

DEVELOPMENT OF A MINERAL FLOTATION FROTHER FOR NCHANGA MINE ON THE ZAMBIAN COPPERBELT

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ABSTRACT

By the time a reagent is finally accepted by a mine for use on its plant it could have gone through several screening and evaluation stages. These stages may include laboratory and plant evaluation testwork.

This paper outlines the steps that were followed to select, design and implement a frother for KONKOLA COPPER MINES PLC Nchanga Copper Concentrator in Zambia. It discusses initial frother screening work conducted at the Betachem metallurgical laboratory and the subsequent laboratory screening testwork conducted at Nchanga Concentrator. A modified Bikerman test method is discussed which was used to design a frother for the Nchanga flotation plant.

The paper also gives an account of several plant scale trials conducted on Nchanga flotation plant and discusses the plant results, frother consumption patterns and some commercial concerns, before the product was finally accepted by the mine.

1. Introduction

Although formulating a frother for the specific requirement of the plant has several benefits, most flotation plants do not use-tailor made products and stick to industry standard products. The complexity of laboratory scale frother screening and the risks associated with extended plant tests is probably the reason why some plants would rather stick to standard products.

Konkola Copper Mines (KCM) Plc launched a project to develop a tailor made frother for the Nchanga Copper Concentrator. A number of frother manufacturers, including Betachem (Pty) Ltd, were invited to help. KCM Plc followed the following steps to develop and test a frother for Nchanga Concentrator:

Step 1: Frother screening by the manufacturer: The frother manufacturers were requested to do in-house frother screening to develop a couple of frothers to be tested at the mine laboratory. Betachem requested a sample of all ore types treated by Nchanga concentrator and used a modified Bikerman test procedure to screen frothers at its metallurgical laboratory in Johannesburg. The method and results of this work is discussed in section 2

Step 2: Laboratory scale testwork: The frothers provided by the manufacturers were tested at the mine laboratory using the traditional Denver type laboratory flotation equipment. This method gives an indication of the expected frother performance, but KCM Plc was well aware of the constraints of this method. For this reason two frothers from Betachem (Pty) Ltd were selected for the next phase. Results of this testwork are discussed in section 3

Step 3: Short plant testwork: A short (one week) plant test was conducted for each of the two frothers selected in the laboratory. Both Betafroth FZN6 and FZN 20 gave promising results. Results of this phase are discussed in section 4

Step 4: Extended plant test: It is well known fact that some frothers build up in the water circuit and the full effect of a frother change is only evident during an extended plant test. Betafroth FZN 20 was tested over an extended period. Results are discussed in section 5

2. Initial frother screening by Betachem (Pty) Ltd

One of the reasons the industry largely uses standard frothers is the absence of a method to screen a large number of frother types and thus design and develop a frother to cater for the specific needs of a mine. The Bikerman method was used to test froth stability during the early column flotation research and development era [J.A.Engelbrecht (1996-2000)]. Betachem has adapted this method to serve as a frother screening method.



Figure 1: Modified Bikerman test rig. Used to test froth characteristics and is a tool to design and select a frother for a specific application.

It is well known that ore type and plant operational factors have an effect on froth stability. For example collector type and dosage rate, gangue content, grind and water quality. It is thus almost impossible to tailor make a frother without taking these factors into consideration. With the modified Bikerman procedure a range of frothers can be tested using the ore, water, grind and reagent suite used by the mine. This largely takes the guesswork out of frother design.

A modified Bikerman test rig is shown in figure 1. The froth stability (height of stable froth, at increasing frother dosing rates) and the time the froth column takes to break down, is used as criteria when selecting a frother.

The two ore types treated by the Nchanga Concentrator, that is underground and opencast ores, were tested. The stable froth height data is shown in figures 2 and 3 for the two ore types. The most suited frother is expected to produce the highest froth column at the lowest frother dosing rate.

A common oversight in frother design is the ability of the froth to break down after flotation (well known “sticky” froth). The time the froth takes to break down is also measured in the test procedure and used as selection criterion. This is shown in figures 4 and 5. The ideal characteristic is the fastest froth breakdown time for the same froth height.

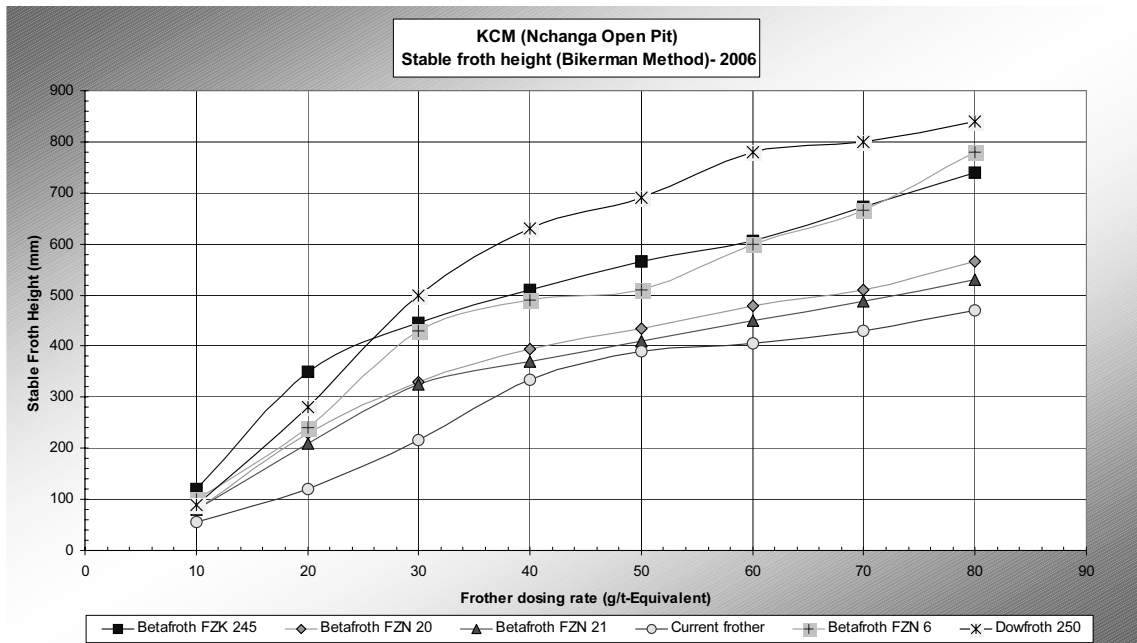


Figure 2: Nchanga Mine, Openpit Ore. Equilibrium froth height at increasing frother dosing rates for a number of frothers tested. Glycol-based frothers: Dowfroth 250, Betafroth FZN 6 and Betafroth FZK 245. Alcohol-based frothers: Betafroth FZN 20 and Betafroth FZN 21

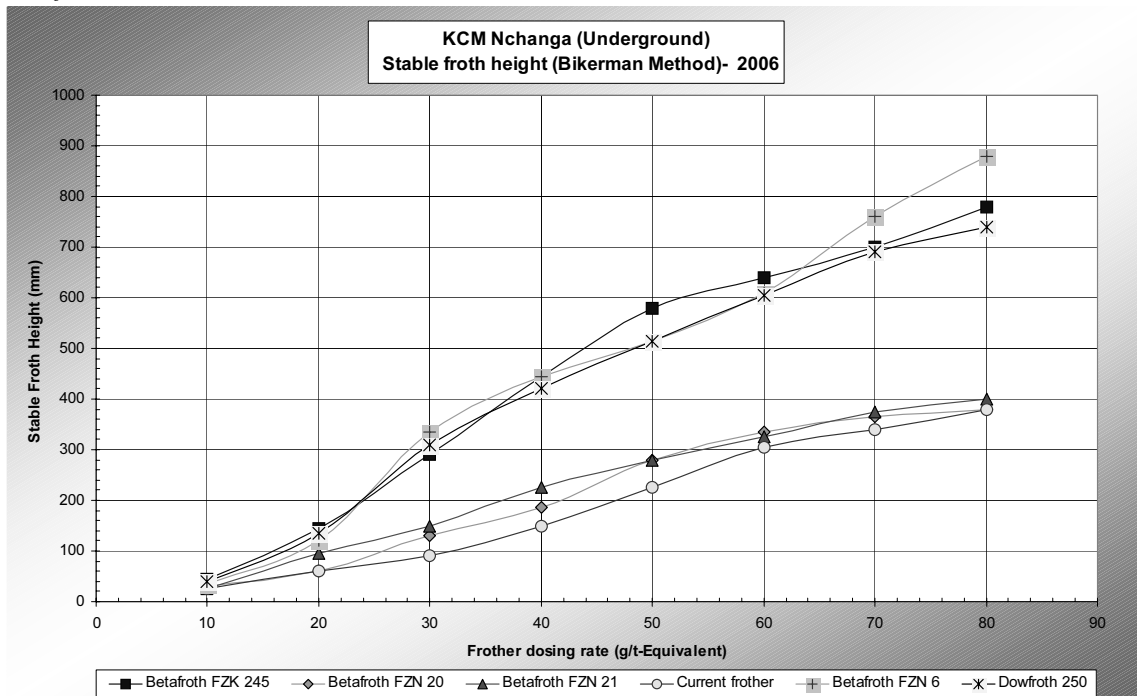


Figure 3: Nchanga Mine, Underground Ore. Equilibrium froth height at increasing frother dosing rates for a number of frothers tested. Glycol-based frothers: Dowfroth 250, Betafroth FZN 6 and Betafroth FZK 245. Alcohol-based frothers: Betafroth FZN 20 and Betafroth FZN 21

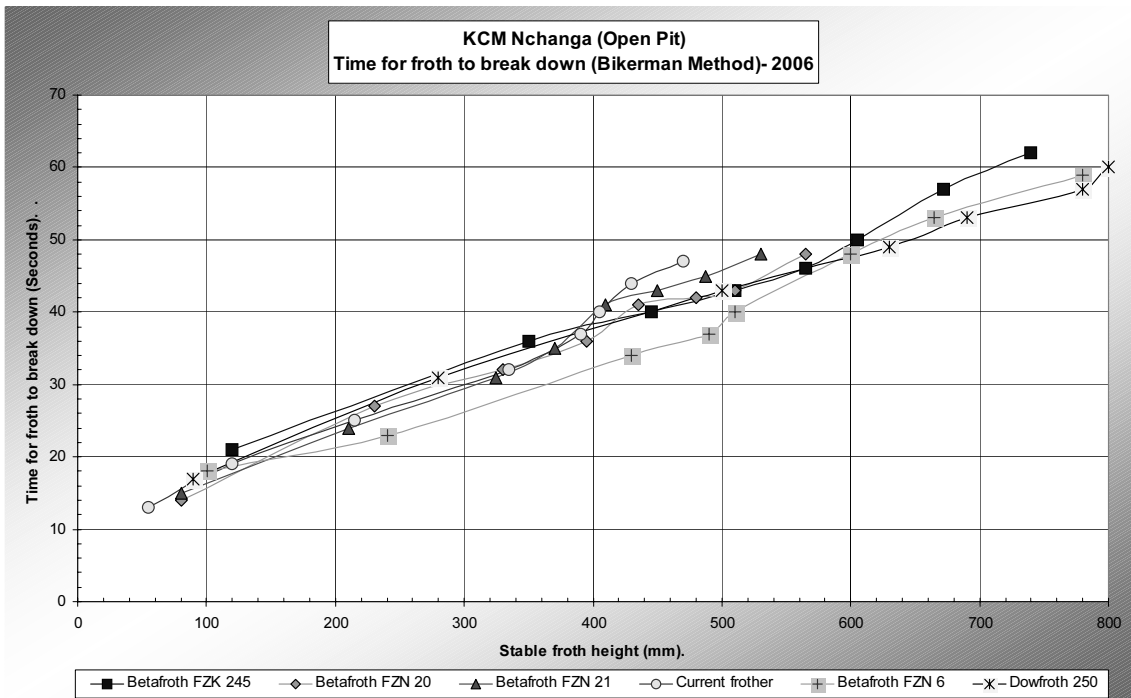


Figure 4: Nchanga Mine, Openpit Ore. Time for froth column to break down. Glycol based frothers: Dowfroth 250, Betafroth FZN 6 and Betafroth FZK 245. Alcohol based frothers: Betafroth FZN 20 and Betafroth FZN 21

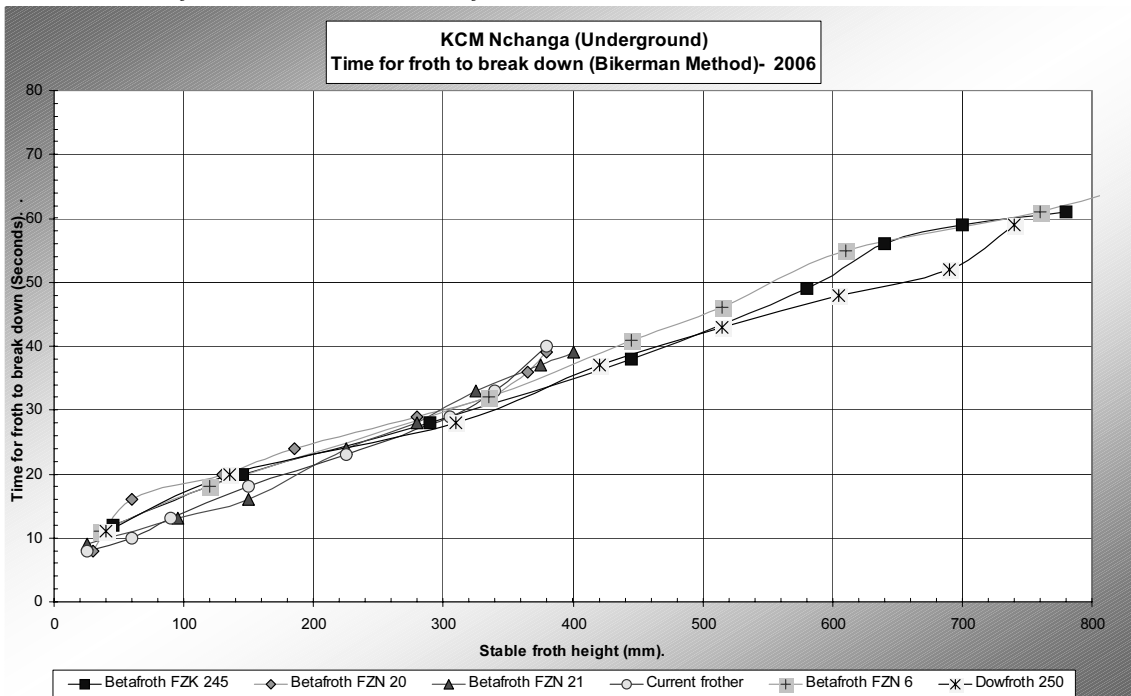


Figure 5: Nchanga Mine, Underground Ore. Time for froth column to break down. Glycol based frothers: Dowfroth 250, Betafroth FZN 6 and Betafroth FZK 245. Alcohol based frothers: Betafroth FZN 20 and Betafroth FZN 21

From the data shown in Figures 2 to 4, Betachem recommended two frothers to be tested at Nchanga Concentrator, namely;

Betafroth FZN 6 is a glycol ether based frother. This frother formed a highest froth column at low dosing rates (figures 2 and 3) without forming a sticky froth (figures 4 and 5). It was predicted that for open pit ore 25 g/t of Betafroth FZN 6 would form the same froth structure as 35 g/t of the current frother used. For underground ore, 30 g/t Betafroth FZN 6 is comparable to 60 g/t of the current frother.

Betafroth FZN 20 is an alcohol based frother. This frother showed the highest froth column of the alcohol frothers tested. It was predicted that 50 g/t Betafroth FZN 20 will give the same froth structure as 60 g/t of the current frother for underground ore. For opencast ore, 70 g/t Betafroth FZN 20 is comparable to 90 g/t of the current frother. This froth broke down fast and no sticky froth problems were predicted.

From figures 2 and 3, it can be shown that the glycol type frothers maintain a reasonable froth height for both ore types. The alcohol frothers struggle to maintain a reasonable froth height for the underground ore, but for the opencast ore the alcohols seem to work well. The reason for this is probably froth stabilisation by gangue particles in the opencast ore. For open-pit ore, the Betafroth FZN 6 froth broke down faster than any of the other frothers tested. This is probably related to better froth drainage and less gangue entrainment.

The unit cost of Betafroth FZN 6 is more than twice that of Betafroth FZN 20. The expected dosing rate for Betafroth FZN 6 needs to be half of Betafroth FZN 20 in order for FZN6 to be considered as a viable option. It is predicted that the glycol-based frothers (FZN 6) would only be cost effective on underground ore, while on opencast ore Betafroth FZN 20 would be more cost effective.

Betafroth FZN 20 and Betafroth FZN 6 were recommended by Betachem for further laboratory screening at Nchanga mine site.

3. Laboratory scale testing of frothers

Frothers Betafroth FZN6 and FZN20 were tested at different times on the combined plant feed pulp. The laboratory flotation tests were conducted in duplicate at 30g/t dose and were tested following the plant's standard laboratory procedure. Table 1 below shows average results of tests compared to tests using the then standard frother.

Table 1 : Results of Laboratory testwork done at Nchanga metallurgical laboratory on selected frothers .

Frother used	Dose g/t	Concentrate Grade			Recovery		
		Total Cu	Acid Soluble Cu	Acid Insoluble Cu	Total Cu	Acid Soluble Cu	Acid Insoluble Cu
Standard	30	21.4	3.24	18.1	60.9	26.7	79.0
Betafroth FZN 6	30	20.4	2.72	17.7	58.9	19.5	85.5
Standard	30	15.0	2.96	12.0	60.9	29.4	81.0
Betafroth FZN 20	30	14.4	2.88	11.5	67.0	36.7	84.5

Both test frothers (FZN6 and FZN20) improved acid-insoluble (sulphide) copper recoveries at comparable acid-insoluble (sulphide) grades. Only the alcohol based frother Betafroth FZN 20 showed higher acid soluble (oxide) copper recoveries at similar concentrate grades. As predicted by the Bikerman test results, drainage of the froth produced by the glycol frother Betafroth FZN 6 is better and thus lower entrainment and lower oxide copper grade and recoveries.

During the laboratory scale test phase, both frothers selected during the screening phase, showed potential:

Betafroth FZN 20 would increase the recovery of sulphide copper minerals (acid insoluble Cu) AND oxide copper mineral (acid soluble Cu).

Betafroth FZN 6 would only increase the recovery of sulphide copper minerals (acid insoluble Cu). The benefit of this would be more selective flotation of sulphides in the sulphide flotation circuit and let the oxides go to leach circuit.

4. Short plant scale testing of selected frothers

Short plant tests, lasting one week, were conducted on the two frothers that showed potential in the laboratory. The first frother to be tested was Betafroth FZN6. It was tested on both underground (lower ore body, LOB ore) and open pit (Nchanga open pit) flotation circuits. Betafroth FZN20 was tested on underground circuit only. The plant performance results obtained during the test period were compared with results obtained from the period before and after test frothers. Table 2 shows performance results obtained.

Table 2 : Plant production result for short periods when frothers were tested 3

Frother	Tonnage	Frother Dose	Conc Grade		Recovery		Ore Type
		(g/t)	(%TCu)	(%Insols)	(%TCu)	(%AICu)	
STD	243448	61	40.64	19.74	38.74	64.52	LOB+NOP
FZN6	409776	35	42.36	19.85	43.31	70.47	LOB+NOP
STD	58894	61	34.57	27.83	33.62	60.76	LOB
FZN20	65636	53	32.35	23.36	40.56	70.54	LOB

The Bikerman test results (in section 2) predicted a reduction in frother from 60 g/t to 35 g/t when Betafroth FZN 6 is used. The plant results showed a reduction from 61 g/t to 35 g/t. Sulphide mineral recovery (acid insoluble copper) recovery increased by 6 percent as predicted during the lab scale test (section 3). During the plant test both the total copper recovery and total copper grades increased, which was not expected.

The Bikerman test results (in section 2) predicted a reduction in frother from 60 g/t to 50 g/t when Betafroth FZN 20 is used. The plant results showed a reduction from 61 g/t to 53 g/t. Sulphide mineral recovery (acid insoluble copper) recovery increased by 10 percent which was higher than predicted during the lab scale test (section 3). Total copper recovery increased by 6 percent as expected. The concentrate grade was lower as expected from the laboratory scale work (section 3).

The short plant trial results motivated an extended plant test. For commercial reasons only Betafroth FZN 20 was tested over a longer period of time.

5. Extended plant scale testing of Betafroth FZN 20

Following successful laboratory and short period plant scale tests, a decision was made at Nchanga Concentrator to conduct a longer period plant scale testing of FZN 20. The trial period covered the whole month of September 2006. However, the test frother was introduced on the plant on 23 August 2006, well before the beginning of the trial period on the first of September 2006. This early start was meant to resolve any start-up problems associated with introduction of a new reagent on the plant.

The results obtained during the month of September 2006 trial are presented in Table 3. These results show that FZN 20 achieved higher acid-insoluble copper (AICu) recovery than the frothers that were used in August and October 2006. The AICu recovery achieved with FZN 20 was 75.2 percent in September as compared to 66.9 percent and 59.7 percent for August and October 2006 respectively.

Table 3: Plant production data for extended periods when frothers were tested.

Month	Frother used	Recovery Acid Insoluble Copper	Concentrate grade Total Copper
August 2006	Current combination frother (Alcohol and phthalate)	66.9%	35.9
September 2006	Betafroth FZN 20	75.2%	36.9
October 2006	Current alcohol frother	59.7%	43.5

After the longer plant trial, the frother was re-introduced on the plant in February 2007. The AICu recovery for the month of February 2007 is presented in Table 4, and compared to January 2007 AICu recovery.

Table 4: Plant production data for extended periods when frothers were tested.

Month	Frother used	Recovery Acid insoluble Copper	Concentrate grade Acid insoluble Copper
January 2007	Current combination frother (Alcohol and phthalate)	50.1%	31.1
February 2007	Betafroth FZN 20	64.5%	32.7

6. Conclusion

From experience during the project to find a tailor made frother for Nchanga concentrator, the following can be concluded:

- A frother that is tailor made for the application can lead to significant grade and recovery benefits.
- When a step-by-step process is followed, much of the risk in designing and testing a new frother can be eliminated.
- The modified Bikerman test method can be used effectively to screen frothers and predict its effect on plant performance.
- Testing of frothers using traditional bench scale laboratory equipment is only indicative and should only be used to manage risk of subsequent plant scale tests.

Reference

J.A. Engelbrecht, Various personal communications.