CONSTRUCTION & COMMISSIONING OF BFPL'S 2200 MTPD - WORLD'S LARGEST PURIFIER™ AMMONIA PLANT

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In early 2006, Burrup Fertilisers Pty Ltd (BFPL) completed construction and started up of its 2200 MTPD Ammonia Plant – the world's largest, single train Purifier based ammonia plant. The plant is located on the Burrup Peninsula, near Karratha, in the north west of Western Australia. Commissioning was successfully completed in April 2006 with the inaugural shipment of liquid ammonia departing from the Port of Dampier in June 2006. This paper presents an overview of the project and its journey through the various stages of project development, approval, design, engineering and construction as well as setting out some design specifications and features of the ammonia plant.

The paper also highlights the environmental and native title management initiatives that were implemented during the design and construction of this plant to minimize the environmental and native title impacts on the Burrup Peninsula.

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PROJECT OVERVIEW

Burrup Fertilisers Pty Ltd (BFPL) has constructed and commissioned a 2200 metric tons per day ammonia plant in April 2006. It is the world's largest single-train KBR Purifier™ based ammonia plant. BFPL is a private company incorporated in Australia in July 2000 and promoted by Oswal Projects Limited, New Delhi, India. Financial closure for the project was achieved on 18th December 2002 with the inaugural shipment of liquid ammonia departing from the Port of Dampier in Western Australia in June 2006. This was a remarkable achievement given the scale of this private development coupled with the numerous regulatory approvals required.

Having incorporated a company in Australia and assembled a number of reputable consultants to provide services to BFPL, Company representatives first met with officials of the Department of Industry and Resources in October 2000 to express the company's interest in using a portion of Western Australia's vast natural gas supply to manufacture liquid ammonia, and then ship it to various world markets for use as feed stock in the growing fertiliser businesses on the subcontinent.

BFPL received strong Governmental support and were granted Major Project Facilitation Status by the Federal Government of Australia.

The speed at which the project advanced from this first meeting was extraordinary, given the extremely detailed and complex negotiations associated with native title and heritage issues, environmental and other statuary regulations, plus the equally demanding due diligence and bank-ability processes.

As a matter of history, when BFPL initiated discussions with government officials regarding construction of its world scale ammonia plant, five other major projects were in similar discussions; however only BFPL completed its project with no others yet to commence.

LOCATION

The new plant is located on the Burrup Peninsula in the Pilbara region of Western Australia. The site is in the King Bay – Hearson Cove industrial area, which is leased from the Western Australian Government. It is approximately 1,550 kilometers north-east of the state capital, Perth.

The Burrup Peninsula is characterized by large areas of steep, bare rock piles, a high rocky plateau, stony planes, mudflats, beaches and bays. The area is vegetated with woodland, shrubs and grasslands and is populated by birds and a range of wildlife.

As a result of the areas proximity to offshore oil and gas supplies and port facilities the Burrup Peninsula has developed as one of Australia's most significant industrial sites and port areas. Existing industries on the Burrup Peninsula include the North West Shelf Joint Venture LNG/LPG Facility, Rio Tinto's iron ore and salt production and export facilities.

The plant is serviced locally from the township of Karratha, 25 kilometers to the south-east. Karratha has a population of approximately 12,500 people and is geared towards servicing the resources industry.

BFPL's ammonia plant is the very first down stream gas processing facility to operate in the region and indeed has introduced Australia to the production of ammonia on a world scale.

FEED STOCK, PORT FACILITIES AND SHIPPING

Natural gas is supplied to BFPL by the participants in the Harriet Joint Venture, comprising subsidiaries of operator Apache Energy Limited (**Apache**), the Kuwait Foreign Petroleum Exploration Company (**KUFPEC**) and Tap Oil Limited (**Tap**). Apache's parent company, Apache Corporation, is one of the world's leading independent oil and gas companies. Gas is supplied by the Harriet Joint Venture from the Varanus Island production hub. The design composition is shown in Table 1.

	Volume Percent
Methane	80.49
Ethane	6.38
Propane +	4.63
Carbon Dioxide	5.00
Nitrogen	3.50
	100.0

Table 1: Design composition of natural gas feed.

Water – seawater for cooling purposes and desalinated for use in ammonia production – will be supplied by the Western Australian Governments' Water Corporation. The Water Corporation has constructed a new desalination plant adjacent to BFPL's ammonia plant.

Ammonia will be stored at the plant site in two 40,000 tons storage tanks until ready for loading at the Port of Dampiers' new Bulk Liquids Berth (BLB) facility. It will be transported to the Port via a 5.5 kilometer product pipeline and loaded directly onto ships using dedicated ship loading facilities established by BFPL on the new BLB.

Vessels capable of storing up to 40,000 tons of refrigerated liquid ammonia will be used to transport the ammonia to the world markets.

Yara, one of the world's largest traders and shipper of ammonia, will purchase 100% of ammonia produced at the plant. BFPL and Yara have agreed on the terms of an Off-take and Marketing Support Agreement. Subsequent to establishing that agreement Yara has taken out a portion of ownership in BFPL thus strengthening the relationship between the two parties.

PROJECT EXECUTION

Development of the project was managed by BFPL who was supported by a number of external technical, consulting and management service providers. A key feature of the execution strategy was to ensure that a safe, efficient and reliable plant was designed and constructed on the strength of proven technology enlisting the support of experienced contractors, suppliers and vendors.

As the major investor, Oswal/BFPL assumed full responsibility for the project. Comprehensive and effective management was achieved by adopting international good practices in contracting and construction management. Contracts for license, and basic engineering design packages relating to the ammonia plant were awarded to Kellogg Brown & Root, Inc. (KBR), now Kellogg Brown & Root, LLC. Training and start-up advisory services were provided by KBR. Emphasis was placed on working as a combined project team.

An Engineering, Procurement and Construction Management (EPC) contract was awarded to SNC-Lavalin (SNC) under a lump-sum-turn-key, fixed price arrangement. This arrangement involved ensuring overall compliance with the Construction Environmental Management Plan and other legislative requirements, and assisting in obtaining permits necessary for construction.

Worley Parsons provided independent engineering services, audits and consultancy services.

Construction of the new ammonia plant by BFPL acted as a catalyst for a host of other projects to go forward in the region. The State Government of Western Australia committed AUS$137million for the development of multi-user infrastructure to support new projects on the Burrup Peninsula. The Department of Industry and Resources (DoIR) played a role in facilitating the identification and development of the infrastructure. The infrastructure included a Water Corporation seawater supply and brine return facility, a natural gas supply pipeline to the new ammonia plant, multi-user service corridors by Landcorp connecting the King Bay-Hearson Cove development area to the Dampier Port area, upgrades to the Dampier Port Authority facilities including a new bulk liquids berth and utilities such as roads and telecommunications. Another significant project was the construction of a new desalination plant adjacent to the ammonia plant.

KBR on-site representatives and vendor representatives monitored the start up and commissioning.

Project Milestones

A summary of the project milestones is shown in Table 2.

First Meeting with Government Officials	October 2000
Works Approvals Granted	Q2 2002
Environmental & Heritage Clearances Received	Q3 2002
Engineering Commenced	Q4 2002
Financial Close	18 Dec. 2002
Planning Approval Received. Aboriginal Heritage Management Plan Approved	Q1 2003
Construction commenced on-site	Q2 2003
Major earthworks and site preparation completed. Concrete works commenced	Q3 2003
Desalination plant area handed over to Water Corporation. Major design review conducted	Q4 2003
Ammonia Tanks Erection Commenced & Structural Steel Erection Package Awarded	Q1 2004
Structural Mechanical Contractor mobilised	Q2 2004
Electrical Installation Commenced	Q3 2004
Roof raised into position on first ammonia storage tank & 41 large vessels erected over a six week period (heaviest was the ammonia synthesis converter at 780 tons)	Q4 2004
Emergency Diesel Generator commissioned	Q1 2005
Two boilers (150 tph and 50 tph) commissioned	Q2 2005
Other OSBL Components commissioned	Q3 2005
Pre-commissioning of ISBL components commenced	Q4 2005
Mechanical Completion	Q1 2006
First Ammonia Production	Q2 2006
Performance Test	Q2 2006
Inaugural Shipment	Q2 2006

Native Title, Environmental & Health and Safety Issues

The Burrup Peninsula and surrounding Dampier Archipelago in the Western Australia's Pilbara region have significant biodiversity values with many flora species. Many of the Peninsula's fauna are found throughout the Pilbara region and numerous archaeological surveys confirmed that Aboriginals have inhabited the Burrup Peninsula for over 7,000 years. In view of all this BFPL initiated the development of the following three plans:

- ***Aboriginal Heritage Management Plan:*** During the feasibility study phase of the project BFPL engaged consultants to undertake archaeological surveys and developed an Aboriginal Heritage Management Plan. BFPL, in consultation with the Native Title Groups, engaged a number of Aboriginal employees on site during earthworks to ensure that the project protected and preserved existing Aboriginal sites. Where disturbance could not be avoided the disturbance was undertaken in accordance with conditions pursuant to the Aboriginal Heritage Act.

- ***Construction Environmental Management Plan (CEMP):*** This CEMP was prepared to outline strategies that would be initiated in order to reduce any adverse environmental impacts that might occur and to ensure that environmental standards are achieved during construction. The CEMP addressed a number of specific environmental factors such as dust, noise and traffic management during construction.

- ***Health and Safety Management Plan:*** This plan was prepared to provide guidance in Health and Safety related matters to all parties associated with the project. This plan provided advice on safe work practices and safety procedures, safety inspections and audits, incident and accident management measures and information concerning occupational health.

The potential impact of the new plant in relation to emissions, flora and fauna, water pollution and waste was assessed and documented in a Public Environmental Review (PER). The PER was prepared by BFPL's Corporate Environmental Advisors, Sinclair Knight Merz (SKM) and concluded that:

- The impact of the plant development and operations in relation to flora and fauna, marine environment, noise, waste, public safety and aesthetics will be minimal.
- The plant will produce atmospheric emissions but these are well within "national environmental protection measures" at "best available techniques".
- BFPL was committed to formulating and implementing a comprehensive environmental management plan.
- During the PER public consultation period, BFPL did not receive any public submissions objecting to the project.

THE AMMONIA PLANT PROCESS

The ammonia process (refer figure 1) is based on the Purifier™ Process, a low energy natural gas reforming process offered and licensed by KBR. The ammonia plant design is based upon producing cold 2200 MTPD ammonia, which is exported to atmospheric ammonia storage at -33 °C.

All the components of the ammonia plant are based on well proven technology features. All process equipment is single train. All compressors are centrifugal compressors and each is driven by a steam turbine.

The desulfurized feed is mixed with medium pressure steam, and the mixture is preheated in the convection section of a top fired primary reformer. The preheated mixed feed is then distributed to tubes suspended in the radiant section. The tubes contain nickel reforming catalyst. The heat for the endothermic reforming reaction is provided by combustion of fuel gas and waste gas from Purifier. The burners are located between the rows of catalyst tubes and operate with downward firing. In this manner, the tubes are heated from both sides. Also, the heat flux is the highest at the top of the tubes, where the process temperature is the lowest. That results in a relatively even load on the tubes.

The outlet manifolds and the riser tubes are located inside the reformer furnace, for heat conservation.

The primary reformer uses the latest refractory and insulation technology. Ceramic fiber lining in the radiant section provides rapid thermal response due to low heat storage. Super duty hard refractory is used where flames may contact the sidewalls. This reformer design allows operation of the primary reformer with only two percent oxygen (on dry basis) at the exit of the radiant section.

The primary reformer is designed to obtain maximum thermal efficiency (93 % plus) by recovering heat from the flue gas in a convection section. The recovered heat is used for the following services:

- Mixed-feed (gas-steam) preheating
- Process air preheating
- Steam superheating
- Feed gas preheating
- Combustion air preheating

In the secondary reformer, the partially reformed gas from the primary reformer is reacted with air. In a traditional ammonia plant, the air flow rate is set to provide the amount of nitrogen required for the ammonia synthesis reaction. In a Purifier™ ammonia plant, up to 50 percent excess air is used. The oxygen in the air burns some of the process gas, to provide heat for the reforming reaction. The gas then flows downward through a bed of nickel reforming catalyst, where the temperature decreases due to the endothermic reforming reaction.

The excess air in the Purifier™ process provides heat for more reaction in the secondary reformer. This reduces the size of the primary reformer by about one third, and lowers the process outlet temperature (~725 °C) substantially, as compared to a traditional ammonia plant. The lower operating temperature results in a longer tube and catalyst life. The shift of reforming duty from the primary to the secondary reformer is advantageous, because the heat in the secondary reformer is recovered 100 percent in the process, with no stack loss.

The secondary reformer has a dual-layer refractory lining. An outside water jacket protects the shell against hot spots in the event of a refractory failure The effluent from the secondary reforming containing about 2.0% (dry basis) methane is cooled by generating and superheating high pressure steam prior to shift conversion.

Shift conversion uses the traditional two-stage high and low temperature reactors. Carbon dioxide is removed by a two stage proven processes licensed from by BASF. Process condensate is recovered, stripped with medium pressure steam in the Condensate Stripper, and recycled as process steam to the reforming section. The synthesis gas from the CO2 absorber overhead is heated in a feed/effluent exchanger and then passed over methanation catalyst to convert residual carbon oxides to methane.

In preparation for drying, the methanator effluent is cooled by heat exchange with methanator feed and cooling water. The methanator effluent, then combines with recycle synthesis loop purge gas and are further cooled with ammonia refrigerant to about 4°C. The chilled gas from the condensate separator drum goes to the syngas dryers. Two dryers are provided. They contain mol sieve desiccant and operate on a 24-hour cycle. Exiting these driers the total of water, CO_2 and NH_3 content is reduced to less than 1.0 ppmv. The regeneration of the molecular sieve dryers is done with the waste gas from the Purifier.

The cryogenic Purifier does the final purification of the raw synthesis gas. It consists of three pieces of equipment, a feed/effluent exchanger, a low speed expander and a rectifying column with an integral overhead condenser. The dried feed to the Purifier with H/N ratio of about 2.0 is first cooled in the top part of the feed/effluent exchanger by exchange with the purified gas and waste gas. It then flows through a turbo-expander where feed is expanded and energy is recovered to develop the net refrigeration required for the cryogenic unit. The expander effluent is further cooled and partially condensed in the bottom of the exchanger and then enters the rectifier column. All of the methane, about 60% of the argon and all the excess nitrogen coming to the Purifier are removed as rectifier "bottoms". Liquid from the bottom of the rectifier is partially evaporated at reduced pressure in the shell side of the rectifier overhead condenser to provide reflux for the column.

It is further reheated by exchange with Purifier feed gas and then leaves as a waste gas to regenerate the molecular sieve dryers. The waste gas is then used as fuel in the process heater. The synthesis gas containing about 0.25 percent argon and an H/N ratio of three is reheated by exchange with Purifier feed and then goes to the suction of the synthesis gas compressor.

The purified gas is compressed to about 150 bars while combining with unreacted recycle gas. Compressor discharge is heated by feed/effluent exchange, and enters the horizontal converter. In the converter ammonia conversion is raised from about two percent to nineteen percent while passing over three beds of magnetite catalyst. Converter effluent is cooled by generating high pressure steam, by feed/effluent exchange, with cooling water, and finally in KBR's proprietary "Unitized Chiller". A conventional refrigeration system provides the necessary chilling. A small purge stream is recycled to upstream of the dryers in order to recover the hydrogen and nitrogen. Cold ammonia product is exported from the synthesis loop to storage.

PROCESS DESIGN FEATURES

There were several unique features in the BFPL design, as discussed below.

- Integral gear process air compressor driven by a steam turbine – first large capacity Purifier™ ammonia plant, which has not used gas turbine
- Mild operating conditions for primary reforming
- About 42 percent excess air to the secondary reformer
- Non metallic mixing chamber – no metallic mixer/burner in the secondary reformer
- BASF's aMDEA two stage process for carbon dioxide removal
- KBR's cryogenic Purifier to remove inerts from the raw synthesis gas
- Three beds with two exchangers horizontal magnetite converter
- Unitized ammonia chiller

The ammonia plant for BFPL is the second KBR plant to combine features of both Kellogg and Braun technologies. The first plant was the CNOOC(1) ammonia plant, which was commissioned in September 2003. Compared to previous Purifier plant designs, the BFPL & CNOOC ammonia plants use KBR's proprietary high efficiency reformer furnace design with reforming at a pressure of 40 bars, about 10 bars higher than previously used. This raises the pressure in the Purifier column, which makes the separation easier. Thus the higher than normal methane slip from the reforming section was easily accommodated. The horizontal ammonia converter and unitized chiller reduce the synthesis loop pressure drop by about 3 bars when compared to previous Purifier loops. These factors help reduce energy consumption of the ammonia plant.

PLANT PERFORMANCE

The ammonia plant was started up in March 2006. Gas feed was on March 12 and first ammonia produced on April 11. The performance test for the ammonia plant was conducted in June of 2006 and all performance guarantees were met. Ammonia plant has been operating at more than 100% of the design capacity.

The ammonia plant energy consumption and quality achieved during the performance test is shown in Table 3. The values represent energy in terms of Gcal per metric ton of cold ammonia product on a lower heating value basis.

	Measured	Expected
Natural Gas Gcal/mt		
Feed	5.76	6.05
Fuel	1.59	1.43
Export steam	-0.61	-0.66
Electricity import	0.04	0.04
Total Gcal/mt	**6.78**	**6.86**
Ammonia Quality		
Water, wt%	0.04	0.1
Oil. ppmw	Not Detected	5 max

Table 3: A comparison of ammonia plant energy consumption as measured during performance test and as expected from the process flow diagrams

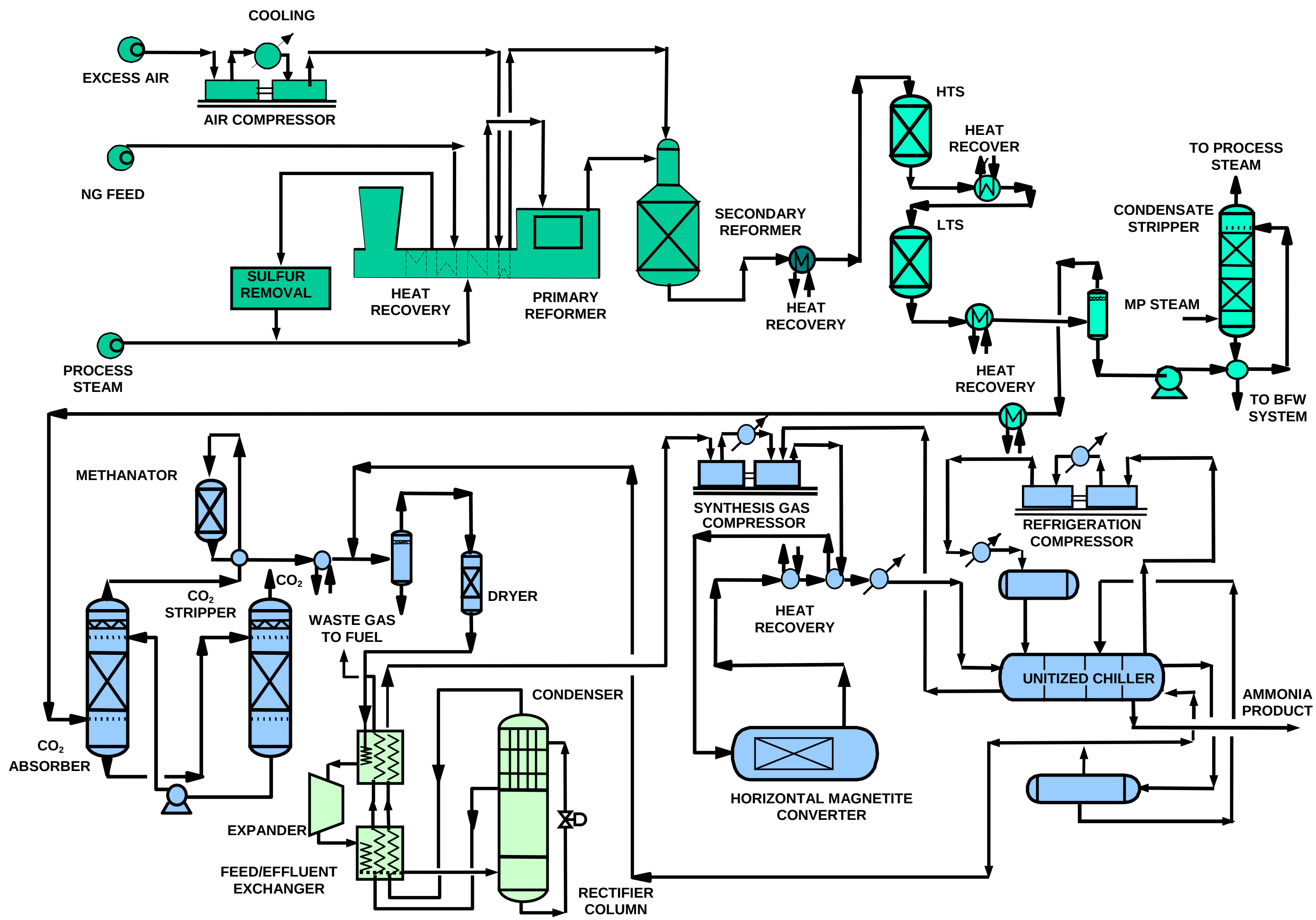
The "measured" values were calculated from the performance test. The "expected" values are from the design issue of the process flow diagrams.

SUMMARY

The new ammonia plant is a major accomplishment for BFPL. A private company has successfully introduced world scale ammonia technology to Australia and done so in an extraordinarily short space of time –given the extremely detailed and complex negotiation associated with a plant of its size and nature. BFPL has succeeded where many other, larger publicly listed organizations have not. The plants' successful completion represents the first downstream gas processing facility in Western Australia. Indeed the Major Project Facilitation Status afforded to the project by the Federal Government of Australia coupled with the level of Western Australian Government investment in infrastructure demonstrates the strong support that BFPL received from both Governments.

The ammonia plant also represents a significant accomplishment for KBR in the provision of its leading edge technology. It is the second KBR Purifier™ based ammonia plant to come-on stream which includes features from both Kellogg and Braun Technologies – the result being a new KBR Purifier™ Process that is now a proven technology for one of the largest capacity single stream ammonia plant. The combination of features from the two former companies has further reduced the energy consumption of the Purifier™ Process.

(1) Yang Yexin & Gosnell, J. H. "CNOOC Chemicals Ltd. New Fertilizer Plant", AIChE Safety in Ammonia Plants & Related Facilities Symposium 2004, Denver, Colorado, USA, September 2004.



KBR Purifier™ Ammonia Process

Figure 1

Figure 2 Overview of BFPL Complex

Figure 3 Ammonia Plant