GRINDING AND FLOTATION CIRCUITS OF THE CONCENTRATOR II OF GERMANO[1]

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Abstract
By using learned experiences of thirty years of operation in Samarco Mineração SA and standardized tests, Process Crew conceited a new concentrator simpler and more efficient than the first one, in the context of "Third Pelletizing Plant Project".
Key words: Flotation; Grinding; Sizing.

O CIRCUITO DE MOAGEM E FLOTAÇÃO DO CONCENTRADOR II DE GERMANO

Resumo
A aplicação de experiências aprendidas ao longo dos trinta anos de operação na Samarco Mineração S.A., bem como o uso de técnicas experimentais consolidadas pela equipe de processo possibilitaram a conceituação de um novo concentrador de fluxograma mais simples e eficiente que o concentrador atual, no contexto do Projeto Terceira Pelotização.
Palavras-chave: Flotação; Moagem; Dimensionamento.

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1 INTRODUCTION

The Concentrator II of Germano started up in 2008, May. This new plant will product 7.5 millions of concentrate per year, which will increase Germano's production in 30 percent.
The concept of this new concentrator is a result of all the learned experiences in thirty yeas of operation in Samarco. In its circuits all the improvements done in concentrator I were incorporated.
As a result, grinding and flotation circuits, in special, are much simpler and easier to operate than the circuits of Concentrator I. The Figure 1 shows the flow sheet of the Concentrator II.

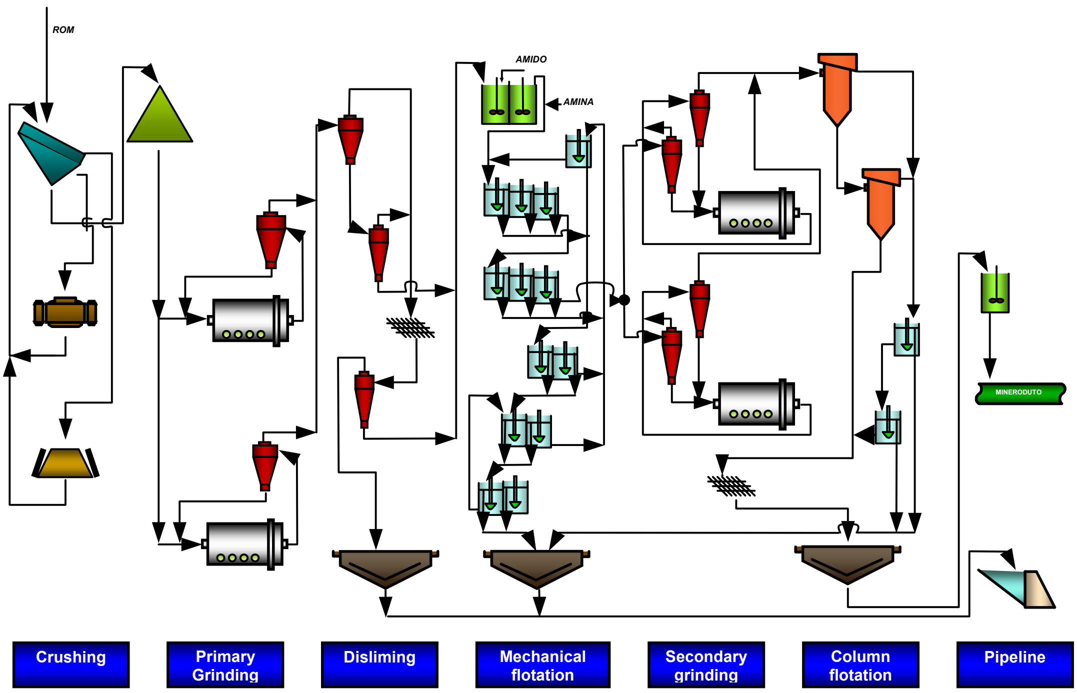

Figure 1 – Concentrator II flow sheet.

This paper shows the studies needed to concept the grinding and flotation circuits of the new concentrator.

2 METHODOLOGIES

2.1 Grinding

In order to define the new grinding circuit it was necessary to size the mineral energy consumption needed to achieve size specifications for flotation (primary grinding) and for pelletizing (secondary grinding).
Monthly, grinding tests are performed in Germano Process Control Lab (LCP), with industrial samples, to monitor the specific energy consumption of Samarco ore. The methodology used was proposed by DONDA et al.(1)
By comparing industrial data and lab results it's easy to see that LCP method is reliable as shown in Figure 2:

Figure 2 – Industrial and lab data of primary grinding.

Figure 2 shows data from year 2004 because that was the period when the studies to size the mills for Concentrator II were done but, Process crew confirm lab data frequently and they remain reliable.
The test consists in four grindings that are run in different times in a 12"x12" ball mill. Table 1 shows the conditions of the tests.

Table 1 – Primary grinding tests.

Parameters	Conditions
Ball Charge weight	30.578 kg
%Critical speed	70
%Solids	80
Ore weight	5.664 kg
Media type	Bolas
Charge distribution	Between 63 and 25mm

Each grinding time is converted in specific energy consumption by the following equation:
Specific energy consumption (kwh/ton) = (0.1114 x $t_{grinding}$)/ (5.664 x 60)
Where, $t_{grinding}$ is the period of one grinding time.
Grinding tests were performed with samples of the ores considered to the Third Pelletizing Plant Project, called Samarco Remanescente 03 and Fazendão 04, and also with a mix of these samples. After that, it was calculated the specific energy need to achieve the specifications of Primary Grinding output: 90% - 0.149mm.
Similar tests are performed in LCP to evaluate specific energy consumption in Secondary Grinding. The methodology was proposed by Donda.[2]
They are standardized test as well and their reliability can be confirmed by comparing the results with industrial data, as shown in Figure 3:

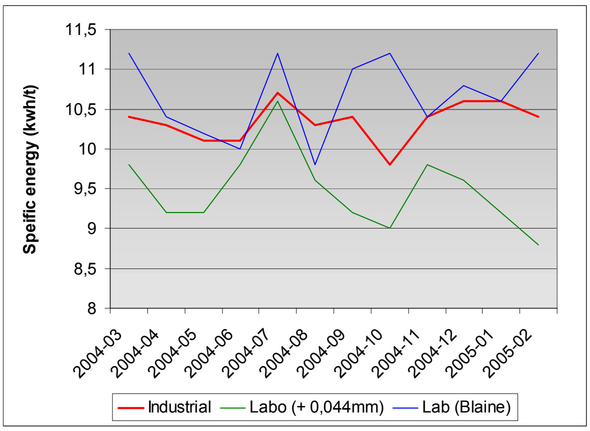

Figure 3 – Industrial and lab data for Secondary Grinding.

As can be seen in Figure 3 the results obtained by Blaine are more similar to the industrial data than the ones obtained by size analysis so Blaine was the parameter chosen to size secondary ball mills. Tests were realized with samples of Samarco Remanescente 02, Fazendão 03 and with the composition of both minerals. By the end it was determined the energy required to reach the specifications of product: 14% retained in 0,044mm (at most) and minimum Blaine of 1500. The Table 2 summarizes the conditions of the tests:

Table 2 – Secondary grinding tests.

Parameters	Conditions
Inside mill diameter	12”
Inside mill length	12”
Ball charge weight	18 kg
%Critical speed	65
%Solids	75
Ore weight	3,5 kg
Charge distribution	Between 30 and15mm

2.2 Flotation

2.2.1 Mechanical flotation

By all this years the operation of Germano’s Concentrator I, the search of metallic recuperation increasing was constant. Although, after all this work, Concentrator I has achieve high efficiency, in the conception of the flotation circuit of the new concentrator, a question became unavoidable: “how to reduce the loss of iron in tails?”

The immediate answer would be the “correct” dosage of reagents.

Samarco has a standardized flotation kinetics test, which is done frequently by LCP. They are bench scale tests and in determined periods of time, the froth is collected and each sample is analyzed in a separated way in order to determine %Fe.

Samples called Samarco Remanescente 01 and Fazendão 02 were submitted for this test in conditions presented in Table 3.

Table 3 – Flotation kinetics tests.

Conditions	Amine dosage (g/t)	Starch dosage (g/t)
Standard	50	400
Amine reduction	20	400
Starch increase	30	600

But beyond the reagent’s dosage, this questioning lead to an investigation of a more efficient circuit. The logical solution would be increase the number of scavenger stages related to the Concentrator I circuit- that has only one stage.

A sample of a compound daily collected in the alimentation of flotation of Concentrator I was submitted to bench tests. Figure 4 explains the procedure:

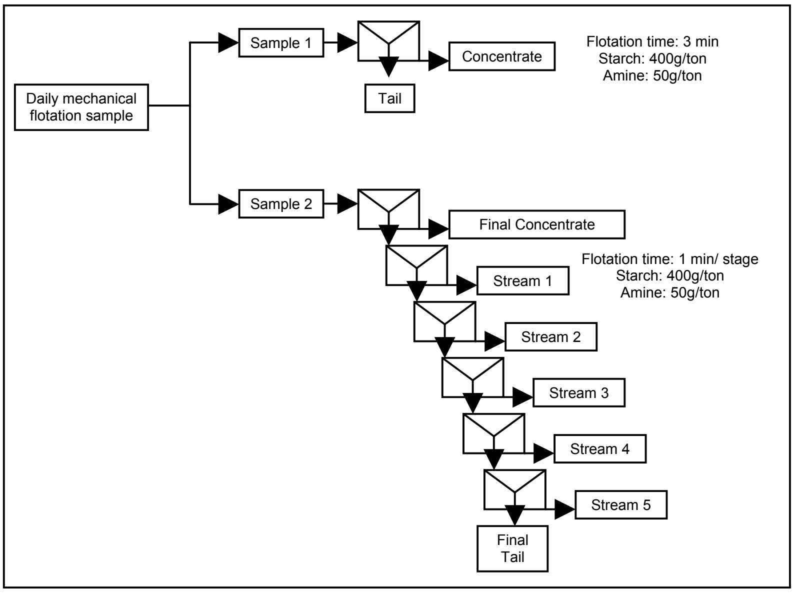

Figure 4 - Flotation tests procedure.

2.2.2 Column flotation

In principle column flotation circuit of Concentrator II should be the same of Concentrator I which has rougher, cleaner and scavenger stages. In plant I the scavenger concentrate feeds another flotation circuit designed to treat fine particles.
Since the Concentrator II would not have this facility, scavenger concentrate would feed a hidrociclones classification. Then, the overflow of the cyclones would feed a mechanical flotation cell, which is more efficient to float the coarse silica.
However, industrial data form Concentrator I showed that scavenger columns were not working satisfactorily, as presented in Figure 5:

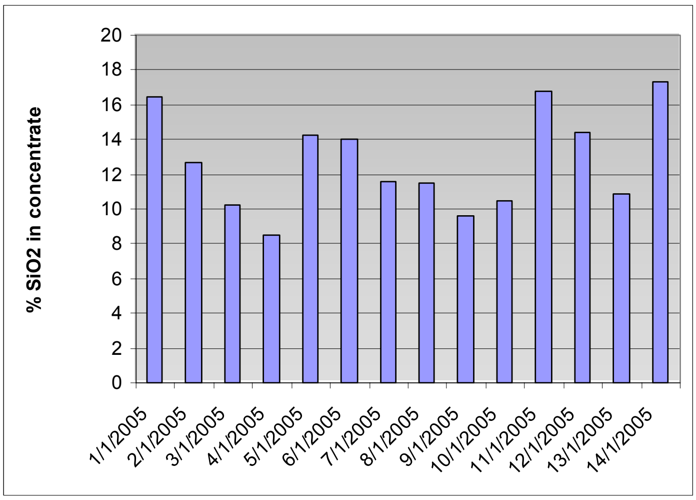

Figure 5 – Silica content in scavenger concentrate.

Therefore the option was to evaluate the application of mechanical cells in this stage. Bench flotation tests were run in LCP with samples of the feed of scavenger columns.

3 RESULTS AND DISCUSSIONS

3.1 Grinding

3.1.1 Mills sizing

Figure 6 shows the results of primary grinding tests:

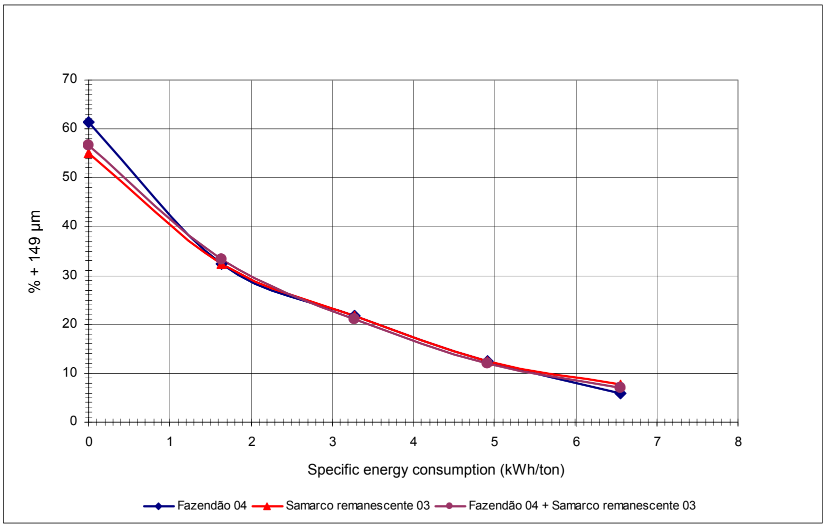

Figure 6 – Specific energy consumption for primary grinding.

As can be seen in Figure 6, it is necessary 5.5kWh/ton to achieve the primary grinding specification. This value was used to size primary ball mills.

Figures 7 shows the results of secondary grinding tests:

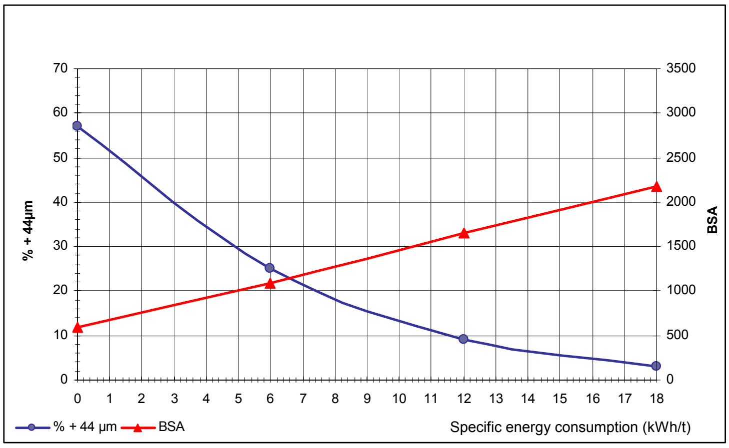

Figure 7 – Specific energy consumption for secondary grinding.

According to Figure 7, it is necessary 10.4 kWh/ton to achieve minimum Blaine of 1500. To size the secondary ball mills it was used the value of 11kWh/ton.

Therefore, the choice of the ball mills was done as follows:

Primary mills:

- Feed rate = 1640 ton/h of ore crushed in 12.5mm. Considering two mills = 820 ton/h.
- Power requirement = 5.5 x 820 = 4510 kW per mill.

Secondary mills:

- Feed rate = 902 ton/h of concentrate. Considering two mills = 451ton/h.
- Power requirement = 11.0 x 451 = 4961 kW per mill.

The choice of two mills per stage was due to the circulation load of 200%, that is usually practiced in Concentrator I, otherwise the mills feed would be too high.
Instead of considering project factors, primary mills were sized to work with 34% of their volume occupied. For the secondary mills this fraction is 32%, so that possible future changes in the ore characteristics can be absorbed by increasing the fraction of mills occupied by charge.
Therefore the mills choose to the Concentrator II are presented in Table 4:

Table 4 – Mills characteristics:

	Diameter (ft)	Length (ft)
Primary mills	18	33
Secondary mills	18	37

3.1.2 Circuit definitions

The feed of Primary Grinding is composed by a high percentage of material passing in 0.149mm – which means there is high percentage of material that attends product specifications. Considering this it would be interesting to adopt an inverse circuit. However SANTOS et al[3] showed that by passing the material passing in 0.149mm through the mills it is possible to increase flotation performance.
Therefore, the primary grinding circuit adopted is as shown in Figure 1.
The secondary grinding in Concentrator II is done in two stages: the first one works in open circuit before the column flotation and the second one works in closed circuit and is fed by the columns concentrate. These circuits were adopted due a problem observed in flotation columns that received coarse silica in their feed, what used to difficult iron recovery. Figure 8 shows what happened in the particle recovery when this problem was detected:

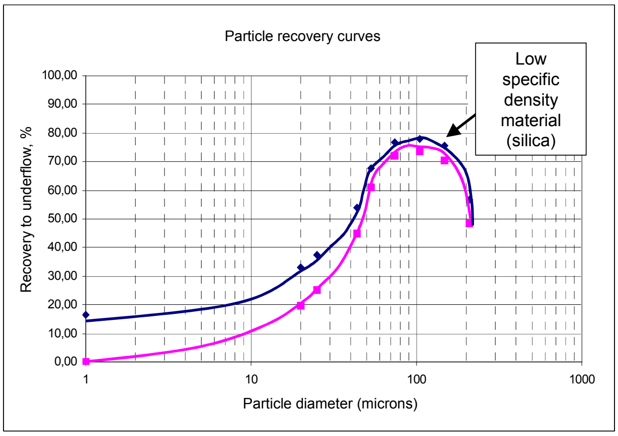

Figure 8 – Silica density effect.

As shown in Figure 8, due its low density, coarse silica went to cyclones overflow and, so, was not ground. The circulation load of the circuit has a high percentage of solids and used to contribute to this effect. Therefore the solution to this problem was to operate the mill in open circuit what decreased %solids in their feed and, consequently, increased flotation columns performance.
This learning should be used to define secondary grinding circuit of Concentrator II. However the circuit of plant I has showed low efficiency trough energy point of view and requires a complex lay out. Besides that, it would be interesting to guarantee that the columns feed were finer than that practiced in Concentrator I, because that would increase iron recovery. For all these reasons, the final circuit is the shown in Figure 1.

In this circuit all material is reground before feeding the flotation. The first stage of classification is done in open circuit to ensure that coarse silica will pass through the mills and the circuit is closed in the same mill by another cyclones cluster what guarantees grinding efficiency. Since the mass of silica that will feed the mills will be smaller than in Concentrator I, the media consumption will probably be smaller as well.

3.2 Flotation

3.2.1 Mechanical flotation

Figures 9, 10, and 11 show, respectively, the results of flotation kinetics tests on standard conditions, with amine reduction and with starch increase:

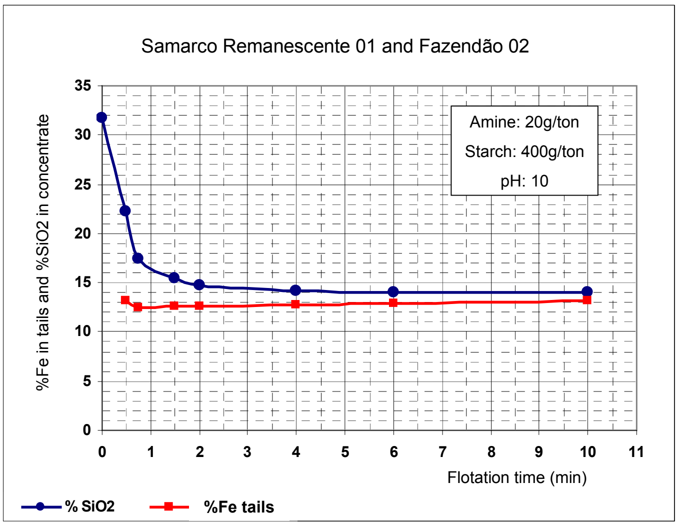

Figure 9 – Standard flotation tests.

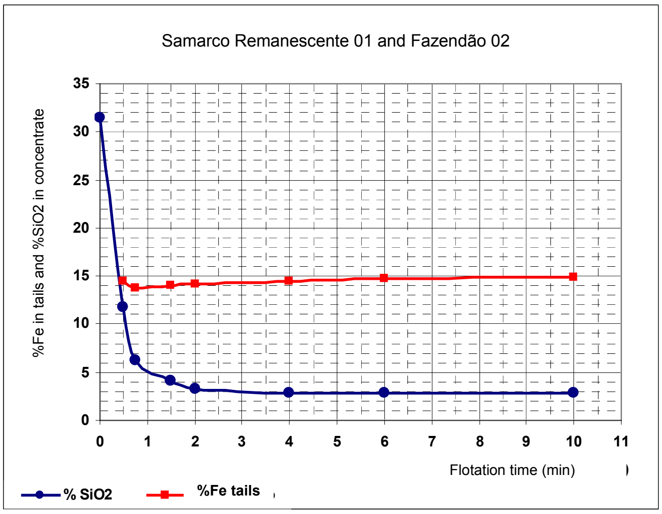

Figure 10 – Flotation tests with reduced amine dosage.

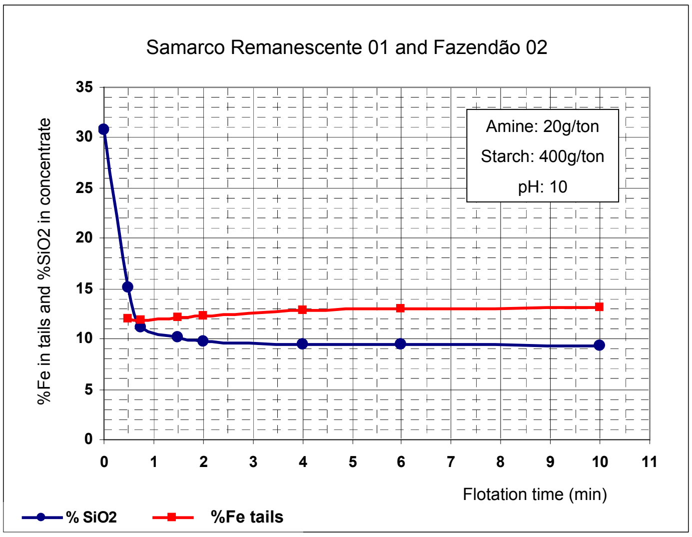

Figure 11 – Flotation tests with increased starch dosage.

As shown in Figures 9, 10, and 11, changes in the reagents dosage were not effective to increase iron recovery. In both cases the amount of Fe in tails had a very low decrease and the silica content in the concentrate increased to unacceptable values. Therefore the best option to increase iron recovery seemed to be an alternative circuit. Tables 5 and 6 shows the results for the tests described in Figure 6:

Table 6 – Rougher flotation.

Output	%		Recoveries	
	Fe	SiO2	Weight	Fe
Concentrate	66,64	2,12	62,88	85,74
Tail	18,77			

Table 7 – Flotation in 5 stages.

Flotation Stage	Concentrates		Contents (accumulated)		Recoveries		Weight (g)	%Solids
	%Fe	%SiO2	%SiO2 conc.	%Fe tails	Weight	Iron		
Concentrate	66,43	2,23	2,23	22,07	61,65	82,88	927,2	42,5
Stream 1	63,90	6,41	2,68	11,9	69,15	92,57	112,8	20,6
Stream 2	58,20	14,74	3,05	8,44	71,3	95,10	32,3	17,1
Stream 3	48,80	29,53	3,45	6,81	72,41	96,20	16,7	16,1
Stream 4	41,60	32,30	3,74	5,86	73,15	96,82	11,1	15,6
Stream 5	26,03	49,80	4,14	5,36	73,79	97,16	9,6	15,2
Tail	5,36						394,2	

As shown in tables above, it’s possible to reduce %Fe in tails by increasing the number of stages in flotation circuit. Meanwhile, after 3 stages the reduction of Fe in tails decreases. Therefore it’s not feasible to run more than 3 stages of flotation.
By the way, intermediate concentrates usually returns to the rougher feed and difficult the recovery in this stage. So, the best option would be to treat the circulation load in an individual cell, before returning this to the rougher cells, as shown in Figure1.
In order to validate this circuit “Locked Cycle Tests” were run with samples from industrial flotation circuit feed, Samarco Remanescente 02 and Fazendão 03. All of

them showed similar results. Figures 12 and 13 show, respectively, the results of Locked Cycle test of industrial samples and the rougher flotation test, performed with the same sample, to compare the results achieved.

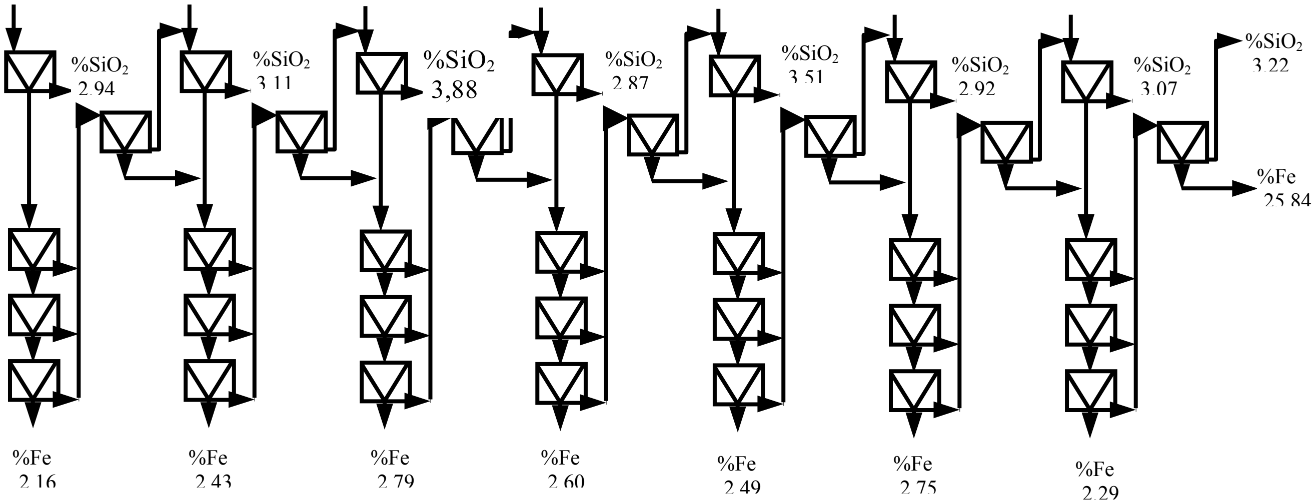

Figure 12 – Locked cycle test.

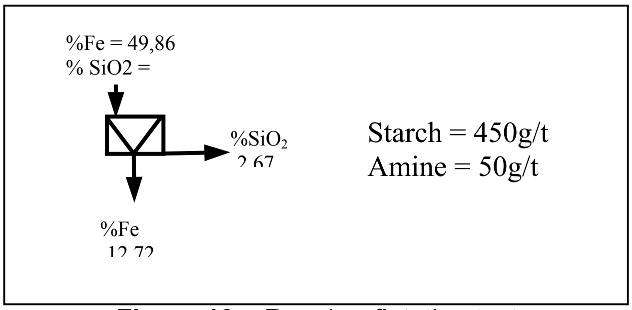

Figure 13 – Rougher flotation test.

Therefore the proposed circuit demonstrated efficiency. Meanwhile, in the industrial circuit are not expected results as good as the achieved in the tests, due hydrodynamic factors, but it will be possible to achieve better results than the ones achieved in circuit of concentrator I.

By comparing industrial and lab results of flotation circuit of concentrator I, it can be realized that, in general there is a difference of 4.5% for CLS (low silica) concentrate and 6.5% for CNS (normal silica) concentrate. Figures 14 and 15 show this comparison for the year of 2004.

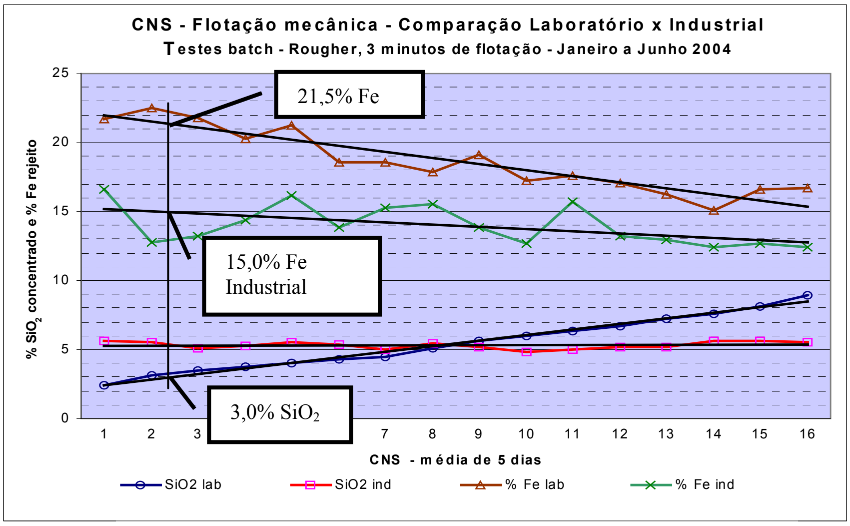

Figure 14 – Industrial x lab data - CNS concentrate.

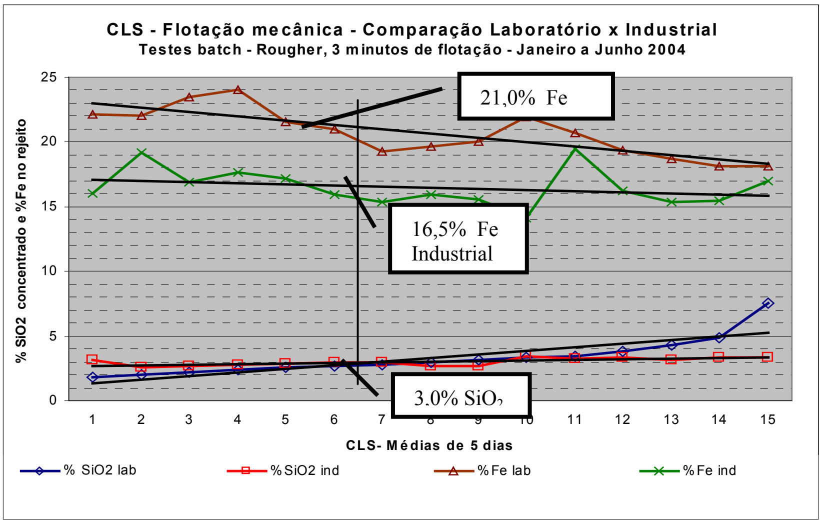

Figure 15 – Industrial x lab data – CLS concentrate.

Considering this difference between industrial and lab results and, since, in the Locked Cycle tests were achieved about 14.8%Fe in the tails, the value of 8.2%Fe in tails was adopted to run the mass balance of the flotation circuit of concentrator II.
The same flotation volume existent in concentrator I was adopted to plant II. So, the final circuit was defined with 11 mechanical cells with 70m³ each.
For the mechanical flotation circuit the following values were adopted:

Table 8 – Mechanical flotation circuit.

	%Fe	%SiO2	Recoveries	
Feed	44.4	--		
Concentrate	64.8	4.0	Weight	Fe
Tails	8.2	--	63.73%	93.30%

3.2.2 Column flotation

Figure 16 shows the results of flotation tests performed with the feed of industrial scavenger columns:

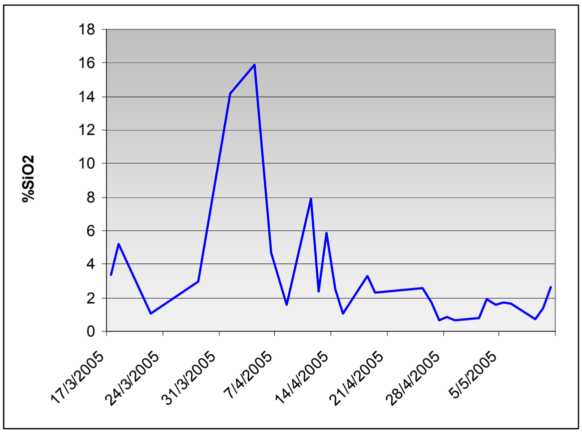

Figure 16 – Batch flotation tests with scavenger columns feed.

In most part of the tests, %SiO2 in the concentrate was lower than the achieved in the industrial columns, what signalizes that mechanical cells better performs in this stage of flotation. Therefore, the concentrator II column circuit was defined as shown in Figure 1: rougher and cleaner stages are performed in columns (2 columns for each stage) and the scavenger cells operate in two steps, to guarantee low %SiO2 in the concentrate.
As done for mechanical flotation, the same volume of concentrator I circuit was adopted for column flotation circuit. The columns have 4.2m of diameter and 14.5m of high. Mechanical cells have 42.5 m³ of volume.
For the columns circuit the following values were assumed:

Table 9 – Columns flotation circuit.

	%Fe	%SiO2	Recoveries	
Feed	65.0	--		
Concentrate	67.2	1.0	Weight	Fe
Tails	25.0	--	94.79%	97.99%

Therefore, the global recoveries for the concentrator II are:

- Weight = 90.91 x 63.73 x 94.79 x $10^{-4} \cong$ 55%
- Iron = 89.69 x 93.30 x 97.99 x $10^{-4} \cong$ 82%

4 CONCLUSIONS

The circuits presented in this paper come from all experience of 30 years of operation of Concentrator I. All learning gained with difficulties, improvements and studies all over these years was incorporated in the concept of the new concentrator.
The tests used to size and define the circuits are standardized and reliable.
Therefore, the circuit itself transmits confidence to Samarco's team.

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