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BLUE PRINT OF CNOOC ORIENTAL CHEMICAL PARK: CONSTRUCTION OF CNOOC FERTILIZERS COMPLEX

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On September 30, 2003 a state-of-art fertilizer facility started up to produce high quality granular urea in the Oriental Industrial Development Zone of Hainan Province. This beautiful and environment-friendly ammonia/urea complex would produce 450,000 tons of ammonia and 800,000 tons of urea per year at very low energy consumption and is a milestone project for CNOOC's efforts to integrate the upstream and downstream industries. CNOOC Chemicals Co. Ltd assumed full responsibility of the overall project management; a US company, Kellogg Brown & Root, was the contractor of ammonia and urea production installations; and Chengda Engineering Corporation of China was responsible for the overall designing of the complex and its public utilities and subsidiary facilities together with the detailed engineering design of the production installations.

1. FEATURES OF THE PROJECT

- **A paradigm of CNOOC' s notion for facility building:** to integrate gas field exploitation and fertilizer production; to enlarge the production capacity; and to build an environment-friendly and technically advanced fertilizer plant by learning from international good practice and adopting modern methods in project and operational management.
- **A best practice in project management:** This project is an optimal combination of low expenditure on infrastructures, short construction period and successful start-up.
- **A project with distinct Chinese characteristics:** This project is a combination of China's experience in building bulk fertilizer plants and international practice in project contracting and management. The plant owner assumed full responsibility of the project. A team was formed to take charge of the natural gas fertilizer project; an outline for project management was drawn up in accordance with the requirements of "Three Major Controls" (process control, cost control and quality controls); and construction supervision was adopted to ensure effective management of the project.

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2. PLANNING AND ASSESSMENT

This project, with an annual capacity of 450,000 tons of ammonia and 800,000 tons of urea, ranks first in single-train fertilizer plants in China. However, its decision-making involved a great many unusual procedures.

2.1 Background

After the discovery of natural gas reserve in Yingge Haiya 13-1 in June 1983, CNOOC made a new discovery of abundant natural gas resources in the southwest waters of Hainan Island. The proven reserves of the Oriental 1-1 Gas Field are as much as 99.68 billion cubic meters, and that of Ledong 15-1 and 22-1 gas field reaching 61 billion cubic meters, with yet more gas fields have been discovered nearby. So CNOOC has great expectations for this area.

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

2.2 Planning and Assessment

Major considerations in this period included: 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 Chengda Engineering Corporation integrated investment and profit assessment into the whole process of its work. By making use of the advantages and transforming the disadvantages, they succeeded in improving the technical and economic viability of the project.

- **The notion of integrating the upstream and downstream industries:**

This new fertilizer complex is CNOOC' s springboard to tap into the downstream business. With CNOOC as its major investor, this plant has guaranteed financing resource and natural gas supply, which could ensure the project to start up on schedule as well as increase its operational rate and annual output. Also, the plant may reduce its energy consumption by utilizing the pressure of more than 30kg/c□created in natural gas pipelines. And the sound

development of downstream business will also drive the exploitation of oil and natural gas resources.

- **Market Survey**

During 1997 and 1998, China's fertilizer industry was undergoing a market downturn and expecting cutthroat competition from international manufacturers after China's entry into WTO. However, after surveys and analysis of the domestic and international fertilizer markets, this project was considered to have strong competence in dealing

with risks and uncertainties. Although China's production capacity of fertilizers ranks first in the world, half of the output came from small-and-medium-sized factories. Moreover, one third of the 30 bulk-fertilizer-plants with an annual capacity of more than 0.3million tons of ammonia use oil or coal as raw material. However, CNOOC's project can produce 450,000 tons of ammonia and 800,000 tons of urea per year and its feedstock will be natural gas instead of coal or oil. So it has a competitive edge in terms of raw material, cost and economy of scale, which enables its products to compete with imported fertilizers after China's entry into WTO.

- **Scale**

Since Hainan Island has an advantage in maritime transportation, the production capacity of single production unit was enlarged to achieve an economic scale return. It is predicted that the investment ratio of a production unit with a capacity of 1500 tons ammonia and 2700 tons urea and one with a capacity of 1000 tons ammonia and 1765 tons urea is 1.30-1.34: 1.0. So enlarging the scale would not only reduce the capital expenditure but also reduce energy consumption and operational cost.

- **Location**

3 locations were listed and 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 4.5million tons and could hold 10000-ton cargo vessels. In October 2000, CNOOC made a successful acquisition of the Fudao Chemical Factory, a fertilizer plant with annual capacity of 300,000 tons of ammonia and 520,000 tons of urea. So this project may share existing offices blocks and maintenance service with the acquired factory and gain access to technical assistance. All these helped to reduce capital cost and improve project and operational management and thus created a competitive edge.

- **Technologies applied to utilize Oriental 1-1 natural gas**

Oriental 1-1 natural gas is an unusual kind of natural gas with low calorific value and high N_2 and CO_2 content. It comprises 17.11% of N_2 and 20.2% of CO_2. Although N_2 is the raw material for producing ammonia, too much N_2 in natural gas would transfer reaction load of the secondary reformer to the primary reformer. Then the primary reformer must operate in very tough conditions. Also, CO_2 is the raw material for producing urea, but too much CO_2 would require enlargement of some equipment and affect the thermal balance of the installation. The selected technology must be applicable to this particular kind of natural gas.

CNOOC paid two visits abroad to examine advanced and energy-efficient ammonia synthesis technologies and to inspect fertilizer plants designed with these technologies.

> All the patent providers affirmed that their technologies could deal with natural gas with high N_2 content. However, there are two diverse opinions on the

treatment of CO_2, which accounts for 20.2% of the natural gas. One is to add one unit to dispose CO_2 before feeding the natural gas into the installation. The other is to feed the natural gas directly into the installation without disposing the CO_2. The first approach would save compressing power and reduce the size and cost of the equipment for transforming procedures. However, the additional unit would demand more capital, operational and maintenance cost. What's more, the sulfides contained in disposed CO_2, would make it difficult to reuse the CO_2 and may consume effective components of natural gas. So all of the patent providers eliminated the additional unit from their final quotations.

The report of feasibility studies and its revised version has gone through the examination of CNOOC, the evaluation of the expert panel organized by China International Engineering Consultation Corporation and eventually approved by state authorities. Then CNOOC eventually decided to build this facility. It negotiated and signed all the technical and commercial contracts during October 2000 to January 2001.

3. PROJECT EXECUTION AND ITS MAJOR EXPERIENCES

As the major investor, CNOOC Chemicals assumed full responsibility of the project. They achieved comprehensive and effective management by adopting international good practice in contracting and construction management.

3.1 Control of Capital Cost

- The project team believes that the best approach to lower capital cost comes from optimal designing. So the design was optimized throughout the whole process, from feasibility studies and basic design to detailed project engineering.

For example:

	Feasibility Report	Budget of Basic Design	Reduced Cost
Total Investment	2,593,280,000RMB	2,660,768,000 RMB	292,512,000RMB

1 USD= 8.28 RMB

The design featured less spot place, open-tube configuration, light structure, efficient use of public utilities and domestic procurement of equipment and construction materials. By adopting good practice of the past, the design was optimized to reduce the capital expenditure while ensuring the domestically produced equipment for infrastructure and subsidiary facilities could meet the requirements and integrate with imported equipment and technologies.

Domestic procurement in this project involved procurement of detailed engineering for production installations from Chengda and construction of all public utilities and subsidiary facilities. 107 of the 334 devices in the production installations as well as appliances, instrument, cable and some other materials were made-in-China products. This contributed a lot to capital cost saving.

- **Other Measures Taken to Reduce Capital Cost**

A) The project team invited international public bidding in bringing in production installations. It broke old conventions and contracted two installations to one well-recognized foreign engineering company. In this way, they obtained a much lower quotation of the contracts.

B) The project team brought in competition to its domestic procurement of equipment and engineering, supervision and construction services.

C) The equipment and services needed for this project were sorted into different categories according to the basic design and purchased strictly within the budget. Meanwhile, major construction materials such as steel, cement and wood were collectively purchased.

D) Management expenses of the project was strictly controlled by making full use of the existing infrastructure of Fudao Chemicals Factory and building as few temporary facilities as possible.

E) Thorough preparation helped to reduce the starting up cost.

By taking these measures, the final expenditure is predicted to be 0.3billion RMB less than the budget. The RMB 2.3 billion total capital expenditure of this project is about 190 million less than that of Fudao Chemicals Factory, even though the production capacity of the new facility is 1.5 times larger than that of Fudao.

3.2 Process Control

From March 1, 2001 when the contracts was valided to the successful start-up on September 30,2003, it took merely 30 months to finish the construction of the project, 2 months less than stipulated in the contracts and 6 months less than the usual construction period of such a project. This is 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 of the project.

Following measures were adopted in project management:

A) Drawing up the schedule: the project team has drawn up overall as well as yearly and quarterly schedules for the project. And they checked every week whether the work was finished on schedule.

B) Coordinating the proceeding of designing: according to the schedule the designing of the project should be carried out from the underground part to aboveground part, from public utilities and subsidiary facilities to production installations. In order to meet the construction schedule, the engineering task engaged in more personnel and involved multi-phase designs. Generally, the design for preparation of equipment manufacturing or construction came out first. Then the formal design for manufacturing and construction would be published in accordance with construction schedule. The designing team also provided technical assistance for on-site construction and dealt with

technical problems occurred in construction and commissioning. And they were very supportive in assuring on-schedule proceeding of the project.

C) Attaching great importance to equipment procurement: representatives were sent to inspect the equipment manufacturers. And special attention was paid to receiving, insuring and checking of the imported equipment.

D) Another two measures were adopted to control the proceeding of the project. One is to apply light steel structures to major structures such as the main framework of the urea installations, the compressor plant and the storehouse of bulk urea. The light steel structures were prefabricated in manufacturing workshops and assembled on construction site. This saved the time of construction and installation (compared with constructing with steel and concrete). The other measure is to enhance automatization. For example, 1200-ton cranes were rented and used in installing the 50 extremely heavy or large devices and high-rise equipment on the main framework of the urea production installations. This was an unprecedented practice in building bulk fertilizer plant in China and helped speed up installation.

E) The project team divided the whole project into separate small projects and put them into different categories. Then public biddings were held for construction services of these projects. And all contractors for constructing and installation carried out their work on schedule by effectively organizing their personnel and equipment.

F) The project team combined the installation and construction with test operations of the pipelines, production units and the facility as a whole so that the commissioning period was shortened.

The facility started up 2 months ahead of schedule and a comprehensive profit of RMB 120 million was created during commissioning. This also helped to reduce the total capital expenditure.

3.3 Quality Control

During commissioning, the new facility successfully produced high quality ammonia and granular urea merely 18 days after introducing the input chemicals, which is a proof of the high quality of the project.

A) Quality Control of the Design:

High quality project is based on optimal design. So Chengda Engineering Corporation strengthened the examination and review in every process to ensure that its design is complying with the requirements of ISO 9000 system, the standards stipulated in the contracts and the requirements of patent providers. Besides, Chengda adopted the following measures to ensure the high quality of its design: First, they applied PDS model and carried out several collision tests to ensure the accuracy of relevant information about the pipelines. This proved to be a successful approach since there were neither major modification to the main pipelines nor shortage and unfavorable storage of the pipeline materials during on-site construction. Second, thorough understanding of manufacturers' information is the premise for correct design. So Chengda stressed communications of equipment manufacturing and on-site construction engineering. It also attached great importance to providing pre-work

technical assistance by clarifying the purpose of the design, issues that should be paid attention to and techniques applied in manufacturing or construction.

For example, the engineering of urea granulation devices was recognized by experts from the patent provider Hydro as a world-class design of urea granulation devices.

B) Quality Control of the Equipment

The project team entrusted a third party to examine the quality of the domestically procured equipment. It also organized its own personnel to inspect the major foreign factories where imported equipment was manufactured.

C) Quality Control of the Construction and Installation

Through public bidding several experienced and recognized companies were chosen to carry out the construction and installation of the production installations. The project team established a quality control system and brought in supervision companies to carry out quality control throughout the whole process. The construction and installation companies were required to examine the quality of their work by themselves. Besides, the project team also organized experts from supervisory and designing companies and on-site representatives of foreign engineering companies to inspect the quality of the construction.

The experts and relevant personnel were organized to make a comprehensive risk assessment before the commissioning, and to provide countermeasures of risk management. This was aimed at ensuring the success of the test operation

D) Performance Examination of the Facility

To achieve high profitability of an established operation, we must ensure that its production facility is able to operate continuously at its full capacity with low energy consumption. Although the commissioning went smoothly, performance examination should only be carried out after a period of careful operations, adjustments and modifications

E) Safe Construction and Operation

The project team attached great importance to the safety and social impacts of the construction and operation. There were no serious accidents that caused labor injury or equipment damages. The construction site was always busy and orderly.

F) Environment Protection

The project team was determined to build a first-class fertilizer facility that is environment-friendly and beautiful. So they paid great attention to environment protection and planted many trees around the factories

4. EVALUATIONS OF THE TECHNOLOGIES APPLIED

KBS, a world-famous American engineering company, was the engineering contractor of the production installations for ammonia and urea. It is also the patent provider of the technology for ammonia production. The urea production technology came from Stamicarbon of the Netherlands; and the urea granulation technique came from Hydro Fertilizer Technology.

4.1 Basic Requirements for the technologies applied

This project is an ammonia/urea complex with daily capacity of 1500 tons of ammonia and 2700 tons of urea. The technologies applied must be commercially proven, reliable and energy-efficient.

The basic requirements include:

- The process should be advanced, reliable and commercially proven. Meanwhile its energy consumption must be less than 6.8 Gcal/mt.
- The ammonia synthesis technology must be applicable to coping with natural gas with high CO_2 and N_2 content.
- Equipment and instruments must be of high quality so that the plant can achieve continuously stable operation at full capacity. The onstream factor must be no less than 91.5%, which means an uninterrupted production run of 8,000 hours per year.
- The technology should offer improved automatization, reduced operator demand and easier maintenance. Meanwhile it should ensure easy sasy startup and shutdown as well as maximum flexibility over a wide range of operating conditions.
- The process should meet all requirements of safety, fire control, and environment protection and reduce contaminants and emissions
- The technology should ensure lower capital cost and shorter construction period.

4.2 Features of KBR' s technology for ammonia production

MW. Kellogg merged with Braun & Root and formed KBR in 1999. At first, Kellogg recommended its KAAP process, that uses a ruthenium-based catalyst, which exhibits an activity of up to 20 times that of the conventional magnetite catalyst, to deal with the high N_2 content in the natural gas.

However, this process did not adapt to the current conditions in China. So we suggested KBR to combine its process so that the combined process could deal with high content natural gas at low energy consumption. KBR took our advice in its final proposal. And this complex became the first adopter of this combined technology.

The technical features of this process include:

- Unique air compressor
- Mild operating conditions for primary reforming. Feeding excess air into secondary reformer
- A cryogenic purifier to remove inerts from the raw synthesis gas
- Energy-efficient □□□□□□□
- Combined ammonia condenser
- KBR's proprietary technologies such as primary reformer, secondary reformer and thermal exchanger
- MDEA decarbonization technology of BASF
- Low energy consumption of 6.673Gcal/MT, 1-2 Gcal/MT less than other domestic fertilizer plants of its kind.

4.3 Features of the technology for urea production

4.3.1 Stamicarbon's proprietary technology of CO_2 evaporating stripping process was adopted in the urea unit. And its features include:

Low energy consumption: Pool condenser was adopted to improve the conversion ratio of CO_2 and NH_3 and promote heat recovery

Simplified processing: no Middle Pressure system in the installation

Enhance Safety: H_2 stripping system was used

High on-stream factor, mild operational condition, optimal selection of materials and low corrosion rate

With the daily capacity of 2,700 metric tons of urea, this facility is one of the largest urea plants in the world.

4.3.2 The fluid bed urea granulation process of Hydro Fertilizer Technology has been adopted in more than 30 urea plants around the world. It is commercially proven and technically reliable. The 96% urea solution is used as raw material for this process, which can reduce the consumption of steam and cooling water as well as the □□□ contained in granular urea and improve the quality of the product.

All of the technical features have been demonstrated in the operation, which proved that the design (including detailed project engineering) and the selection of technologies were successful, even though some parts of the process still need to be further modified.

5. GRAND BLUE PRINT OF CNOOC ORIENTAL CHEMICAL PARK

Now the new fertilizer facility started up with an annual capacity of 450,000 tons of ammonia and 800,000 tons of urea. And the newly acquired Shangyuan Fudao Chemical Factory already has an annual capacity of 300,000 tons of ammonia and 520,000 tons of urea. So CNOOC Chemicals Co. Ltd will attain an annual capacity of 1.32 million tons urea and become the top fertilizer manufacturer in China.

It is predicted that the new fertilizer facility will make an annual profit of RMB 311 to 400 million. CNOOC Chemicals Co. Ltd is also planning to build a methyl alcohol facility with an annual capacity of 0.6 million tons, which demonstrates the great growth momentum of CNOOC Oriental Chemical Park. Along with the further development of natural gas fields and natural-gas-consuming chemical projects, the visionary blue print of CNOOC Oriental Chemical Park is becoming a reality. We look forward to a sound development of CNOOC's chemical business.