners, the required wash recovery can be achieved with one stage less.

4.2 Cost and Payback Implications

Although there is a general perception the High Rate thickener has a lower cost than High Density thickener, the installed costs are similar due to a smaller diameter on the High Density thickener. The use of High Density thickeners at Ruashi resulted in one less stage in the CCD circuit. The High Density thickener had an installed cost similar to that of a High Rate thickener, and with one less thickener in the CCD circuit offered a significant capital and operating cost saving.

If the same number of stages (5) of HRT and HDT's were installed, it would result in a 0.61% difference in recovery. The differential income (assuming similar Capex costs for the HRT thickener and HDT thickener) for the two installations is shown in Table 2. The extra copper recovery from the HDT circuit leads to an extra 1.5 million dollars per annum.

Table 2: Increase in Income Due to Increase in Copper Recovery

Copper Recovery for 45,000tpa Plant			
Thickener Type		High Rate	High Density
Copper Produced	(tons/day)	130.00	
Recovery	(%)	98.78%	99.39%
Copper Produced	(tons/day)	128.41	129.21
Production Days	(Days)	350	
Copper Produced	(tons/year)	44,945	45,222
Copper Price	(\$/ton)	5,404	
Income per Annum	(\$/year)	242,901,639	244,401,639
Increase per Annum	(\$/year)	1,500,000	

4.3 Differences in Thickener Design

There are some differences in the design between the High Rate and High Density thickeners. The following list gives an overview of the main design differences between the two types of thickeners.

Tank Side Wall Depth: High Density thickeners use a combination of gravity and compression to consolidate suspended solids. The mud residence time required to increase the underflow suspended solids concentration is achieved by increasing the sidewall height.

Tank Floor Slope: Due to the greater rheology as a consequence of higher underflow suspended solids concentration, a steeper floor slope is used to assist the slurry movement to the centre of the thickener for discharge.

Rake Drive: Since High Density thickeners are always smaller than High Rate thickeners, the unit torque of “K factor” must be greater. Typically the same rake drive required for a High Rate can be used for a High Density thickener to achieve a significantly increased unit torque input.

Rake Mechanism: The rakes are designed to minimize cross-sectional area of the mechanical members to minimize resistance or torque production and allow the more dense underflow suspended solids to discharge from the thickener. High Density thickeners also have pickets attached to the rake arms to alter permeability of the compacted solids. Pickets create paths for the liquor in the compacted solids to escape allowing solids concentration to continue.

Thickener Discharge: High Density thickeners are designed with discharge cylinders with much more volume than cones to facilitate discharge and to minimize or prevent rat-holing or underflow dilution.

Conclusions

The use of extensive laboratory thickening simulations to measure solid-liquid separation properties and CCD simulations enabled good information to be gathered for the design of the Ruashi II CCD circuit. The use of the CCD simulations showed that higher underflow densities in the thickeners means 5 stages rather than 6 stages in the CCD circuit can be used to achieve the same wash recovery of soluble copper. This led to the decision to use High Density thickeners in the CCD circuit rather than High Rate thickeners. The use of High Density thickeners allowed for Capex and Opex cost savings due to the reduced number of stages.

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Had a bursary from Sappi whilst studying BSc Chemical Engineering. Worked in the Pulp and Paper industry for 6 years in Process and Projects Engineering roles. Spent these years working on optimization projects and large Capital projects in the Pulp, Liquor recovery, Leach and Chlorine dioxide plants. Then spent a year working at Process Projects in a Process Engineering position, primarily working on projects in the Phosphoric acid and Fertiliser industries. Has been with FLSmidth Minerals for 3 years in the Solid Liquid separation part of the business, getting involved in all process related issues on all the projects relating to these technologies.