CNOOC CHEMICAL LTD. NEW FERTILIZER PLANT

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ABSTRACT

In September 2003 CNOOC Chemical Ltd. commissioned a new Ammonia/Urea facility located in Hainan Province, PR of China. The facility began production of ammonia and urea less than three weeks after introduction of natural gas, and thirty months after the contract signing--significant accomplishments for projects of this type. The new ammonia plant is the first to combine the merged technologies of two of KBR's predecessor companies--the M. W. Kellogg Company and the C F Braun & Co.

The paper presents an overview of the project, describes the features of the new ammonia plant flowsheet, discusses the commissioning and start-up, and provides the results of the performance test. This KBR ammonia plant is believed to be one of the lowest energy plants in the world despite using a feedstock that contains less than 65 percent hydrocarbon.

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BACKGROUND TO THE PROJECT

CNOOC Chemical Ltd.'s new fertilizer plant, with a capacity of 1500 ton/day tons of ammonia and 2700 t/d of urea, is the largest single-train fertilizer plant in China. Although the plant came on-line in 2003, the history of this project starts twenty years earlier. After the discovery of natural gas in the South China Sea in 1983, CNOOC made a new discovery of abundant natural gas resources in the southwest waters of Hainan Island. The proven reserves of this "Oriental 1-1" Gas Field are as much as 100 billion cubic meters. Other significant gas fields have been discovered nearby, so CNOOC has great expectations for this area.

In order to use the natural gas resource in an economically rational way, CNOOC entrusted Chengda Engineering Corporation of China (CECC) in May 1995 to carry out feasibility studies to evaluate building a fertilizer plant and to provide technical support in the planning of the project. The feasibility studies were completed in March 1997, revised in June 1998, and eventually approved by the State Development and Planning Committee in October 1998.

Major considerations in this period included the integration of upstream and downstream industries, market survey, location, scale, technologies adopted, and most of all, the commercial value of this project. CNOOC would veto any project with unsatisfactory economic benefits, so CECC integrated investment and profit assessment into the studies. By optimizing the project, they succeeded in improving the technical and economic viability of the project.

Location

Three locations were investigated, but the final decision went in favor of the Oriental Industrial Development Zone in Hainan Province. Its advantages include reliable power and water supply, convenient transportation and Basuo Port, which has an annual capacity of 4.5 million tons and can hold 10,000-ton cargo vessels.

In October 2000, CNOOC acquired the Fudao Chemical Factory, a fertilizer plant with an annual capacity of 300,000 tons of ammonia and 520,000 tons of urea. This acquisition enabled the new project to share office blocks and maintenance service with the existing factory and gain access to technical assistance. This sharing helped to reduce capital cost, improve project and operational management, and thus create a competitive edge.

Oriental 1-1 Natural Gas

Oriental 1-1 Natural gas is an unusual feedstock. It has a low calorific value and high N_2 and CO_2 content. The composition is shown in Table 1.

	Volume Percent
Methane	60.7
Ethane	1.2
Propane +	0.6
Carbon Dioxide	20.7
Nitrogen	16.8
	100.0

Table 1: Design composition of natural gas feed.

Although nitrogen is a raw material for producing ammonia, too much nitrogen in the natural gas would transfer reforming load from the secondary reformer to the primary reformer. Then the primary reformer must operate under much more severe process conditions. Also, although carbon dioxide is the raw material for producing urea, too much carbon dioxide in the natural gas feed would require some equipment to be larger. The extra carbon dioxide also adversely affects the reforming section of the ammonia plant. The selected ammonia technology must be applicable to this particular kind of natural gas. For this reason KBR offered its Purifier Process to CNOOC. As discussed in the next section, Purifier Technology is a unique solution to the problems posed by this feedstock.

PROCESS CONSIDERATIONS FOR AMMONIA PLANT

The composition of the natural gas posed two design considerations for the ammonia plant. The first decision that needed to be made was whether to remove the carbon dioxide prior to reforming the feed. The second decision was how to handle the high nitrogen content of the feed. These issues are discussed in some detail in a previous paper.[(1)] A summary is provided below.

Carbon Dioxide Issue

To determine the answer to the carbon dioxide issue, two cases were studied. A block flow of the two cases is shown in Figure 1

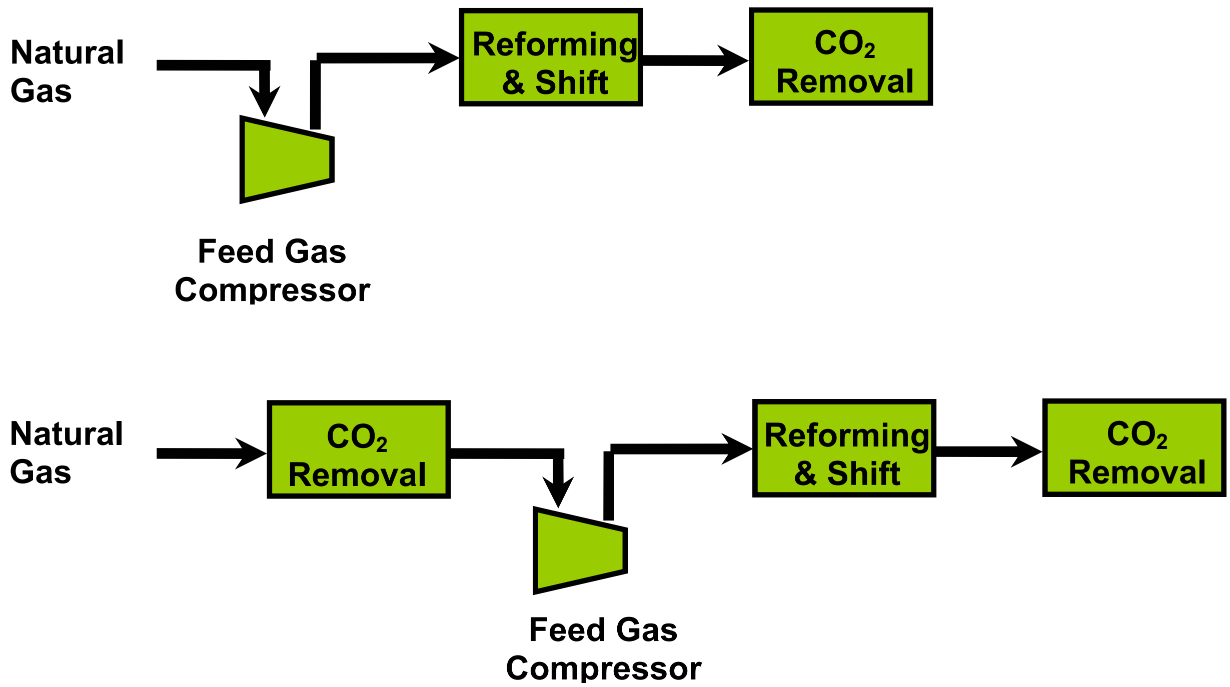

Figure 1: Block flow diagrams of the two cases studied to determine whether to remove carbon dioxide from the feed prior to reforming

The Base Case, shown in the top of Figure 1, feeds the high carbon dioxide content natural gas to the reformer. The bottom scheme removes the carbon dioxide before compressing the feed to the process. The result of KBR's study shows that the Base Case scheme was clearly the better design from economic, operating, and maintenance perspectives. The Base Case design does tend to increase the severity of the reforming operation, as shown in Figure 2. However, with the Purifier Process the tendency towards higher severity can be compensated for by allowing the methane slip to rise. So KBR offered, and CNOOC accepted, a design without pre-removal of carbon dioxide from the natural gas feed.

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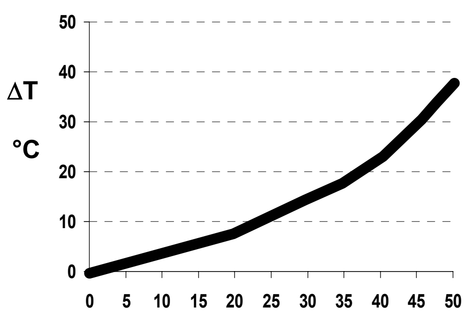

Figure 2: Change in primary reformer outlet temperature as a function of the amount of carbon dioxide in the natural gas feed, at constant methane slip.

Nitrogen Issue

The second feedstock issue was how to handle the high nitrogen content in the natural gas feed. With almost 17 percent nitrogen in the natural gas, about 28 percent of the nitrogen required to make ammonia is supplied with the feed. This would normally require the process air requirement to be reduced significantly, which transfers reforming duty to the primary reformer. Figure 3 shows the relationship between nitrogen in the feed and required primary reformer outlet temperature.

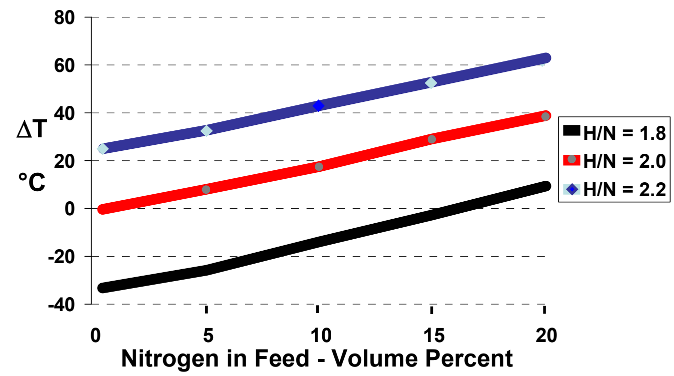

Figure 3: Change in primary reformer outlet temperature required to maintain methane slip, as a function of nitrogen in feed and hydrogen to nitrogen ratio to Purifier.

As Figure 3 shows, the CNOOC feed with about 17 percent nitrogen requires that the primary reformer outlet temperature must be raised by about 35 °C in order to maintain a constant methane slip at the same hydrogen to nitrogen ratio. The typical Purifier Process design uses a hydrogen to nitrogen ratio of 2.0 at the inlet of the Purifier. For the CNOOC design we increased the amount of excess process air to the secondary reformer, despite the high nitrogen content of the feed gas. The hydrogen to nitrogen ratio to the Purifier in the final CNOOC design is about 1.8. As can be seen from Figure 3, this lower ratio keeps the primary reformer temperature approximately the same as it would have been with a ratio of 2.0 and no nitrogen in the feed. The plant is also designed for a methane slip greater than 2.0 percent from the secondary reformer, which is higher than normal. These process design options are not available with other ammonia technologies.

PROJECT EXECUTION

As the major investor, CNOOC Chemicals 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, engineering, procurement, and construction advisory services for the ammonia and urea plants were let to Kellogg Brown & Root, Inc. (KBR). KBR provided the urea plant design through subcontracts with Stamicarbon for the urea melt plant and Yara Fertilizer Technology for the urea granulation plant. Detailed engineering was provided by a KBR sub-contract to CECC. Training and start-up advisory services were provided by KBR. CNOOC provided construction with construction advisory services from KBR. Emphasis was placed on working as a combined project team.

Schedule

From the project kickoff meeting in March 2001 to the successful start-up in September 2003, took 30 months--two months less than stipulated in the contracts and six months less than the usual schedule for such a project in China. This reduction in schedule was due to efficient use of local advantages, which include direct maritime transportation of heavy and large equipment from home and abroad to Basuo Port, and the mild climate which allows year-round construction. A summary of the project milestones is shown in Table 2.

Project Kickoff	March 2001
Mechanical Completion	Sept 5, 2003
Feed gas to Plant	Sept 10, 2003
First Ammonia Production	Sept 28, 2003
First Urea Production	Sept 30, 2003
Performance Test	March/April 2004

Table 2: Overall schedule for CNOOC's fertilizer project.

The performance test was delayed until Spring 2004 primarily due to the unavailability of sufficient quantity of natural gas.

Quality Control

Following commissioning and start-up, the new facility successfully produced high quality ammonia and granular urea only 18 days after introducing the natural gas feed, which is proof of the high quality of the project. This rapid start-up is a tribute to the quality of the engineering design, construction, and pre-commissioning by all parties involved. Considerable attention was paid to the specification, procurement, and inspection of critical equipment.

Several experienced and recognized companies were chosen by CNOOC to carry out the construction and installation of the facility. The project team established a quality control system and brought in supervision companies to ensure quality control throughout the whole process. The construction companies were required to strictly inspect and report the quality of their work. In addition, CNOOC's project team, supervisory company, KBR on-site representatives and vendor representatives monitored and inspected the quality of the construction.

Health, Safety, & Environmental

Because the construction site was always busy, CNOOC's project team attached great importance to the safety and social impacts of the construction and operation. As a result there were no serious accidents that caused labor injury or equipment damage.

CNOOC was determined to build a first-class fertilizer facility that is environment-friendly and beautiful. So they paid great attention to environment protection. The site was landscaped and CNOOC planted many trees around the perimeter of the complex.

CAPITAL COST

CNOOC believes that the best approach to lower capital cost comes from improving the design. So the design was optimized throughout the whole project, from feasibility studies and basic design to detailed project engineering. As the design was optimized and firmed up, the capital cost estimate evolved as shown in Table 3.

	Percentage
Feasibility Study	98%
Project Budget	100%
Actual Cost	89%

Table 3: Evolution of capital cost estimate during project.

Procurement was from a variety of countries. KBR was responsible for the procurement of about two-thirds of the equipment and major materials. CNOOC arranged for procurement of the balance of the major equipment and material, the civil works, and construction of the entire facility. Of the 334 pieces of equipment in the fertilizer plant, 107 were manufactured in China. This contributed to capital cost saving.

Several other measures were taken to keep the capital cost down. Examples are competitive bidding for supply of materials from inside China. Also, as much as possible, the existing infrastructure of the Fudao fertilizer facility was used. By taking these measures, the final expenditure was eleven percent less than the budget. The total capital expenditure of this project is about eight percent less than that of the adjacent Fudao Chemicals Factory, even though the production capacity of the new facility is 1.5 times larger than that of Fudao.

PROCESS DESIGN OVERVIEW

The CNOOC fertilizer plant uses the KBR Purifier Process for ammonia production, Stamicarbon's urea melt process, and Yara's fluid bed granulation process for product finishing. There were several unique features in the CNOOC design, as discussed below.

Features of KBR's Technology for Ammonia Production

The technical features of KBR's Purifier Process include:

- Process air compressor driven by a Frame 5 gas turbine
- Mild operating conditions for primary reforming
- About 55 percent excess air to the secondary reformer
- BASF's aMDEA process for carbon dioxide removal
- KBR's cryogenic Purifier to remove inerts from the raw synthesis gas
- Horizontal, magnetite converter
- Unitized ammonia chiller

The ammonia plant for CNOOC is the first KBR plant to combine features of both Kellogg and Braun technologies. Compared to previous Purifier plant designs, the CNOOC ammonia plant uses KBR's proprietary 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 converter and unitized chiller reduce the synloop pressure drop by about 3 bars when compared to previous Purifier loops. These factors help reduce energy consumption of the ammonia plant.

Features of Stamicarbon's & YFT's Technology for Urea Production

Stamicarbon's proprietary CO_2 stripping process was adopted in the urea unit. Its features include:

- A reactor to remove traces of hydrogen from the CO_2 feed
- A pool condenser to improve the conversion ratio of CO_2 and NH_3 and promote heat recovery

The fluid bed urea granulation process of Yara Fertilizer Technology has been adopted in many urea plants around the world. It is commercially proven and technically reliable. The 96% urea solution is used as raw material for this process. The granular urea is a low biuret product with a nominal particle size of 2-4 mm. The process is also designed to make 4-8 mm size urea granules.

PLANT PERFORMANCE

The fertilizer plant was started up in September 2003. The performance tests for the ammonia and urea plants were run in March/April of 2004. All performance guarantees were met for both plants.

The ammonia plant energy consumption is shown in Table 4. The values represent energy in terms of Gcal per metric ton of ammonia on a lower heating value basis. The ammonia plant was producing all warm product for the urea plant during the test run.

	Measured	Expected
Natural Gas		
Feed	6.25	6.32
Fuel	1.93	1.91
Export steam	-1.72	-1.75
Electricity	0.03	0.03
Total GCal/mt	6.49	6.51

Table 4: 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 fertilizer plant is a major accomplishment and successful project for CNOOC. The project was completed ahead of schedule and under budget. It is the largest fertilizer plant in China. The start-up took less than a month.

The ammonia plant represents a significant accomplishment for KBR. It is the first plant to come on-stream which includes features from both Kellogg and Braun technologies. The result is a new KBR Purifier Process that is now a proven technology. The combination of features from the two former companies has further reduced the energy consumption of the Purifier Process.

(1) Gosnell, J. H. & Miao, T: "Feedstock Composition Consideration in the Design of Ammonia Plants," Nitrogen 98 Conference, CNOOC Chemicals Co. Ltd., Kuala Lumpur, Malaysia. February 1998.