

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Methods of dosing

- The various methods tested are discussed in Chapter 3. The results of different methods can be summarised as follows:
 1. Dry powder was not effective because accurate dosing and dusting was a problem.
 2. Suspensions:
 - Water decomposed the TTC.
 - Hexane reduced the odour of the salt, but is too flammable.
 - Paraffin made a good product, but did not keep the salt evenly dispersed.
 - Emulsions improved on the standard collector for PGM's with improved mass pull on the 60 litre cell.
 - Low concentrations of the iC_3 -TTC salt as an emulsion had poor frothing properties. The optimum concentration was above 30%(m/m) active ingredient in the solvent, but the pumping of thiol suspensions has to be optimised.
 - Mercaptan breakthrough on the plant can be controlled by $CuSO_4$ addition. Collector dosage of iC_3 -TTC should not exceed 60g/ton on Merensky ore.
 - Best frother for iC_3 -TTC on Merensky ore is cresylic acid.
 - Dow 200 showed the best results with the iC_3 -TTC/ C_{12} -mercaptan mixture.

- MIBC had a very low mass pull but very high grade and needs further investigation.
- Mixing of frother and collector showed significant improvement on the standard, but would result in difficult plant operations if dosage levels are changed.

7.2 Properties of TTC's

- The half-life of iC_3 -TTC in water at pH 6 and 9 is between 30-60 minutes.
- H_2S is not a decomposition product at pH levels of 6 and 9.
- With xanthates there was no smell from the decomposing products, but with TTC's mercaptans were detected. This can also be a warning of CS_2 formation as a possible decomposition product.
- The extraordinary ability of TTC's to collect iron minerals explains the higher PGM grades and recoveries obtained with TTC collectors as most of the PGM minerals contain iron.
- The viscosity of iC_3 -TTC in the emulsion for different concentrations showed that the solution formed is a pseudo-plastic and that high shear rates will facilitate pumping.

7.3 Batch floats

7.3.1 Billiton Process Research flotation tests

- Cresillic acid was the best frother.
- The iC_3 -TTC/ C_{12} mercaptan mixture, tablet powder and the iC_3/C_{12} -TTC (20%) had a lower mass pull than just the iC_3 -TTC. The order of mass solids recovered was: Tablet powder < iC_3 -TTC/ C_{12} mercaptan < iC_3/C_{12} -TTC (20) < iC_3 -TTC < STD.
- The emulsion showed improvements on grade for PGM, Cu and Ni with low mass pull. The addition of the long chain mercaptan to the iC_3 -TTC also showed good improvement in PGM recovery. Best froth properties were obtained with 40% TTC emulsion.
- As the ratio of solvent/TTC increases, frothing decreased.
- The iC_3 -TTC on its own performed better than the standard collector suite on PGM's. The SIBX/DTP mixture recovered the most copper. The increased recoveries with the C_{12} -mercaptan are expected to result from long chain effects.
- Tablets produced low PGM grades and did not improve on the standard. Alternative dosing methods are recommended.
- High concentrations of C_{12} -TTC in iC_3 -TTC (>30%) showed improvement on iC_3 -TTC mass pull. They also showed better PGM and Ni recoveries.
- Covalent TTC/ iC_3 -TTC was the best combination tested. Combination of short chain ionic and covalent TTC collectors resulted in higher PGM and Ni recoveries.

Significant improvement on PGM grade also resulted from this combination. Covalent TTC on its own did not perform well.

- Nitrogen conditioning and milling proved to be better for the covalent/C₁₂-mercaptan mixture.
- In multiple collector dosing, there was not a big difference in the order of initial dosing for the same collectors. The iC₃-TTC showed slightly lower recoveries and it seems that the optimum collector dosage for the iC₃-TTC is 50%. C₁₂-TTC and the standard collector had the best recovery results with 25% initial dosage.
- Batch flotation tests are a useful start in comparing different chemicals. For more accurate results the tests should be longer or continuous and more ore sample is needed for each test.

7.3.2 Electrochemistry and Leeds flotation cell

- Potential measurements could suggest a different mechanism of bonding for TTC's than the DTC's. The electrode potential response of the emulsions and the TTC powders suggests the same mechanism; that is a two step drop in potential. The reason for this could be multiple interactions on pyrrhotite, pentlandite and chalcopyrite. A possibility is secondary adsorption of possible reaction products which are formed during primary adsorption. With C₁₂-mercaptan present no such double step was observed.
- iC₃-TTC showed a potential drop in nitrogen and air, and xanthate showed no drop with nitrogen. This could suggest that TTC does not need oxygen to react with the minerals, because a potential drop suggests interaction between the mineral and collector.

- Covalent TTC's are bonded by physical adsorption and no oxygen is needed in surface bonding. The covalent collectors are oxidised forms of ionic TTC and have a different mechanism of absorption. They caused no potential drop on mineral electrodes.
- The ionic TTC had similar mineral potential drops when compared to ionic xanthate.
- The best collector tested was the 30% TTC (emulsion)/C₁₂-mercaptan combination. The two different concentrations of emulsions tested showed improvements over the standard.
- The same trends occurred at BPR as at UCT. The xanthate mass pulls and water recovery were also higher than the other collectors. With the copper and nickel higher grades were obtained with the TTC collectors compared to the standard.

7.4 60 litre flotation cell

- PGM recovery was significantly increased by iC₃-TTC emulsion.
- Higher grades were observed with the iC₃-TTC in water.
- Low mass pull of the combinations of SIBX/DTP/ iC₃-TTC resulted in high grades and low recoveries.
- The iC₃-TTC in water and the solvent showed improvement of final recoveries with copper. Again the iC₃-TTC in water showed higher grades, and the high mass pull of the collector in solvent resulted in better final recoveries.
- The nickel results were almost the same for all collectors tested.

- The iC_3 -TTC in the solvent showed higher recovery of chromite. This probably resulted from the heavy froth and entrainment in the froth phase.
- The coarser grind for the samples used in the TTC in emulsion flotation should have had a negative effect on recovery, but instead the TTC emulsion improved on the standard. The three percent increase in PGM recovery is thus even more significant.
- These results imply that the iC_3 -TTC improved on the standard with standard plant feed with a 60 litre continuous cell and confirm the batch flotation tests indicating that this new collector performs better than the standard xanthate collector on Merensky ore.

7.5 Recommendations

- iC_3 -TTC should not be dosed in an aqueous form.
- Synthesis of iC_3 -TTC should be done in other mediums than water.
- Dow200 should be tested with the emulsion tested on the 60 litre cell.
- Higher concentrations of iC_3 -TTC in water should be investigated. It could be possible that the collector salt decomposes more slowly at the higher pH and then no additional chemicals would be necessary for dosing.
- The half-life times of the TTC in water should be measured at various concentrations from 5 to 60 ppm.

- Combinations between the standard collector at Impala Platinum and TTC collectors should be investigated further for synergistic effects.
- Flash flotation results also showed that it could be useful to spike the pulp further down the flotation section to increase grades. The total collector dosage should be split up.
- Covalent collectors show good mass recoveries and this could also improve on iC₃-TTC's low mass pull. Nitrogen conditioning also showed good results.
- Long and short chain collector combinations showed that the collecting power of the C₁₂-TTC improves recoveries and could be tested on a larger scale. Long chain mercaptans could also be used for the same effect.
- A more exhaustive study should be launched on the mechanisms of the TTC collectors on the different mineral surfaces.
- Samples from the 60 litre cell are available for QEMSEM or SEM analyses, and additional information on mineral distribution can help explain why TTC's perform better than DTC's.
- A plant trial should be conducted with iC₃-TTC in emulsion as the collector.