THE UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

DEPARTMENT OF METALLURGY AND MINERAL PROCESSING

OPTIMIZATION OF SOLVENT EXRACTION AT KANSANSHI MINE WITH THE AID OF CYTEC PILOT PLANT

This report is submitted in partial fulfillment of the requirements in acquisition of the Degree of Bachelor of Mineral Science

BY

MWIKULA BUSTONE CHIBWE

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EXAMINERS:

(i) ---

DR. R. L. NYIRENDA

(Project Supervisor)

(ii) ---

MR. C. V. LUNGU

(Head of Department, Metallurgy & mineral Processing)

(iii) ……………………………………………………

PROF. DAVID J. SIMBI

(Chinhoyi University of Technology - Zimbabwe)

(External Examiner)

This work is dedicated to my mother Jessie Chibwe. The same goes to my brothers, sisters and late father Chibwe M. Kakunta.

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ABSTRACT

A series of laboratory test work were carried out to optimize solvent extraction at Kansanshi mine. Results from the laboratory were transferred to the Cytec pilot plant which simulated the Kansanshi High Grade II solvent extraction plant.

The organic and aqueous contact time was determined using a pregnant solution containing 5g/l Cu and this grade were maintained throughout the laboratory test work. pH isotherms for Cu and Fe were generated. Two extraction stages were established from the McCabe Thiele diagram generated. Also established were the temperature and reagent (LIX 984N) concentration in the organic phase constituting Shellsol as a diluent.

A good result was obtained on the Cytec pilot plant with Cu recovery in the extraction stage ranging between 95 and 98%. Other parameters affecting solvent extraction were also observed. These included: crud at weir; organic and aqueous interface heights. The crud was seen to be rising in the stripping stages while decreasing in the extraction stages. To minimize aqueous entrainment, the organic and aqueous heights used were 13 and 14 cm respectively.

ABBREVIATIONS

O/F	Overflow
U/F	Underflow
SX	Solvent Extraction
CCD	Counter- Current Decantation
HG II	High Grade Two
O/A	Organic to Aqueous phase ratio
SAG	Semi – Autogeneous

CHAPTER ONE

1.0 INTRODUCTION

Kansanshi mine is owned and operated by First Quantum Minerals Limited (FQML) and Zambia Consolidated Copper mines Investment Holdings (ZCCM-IH). The mine began its processing operations in 2005. A total of 150 200 tones of copper is produced per annum. 72 000 and 78 200 tones are copper concentrates and cathodes respectively.

Kansanshi mine produces copper from a mixed Oxide and sulphide ore which is mined and subjected to an oxide / sulphide float. Until recently, all the sulphide concentrate has been exported to copper smelters on the Copperbelt province. The installation of pressure leaching equipment has resulted in some of the sulphide concentrates being leached.

The oxide concentrate is leached with H_2SO_4. After leaching and Solid-Liquid separation, the pregnant solution goes for solvent Extraction (SX). Solvent extraction is done with the reagent LIX 984N. The advance electrolyte from SX goes for electro-winning at the copper tank house where copper cathodes are produced. Details of the metallurgical operations at Kansanshi mine are presented in the later section.

1.1 BACKGROUND

Kansanshi mine has three SX plants. This report however focuses on only one of the plants called High Grade Two (HG II) SX. This plant accounts for half of the copper produced.

In the HG II SX plant, pregnant solution with about 5 g/l Cu at a pH range of 1.2-1.7 is contacted with a solvent containing 22.5% extractant in Shellsol as diluent. Two extraction stages are used in which the organic to aqueous (O/A) phase ratio is about 1.5. The loaded organic with 6-8 g/l Cu is stripped with spent electrolyte containing 170-180 g/l H_2SO_4 from the copper tank house located downstream. Stripping is done at a phase ratio of 2. This results in the production of an advance electrolyte of 45-55 g/l Cu.

Operational parameters such as pH, O/A ratio and concentration of various streams have up to now not been fully optimized. This result in occasional problems like:

- Having a minimal layer of organic such that even aqueous flows into the organic streams.
- Erratic extraction and final recovery of copper
- A large quantity extraction of impurities such as ferrous and ferric ions from the pregnant solution.

Difficulties in attaining the optimum contact time during leaching results in dissolution of Iron, Manganese and some other impurities from feldspar and other sources. These impurities give rise to numerous problems downstream. If careful selection of pH is not done, these impurities compete with copper for extraction at the SX plant. Consequently, the presence of Ferrous and Ferric ions during electro-winning results in cyclic reactions at the copper tank house. A great deal of current is consumed by these reactions.

In order to address the aforementioned problems and to better understand the SX plant, it was decided at the beginning of 2007 to simulate the operations of HG II SX with the Cytec Pilot Plant and to do additional test work in the laboratory. Such work forms the basis of this project which is entitled 'Optimization of solvent Extraction at Kansanshi mine with the aid of Cytec pilot plant'. This project was done at Kansanshi mine from March to April 2007.

1.2 METALLURGICAL OPERATIONS AT KANSANSHI MINE

The processing plant at Kansanshi is divided into two sections. These are the Front and Back ends. The front end is purely a mineral processing section where both oxide and sulphide ores undergo crushing, grinding, classification and flotation in two different routes. The relatively harder sulphide ore is crushed using the much stronger gyratory crusher. It then goes for secondary crushing in the Cone crusher before being taken for grinding in the Semi-Autogeneous (SAG) and Ball mills. Classification is done by a set of cyclones which sends the overflow (O/F) for flotation while the underflow (U/F) goes for further grinding in the ball mill. The sulphide coming from flotation and through the filter section is sold as sulphide concentrate. However, recent installation of the Autoclaves has resulted in some of the sulphide concentrate being treated through pressure leaching.

The relatively less hard oxide ore is mainly crushed by the MMD Sizer. The crushed material is then sent for grinding. The ground pulp goes through a series of flotation cells. The flotation overflow (O/F) from rougher cells is directed to the re-cleaner cells while the underflow (U/F) enters the scavenger cells. The O/F from scavenger cells is taken for cleaning while the U/F from the final scavenger cell is taken for neutralization. The O/F from cleaner cells combines with O/F from the rougher cells in the re-cleaner cells. The overflow gets to the filter section and is either sold or treated by pressure leaching. The U/F is recirculated back to the cleaner cells. The Scavenger U/F enters the back-end section through the pre-leach tank and finally into the leach tanks where all the copper is leached with Sulphuric Acid (H_2SO_4). The back-end section is a purely hydrometallurgical section constituting Leaching, Counter-Current Decantation (CCD), Solvent Extraction (SX) and Electro-Winning. The leached feed is sent for Counter-Current Decantation (CCD).The overflow from the first CCD tank is regarded as high grade pregnant solution with 4-6 g/l Cu and is sent to high grade ponds. Overflow from CCD II is taken as low grade pregnant solution and is sent to low grade ponds. From the ponds, the high grade pregnant solution is sent to high grade I and II solvent extraction (SX) plants for upgrading of copper. The low grade pregnant solution is sent to the low grade SX plant.

At the SX plant, both extraction and stripping are by counter-current flow except for Low Grade SX which runs both Cross Current and Counter current. The pregnant solution is mixed with the stripped (barren) organic to allow for extraction of copper to take place. The mixture is given sufficient time to disengage in the settler. The barren aqueous low in copper content termed raffinate is collected and sent to the raffinate ponds and some of it is used for washing in CCD. The loaded organic is then contacted with the spent/lean electrolyte from the electro-winning tank house and is high in acid concentration. The loaded organic is stripped of copper and is sent for extraction while the aqueous very rich in copper is sent to the tank house as advance electrolyte for copper deposition. Low Grade and High Grade (I) SX sends the advance electrolyte to the old electro-winning tank house while High grade (II) feeds the new tank house.

A simplified material flow diagram of Kansanshi Metallurgical plant is shown in Figure 1.0 at the Appendix II.

High Grade (I) SX has two extraction stages while stripping and washing have one stage each. Low Grade SX has three extraction stages and one stripping stage. High Grade (II) SX has two extraction and two stripping stages.

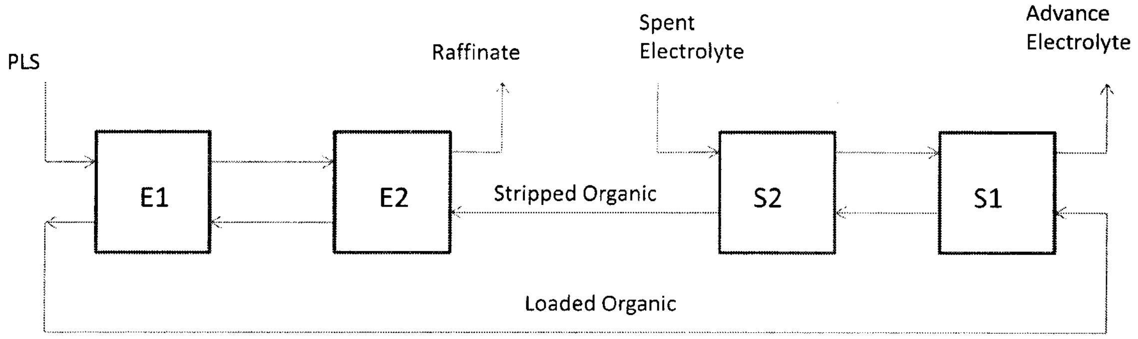

Figure 1.1: High grade II SX plant.

CHAPTER TWO

2.0 LITERATURE REVIEW ON COPPER SOLVENT EXTRACTION

Solvent extraction or liquid-liquid extraction is a unit operation designed to concentrate or purify an aqueous phase with respect to the desired component by using an organic phase (solvent) as the exchange media to effect the selectivity partition of the element in question. Copper SX is therefore a method of purifying and upgrading the copper solution so that it can be suitably treated using electro-winning. The use of copper SX in the mineral industry can be traced as far back as 1968. There are many types of extractants which have been utilized in copper SX. However, those that have been found most suitable are the chelating type. Chelation refers to 'claw' which is a graphic description of the way the extractant chemically bonds the metal in two places as if held in a crab's claw. Examples of chelating extractants are LIX984N, LIX973 and LIX 860-I. With these extractants, the simplified extraction is according to the following reaction:

$$\mathbf{2R\text{-}H}_{(org)} + \mathbf{Cu}^{2+}_{(aq)} \rightleftharpoons \mathbf{R\text{-}Cu\text{-}R}_{(org)} + \mathbf{2H}^{+}_{(aq)} \text{.........} \mathbf{(i)}$$

LIX 984N is a Hydroxyl Oxime Copper extractant which is a mixture of

2-hydroxy-5-nonylacetophenone Oxime

and

5-nonylsalicylaldoxime.

It constitutes an equal volume blend of LIX 84-I with LIX 860-I. An 'I' designation means that there is only one hydroxyl Oxime extractant present in the LIX reagent, e.g. LIX 84-I contains only the 2-hydroxy-5-nonylacetophenone Oxime.

2.1 EFFECT OF AQUEOUS TO ORGANIC (O/A) PHASE RATIO

In normal SX, stages are employed which involves the use of mixers and settlers. Multiple contact is essential and the critical parameter is the Phase Ratio (O/A). The O/A ratio determines the slope of the operating line. When coupled with the equilibrium isotherm, a McCabe Thiele diagram can be realized which will give the number of stages required. An extraction distribution isotherm can be constructed using data obtained from experiments in which different O/A ratios are used while all other parameters are kept constant. Solute analyses are made in the organic and aqueous phases equilibrated at different O/A ratios. For the different organic to aqueous aliquots contacted at different O/A ratios, a plot of the solute concentration in the organic extract against the solute concentration in the corresponding raffinate is termed an extraction distribution isotherm. The greater the displacement of an extraction isotherm from the horizontal axis, the greater is the ability of an extractant to concentrate solute into the organic phase. However, the most important use of an extraction isotherm is that it enables estimation of the number of stages that would be required in the solvent extraction process to achieve a specified level of extraction under specified operation conditions. It is for this reason that experiments were done to realize the equilibrium isotherm for the generation of a McCabe Thiele diagram and thus determine the number of ideal stages.

A hypothetical McCabe Thiele diagram is as shown in Figure 2 in Appendix II.

2.2 EFFECT OF pH ON EXTRACTION OF COPPER BY LIX 984N

The pH of the aqueous phase plays a major role in influencing the extent and selectivity of solute extraction. A reduction in the pH implies an increase in the free hydrogen ion content of the aqueous solution. Therefore, a reduction in the pH lowers the extraction of copper. An increase in the pH implies a reduction in the free hydrogen ions and therefore an increase in the extraction of the solute. Careful control of the pH of the aqueous phase from which the desired solute is to be extracted is essential to the success of the extraction process. A pH isotherm such as the one shown in Figure 2.1 is a convenient graphical representation of the influence of pH on the extent of solute extraction into the organic phase. It shows pH isotherms for copper, iron (III), nickel, cobalt and zinc.

A pH isotherm is smooth curve showing the concentration of solute in organic phase aliquots after extraction from the aqueous phase aliquots obtained at different pH values while maintaining all other parameters constant. It is a convenient representation of the influence of pH on the extent of solute extraction into the organic phase. When pH isotherms of many solute of interest are plotted on a single diagram, it becomes easy to deduce the pH at which to maintain an aqueous phase so as to exclude one or more solutes present in the aqueous phase from being extracted. In the experiments performed at Kansanshi, the aim was to maximize copper extraction by LIX 984N while leaving most or all the iron in the aqueous phase.

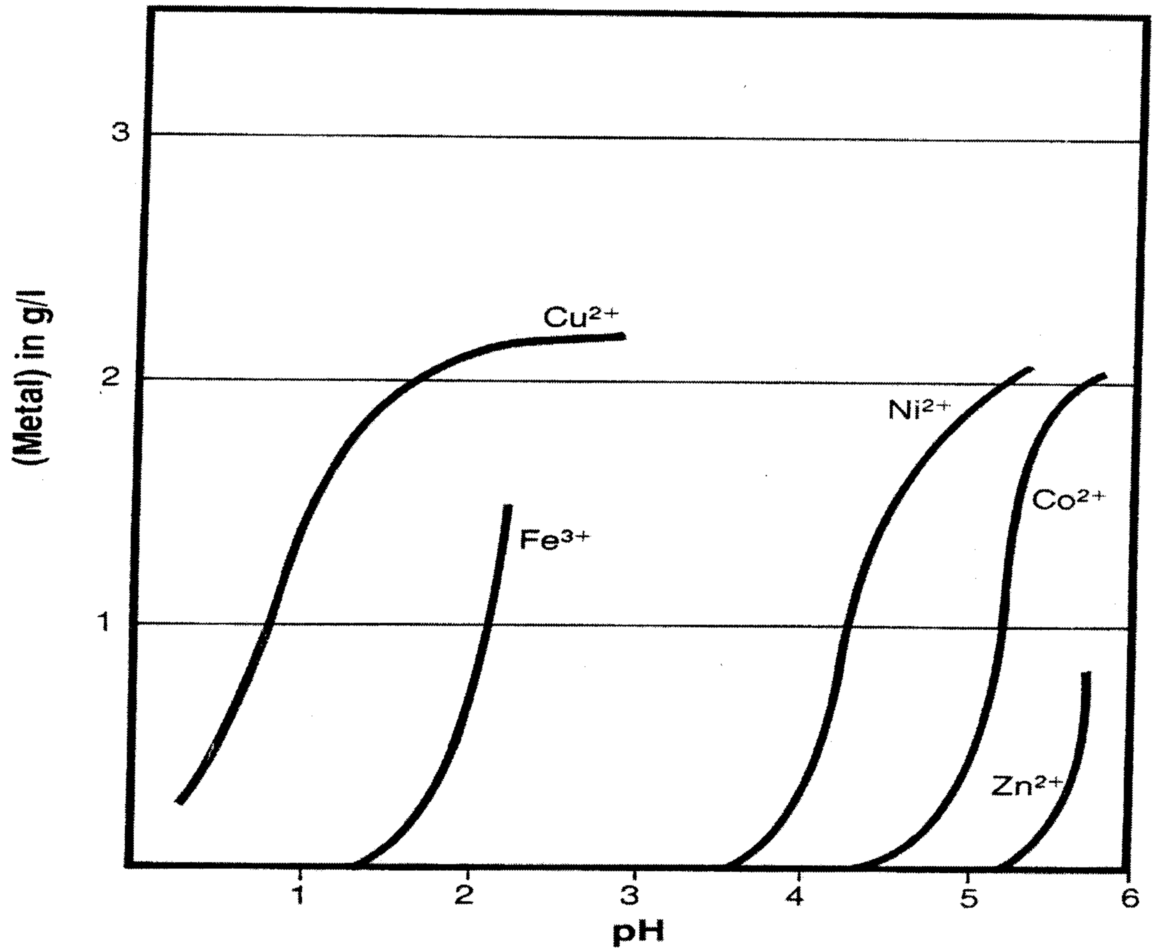

Figure 2.1: pH Isotherm using LIX 64N

2.3 EFFECT OF EXTRACTANT CONCENTRATION ON THE EXTRACTION OF COPPER BY LIX 984N

Extratant concentration refers to the volume percent of the active reagent in the solvent or organic phase. A reduction in the extractant concentration results in a decrease in the loading capacity of the solvent. An increase in the extractant concentration results in a corresponding increase in the viscosity of the organic phase. This leads to poor disengagement and extraction of solutes. It was therefore necessary to optimize the reagent concentration.

2.4 CONTACT TIME

Although solvent extraction reactions are known to be very fast, use of very short times would lead to inadequate extraction. Extended contact times on the hand leads to higher extraction but reduces on the liquor through put or metal throughput of the plant. It is thus essential to experimentally determine the optimal time for SX.

2.5 TEMPERATURE

Temperature may have a possible influence on SX mainly on account of its effect on viscosity. A reduction in temperature leads to an increase in viscosity of the solvent. There will therefore be no intimate contact between the aqueous and organic phases. It should however be noted that temperatures above 45 °C have a degenerating effect on the organic phase. Nevertheless, this parameter is not subject to much variation at Kansanshi. Preliminary experiments showed that after extraction, the raffinate has a temperature of about 35 °C. In this project, most of the experiments were done at room temperature. A few were also done at 35 °C to simulate the plant temperature.

2.6 COMPOSITION OF THE PREGNANT SOLUTION

The SX plant which was to be studied has a copper tenor of the entering aqueous at 3-6 g/l Cu. Although variation in copper tenor has an influence on recovery, most of the experiments were done without much variation.

2.7 AGITATION OF THE AQUEOUS AND ORGANIC PHASES

Sufficient agitation is required for intimate contact of the organic and aqueous phases. Increased agitation improves metal transfer although it comes with a cost and splashing out of liquor.

Once a plant has been designed and is in operation, the agitation rate is not a variable parameter. Thus, in the laboratory experiments, the agitation rate could not be considered.

CHAPTER THREE

3.0 LABORATORY EXPERIMENTS ON EXTRACTION OF COPPER USING LIX 984N

3.1 MATERIALS

- LIX 984N (Extractant)
- Shellsol (Diluent)
- Sulphuric acid (98% H_2SO_4)
- Sodium Bicarbonate ($NaHCO_3$) powder
- Aqueous solution (5g/l Cu)

3.1.1 LIX 984N

The active reagent used was LIX 984N. (See Appendix II)

3.1.2 SHELLSOL (Diluent)

The active reagent in its undiluted form is quite viscous. There is thus need for dilution to achieve the desired viscosity and reagent concentration. The diluent in which the extractant was dissolved is Shellsol supplied by Shell South Africa limited.

3.1.3 SULPHURIC ACID

For pH variations, sulphuric acid (H_2SO_4) with a concentration of 98% was used. Sodium Bicarbonate was also used in some cases to adjust and achieve the required pH range.

3.1.4 AQUEOUS SOLUTION USED

The aqueous solution used was the Pregnant Solution from Counter-Current Decantation (CCD). This was obtained at the point that it was exiting CCD on its way to Solvent Extraction (SX).

3.2 APPARATUS

- Electromagnetic Shaker
- Two Measuring cylinders
- Four Mixing bottles
- Stop watch
- Oven
- Stirrer
- Two Beakers
- 1l Plastic bottles (8)

3.3 PROCEDURE / METHODOLOGY

A given volume of LIX 984N was dissolved in a chosen volume of the diluent (Shellsol) and this constituted the solvent. A portion of the given volume of solvent was contacted with a known volume of the aqueous solution.

The pH of the aqueous solution was adjusted by addition of sulphuric acid (H_2SO_4) or Sodium Bicarbonate ($NaHCO_3$) to a given pH. The organic and aqueous phases were then contacted at known time intervals.

The loaded organic and raffinate were thus analyzed for copper (Cu) and Iron (Fe).

3.4 ANALYSES

In the samples of organic and aqueous taken, Cu and Fe were analyzed by spectrophotometry with appropriate standards.

3.5 LABORATORY RESULTS / DISCUSSION

3.5.1. EFFECT OF CONTACT TIME.

The pregnant solution with 5g/l Cu at a pH and temperature of 1.7 and 25° C respectively were contacted with the organic phase having a reagent (LIX 984N) concentration of 20 v/v %. While maintaining other parameters constant, the contact time was varied from 1 to 14 minutes and the results obtained are shown in Figure 3.1.

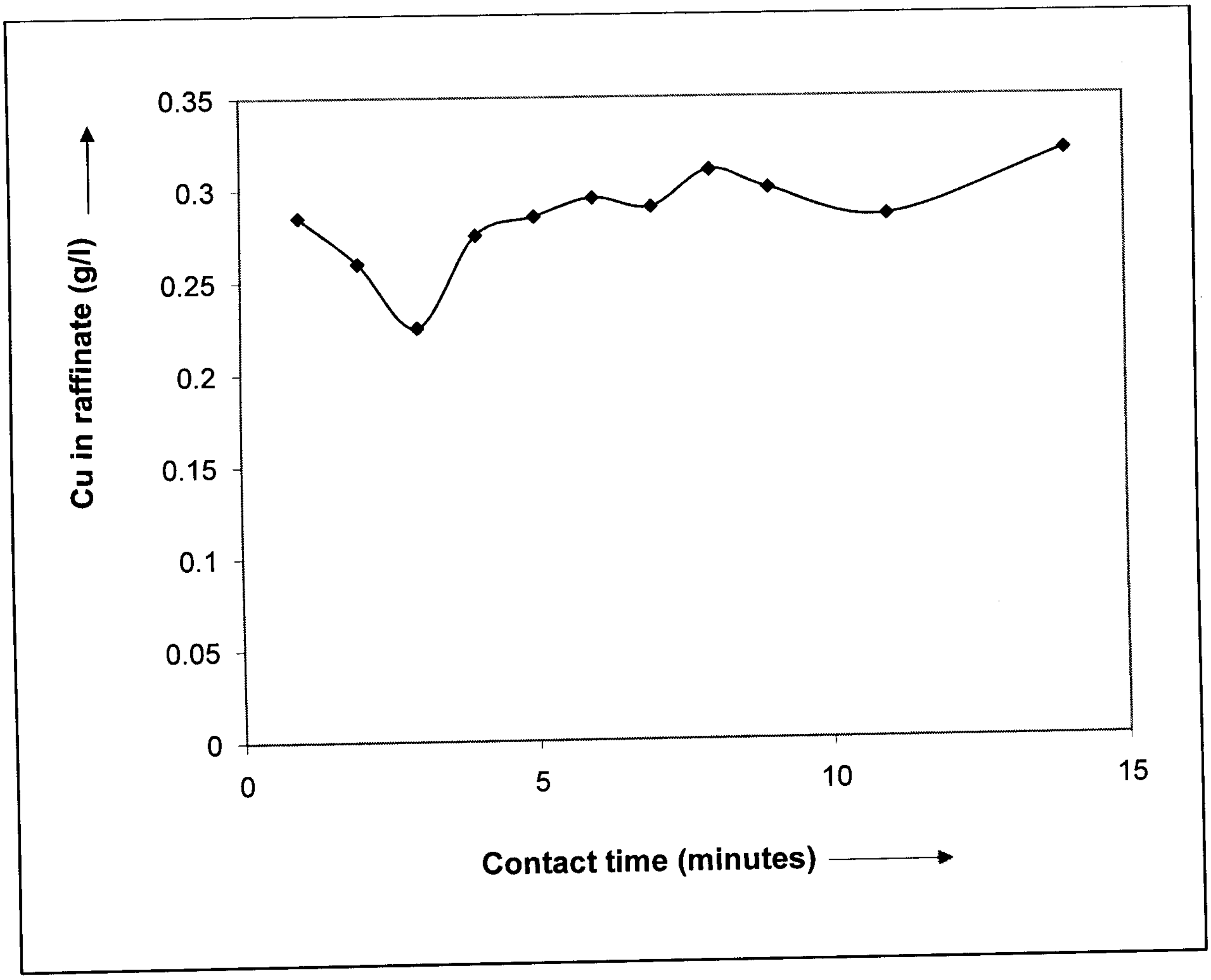

Figure 3.1: Effect of Contact time on extraction of Cu with LIX 984N at 20 v/v %. Pregnant Solution grade= 5 g/l, pH = 1.7 and temperature = 25° C.

The results in Figure 3.1 are in agreement with theory as they attest to the fact that solvent extraction reactions are very fast. Thus, within three (3) minutes, all reactions must have taken place and extension of time would just be a waste of energy which also comes with a cost.

3.5.2. REAGENT (LIX 984N) CONCENTRATION

For the same reagent concentration, experiments were done at both 25 and 35° C. While varying the LIX 984N concentration from 10 to 35 v/v %, the pregnant solution grade and pH were maintained at 5 g/l Cu and 1.6 respectively. The results obtained are shown in Figure 3.2.

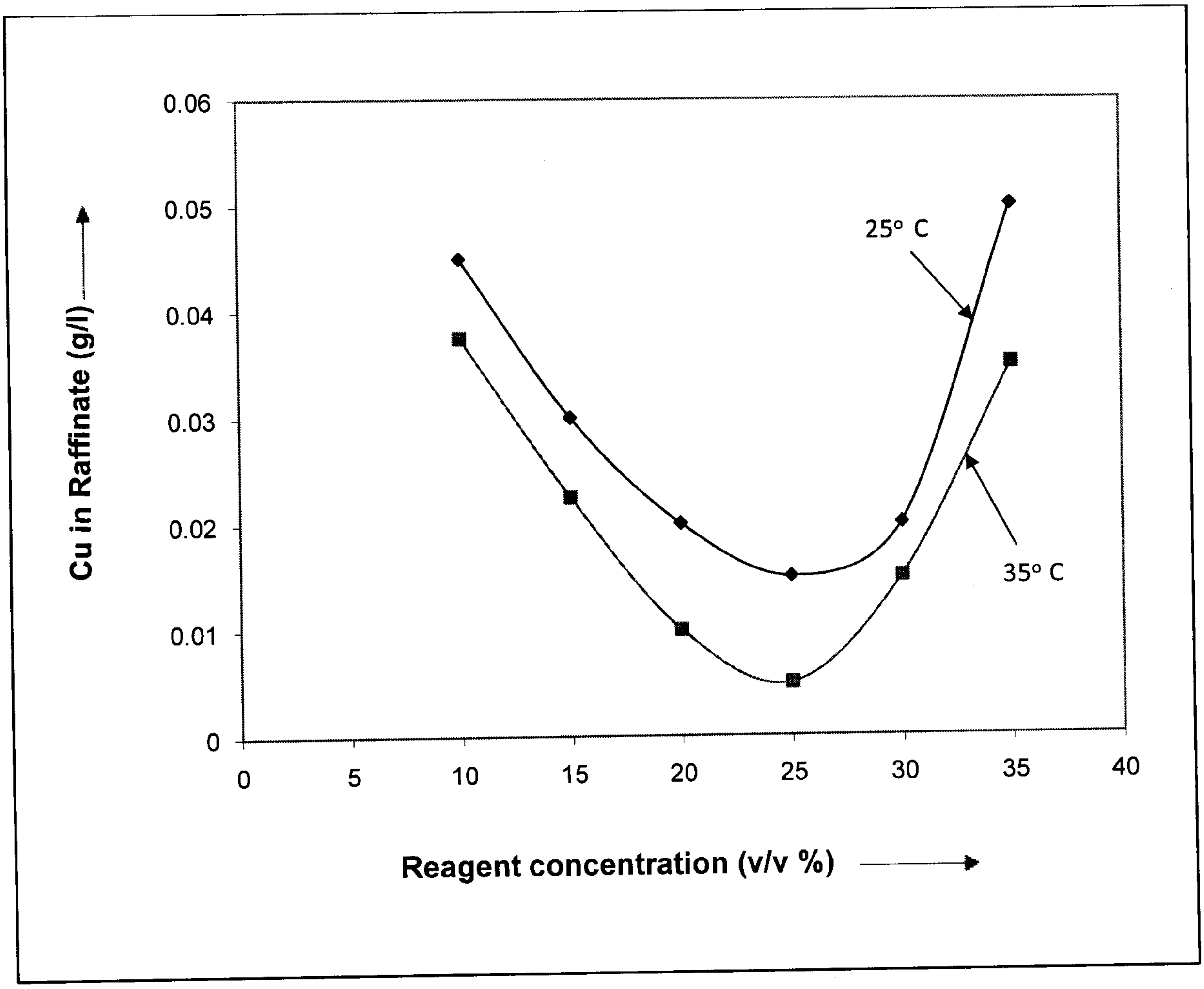

Figure 3.2: Effect of reagent concentration (LIX 984N) on extraction of Cu. pH = 1.7, Pregnant Solution grade = 5 g/l Cu.

It can clearly be seen from Figure 3.2 that maximum extraction is obtained at a reagent (LIX 984N) concentration of 25 v/v %. Besides, the results are in agreement with theory on the effects of viscosity. Beyond 25 v/v % reagent concentration, viscosity becomes more pronounced thereby inhibiting proper mixing between the organic and aqueous phases. Below 25 v/v %, viscosity is low and there is thus maximum contact between the two phases. It can also be observed that extraction increases with temperature. Fluctuations are therefore expected in solvent extraction operations as the plant runs throughout the year. In hot season, the fluid viscosity will be low thereby improving extraction while the opposite occurs in cold season. Taking into account the cost of LIX 984N and the fact that the graphs were curving smoothly, the reagent concentration was optimized at 22.5 v/v %. The cost 2.5 v/v % outweighs the gains. The other experiments were thus done at 22.5 v/v %.

3.5.3 EFFECT OF pH ON EXTRACTION OF COPPER

Using a pregnant solution with a constant grade, temperature and LIX 984N concentration of 5 g/l Cu, 25° C and 22.5 v/v % respectively, the pH was varied between 0.8 and 2.6. Basing on the organic lording, pH isotherms for Copper (Cu) and Iron (Fe) were generated and are shown in Figure 3.3.

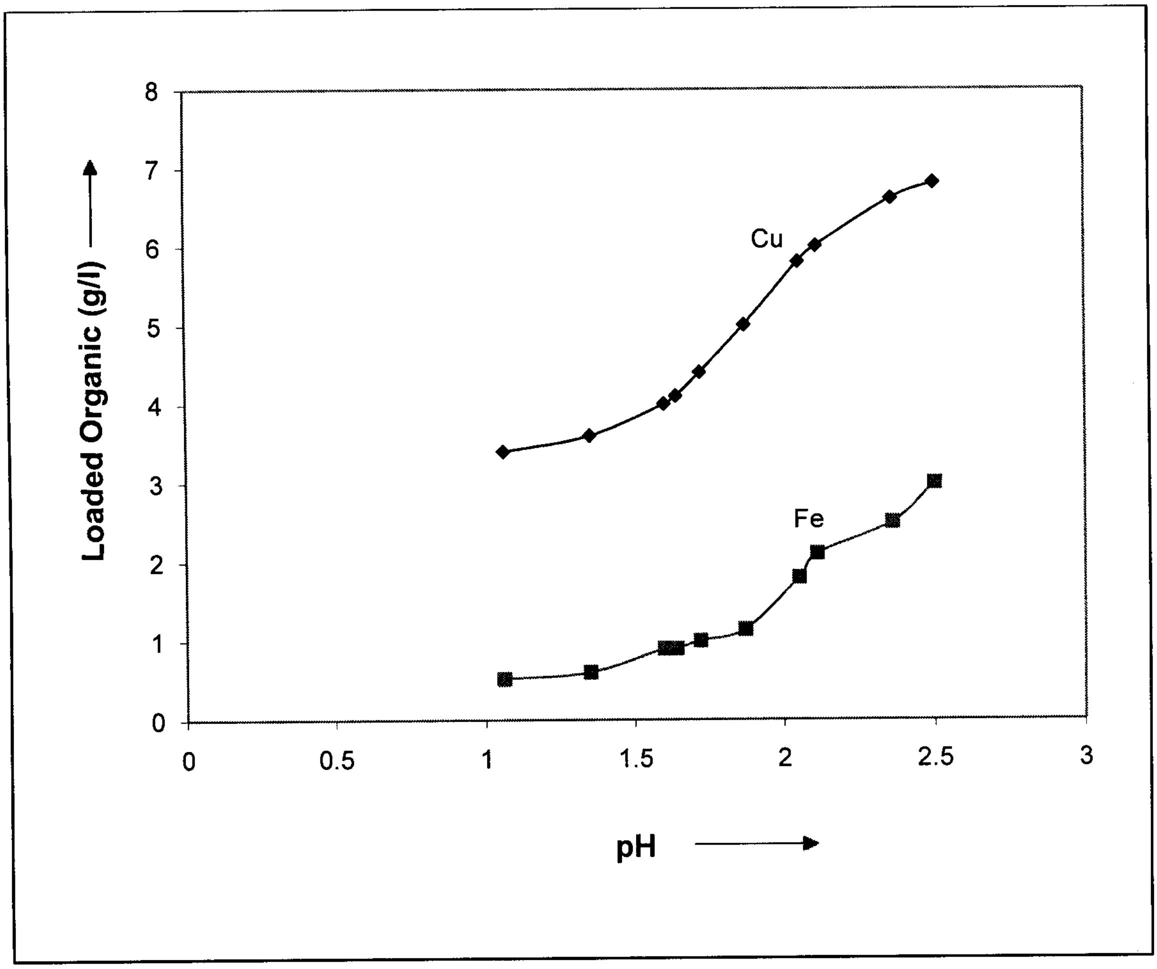

Figure 3.3: pH Isotherm obtained using LIX 984N. Pregnant solution at 5 g/l Cu, LIX 984N concentration = 22. 5 v/v % and temperature= 25 °C.

Within the pH range investigated, the Copper and Iron (Fe) loading were seen to be rising. It should however be noted that Fe together with its ferrous and ferric ions present problems downstream in the electro-winning section by way of cyclic reactions. These reactions consume a lot of current and are therefore undesirable. Use of low pH values however has an effect on copper loading by way of reversing the organic to aqueous reaction shown in equation (i) of the Literature review section (Chapter 2). There is thus need to raise the pH to a value which will tend to give a maximum and minimum copper and iron loading respectively. It should also be pointed out that high leaching efficiencies are obtained at lower pH values. Care should be taken in the selection of a neutralizing agent. Whereas good neutralizing agents can prove to be costly, cheap neutralizing agents may introduce impurities. The pH of 1.7 was thus chosen for other experiments.

3.5.4 McCABE THIELE DIAGRAM

The organic and aqueous phases were mixed in proportions ranging between 1:10 to 10:1. The pregnant solution grade, pH, temperature and LIX 984N concentration were maintained at 5g/l Cu, 1.7, 25° C and 22.5 v/v % respectively. The results obtained are shown in Figure 3.4.

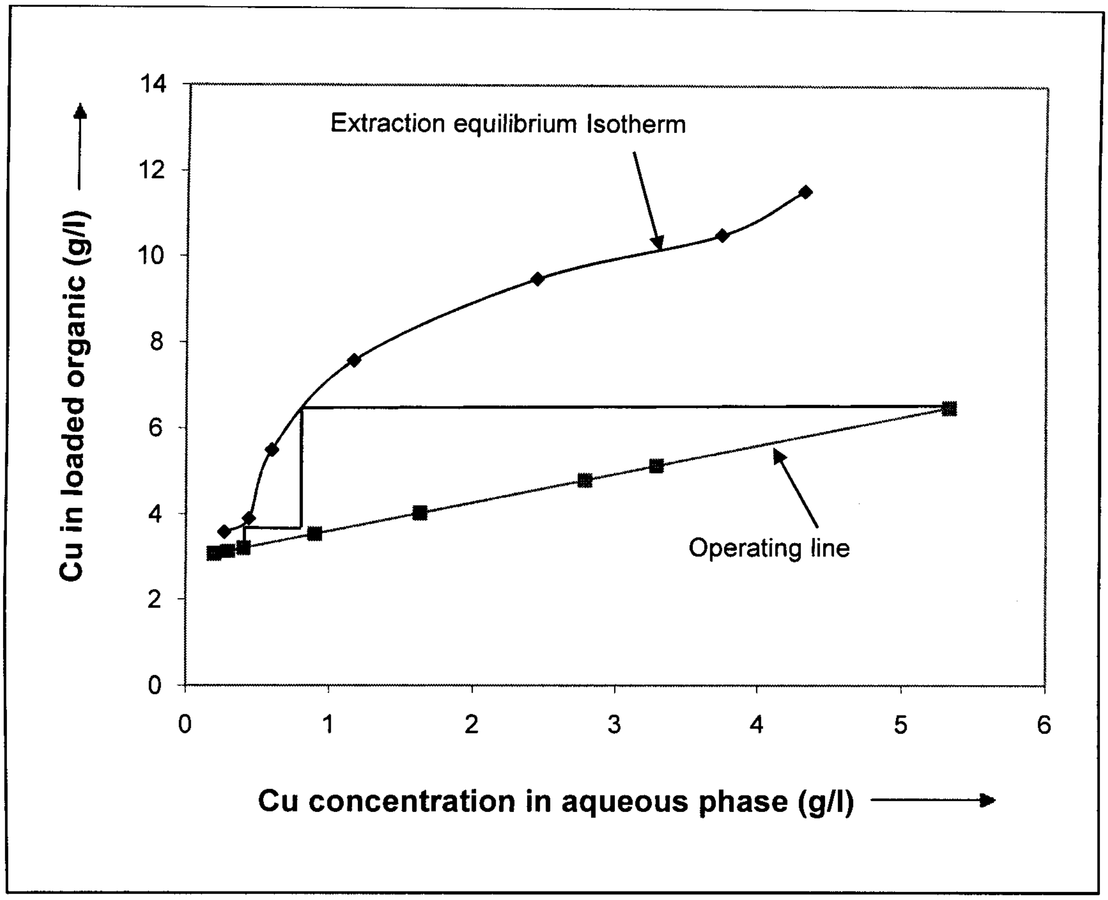

Figure 3.4: **McCabe Thiele diagram for LIX 984N at 25 ° C. (pH = 1.7, Pregnant Solution grade = 5.33 g/l Cu)**

From the McCabe Thiele diagram generated in Figure 3.4, it was established that two extraction stages are required to achieve a final raffinate of 0.15 g/l Cu. It is also worth noting that a very flat operating line results in fewer stages. Besides, the maximum copper loading of the organic will be very low. Such a set up thus requires too much organic to achieve a significant extraction of copper from the pregnant solution. A steep operating line on the other hand results in many stages. This is just a waste of resources as more money has to be used in the setting up of such equipment as mixers and settlers.

3.6 EXPERIMENTS ON COPPER SX USING CYTEC PILOT PLANT

From the work done on the laboratory scale, and McCabe Thiele diagram realized, it was concluded that two stages each were necessary for extraction and stripping.

The Cytec pilot plant was arranged with extraction and stripping having two stages each. Simulated to the Kansanshi High grade II SX plant, the two extraction mixer-settlers where labeled E1 and E2 while the stripping mixer-settlers where designated S1 and S2. E1 was connected to the loaded organic and pregnant liquor solution (PLS) stock tanks. S1 was connected to the spent electrolyte stock tank. PLS was fed to E1 by means of a pump and mixed with the partially loaded organic coming from E2. From E1, the organic left as loaded organic and got to the stock tank. Partially extracted PLS gravitated to E2 where it was mixed with the barren organic and came out as final raffinate.

In Stripping, the loaded organic were pumped to pumped to the S2 mixer while the spent electrolyte were pumped to the S1 mixer. In S2, the loaded organic was mixed with the partially strong electrolyte and after disengagement in the settler, it got to S1 as partially stripped organic. The aqueous left S2 as advance electrolyte. The partially stripped organic where mixed with the spent electrolyte in the S1 mixer. After disengagement, it came out as barren organic and was sent to the extraction stage to begin the cycle.

The pregnant solution coming from leaching had a grade ranging between 3 to 6 g/l Cu with a pH of about 1.2-1.7. The solvent used had concentration of 22.5 v/v%. The volumetric flow rates for pregnant solution, spent electrolyte and organic were 5 l/min, 2 l/min and 7.5 l/min respectively.

Shown below is a picture of the Cytec Pilot plant.

Figure 3.5: Picture of Cytec Pilot Plant.

3.6.1 PROCEDURE

The flow rates for loaded organic, spent electrolyte and PLS were measured hourly. Each mixer-settler were checked for phase disengagement time, phase ratios, phase continuities every after two hours. The dispersion band, crud at weir, organic and aqueous heights were recorded every after three hours. Organic recycle lines were opened in some cases to achieve the extraction and stripping mixer ratios of 1.5 and 2.0 respectively. As in the laboratory experiments, analysis in the pilot plant were done using spectrophotometry (AAS).

3.7.0 CYTEC PILOT PLANT RESULTS AND DISCUSSION

3.7.1 CYTEC PILOT PLANT PERFOMANCE

The Cytec pilot plant were arranged with two extraction stages and was fed with the same pregnant solution as that going to High grade II solvent extraction plant. The pilot plant performance was observed for a period of six (6) days. The copper tenor and pH of the pregnant solution were as shown in Figure 3.6. During the same period, the organic, aqueous interface heights and the crud at weir were observed and were shown in Figures 3.7, 3.8 and 3.9 respectively.

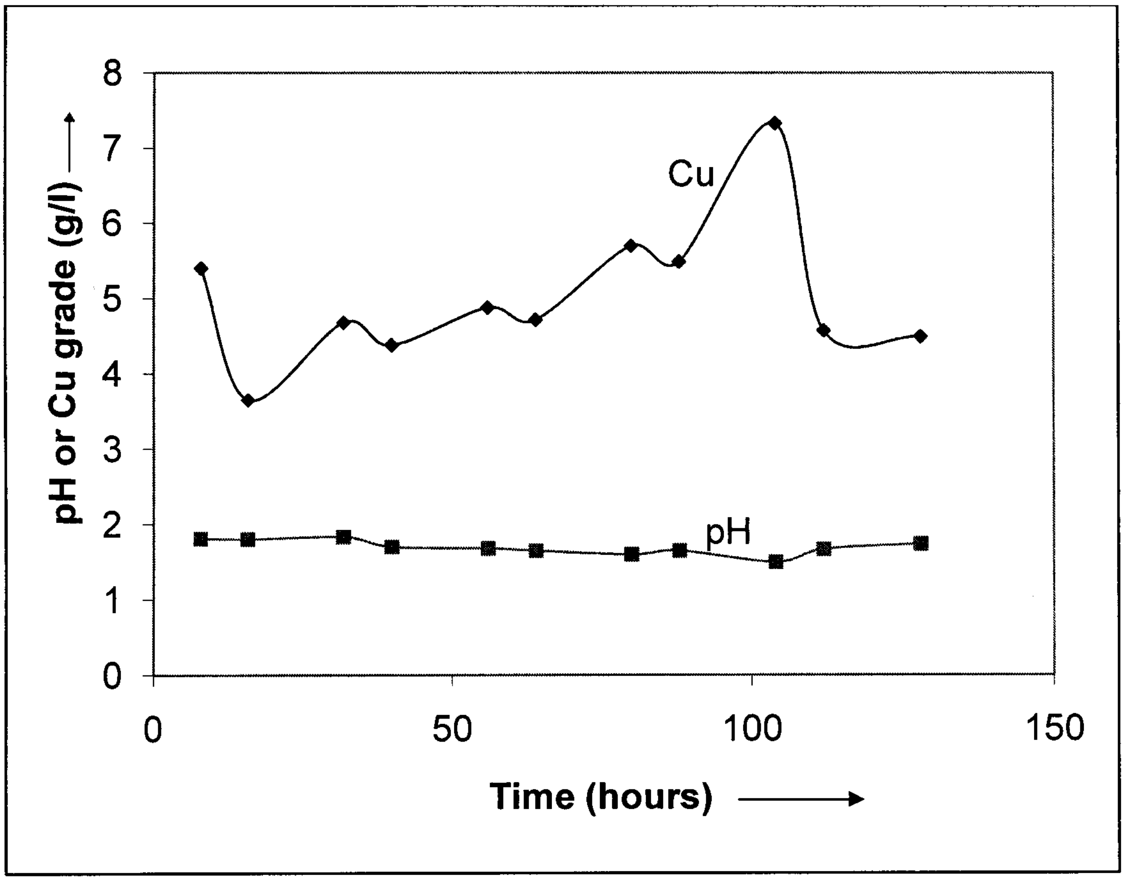

Figure 3.6: Pregnant solution with respective pH into the Cytec Pilot Plant.

The pregnant solution grade from leaching and counter-current was varying considerably as can be seen from Figure 3.6. The minimum and maximum grades recorded were 3.5 and 7.5 g/l Cu. The copper grade of the pregnant solution is largely dependent upon the leaching conditions, the type of ore and the extent of leaching. Such a grade and pH gave the results shown in Figure 4 .

The organic and aqueous interface heights for the Cytec pilot plant were as shown in Figures 3.7 and 3.8.

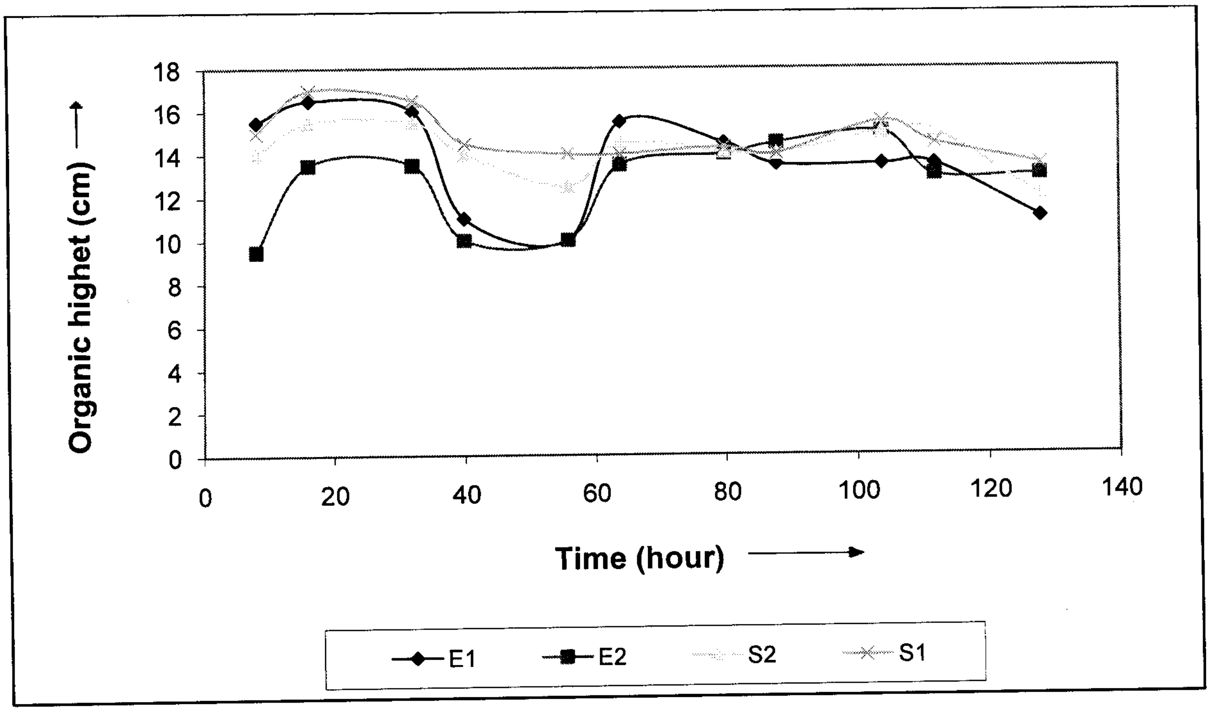

Figure 3.7: Organic interface height in the Cytec pilot plant.

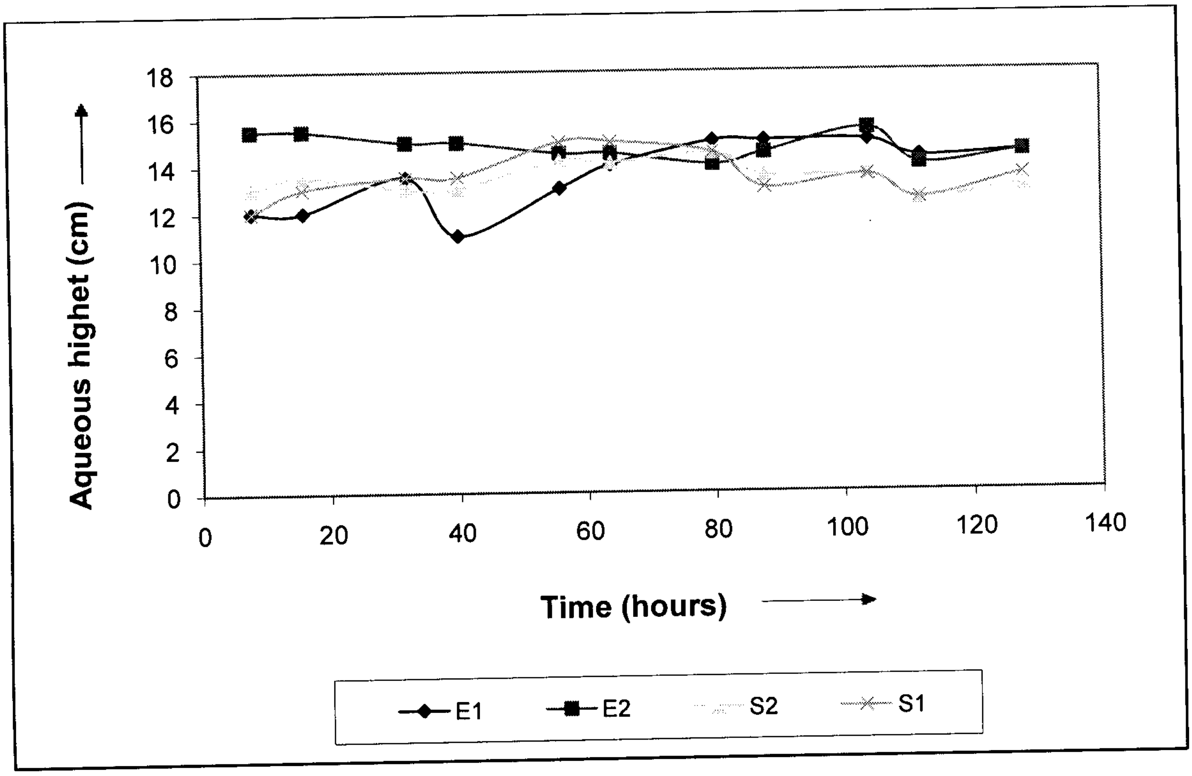

Figure 3.8: Aqueous interface height in the Cytec pilot plant.

As can be seen in Figures 3.7 and 3.8, the Cytec pilot plant was run at average aqueous and organic heights of 14 and 13 cm respectively. From theory, a smaller organic interface height results in entrainment of aqueous pockets into the organic phase. This also causes a carryover of impurities in the organic phase. In many cases, there is a loss of organic due to spillages which may as well be a result of improper flow rates. There is thus need for adequate organic and aqueous heights. It is difficult to measure the aqueous height on the main plant. However, it would be recommended that the High Grade II SX plant is run between 15 to 25 cm organic heights.

The crud at weir recorded over a period of six days was as shown in Figure 3.9 below.

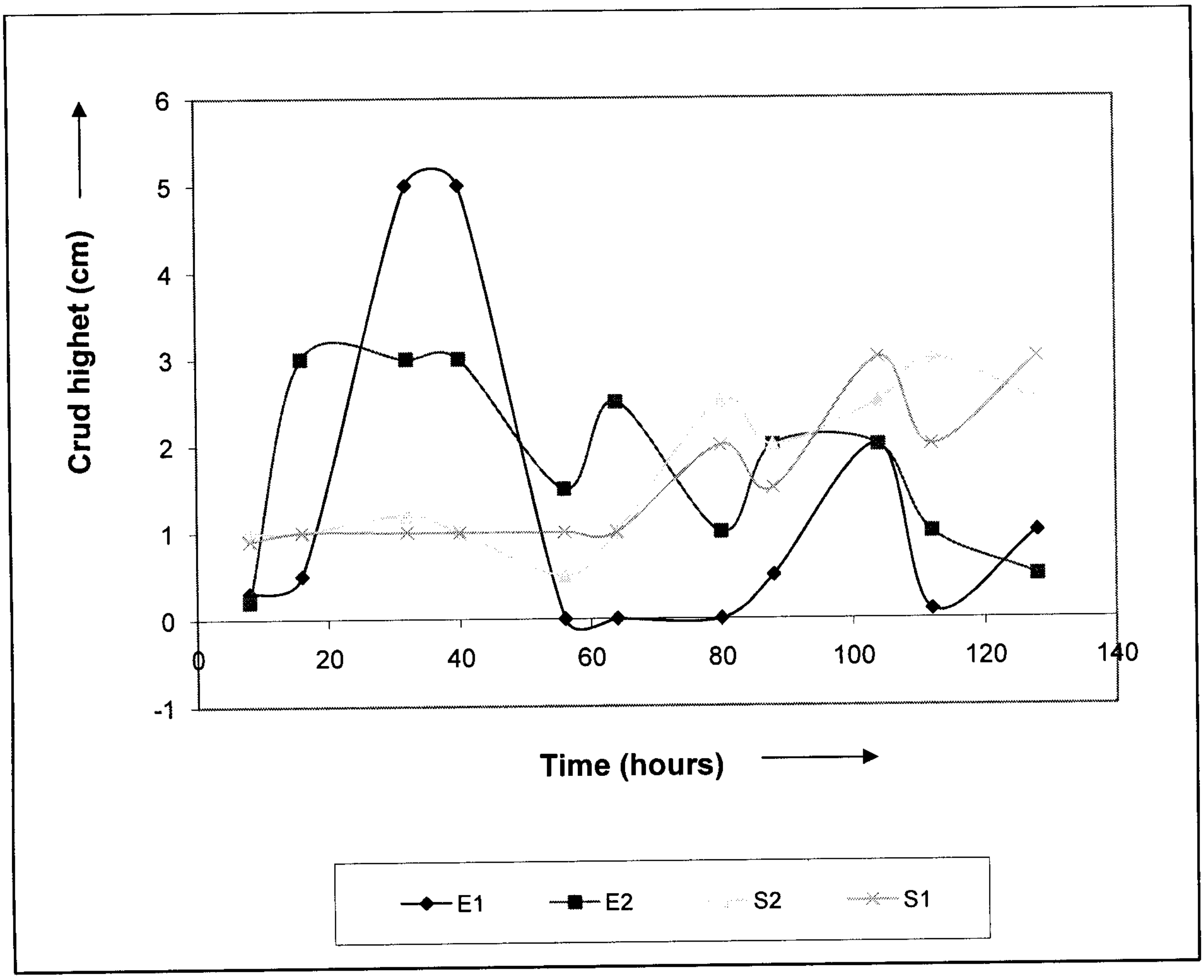

Figure 3.9: Crud height at weir in the Cytec pilot plant.

From figure 3.9, the crud was seen to be disappearing in the extraction stages while increasing in the stripping stages. On the main plant, this problem is however minimized by continuous pumping out of crud to a machine which squeezes out the organic. Figure 4 shows the overall performance of the Cytec pilot plant.

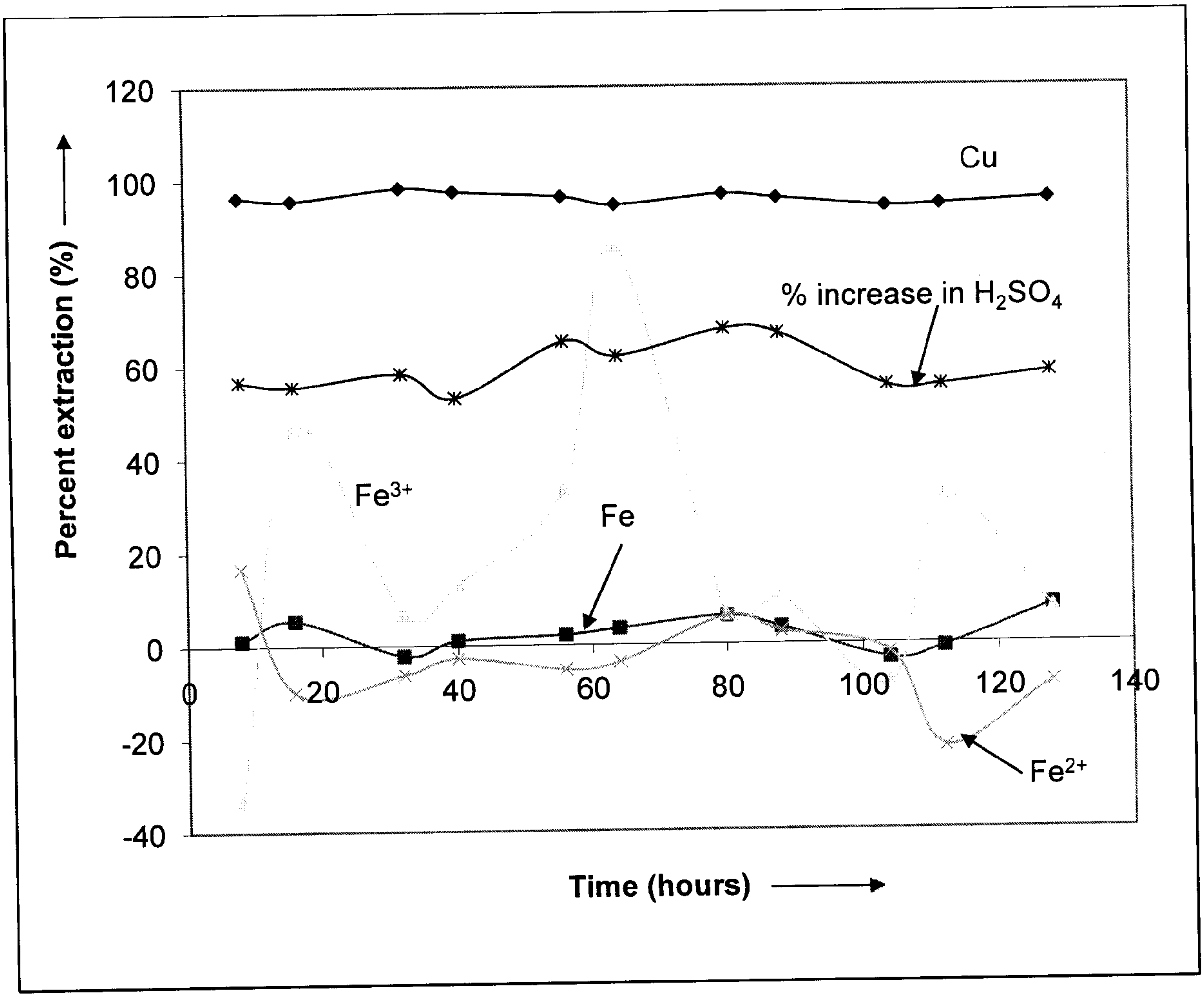

Figure 4: Cytec Pilot Plant Performance. (LIX 984N concentration = 22. 5 v/v %, Pregnant solution grade and pH as in figure 5, temperature 35-36 ° C.)

Application of the optimized parameters to the Cytec pilot plant gave an impresive result as can be seen from Figure 4. A good copper recovery of 95 to 98% was obtained from the pregnant solution with an average grade of 5 g/l Cu. The variation in pregnant solution grade can therefore be seen to have no effect on copper recovery. It can also be noticed that the iron and ferrous ion recoveries were very minimal and within acceptable standards. Ferric ion recoveries were inconsistent. This however represents negligible changes in quantitative terms and is far less than the amounts of iron and ferrous ions. It can thus be described to be within acceptable levels.

CHAPTER FOUR

4.1 CONCLUSION

A good copper recovery can be obtained with minimum transfer of impurities provided the operating parameters are well set. Besides, losses of organic due to spillage can be minimized provided the organic and aqueous heights are in correct ratios.

4.2 RECOMMENDATIONS

It would be recommended that the High Grade II SX plant continues operating at the current operating parameters in terms of extraction stages, temperature, organic and aqueous flow rates. A pH of 1.7, an organic height of 15 to 25 cm and a reagent (LIX 984N) of 22.5 v/v % should be implemented in the extraction stage.

Finally, the staff at Kansanshi mine should look into optimizing the stripping stage.

REFERENCES

1. Allan, H. F. (ed), Extractive Metallurgy Laboratory Exercises; Instructor's guide and solution Manual. New York: AIME Inc., 1983.

2. Chewe, S. Zinc and Cobalt removal from Nkana Cobalt plant ferric overflow solution using Di-2-Etheyhexyl Phosphoric acid (D2EPHA). Final year Project, 1998.

3. Jackson, E. Hydrometallurgical Extraction and Reclamation. England: Ellis Horwood Limited, 1986.

4. Mtonga, J. A preliminary Laboratory evaluation of Solvent Extraction of Copper in ZCCM Cobalt plants. Final year Project, 1995.

5. NYIRENDA, R. L. UNZA, School of Mines, Department of Metallurgy and Mineral Processing, Fourth year "hydrometallurgy" Lecture notes, 2006.

6. Solvent Extraction Operating Manual, Kansanshi Mine, 2004.

7. Solvent Extraction Reagents and Applications, Cognis MCT Redbook, 2007.

APPENDIX I

Table 1: Mixing time

Mixing time (minutes)	Cu in Raffinate (g/l)		
Time (minutes)	At 25^0 C	At 35^0 C	Average
1	0.39	0.18	0.285
2	0.35	0.17	0.26
3	0.3	0.15	0.225
4	0.39	0.16	0.275
5	0.39	0.18	0.285
6	0.4	0.19	0.295
7	0.39	0.19	0.29
8	0.42	0.2	0.31
9	0.4	0.2	0.3
11	0.38	0.19	0.285
14	0.42	0.22	0.32

Table 2: Reagent concentration

Reagent Concentration (v/v %)	Mixing time (Min)	Cu in Raffinate (g/l)								
		A	B	Av	C	D	Av	E	F	Av
10	3	0.06	0.03	0.045	0.08	0.06	0.07	0.04	0.035	0.0375
15	3	0.04	0.02	0.03	0.04	0.03	0.035	0.03	0.03	0.03
20	3	0.03	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.015
25	3	0.02	0.01	0.015	0.01	0	0.005	0	0.01	0.005
30	3	0.02	0.02	0.02	0.02	0.02	0.02	0.015	0.015	0.015
35	3	0.04	0.06	0.05	0.04	0.02	0.03	0.04	0.03	0.035

Table 3: Effect of pH

pH	Cu in organic (g/l)	Fe in organic (g/l)
2.5	6.8	3
2.36	6.6	2.5
2.11	6	2.1
2.05	5.8	1.8
1.87	5	1.14
1.72	4.4	1
1.64	4.1	0.9
1.6	4	0.9
1.35	3.6	0.6
1.06	3.4	0.52

Table 4.1: Cytec pilot plant performance

Time (hours)	Cu			Fe		
	PLS(g/l)	Raffinate(g/l)	% Recovery	PLS (g/l)	Raffinate (g/l)	% Recovery
8	5.40	0.20	96.30	0.87	0.86	1.15
16	3.65	0.16	95.62	0.55	0.52	5.45
32	4.68	0.08	98.29	0.94	0.96	-2.13
40	4.38	0.11	97.49	0.95	0.94	1.05
56	4.88	0.18	96.31	0.94	0.92	2.13
64	4.72	0.26	94.49	0.87	0.84	3.45
80	5.70	0.19	96.67	0.84	0.79	5.95
88	5.49	0.23	95.81	0.86	0.83	3.49
104	7.33	0.44	93.99	1.23	1.27	-3.25
112	4.58	0.26	94.32	1.20	1.21	-0.83
128	4.50	0.20	95.56	1.24	1.14	8.06

Table 4.2: Cytec pilot plant performance

Time	Fe^{3+}			Fe^{2+}		
(hours)	PLS(g/l)	Raffinate(g/l)	% Recovery	PLS(g/l)	Raffinate(g/l)	% Recovery
8	0.27	0.36	-33.33	0.60	0.50	16.67
16	0.15	0.08	46.67	0.40	0.44	-10.00
32	0.30	0.28	6.67	0.64	0.68	-6.25
40	0.23	0.2	13.04	0.72	0.74	-2.78
56	0.18	0.12	33.33	0.76	0.80	-5.26
64	0.07	0.01	85.71	0.80	0.83	-3.75
80	0.16	0.15	6.25	0.68	0.64	5.88
88	0.10	0.09	10.0	0.76	0.74	2.63
104	0.23	0.25	-8.70	1.00	1.02	-2.00
112	0.48	0.33	31.25	0.72	0.88	-22.22
128	0.40	0.37	7.50	0.84	0.91	-8.33

Table 5: Vales for the McCabe Thiele Diagram

0/A Ratio	Cu in aqueous phase (g/l)	Cu in Organic phase (g/l)	Operating line
10:1	0.2	3.84	3.066667
5:1	0.295	4.085	3.13
2:1	0.405	5.28	3.203333
1:1	0.9	6.96	3.533333
1:2	1.63	8.775	4.02
1:5	2.785	9.9	4.79
1:10	3.29	10.74	5.126667
	5.33		6.486667

APPENDIX II

1.

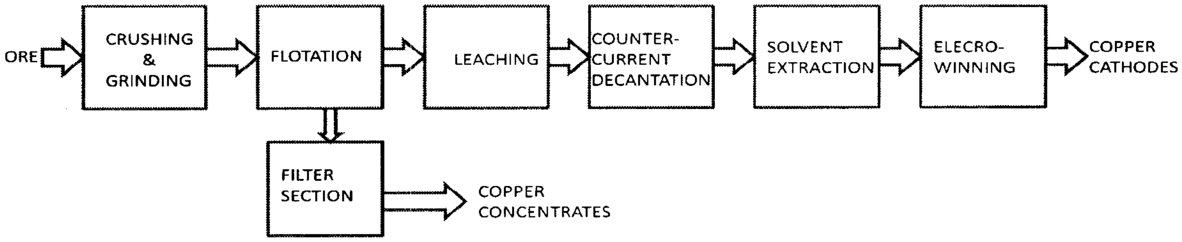

Figure 1.0. Simplified flow sheet of the Kansanshi Metallurgical Plant

2. Overflow (O/F) and Underflow (U/F)

In any separation technique, overflow refers to the much finer and lighter component of the slurry and is usually richer in mineral values. Usually gets out from the top of the vessel.

Underflow refers to the coarser and denser component of the slurry and is usually subjected to further treatment for the recovery of mineral values. Usually gets out from the bottom of the vessel.

3. McCabe Thiele diagram.

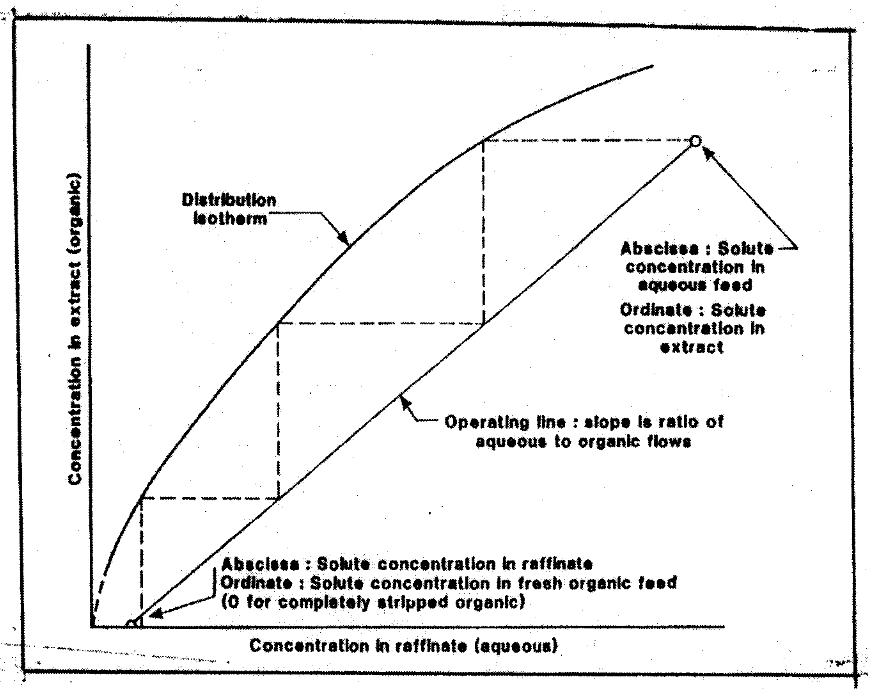

FIG 2 Hypothetical McCabe Thiele diagram