PHOSPHATE ROCK PRODUCTION AT LANGEBAAN*

H E KRUMM, G BENFIELD & P R B HEYMANN, Chemfos Limited

Historical background

The existence of phosphate rock in the Langebaanweg area was known for many years before the African Metals Corporation Limited (AMCOR) decided to exploit the deposit in 1942. African Explosives and Chemical Industries had explored the possibility of using the ore for superphosphate manufacture but abandoned the project as the average phosphorus content was too low to make it a viable proposition. Sections of the ore body contained high grade nodular material with 32 per cent P_2O_5 (14 per cent P) but the quantity was too small to justify the exploitation of the deposit as a whole.

AMCOR's decision was taken during World War II due to the shortage of imported phosphate rock on which the Corporation depended for the production of phosphoric pig iron. As the result of an intensive investigation, instigated by the late Dr H J van der Bijl, then AMCOR's Chairman, it was agreed to acquire and exploit the deposit situated on the farm Langberg at Langebaanweg. The high grade nodular material was to be hand-sorted and railed to the Corporation's blast furnaces at Newcastle in Natal.

The shortage of imported phosphate rock also had an effect on the fertilizer industry. To supplement imports, it was decided to turn the low-grade portion of the ore body into a ground rock phosphate fertilizer with a phosphorus content of 15 per cent P_2O_5 (6,5 per cent P) for direct application to the soil. A plant was erected at Bellville in the Cape and operations commenced during the latter part of 1943.

The process was fairly simple. After travelling 145 km by rail from Langebaanweg Station, the rock was crushed, dried in a rotary kiln and pulverized to 80 per cent minus 100 mesh in a ball mill. The product was bagged without further treatment and sold under the name of Kalfos. The name was later changed to Langfos.

The plant had a designed capacity of 35 000 short tons per year. This was progressively increased to 128 000 short tons (116 000 metric tons) per year by installing classifiers in the milling circuit.

As the demand for the product increased it became necessary to open a second mine (Varswater) on another portion of the farm Langberg, approximately five kilometers due west of the original workings. A washing and screening plant was built on the site which had the effect of raising the phosphorus content of the ore to 17 per cent P_2O_5 (7,4 per cent P). This was subsequently reduced to 16 per cent P_2O_5 (7 per cent P) for technical reasons. A washing and screening plant was also built at Langebaanweg to improve the recovery of high-grade ore.

In due course reserves of suitable ore became depleted and attention was directed to the possible exploitation of an extensive deposit of low-grade phosphatic sands adjacent to the Varswater workings. Laboratory and pilot plant research work showed that these sands could be upgraded from 9 per cent P_2O_5 (3,9 per cent P) to 29 per cent P_2O_5 (12,7 per cent P) by fatty-acid flotation. Phosphate rock where the phosphatic material acts as the cementing material between silica grains is neither economically nor technically amenable to this treatment. The old Varswater ore is an example.

Towards the end of 1963 plans had been completed for the erection of a flotation plant on site at a cost of R4 million with a production capacity of 136 000 metric tons per year of concentrates with 12,7 per cent P. Construction started in April 1964 and the plant was commissioned in October 1965. The Bellville plant was shutdown at about this time, having produced 1,8 million short tons (1,63 million metric tons) of ground rock phosphate fertilizer during 22 years of operation.

Slight modifications to the Langebaan concentrator plant made during the past eight years have raised production to its present-day level of 250 000 metric tons per year.

Approximately 200 000 tonnes are ground to a fineness of 80 per cent minus 100 mesh and sold as Langfos Premium. The remaining 50 000 tonnes of concentrates are bulk loaded for sale to manufacturers of proprietary fertilizer products.

Langebaan phosphate rock is of sedimentary origin. Frankel (1948) concludes that most of the phosphate mineral is a type of carbonate apatite (francolite) $3Ca_3P_2O_8$, $Ca(CO_3,F_2)H_2O$. Investigations on this mineral in America in 1948 indicated that it was probably a type of collophanite: $3CaP_2O_8$, $Ca(CO_3,F_2,SO_4)n\ H_2O$.

The presence of CO_3 in the matrix should be noted. Research work carried out by ourselves and elsewhere has shown that the availability to plants of naturally occurring phosphates is a function of the presence of the CO_3 group in the matrix. The higher the percentage the greater the availability. Magmatic phosphates are characterised by the absence of this grouping.

Fluorine content cannot be correlated with relative availability. Low fluorine does not necessarily indicate high availability and vice versa.

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A typical analysis of the Langebaan concentrate is as follows:

	per cent	
Total phosphoric oxide (P_2O_5)	29,2	(12,7% P)
Citric-soluble phosphoric oxide (P_2O_5)	7,4	(3,2% P)
Calcium oxide (Ca O)	42,2	(30,1% Ca)
Iron oxide (Fe_2O_3)	1,7	(1,2% Fe)
Aluminium oxide (Al_2O_3)	1,9	(1,0% Al)
CO_3 (as CO_2)	2,4	
Fluorine (F)	2,9	
Titanium (Ti)	0,5	
Insolubles	14,0	
Mg, Na, K etc.	Traces	

Adventitious calcium carbonate was removed before the above analysis was carried out. Carbonate is, therefore, derived from the phosphate matrix.

Mining operations

The Langebaan phosphate deposit, known as New Varswater, covers an area of 2,6 km^2 and is a sedimentary deposit which has accumulated upon a raised beach which today lies 30 m above present sea-level and at a distance of 11 km from the sea. (See Fig 1).

Basal beach

The raised beach was cut on a phosphatic sandstone horizon resulting in a 1 m thick discontinuous layer of brown phosphatic sandstone overlain by rounded beach pebbles and gravel of phosphatic sandstone. Also present are granitic gravel, rolled bone fragments and sharks teeth. Where the solid phosphatic sandstone is absent, beds of accumulations of shells and shell casts (all phosphatised) and beach gravel are found. Associated with this marine horizon are fossils such as whales, penguins, seals, fish, sharks and sting rays.

The average grade of this phosphatic sandstone is 15 per cent P_2O_5 (6,5 per cent P), but it is not mined because most of the phosphate is present in the form of a cement which binds the quartz grains. When the rock is crushed and milled the phosphate is liberated as a slime which is too fine to be recovered and upgraded.

Sand ore body

Immediately overlying this basal zone is the phosphatic sands ore body. This consists of two distinct types of phosphate particles associated with a host mineral of ordinary quartz sand. The phosphate particles are either flat, platelike shell fragments which have been phosphatised through a replacement of the carbonate by phosphate to give a calcium phosphate, or spherical phosphatic pellets which appear to have grown as accretions usually around a nucleus of quartz but sometimes ilmenite or felspar.

Detailed screenings of the phosphatic sands have been carried out and plots of cumulative mass percentages against values, show a bi-modal distribution indicating both a wind and water means of emplacement. (See Fig 2).

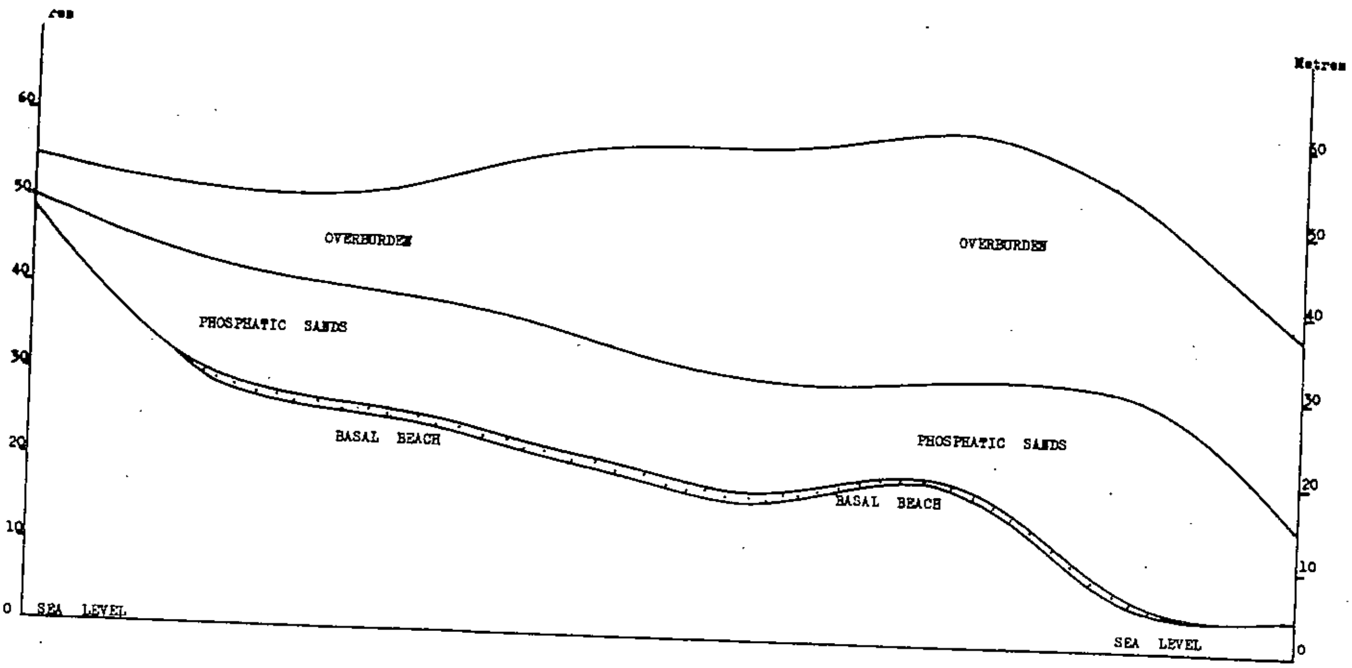

Fig 1 North-east, South-west section through the New Varswater phosphate deposit (Langebaan)

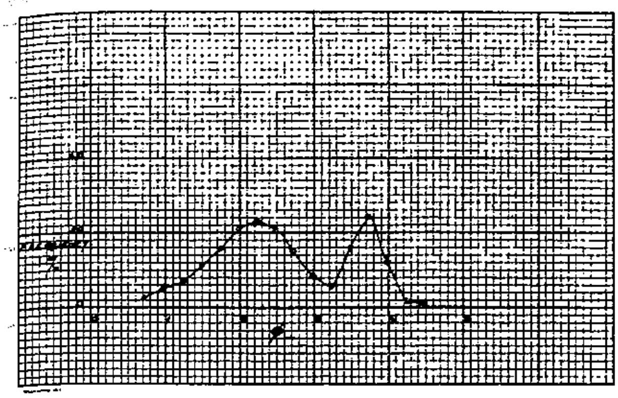

Fig 2 Particle size distribution of the Langebaan phosphatic sands

(ϕ 0,7 = 599 microns; ϕ 1,2 = 422 microns; ϕ 2,7 = 152 microns; ϕ 3,3 = 104 microns; ϕ 3,7 = 76 microns; ϕ 4,5 = 44 microns)*

Table 1 shows a typical screening analysis through a full section of the ore body. The important feature is the low P_2O_5 grade of the -150 +200 mesh fraction.

Within the ore body diagenetic changes as a result of solution and reprecipitation of phosphate have given rise to layers of slabby rock referred to as consolidated phosphatic sand. This is the richest type of rock encountered and has an average grade of 18 per cent P_2O_5 (7,8 per cent P), although values as high as 25 per cent P_2O_5 (10,9 per cent P), can be attained. This rock is a phosphatic sand which has been enriched by phosphate cementing the individual phosphate and quartz grains.

Towards the base of the ore body terrestrial fossils are found.

Reserves

The deposit is worked to a 3 per cent P_2O_5 (1,3 per cent P) cut-off value, while the average grade of the deposit is 9,0 per cent P_2O_5 (3,9 per cent P).

The average thickness of the ore body is 11 m with a maximum thickness of 24 m. Reserves at New Varswater have been calculated at 38 million tonnes. Additional reserves on the nearby farm Sandheuwel total 28 million tonnes at an average grade of 6 per cent P_2O_5 (2,6 per cent P).

These reserves at the present rate of mining provide a life of about 50 years.

Overburden

Overlying the ore body is the overburden which attains a maximum thickness of 51 m and which has a stripping ratio of 2:1. The overburden consists of a wind-blown accumulation of quartz sand and lime sand. The latter which is more abundant shows a complete range of diagenetic changes which have given rise to limestone rocks of varying degrees of hardness.

Mining methods

1 Overburden

Overburden is removed by 631C Caterpillar scrapers which have a 23 m^3 heaped capacity rating. These machines are push-loaded by Caterpillar D9G bulldozers which also preloosen and break up large rocks by ripping. The overburden is removed, via a round trip haul of the order of 4 km, to the slimes dam area where it is used to build dam walls for the retaining of plant tailings and slimes. These walls are 20 m high with a top width of 20 m and a base width of 130 m.

Removal rate is 2,4 million tonnes per annum.

2 Phosphate Ore

Because of the water table the ore body is mined in two cuts with 7 m faces and a common bench for the two excavators. The top-cut is mined with a face shovel and the bottom-cut is mined with a dragline. Both excavators are Ruston Bucyrus RB 54 machines which are electrically powered by 3,3 kV and which are equipped with 1,9 m^3 buckets. The ore is loaded by these excavators into Euclid R24 rear end dump trucks, rated at 22 tonnes and which transport the ore 1,2 km to the primary crushing station.

Quality control

A feature of the deposit is the extreme variability of the ore from one point to another as well as through the vertical section. The three factors which have to be considered are the grade of P_2O_5, the phosphatic slimes content and the quality and quantity of the -150 mesh fraction. With this in mind, regular sampling of the faces is carried out as well as the drilling of boreholes ahead of the mining faces. Such samples are subjected to detailed screening and P_2O_5 analysis as well as small-scale flotation tests.

Fossils

Since 1958 scientists have been collecting from the mine the fossil remains of creatures which inhabited the area about 4 million years ago during the Pliocene epoch. The mine has produced the most important Pliocene fossil assemblage yet recorded from southern Africa and it is known to palaeontologists throughout the world. Many of these, authorities in their respective fields, have visited the mine.

The fauna is more diverse than that from any other fossil site in sub-Saharan Africa and the scores of species represented include the following:

TABLE 1 *Typical screening analysis: Borehole No S – 12*

Depth in ft	% Mass							% P_2O_5								P_2O_5 Distribution						
	+25	-25 +36	-36 +100	-100 +150	-150 +200	-200 +350	-350	Head Sample	+25	-25 +36	-36 +100	-100 +150	-150 +200	-200 +350	-350	+25	-25 +36	-36 +100	-100 +150	-150 +200	-200 +350	-350
96,5 – 100	7,8	10,8	46,0	9,5	18,4	1,8	5,7	4,9	5,4	4,6	3,6	3,5	1,4	4,6	15,7	10,1	12,0	40,0	8,0	6,3	1,9	21,7
100 – 103,5	6,0	10,8	39,9	7,3	28,4	2,8	4,8	6,9	8,4	7,1	10,0	8,6	1,3	4,0	12,3	7,2	11,0	57,3	9,0	5,3	1,7	8,5
103,5 – 107	5,0	10,5	41,6	9,0	26,0	3,0	4,9	11,8	9,4	12,2	18,0	14,4	1,8	3,6	10,2	4,1	11,0	64,5	11,1	4,1	0,9	4,3
107 – 110,5	1,7	3,7	45,7	13,1	25,9	2,7	7,2	15,0	11,3	14,4	21,3	18,2	3,7	5,7	13,6	1,3	3,5	65,3	15,9	6,4	1,0	6,6
110,5 – 114	4,9	5,3	49,9	10,8	18,5	2,5	8,1	17,6	19,9	18,1	22,2	19,8	4,5	7,3	17,4	5,6	5,5	63,1	12,1	4,7	1,0	8,0
114 – 117,5	3,0	4,8	52,8	11,3	17,9	1,9	8,3	17,7	20,7	17,6	21,9	19,2	4,5	8,2	17,1	3,5	4,8	65,8	12,3	4,6	0,9	8,1
117,5 – 121	3,3	5,9	50,8	9,1	22,5	2,2	6,2	16,0	13,6	16,0	22,8	18,8	3,2	4,6	10,0	2,8	5,8	71,9	10,6	4,5	0,6	3,8
121 – 124,5	3,2	5,1	54,6	12,9	19,0	1,9	3,3	17,8	14,0	16,8	23,4	20,8	3,4	6,0	10,0	2,6	4,8	71,6	15,0	3,6	0,6	1,8
124,5 – 128	1,4	6,2	53,8	7,6	24,7	2,6	3,8	16,9	14,7	18,1	25,6	19,3	2,6	5,2	7,1	1,2	6,4	78,3	8,3	3,6	0,7	1,5
128 – 131,5	2,0	6,5	53,6	7,8	23,0	2,1	5,0	18,4	18,2	19,4	26,0	19,4	3,2	6,2	7,2	2,0	6,9	76,1	8,3	4,0	0,7	2,0
131,5 – 135	12,0	3,3	41,2	7,8	18,5	2,1	15,1	20,0	25,0	22,0	26,2	20,0	4,6	14,6	22,2	14,5	3,5	52,5	7,6	4,1	1,5	16,3
135 – 138,5	29,4	3,3	39,9	7,8	11,2	1,5	6,9	21,2	20,8	21,4	24,2	19,6	6,2	18,0	24,6	29,6	3,4	46,7	7,4	3,4	1,3	8,2
138,5 – 142	22,7	1,0	11,2	9,2	47,7	4,5	3,7	8,0	14,6	13,4	16,0	14,4	1,6	4,6	17,2	40,7	1,6	22,0	16,2	9,3	2,5	7,7
142 – 145,5	43,7	3,2	24,0	6,0	18,6	2,5	2,0	7,8	12,8	5,6	4,6	4,8	1,4	4,4	12,4	71,9	2,3	14,2	3,7	3,3	1,4	3,2
145,5 – 148	39,3	1,2	8,7	5,5	17,9	11,6	15,8	6,5	12,0	5,9	4,4	2,0	0,5	0,7	2,1	81,6	1,2	6,6	1,9	1,6	1,4	5,7

Invertebrates: Sea urchins, shellfish and barnacles

Vertebrates: Fish: sharks, skates, rays and mussel-crackers

Frogs and reptiles: snakes, lizards and tortoises

Birds: ostriches, penguins, cormorants, plovers and ducks

Mammals: sixty species which include mice, shrews, cats, hyenas, horses, rhinos, pigs, giraffes, antelopes, elephants and whales.

Many of these species are new to science and of special interest are:

- The first fossil penguin from Africa
- The first bear recorded from sub-Saharan Africa
- One of the earliest of the true elephants
- One of the earliest ancestors of the white rhinoceros
- The smallest and one of the largest fossil pigs known from South Africa.

At the time these animals were still living, the environment was very different from that of the present. The vegetation must have been more luxuriant and the presence of giraffes indicates the presence of trees, while other herbivores suggest grasslands. It is probable that a large river, a precursor of the Berg River entered the sea nearby and it was perhaps this fresh-water that attracted many of the animals whose remains are being revealed today.

Process

The flowsheet for the plant is illustrated in Fig 3.

Ore receipt and preparation

The ore, mined on two shifts, six days per week, is delivered over a grizzley with 200 mm bar spacing. The undersize of this grizzley is fed over a secondary grizzley, with 114 mm spacings. The −114 mm material discharges onto a 750 mm conveyor. Oversize of the primary grizzley is reduced to −125 mm in a 30 x 42 Hadfields single toggle crusher and the oversize of the secondary grizzley is crushed to −114 mm in a 18 x 30 Kue-Ken jaw crusher. The broken rock from both crushers join up with the original fines on the 750 mm conveyor. This material is discharged on a radial blending conveyor from which the ore is stockpiled on two stock piles: one being built up while the other is reclaimed for plant input. The capacity of the two stockpiles is 4 500 tonnes. This is equivalent to 30 hours' supply to the concentrator when operating in full plant capacity.

Scrubbing and desliming

The scrubbing plant is fed with front-end loaders which discharge on to an apron feeder with variable speed, for control of feed rate to the scrubber. In the scrubber water is added to form a pulp of approximately 50 per cent solids consistency. Sodium silicate is also added at a rate of 200 g/t dry plant feed. This sodium silicate plays a double role in our process, viz. (i) As a dispersant for slimes and clay agglomerates in the ore, and (ii) as a depressant for quartz and other minerals with cationic surface properties. In the rotary scrubber vigorous agitation of the pulp breaks up clay balls and soft ore lumps, this action being aided by the load of hard lumps in the scrubber acting as grinding pebbles. To reduce the secondary formation of slimes in the scrubber, the retention time was drastically reduced by widening the discharge opening of the scrubber.

The scrubber discharges on a double deck vibrating screen fitted with screens of 15 mm and 6 mm openings. The rock on the decks is washed with watersprays to remove as much as possible adhering fines. The washed +15 mm rock is railed to the Kookfontein Works of Chemfos where it is used as partial furnace burden for the production of phosphorus and thermal phosphoric acid. The -15 +6 mm pebbles are fed to the wet ball mill, and the -6 mm pulp is pumped to a stock surge bin which acts as a large sized pump sump to eliminate surges of the underflow pumps.

Desliming of the ore is conducted in three stages. This is essential because the highest possible degree of elimination of the −105 µm fraction of the ore must be obtained. As illustrated in Table 1, the -105 +76 µm particle range is very low in phosphate content, analysing hardly better than normal plant tailings. For this reason the standard desliming cut for Langebaan ore has been taken as 105 µm.

Primary desliming is carried out by pumping the underflow of the stock surge bin through a 750 mm hydrocyclone. Overflow of this cyclone is pumped to the slimes dam as waste. The underflow is diluted with fresh water and passed over six DSM screens (sieve bends) with 1,0 mm bar spacing. The DSM screen oversize product joins the fine pebble feed to the wet ball mill. The discharge of the ball mill is recirculated to the stock surge bin.

Secondary desliming is carried out on the DSM sieve bend undersize product by passing the material through a 600 mm hydrocyclone. The overflow is used as dilution water for the ball mill discharge being returned to the stock surge bin. The cyclone underflow is diluted and recycloned in a second 600 mm cyclone. The overflow of this cyclone is pumped to the scrubber as pulping water. The underflow of this tertiary cyclone is fed to the flotation conditioner.

The desliming process described above, has been arrived at after considerable experimentation on the plant with various schemes, and as this system has only been in operation for a few weeks its full effectiveness has not yet been finally evaluated. Prior to the introduction of this scheme, desliming was carried out in only two stages. This removed between 60 and 70 per cent of the total -105 µm fraction in the new feed to the plant.

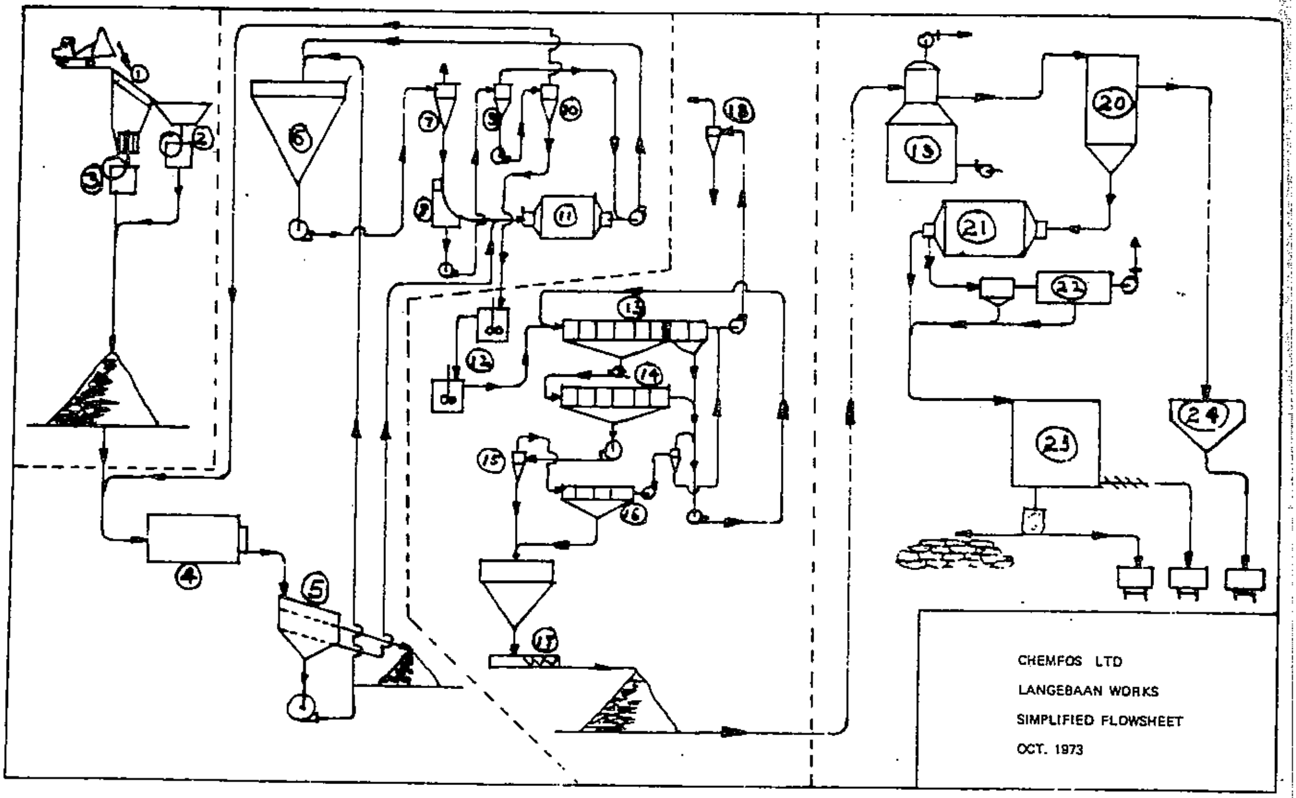

Fig 3 Flowsheet for Langebaan Works of Chemfos Ltd

1 *Grizzley*
2 *30 x 42 Hadfields crusher*
3 *15 x 30 Kue Ken crusher*
4 *Rotary scrubber*
5 *Double deck screen*
6 *Surge bin*
7 *Primary cyclones, 750 mm*
8 *DSM Screens, 6 parallel*
9 *Secondary cyclones, 600 mm*
10 *Tertiary cyclones, 600 mm*
11 *7 x 8 wet ball mill*
12 *Conditioners*
13 *Rougher flotation: 3 banks*
14 *Cleaner flotation*
15 *Cleaner concentrate cyclone*
16 *Recleaner flotation*
17 *Concentrate surge bin and filter*
18 *Tailings thickening cyclones*
19 *Fluosolids dryers, 2 off*
20 *Concentrate bins*
21 *Compeb mill 7 x 20*
22 *Bag filter*
23 *Langfos bin*
24 *Concentrates loading bin*

The actual mass percentage of -105 µm material in the orebody varies between 25 and 50 per cent, which dictates that as flexible a desliming system as possible is required to cope with these variaitons. For this reason the new system has been designed to enable the by-passing of the third stage cyclone when dealing with ore that is lower in fines content.

Flotation

The principles of the fatty-acid flotation of phosphates have been adequately described in the paper delivered by Roux (1973) and therefore we shall not repeat basic information in this paper.

All ore bodies, however, behave differently from one another, due to mineralogical composition, nature of organic material present in the ore, particle size and shape differences, and differences in the quality and analysis of the water used in the process.

The flotation reagents used for Langebaan ore are as follows:

(a) Semi-refined tall oil, containing approximately 80 per cent unsaturated fatty acids in the oleic and linoleic forms. Consumption of this reagent is 1,85 kg/t flotation feed, which is much higher than the comparative consumption of Foskor ores.

(b) Caustic soda, which acts as saponifier for the fatty acids, rendering the formation of long chain carbolic acid ions easier than for the unsaponified acids. Conditioning takes place at a pH of 8,9 – 9,2.

(c) Sodium silicate, as depressant for quartz.

(d) For the control of excessive frothing in the flotation machines a small quantity of diesel fuel is added at a rate of 0,11 kg/t.

The reagents are added to the deslimed underflow of the tertiary hydrocyclone in two conditioning tanks in series where intensive agitation is maintained to allow reaction of the reagents with the mineral particle surfaces.

After conditioning, rougher flotation is carried out on three parallel banks of flotation machines, consisting of six rougher cells and two scavenger cells each. The rougher concentrate is refloated in a bank of cleaner cells, whereas the concentrate from the scavengers is returned to the head of the flotation section.

Concentrates from the cleaner bank are classified into nominally a +105 µm and a –105 µm fraction by pumping them through a 450 mm cyclone. The coarse fraction (+105 µm) normally assays over 30 per cent P_2O_5 (13,1 per cent P) which is higher than standard specification. The fine fraction (–105 µm), however, usually assays approximately 10 per cent P_2O_5 (4,4 per cent P). This fraction is subjected to a recleaner flotation stage which improves its grade to 12 – 15 per cent P_2O_5 (5,3 – 6,5 per cent P).

The ideal condition for obtaining a concentrate assaying higher than 30 per cent P_2O_5 (13,1 per cent P), would be to have a flotation feed from which all the –105 µm material has been removed. This, as is well-known, to all ore dressing metallurgists, is unattainable, since to eliminate all of this fraction would require sacrificing too large a portion of high grade coarse material.

A present various avenues with respect to better elimination of this fraction and upgrading of the remaining fines are being studied. Under present operating conditions we are already eliminating 90 per cent of the –105 µm fraction in the plant feed in the desliming and flotation processes.

Tailings from the flotation plant are thickened in three 300 mm hydrocyclones in parallel, after which the thickened tailings are pumped to the slimes dam.

Final concentrates are filtered on a 3,5 m horizontal filter before being stockpiled on an intermediate stockpile prior to drying.

From the description given above it is clear that extensive use is made of hydrocyclones for desliming, classification and thickening. Some years ago an attempt was made to replace the DSM sieve bends by cyclones, but the efficiency of these units was not sufficient, and resulted in too large a circulating load through the wet ball mill, and subsequent overgrinding, and overflowing of the ball mill discharge pumps.

A typical metallurgical balance for the concentrator is shown in Table 2.

Product drying, milling and handling

The concentrates are dried in two forced draught fluidized bed (Dorrco Fluosolids) dryers, each with a 1,07 m diameter bed. Heavy furnace oil is the fuel used.

After drying, the concentrates are milled in a 2,13 x 6,10 m compeb mill, using cylpebs. Originally the grinding medium make-up was done by 25 mm steel balls. Milling capacity at that stage was approximately 19 t/h. After changing to the use of 25 mm cylpebs the capacity of the mill was increased to 23,5 t/h. Since June 1973 the medium in the second compartment was replenished with 16 mm cylpebs, and the capacity of the mill increased dramatically to 29,5 t/h. This step obviated the necessity of installing an additional mill for increased production.

The milled product, Langfos Premium, is either bagged with a fluidizing packer, for direct railing or to stacks, or loaded in bulk for despatch to a number of depots whence the product is spread on the customer's lands before ploughing.

References

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ROUX, E.H., 1973. Reserwes, ontginning en verwerking van fosfate. Fert. Soc. S.A. J. 2, 45–54.

TABLE 2 A typical metallurgical balance for the concentrator

	t/h	% P_2O_5	(% P)	P_2O_5 Distribution (%)
Feed	116,3	11,0	(4,8)	100,0
Rock	6,1	19,0	(8,3)	9,0
Concentrator feed	110,2	10,6	(4,6)	91,0
Slimes	51,3	6,8	(3,0)	27,3
Concentrates	25,3	29,0	(12,6)	57,3
Tailings	33,6	2,4	(1,0)	6,4