THE UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

DEPARTMENT OF METALLURGY AND MINERAL PROCESSING

MM 590-FINAL YEAR PROJECT REPORT

THE EFFECT OF GRIND AND INCREASED RESIDENCE TIME ON THE FLOATABILITY OF MUFULIRA COPPER ORE

BY

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THE SUBMISSION OF THIS REPORT WAS THE PARTIAL FULFILMENT TO OBTAIN THE BACHELOR'S DEGREE OF MINERAL SCIENCE (B. Min.Sc.) OF THE UNIVERSITY OF ZAMBIA, SCHOOL OF MINES.

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DEDICATION

To my sweetest Mum and Dad for them being there for me, their patience and encouragement rendered through out my entire years of study.

My brothers, sisters and friends for giving me your support, care, inspiration and the confidence you thus gave me to go on.

ACKNOWLEDGEMENTS

I wish to express my indebtedness to the following people for their assistance in one way or another without which this the project would not have been a success.

I am grateful to all the Metallurgists at Mufulira Concentrator, for their invaluable advice particularly Mr. Sichivula, Mr. Sikaona and Mr. Jose Chamanika.

I would also like to express my appreciation to Mr. J.Manchisi, my project supervisor and lecturer, for sharing his time in giving me advice on the composition, and arrangement and making helpful and valuable comments of this project.

ABSTRACT

The purpose of this project was to evaluating the effect of grind time and increased residence time on the floatability of the Mufulira copper ore on a laboratory scale. The project was proposed mainly because of periodic fluctuations in the mineralogy of this complex copper sulphide ore. The aim was therefore to address this problem and generally improve the flotation performance of the Mufulira concentrator.

Systematic sampling was employed where copper ore samples were cut from six different selected conveyor belts each feeding the ball mills. Grinding time was done from 15 to 40 minutes at an interval of 5 minutes. Thereafter, flotation testworks were carried out to determine the effect of increased residence time on the flotation performance. However, 25 minutes grind time was the optimum mesh of grind with corresponding copper recovery of 94.8% and a grade of 24.9%. At 4 minutes rougher and 8 minutes scavenger was the optimum residence time with copper recovery and grade of 88.9% and 21.2% respectively. All other parameters were kept constant such as reagent dose rate at 30 gram per litre and pulp density except for time which was under evaluation. It is recommended that the optimum mesh of grind should be 25 minutes at flotation time of 4 minutes rougher and 8 minutes scavenger and testworks should be done at a decreased grind time and decreased residence time to determine the floatability of the Mufulira copper ore.

TABLE OF CONTENTS

ABBREVIATIONS

Cum.	Cumulative
TCu.	Total copper
AICu	Acid insoluble copper
ASCu	Acid soluble copper
Tails	Tailings
%wt	weight percent
Conc	concentrate
SIPX	Sodium isopropyl xanthate
PAX	Potassium Amyl xanthate
R	Rougher
S	Scavenger
MIN	Minutes

CHAPTER ONE

1.1 INTRODUCTION

For a long time, the study of size reduction was based on energy consumption during grinding. This is because of the fact that size reduction operation prior to flotation is accompanied by large cost due to the high power consumption.

Therefore, this report is based on laboratory grinding and flotation testwork carried at Mopani Copper Mine, in Mufulira.

1.2 BACKGROUND

Basically, Mufulira concentrator treats copper sulphide ore from the east section of the mine, at a rate approximately 250 000 to 300 000 tonnes of ore per month. The Mufulira ore consists of chalcopyrite, chalcocite and bornite as disseminated particle in fine grained, siliceous rock. Other minerals presenting small content in the ore are malachite, covellite, chrysocolla and some native copper.

The Mufulira concentrator produces high-grade copper concentrate which is subsequently sent to the Mufulira smelter. The operations of the concentrator are maintained and effectively controlled with the aim of achieving their target setting.

The project was formulated because of the fluctuations in the mineralogy of the complex copper sulphide ore over a short period of time. Therefore, the technical management at Mufulira concentrator formulated this study in order to evaluate the effect of grind time and the increased residence time on the floatability of the Mufulira copper ore in view to improving the flotation performance.

1.3 OBJECTIVE

The main objectives of this study were to

- determine the effect of grind time on the flotation performance, and subsequently
- determine the effect of increased residence time on the flotation performance.

1.4 PLANT DESCRIPTION

The Mufulira concentrator is sub-divided into the east crushing plant; the milling, flotation, filter plant as well as the tailing pump house and tailing dump.

1.4.1 Crushing Plant

The purpose of crushing is to reduce the run of mine ore to the size that can be milled cost effectively. Ore crushed by the primary crushers to less than 150mm underground is hoisted into the surface bin and a series of conveyors or networks facilitates the delivery of the ore from the shaft bins to standard bin. The smooth flow of the ore on the conveyors is influenced by the vibratory feeders under the bin. However, moisture content must be less than or equal to 2.00% H_2O for the ore hoisted in the surface bin. There are two types of crushers currently being used and these are the Hydrocone H6800 and the Standard Symons cone crusher. The ore is screened whereby the oversize is re-circulated in the closed circuit operation with the crusher. The screened undersize which is the final product of this operation is conveyed to the milling section in the fine storage bins.

1.4.2 Milling

The purpose of the milling is to reduce the crushing plant product to the size that can be floated cost effectively. The milling section receives crusher product at a minimum size of 70% passing 9.51mm. The product is fed into the ball mills which also operate in closed circuit with the hydrocyclone. The overflow from the cyclone goes for flotation whereas the underflow is fed back to the ball mill for regrind. This is aimed at 55% passing 75microns with the pulp density in the range of 1240-1600 gram per litre (gpl).

1.4.3 Flotation

This section consists of a three stage process i.e. the rougher, cleaner and scavenger. It is in this section where reagents are utilized and these are sodium isopropyl xanthate (SIPX) and potassium amyl xanthate (PAX) for the rougher and scavenger respectively. Aero-froth 65 and beta-froth 65 are the frothers used. Lime is added as a modifier to raise the pH of the pulp in the range of 10.5-12.5.

THE CURRENT CONCENTRATOR CIRCUIT

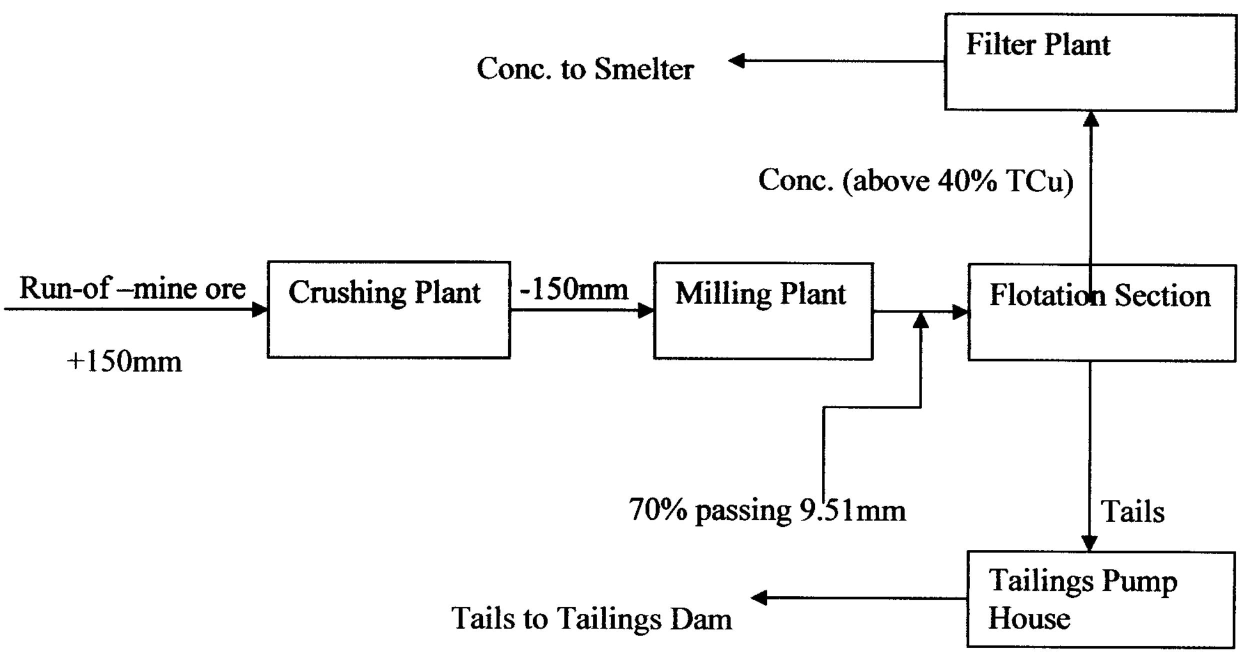


FIG.1. Material flow diagram for Mufulira Concentrator

CHAPTER TWO

2.0 Literature Review

2.1 Grinding

This is the last stage in the process of comminution where particles are reduced in size by a combination of impact and abrasion either wet or dry. It is performed in rotating cylindrical vessels mainly made of steel and are called tumbling vessels. These comprises of loose grinding media, which are free to move inside the mill, thus grinding the particle. The grinding media may be steel rods or balls hard rock or in some cases the ore it self (Wills, 1988).

Naturally, most minerals are finely disseminated and intimately associated with the gangue. Before separation can be under taken, the mineral must be initially "unlocked or liberated". While, this is achieved by crushing and grinding, to be specific grinding prior to flotation size reduction is up to some extent. It has been observed that grinding should be done at the optimum mesh of grind which is the particle size at which there is maximum profitability (Deelder, 1996).

Grinding is the most energy intensive operation in mineral processing and accounts for about 50% of the concentrator's energy consumption. Therefore over grinding and under grinding should be avoided to reduce difficulties faced in the flotation of slimes and coarse material respectively. Hence, there is a lower and upper size limit for the particle to be floated. Size reduction to a relatively coarse size does not liberate the mineral particle, flotation recoveries in this case will be poor as the particle size will not be small enough to be lifted by the air bubbles during flotation.

Grinding with a tumbling mill is influenced by a variety of factors which include speed of the mill load of grinding media and material, pulp level, size distribution of grinding media and solid-liquid ratio and circulating load.

i. **Speed of mill.**

The speed must not be too high because this brings about centrifuging of the charge and thus grinding does not take place. At the same time the speed must not be too low because this will promote the production of slimes. An action called cateracting action must result from the speed of the mill accompanying a free fall of grind media for favourable impact giving a high capacity and efficiency.

ii. **Load of grind media and material.**

Increasing these will require more power until the maximum value is achieved and the power requirements decreases with increasing load as the center of the load approaches the axis of rotation.

iii. **Pulp level.**

This will require high power if the pulp level is high. The lower pulp level entails greater freedom of movement of grinding media hence more effective grinding. Therefore, the ball mills should be filled slightly more than half full with the materials and balls.

iv. **Solid-liquid ratio (Pulp dilution)**

Too dilute a pulp increases metal to metal contact, giving increased steel consumption and reduced efficiency. Therefore, ball mills should operate between 65 – 80% solids by weight depending on the ore. The viscosity of the pulp increases with the fineness of the particle, fine grind circuit may need lower pulp densities.

v. **Circulating load.**

In order to achieve grinding to required size in a single step might result in wasteful over grinding. To avoid over grinding and giving an effective grinding, the residence time for material to be in the mill must be short.

Generally, increased circulating load results due to the average size of entering feed becoming lower, interstitial loading is improved with closed adjustment of solid-liquid ratio.

In practice, ores are ground to an optimum mesh of grind determined by laboratory and pilot scale test work to produce an economic "degree of liberation" which is the percentage of the mineral occurring as the particle in the ore in relation to the total content. This can be high if there are weak boundaries between mineral and gangue particles. The optimum mesh of grind is the particle size at which the most economic recovery can be obtained. This depends not only on the grindability which is the ease with which the ore can be comminuted but also the ease with which the comminuted ore can be floated (Wills, 1988).

2.2 SIEVE ANALYSIS

Size control is important in order to check the quality of grinding, the extent to which values are liberated from the gangue at various particle sizes and to aid specific examination of ore constituents. Size analysis of the ground ore shows whether mineral particles are properly liberated and how grinding affect recovery of the mineral values from the ore.

Standard test sieves are used for sieve analysis. Laboratory sieves consists of woven wire, which results in square aperture with small tolerance (Kelly, 1982). There are different types of sieve series. These series differ mainly in their relationship between aperture and wire size. They include US sieve series, international test sieve series and British standard series. Sieve analysis is accomplished by passing a known weight of sample material through the stack of test sieves and the entire stack shaken. The weight retained on each sieve is then used to determine the percentage weight in each size fraction. Sieving can be carried out on dry or wet material.

Sieving when applied to irregularly shaped particle is complicated because "near mesh" particles may pass only when presented in favorable position. This in many cases causes the blinding and obstruction of the sieve aperture and thus reduces the effective area of the sieving medium. Blinding is most serious with sieves of very small aperture size (Wills, 1988). Therefore, the effectiveness of a sieving test depends on the amount of material put on the sieve and the type of movement imparted to the sieve. The charge material should not be too large, so that each particle is given a chance to meet an aperture in the most favourable position, for sieving in a reasonable time. On the other hand, the charge must contain enough particles to be representative of the bulk sample (Wills, 1988).

2.3 FROTH FLOTATION

Froth flotation is a means of treating a pulp of finely ground ore so that valuable or desired mineral is obtained in a concentrate which will be amenable to further process. The process involves imparting a water repellent (hydrophobic) character to the desired mineral with the aid of chemicals that are called collectors or promoters under favourable conditions, these chemically coated particles becomes attached to the air bubbles rising through a pulp and will thus float to the surface.

This is the cheapest and most extensively used process for the separation of chemically similar mineral and to concentrate ore for economical smelting.

Floatable minerals can be classified into non polar and polar type. The difference between the two types is based on the surface bonding. The surfaces of the non polar mineral have relatively weak molecular bonds, difficult to hydrate, and in consequence such mineral are hydrophobic. The ores containing these minerals for beneficiation usually require the addition of non specific collector to their pulp to aid the natural hydrophobicity of the floatable fraction.

Polar minerals have a strong covalent or ionic surface bonding and exhibit high free energies at their surface. These species are hydrophilic (water seeking) and need surface modifiers to render them amenable to flotation.

In froth flotation, the mineral is transferred to the froth or float fraction, leaving the gangue in the pulp. This is referred to as direct flotation which is the most widely practiced flotation process. The other types of flotation are bulk, reverse and differential flotation.

Froth flotation, therefore, consist of producing condition in which air bubbles form, or are introduced to the slurry of ground ore in water and the desired minerals are made to attach themselves to the bubbles. Air bubbles only continue to support the mineral if they form a stable froth, otherwise, they will burst and drop the mineral. These conditions can be achieved by using numerous chemical reagents.

2.3.1 Flotation reagents in general

For flotation to be effective, reagents must be added to the pulp. In general, the reagents are interfacial surface tension modifiers and/or flocculants (Crozier, 1992). Usually, these reagents are classified under five heading which are:

- Collector
- Frother
- Activator
- Modifier

i) Collector

Collectors are organic compounds used in flotation, which render selected mineral water repellent by absorption of molecules or ions on to the mineral surface, reducing the stability of the hydrated layer, separating the mineral surface from the air bubble to the level that attachment of the particle to the bubble can be made on contact.

Collectors may be non-ionizing or ionizing compound. Ionizing collectors are mostly widely used in sulphide flotation. They are usually sodium and potassium salts of certain acids. They dissociate into ions in water and have chemical structures which are heteropolar: i.e. the molecules contain a non polar hydrocarbon group and a polar group.

The non polar parts of the molecules are oriented towards the water phase and the polar orient itself towards the mineral surface. The non polar hydrocarbon radial has pronounced water repellent properties and hence they render the mineral surface hydrophobic by keeping water away from the mineral surface. Non ionizing collectors which are non polar compounds are practically insoluble in water. They render the mineral water repellent by its surface with a thin film.

Collectors are used in small amounts, substantially those necessary to form a monomolecular layer on particle surface. An increase in concentration apart from the cost tends to float other minerals, thus, reducing selectivity. An excessive concentration of the collector can have an adverse effect on the recovery of the valuable mineral, due to the development of multi-layer on the particle, reducing the proportion of hydrocarbon radicals (non polar group) oriented into the bulk solution. The hydrophobicity of the particles is thus reduced, and hence their floatability (Wills, 1988).

ii) Frother

These are surface active reagents that aid the formation and stabilization of air induced flotation froths. They concentrate at the air-water interface, helping to keep the air bubbles dispersed and preventing their coalescence.

The other functions of frothers are to:

- reduce the surface tension of the air-liquid interface in order that a stable bubble is produced in the system.
- influence the kinetics of bubble-particle adhesion.

- thin the liquid layer by interacting with the collector.
- stabilizes the bubble-particle aggregates.(Kelly,1982)

iii) Activator

Activators are reagents that alter the chemical nature of the mineral surfaces so that they become hydrophobic due to the action of the collector. They are generally soluble salts, which ionizes in solution, the ion then reaching the mineral surface. A good example, if the mineral to be floated is an oxide in nature, an activator to form a pseudo-sulphide layer around the mineral can activate it surface. This will then render the mineral amenable to the action of a collector.

iv) Modifier

These are reagents used in flotation to modify the action of the collector, either by intensifying or reducing its water-repellent effect on the mineral surface. Thus, they make the collector action more selective towards certain minerals. These are classed as the regulating agents which also include the activators, depressants and pH modifiers i.e. lime. The same modifiers can perform as a depressant or activator or both depending on the condition under which it used.

2.3.2 EFFECT OF GRINDING ON FLOTATION

Many factors influence the flotation process. According to Matis and Zouboulis, (19995) among the principal factors are particle size, pulp aeration, bubble mineralization, agitation intensity, residence time of bubble in the pulp, pulp density. Others includes the specific gravity of the particle, presence of slimes, hydration of the surface, and adsorbed layer of flotation reagents (Matis and Zouboulis, 1995)

Grinding has the obligation exercise close control on product size. Undergrinding of the ore will of course result in the product that is too coarse with the degree of liberation too low for economic separation while over-grinding needlessly reduces the particle size of the substantially liberated major constituents usually the gangue and may reduce the particle size of the minor constituent (usually the mineral) below the size required for most efficient separation.

2.3.3 Flotation of large particles

In froth flotation, the particle size upper limit is 200-300 micron, whereas the lower limit is 5-10 micron with the desired mineral exposed at part of the particle's surface. Therefore, if the particle exceeds the upper limit in a given instance, they can not be floated under the prevailing condition. The upper size limit defines the size at which the air bubbles can no longer physically lift the particles to the surface. The probability of the particle being detached from the air bubble is high due to the heaviness of the particle as a result the larger particle are retained at the bottom of the flotation cell and this will lead to the loss of the valuable mineral in the tailing fraction. However, in order to recover the valuable mineral that reports to the tailing, a further regrind or liberation will be required and this entails an extra cost because grinding alone is the highest cost operation (Wills, 1988).

On the other hand there are essential conditions necessary for the flotation of large particles. This includes the following:

- Particle surfaces must be rendered as water repellent as possible by the use of increased amount of collector.
- Increased pulp aeration must be employed in order to produce favourable condition for "group" flotation of large particles by several bubbles.

2.3.4 Flotation of extreme fine particles

According to Glembtskii (1972), the extremely fine slimes particles which are present in the pulp have profound effect on flotation.

The following phenomena are apparent when slimes are present in the pulp:

- It becomes significant with the increasing demand for minerals and the continuously declining grade of available ore.
- Low particle momentum
- Contamination of the froth product by small gangue fraction due to physical entrainment.
- Low probability of particle collision (Pc)

  Pf= Pc. Pa. Pd

  Where Pf = flotation probability

  Pc = probability of particle-bubble collision

  Pa = probability of particle-bubble attachment

  Pd = probability of particle-bubble detachment
- There is undesirable coating of air-bubble surface by slime particle. This will prevent normal sized flotation particles from adhering to these coated air bubble thus hindering flotation of valuable.
- There is also an undesirable coating of a valuable particle with ultra fine gangue slime. This will render the valuable particle surface hydrophilic, thus suppressing flotation because slimes are generally hydrated in many ways.

2.3.5 Air

Air used in flotation is either induced by the action of the impeller of the flotation machine or super charged i.e. it is introduced through the internal blower. The role of air in flotation is to provide the necessary bubble, which in turn generate the froth which will act as separating medium to segregate and remove the valuable mineral from the gangue. (Arbiter, 1985)

CHAPTER THREE

3.0 EXPRIMENTAL PROCEDURE

The testwork was done on laboratory batch grinding and flotation basis for the Mufulira copper ore.

3.1 Apparatus

- One meter long sample cutter
- Buckets
- Scoops
- Electric balance
- Nest of sieves and sieve shaker machine
- Laboratory ball mill. Mill steel balls of 0.1153kg on average as grinding media and volume of 7.5litre.
- Laboratory Denver flotation machine (1500 RPM)
- Flotation cell 5000 cm^3 capacity
- Drying oven
- Measuring cylinder (1000ml), stop watch, wash bottle, syringes, funnel, flotation collection plates, paddle, sample envelop, brush and washing detergent and plastic bags.

3.2 Reagents

Xanthate collectors were used, especially for easy to treat ore where selectivity is not an issue. These were in powder and pellet form, and are readily soluble in water and were made up to 6ml at 1% strength. The following are the reagents which were used:

- Sodium Isopropyl Xanthate (SIPX) the most widely used in the flotation of sulphide minerals of copper.
- Potassium Amyl Xanthate (PAX) the most powerful and least selective xanthate. Often used as a scavenger collector following a more selective rougher collector.

- Aero-frother 65 is a polyglycol that exhibits strength and longevity in flotation circuits.

3.3 Sample preparation

The technique employed during sampling was called a systematic sampling. Copper ore samples were cut from six different selected conveyor belts each feeding the ball mills. A one meter sample cutter was struck along the stopped belt and all the ore confined within the one meter was collected and put into the buckets. Samples were taken to the Analytical Laboratory Service for crushing to 100% passing 2mm and after which the product was stored in covered buckets to prevent contamination, oxidation and surface ageing of the minerals. Homogenization of the fresh ore was done manually using a scoop upon pouring the ore on the preparation bench.

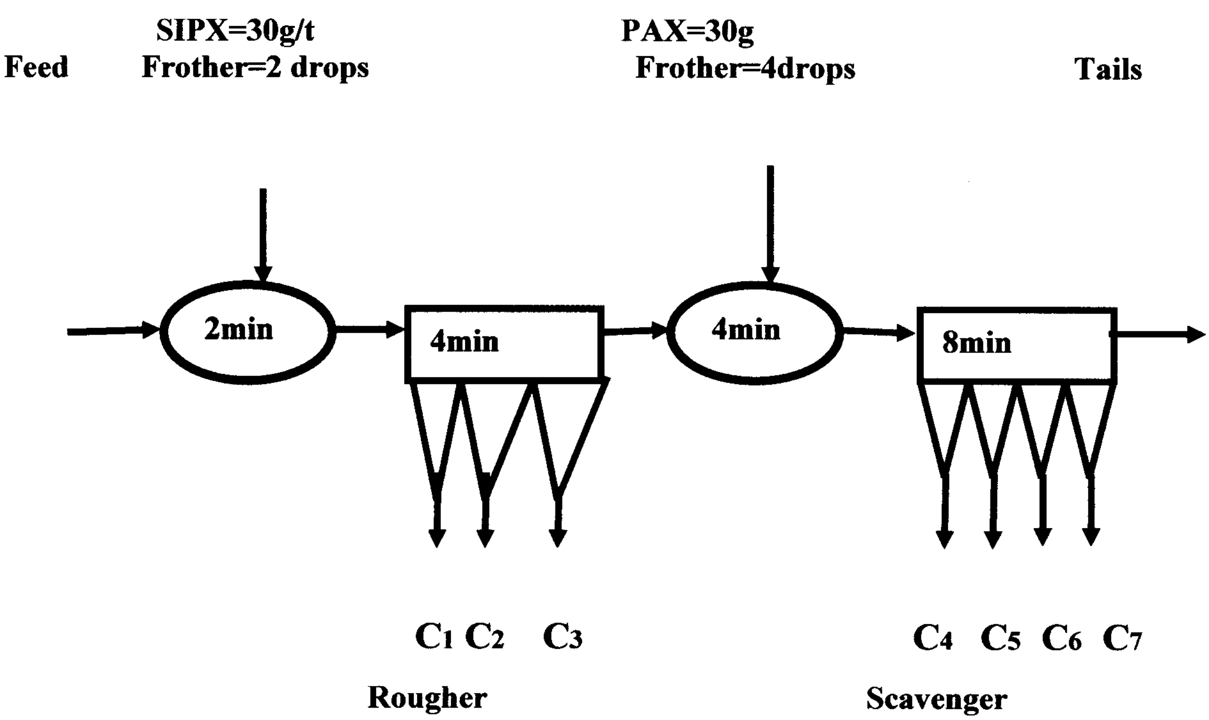
3.4 Grind and Sieving

Wet grinding was carried out in the laboratory ball mill. The charge to the mill included of 2000g of ore, 1500ml of water and mill balls of different sizes. The pulp density of 57.1% solid was maintained or kept constant for every test. Grinding time evaluation was done at the following times; 15, 20, 25, 30, 35 and 40 minutes for every 2000g respectively. After grinding, the ball mill discharge was wet screened passing through 45 microns which provided a removal of slimes and loss of dust. The oversize (what was retained on the +45 micron) was then dried, weighed and screened on the nest of sieve (250, 180, 150, 150, 125, 106, 90, 75, 63, 45 microns) were arranged in the decreasing order from the top to the bottom on the sieve shaker machine. The undersize (-45 microns) was however weighed and then discarded.

From the sieve analysis, the cumulative weight percent passing was computed. All the tests work were done in duplicates.

3.5 Flotation Testwork

The Denver laboratory flotation machine was used for each test. Ground ore sample from the ball mill was immediately placed in a 5000ml flotation cell and more water was added to make up to the mark with the pulp density of 33.3% solids by weight. This was followed by vigorous agitation to keep all solid in suspense, at an impeller speed of 1500 rpm.



SIPX (ml) = 6.0@ 1% strength **PAX (ml) = 6.0@ 1% strength**

Figure 3.1: The Mufulira **standard differential laboratory flowsheet for copper ore.**

To simulate plant practice a differential mode for the Mufulira ore was used. This is where sulphides are recovered in the rougher and scavenger stages under the addition of different chemical reagents.

Sulphide Roughing

Initially, the collector was prepared and the required amount was accurately measured and added to the slurry. The collector sodium isopropyl xanthate (SIPX) was added then conditioned for the desired period (standard is 2min) and with only a minute remaining of the collector conditioning time, the desire amount of sulphides frother (aero-frother65 with only 2drops) was added.

After the conditioning time, air was introduced into the cell by opening the valve on the stand pipe.

However, using plastic paddles, the froth being generated into the cell was pulled by running the paddles across the pulp surface (the froth falls into the plates) for the desired period of 10 seconds interval. Water was added occasionally to the cell to maintain the pulp level; hence, froth collection period was for 4, 5, 6 and 7 minutes for every 2000g ground ore respectively.

Air addition to the cell was removed by closing the air valve on the stand pipe. Samples collected in the plates as the sulphide concentrate using appropriate prepared labels were identified and taken for drying in oven.

Sulphide scavenging

The procedure employed in roughing stage was the same as in scavenging stage but only differed in terms of chemical reagents addition and the conditioning time. Potassium Amyl Xanthate (PAX) and aero-froth 65 were added and 4min of conditioning time. The sulphide scavenger concentrate was collected for 8, 9, 10 and 11 minutes.

Samples generated from the laboratory were analyzed for total copper (TCu) and acid soluble (ASCu), which are analytical estimates for the total copper content in the ore. The copper sulphide minerals are estimated as acid insoluble which is the difference between the TCu and ASCu estimate.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter presents a discussion of results and the main findings that were obtained in this study. The main parameters that were considered are the effect of grind time and increased residence time on flotation performance of Mufulira copper sulphide ore.

4.1 SEIVE ANALYSIS

From the graph below, an estimated optimum grinding time was approximately 17 minutes which gave 55% solids passing 75 µm. It also shows that, any increase in grind time results in more finely particles being produced i.e. more particles passes 75µm, therefore size distribution is important prior to flotation.

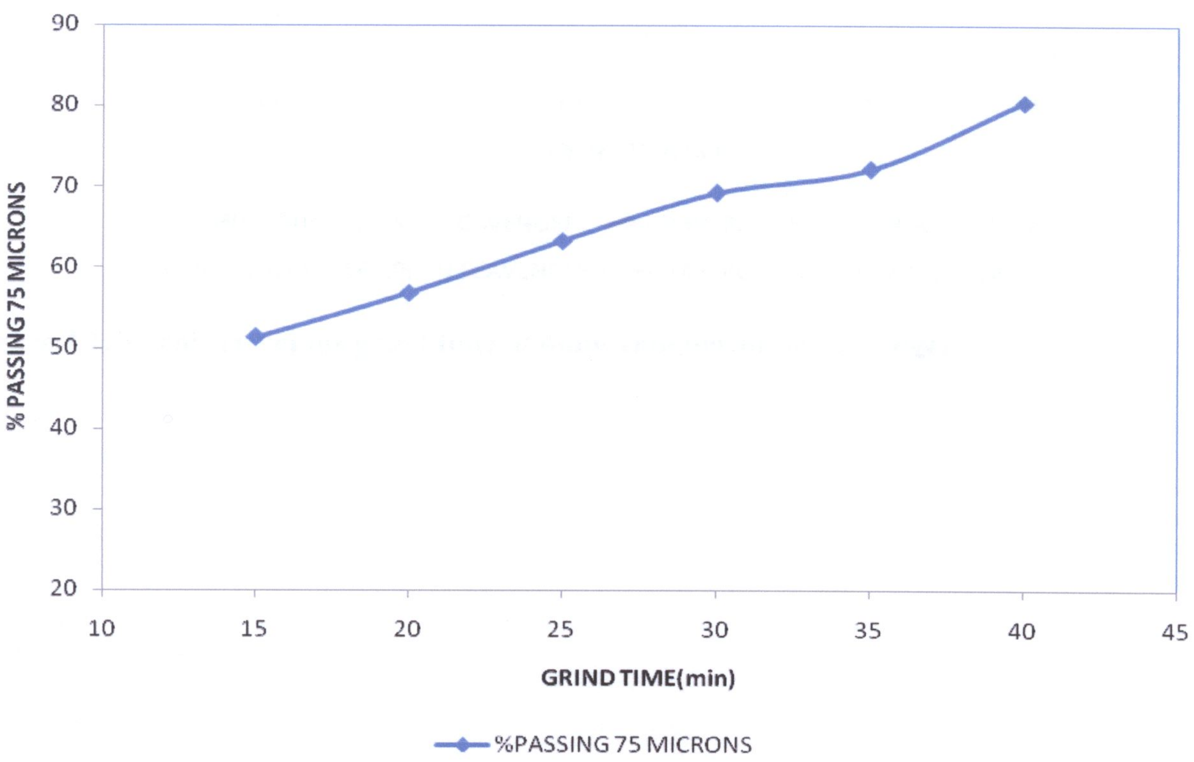


Figure 4.1: Percentage of solids passing 75µm plotted against grind time

4.2 THE EFFECT OF GRIND TIME ON FLOTATION PERFORMANCE

Figures 4.1-4.3 below show, the effect of grind time on copper recovery and grade at constant residence time of 4 minutes rougher and 8 minutes scavenger.

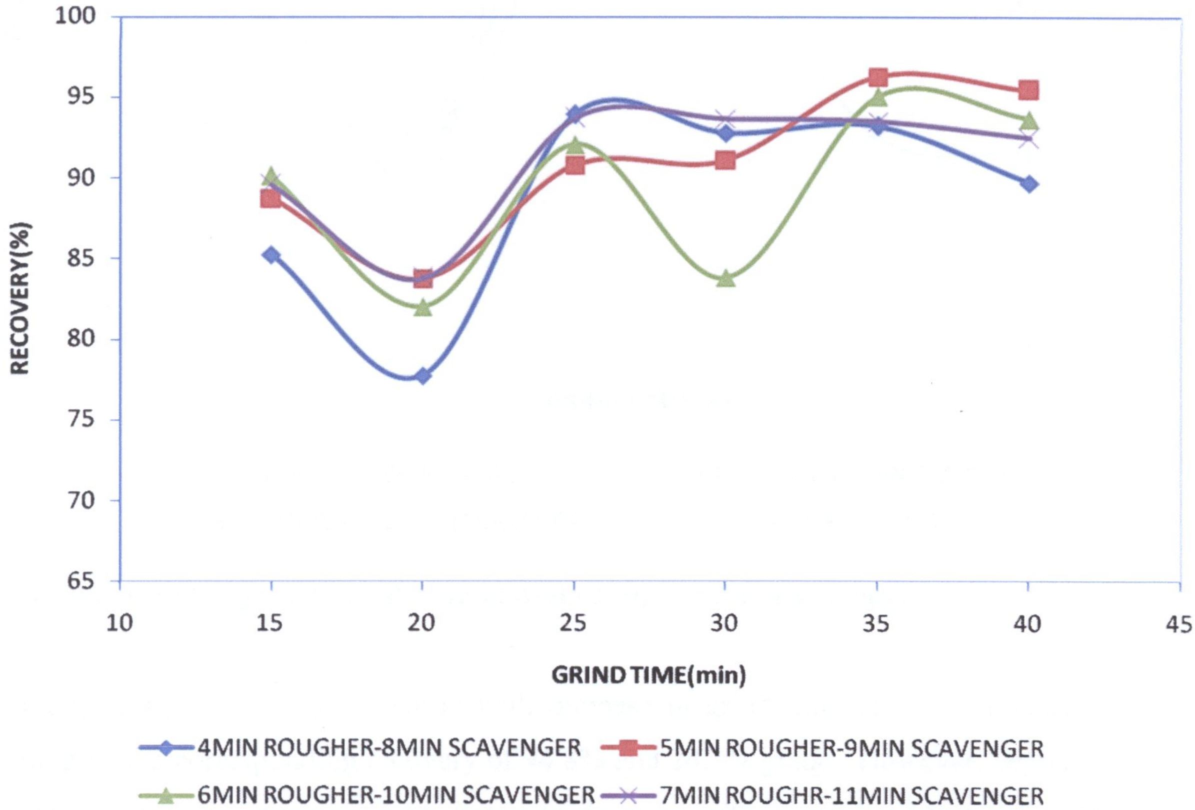


Figure 4.1: Recovery versus grind time at 4min rougher-8min scavenger

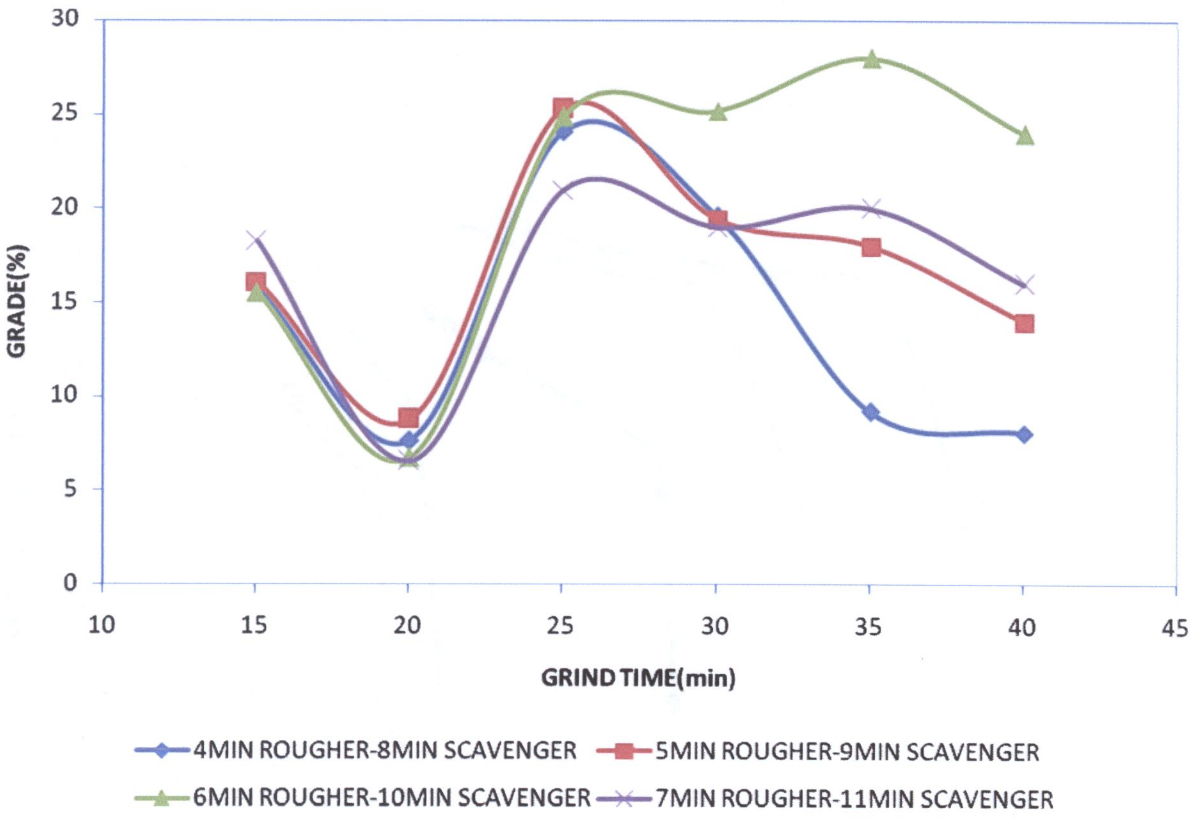


Figure 4.2: Grade against grind time at 4min rougher-8min scavenger

Generally, copper recovery increased with increase in grind time up to 25 minutes of grinding with a corresponding recovery of 94.8% and 24.9% grade. However, beyond 25 minutes grind time, copper recovery begun to decrease with increasing grind time and it also occurred at 35 minutes grind time, which gave a recovery of 94.6% but a low grade of 9.3%. This result in high cost of energy consumption hence slimes production which has a deleterious effect on flotation performance. A drop at 20 minutes grind time with copper recovery of 76% could be as a result of the hardness of the ore and also the discrepancies incurred during the test. Figure 4.3, the recovery and grade graph below shows that, at six different grind times from 15 – 40 minutes at an interval of 5 minutes, copper recovery decreases with an increase in grade. The 25 minutes grind time gave the highest recovery indicating that the degree of liberation is highest at this time having a copper recovery of 88.9% and a grade of 21.2% at a fixed residence time of 4 minutes rougher and 8 minutes scavenger.

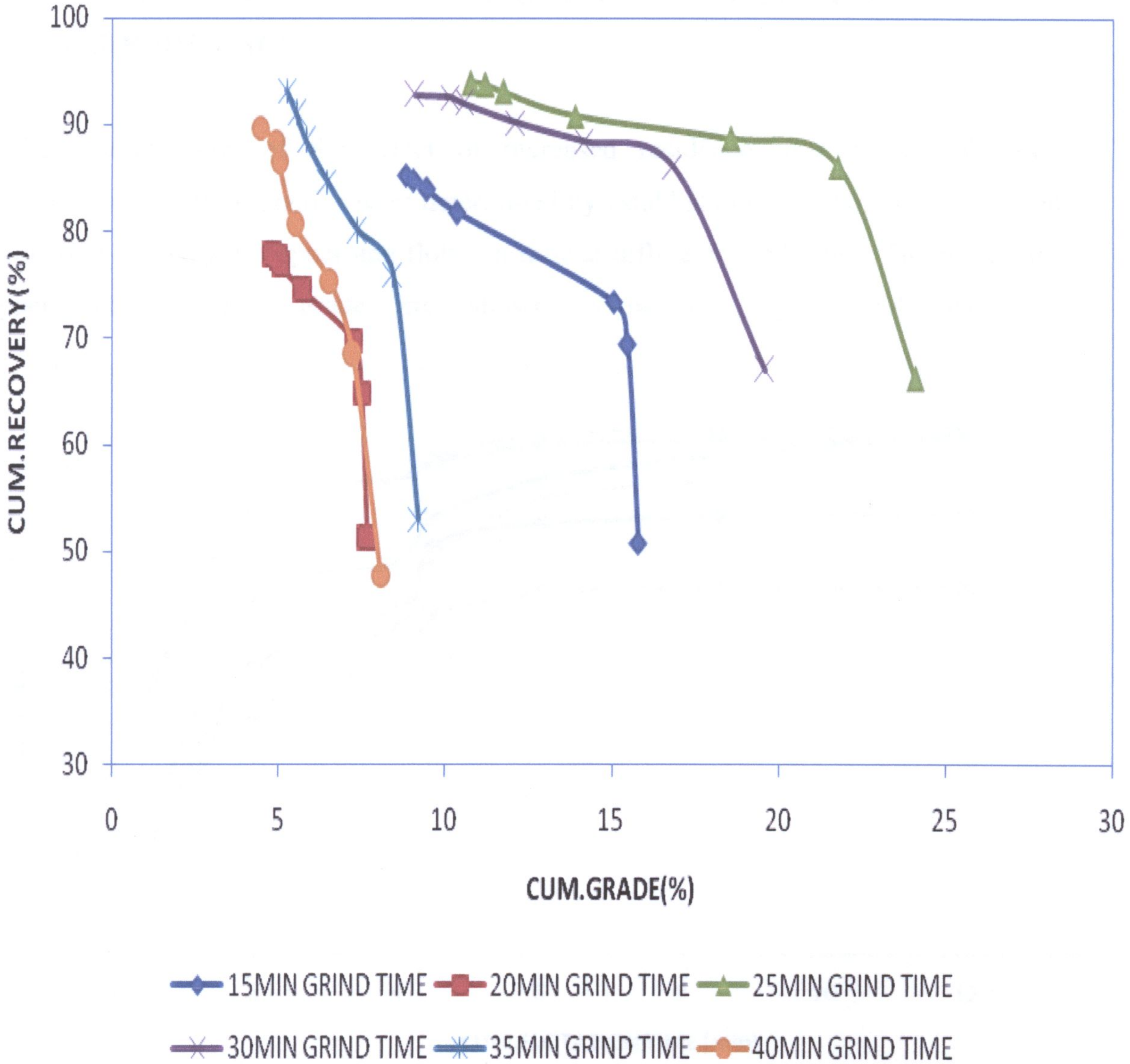


Figure 4.3: Copper recovery plotted against grade at 4 minutes rougher - 8 minutes scavenger

4.3 THE EFFECT OF INCREASED RESIDENCE TIME ON FLOTATION PERFORMANCE

In the determination of the effect of increased residence time on the flotation performance, flotation kinetics were determined by establishing the relationship between cumulative recovery of copper and flotation time at different grind times. The results for copper recovery and grade are shown below in Figures 4.4 and 4.5.

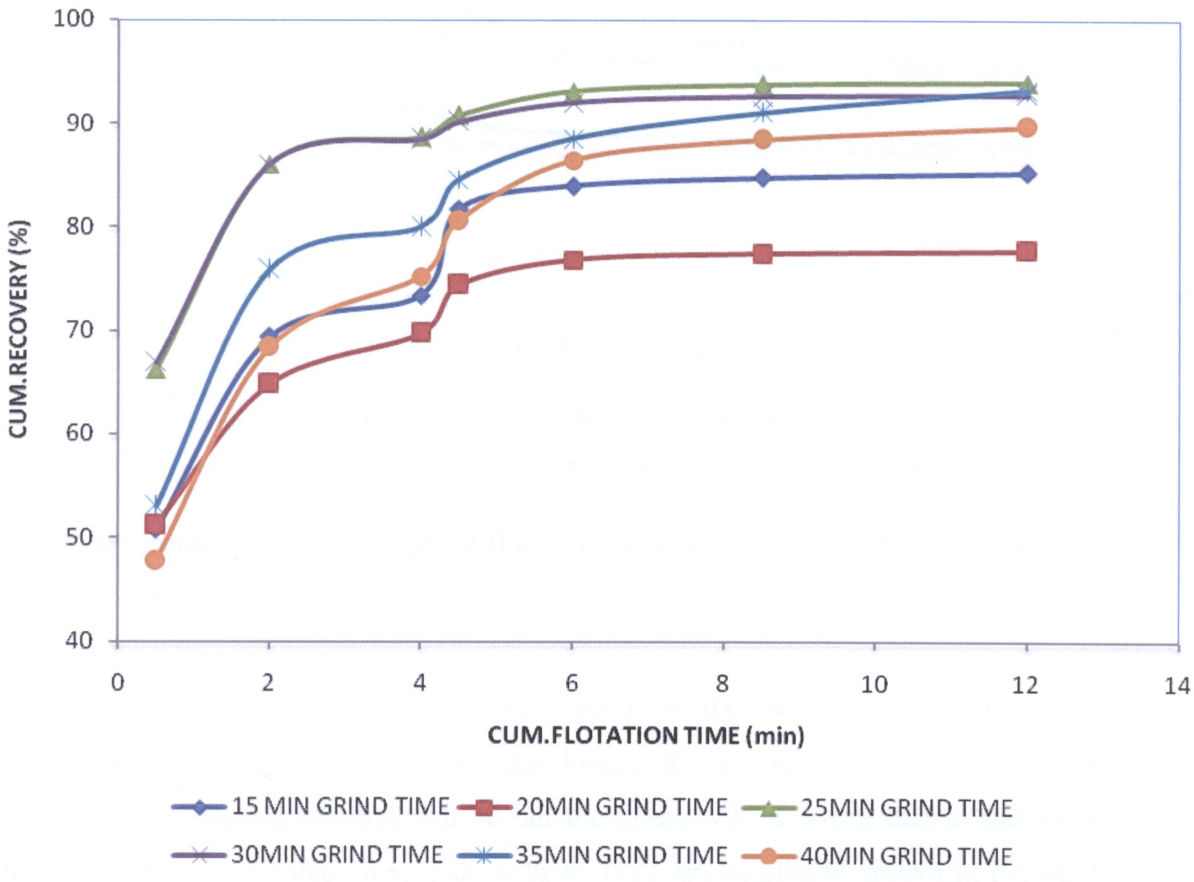


Figure 4.4: Cumulative recovery vs. flotation at a fixed residence time of 4 minutes Rougher-8 minutes scavenger

The uppermost curve which is the 25 minutes grind time represents the best flotation conditions with corresponding copper recovery of approximately 94.5% while the 20 minutes is the bottom most with approximately 79% copper recover. After 25 minutes of grind time recovery significantly starts to decrease because of slime formation and this have a huge effect on the recovery even as residence time is increased.

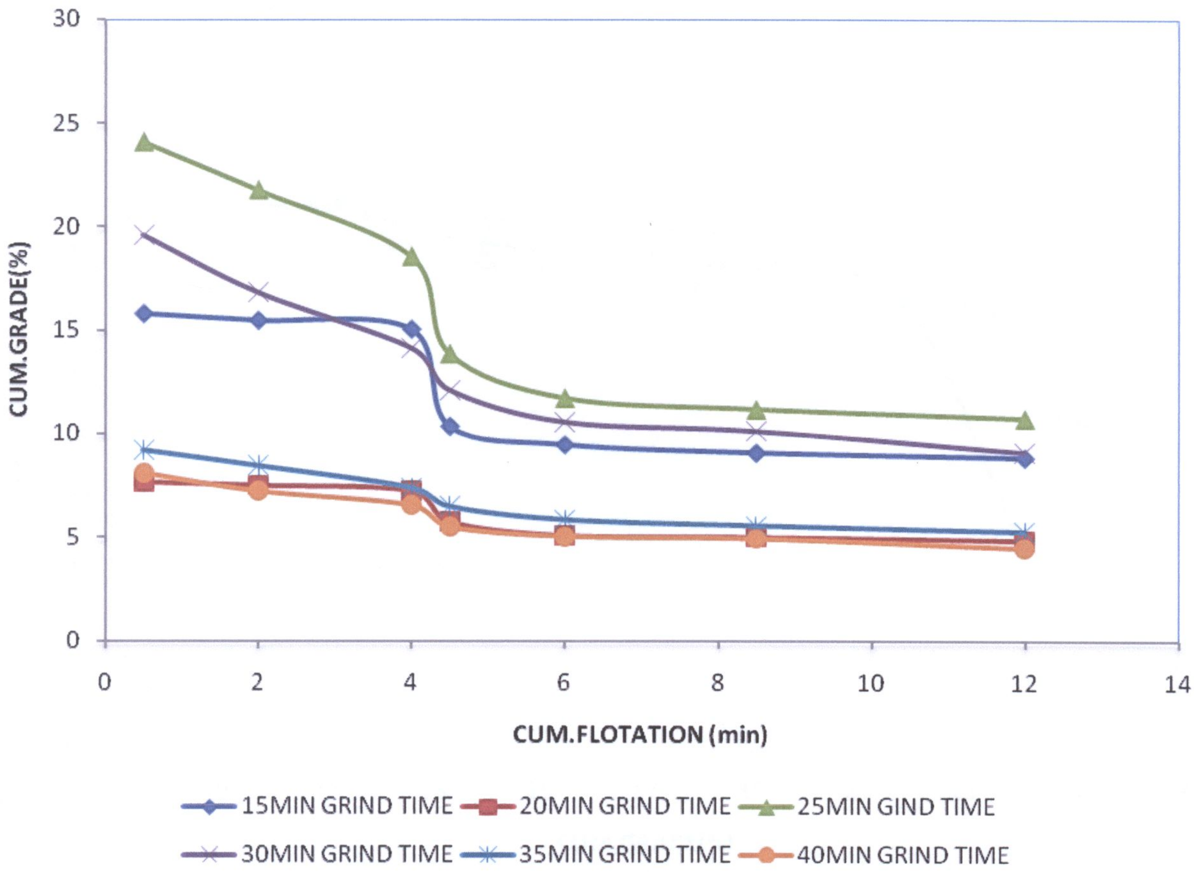


Figure 4.6: Cumulative grade against flotation time for TCu at 4min rougher-8min scavenger.

The figure above shows that, after 4 minute of roughing the recovery of copper increased with the decrease in grade. However, the longer the residence time the higher the recovery of the valuable mineral will be but the grade will be lower due to the gangue minerals that will be floated along side with it. This can be clearly shown in Figure 4.7 where 4 minutes rougher and 8 minutes scavenger has a copper recovery and grade of 88.9% and 21.2%TCu, respectively. While for the residence times of 5 minutes rougher – 9 minutes scavenger and 6 minutes rougher – 10 minutes scavenger the corresponding recoveries are 85.5% and 85.3 respectively. 7 minutes rougher – 11 minutes scavenger significantly decreased in both recovery and grade because the mineralized sulphide froth which was carefully skimmed off became partially barren meaning that what remained in the flotation cell were literally tailings.

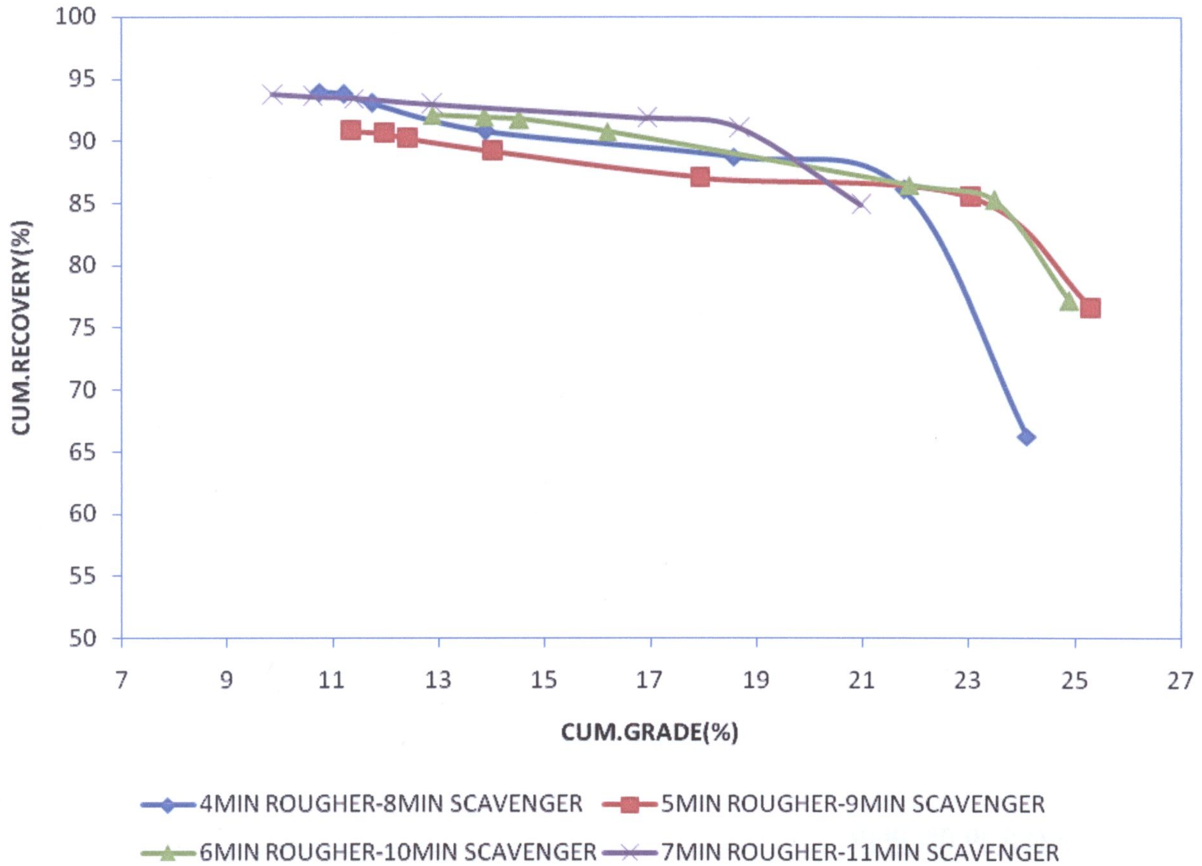


Figure 4.7: Relationship between cumulative copper recovery and grade at four different residence times.

However, the 4 minutes roughing and 8 minutes scavenging with recovery and grade of 88.9% and 21.2% respectively is relatively better than the other graphs. The other graphs show good recoveries which could be nearly the targets of the plant, but these cannot be the optimum residence time because of the lower grades obtained. The low grades could have been due to entrainment of gangue particles as sufficiently hydrophobic surface conditions could not be developed on the particle surfaces to overcome the hydrophilic tendency, thus lowering the floatability. These could also have been due to:

,

(a) When batch laboratory flotation tests are carried out, a number of operations are undertaken and consequently experimental errors are inevitable. Thus a number of duplicate flotation tests always produce results which show some significant variance, as was the case in this test work. Some of the operations, which could have led to the discrepancies, are:

(i) Variation in trying to skim or scoop the froth volume at a constant rate after every ten minutes. Hence, different concentration weights and grades of the repeat tests were obtained.

(ii) Continuous variations in the pulp density from the beginning to the end of flotation as solids were continuously being removed with the froth and water added to maintain the cell pulp level. This resulted in a change in concentration of all the reagents and pH levels in the pulp.

CHAPTER FIVE

5.1 CONCLUSION

It can be concluded that;

1) The mesh of grind was determined to be 25 minutes grind time. This gave copper recovery of 94.8 % with a grade of 24.4% at a fixed residence time of 4 minutes rougher and 8 minutes scavenger.
2) The optimum residence time was determined to be 4 minutes rougher and 8 minutes scavenger, with copper recovery of 88.9% with a grade 21.3% at constant grind time of 25 minutes.

5.2 RECOMMENDATIONS

- It is recommended that for an increased grind time, 25 minutes should be the optimum while for increased residence time, 4 minutes rougher and 8 minutes scavenger flotation time should be maintained.
- Mineralogical examinations should be carried out on the Mufulira copper ore together with its associated concentrates and final tailing. This will aid not only in positive identification of minerals but also the behavior of the same constituent minerals or how they will respond to ore treatment.
- Since the optimum grind time is dependent on the speed of mill, amount and size distribution of the grinding media, they must be a consistence in replacing the grinding media in order to improve the efficiency of grinding and also on the reduction of power consumption.
- Testworks should be done at a decreased grind time and decreased residence time to determine the floatability of the Mufulira copper ore.

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APPENDIX 1

REAGENT ADDITION CALCULATIONS

ADDITION OF COLLECTOR (SIPX)

Given,
1% solution strength
Dose rate of 30g/ton
Basing on 2000g of dry solids in the cell

$$Volume\ of\ reagents = \frac{[Doserate \times Mass\ of\ solids]}{[\%strength \times 10^6]}$$

$$= \frac{[30 \times 2000]}{[0.01 \times 10^6]}$$

$$= 6ml$$

Note; this calculation is employed also for the addition of PAX

APPENDIX 2

TABLES FOR SEIVE ANALYSIS

SEIVE ANALYSIS

15 MINUTES GRIND TIME

Sieve size (microns)	weight (g)	weight (%)	cum. weight %	% passing
250	20.00	3.86	3.86	100.00
180	57.00	11.00	14.86	89.00
150	37.00	7.14	22.01	81.85
125	47.00	9.07	31.08	72.78
106	40.00	7.72	38.80	65.06
90	52.00	10.04	48.84	55.02
75	19.00	3.67	52.51	51.35
63	33.00	6.37	58.88	44.98
45	13.00	2.51	61.39	42.47
-45	200.00	38.61	100.00	3.86
Total	518.00	100.00		

20 MINUTES GRIND TIME

Sieve size (microns)	weight (g)	weight (%)	cum. weight %	% passing
250	3.00	0.60	0.60	100.00
180	21.00	4.17	4.77	95.83
150	27.00	5.37	10.14	90.46
125	43.00	8.55	18.69	81.91
106	43.00	8.55	27.24	73.36
90	61.00	12.13	39.36	61.23
75	22.00	4.37	43.74	56.86
63	44.00	8.75	52.49	48.11
45	17.00	3.38	55.86	44.73
-45	222.00	44.14	100.00	0.60
Total	503.00	100.00		

25 MINUTES GRIND TIME

Sieve size (microns)	weight (g)	weight (%)	cum. weight %	% passing
250	1.00	0.19	0.19	100.00
180	7.00	1.34	1.53	98.66
150	13.00	2.49	4.02	96.18
125	32.00	6.12	10.13	90.06
106	34.00	6.50	16.63	83.56
90	81.00	15.49	32.12	68.07
75	25.00	4.78	36.90	63.29
63	42.00	8.03	44.93	55.26
45	17.00	3.25	48.18	52.01
-45	271.00	51.82	100.00	0.19
Total	523.00	100.00		

30 MINUTES GRIND TIME

Sieve size (microns)	weight (g)	weight (%)	cum. weight %	% passing
250	0.00	0.00	0.00	100.00
180	2.00	0.39	0.39	99.61
150	5.00	0.98	1.37	98.63
125	14.00	2.75	4.12	95.88
106	26.00	5.10	9.22	90.78
90	80.00	15.69	24.90	75.10
75	30.00	5.88	30.78	69.22
63	50.00	9.80	40.59	59.41
45	21.00	4.12	44.71	55.29
-45	282.00	55.29	100.00	0.00
Total	510.00	100.00		

35 MINUTES GRIND TIME

Sieve size (microns)	weight (g)	weight (%)	cum. weight %	% passing
250	0.00	0.00	0.00	100.00
180	1.00	0.19	0.19	99.81
150	2.00	0.39	0.58	99.42
125	9.00	1.75	2.33	97.67
106	20.00	3.89	6.23	93.77
90	73.00	14.20	20.43	79.57
75	38.00	7.39	27.82	72.18
63	49.00	9.53	37.35	62.65
45	22.00	4.28	41.63	58.37
-45	300.00	58.37	100.00	0.00
Total	514.00	100.00		

40 MINUTES GRIND TIME

Sieve size (microns)	weight (g)	weight (%)	cum. weight %	% passing
250	0	0.00	0.00	100.00
180	1.00	0.20	0.20	99.80
150	1.00	0.20	0.40	99.60
125	5.00	0.99	1.38	98.62
106	15.00	2.96	4.35	95.65
90	52.00	10.28	14.62	85.38
75	25.00	4.94	19.57	80.43
63	61.00	12.06	31.62	68.38
45	27.00	5.34	36.96	63.04
-45	319.00	63.04	100.00	0.00
Total	506.00	100.00		

APPENDIX 3

TABLES AND GRAPHS ON FLOTATION PERFORMANCE

15MINUTES GRIND TIME 4MINUTES ROUGHER-8MINUTE SCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE							RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WEIGHT(g)				GRADE(%)											
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu
C1	0.5	114	18.01	0.114	17.898	15.8	0.1	15.7	50.7958	13.974	51.663	50.79584	13.97401	51.66292	15.8	0.1	15.7
C2	2	45	6.593	0.0585	6.534	14.65	0.13	14.52	18.5916	7.1709	18.861	69.38742	21.14489	70.52344	15.47453	0.108491	15.36604
C3	4	14	1.434	0.014	1.4196	10.24	0.1	10.14	4.04291	1.7161	4.0977	73.43033	22.861	74.62114	15.05092	0.107803	14.94312
C4	4.5	107	2.953	0.0749	2.8783	2.76	0.07	2.69	8.32835	9.1812	8.3083	81.75868	32.04217	82.92941	10.35404	0.093357	10.26068
C5	6	35	0.781	0.0315	0.749	2.23	0.09	2.14	2.2011	3.8612	2.162	83.95977	35.90341	85.09142	9.451365	0.092984	9.358381
C6	8.5	17	0.299	0.0204	0.2788	1.76	0.12	1.64	0.84378	2.5006	0.8048	84.80355	38.40402	85.89618	9.05753	0.094367	8.963163
C7	12	11	0.169	0.0132	0.1562	1.54	0.12	1.42	0.47773	1.618	0.4509	85.28128	40.02206	86.34705	8.816443	0.09519	8.721254
Tail 4		1631	5.219	0.4893	4.7299	0.32	0.03	0.29	14.7187	59.978	13.653	100	100	100	1.796332	0.041327	1.755005
TOTAL		1974	35.46	0.8158	34.644												

20MINUTES GRIND TIME 4MINUTESROUGHER-8MINUTESSCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE							RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WEIGHT(g)				GRADE(%)											
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	Tcu	ASCu	AlCu	TCu	ASCu	AlCu
C1	0.5	122	9.37	0.1586	9.211	7.68	0.13	7.55	51.2193	11.11	54.614	51.21931	11.11033	54.61413	7.68	0.13	7.55
C2	2	36	2.498	0.054	2.4444	6.94	0.15	6.79	13.6576	3.7828	14.493	64.87692	14.89317	69.10753	7.511392	0.134557	7.376835
C3	4	18	0.891	0.0846	0.8064	4.95	0.47	4.48	4.87069	5.9264	4.7813	69.74761	20.81961	73.88886	7.249432	0.168864	7.080568
C4	4.5	61	0.854	0.0488	0.8052	1.4	0.08	1.32	4.66843	3.4186	4.7742	74.41604	24.23818	78.66308	5.743882	0.145992	5.59789
C5	6	40	0.444	0.048	0.396	1.11	0.12	0.99	2.42714	3.3625	2.348	76.84318	27.6007	81.01105	5.074729	0.142238	4.932491
C6	8.5	7	0.108	0.0028	0.105	1.54	0.04	1.5	0.58929	0.1961	0.6226	77.43247	27.79685	81.63362	4.987606	0.139718	4.847887
C7	12	11	0.063	0.0143	0.0484	0.57	0.13	0.44	0.34275	1.0018	0.287	77.77523	28.7986	81.9206	4.822881	0.139356	4.683525
Tail		1694	4.066	1.0164	3.0492	0.24	0.06	0.18	22.2248	71.201	18.079	100	100	100	0.919713	0.07177	0.847944
TOTAL		1989	18.29	1.4275	16.866												

25MIN GRIND TIME 4MINUTES ROUGHER-8MINUTES SCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE							RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WEIGHT(g)				GRADE(%)											
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu
C1	0.5	137	33	0.2603	32.743	24.09	0.19	23.9	66.2547	14.532	68.184	66.25466	14.53216	68.1839	24.09	0.19	23.9
C2	2	60	9.882	0.168	9.714	16.47	0.28	16.19	19.8383	9.3792	20.228	86.09293	23.91134	88.4123	21.76919	0.217411	21.55178
C3	4	41	1.304	0.0738	1.23	3.18	0.18	3	2.6174	4.1201	2.5613	88.71033	28.03149	90.97365	18.56685	0.210966	18.35588
C4	4.5	88	1.056	0.0616	0.9944	1.2	0.07	1.13	2.11994	3.439	2.0707	90.83027	31.47052	93.04438	13.87887	0.172914	13.70595
C5	6	69	1.125	0.1173	1.0074	1.63	0.17	1.46	2.25785	6.5487	2.0978	93.08812	38.01921	95.14219	11.73919	0.172405	11.56678
C6	8.5	22	0.337	0.0352	0.3014	1.53	0.16	1.37	0.67573	1.9652	0.6276	93.76385	39.98437	95.76982	11.20058	0.171751	11.02882
C7	12	18	0.086	0.018	0.0684	0.48	0.1	0.38	0.17345	1.0049	0.1424	93.9373	40.98928	95.91226	10.75697	0.168782	10.58818
Tail 4		1510	3.02	1.057	1.963	0.2	0.07	0.13	6.0627	59.011	4.0877	100	100	100	2.561069	0.092093	2.468977
TOTAL		1945	49.81	1.7912	48.022												

30MINUTES GRIND TIME 4MINUTES ROUGHER-8MINUTES SCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE							RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WEIGHT(g)				GRADE(%)											
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu
C1	0.5	141	27.62	0.141	27.481	19.59	0.1	19.49	66.9661	6.4328	70.363	66.96608	6.432775	70.36335	19.59	0.1	19.49
C2	2	70	7.875	0.084	7.791	11.25	0.12	11.13	19.092	3.8323	19.948	86.0581	10.26507	90.31179	16.82318	0.106635	16.71654
C3	4	47	0.992	0.0517	0.94	2.11	0.11	2	2.40426	2.3587	2.4068	88.46236	12.62375	92.7186	14.14287	0.107248	14.03562
C4	4.5	49	0.706	0.0392	0.6664	1.44	0.08	1.36	1.71064	1.7884	1.7063	90.173	14.41215	94.42489	12.11537	0.102899	12.01248
C5	6	52	0.749	0.0676	0.6812	1.44	0.13	1.31	1.81538	3.0841	1.7442	91.98838	17.49624	96.16906	10.56908	0.106825	10.46226
C6	8.5	18	0.241	0.0198	0.2214	1.34	0.11	1.23	0.58476	0.9033	0.5669	92.57314	18.39956	96.73594	10.12844	0.106976	10.02146
C7	12	44	0.088	0.066	0.022	0.2	0.15	0.05	0.21335	3.0111	0.0563	92.78649	21.41065	96.79227	9.090784	0.111473	8.979311
Tail 4		1566	2.975	1.7226	1.2528	0.19	0.11	0.08	7.21351	78.589	3.2077	100	100	100	2.075873	0.110312	1.965561
TOTAL		1987	41.25	2.1919	39.056												

35MINUTES GRIND TIME 4MINUTES ROUGHER-8MINUTES SCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE							RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WEIGHT(g)				GRADE(%)											
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu
C1	0.5	134	12.33	0.0804	12.248	9.2	0.06	9.14	53.0291	7.8785	55.102	53.02913	7.878491	55.10211	9.2	0.06	9.14
C2	2	75	5.325	0.0375	5.2875	7.1	0.05	7.05	22.9056	3.6747	23.789	75.93472	11.55316	78.89063	8.446411	0.056411	8.39
C3	4	43	0.95	0.0258	0.9245	2.21	0.06	2.15	4.08773	2.5282	4.1593	80.02245	14.08133	83.04997	7.382262	0.057024	7.325238
C4	4.5	52	1.071	0.026	1.0452	2.06	0.05	2.01	4.60779	2.5478	4.7024	84.63024	16.6291	87.75234	6.471875	0.055822	6.416053
C5	6	49	0.911	0.0294	0.882	1.86	0.06	1.8	3.9204	2.8809	3.9681	88.55065	19.51004	91.72047	5.8317	0.056402	5.775297
C6	8.5	29	0.589	0.0174	0.5713	2.03	0.06	1.97	2.5323	1.705	2.5703	91.08295	21.21509	94.29075	5.543089	0.056675	5.486414
C7	12	31	0.496	0.0155	0.4805	1.6	0.05	1.55	2.13355	1.5189	2.1618	93.2165	22.73395	96.45253	5.247119	0.056174	5.190944
Tail 4		1577	1.577	0.7885	0.7885	0.1	0.05	0.05	6.7835	77.266	3.5475	100	100	100	1.168221	0.051281	1.11694
TOTAL		1990	23.25	1.0205	22.227												

40MINUTES GRIND TIME 4MINUTES ROUGHER-8MINUTES SCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE							RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WEIGHT(g)				GRADE(%)											
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu
C1	0.5	101	8.181	0.0808	8.1002	8.1	0.08	8.02	47.7703	9.7104	49.714	47.77031	9.710371	49.714	8.1	0.08	8.02
C2	2	61	3.538	0.0366	3.5014	5.8	0.06	5.74	20.659	4.3985	21.489	68.42932	14.10888	71.20342	7.233951	0.072469	7.161481
C3	4	35	1.173	0.014	1.1585	3.35	0.04	3.31	6.84644	1.6825	7.1102	75.27576	15.79137	78.31357	6.543909	0.066701	6.477208
C4	4.5	54	0.918	0.027	0.891	1.7	0.05	1.65	5.36036	3.2448	5.4684	80.63612	19.03617	83.78198	5.501793	0.063108	5.438685
C5	6	43	0.993	0.0129	0.9804	2.31	0.03	2.28	5.80005	1.5503	6.0171	86.43617	20.58647	89.79906	5.034966	0.058265	4.976701
C6	8.5	14	0.347	0.0056	0.3416	2.48	0.04	2.44	2.02736	0.673	2.0965	88.46354	21.25946	91.89559	4.918831	0.057435	4.861396
C7	12	37	0.215	0.0148	0.1998	0.58	0.04	0.54	1.25309	1.7786	1.2262	89.71662	23.0381	93.12184	4.453507	0.055565	4.397942
Tail		1601	1.761	0.6404	1.1207	0.11	0.04	0.07	10.2834	76.962	6.8782	100	100	100	0.880046	0.04276	0.837287
TOTAL		1946	17.13	0.8321	16.294												

15MINUTES GRIND TIME 5MINUTES ROUGHER-9MINUTESSCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE							RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WEIGHT(g)				GRADE(%)											
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu
C1	1	168	27.0312	0.1344	26.8968	16.09	0.08	16.01	69.93752	18.02817	70.95845	69.93752	18.02817	70.95845	16.09	0.08	16.01
C2	2.5	21	2.8182	0.0231	2.7951	13.42	0.11	13.31	7.291497	3.098592	7.373961	77.22901	21.12676	78.33241	15.79333	0.083333	15.71
C3	5	13	0.7696	0.0156	0.754	5.92	0.12	5.8	1.991177	2.092555	1.989183	79.22019	23.21932	80.32159	15.15792	0.085693	15.07223
C4	6	64	2.7008	0.0384	2.6624	4.22	0.06	4.16	6.987749	5.150905	7.023875	86.20794	28.37022	87.34547	12.52624	0.079511	12.44673
C5	7.5	19	0.5472	0.0114	0.5358	2.88	0.06	2.82	1.415764	1.529175	1.413534	87.6237	29.8994	88.759	11.88316	0.078211	11.80495
C6	10	11	0.2893	0.0077	0.2816	2.63	0.07	2.56	0.748503	1.032864	0.74291	88.37221	30.93226	89.50191	11.53929	0.077905	11.46139
C7	14	17	0.1496	0.0136	0.136	0.88	0.08	0.8	0.387058	1.824279	0.358792	88.75927	32.75654	89.8607	10.96035	0.078019	10.88233
Tail 5		1671	4.3446	0.5013	3.8433	0.26	0.03	0.23	11.24073	67.24346	10.1393	100	100	100	1.94811	0.037576	1.910534
TOTAL		1984	38.6505	0.7455	37.905												

20MINUTES GRIND TIME 5MINUTES ROUGHER-9MINUTESSCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE							RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WEIGHT(g)				GRADE(%)											
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	Tcu	ASCu	AlCu	TCu	ASCu	AlCu
C1	1	140	12.32	0.126	12.194	8.8	0.09	8.71	67.56646	13.68227	70.43262	67.56646	13.68227	70.43262	8.8	0.09	8.71
C2	2.5	25	1.6625	0.025	1.6375	6.65	0.1	6.55	9.117633	2.714736	9.458211	76.68409	16.397	79.89083	8.474242	0.091515	8.382727
C3	5	31	0.403	0.0248	0.3782	1.3	0.08	1.22	2.210169	2.693018	2.184486	78.89426	19.09002	82.07532	7.339541	0.089694	7.249847
C4	6	92	0.552	0.0552	0.4968	0.6	0.06	0.54	3.027328	5.994136	2.86952	81.92159	25.08416	84.94484	5.186632	0.080208	5.106424
C5	7.5	18	0.2322	0.0126	0.2196	1.29	0.07	1.22	1.273452	1.368227	1.268411	83.19504	26.45238	86.21325	4.957418	0.079608	4.87781
C6	10	12	0.06	0.0072	0.0528	0.5	0.06	0.44	0.329057	0.781844	0.304973	83.5241	27.23423	86.51822	4.789214	0.078868	4.710346
C7	14	25	0.045	0.0125	0.0325	0.18	0.05	0.13	0.246793	1.357368	0.18772	83.77089	28.5916	86.70594	4.453265	0.076764	4.376501
Tail 5		1644	2.9592	0.6576	2.3016	0.18	0.04	0.14	16.22911	71.4084	13.29406	100	100	100	0.91766	0.046346	0.871314
TOTAL		1987	18.2339	0.9209	17.313												

25MINUTES GRIND TIME 5MINUTES ROUGHER-9MINUTESSCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE							RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WEIGHT(g)				GRADE(%)											
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu
C1	1	111	28.083	0.0999	27.9831	25.3	0.09	25.21	76.58304	6.265287	79.77962	76.58304	6.265287	79.77962	25.3	0.09	25.21
C2	2.5	25	3.265	0.025	3.24	13.06	0.1	12.96	8.903736	1.56789	9.237217	85.48677	7.833177	89.01684	23.05	0.091838	22.95816
C3	5	42	0.5712	0.0378	0.5334	1.36	0.09	1.27	1.557677	2.370649	1.52072	87.04445	10.20383	90.53755	17.93213	0.091404	17.84073
C4	6	55	0.7865	0.0385	0.748	1.43	0.07	1.36	2.144805	2.41455	2.132543	89.18926	12.61838	92.6701	14.03678	0.086352	13.95043
C5	7.5	33	0.3663	0.0264	0.3399	1.11	0.08	1.03	0.998909	1.655691	0.969052	90.18816	14.27407	93.63915	12.43308	0.085564	12.34752
C6	10	11	0.1496	0.0077	0.1419	1.36	0.07	1.29	0.407963	0.48291	0.404556	90.59613	14.75698	94.04371	11.99336	0.084946	11.90841
C7	14	16	0.0784	0.0112	0.0672	0.49	0.07	0.42	0.213799	0.702415	0.191587	90.80993	15.45939	94.23529	11.36519	0.08413	11.28106
Tail 5		1685	3.37	1.348	2.022	0.2	0.08	0.12	9.190074	84.54061	5.764708	100	100	100	1.853893	0.080612	1.773281
TOTAL		1978	36.67	1.5945	35.0755												

30MINUTES GRIND TIME 5MINUTES ROUGHER-9MINUTESSCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE WEIGHT(g)				AVEARGE GRADE(%)			RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu
C1	1	168	32.6088	0.1512	32.4576	19.41	0.09	19.32	76.84303	10.90201	79.07096	76.84303	10.90201	79.07096	19.41	0.09	19.32
C2	2.5	48	3.9984	0.0816	3.9168	8.33	0.17	8.16	9.422278	5.883625	9.541837	86.26531	16.78564	88.61279	16.94778	0.107778	16.84
C3	5	31	0.8401	0.0465	0.7936	2.71	0.15	2.56	1.979706	3.352801	1.933313	88.24501	20.13844	90.54611	15.16085	0.113077	15.04777
C4	6	85	0.51	0.0935	0.4165	0.6	0.11	0.49	1.201821	6.741654	1.014648	89.44683	26.88009	91.56076	11.43292	0.112289	11.32063
C5	7.5	38	0.5434	0.0418	0.5016	1.43	0.11	1.32	1.280529	3.013916	1.221963	90.72736	29.89401	92.78272	10.40559	0.112054	10.29354
C6	10	16	0.0992	0.0112	0.088	0.62	0.07	0.55	0.233766	0.807556	0.21438	90.96113	30.70156	92.9971	9.999974	0.110311	9.889663
C7	14	29	0.0725	0.0203	0.0522	0.25	0.07	0.18	0.170847	1.463696	0.127166	91.13197	32.16526	93.12426	9.318651	0.107494	9.211157
Tail 5		1568	3.7632	0.9408	2.8224	0.24	0.06	0.18	8.868026	67.83474	6.875735	100	100	100	2.13997	0.069939	2.07003
TOTAL		1983	42.4356	1.3869	41.0487												

35MINUTES GRIND TIME 5MINUTES ROUGHER-9MINUTESSCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE WEIGHT(g)				AVEARGE GRADE(%)			RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu
C1	1	162	29.16	0.081	29.079	18	0.05	17.95	81.58971	7.079182	84.05404	81.58971	7.079182	84.05404	18	0.05	17.95
C2	2.5	43	0.4644	0.0215	0.4429	1.08	0.05	1.03	1.299392	1.879042	1.280221	82.8891	8.958224	85.33426	14.45093	0.05	14.40093
C3	5	140	3.08	0.07	3.01	2.2	0.05	2.15	8.617843	6.117812	8.700528	91.50695	15.07604	94.03479	9.479536	0.05	9.429536
C4	6	54	0.729	0.027	0.702	1.35	0.05	1.3	2.039743	2.359727	2.02916	93.54669	17.43576	96.06395	8.379298	0.05	8.329298
C5	7.5	36	0.4464	0.018	0.4284	1.24	0.05	1.19	1.249028	1.573152	1.238308	94.79572	19.00891	97.30226	7.78846	0.05	7.73846
C6	10	33	0.3003	0.0165	0.2838	0.91	0.05	0.86	0.84024	1.442056	0.820336	95.63596	20.45097	98.12259	7.30344	0.05	7.25344
C7	14	48	0.2304	0.024	0.2064	0.48	0.05	0.43	0.644659	2.097535	0.596608	96.28062	22.54851	98.7192	6.668702	0.05	6.618702
Tail 5		1477	1.3293	0.8862	0.4431	0.09	0.06	0.03	3.719383	77.45149	1.280799	100	100	100	1.793266	0.057411	1.735855
TOTAL		1993	35.7398	1.1442	34.5956												

40MINUTES GRIND TIME 5MINUTES ROUGHER-9MINUTESSCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE WEIGHT(g)				AVEARGE GRADE(%)			RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu
C1	1	113	15.82	0.113	15.707	14	0.1	13.9	66.30677	11.48724	68.66418	66.30677	11.48724	68.66418	14	0.1	13.9
C2	2.5	41	3.772	0.0902	3.6818	9.2	0.22	8.98	15.80968	9.169462	16.09523	82.11645	20.6567	84.75941	12.72208	0.131948	12.59013
C3	5	29	1.2296	0.0638	1.1658	4.24	0.22	4.02	5.153654	6.485717	5.096371	87.27011	27.14242	89.85578	11.37792	0.145902	11.23202
C4	6	66	1.0296	0.1188	0.9108	1.56	0.18	1.38	4.315389	12.07685	3.981622	91.58549	39.21927	93.8374	8.775582	0.15494	8.620643
C5	7.5	34	0.5202	0.051	0.4692	1.53	0.15	1.38	2.180328	5.184507	2.051139	93.76582	44.40378	95.88854	7.905088	0.154346	7.750742
C6	10	17	0.2363	0.0408	0.1955	1.39	0.24	1.15	0.99041	4.147606	0.854641	94.75623	48.55139	96.74318	7.5359	0.1592	7.3767
C7	14	26	0.1612	0.039	0.1222	0.62	0.15	0.47	0.675642	3.964623	0.534205	95.43187	52.51601	97.27739	6.984325	0.158466	6.825859
Tail 5		1557	1.0899	0.4671	0.6228	0.07	0.03	0.04	4.568126	47.48399	2.722611	100	100	100	1.267063	0.052241	1.214822
TOTAL		1883	23.8588	0.9837	22.8751												

15MINUTES GRIND TIME 6MINUTES ROUGHER-10MINUTES SCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE WEIGHT(g) WT	TCu	ASCu	AICu	GRADE(%) TCu	ASCu	AICu	RECOVERY TCu	ASCu	AICu	CUMULATIVE RECOVERY TCu	ASCu	AICu	CUMULATIVE GRADE TCu	ASCu	AICu
C1	1	164	25.4856	0.1312	25.3544	15.54	0.08	15.46	68.4269	17.43753	69.51725	68.4269	17.43753	69.51725	15.54	0.08	15.46
C2	3	21	2.7258	0.0294	2.6964	12.98	0.14	12.84	7.318566	3.907496	7.393048	75.74547	21.34503	76.9103	15.24941	0.086811	15.16259
C3	6	36	0.9864	0.036	0.9504	2.74	0.1	2.64	2.648409	4.784689	2.605827	78.39388	26.12972	79.51612	13.21167	0.088959	13.12271
C4	7	117	3.51	0.0468	3.4632	3	0.04	2.96	9.424084	6.220096	9.495477	87.81796	32.34981	89.0116	9.676864	0.072012	9.604852
C5	9	21	0.5439	0.0105	0.5334	2.59	0.05	2.54	1.46033	1.395534	1.462488	89.27829	33.74535	90.47409	9.262312	0.070724	9.191588
C6	12	13	0.1859	0.0091	0.1768	1.43	0.07	1.36	0.499127	1.209463	0.484754	89.77742	34.95481	90.95884	8.988602	0.070699	8.917903
C7	16	19	0.1368	0.0133	0.1235	0.72	0.07	0.65	0.367298	1.767677	0.338615	90.14472	36.72249	91.29746	8.586803	0.070665	8.516138
Tail 6		1587	3.6501	0.4761	3.174	0.23	0.03	0.2	9.800242	63.27751	8.702542	100	100	100	1.881926	0.038038	1.843888
TOTAL		1978	37.2245	0.7524	36.4721												

20MINUTES GRIND TIME 6MINUTES ROUGHER-10MINUTES SCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE WEIGHT(g) WT	TCu	ASCu	AICu	GRADE(%) TCu	ASCu	AICu	RECOVERY TCu	ASCu	AICu	CUMULATIVE RECOVERY Tcu	ASCu	AICu	CUMULATIVE GRADE TCu	ASCu	AICu
C1	1	172	11.6444	0.1548	11.4896	6.77	0.09	6.68	66.14107	7.908046	73.42583	66.14107	7.908046	73.42583	6.77	0.09	6.68
C2	3	22	1.3728	0.0242	1.3486	6.24	0.11	6.13	7.797608	1.236271	8.618409	73.93868	9.144317	82.04424	6.709897	0.092268	6.617629
C3	6	11	0.2992	0.0099	0.2893	2.72	0.09	2.63	1.699479	0.505747	1.84881	75.63816	9.650064	83.89305	6.495805	0.092146	6.403659
C4	7	69	0.9177	0.0621	0.8556	1.33	0.09	1.24	5.212605	3.172414	5.467826	80.85076	12.82248	89.36087	5.194927	0.091606	5.103321
C5	9	26	0.1248	0.0156	0.1092	0.48	0.06	0.42	0.708873	0.796935	0.697857	81.55964	13.61941	90.05873	4.7863	0.088867	4.697433
C6	12	11	0.0528	0.0099	0.0429	0.48	0.09	0.39	0.299908	0.505747	0.274158	81.85954	14.12516	90.33289	4.633987	0.088907	4.54508
C7	16	20	0.034	0.018	0.016	0.17	0.09	0.08	0.193123	0.91954	0.10225	82.05267	15.0447	90.43514	4.36426	0.088973	4.275287
Tail		1663	3.1597	1.663	1.4967	0.19	0.1	0.09	17.94733	84.9553	9.564862	100	100	100	0.882919	0.09817	0.784749
TOTAL		1994	17.6054	1.9575	15.6479												

25MINUTES GRIND TIME 6MINUTES ROUGHER-10MINUTES SCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE WEIGHT(g) WT	TCu	ASCu	AICu	GRADE(%) TCu	ASCu	AICu	RECOVERY TCu	ASCu	AICu	CUMULATIVE RECOVERY TCu	ASCu	AICu	CUMULATIVE GRADE TCu	ASCu	AICu
C1	1	157	39.0773	0.1727	38.9046	24.89	0.11	24.78	77.17768	6.106789	81.38203	77.17768	6.106789	81.38203	24.89	0.11	24.78
C2	3	27	4.1094	0.0405	4.0689	15.22	0.15	15.07	8.116067	1.432107	8.511471	85.29375	7.538897	89.8935	23.47103	0.11587	23.35516
C3	6	16	0.5808	0.016	0.5648	3.63	0.1	3.53	1.14708	0.565771	1.181469	86.44083	8.104668	91.07497	21.88375	0.1146	21.76915
C4	7	84	2.1924	0.1008	2.0916	2.61	0.12	2.49	4.329991	3.564356	4.375284	90.77082	11.66902	95.45026	16.18306	0.116197	16.06687
C5	9	36	0.5004	0.0432	0.4572	1.39	0.12	1.27	0.98829	1.527581	0.956387	91.75911	13.19661	96.40664	14.51884	0.116625	14.40222
C6	12	16	0.0976	0.0176	0.08	0.61	0.11	0.5	0.19276	0.622348	0.167347	91.95187	13.81895	96.57399	13.85652	0.11631	13.74021
C7	16	26	0.065	0.0312	0.0338	0.25	0.12	0.13	0.128375	1.103253	0.070704	92.08025	14.92221	96.6447	12.87925	0.116575	12.76268
Tail 6		1604	4.01	2.406	1.604	0.25	0.15	0.1	7.919752	85.07779	3.355305	100	100	100	2.575427	0.143845	2.431582
TOTAL		1966	50.6329	2.828	47.8049												

30MINUTES GRIND TIME 6MINUTES ROUGHER-10MINUTES SCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE							RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WEIGHT(g)				GRADE(%)											
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu
C1	1	132	33.2244	0.2244	33	25.17	0.17	25	67.38095	13.72561	69.22099	67.38095	13.72561	69.22099	25.17	0.17	25
C2	3	36	0.8352	0.0756	0.7596	2.32	0.21	2.11	1.693832	4.624136	1.593341	69.07478	18.34975	70.81433	20.27357	0.178571	20.095
C3	6	40	4.892	0.096	4.796	12.23	0.24	11.99	9.921251	5.871919	10.06012	78.99603	24.22166	80.87445	18.72673	0.190385	18.53635
C4	7	73	1.5257	0.0949	1.4308	2.09	0.13	1.96	3.094205	5.804636	3.001254	82.09024	30.0263	83.8757	14.40473	0.174698	14.23004
C5	9	35	0.5495	0.07	0.4795	1.57	0.2	1.37	1.114417	4.281607	1.005802	83.20465	34.30791	84.88151	12.98316	0.1775	12.80566
C6	12	22	0.2134	0.0572	0.1562	0.97	0.26	0.71	0.432787	3.498685	0.327646	83.63744	37.80659	85.20915	12.20124	0.18287	12.01837
C7	16	22	0.1056	0.0418	0.0638	0.48	0.19	0.29	0.214163	2.556731	0.133827	83.8516	40.36332	85.34298	11.48494	0.183306	11.30164
Tail 6		1625	7.9625	0.975	6.9875	0.49	0.06	0.43	16.1484	59.63668	14.65702	100	100	100	2.484045	0.082363	2.401683
TOTAL		1985	49.3083	1.6349	47.6734												

35MINUTES GRIND TIME 6MINUTES ROUGHER-10MINUTES SCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE							RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WEIGHT(g)				GRADE(%)											
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu
C1	1	125	35	0.075	34.925	28	0.06	27.94	81.69	7.321359	83.51167	81.69	7.321359	83.51167	28	0.06	27.94
C2	3	37	3.293	0.0222	3.2708	8.9	0.06	8.84	7.685862	2.167122	7.821045	89.37587	9.488481	91.33272	23.63765	0.06	23.57765
C3	6	25	0.3525	0.015	0.3375	1.41	0.06	1.35	0.822735	1.464272	0.80702	90.1986	10.95275	92.13974	20.66604	0.06	20.60604
C4	7	87	0.9657	0.0522	0.9135	1.11	0.06	1.05	2.253944	5.095666	2.184335	92.45254	16.04842	94.32408	14.45664	0.06	14.39664
C5	9	47	0.5875	0.0235	0.564	1.25	0.05	1.2	1.371225	2.294026	1.348621	93.82377	18.34244	95.6727	12.52296	0.058536	12.46442
C6	12	21	0.3171	0.0105	0.3066	1.51	0.05	1.46	0.740111	1.02499	0.733133	94.56388	19.36743	96.40583	11.84673	0.058012	11.78871
C7	16	15	0.201	0.0075	0.1935	1.34	0.05	1.29	0.469134	0.732136	0.462692	95.03301	20.09957	96.86852	11.40527	0.057675	11.34759
Tail 6		1637	2.1281	0.8185	1.3096	0.13	0.05	0.08	4.966986	79.90043	3.131479	100	100	100	2.148691	0.051374	2.097317
TOTAL		1994	42.8449	1.0244	41.8205												

40MINUTES GRIND TIME 6MINUTES ROUGHER-10MINUTES SCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE							RECOVERY (%)			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WEIGHT(g)				GRADE(%)											
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu
C1	1	115	27.6	0.414	27.186	24	0.36	23.64	68.02118	14.772	71.97204	68.02118	14.772	71.97204	24	0.36	23.64
C2	3	57	5.9052	0.1767	5.7285	10.36	0.31	10.05	14.55357	6.30486	15.16559	82.57475	21.07686	87.13764	19.47977	0.34343	19.13634
C3	6	69	1.1937	0.1518	1.0419	1.73	0.22	1.51	2.941916	5.416399	2.758319	85.51667	26.49326	89.89596	14.39788	0.308091	14.08979
C4	7	127	1.8669	0.4191	1.4478	1.47	0.33	1.14	4.601041	14.95397	3.832897	90.11771	41.44723	93.72885	9.936359	0.315652	9.620707
C5	9	46	0.7958	0.2392	0.5566	1.73	0.52	1.21	1.961277	8.534932	1.473539	92.07898	49.98216	95.20239	9.024541	0.338357	8.686184
C6	12	24	0.348	0.1248	0.2232	1.45	0.52	0.93	0.857658	4.453008	0.590898	92.93664	54.43517	95.79329	8.609498	0.348311	8.261187
C7	16	46	0.299	0.069	0.23	0.65	0.15	0.5	0.736896	2.462	0.608901	93.67354	56.89717	96.40219	7.853017	0.329463	7.523554
Tail 6		1510	2.567	1.208	1.359	0.17	0.08	0.09	6.326462	43.10283	3.597808	100	100	100	2.034885	0.140552	1.894333
TOTAL		1994	40.5756	2.8026	37.773												

15MINUTES GRIND TIME 7MINUTES ROUGHER-11MINUTES SCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE							RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WEIGHT(g)				GRADE(%)											
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu
C1	1	144	26.28	0.1728	26.1072	18.25	0.12	18.13	64.95031	20.78172	65.87703	64.95031	20.78172	65.87703	18.25	0.12	18.13
C2	3.5	37	5.069	0.0555	5.0135	13.7	0.15	13.55	12.5279	6.674684	12.65071	77.47821	27.4564	78.52774	17.31989	0.126133	17.19376
C3	7	24	0.6864	0.0168	0.6696	2.86	0.07	2.79	1.696419	2.020445	1.689621	79.17463	29.47685	80.21736	15.62702	0.119561	15.50746
C4	8	107	3.1672	0.0642	3.103	2.96	0.06	2.9	7.827649	7.720986	7.829887	87.00228	37.19784	88.04725	11.28288	0.099135	11.18375
C5	10.5	29	0.7221	0.0203	0.7018	2.49	0.07	2.42	1.784651	2.441371	1.770872	88.78693	39.63921	89.81812	10.5351	0.096657	10.43845
C6	14	9	0.2142	0.0072	0.207	2.38	0.08	2.3	0.52939	0.865905	0.522329	89.31632	40.50511	90.34045	10.3254	0.096229	10.22917
C7	18	9	0.1134	0.009	0.1044	1.26	0.1	1.16	0.280265	1.082381	0.263435	89.59658	41.58749	90.60388	10.09813	0.096323	10.00181
Tail 7		1619	4.2094	0.4857	3.7237	0.26	0.03	0.23	10.40342	58.41251	9.396117	100	100	100	2.045586	0.042037	2.003549
TOTAL		1978	40.4617	0.8315	39.6302												

20MINUTES GRIND TIME 7MINUTES ROUGHER-11MINUTES SCAVENGER

FRACTION	CUMULATIVE TIME (MIN)								RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WEIGHT(g)				GRADE(%)											
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	Tcu	ASCu	AlCu	TCu	ASCu	AlCu
C1	1	203	13.3371	0.1421	13.195	6.57	0.07	6.5	73.29849	14.89362	76.53046	73.29849	14.89362	76.53046	6.57	0.07	6.5
C2	3.5	35	0.161	0.021	0.14	0.46	0.06	0.4	0.884829	2.201027	0.811994	74.18332	17.09464	77.34246	5.671471	0.068529	5.602941
C3	7	28	1.0752	0.0224	1.0528	3.84	0.08	3.76	5.909121	2.347762	6.106197	80.09244	19.44241	83.44866	5.478684	0.069737	5.408947
C4	8	100	0.45	0.08	0.37	0.45	0.08	0.37	2.473125	8.384865	2.145985	82.56557	27.82727	85.59464	4.104727	0.072541	4.032186
C5	10.5	27	0.135	0.0243	0.1107	0.5	0.09	0.41	0.741938	2.546903	0.642056	83.3075	30.37417	86.2367	3.857074	0.07374	3.783333
C6	14	13	0.026	0.0117	0.0143	0.2	0.09	0.11	0.142892	1.226287	0.082939	83.45039	31.60046	86.31964	3.739975	0.074261	3.665714
C7	18	14	0.0644	0.0322	0.0322	0.46	0.23	0.23	0.353932	3.374908	0.186759	83.80433	34.97537	86.50639	3.630643	0.079452	3.55119
Tail 7		1551	2.9469	0.6204	2.3265	0.19	0.04	0.15	16.19567	65.02463	13.49361	100	100	100	0.923166	0.048407	0.874759
TOTAL		1971	18.1956	0.9541	17.2415												

25MINUTES GRIND TIME 7MINUTES ROUGHER-11MINUTES SCAVENGER

FRACTION	CUMULATIVE TIME (MIN)	AVEARGE							RECOVERY			CUMULATIVE RECOVERY			CUMULATIVE GRADE		
		WEIGHT(g)				GRADE(%)											
		WT	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu	TCu	ASCu	AlCu
C1	1	197	41.3109	0.197	41.1139	20.97	0.1	20.87	84.85641	14.68396	86.845	84.85641	14.68396	86.845	20.97	0.1	20.87
C2	3.5	40	2.992	0.04	2.952	7.48	0.1	7.38	6.145845	2.981515	6.235518	91.00225	17.66547	93.08052	18.69321	0.1	18.59321
C3	7	27	0.4158	0.027	0.3888	1.54	0.1	1.44	0.854092	2.012522	0.821263	91.85634	19.678	93.90178	16.9389	0.1	16.8389
C4	8	87	0.5394	0.0696	0.4698	0.62	0.08	0.54	1.107977	5.187835	0.99236	92.96432	24.86583	94.89414	12.89405	0.095043	12.799
C5	10.5	48	0.2352	0.0384	0.1968	0.49	0.08	0.41	0.483123	2.862254	0.415701	93.44745	27.72809	95.30984	11.40183	0.093233	11.3086
C6	14	30	0.06	0.024	0.036	0.2	0.08	0.12	0.123246	1.788909	0.076043	93.57069	29.51699	95.38589	10.61848	0.092308	10.52618
C7	18	33	0.066	0.0264	0.0396	0.2	0.08	0.12	0.13557	1.9678	0.083647	93.70626	31.48479	95.46953	9.874307	0.091429	9.782879
Tail 7		1532	3.064	0.9192	2.1448	0.2	0.06	0.14	6.293739	68.51521	4.530467	100	100	100	2.441489	0.067282	2.374208
TOTAL		1994	48.6833	1.3416	47.3417												

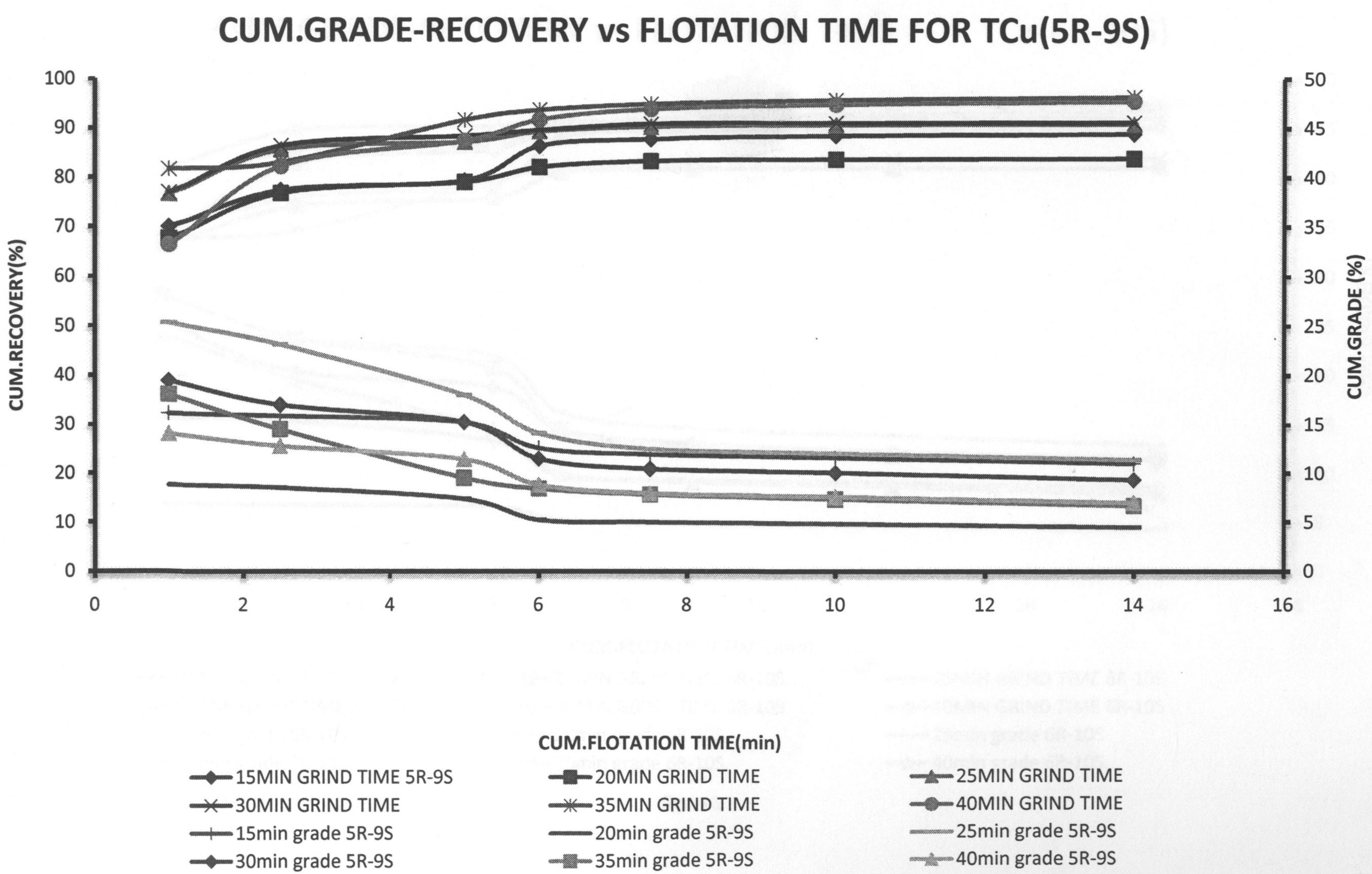

CUM.GRADE-RECOVERY vs FLOTATION TIME FOR TCu(5R-9S)
CUM.RECOVERY(%)
CUM.GRADE (%)
CUM.FLOTATION TIME(min)
0
2
4
6
8
10
12
14
16
100
90
80
70
60
50
40
30
20
10
50
45
40
35
30
25
20
15
5
15MIN GRIND TIME 5R-9S
20MIN GRIND TIME
25MIN GRIND TIME
30MIN GRIND TIME
35MIN GRIND TIME
40MIN GRIND TIME
15min grade 5R-9S
20min grade 5R-9S
25min grade 5R-9S
30min grade 5R-9S
35min grade 5R-9S
40min grade 5R-9S

figure 1...

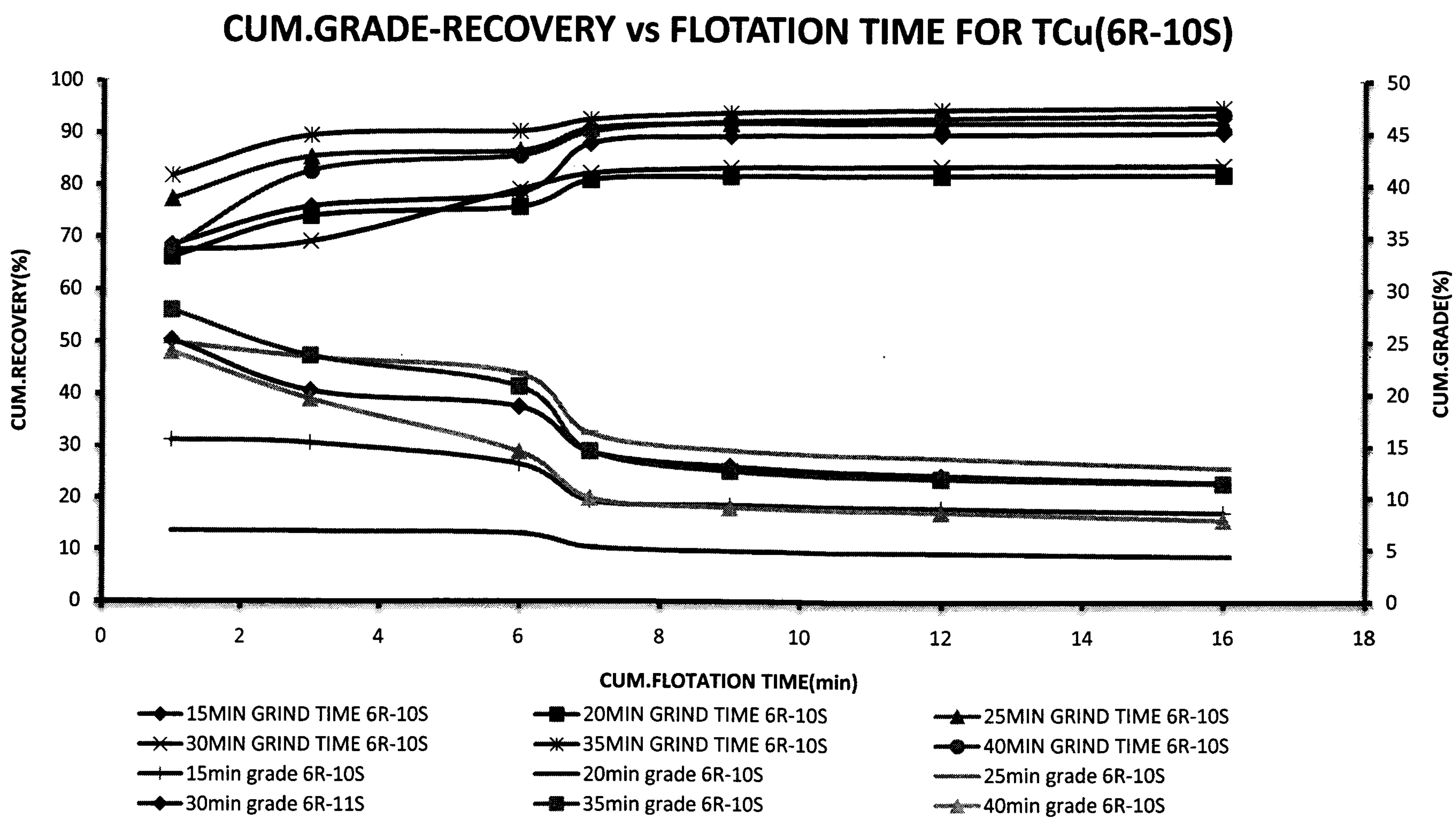
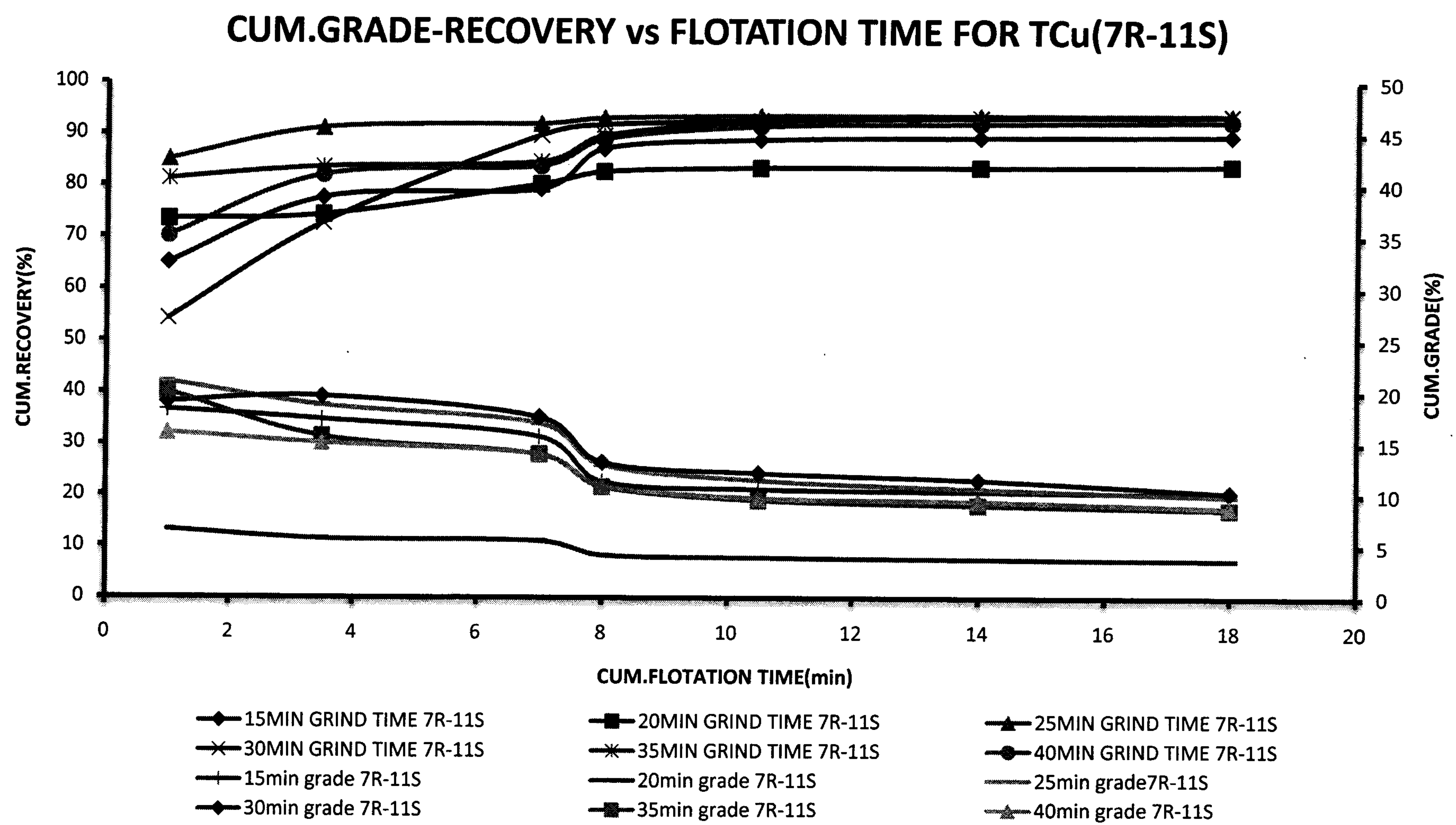

CUM.GRADE-RECOVERY vs FLOTATION TIME FOR TCu(6R-10S)
CUM.RECOVERY(%)
CUM.GRADE(%)
CUM.FLOTATION TIME(min)
15MIN GRIND TIME 6R-10S
20MIN GRIND TIME 6R-10S
25MIN GRIND TIME 6R-10S
30MIN GRIND TIME 6R-10S
35MIN GRIND TIME 6R-10S
40MIN GRIND TIME 6R-10S
15min grade 6R-10S
20min grade 6R-10S
25min grade 6R-10S
30min grade 6R-11S
35min grade 6R-10S
40min grade 6R-10S

figure2


CUM.GRADE-RECOVERY vs FLOTATION TIME FOR TCu(7R-11S)
CUM.RECOVERY(%)
0
10
20
30
40
50
60
70
80
90
100
CUM.GRADE(%)
0
5
10
15
20
25
30
35
40
45
50
CUM.FLOTATION TIME(min)
0
2
4
6
8
10
12
14
16
18
20
15MIN GRIND TIME 7R-11S
20MIN GRIND TIME 7R-11S
25MIN GRIND TIME 7R-11S
30MIN GRIND TIME 7R-11S
35MIN GRIND TIME 7R-11S
40MIN GRIND TIME 7R-11S
15min grade 7R-11S
20min grade 7R-11S
25min grade7R-11S
30min grade 7R-11S
35min grade 7R-11S
40min grade 7R-11S
figure3

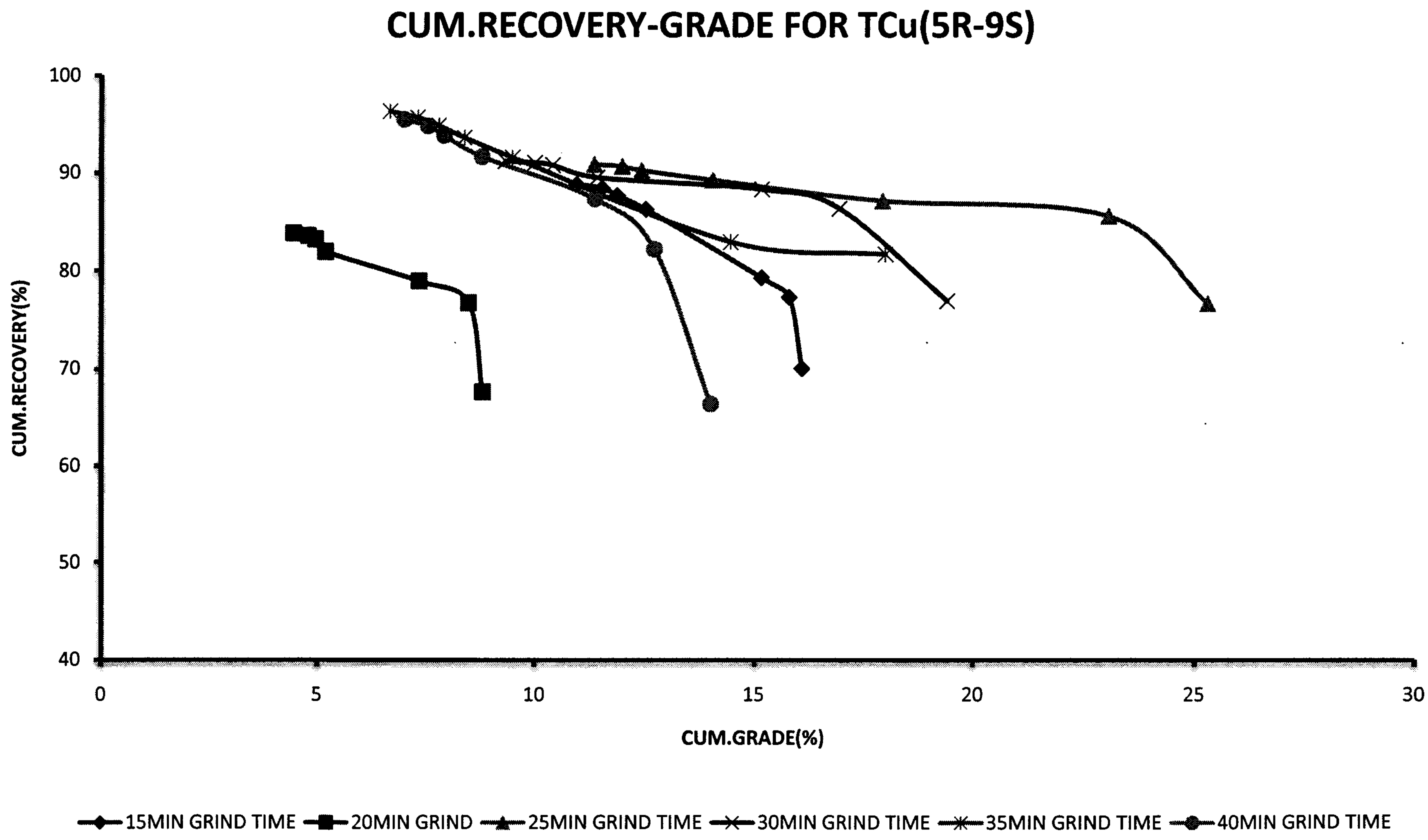
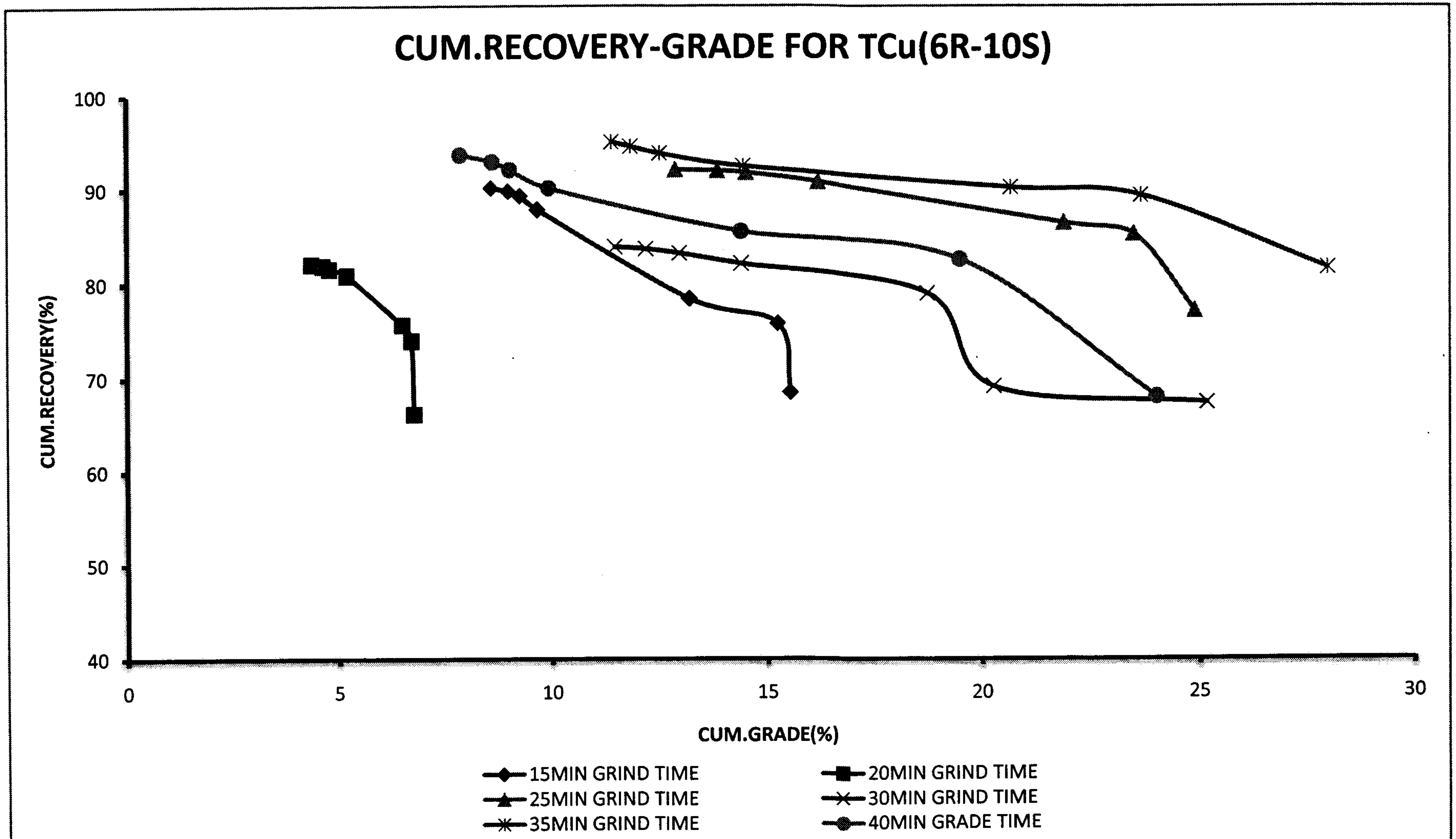

CUM.RECOVERY-GRADE FOR TCu(5R-9S)
CUM.RECOVERY(%)
100
90
80
70
60
50
40
0
5
10
15
20
25
30
CUM.GRADE(%)
15MIN GRIND TIME
20MIN GRIND
25MIN GRIND TIME
30MIN GRIND TIME
35MIN GRIND TIME
40MIN GRIND TIME

figure 4


CUM.RECOVERY-GRADE FOR TCu(6R-10S)
CUM.RECOVERY(%)
100
90
80
70
60
50
40
0
5
10
15
20
25
30
CUM.GRADE(%)
15MIN GRIND TIME
20MIN GRIND TIME
25MIN GRIND TIME
30MIN GRIND TIME
35MIN GRIND TIME
40MIN GRADE TIME
figure5

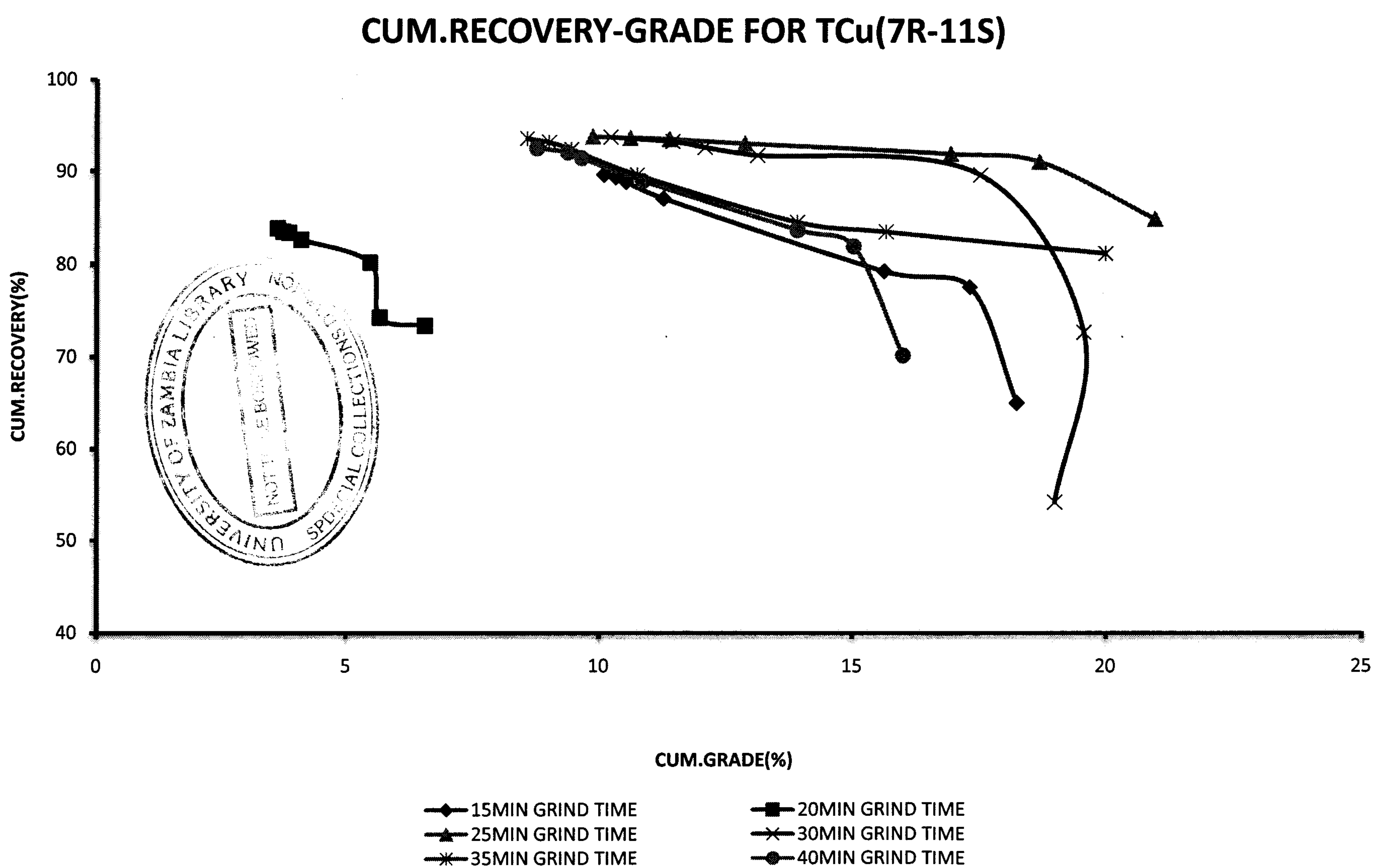

CUM.RECOVERY-GRADE FOR TCu(7R-11S)
CUM.RECOVERY(%)
100
90
80
70
60
50
40
0
5
10
15
20
25
CUM.GRADE(%)
15MIN GRIND TIME
20MIN GRIND TIME
25MIN GRIND TIME
30MIN GRIND TIME
35MIN GRIND TIME
40MIN GRIND TIME

figure 6