International
Fertilizer Industry
Association

IFA Technical Conference

Beijing, China
20-23 April 2004

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PHOSPHORIC ACID EXPANSION IN BRAZIL

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PRÉCIS

Whilst the rest of the world market is going through a relatively quiet period, Brazil's agricultural production is increasing at an astounding pace. The cultivation of the areas of "Cerrado", Goiás and Mato Grosso, is creating an enormous additional demand for fertilisers. Also the use of DCP in these areas is on the increase. This growth in agribusiness is putting pressure on the Brazilian fertiliser industry to expand and all the major players in the Brazilian market have projects in hand or recently completed to increase their production capacity. New plants have been built, revamps have been completed or are in the planning or execution phase. To meet these needs for raw material the prospecting for new indigenous phosphate reserves is also in full swing.

This paper presents some of the data on agricultural production, some of the installed and proposed capacities and the details of technology being used for these projects.

EXPANSION OF AGRICULTURAL HORIZONS

Although agriculture has always had a major role in the Brazilian economy but during the past three decades there has been an emphasis on industrial expansion. Recently there has been a reawakening of interest in agribusiness. The climate of Brazil with sun all the year round and enough rain throughout the year means that for many crops it is possible to have two harvests a year thus doubling the agricultural production per hectare. Besides this there has been an expansion of agricultural horizons as farmers have moved westwards into the "Cerrado" or Savannah regions of Brazil. Until recently these soils, high in aluminium and iron, were considered to be too poor for agricultural use but special hybrids of plants have been developed by Embrapa, the Brazilian State agricultural R&D organisation, and results are astounding. However, to have a reasonable agronomic response these soils need the addition of supplementary nutrients, principally phosphorus, in the form of mineral fertilisers. Additionally, irrigation is extremely important to maximise yields. There are some criticisms that the soybean expansion is at the expense of the Amazonian Rain Forest; this is not totally true, the majority of planted area is arable land outside the Rain Forest where it is in substitution to the Savannah type of vegetation.

Received 28 January 2004 for presentation at the 2004 IFA Technical Conference, 20-23 April, Beijing, China
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Brazil is one of the biggest producers of grains and cereals in the world .The major products are corn, soybeans, soybean meal, sugar and rice. The total grain production of Brazil adds up to 107 millions tons. Sugar production is forecast to reach a record 23 million tonne in 2002/03, which could result in exports approaching 13 million tonnes. Sugar production has more than doubled over the decade from 1992/93 when output was slightly more than 11 million tonnes. Corn production is estimated to be over 30 million tonnes. Brazil is responsible for some 25 percent of the world's soybean production. This year, 2004, it is expected that Brazil will surpass the total production of soybeans of the USA and become the largest producer of soybeans in the world.

Soybeans and derivatives are the main item in the country's trade balance, with exports of about US$5 billion in 2001. The soybean production is expected to reach 50 million tonnes in 2006. The growth in grain production is shown in Table 1.

Grain production in Brazil
Million tonnes

Product	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/2000	2000/01	2001/02	2002/03
Cotton	1,357	1,254	774	951	998	762	568	763	924	1,187	1,522	1,245	1,365
Peanuts (total)	139	164	147	160	143	139	137	184	172	172	197	189	175
Peanuts (1ª harvest)	108	127	116	124	114	113	111	150	138	147	169	158	143
Peanuts (2ª harvest)	31	37	30	35	29	26	27	34	34	25	28	32	32
Rice	9,997	10,103	9,903	10,523	11,238	10,038	9,525	8,463	11,582	11,423	10,386	10,626	10,428
Oats	386	479	292	309	191	196	214	197	287	194	331	285	359
Rye	8	7	6	5	3	8	8	8	8	7	9	6	4
Barley	209	153	132	110	146	225	246	302	315	319	283	235	283
Beans (total)	2,808	2,903	2,379	3,244	3,158	3,039	2,915	2,232	2,896	3,098	2,592	2,983	3,261
Beans (1ª harvest)	1,070	1,292	1,234	1,152	1,007	937	1,031	916	1,247	1,412	1,156	1,303	1,240
Beans (2ª harvest)	1,453	1,301	782	1,798	1,840	1,791	1,581	997	1,354	1,456	864	1,027	1,263
Beans (3ª harvest)	285	310	363	295	311	310	302	318	295	230	572	653	758
Sunflower	-	-	-	-	-	-	-	16	49	97	56	71	59
Castor Oil Seed	134	116	38	63	44	48	96	19	31	107	80	72	86
Corn (total)	24,096	30,771	29,208	33,174	37,442	32,405	35,716	30,188	32,393	31,641	42,290	35,281	47,384
Corn (1ª harvest)	23,041	29,242	26,806	30,924	33,991	28,895	31,704	24,605	26,742	27,715	35,833	29,100	34,773
Corn (2ª harvest)	1,056	1,529	2,402	2,250	3,451	3,510	4,011	5,583	5,651	3,925	6,457	6,181	12,611
Soybeans	15,395	19,419	23,042	25,059	25,934	23,190	26,160	31,370	30,765	32,345	38,432	41,917	52,067
Sorgo	295	294	281	300	244	319	436	630	613	781	896	798	1,570
Wheat	3,078	2,739	2,052	2,138	1,524	3,198	2,407	2,188	2,403	1,658	3,194	2,914	5,127
Brazil	57,900	68,400	68,253	76,035	81,065	73,565	78,427	76,559	82,438	83,030	100,267	96,761	122,380

Source : Conab.

Table 1 - Brazilian Agricultural Production

Orange juice is also a major export from Brazil. The citrus sector alone employs about 400,000 people and is the essential economic activity of 320 cities in the State of São Paulo and 11 in the State of Minas Gerais, generating foreign currency to the tune of US$ 1,5 billion a year and corresponding to 53% of all concentrated orange juice produced in the world, or 80% of that offered on the international market.

These are just a few examples of the growth in agribusiness in Brazil and this increase in arable farming has affected the demand for fertilisers as shown in the following graph, the figures from 2003 onwards are the predictions of ANDA, Brazilian Association for Fertiliser Distributors. Data on total phosphate fertiliser consumption in Brazil and also the “Cerrado” or Savannah is given in Table 2.

Table 2 – Phosphate Fertiliser Consumption (Brazil & "Cerrado")

Fertiliser Consumption (Thousands of tonnes P2O5)	2001	2002	2003	2004	2005	2006	2007	
Brazil	2,482	2,807	3,287	3,440	3,600	3,770	3,947	59%
Annual growth (%)		13%	17%	5%	5%	5%	5%	
Central West Region	720	880	977	1045	1118	1197	1280	78%
Annual growth (%)		22%	10%	7%	7%	7%	7%	

* From 2003 estimated values

Also the expansion in animal farming, cattle, pigs and chickens, for home consumption and export has put pressure on the supply of DCP especially with the reduction in bone-meal use due to the effect of the "Mad Cow" disease. The state of the Brazilian agribusiness industry is treated in detail in the following FAO report http://www.fao.org/WAIRDOCS/LEAD/X6371E/x6371e0h.htm

The growth in the Brazilian cattle herd is also contributing to increased DCP requirements (Table 3.)

REGIONS	1991	1992	1993	1994	1995	1996	1997	1998	1999
NORTH	15,361,795	15,846,530	17,066,794	17,966,117	19,183,392	17,982,582	19,297,809	21,098,665	22,430,811
NORTHEAST	26,668,890	26,911,981	22,527,240	22,824,686	23,173,936	23,882,203	23,830,908	21,980,699	21,875,110
SOUTHEAST	36,723,631	37,231,470	37,626,538	37,604,020	37,168,199	36,604,615	36,977,462	37,073,604	36,898,631
SOUTH	25,272,150	25,451,315	25,727,020	26,428,553	26,641,412	26,420,652	26,683,421	26,599,844	26,189,653
C. WEST	48,109,039	48,788,007	52,186,481	53,419,853	55,061,299	53,398,488	54,626,557	56,401,545	57,226,833
BRAZIL	152,135,505	154,229,303	155,134,073	158,243,229	161,228,238	158,288,540	161,416,157	163,154,357	164,621,038

Source: IBGE - Instituto Brasileiro de Geografia e Estatística. (www.ibge.gov.br)

* Heads of cattle at 31st of December each year.

Revised: 14/02/2003

Table 3 – Heads of Cattle

Besides cattle similar growth has occurred in pig and chicken farming. In terms of exports of pork Brazil is fourth in the rankings, the European Union has 31% of total world exports followed by Canada (22%), the US (19%) and Brazil (13%). The Brazilian swine sector is concentrated basically in the south that is responsible for 60% of the national pork production. From 1997 to 2001, the Brazilian pork production and consumption presented growing trends (8.9% and 8.4% respectively). During this same period pork meat exports increased by 17.7% (Tables 4 & 5.) Production of chicken has also increased drastically, see Table 6. All this expansion has caused a great increase in DCP use (Graph 1.). The expected growth rate in DCP consumption from 2004 onwards is expected to be at least 5% per year.

Table 4 – Pig Farming

Discrimination	Year	1980	1985	1990	1995	1996	1997	1998	1999	2000
Swine	Million heads	32.5	32.2	33.6	36.0	29.2	29.6	30.0	30.8	29.6
Slaughter	Million heads	17.5	14.0	16.0	19.2	20.4	20.0	22.4	23.5	24.9
Per Capita	kg	9.7	7.0	7.1	8.8	9.1	9.3	10.1	10.4	10.9
Pork production	thousand tonnes	1.2	1.0	1.0	1.4	1.5	1.5	1.7	1.8	2.0
Imports	thousand tonnes	1.0	2.0	1.4	8.5	1.2	5.0	1.2	0.7	0.7
Exports	thousand tonnes	0.2	5.2	13.1	37.5	73.0	76.0	95.8	87.0	128.0
Brazilian pop.	Millions	-	-	144.7	155.8	157	162.2	166	168	170

Table 5 - Brazilian Pork Exports

Year	Mio USD	x 1000 t
2000	171.9	127.9
2001	358.4	264.5
2002	481.4	475.9
2003*	532.4	528.3

* = estimated on figure to Sept.

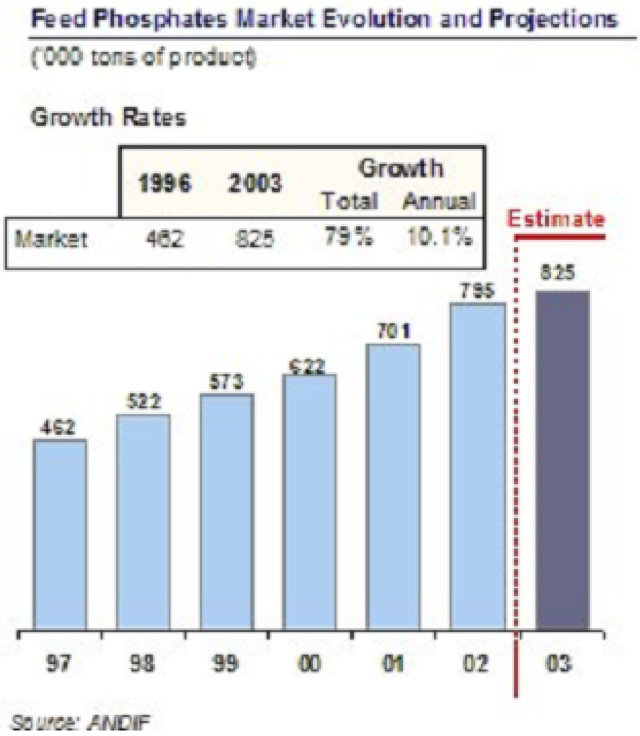
Source; MHR

Table 6 – Chicken Production / Consumption (thousands of tonnes)

Year	Production	Consumption
1986	1,617	1,393
1987	1,798	1,584
1988	1,947	1,706
1989	2,082	1,839
1990	2,356	2,057
1991	2,627	2,306
1992	2,872	2,500
1993	3,144	2,727
1994	3,491	3,010
1995	4,050	3,620
1996	4,058	3,489
1997	4,461	3,812
1998	4,853	4,242
1999	5,526	4,756
2000	5,977	5,070
2001	6,735	5,486
2002	7,517	5,917
2003*	7,870	6,110

* Estimate

Graph 1 - DCP Market Data



STRUCTURE OF THE BRAZILIAN PHOSPHATE INDUSTRY

There are seven main players in the Brazilian phosphate industry but not all of them have fully vertical integration. Their individual activities are shown below in Table 7.

Table 7 – Main Phosphate Companies of Brazil

COMPANY	MINES	PHOS ACID	SSP/TSP	DCP
Fosfértil – Ultrafértil	Tapira – MG Patos de Minas – MG Catalão - GO	1 @ Cubatão -SP 3 @ Uberaba - MG	1 @ Uberaba - MG 1 @ Catalão – GO	NO
Bunge Fertilizantes	Cajati – SP Araxá – MG	1 @ Cajati – SP	6 Units	5 Units
Copebrás	Ouvidor, Catalão - GO	1 @ Cubatão – SP 1 @ Catalão – GO	1 @ Cubatão – SP 1 @ Catalão – GO	1 @ Catalão – GO
Cargill	NO	NO	1 @ Cubatão – SP 1 @ Paranagua – PR	1 @ Cubatão – SP
Galvani	Lagamar – MG Iracê - BA	NO	2 @ Paulinia – SP 1 @ Barreiras – BA	NO
Tortuga	NO	NO	NO	Mairinque – SP
PCS	NO	NO	NO	São Vicente – SP

Fosfértil – Ultrafértil (www.fosfertil-ultrafertil.com.br)

Fosfértil was originally a state owned company, a subsidiary of Cia. Vale de Rio Doce and was named Valefertil. Following government policies the company was privatised and shares were purchased by several small fertiliser blending companies, who formed the group Fertifos, to ensure their supply of intermediates. The shareholding of Fosfértil is shown in Fig 1. The other fertiliser companies that are shareholders, besides Fertifos, are Bunge Fertlizantes and Fertibrás whilst nearly 25% is owned by individuals, banks and investment companies. Although initially the shareholders of Fertifos were the small superphosphate and blending companies with consolidation of the industry the present situation is very different with the number of major shareholders in Fertifos being only three (Fig. 2.)

Bunge Fertilizantes (www.bungefrtilizantes.com.br)

Besides being the largest shareholder in Fosfértil, Bunge also is the largest fertiliser and DCP manufacturer in Brazil. Bunge has 31 production and blending and/or bagging units throughout Brazil. Although Bunge was originally an Argentinean company it is now a public company quoted on the New York stock exchange. Bunge's principal activity in Brazil and world-wide is the trading and processing of grains, principally soybeans, the only country where they also produce fertilisers is Brazil.

Figure 1 – Shareholders of Fosfértil

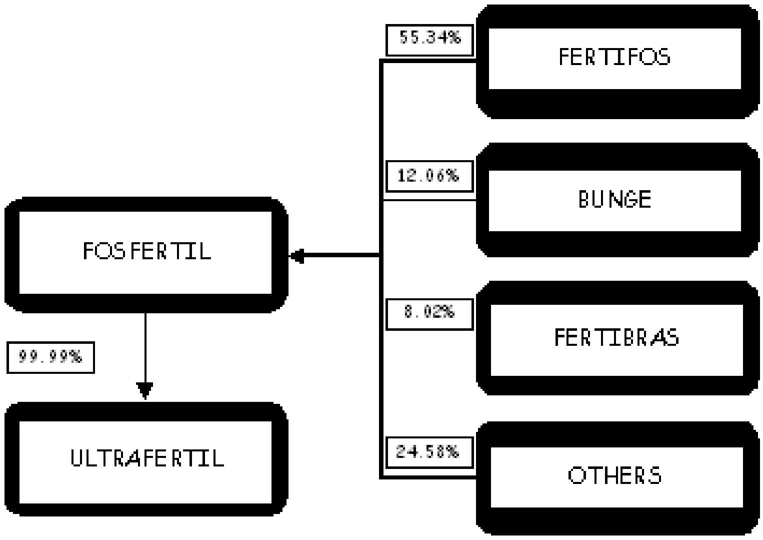
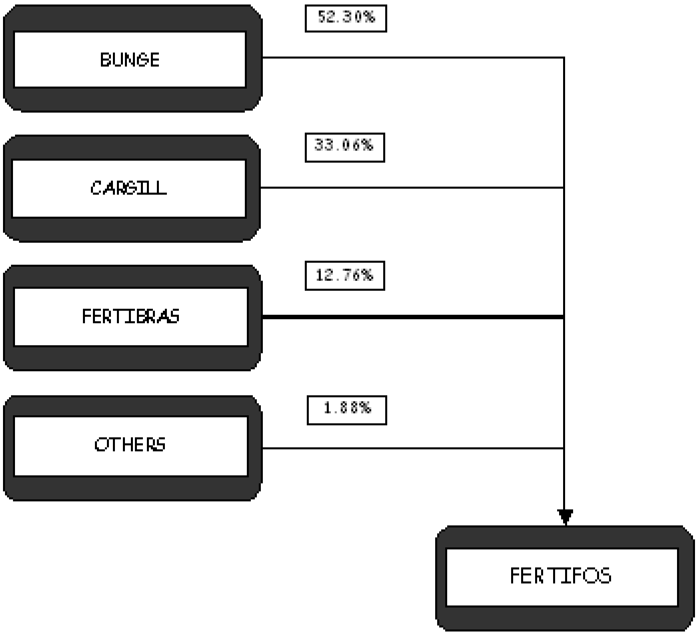


Figure 2 – Shareholders of Fertifos



Copebrás (www.copebras.com.br)

Copebrás, which was originally Compania Petroquimica Brasileira, no longer has any connections with petrochemicals, and today is Copebrás Ltda and is solely a phosphate producer. The shareholdings of Copebrás are the Anglo American Brasil Ltda. who hold 73% and Elko Chemicals who hold the balance of shares. Copebrás has two production sites, one in Cubatão close to the port of Santos and another in Catalão in Goiás state. The older Cubatão site used to be logistically placed when raw materials were being imported but now with this site over 600 km from the Copebrás mine in Catalão it has to receive the phosphate by rail. Recently Copebrás launched "Projeto Goiás" ; the aim of this project was to build a Phosphate Complex at the mine site in Catalão which is also close to the growth areas of the "Cerrado". The plan was to produce 500,000 tpa of phosphate concentrate at 37% P_2O_5. This phosphate is solubilised using 459,000 tpa H_2SO_4 produced in a conventional Double Contact / Double Absorption unit. This acid is used to produce 350,000 mtpa SSP and 117,000 mtpa P_2O_5 of phosphoric acid. This phosphoric acid is in turn used to produce 56,400 mtpa MAP, 21,000 mtpa as TSP and 90,000 mtpa P_2O_5 as DCP.

Cargill Fertilizantes (www.cargillferts.com.br)

Cargill's interests in Brazil are many and varied from orange juice to starch. Like Bunge they are also a world-wide trader in grains. Their participation in the Brazilian fertiliser industry is nowhere near the size of that in the USA but it is still a significant player. Besides their participation in Fosfértil via Fertifos they also have two fertiliser units producing superphosphates and NPKs one in Cubatão, São Paulo State and one in Paranagua, Paraná. Paranagua is ideally situated for the importation of raw materials. Unlike the previous companies Cargill does not yet have access to their own phosphate nor do they produce phosphoric acid.

Galvani

Galvani began as a transport company situated at the railhead in Paulinia, São Paulo state. Due to differences in gauge it was necessary to off-load phosphate rock arriving by rail from the mines in Minas Gerais state and to load it onto wagons of a different gauge to have access to the fertiliser plants on the coast of São Paulo state. With time Galvani rebuilt 2 second-hand sulphuric acid plants at Paulinia and started to produce superphosphate at that site. Today he has access to two phosphate mines one in Lagamar, near Patos de Minas, Minas Gerais state and another at Iracê in the state of Bahia.

Tortuga (www.tortuga.com.br)

Tortuga is an animal feed producer that produces DCP from imported acid and lime for their own captive use. They have no activity in fertilisers nor in phosphates other than DCP.

PCS (www.potashcorp.com)

The factory of PCS is situated in São Vicente near the port of Santos. This unit produces DCP from imported phosphoric acid and although PCS is very big in fertilisers in North America so far this is their sole phosphate activity in Brazil.

PRODUCTION FACILITIES – RECENT PROJECTS AND PROPOSED EXPANSIONS

Fosfértil- Ultrafertil - Uberaba

The Uberaba–1 Complex, originally named Valefertil, was a pioneer in phosphate transport as it was the first factory world-wide to be fed with phosphate by a mineral pipeline. This pipeline is over 125 km in length from the mine and beneficiation unit in Tapira, close to Araxá, to the chemical complex in Uberaba and has one intermediate pumping station. The phosphate slurry is pumped at about 60% solids and at the terminal it is thickened to 68% solids for feed to the phosphoric acid plant as a slurry. The chemical units, which started up in 1980, were designed with the following capacities/technologies :-

H_2SO_4 mtpd H_2SO_4	PHOS ACID mtpd P_2O_5	EVAPORATION mtpd H_2O
Lurgi	R-P, Krebs	R-P, Krebs
2 x 1300	2 x 470 (490)	3 x 800 (825)
Double contact, Double absorption	P_2O_5 = > 29.5% μ = > 96%	29.5 – 53% P_2O_5
	Reactor 800m^3 UCEGO #9, Robin HPM	Carbon Blocks 340 m2/unit

In parallel to the expansion plans that have been implemented in the chemical units which are outlined below, there have also been progressive capacity increases in the mining and beneficiation units to accompany the increased demand for phosphate concentrate.

After several de-bottlenecking exercises which included reduction from 3 to 2 washes on the filter, the provision of additional heat exchange area on the two evaporation units and modifications to the scrubbing systems, the instantaneous capacities in 1983 reached the following figures:-

H_2SO_4 mtpd H_2SO_4	PHOS ACID mtpd P_2O_5	EVAPORATION mtpd H_2O
2 x 1500	2 x 600	2 x 1100
	P_2O_5 ==> 26.5% μ = > 95.5%	26.5 – 53% P_2O_5
	Filter reduced from 3 to 2 washes	Carbon Blocks increased to 400 m2/unit

In 1998 it was decided to implement the First Phase of an Expansion Plan, this envisaged a new H_2SO_4 unit and a new Reactor to complement the two existing ones. The sulphuric acid plant was built by Krebs to the Monsanto process. For the phosphoric acid section the Rhône-Poulenc / Krebs proposition was, in order to reduce the evaporation duty, that two of the phosphoric acid reactors should operate in series according to the DIPLO process to enable a higher strength acid to be produced at a higher efficiency.

The third train would continue as a single-tank Rhône-Poulenc design. The evaporators were not modified. Thus a new reactor of 800m^3 was situated upstream of one of the existing units with a larger cooling capability and a more effective scrubbing system. the reactor was fitted with a more modern design of Robin agitator HPM 60. The main differences being the following.

	Old Reactors	New Reactor
Reactor Volume (m3)	800	800
Tank Dia (mm)	12750	12750
Liquid Height (mm)	6.25	6.25
Motor power (kW)	400	250
Speed (rpm)	46.5	23.6
Tip speed (mps)	10.0	6.1
Impeller type	HPM 30	HPM 60
Pumping	Down	Down
Number of blades	4	4
Number of Impellers	2	2
Impeller diameter (mm)	4100	4950
D/T	0.32	0.39

An unused second-hand UCEGO #9 filter was purchased but it was not fitted with the single horizontal separator of the original design but used "Tee" separators directly on the filtrate outlet pipes. Additional decantation and storage tanks were also provided. With this set-up the capacities attained were the following. In fact the operators found it easier to continue operating all three units in parallel according to the Rhône-Poulenc single-tank process. They find that this configuration is more flexible and that there is very little difference in performance from the proposed DIPLO/single tank configuration.

H_2SO_4 mtpd H_2SO_4	PHOS ACID mtpd P_2O_5	EVAPORATION mtpd H_2O
2 x 1500 + 1 x 1800	3 x 500	2 x 1100
Double contact, double absorption	P_2O_5 ==> 29.5% $\mu \cong$. 95.5%	29.5 – 52% P_2O_5
1800 mtpd Krebs - Monsanto unit added	800 m^3 reactor, UCEGO #9	No changes

Late last year, 2003, authorisation was given to expand production by the installation of two more evaporators of similar evaporative capacity to the existing units but with carbon tube heat exchangers and axial-flow pumps. This additional evaporative capacity will allow the strength of the acid in the reactor to be reduced and the gain in filterability will allow increases in production capacity on the reaction and filtration sections.

The design figures are the following.

H_2SO_4 mtpd H_2SO_4	PHOS ACID mtpd P_2O_5	EVAPORATION mtpd H_2O
2 x 1500 + 1 x 2450	3 x 667	2 x 1000 + 2 x 1070
	P_2O_5==> 25.4% □□□≅□ 96%	2 x Carbon Tubes 2 x Carbon Blocks

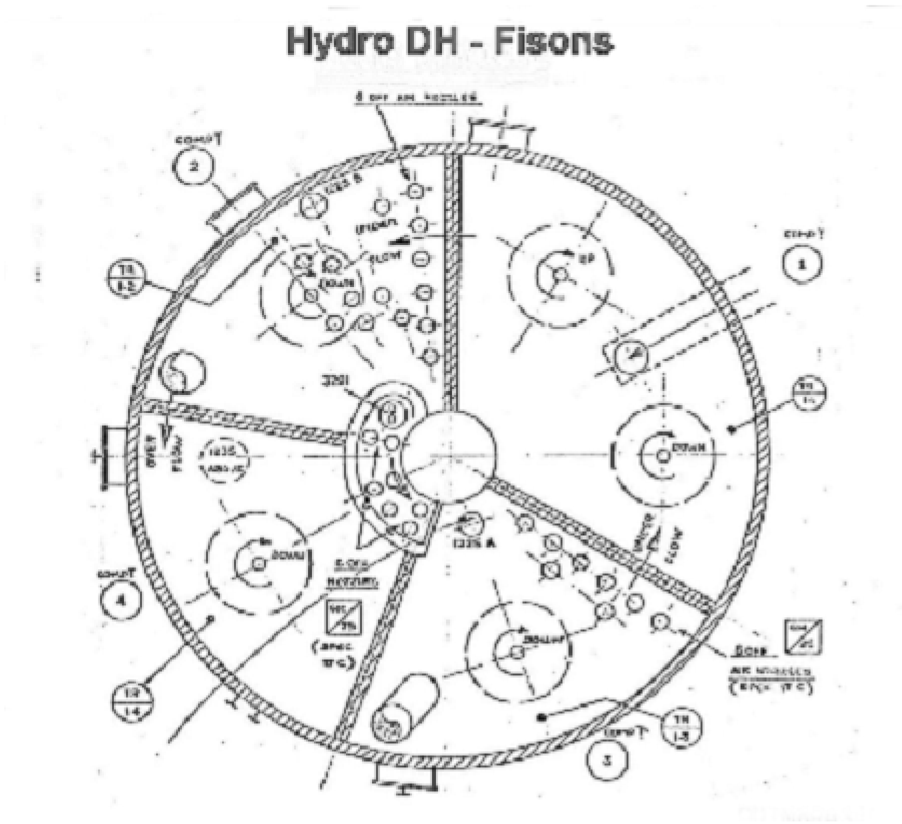
The next and final phase, probably the original Phase 3 and 4 will be implemented simultaneously, envisages an additional sulphuric acid plant, another reactor and filter and a further evaporator. This should take the total capacity to the following figures.

H_2SO_4 mtpd H_2SO_4	PHOS ACID mtpd P_2O_5	EVAPORATION mtpd H_2O
2 x 1500 + 1 x 2450	4 x 630	3 x 1000 + 2 x 1070
add 1 x 2000	P_2O_5 ==> 25.9% □□□≅□96%	3 x Carbon Tubes 2 x Carbon Blocks

Bunge Fertilizantes – Cajati

The Cajati Complex of Bunge Fertilizantes has now become the Animal Feeds capital of Brazil. Fertilisers are no longer produced at this site as the purity of the phosphate concentrate produced from the local Jacupiranga mine makes it ideal for the production of DCP.

Figure 3 – Hydro DH (Fisons) Reactor



The complex was started up in 1973 with a Davy Power Gas (SC-SA) sulphuric acid plant and used Fisons' dihydrate technology for phosphoric acid production and Fisons' Minifos process to produce powder MAP. The policy of Quimbrasil, the predecessors of Bunge, was to produce powder MAP at the mine site and ship it to existing NPK granulation plants in São Paulo and also to newer units sited closer to the point of sale. The capacity of the unit was nominally 210 mtpd P_2O_5 and the acid produced at 29% P_2O_5 was evaporated to 46% in a single carbon-tube evaporator.

The 46% acid was reacted with gaseous ammonia in the Minifos reactor and sprayed down a PVC/polyester canvas tower where it was reclaimed and transported to store. Later an acidulation den was built to produce SSP and TSP and a granulation plant was built at the Cajati site. The plant was converted to wet phosphate feed as the rock drier was supplying rock at 110°C and this was causing cooling problems with the limited capacity of air cooling available. The size of the small compartments is 116 m^3 and the larger one is 232 m^3. Agitators, originally fabricated in 316L, have an installed power of 125 HP and each one consists of two sets of 45° pitched 4-PBTs supplied by and the gearboxes by David Brown - Radicon.

In 1986 Quimbrasil decided to increase the capacity of the phosphoric acid plant to 380 mtpd P_2O_5 and P. Smith & Associates was retained to lead a task-force to implement this re-vamp. The revamp consisted of the following modifications :-

- An additional ellipsoidal reactor with 2 compartments of 125 m^3
- 2 agitators of 125 HP (installed), made in Brazil
- a Low Level Flash Cooler of novel design, 4.3 m ϕ with an inverted conical base
- an axial-flow pump on the outlet of the flash cooler
- an additional belt filter of 30m^2 with the belt made in Brazil
- a new carbon-tube evaporator identical to the existing unit
- a cooling tower with 9 cells, before the plant used once through river water

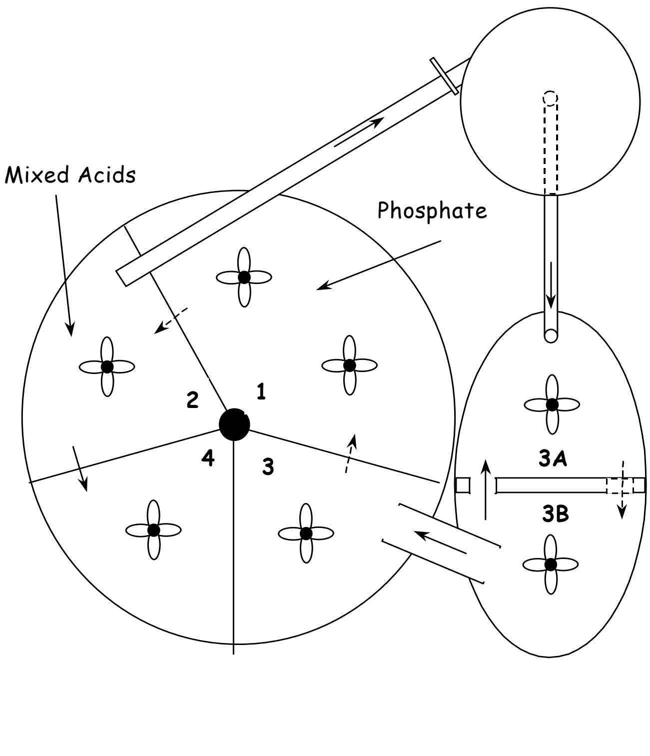


Figure 4 – Modified Reactor and Flash Cooler

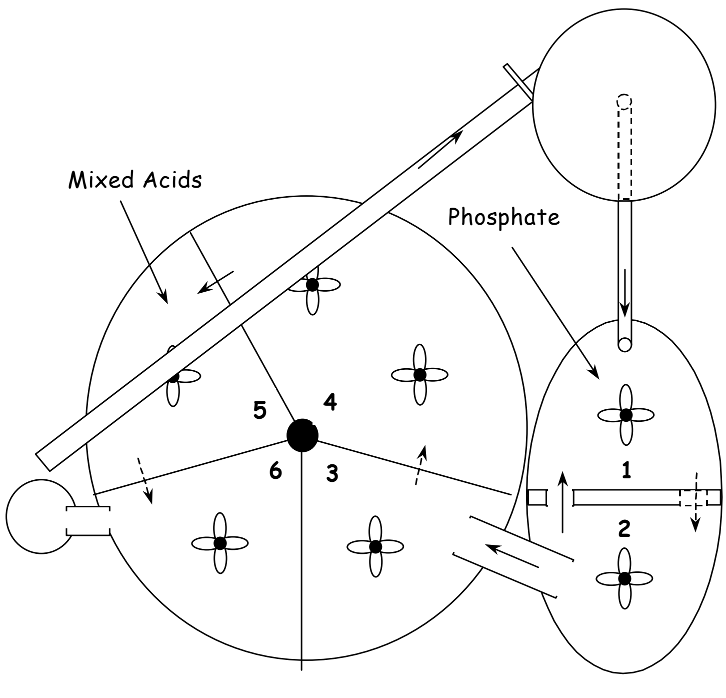
The revamped plant could operate at instantaneous capacities of above 480 mtpd P_2O_5 but due to the fact that the balance of sulphuric acid had to be imported there was not enough steam to run at this rate continuously.

The performance of the new design of flash-cooler was a revelation, there was no need to clean it or the discharge pipe even at annual shutdowns.

In 1995 it was decided to convert to high strength single-stage hemihydrate process of Hydro, the successors to Fisons' technology, which reduced steam requirements. The circuit of the two reactors was changed feeding the phosphate to the old 3A which became C1. The compartments C1, C2, C3 & C4 form the low sulphate zone which now overflow to the compartments C5 & C6 which were converted to underflow and form the high sulphate zone. A dip-pipe was fitted to the flash-cooler and because of the increased head, the axial-flow pump on the outlet was replaced with a horizontal mixed flow pump on the feed to the flash-cooler. Once again the flash-cooler operated trouble free without any need for cleaning. The operating temperature of the reactor was 100°C and as such even with a Δt of 10 °C the boiling temperature of the 40% P_2O_5 acid was 90°C.

This proved to be too much for the natural rubber lining and the flash-cooler was replaced with an identical new unit with chloro-butyl rubber and carbon brick lining on the floor and walls. This plant was now producing 550 mtpd P_2O_5 on the single belt filter of 30 m^2, more than 18 tpd P_2O_5/m^3, but one must consider the cycle time of this filter being of the order of 40 seconds. The agitators, originally in 316L, had to be replaced with higher grade alloys such as DIN 1.4359, Sanicro 28 or Hastelloy G30. Addition of kaolin as a slurry feed reduced the corrosion rate and improved the crystallisation.

Figure 5 – Cajati Plant - HH Reaction Section



In 1995 problems with the disposal of hemihydrate and a demand for a purer gypsum product for sale created conditions for the conversion of the plant to the Hydro two-stage HDH process. A hydration or transformation tank was added and the old 52.5 m^2 EIMCO tilting-pan filter was brought out of retirement to be used as the DH filter.

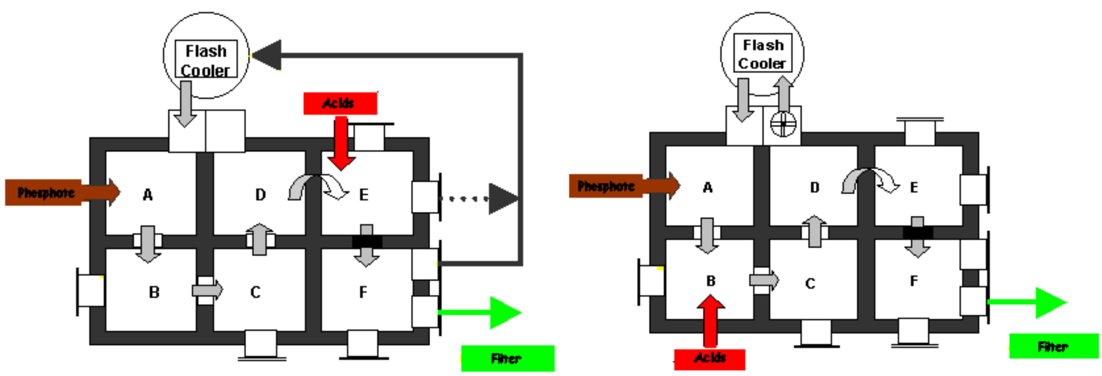
However this old filter was not really designed for the capacity and the water soluble losses were relatively high. Maximum capacity was of the order of 500 mtpd P_2O_5. Efficiencies with this limitation were only about 96% due to this limitation.

In 2000 it was decided to take full advantage of the hydration process and build a new HH filter of 60 m^2, replace the single transformation tank with two tanks in series and use the old 30 m^2 belt for DH filtration. With this set-up it was possible to run at 550 mtpd P_2O_5 with efficiencies of 97-98%. This filter is still a little small for the nominal capacity of 550 and water-soluble losses are still a little high.

Presently the existing circular pie reactor is becoming old and replacement of the old natural rubber with chloro-butyl rubber is occurring progressively as failures cause shutdowns for repairs. As such the two reactors are being replaced with a single six-compartment reactor designed for 800 mtpd P_2O_5 in HH or DH mode. The intention is to continue operating in HDH process but as the Jacupiranga phosphate is igneous and hydration of HH from igneous phosphates is sometimes difficult the precaution was taken to design the revamp to run in the DH mode if necessary. Start-up is scheduled for the end of April 2004. In fact with the present quality of phosphate there is absolutely no problem in getting a good hydration, > 95%, with the present residence time of 4 hours. The filtration of the HH is excellent and the residual water soluble P_2O_5 in the HH cake is very low, as such the transformation tank runs at about 2-3% P_2O_5 and 2-3% SO_4. However prudence decided that the new reactor should also be capable of DH operation.

Figure 6 – New Reactor Design

HH mode DH mode



In the HH design phosphate is fed to compartment A and the first 4 compartments each of 216 m^3 form the low sulphate zone. The mixed acids are fed to compartment

E and as such final two compartments, of the same size, form the high sulphate zone. The flash cooler will be fed from the compartment F or alternatively from compartment E.

The recirculation rate around the flash-cooler defines the amount of precipitation of hemihydrate in the low sulphate zone and is controlled with a variable speed pump. The Δt of the flash-cooler is 10°C.

For eventual DH operation the phosphate fed point is the same, compartment A, but the low sulphate zone is formed solely by the first compartment. Mixed acids are fed to the compartment B and the dissolution occurs in the first 4 compartments, feed to the flash-cooler being from the compartment D. The flowrate was calculated for a Δt of 3°C. Slurry at a rate equivalent to the filter fed rate overflows from D to E and de-supersaturation occurs in E and F prior to feeding to the filter.

The reactor is reinforced concrete using river pebble as aggregate. The lining is being done by a Brazilian firm, Tecnolita, using auto-vulcanising Chemoline 4B (bromo-butyl) rubber from TipTop in Germany and their own carbon bricks Carbolit CF with Furane resin. The agitators will be supported directly on the concrete roof and the travelling crane is supported on the side of the reactor. The agitators with a process design from P. Smith & Associates have been manufactured in Uranus 52N+ by Robin, now Milton Roy Mixing, of Samoreau, France.

The surface de-foaming blades of 1.7 m diameter are inclined downwards at 15°, the middle set is a 2.83m diameter 4-PBT @ 45° and the bottom Hydrofoil blades are Robin HPM 20 of the same diameter. The power train is rated at 160kW and the gearbox is supplied by Hansen Patent in Belgium.

The flash-cooler also designed for the heat load of DH operation of is the inverted cone design and has a diameter of 7.09 meters and for HH operation will have a circulation rate of 2500m^3/h at the 800 mtpd P_2O_5 production rate. The Δt will be 10°C. The lining is Chemoline 4A un-vulcanised bromo-butyl rubber on the base and walls to the upper tyan-line with Carbolit CF bricks and chloro-butyl rubber on the inclined roof where the temperature is lower and adhesion is critical. The unit will be site vulcanised using 1.5 bar steam.

On start-up the plant capacity will still be limited to the present value of 550-600 mtpd P_2O_5 by the present DH filter of 30m^2 but plans are already being laid for expansion of the beneficiation plant and its replacement with a 60 m^2 belt filter in 2005/6 allowing the reactor to attain its nominal 800 mtpd P_2O_5.

Copebrás

The phosphoric acid plant in Cubatão, near the port of Santos, was originally conceived to operate on Moroccan phosphate and the Nissan "H" Hemihydrate Recrystallisation Process (HRC) was selected with a single filter, a UCEGO #7. The process was a classical Nissan "H" with the 4 small HH digesters in series and overflow to 4 large, 450 m^3, RLCS crystallisers with bricked floors.

Operation of the unit was according to design up to the time the Moroccan phosphate was replaced with the indigenous Catalão phosphate from Copebrás' own mine 600 km distant in Goiás state. Problems with recrystallisation, a well known fact with igneous phosphates, were eventually solved by changes in operating parameters.

In order to increase capacity whilst reducing pollution, the air cooling of the Nissan "H" process was replaced by flash-cooling on the Nissan "C" process. The local environmental authority, CETESB, insists that all expansions should not increase the amount of pollution in kg/day. The Nissan "C" process also differs from the Nissan "H" in the following manner. It is a true two-stage process with two filters, one DH and one HH, it produces strong acid 46% P_2O_5 with a low sulphate of about 2%. This was a revamp and the old crystallisers were converted into reactors. New first and second reactors were installed of the same size as the crystallisers but fitted with higher powered rubber lined Hoesch 2 x 2PBT agitators of 450 HP due to the process duty being very different from that of a crystalliser. The flash-cooler was sized for HH duty and had a 6°C Δt. The down-leg from the flash cooler was sealed in a seal tank. The recirculation required for Reactor 1 was taken from this tank and excess returned to the tail of the HH reaction system. The HH slurry was fed to a new Envirotech 90 m^2 belt filter, made in Brazil, and HH cake was discharged into the recrystallisation section. DH slurry being fed to the old UCEGO #7 filter, liquors from this filter being recycled to the head of the recrystallisation section and as wash to the HH filter.

The agitators in the recrystallisation section were the old Hoesch rubber covered design with two sets of up-pumping 45° 2-PBT blades. This level of agitation was not sufficient and build-up on the walls had to be removed frequently.

Acid from this unit is principally used for STTP manufacture a part being defluorinated and sold to Cargill for and a precipitation clean-up process was used. As time went by the iron content of the phosphate increased and as the iron is precipitated as iron phosphate, production costs increased. In laboratory studies it was found that comparing a HH attack at 90 - 100°C and a DH attack at 75-78°C the quantity of solubilised iron was greatly different. This effect, lower iron in the DH acid, and the problems of on-line time and maintenance costs of the high temperature process convinced Copebrás to convert the plant to a DH process.

They enlisted Tecplan of Araxá in Brazil to do the process engineering and a simple process was developed using the reactors of the Nissan "C" only. The flash-cooler from the Nissan process was also used. The belt filter was pensioned off as the UCEGO discharge goes directly to the gypsum conveyor. The only problem is that the flash-cooler was designed for HH duty and the DH duty is much higher. The use of the Catalão phosphate, which has high scaling tendency and the high Δt means that the flash-cooler body, the down-leg and the seal tank all need cleaning at 3-4 monthly intervals. There is also a considerable amount of entrainment. Copebrás have plans to solve this problem and details can be found below.

Copebrás made a bold decision to invest in the interior, at the mine site in Catalão, and have built a phosphate complex "from scratch" on a green field site. The results of the phosphoric acid plant in Cubatão meant that they had no doubts that they would use their own three reactor technology. They were however looking to improve the flash-cooler design. They knew that the unit in Cajati worked well and so through Tecplan they bought the rights to use the P. Smith and Associates design with the inverted cone.

The process design and basic engineering was done by Tecplan and Tecnip/Krebs Brasil did the detailed engineering.

The reactor system is similar to Cubatão but in this case the flash-cooler feed pump is an Ensival axial-flow pump of 5,100 m^3/h. The design Δt of the flash cooler at the nominal capacity is 2.2°C. The flash-cooler has a diameter of 5,000mm and the axial down-leg seals directly in the first reactor. Agitators in Uranus 52N+ with bolted blades were purchased from Robin in France, now Milton Roy Mixing. There is no significant scaling in the flash-cooler body and the down-leg scaling is almost non-existent when compared with the Cubatão experience.

Based on this experience they have decided to retrofit the Cubatão plant with a flash-cooler of the same type. In this case NEWcad Engenharia of Cubatão is executing the engineering with a license from P. Smith and Associates. There were some detailed engineering difficulties due to the size and placing of the existing beams but the pipes have been "shoe-horned" in. This flash-cooler will be rubber and brick lined up to the upper tan-line and has a 5,100mm diameter inside shell. The Ensival 5,100 m^3/h axial-flow pump will sit on a lowered portion of the roof and the launder between the first and second tank has needed to be doubled in size.

Start-up is scheduled for the end of February 2004 and so by the time of the IFA Technical Conference we should have some operating information. The main justification for this conversion was to reduce maintenance cost, increase on-line time and reduce energy consumption.

CONCLUSIONS

The Brazilian economy is strongly impacted by the exports in agribusiness and the existence of indigenous phosphate has stimulated the Brazilian industry to accept the challenges to substitute imported raw materials for fertiliser production to the minimum. There is still however a massive importation of fertilisers.

Prospecting for indigenous phosphate deposits has enabled, with adaptation of technologies of beneficiation, to partially replace the importation of phosphate rock and phosphoric acid. As can be seen “state of the art” equipment and technology compatible with local requirements are available in Brazil. Local solutions to local needs using the majority of technology and equipment “Made in Brazil” is the main aim of the Brazilian fertiliser industry. In fact all the DCP units constructed in Brazil are processes developed locally.

The market for phosphatic fertilisers in Brazil is enormous and there is no doubt that further expansion in phosphate and phosphoric acid production will continue long into the future. However the figures show that Brazil will always be a net importer of phosphate fertilisers. The author would like to thank Bunge Fertilizantes, Fosfertil-Ultrafertil and Copebrás for their help in supplying data for this paper.