



Start-Up of one of the Worlds Largest DAP Plants – WMC Fertilizers

D M Ivell, Manager of Granulation Technology, Jacobs Engineering, Lakeland, Florida, USA

M Blackwell, DAP & Ammonia Plant Superintendent, WMC Fertilizers, Queensland, Australia

Introduction

Two decades after the Queensland Phosphate project was first mooted, the economics eventually fell into place and the operation was finally put into commercial operation this year.

In addition to the rock mining and beneficiation operation, production facilities include a 600 mtpd Ammonia plant, a 1500 mtpd Hemi-Hydrate Phosphoric Acid plant and a 1 million mtpa, single stream DAP/MAP Granulation Plant. Sulfuric Acid is also produced by WMC Fertilizers (WMCF) at the nearby Mt. Isa Mines (MIM) site and transported to the Phosphate Hill site by rail.

The technology and basic engineering for the granulation plant was supplied by Jacobs Engineering of Lakeland, Florida. Fluor Daniel, Australia, executed the contract on a lump sum, turnkey basis. The design kicked off in October 1997 and was mechanically complete by September 1999. Due to delays in completion of some of the other plants, the first product was not produced until December 1999.

Australia's phosphate industry was relatively small before the implementation of WMCF's project. Experienced operators were therefore in very short supply. However, WMCF invested heavily in the training of their young and inexperienced crews. A group of production people spent a month in Florida being trained both in the classroom at Jacobs' offices and on operating plants. This training was reinforced on site by involving the operators in the pre-commissioning activities as well as in more classroom tuition.

Logistics: a key to success in the Outback

The Queensland Fertilizer Project is unique in many respects, not the least being its location; it is the most remote fertilizer processing facility in the world. This remoteness in the Australian Outback introduces three key logistical issues not normally associated with fertilizer manufacture:

- How to get the people to the site to mine and process the resource
- How to cost effectively get raw materials and reagents to the site for processing
- How to transport the bulk final product in a cost-effective manner to the ports for shipping

People

WMCF operates Phosphate Hill as a “fly-in, fly-out” operation with all personnel on staff contracts. All of WMCF’s 240 people work the equivalent of a 2 weeks on, 1 week off roster.

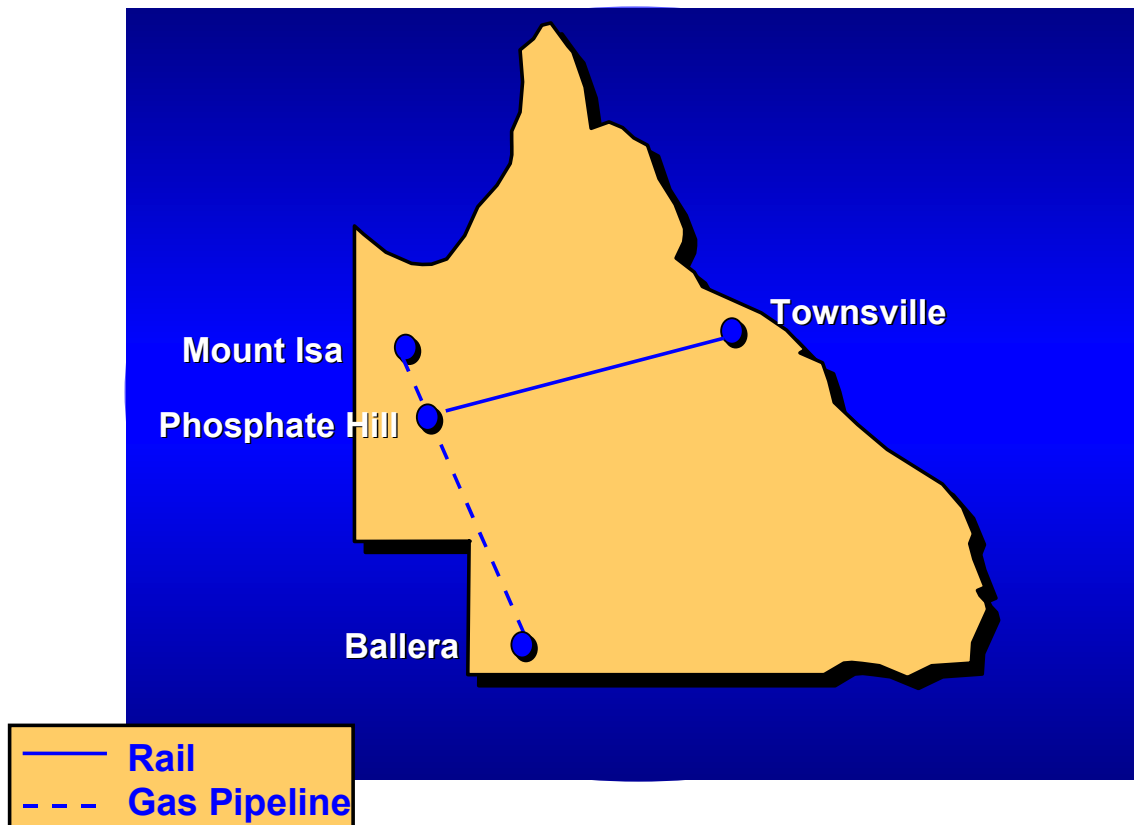
Staff stay in village style accommodation complete with mess facilities, a fitness center and sporting facilities. Single person accommodation is in two room units with en-suite.

The DAP plant is operated by 4 process technicians. During commissioning this level of manning was supplemented by 2 laborers per shift to assist with extra sampling requirements and cleaning duties.

Raw Materials

At Phosphate Hill the processing plant is at most 3km from the ore body making the mining and beneficiation proximate and simple. Unfortunately, the ore body is situated over 950km by rail from the closest coastal port and restricted to access by unsealed dirt road from the provincial town of Mt Isa, just over 200km to the north. These distances create logistics issues somewhat unique in the fertilizer manufacturing industry.

Fig. 1 The Queensland Fertilizer Project



All chemical supplies for the operation are transported to the site by road. The long distances and substandard condition of the outback roads prevent a “just-in-time” strategy for many of the operations supplies.

The Sulfuric Acid plant was built in the mining community of Mt Isa to take advantage of the readily available SO_2 gas generated by MIM’s copper smelting process. Rail movements of over 1200 kt per annum between Mt Isa and the Phosphate Hill site will be needed to operate the Phosphoric Acid and Granulation Plants. The GATX wagon system, designed with a single load and unload point, was chosen by WMC as the most suitable system from both a safety and economical standpoint. Approximately 200kt of acid is also transported from a zinc smelter on the coast to smooth consumption from the Mt Isa plant.



WMCF is dependent on airfreight for deliveries of urgently required components and materials. Chartered flights land at Phosphate Hill almost twice a day, allowing most freight to be delivered from anywhere in the country within 24 hours.

Final Product

A key driver to the financial success of the project was the need to secure a very competitive freight agreement with Queensland Rail (QR). Transportation costs had proven in the past to be a significant block to the viability of the high-volume, low value-added rock sales.

WMCF's requirements of QR were relatively simple; clean, dedicated rolling stock that would prevent damage to the material during loading, transport and unloading at the lowest possible price. However, QR's flexibility in pricing was somewhat limited by union requirements on driver hours and the capital cost of designating rolling stock to the fertilizer operation. QR set a maximum loading time of just 2 hours as the operational requirement.

To meet this requirement WMCF built a silo of 3400 t capacity which, via a certified weigh-bin can automatically load a 3200-t train in under 1.5 hours. Each of the 50 wagons is loaded with an accuracy of +/- 100 kg.

The doors on the top of each wagon automatically open, one at a time, the pre-set weight is batched into the wagon via pant-leg chutes from the loading hopper, the chutes retract and the door closes. The sequence is repeated for the next 49 wagons. At no time during the sequence does the train need to stop, nor the driver leave the locomotive. A WMCF employee only monitors the automatic system.

To facilitate accurate and timely transfer of load data, the manifest is emailed to WMCF prior to train arrival, updated by the loadout control system during the loading process, then returned electronically to QR's control center for processing.



At the port facility the train travels through a bottom discharge facility where the bottom doors are automatically opened, and the DAP is discharged on to a conveyor for transport into the 90,000 t port storage facility.

Product Marketing

WMCF has the vision of becoming the “Supplier of choice of high analysis Fertilizers” to its chosen markets. To achieve this, differentiation is necessary. WMCF believes this differentiation can be achieved by marketing a product of the required chemical grade and superior physical characteristics.

Marketing Mix

The marketing mix for WMCF is MAP (10-50-0) and DAP (18-46-0), although only DAP will be produced initially due to the market’s requirements. DAP will be sold domestically and internationally; it is envisaged that MAP will only be produced for the domestic market.

Target Markets

WMCF will produce approximately 1million mtpa of fertilizer, which could in effect supply much of the domestic market. Due to seasonal fluctuations and the enormous storage requirements this is not feasible.

Through its relationship with Cargill Fertilizers Inc., WMCF will export approximately 50% of its production volume into SouthEast Asia, predominately Thailand, Vietnam, Malaysia and the Philippines. The remaining product will be sold in Australia through its wholly owned subsidiary Hi-Fert and other commercial fertilizer wholesalers.

Production Information Management System

During the execution of the project, WMC was also embarking on its company wide Information Integrity Program (IIP), a program aimed at providing consistent and transparent information to all it’s people. The main drive of the IIP was the roll out of SAP and consistent business processes across



its global operations. This scope was expanded at the Queensland Fertilizer Project to include a total solution to plant information management.

The result was a fully integrated Production Information Management System (PIMS) capable of delivering timely, relevant information on almost every aspect of the plants operation at any time, to any person in the organization, anywhere in the world.

Structure of the PIMS System

A Yokogawa Centum Distributed Control System (DCS) controls the processing plants at Phosphate Hill and Mt Isa; some specialist equipment is fully controlled by Programmable Logic Controllers (PLC).

The DCS is the operational interface and the primary source of immediate and detailed plant operational history. Real-time data is fed from the DCS to the Plant Historian Database (PHD) provided by Honeywell.

The integrated information management solution (process, maintenance and laboratory) captures real-time data, laboratory information and operator inputs.

Web technology is used to report and display plant operational conditions as well as real-time and calculated information from the integrated system. The integrated solution produces production results and maintenance measurements that are automatically transferred to SAP.



On a daily basis the actual production physicals are loaded up into SAP against that process order to allow product costing to be determined and inventory reconciled. This real-time system allows maintenance activities to be planned with a higher level of accuracy and less manual data input through the integration of the SAP maintenance module.

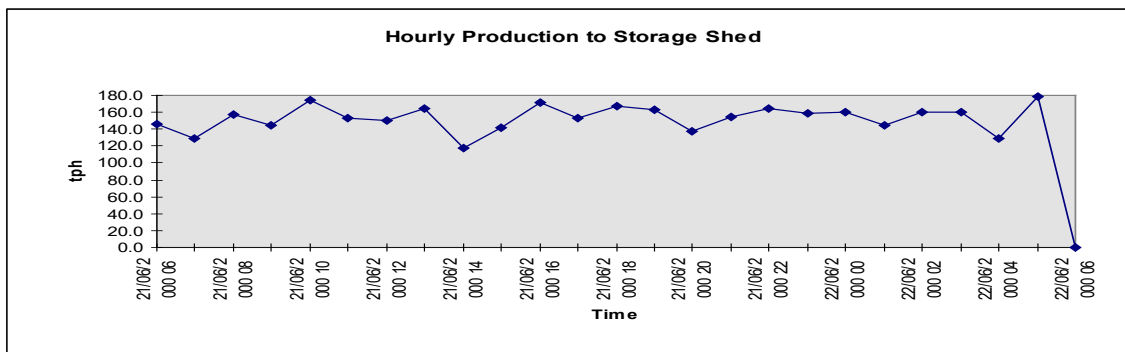
The highly automated processing of laboratory information and DCS data enabled the commissioning team (Jacobs Engineering, Fluor Daniel and WMCF) to continually assess the plant's operational performance with minimum data collection effort. Figure 3 below shows a partial view of a daily log sheet summary:

Fig. 3 Daily Production Logsheet

DAILY PRODUCTION LOGSHEET FOR THE GRANULATION PLANT

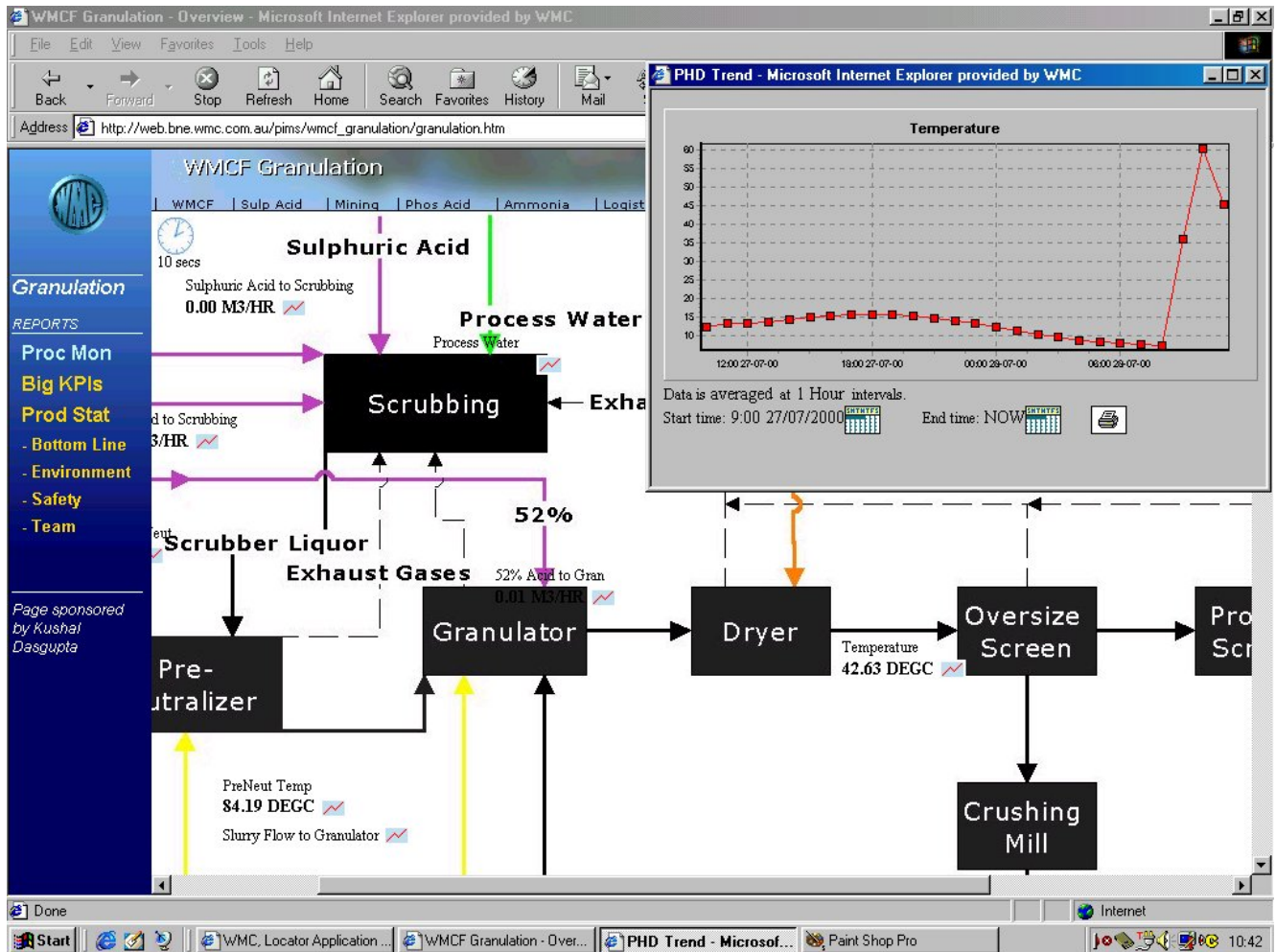
Start of shift hours			Total Prodn. Period				
Start	21/06/2000 06:00	21/06/2000 06:00					
Finish	21/06/2000 18:00	22/06/2000 06:00					
Total DAP Production Per Day			3440.4	Tonnes	Weekly Production (DAP)	12,938	Tonnes
Total MAP Production Per Day			0.0	Tonnes	Weekly Production (MAP)	0	Tonnes
Plant Operating Time			22.98	Hours			
Consumption of Feed Material							
Total 20% Phosphoric Acid Consump.			606.6	m ³	Total Natural Gas Consumption	15412.4	m ³
40% Phosphoric Acid [to Preneutralizer]			667.0	m ³	Total Natural Gas Consumption	608.4	GJ
40% Phosphoric Acid [to Pre-Scrubber]			76.2	m ³	Total Defoamer Consumption		m ³
40% Phosphoric Acid [to Primary Scrubber]			254.2	m ³	Total Coating Oil Consumption	5249	L
Total 40% Phosphoric Acid Consump.			997.4	m ³			
52% Phosphoric Acid [to Preneutralizer]			890.8	m ³	Total Power Consumption	96	MWH
52% Phosphoric Acid [to Granulator]			0.3	m ³	Total Biodunder Consumption	0.0	m ³
Total 52% Phosphoric Acid Consump.			891.1	m ³	Indicators		
					Power cons./ t DAP	28	kWH/tDAP
Sulfuric Acid [to Preneutralizer]			21.23	m ³	NG cons./t DAP	0.18	GJ/t DAP
Sulfuric Acid [to Tailgas Scrubber]			0.84	m ³	Coating Oil cons./t DAP	1.5	L/t DAP
Total Sulfuric Acid Consump.			22.07	m ³	20% PA cons./t DAP	0.18	m ³ /t DAP
					40% PA cons./t DAP	0.29	m ³ /t DAP
Ammonia Consumption in Preneutralizer			446.7	Tonne	52% PA cons./t DAP	0.26	m ³ /t DAP
Ammonia Consumption in Granulator			221.1	Tonne	Ammonia cons./t DAP	0.20	tNH ₃ /t DAP
Total Liquid Ammonia to Gran. Plant			667.8	TONNE			

	PRODUCT CHARACTERISTICS					PRENEUTRALIZER				PRESCRUBBER		PRIMARY SCRUBBER		PRODUCT	
	%N	%P2O5 (Avail)	%Moist	SGN	UI	Temp, °C	MR	Density, kg/m3	Slurry, m3/h	MR	Density, kg/m3	MR	Density, kg/m3	To shed, tph	Temp, °C
6/21/00 6:00	17.52	45.99	1.55	284	59	118.1	1.54	1575	101	1.50	1343	0.80	1254	145.54	48.1
6/21/00 8:00	17.68	45.94	1.86	267	60	118.6	1.55	1579	104	1.59	1355	0.67	1277	156.89	49.8
6/21/00 10:00	17.73	45.93	1.80	280	65	118.3	1.49	1572	105	1.65	1351	0.99	1276	174.55	54.9
6/21/00 12:00	17.63	46.81	1.23	289	60	117.0	1.55	1573	102	1.56	1348	0.75	1268	150.00	49.3
6/21/00 14:00	17.63	47.42	1.33	279	61	117.8	1.52	1574	102	1.42	1342	0.56	1267	117.37	44.2
6/21/00 16:00	17.87	47.81	1.58	287	60	118.4	1.53	1579	101	1.50	1348	0.53	1266	171.74	54.3
6/21/00 18:00	17.65	46.14	1.48	278	61	118.3	1.54	1577	101	1.51	1353	0.66	1283	166.79	51.3



Further, the transparency of information assisted in creating ownership of the process among the operating and maintenance technicians. The Intranet web pages, which are available to all levels of the organization, proved to be the most popular source of information. A partial view of the web page is shown in Figure 4 below:

Fig. 4 Intranet Web Page



Features of the Granulation Plant

The plant was designed to produce both MAP and DAP, although to date only DAP has been produced. The nameplate capacity of the plant is 1 million mtpa, with a rated hourly capacity of 135 mtph of either product. In view of the large capacity WMCF felt more comfortable with a process based upon a tank rather than a pipe reactor. Nevertheless, the plant was designed for a recycle ratio of 4:1. The “back-titration” route was chosen for the production of MAP.

WMCF has entered into sales contracts with all its suppliers that place considerable emphasis on the physical characteristics of the product. This is in response to the growing demand from the end-user for a product that does not break down or cake in transport.

The typical production specification for the WMCF product is:

H ₂ O (ground)	2.0% max
Size:	+4 mm 5% max
	+2 mm 95% min
SGN	280 - 310
UI	60-70
Hardness:	12 – 16 lbs (5.4 – 7.3 kg)
Cd	2 ppm max
Hg	<0.1 ppm max
Pb	<1 ppm max

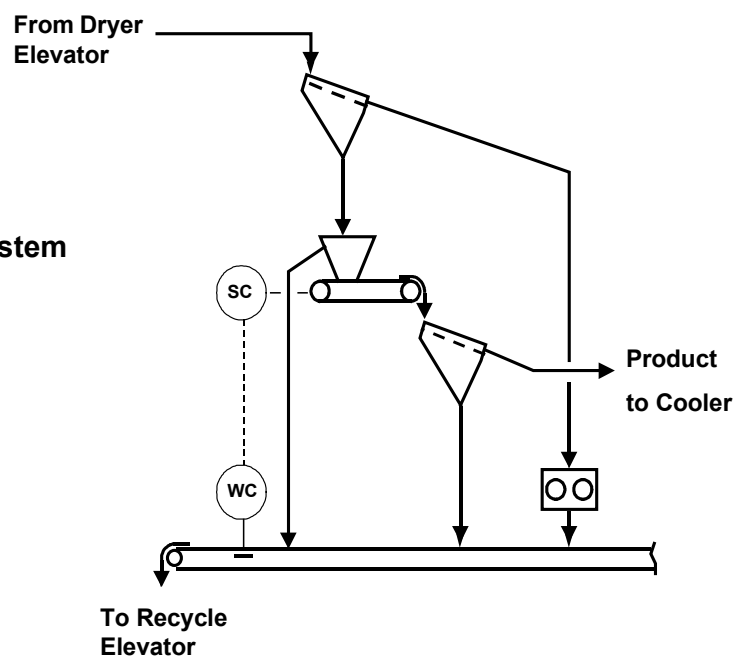
The plant is designed to achieve product temperatures to storage of less than 50°C at all times. Facilities are also installed to coat the final product with an anti-dusting agent. Application of coating oil has been at the lowest end of known producers (less than 1.8 l/t); this can be attributed to the low porosity of the granule and the high overall uniformity.

Screening

In order to meet the size specifications Jacobs installed a comprehensive screening system. All screens were of the inclined cloth vibrated type. All the ex-dryer material is passed over three single deck machines to separate oversize, which is then crushed in double opposed chain mills located above a wide, slow speed, enclosed recycle conveyor belt. The conveyor belt is fitted with a weighscale, which allows the recycle to be accurately controlled. The undersize from the oversize screens passes to a holding hopper. The recycle weighscale automatically controls the speed of the extractor belt underneath the hopper so that any excess product overflows from the hopper to the recycle conveyor. This scheme minimizes the amount of material which has to be screened for fines removal. Four single deck screens are provided for this purpose.

After cooling, a further two double deck polishing screens are provided to clean up the product before transportation to storage. The scheme is shown in Figure 5 below.

Fig. 5
Recycle Control System



Cooling

A fluidized bed type cooler was selected because of the flexibility it allows in the layout of the plant and because of its gentle cooling action. The cooler is a true fluidized bed; in other words material transport is by fluidization only – there is no vibratory action. In view of the very high ambient temperatures that are experienced at the plant site (frequently in excess of 40°C) the incoming air for cooling is chilled to 12°C using ammonia.

Coating

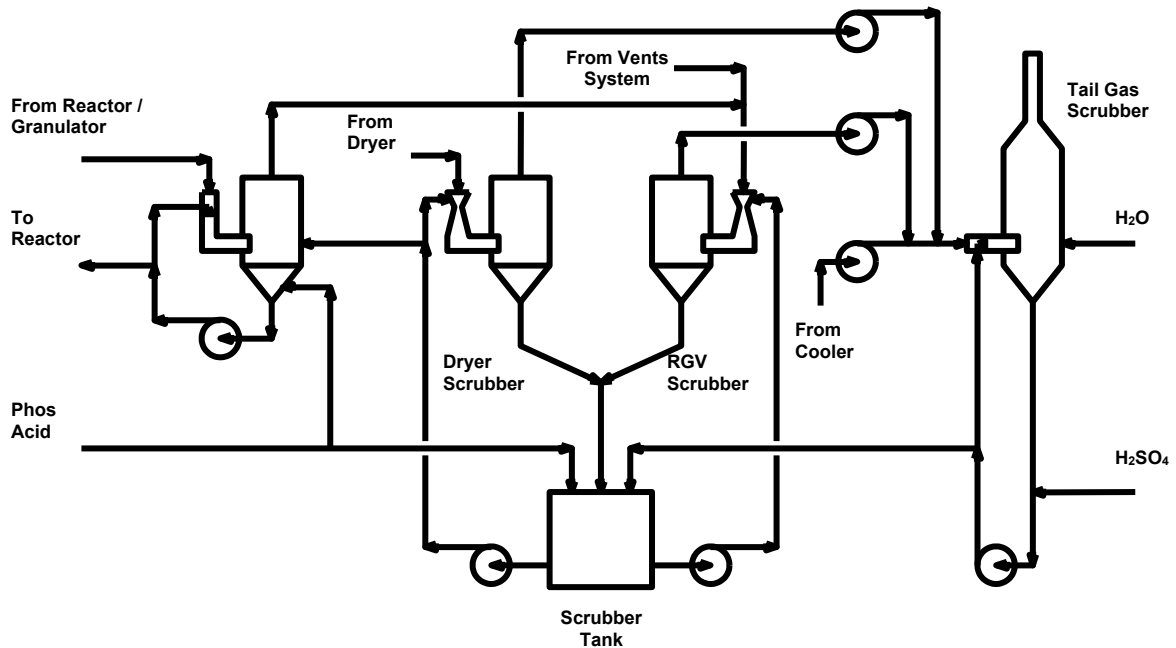
In order to minimize problems with dusting on downstream handling of the product, an oil coating system was installed. In preference to an expensive rotary drum, a ribbon blender was installed. The oil is sprayed onto the product in the feed chute to the blender. The rate of application is linked automatically to the production rate measured as the product leaves the blender.

Scrubbing

A state-of-the-art scrubbing system is installed consisting of “dual mole” scrubbing and a tail gas scrubber. The system is shown in Figure 6 below.

The gases from the reactor and granulator are first scrubbed in a simple, low pressure drop spray-cyclonic pre-scrubber, using scrubber liquor bled forward from the primary scrubbers. Two identical venturi-cyclonic scrubbers are installed. One scrubs the gases from the dryer cyclones and the other scrubs the exhaust from the pre-scrubber and the gases from the general plant dedusting cyclones. The scrubbing medium is weak phosphoric acid. As the acid passes through the primary scrubber, on through the pre-scrubber and finally on to the reactor the mole ratio increases so that it is below 1.0 in the primary scrubber and above 1.0 in the pre-scrubber. This method of operation has been shown to minimize fluorine evolution from the scrubbing system, as well as maximizing ammonia recovery.

Fig. 6
Dual Mole Ratio Scrubbing



The tail gas scrubber is used to scrub the exhausts from each primary scrubber along with the gases from the cooler cyclones. This is a cyclonic scrubber with the stack located on top. The pH of the scrubbing water is adjusted using a small amount of sulfuric acid injected into the recirculation line to maximize ammonia recovery.

There is no liquid effluent from the plant – all the scrubber liquor is recycled back through the primary scrubbing system and eventually to the reactor.

Reactor

The reactor is constructed in 316L stainless steel and is of the expanded freeboard type, designed with a residence time of about 30 minutes. It has been shown that this type of design limits the generation of citrate insoluble compounds and thus maximizes the available P_2O_5 in the final product.

Granulator

In order to produce as spherical a granule as possible, the granulator was designed with a high rotational speed equivalent to 40% of critical. Jacobs' philosophy is to distribute the slurry as well as possible by utilizing multiple spray nozzles. In this case the slurry was distributed through four large, hollow cone nozzles, which contain no internals subject to clogging.

Unlike many designs, the back-end of the granulator is left open to encourage a through draft of air. This arrangement also allows a very useful opportunity to observe the quality of the spray pattern.

Dryer

The dryer is fitted with an integral grizzly containing lifting flights. This design feature enables the lump breaker, which is often the source of many maintenance problems, to be eliminated. The hot air to the dryer is introduced via a duct bifurcated to pass either side of the chute from the granulator. This arrangement not only prevents the hot air impinging on the back of the chute but also ensures that the air is well distributed across the full cross section of the drum.

Plant Performance

The performance test for the granulation plant was undertaken in mid-June, 2000 and all guarantee parameters were successfully demonstrated. The commissioning period was extended with several breaks, mainly due to raw material shortages caused by problems in the upstream plants. The granulation plant was the first of the production units to successfully complete a performance test.

A summary of some of the average operating and performance parameters of the plant during the performance test is given in Table 1 below:

Table 1

Production	10,122 tonnes
Production Period	74 hrs 25 mins
Plant Availability	72 hrs
Running Time	71 hrs 30 mins

<u>Cooler</u>
Air Inlet Temperature 12°C
Product Temperature 49°C

Product Size:	+4 mm 2.16%
	+2 mm 97.23%
SGN	284
UI	61.3

<u>Prescrubber</u>	
Temperature	85°C
Mole Ratio	1.51
Density	1336 kg/m ³

Moisture	1.38%
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<u>Primary Scrubber</u>	
Temperature	64°C
Mole Ratio	0.68
Density	1260 kg/m ³

Reactor

Temperature	118°C
Density	1574 kg/m ³
Mole Ratio	1.53

<u>Tail Gas Scrubber</u>	
Temperature	55°C
pH	5.37

Granulator

Temperature	92°C
Mole Ratio	1.87
Recycle	571 mtph

<u>Emissions</u>	
Particulate	5 mg/m ³
Ammonia	20 mg/m ³
Gaseous F	1.4 mg/m ³

Dryer

Air Inlet Temperature	176°C
Air Outlet Temperature	98°C
Solids Outlet Temperature	89°C

<u>Utility Consumptions</u>	
Steam	29.7 kg/t
Water	0.056 m ³ /t
Natural Gas	45,509 kcal/t
Power	28.4 kWh/t
Defoamer	0.21 kg/t

In order to minimize recycle requirements it was found necessary to operate with a slurry density of 1570-1580 kg/m³. Tight control was made possible by online measurement with a nucleonic. Minute to minute adjustments could be affected by changing the ratio of 40 and 52% acids being fed to the reactor. Mole ratio in the range 1.50-1.55 was found to be the optimum. Too high and the granulation turned dry and small, too low and higher recycle ratio was required. Mole ratios were measured in the plant using an auto-titrator. Blockages in the slurry line or the spray nozzles were a very rare occurrence.

Optimum mole ratios in the scrubbers were found to be 1.5 and 0.7 for the pre-scrubber and primary scrubber respectively. Lower mole ratios gave higher fluorine losses whereas higher mole ratios gave higher ammonia losses. The mole ratios were independently adjustable by feeding part of the acid directly to the pre-scrubber. Again on-line measurement of scrubber liquor density was extremely useful in controlling the plant. Density was controlled either by adjusting the ratio of 20 and 40% acids fed to the primary scrubber or by the amount of tail gas scrubber liquor being bled forward. Losses of ammonia from the process to the scrubbing system were relatively low. In order to control the scrubber mole ratios at the target values less than 25% of the overall P₂O₅ fed to the plant was fed via the scrubbers. Tailgas scrubber pH was measured on-line and controlled automatically by injecting a small amount of sulfuric acid into the recirculation line.

The principle of using a conveyor belt, fitted with a weighscale was a huge success, enabling recycle to be accurately measured and controlled. The conveyor enclosure was connected to the dust extraction system and the area around the conveyor was practically dust free. The recycle rate was generally controlled automatically by adjusting the speed of the product screen feeder. At times there appeared to be a lack of product sized material in the plant and obviously during these periods no controller can work. The problem was traced to poor geometry of the product hopper leading to bridging on the back wall of the hopper. This resulted in the product from two out of the three screens permanently overflowing to the recycle conveyor. A liner was installed within the hopper, the outlet modified to improve extraction and one of the feed chutes relocated. These modifications dramatically improved the operation of the hopper and therefore the control system.

The screens generally worked very well as evidenced by the product quality that was achieved. It proved necessary however to enlarge the feed chutes to both the oversize and polishing screens to

prevent material backing up the chutes at high rates. Also, the originally supplied fines meshes on both the product and polishing screens suffered from frequent breakages. These have now been replaced with cloths with a larger wire diameter.

The integral grizzly in the dryer discharge was a complete success. The dryer was inspected on many occasions and was always found to be spotless and free from any signs of lumps at the discharge grizzly.

Probably the biggest problem faced during the commissioning, certainly during the early stages, was the difficulty in keeping the chute between the granulator and dryer free from build up. Due to some misunderstanding with the detailed engineering contractor, the chute design was not quite as Jacobs had intended. The problem was eventually solved by the installation of a loose, hanging rubber panel running down the back wall of the chute.

The product turned out to be the best-looking material that most people who have seen it have encountered anywhere in the world. Not only is it substantially all 2 - 4mm, it is very uniform in size and incredibly spherical. This is achieved while operating at a recycle ratio of about 4:1. Operation at slightly lower production rates and higher recycle ratios improves the already high uniformity and sphericity still further.