65° CONGRESSO ABM INTERNACIONAL
65th ABM INTERNATIONAL CONGRESS
ANAIS PROCEEDINGS
ISSN 1516-392X

DEVELOPMENT IN CO-DEPRESSANTS FOR PHOSPHATE ORE[1]

Arthur Pinto Chaves[2]
Bianca Foggiatto[2]
Antonio Carlos Papes Filho[3]

Abstract

Experimental flotation testing on phosphate ore samples from Araxa, MG, was conducted at the University of Sao Paulo (USP) using a novel depressant developed by Georgia Pacific (GPR-863), in comparison with chemicals currently used (soy oil and starch). Optimum results were achieved associating starch and GPR-863, at a 10:1 ratio, where the new chemical acts as a co-depressant. The best condition consisted in 200 g/t of soy oil, 600 g/t of starch and 60 g/t of GPR-863, showing significant improvements over the reference scenario with 200 g/t of soy oil and 600 g/t of starch: increase of 39% on mass yield, 31% increased P_2O_5 recovery, reduced P_2O_5 lost on reject (-6%), with lower silica (-12%) and Fe_2O_3 (-2%) on concentrate. Selectivity indexes confirmed the superior performance of the proposed condition. P_2O_5 assay on concentrate was somewhat smaller than reference, but the target can be easily achieved after dosage optimization with small impact on recovery. Validation trials were performed at another laboratory, in batch flotation machine and in flotation column, confirming the improved performance of the new reagent in both equipments.

Key words: Phosphate rock; Froth flotation; Depressant.

DESENVOLVIMENTOS EM CO-DEPRESSORES PARA FOSFATO

Resumo

Estudos de flotação foram conduzidos pela USP com amostra de rocha fosfática de Araxá, MG, utilizando um novo depressor desenvolvido pela Georgia Pacific (GPR-863), comparando-o com reagentes comumente empregados (óleo de soja e amido). Resultados positivos foram obtidos associando-se amido ao GPR-863, na proporção de 10:1, onde o novo reagente atua como um co-depressor. A melhor condição consistiu em 200 g/t de óleo de soja, 600 g/t de amido e 60 g/t de GPR-863, apresentando ganhos significativos em comparação à referência (200 g/t de óleo de soja, 600 g/t de amido): aumento de 39% na recuperação mássica, aumento de 31% na recuperação de P_2O_5, redução de 6% no P_2O_5 perdido no rejeito, com menor sílica (-12%) e Fe_2O_3 (-2%) no concentrado. Os índices de seletividade confirmaram o desempenho superior da condição apresentada. Os teores de P_2O_5 foram um pouco menores que a referência, porém a especificação pode ser facilmente atingida com a otimização das dosagens com pequeno impacto esperado nas recuperações. Testes de validação foram conduzidos num outro laboratório, tanto em coluna como em célula mecânica, confirmando o bom desempenho do novo reagente em ambos os equipamentos.

Palavras-chave: Fosfato; Flotação; Depressores.

[1] *Technical contribution to 65th ABM Annual Congress, July, 26th to 30h, 2010, Rio de Janeiro, RJ, Brazil.*
[2] *Departamento de Engenharia de Minas e de Petróleo, EPUSP*
[3] *Georgia Pacific*

ISSN 1516-392X

HEAD SAMPLE CHARACTERIZATION

The sample used in the experimental work came from Araxá, MG. It weighted approximately 100 kg. It was quartered by the long pile method in order to give aliquots around 500 g for testing. Aliquots were stored in sealed plastic bags in order to avoid contamination. One of them was sent to mineralogy determination by X-ray diffraction, another one to chemical analysis via X-ray fluorescence and a third one was size analyzed by screening up to 200# Tyler and cyclosizer for the -200#. Size fractions were sent to chemical analysis as well. Loss on ignition (LOI) was measured on a separated aliquot.

The mineralogical assembly of the head sample is fluorapatite, quartz, vermiculite, gorceixite, magnetite, hydrobiotite, goethite, barite and perovskite. The presence of the last two is not fully evident from the diffractogram.

Table 1 presents the head sample size distribution, chemical analysis per size fraction and head analysis as analysed and calculated from size fractions.

Table 1 - Size distribution and chemical analysis

mesh (#)	%	P_2O_5	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	TiO_2	BaO	PF
48	1.8	14.9	18.4	37.4	2.8	10.4	3.1	2.9	0.9	4.8
65	6.4	20.7	26.3	24.4	2.0	10.8	1.7	4.3	1.1	4.1
100	12.4									
200	36.0	21.4	27.2	15.6	1.7	15.7	1.3	6.9	1.6	3.6
-200	43.4	18.1	22.2	10.6	1.8	24.8	1.2	9.1	2.4	3.6
back-calculated		17.1	21.5	12.5	1.6	17.3	1.2	6.7	1.7	3.2
head 1		18.9	23.6	15.7	1.79	18.9	1.4	7.1	1.8	4.2
head 2		19.3	23.9	16.3	1.88	18.9	1.4	7.2	1.8	4.2

REFERENCE PERFORMANCE AND TARGETS

Present practice at Araxá's region plants is to use soy oil as a collector and corn starch as a depressant. Conditioning and flotation are done at pH 10.5. Starch conditioning takes 5 minutes and then saponified soy oil is added and conditioned for further 2 minutes. A frother is not necessary, once the saponified soy oil provides all froth necessary to the flotation.

Starch (corn brick) used in this study is the same product used industrially. The addition was done on a volumetric basis (ml of causticized starch solution) calculated on basis of g/t of feed to the test.

A Denver laboratory flotation machine was used. Speed was adjusted at 1,100 rpm for conditioning and flotation. Slurry dilution for conditioning was adjusted as to cover the cell's ring and to provide good mixing. After conditioning, flotation water at the predefined pH was added till the proper level in the cell and then the air valve was opened. Flotation was done till froth extinction and flotation time registered. Airflow rate was kept constant in all tests as rpm was always the same. The test procedure was standardized throughout the program and flotation tests were carried out only as a rougher stage.

After each test, the flotation cell and machine were washed with a diluted caustic soda solution followed by a diluted hydrochloric acid solution and rinsed with water, to remove all traces of chemicals.

The order of adding chemicals was always collector after depressant. Depressants, at a dosage rate between 500 and 1,200 g/t, were added to the slurry and then allowed to condition for 5 minutes. Afterwards, collectors, at a dosage rate from 50 to 300 g/t, were also added to the slurry and then allowed to condition for 2 minutes. Once again, pH was adjusted. Subsequently, the flotation was started by opening the air supply and the froth was scummed off the surface of the slurry.

The experimental conditions for these tests are shown in table 2 as well as the chemical grades (%) of the products and the feed grades as back calculated from these results. Dosage figures are shown in g/t, using saponified soy oil as collector and corn starch as depressant (reference condition). Flotation experiments were performed at USP laboratories.

Table 2 - Experimental conditions and products grades (%) - reference tests

test	collector	depressant	product	P_2O_5	CaO	SiO_2	Fe_2O_3	LOI
3	100	600	concentrate	34.4	44.8	2.42	4.88	2.73
			tailings	17.1	20.9	19.1	20.70	3.95
			calc. feed	19.4	24.1	16.9	18.61	3.79
4	200	600	concentrate	34.0	44.2	2.33	5.00	2.73
			tailings	13.0	15.8	22.8	24.40	4.10
			calc. feed	18.0	22.2	18.2	20.05	3.79
5	100	1,000	concentrate	33.8	45.7	1.81	3.87	2.73
			tailings	16.2	21.3	18.2	21.20	3.94
			calc. feed	18.3	24.2	16.3	19.15	3.80
6	200	1,000	concentrate	34.1	45.7	1.59	3.89	2.85
			tailings	14.4	18.6	21.6	22.80	3.95
			calc. feed	18.8	24.6	17.2	18.62	3.71

Table 3 quantifies these tests' performance and compares them in terms of mass recovery (% floated), concentrate grades (%P_2O_5, Fe_2O_3 and SiO_2) and metallurgical recoveries for these elements. Gaudin's selectivity indexes (S.I.) are calculated for iron oxide and silica. This index is very useful as it indicates the quality of the separation as it takes into account not only the grades of the key elements, but their recoveries to the concentrate. It is defined as:

$$SI = [(P_c / S_c) \times (S_T / P_T)]^{0.5},$$

where P and S are the elements' grades (respectively referring to P_2O_5 and the contaminant - Fe_2O_3 or SiO_2). C and T refer to concentrate and tails.

Best results were gotten with tests 4 and 6, both with a 200 g/t soy oil addition. These results provided the targets for the experimental work with Georgia Pacific's chemicals:

- over 34% P_2O_5 in the concentrate, recovering over 42 % of the contained P_2O_5;
- Fe_2O_3 maximum grade in the concentrate should be 5.0 %;
- SiO_2 maximum grade in the concentrate should be 2.5%;
- Fe_2O_3 selectivity index over 3.5.

Table 3 - Metallurgical balances – reference tests

test	product	mass (%)	recoveries (%) P_2O_5	Fe_2O_3	SiO_2	Fe_2O_3 S.I.	SiO_2 S.I.	collector (g/t)	depressant (g/t)
3	concentrate	13.2	23.4	3.5	1.9	2.92	3.98	100	600
	tailings	86.8	76.6	96.5	98.1				
	Calc. feed	100	100	100	100				
4	concentrate	22.4	42.3	5.6	2.9	3.52	4.98	200	600
	tailings	77.6	57.7	94.4	97.1				
	calc. feed	100	100	100	100				
5	concentrate	11.8	21.9	2.4	1.3	3.38	4.58	100	1000
	tailings	88.2	78.1	97.6	98.7				
	calc. feed	100	100	100	100				
6	concentrate	22.1	40.2	4.6	2.1	3.73	5.67	200	1000
	tailings	77.9	59.8	95.4	97.9				
	calc. feed	100	100	100	100				

GEORGIA PACIFIC'S CHEMICAL GPR-863

The co-depressant tested in this work was supplied by Georgia Pacific Brazil (GP), in form of low viscosity liquid, specially developed for phosphate flotation. Industrially, this reagent is to be used pure, requiring no preparation or dilution. In laboratory, it was diluted to 1% solution in order to allow easy dosage. This group of chemicals consists in low molecular weight cationic polymers generically described as pertaining to the poliamide-polyamine family. Figure 1 shows a generic representation of the reagent chemistry.

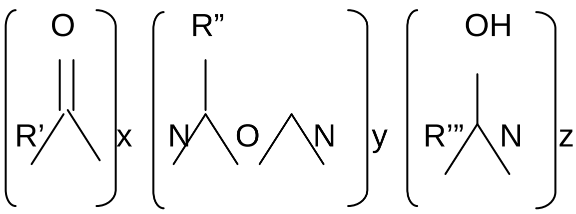

Figure 1 – Schematic representation of GP's depressant.

TESTS WITH GP'S DEPRESSANT GPR-863, AS TOTAL REPLACEMENT OF STARCH

In Table 4, experimental conditions and results for GPR-863 are shown, and in Table 5, assays and metallurgical balances. In these experiments, GPR-863 was used alone, in replacement of starch. Dosages again in g/t.

The best dosage was the one corresponding to test TR-4, i.e., 200 g/t of collector and 200 g/t GP depressant. It yielded 45.5% mass recovered as a concentrate assaying 28.1% P_2O_5, 3.2% SiO_2 and 11.1% Fe_2O_3. The P_2O_5 recovery was 69%, SiO_2 recovery was 8.6%, and Fe_2O_3 recovery was 27.3%. Selectivity indexes were 2.4 for Fe_2O_3 and 4.9 for SiO_2.

When used alone, in total replacement of starch, GP depressant GPR-863 provided high P_2O_5 recovery when compared to the reference conditions, but with poor selectivity to Fe_2O_3.

ISSN 1516-392X

Table 4 – Assays (%) – soy oil and GPR-863 tests

test	collector	depressant	product	P_2O_5	CaO	SiO_2	Al_2O_3	Fe_2O_3	LOI
TR-1	200	600	concentrate	27.2	36.6	3.89	1.54	12.7	3.82
			tailings	10.0	12.5	28.7	2.11	26.2	4.15
			calc. feed	18.4	24.3	16.6	1.83	19.6	3.99
TR-3	200	400	concentrate	27.8	37.3	3.50	1.46	12.1	3.95
			tailings	10.5	13.2	28.3	2.20	24.7	4.22
			calc. feed	18.5	24.3	16.9	1.86	18.9	4.10
TR-4	200	200	concentrate	28.1	37.7	3.21	1.43	11.1	3.78
			tailings	10.5	13.3	28.4	2.21	24.7	3.91
			calc. feed	18.5	24.4	17.0	1.86	18.5	3.85

Table 5 – Metallurgical balances – soy oil and GPR-863 tests

test	product	mass	recoveries (%)			Fe_2O_3	SiO_2	collector	depressant
		(%)	P_2O_5	Fe_2O_3	SiO_2	S.I.	S.I.	(g/t)	(g/t)
TR-1	concentrate	49.0	72.4	31.8	11.5	2.37	4.49	200	600
	tailings	51.0	27.6	68.2	88.5				
	calc. feed	100	100	100	100				
TR-3	concentrate	46.0	69.3	29.4	9.5	2.32	4.63	200	400
	tailings	54.0	30.7	70.6	90.5				
	calc. feed	100	100	100	100				
TR-4	concentrate	45.5	69.1	27.3	8.6	2.44	4.87	200	200
	tailings	54.5	30.9	72.7	91.4				
	calc. feed	100	100	100	100				

TESTS USING GPR-863 IN COMBINATION WITH STARCH

Based on previous studies,[(1)] the best performance of GP depressants is achieved with partial replacement of starch. Acting as a co-depressant, the synergic effect of GP+starch achieves higher P_2O_5 recoveries, keeping gangue assays on concentrate equal or below reference. Additional tests were carried out using a combination of GPR-863 + starch as depressants and saponified soy oil as a collector. In all tests it was used same dosages, i.e., soy oil: 200 g/t, starch: 600 g/t, and GPR-863: 60 g/t.

The experimental conditions and results are shown in tables 6 and 7. Dosage figures are always shown in g/t.

The best combination was identified as test PR-1, i.e., 200 g/t of soy oil, 600 g/t of starch and 60 g/t of GPR-863. It yielded 31.2% mass recovered as a concentrate assaying 32.8% P_2O_5, 2.1% SiO_2 and 4.9% Fe_2O_3. The P_2O_5 recovery was 55%, SiO_2 recovery, 3.9%, and Fe_2O_3 recovery, 8.1%. Selectivity indexes were 3.7 for Fe_2O_3 and 5.5 for SiO_2. Higher dosages of GPR-863 provide better recovery, but in these conditions, the iron assay on concentrate is excessively high.

Best results for soy oil and starch dosages were 200 g/t and 600 g/t, respectively, as presented before. It yielded 22.4% mass recovered as a concentrate assaying 34.0% P_2O_5, 2.3% SiO_2 and 5.0% Fe_2O_3. The P_2O_5 recovery was 42%, SiO_2 recovery, 2.9%, and Fe_2O_3 recovery, 5.6%. Selectivity indexes were 3.5 for Fe_2O_3 and 5.0 for SiO_2.

Table 6 – Experimental results – soy oil and (starch+GPR-863) tests

test	collector	starch +GPR-863	product	P_2O_5	CaO	SiO_2	Al_2O_3	Fe_2O_3
PR-1	200	600 + 60	concentrate	32.8	44.3	2.07	0.89	4.92
			tailings	12.2	15.4	23.1	2.27	25.2
			calc. feed	18.6	24.4	16.5	1.84	18.9
PR-2	200	600 + 120	concentrate	30.7	40.6	3.39	1.02	8.50
			tailings	11.5	14.6	24.6	2.19	26.0
			calc. feed	19.1	24.9	16.2	1.73	19.1
PR-3	200	600 + 90	concentrate	31.4	41.4	3.28	1.07	8.19
			tailings	12.1	15.4	24.3	2.23	25.6
			calc. feed	19.2	25.0	16.6	1.80	19.2
PR-4	200	1,000+100	concentrate	32.1	42.6	2.96	0.87	6.70
			tailings	12.4	15.9	23.5	2.19	25.3
			calc. feed	18.9	24.7	16.7	1.75	19.2
PR-5	200	1,000+150	concentrate	32.7	43.4	2.67	0.75	5.87
			tailings	13.1	16.8	22.8	2.25	24.6
			calc. feed	18.9	24.6	16.9	1.81	19.1
PR-6	200	1,000+200	concentrate	31.9	42.0	4.22	1.10	7.43
			tailings	11.6	14.6	25.8	2.40	25.1
			calc. feed	18.8	24.4	18.1	1.94	18.8

Table 7 – Metallurgical balances – soy oil and (starch+GPR-863) tests

test	product	mass (%)	CaO/P_2O_5	recoveries (%)			Fe_2O_3 S.I.	SiO_2 S.I.	collector (g/t)	depressant (g/t)
				P_2O_5	Fe_2O_3	SiO_2				
PR-1	concentrate	31.2	1.35	54.9	8.1	3.9	3.71	5.48	200	600+60
	tailings	68.8	1.26	45.1	91.9	96.1				
	calc. feed	100	1.31	100	100	100				
PR-2	concentrate	39.6	1.32	63.6	17.6	8.3	2.86	4.40	200	600+120
	tailings	60.4	1.27	36.4	82.4	91.7				
	calc. feed	100	1.30	100	100	100				
PR-3	concentrate	36.8	1.32	60.2	15.7	7.3	2.85	4.38	200	600+90
	tailings	63.2	1.27	39.8	84.3	92.7				
	calc. feed	100	1.30	100	100	100				
PR-4	concentrate	33.0	1.33	56.1	11.6	5.9	3.13	4.53	200	1000+100
	tailings	67.0	1.28	43.9	88.4	94.1				
	calc. feed	100	1.31	100	100	100				
PR-5	concentrate	29.3	1.33	50.9	9.0	4.6	3.23	4.62	200	1000+150
	tailings	70.7	1.28	49.1	91.0	95.4				
	calc. feed	100	1.31	100	100	100				
PR-6	concentrate	35.6	1.32	60.3	14.1	8.3	3.05	4.10	200	1000+200
	tailings	64.4	1.26	39.7	85.9	91.7				
	calc. feed	100	1.29	100	100	100				

GPR-863 showed improved selectivity when used in association with starch at a 10% rate. Selectivity indexes were slightly higher, P_2O_5 recovery increased 31% (+13 percentage points) and mass recovery increased 39% (+8.8 percentage points). P_2O_5 assay on concentrate was somewhat smaller than reference, but the target can be easily achieved after dosage optimization with small impact on recovery. The Fe_2O_3 recovery was a little higher than expected, however the Fe_2O_3 grade was maintained at the target.

TRIALS AT AN INDEPENDENT LABORATORY

These tests were done for validation purposes. A laboratory flotation cell and a pilot column were tested using soy oil as collector and starch as depressant. GPR-863 was tested as co-depressant. Chemicals were added by volume and on the basis of g/t of feed to the test. Conditioning and flotation were done at pH 11.5. Starch conditioning was done for 5 minutes and then saponified soy oil was added and conditioned for other 2 minutes.

Conditioning agitation was significantly higher than flotation speed, which was adjusted to 1,100 rpm. This is the practice defined as High Intensity Conditioning (CAI, or "condicionamento de alta intensidade"). Slurry dilution for conditioning was adjusted to provide adequate mixing.

After conditioning, water from the plant circuit was added in order to obtain 50 % solids in the cell. The slurry was then transferred to the flotation machine or to the pilot column and the air valve was opened. Flotation was done till froth extinction. Airflow rate was kept constant in all cell tests and they were carried out only as a rougher stage.

A new sample was used and for both laboratorial and pilot scale, the same sample was tested. A comparative test was then performed to compare this sample behaviour with that of the previous one.

Laboratorial Cell Tests

Four tests were carried out in the laboratorial cell. Tables 8 and 9 show all experimental conditions and results.

Table 8 – Products grades (%) – flotation machine tests

test	collector	Starch+ GPR-863	product	P_2O_5	CaO	SiO_2	Al_2O_3	Fe_2O_3
BC-1	100	500 + 50	concentrate	31.8	39.8	3.0	0.7	8.0
			tailings	12.2	13.8	22.6	2.0	26.1
			calc. feed	20.0	24.2	14.8	1.5	18.9
BC-3	100	500 + 0	concentrate	37.7	46.2	1.8	0.5	4.7
			tailings	14.0	16.6	20.4	1.9	24.8
			calc. feed	21.1	25.4	14.9	1.5	18.8
BC-4	100	500 + 0	concentrate	32.3	42.0	3.4	0.7	7.7
			tailings	12.2	13.9	22.1	2.1	25.2
			calc. feed	19.1	23.6	15.7	1.6	19.2

Table 9 – Metallurgical balances – flotation machine tests

test	product	mass (%)	recoveries (%)			Fe_2O_3 S.I.	SiO_2 S.I.	collector (g/t)	Depressant (g/t)
			P_2O_5	Fe_2O_3	SiO_2				
BC-1	concentrate	40.0	63.4	17.0	32.5	2.91	1.90	100	500 + 50
	tailings	60.0	36.6	83.0	67.5				
	calc. feed	100	100	100	100				
BC-3	concentrate	29.8	53.3	7.5	16.0	3.76	2.45	100	500 + 0
	tailings	70.2	46.7	92.5	84.0				
	calc. feed	100	100	100	100				
BC-4	concentrate	34.4	58.1	13.8	26.2	2.95	1.98	100	500 + 0
	tailings	65.6	41.9	86.2	73.8				
	calc. feed	100	100	100	100				

Pilot Column Tests

Table 10 shows all experimental results of trials carried out at the flotation column. Tables 11 and 12 show their assays and metallurgical balances, respectively.

Table 10 – Experimental conditions –flotation column tests

test	collector (g/t)		depressant (g/t)	
	planned dosage	Chemical	planned dosage	chemical
CO-3	50	soy oil	500	starch
CO-4	100	soy oil	500	starch
CO-6	50	soy oil	500 + 50	starch + GP863
CO-7	100	soy oil	500 + 50	starch + GP863
CO-10	100	soy oil	500	starch

Table 11 – Products grades (%) –flotation column tests

test	product	P_2O_5	CaO	SiO_2	Al_2O_3	Fe_2O_3	LOI
CO-3	concentrate	35.6	46.8	1,0	0.37	4.61	2.89
	tailings	17.1	21	16.9	1.68	22.7	5.27
	calc. feed	20.2	25.4	14.2	1.46	19.6	4.87
CO-4	concentrate	34.7	46.8	1.64	0.54	5.59	3.17
	tailings	15.2	18.4	19	1.85	24.4	5.42
	calc. feed	20.1	25.6	14.6	1.52	19.7	4.85
CO-6	concentrate	36.1	47.8	1.2	0.42	4.58	2.81
	tailings	15.9	19.3	17.8	1.82	23.7	5.26
	calc. feed	19.8	24.9	14.6	1.55	20.0	4.78
CO-7	concentrate	34.5	46.2	1.63	0.45	5.73	5.07
	tailings	13.6	16	20.1	1.98	26.6	5.45
	calc. feed	19.8	24.9	14.6	1.53	20.4	5.34
CO-10	concentrate	33.6	44.3	2.3	0.77	6.98	3.33
	tailings	13.6	16.1	21.5	1.96	25.7	4.43
	calc. feed	19.9	25.0	15.5	1.59	19.8	4.08

Table 12 – Metallurgical balances –flotation column tests

test	product	mass (%)	recoveries (%)			S.I.	S.I.	collector (g/t)	depressant (g/t)
			P_2O_5	Fe_2O_3	SiO_2	Fe_2O_3	SiO_2		
CO-3	concentrate	16.9	29.8	4.0	10.0	3.20	1.95	50	500
	tailings	83.1	70.2	96.0	90.0				
	calc. feed	100	100	100	100				
CO-4	concentrate	25.2	43.4	7.2	16.4	3.16	1.98	100	500
	tailings	74.8	56.6	92.8	83.6				
	calc. feed	100	100	100	100				
CO-6	concentrate	19.6	35.6	4.5	11.5	3.43	2.06	50	500+50
	tailings	80.4	64.4	95.5	88.5				
	calc. feed	100	100	100	100				
CO-7	concentrate	29.6	51.6	8.3	28.1	3.43	1.65	100	500+50
	tailings	70.4	48.4	91.7	71.9				
	calc. feed	100	100	100	100				
CO-10	concentrate	31.4	53.1	11.1	25.6	3.02	1.81	100	500
	tailings	68.6	46.9	88.9	74.4				
	calc. feed	100	100	100	100				

Both series of tests have shown a superior performance as compared to the trials performed at USP. For column flotation these better results can be initially explained by the superiority of this equipment over the conventional flotation cell. But, more important than this, and regarding the conventional machine, is the practice of CAI. This practice was developed at UFRG (Federal University at Rio Grande do Sul) by Prof. Jorge Rubio. This development is described at Testa, Fonseca and Rubio[2]. The procedure consists in conditioning the depressant at higher rotation speeds. The differential in energy provided to the system is translated into:
(i) proper dispersion of the particles in the full size range;
(ii) cleaning of particle surfaces;
(iii) selective aggregation of the hydrophobic particles;
(iv) better chemicals dispersion, and
(v) bubbles generation on mineral surface during conditioning.

As a result it was obtained an increase in apatite recovery (2 to 4.8%) without P_2O_5 grade decrease or contaminants grade increase. Nonobstant, as the rotation speed in the batch flotation cell increased, the air rate also increased. A recent work[3] shows that flotation recovery increases, passes through a peak and decreases as aeration is increased.

The results achieved at the independent lab validated the ones performed at USP. In the cell flotation, higher recovery was obtained with the association GPR-863 + Starch (BC-1), when compared to starch alone (BC-4). Mass recovery increased 5.6 p.p. or 16%; P_2O_5 recovery improved 9%. The assays and the S.I. were practically the same.

In the column flotation, higher performance was obtained with GPR-863+Starch (CO-6 and CO-7), when compared to starch alone (CO-3 and CO-4). Using 100 g/t of collector, GPR-863 at 10% rate increased mass recovery in 17% (4.4 p.p.) and P_2O_5 recovery in 19% (8.2 p.p.). The assays were practically the same and the iron S.I. was slightly higher.

The experiments BC-3 and BC-4 are not exact replicates. BC-3 trial was performed using the ore sample tested at USP. The same occurred with experiment CO-10, which used the same ore sample tested at USP and it is not the replicate of CO-4. The differences on the results between BC-3 and BC-4, as well as between CO-10 and CO-4 reinforce the fact that different ore samples might present different behaviours due to its particular mineralogical composition. Nevertheless, these differences do not change the findings described above.

CONCLUSIONS

Efficacy study at laboratorial scale was conducted with a novel reagent developed by Georgia Pacific for phosphate flotation. The new chemical acts as a co-depressant to be used in association with starch.

Experimental work performed at USP, using a lab cell flotation, showed significant superior performance when GPR-863 was used with starch in a 10% rate, when compared to starch alone. Selectivity indexes were slightly higher, P_2O_5 recovery increased 31% (+13 percentage points) and mass recovery increased 39% (+8.8 percentage points). P_2O_5 assay on concentrate was somewhat smaller than reference, but the target can be easily achieved after dosage optimization with small impact on recovery. The Fe_2O_3 recovery was a little higher than expected, however the Fe_2O_3 grade was maintained at the target.

Validation trials were performed, using a lab cell flotation and a pilot column, and the results corroborated the conclusions of USP experiments. In the cell flotation, higher recovery was obtained with the association GPR-863 + Starch (BC-1), when compared to starch alone (BC-4). Mass recovery increased 5.6 p.p. or 16%; P_2O_5 recovery improved 9%. The assays and the S.I. were practically the same. In the column flotation, higher performance was obtained with GPR-863+Starch (CO-6 and CO-7), when compared to starch alone (CO-3 and CO-4). Using 100 g/t of collector, GPR-863 at 10% rate increased mass recovery in 17% (4.4 p.p.) and P_2O_5 recovery in 19% (8.2 p.p.). The assays were practically the same and the iron S.I. was slightly higher.

These positive results validated the conclusions of USP trials and demonstrated the potential of GPR-863 to act as a co-depressant for phosphate flotation. Thus, plant trials are recommended to scale up this study to industrial level.

REFERENCES

1 ARAUJO, A.C.; HINES, J.B.; PAPES FILHO, A. C.; PAPINI, R.M.; VIANA, P.R.M. *Optimizing* the use of depressants in iron ore flotation. INTERNATIONAL SYMPOSIUM ON IRON ORE, II, Anais, v.1, p. 321-331, São Luis – MA, 2008.

2 TESTA, F.; FONSECA, R.; RUBIO, J. O condicionamento de alta intensidade (CAI) na flotação de fosfatos. ENCONTRO NACIONAL DE TRATAMENTO DE MINÉRIOS E METALURGIA EXTRATIVA, XXIII, Anais, v.1, p. 331-338, Gramado, 2009.

3 HADLER, K.; CILLIERS, J.J - The relationship between the peak in air recovery and flotation bank performance, *Minerals Engineering*, 22(5), p. 451-455, 2009.