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THE PRESENT SITUATION OF CHEMICAL FERTILIZER INDUSTRY IN CHINA AND ITS FUTURE

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Abstract

This article outlines the great development of the chemical fertilizer industry in China during the past 35 years since the founding of the People's Republic of China, the present fertilizer structures and features. It also points out that emphasis must be given to three main areas, namely, adjustment of the ratio among N,P,K fertilizers, technical rehabilitation with the focus on energy conservation, and raising the application effectiveness of chemical fertilizers. Finally, the article puts forward some tentative suggestions for the future development of the chemical fertilizer industry in China.

China is a developing socialist country. By relying mainly on its own resources, technique and equipment, and positively importing advanced technology from abroad, and conducting technical exchanges with foreign countries, a chemical fertilizer industrial system has been gradually established over the past 35 years since the founding of the People's Republic of China.

At present, our country has 1987 chemical fertilizer plants, ranging from large, medium and small sizes. Among them, there are 1272 nitrogen fertilizer plants and 697 phosphate fertilizer plants. The total annual output of chemical fertilizers and that of nitrogen, phosphate, potash fertilizers, based on N, P_2O_5 and K_2O respectively, from 1949 to 1983 are shown in the table below.

Annual output of chemical fertilizers
(Thousand metric tons)

Year	1949	1953	1969	1979	1982	1983
Total	6.0	266.0	1749.0	10653.4	12781.0	13789.0
N	6.0	164.0	1023.0	8820.5	10219.0	11094.0
P_2O_5	--	90.0	723.0	1817.2	2537.0	2666.0
K_2O	--	12.0	3.0	15.7	25.0	29.0

From 1949 to 1983, the output of chemical fertilizer in China increased in average at an annual growth rate of 25.8%. Based on the products manufactured in China, chemical fertilizer applied in arable land was increased from 0.0038 Kg per Mu (0.057 Kg/hectare) in 1949 to 9.19 Kg per Mu (137.85 Kg/hectare) in 1983. Especially, since 1978, the output of both chemical fertilizer and grain products have increased vigorously and simultaneously. (See the table below).

		1978	1979	1980	1981	1982	1983
Grain	billion Jin	609.53	664.23	641.11	650.04	706.86	774.56
products	growth rate %	100	108.9	105.1	106.6	115.9	127.0
Chemical	million tons	8.693	10.654	12.320	12.390	12.780	13.789
fertilizer	growth rate %	100	122.6	141.7	142.5	146.7	158.6

* Note: One Jin = 1/2 Kg

The fact that China's agriculture is able to feed one-fourth of the world

population with only 7% of the world arable land shows that, on one hand, our agriculture policy has been correct and successful and, on the other, the vigorous development of chemical fertilizer has played an important role.

PART I

In the initial industrialization period of 1950s, a process was developed for making ammonia and associated ammonium bicarbonate. In this process, the carbonation section is substituted for CO_2 removal section, which is conventionally necessary for the purification of the gas stream after CO shift conversion, and in the meantime it accomplishes CO_2 utilization and NH_3 processing.

This process is adopted by most of over 1200 small nitrogen fertilizer plant with each producing 10,000 to 20,000 tons of ammonia annually. The output from these plants in 1983 was 9.457 million tons of ammonia, accounting for 56.8% of the total ammonia output in China.These plants are featured by small size, easy collection of investment, short amortization period, lower requirements for equipment and materials,simple maintenance and management, and flexible feed stocks. Most of them use local resources as the feed stocks and their products are sold and consumed locally. These features are very valuable to a country like China, which is a developing country with a vast land and a large population.

China has rich resources in coal, petroleum and natural gas, and is one of the richest coal resource countries in the world. Considerable amount of coal resource in China is anthracite. This situation results in the fact that most of the small nitrogen fertilizer plants use coal or coke as the feed stock. As the cost of anthracite is about half of that of the coke and the coke cost accounts for about 40% of the ammonia cost if coke is the feedstock, the ammonia cost can be reduced by 20% if anthracite is used as the feedstock. Hence, an anthracite gasification process was developed in 1950s by using the fixed bed gasifier operating intermittently. However, the gasifier requires certain granularities of the lump coal (granular size between 13 and 60 mm is suitable), while the lump coal accounts for only 20 to 30% of the total coal production, the remainder is the coal powder with the size less than 13 mm. To solve this problem, we conducted in 1960s the research work on manufacturing carbonated coal briquettes with slaked lime as solidifying agent and since then this technique was applied in the ammonia plants. At present, over 700 ammonia plants

with the daily capacity ranging from 40 to 100 tons used carbonated coal briquette or 70 to 85% of carbonated coal briquettes mixed with 15 to 30% of lump coal and coke as the feedstocks. We have achieved successful results on the gasification of coke. lump anthracite and briquettes for preparation of the raw gas in ammonia production by using fixed bed gasifiers operating intermittently, both the gas composition and gasification efficiency being satisfactory. Feedstock flexibility, to which enough attention has been given, is one of the reasons why the small ammonia plants are viable.

Through the continuous efforts on energy saving and technical rehabilitation in many years, some well-managed small ammonia plants with coal or coke as the feedstocks have achieved, for each ton of ammonia, consumption of coal, as the raw material, electric power and total energy consumption of 1.3 tons, 1200 KWH and 15 million Kcal respectively. Taicang Chemical Fertilizer Plant in Jiangsu Province is the best which has a total energy consumption of 12.53×10^6 Kcal per ton of ammonia.

Since 1970s, we have imported 17 large-sized nitrogen fertilizer plants with advanced technology, 14 of them have been put into operation successively. In recent years, a lot of work on how to operate and manage these plants well has been done and very good results have been achieved. Except for few plant, which are in short of feedstock supply, the annual outputs of ammonia and urea for most of the plants have reached or exceeded the design values. The consumptions are normally lower than the guarantee figures. One ammonia plant was on stream continuously and safely for 379 days and reached maximum daily output of 1069 tons and an annual output of 347,000 tons.

Necessary improvements have been made in some imported plants, which were bottlenecked by certain process sections. For example, the CO_2 removal section in one plant could not reach the design figures. We applied hot potassium carbonate solution with double promoters, the practice showed that CO_2 content in the purified gas stream was reduced from 0.25 -- 0.35% to less than 0.1%, normally 0.06 -- 0.08%, at 83 -- 94% load, and energy consumption for each ton of ammonia was cut down by 0.2 million Kcal.

Starting from 1982, several large-sized ammonia plants were equipped with computers or intelligent instruments with microprocessors for process control. Computer close-loop control was applied for key parameters, which have long response time and quite a few interference factors, and have influence on stable operation, output and energy consumption, and successful result was

achieved. The key parameters are mainly H_2O/C ratio of the primary reformer, H_2/N_2 ratio in synthesis loop, gas outlet temperature and tube wall temperatures of the primary reformer, residual oxygen content in the flue gas of the primary reformer, and methane and argon content in purge gas. When computer control system was introduced in one plant, the H_2/N_2 ratio deviation from set point was decreased from 0.2 to 0.015, the gas outlet temperature fluctuation of the primary reformer was reduced from $\pm$ 6 ~ 8 °C to $\pm$ 3 °C, the fluctuation of residual oxygen content in flue gas was reduced from over $\pm$ 1.0% to $\pm$ 0.3%. Besides, computer also monitors and tabulates more than one hundred process parameter, after datum and processed results are shown on the terminal display, thus providing various informations for management. All these have raised the scientic management level of the plant and brought about economic benifits of more production and less energy consumption. For instance, when H_2/N_2 ratio was computer-controlled, 1.5% output increase was achieved.

Positioned between many small and large-sized nitrogen fertilizer plants, some dozens of medium-sized ammonia plants, built by ourselves, with the daily capacity of about 200 tons of ammonia for each and with coal, oil or natural gas as the feedstocks, have played an important role in chemical fertilizer industry in China. These plants are quite diversified. Among them are the chemical enterprises of the first generation in China, i.e. Dalian Chemical Plant and Nanjing Yonglining Plant; the key chemical fertilizer enterprises built during the initial period of industrialization after the founding of the People's Republic of China, i.e. Jilin Chemical Fertilizer Plant and Lanzhou Chemical Fertilizer Plant with oil gasification under atmospheric pressure, Taiyuan Chemical Fertilizer Plant and Quzhou Chemical Plant with coke, on fixed bed, as feedstock, and Sichuan Chemical Plant with natural gas intermittent reforming process. However, the most of the medium-sized plants were ammonia--urea plants built in 1960s and 1970s with catalytic purification process for preparation of syn- gas.

In recent years, a lot of work was done to improve management and to develop the potential in capacity of the plant, meanwhile, technical rehabilitation with energy-saving as the focus was also conducted in nation-wide scale, thus resulting in an increase in technical level of the medium-sized fertilizer plants. The example in this respect are as follows: low pressure fixed bed boilers replaced by fluidized bed boilers resulting in the carbon content reduction in residue down to less than 1% and remarkabe reduction in coal consumption; adoption of automatic feeder on the gas generator resulting in an average coal consumption reduction of 113 Kg per ton ammonia; installation of

a boiler after ammonia converter leading to the recovery of 0.5 — 0.6 million Kcal per ton ammonia; CO_2 removal by water washing replaced by propylene carbonate scrubbing resulting in a reduction of energy consumption by 0.35 million Kcal per ton ammonia and an increase in ammonia output by 2%; adoption of ball-shaped catalyst in ammonia converter enabling an capacity increase of 15%; replacement of catalyst B 106 by catalyst BMC for medium-temperature shift conversion in medium and small-sized ammonia plants resulting in a steam consumption reduction of 20%. Besides, high and medium pressure boiler is being used both for heat supply and power generation, and hydrogen recovery by PSA or cryogenic separation is being applied for the comprehensive use of purge gas in large-and medium-sized ammonia plants.

The nitrogen fertilizer industry in China has now formed an industrial system, fairly wide in scale, which integrates large—, medium—, and small—sized plants with coal, oil or natural gas as the feedstocks, and has the capability for process design, equipment manufacturing, construction and operation of fertilizer plants.

Compared with nitrogen fertilizer industry, phosphate fertilizer industry in China is quite weak. Before Liberation, there was no phosphate fertilizer industry in China. Over the last 35 years since the founding of our country, phosphate fertilizer industry has undergone repia development. At present, there are about seven hundred phosphate fertilizer plants, spread over more than one-fourth of the counties in China. Among them are several large- and medium-sized plants, the remaining are small plant built with local investment but producing 90% of the total phosphate fertilizer in China.

The main products of phosphate fertilizer in China are single superphosphate, containing 12 — 18% of P_2O_5, and calcium magnesium phosphate, containing 14 — 20% of P_2O_5. Their capacity and output account for over 90% of that of total phosphate fertilizer.

Single superphosphate was initially produced in small quantity in 1955. However, its output reached 1.92 million tons on basis of P_2O_5 in 1983 from the plants with the capacities of 25, 50, 100, 200, or 400 thousand tons per year. These plants are normally integrated with contact process sulfuric acid units having the capacities of 10, 20, 40, 80, or 160 thousand tons per year. Single superphosphate is manufactured by reacting the ground phosphate rock with sulfuric acid. The final product is obtained after forming and curing.

The fluorine released during superphosphate production is absorbed with water to form 10% fluorosilicic acid and this acid is finally processed into sodium fluorosilicate or other by-products.

Next to the superphosphate, calcium magnesium phosphate fertilizer is one kind of phosphate fertilizers in China, which was developed quite early and has been developed rather fast. The calcium magnesium phosphate fertilizer is mainly manufactured in blast furnaces, with a few exceptions in electric furnaces and cyclone furnaces. By taking the measures such as feeding the raw materials with right proportion to the furnace, improving the furnace construction, purifying the furnace gas for reuse, etc., the product contains up to 17 -- 19% of active P_2O_5 and P_2O_5 conversion efficiency reaches 99% when the input phosphate rock contains 27 -- 29% of P_2O_5.

The production of calcium magnesium phosphate fertilizer in blast furnace is featured by simple process, low coke consumption. The coke consumption for each ton of P_2O_5 product is only 800 -- 850 Kg in some well-managed plants. For the areas where sulfur resource is in shortage and where slightly basis fertilizer is suitable to apply, this kind of fertilizer is one of the best citric soluble fertilizers.

A commercial test has been conducted on the vertical cyclone boiler, having steam generation capacity of 75 tons per hour and taking powder coal as fuel, to produce calcium magnesium phosphate fertilizer, so that the boiler not only generates steam but also produces calcium magnesium phosphate fertilizer, resulting in cost reduction and elimination of waste residues.

Among the varieties of phosphate fertilizer in China, the fertilizers which contain high phosphorus concentration and which are also compound fertilizers account for only a small percentage. Attention has been drawn to this situation.

A phosphoric acid unit of dihydrate process with a daily capacity of 50 T P_2O_5 was built in Phosphate Fertilizer Plant of Nanjing Chemical Industrial Company. Recently, a phosphoric acid unit with a daily capacity of 100 T P_2O_5 was built in Yunnan Phosphate Fertilizer Plant. An ammonium phosphate unit having a daily capacity of 100 T was built in Phosphate Fertilizer Plant of Nanjing Chemical Industrial Company. Another DAP unit with a capacity of 120,000 tons per year built at Tongguanshan in Anhui Province.

A triple superphosphate unit with hot process for making phosphoric acid was built in Guangxi, and another TSP unit, adopting recycled dilute acid

solidifying process, was built in Yunnan Phosphate Fertilizer Plant.

Besides, phosphate fertilizers such as precipitated calcium phosphate. Potassium dihydrogen phosphate, ground phosphate etc. are also produced in China.

China is rich in peat and lignite resources. Over the last ten years, humic fertilizers were developed rapidly and applied widely in various places. Nitric humic compound fertilizer can be manufactured from nitric humic fertilizer, which is made by using peat or lignite and treated with nitric acid, with the addition of N,P,K. This fertilizer, being inorganic and organic, can improve soil quality, promote fertilizer efficiency and stimulate crop growth. Especially, it can raise the output and improve the quality of the plants like fruit trees, melons and tobacco.

In 1950s, research work was conducted for the development of making phosphoric acid with wet process and ammonium phosphate fertilizer. In mid 1960s, commercial unit for making diammonium phosphate was built. Based on the condition that phosphate rock in some places of China is poor in quality and contains high impurities such as aluminium, iron and magnesium, in early 1980s, a slurry concentration process for making solid ammonium phosphate was developed. This process includes following main steps: preparation of phosphoric acid with dihydrate process --- neutralization with gaseous ammonia --- slurry concentration by double effect evaporation --- spray drying or drum granulation and drying. The product is mainly monoammonium phosphate with N: P_2O_5 : K_2O of 10.5 : 42 : 0. Its active P_2O_5 is higher than 99% and water solubility is over 65%. This process allows the use of medium--grade phosphate rock (P_2O_5 : 25%, Al_2O_3; 4%, Fe_2O_3: 3%; MgO: 2.5 -- 3.5%), and has no stringent material requirement on the concentration equipment. More important is the fact that it avoids the serious scaling, which is formed during concentration of phosphoric acid extraction and is hard to treat, and therefore it is of great significance to the production of high concentrated phosphate compound fertilizer with domestic resources.

The process we have developed for producing nitro--phosphate fertilizer is available for commercial use.

Most of the phosphate deposits in China are found in slowly inclined beds with moderate thickness. The mining operation is difficult. The impoverishment and loss of phosphate rock are high. Achievements from research work have been applied in the new design for a benificiation plant having an annual capacity of over one million tons and using weathered and semi-weathered de-

posits on ground, calcium-bearing phosphate rocks, and silicon--, calcium-bearing phosphate rocks as the raw materials.

China is relatively rich in phosphate deposits. The proved resources can meet the long term requirement of China's phosphate fertilizer industry. It is expected that as a result of the development in mining technique and production process, the future of the phosphate fertilizer industry in China is prosperous.

The output of potash fertilizer in China is low, it was only 29,000 tons in 1983.

In recent years, China has also developed microelement fertilizers. The main products are boron, zinc, manganese, copper, molybdenum fertilizers. Experiments in large areas on cotton, rape and fruit trees have resulted in remarkable yield increase.

PART II

During the past 35 years, the development of chemical fertilizer industry in China is vigorous. However, the task of fertilizer industry is still heavy if we compare its present situation with the target of the national economy at the end of this century and with the increasing demands of various kinds from agriculture. The main tasks are as follows:

1. At present, there exists a serious problem in China's chemical fertilizer industry, in which fertilizer both produced and consumed are lacking in phosphorus and potassium, and are out of proporation among N,P,K nutrients. In 1980, the chemical fertilizers produced in China have N: P_2O_5 : K_2O of 1 ; 0.23 : 0.002. It is anticipated that the ratio of N : P_2O_5 : K_2O must be adjusted to 1 : 0.4 — 0.5 : 0.1 in near future, the ratio of phosphate and potash fertilizers must be increased when nitrogen fertilizer is developed steadily, focus must be given to the development of compound and blended fertilizers so that at the end of this century the ratio of N : P_2O_5 : K_2O will be 1 : 0.6 : 0.2 and the total output of chemical fertilizers will reach 0.12 -- 0.15 billion tons. As a result, the total grain output will

reach 960 billion Jin by that time.

2. Technical rehabilitation should be done in existing chemical fertilizer plants. Special attention must be given to the redustion of energy consumption. Of course, the plants should be revamped in a planned way so that the best economic benifit will be achieved.

3. Close co-operation must be made between chemical fertilizer industry and agriculture so that chemical fertilizers will be applied scientifically and economically and fertilizer application effeciency will be increased. It is very important that the increase in social and economic benifits of the chemical fertilizer must be greater than the growth of the chemical fertilizer output.

PART III

In order to fulfill the above tasks, great efforts must be made in various aspects. Following are my tentative opinions so far as the chemical fertilizer technology is concerned.

The nitrogen fertilizer should be further developed in the short and medium term. However, it is more important to conduct technical rehabilitation step by step for existing plants with the focus on energy saving. As for the varieties of fertilizers, we should develop compound fertilizers and adjust the ratio of N,P,K.

So far as the large-sized ammonia plants are concerned, technical revamping should be done in a planned way by applying the advanced and proved technology developed either at home or abroad. The items which are available for revamping are as follows: addition of combustion air preheater and steam superheater burners, improved Benfield system for CO_2 removal, molecular sieve for water removal, pressure swing absorption, purge gas treatment by cryogenic or permeation processes, CO selective oxidation, etc. It is anticipated that total energy consumed for each ton of ammonia will be reduced from 9.5 -- 10 x 10^6 Kcal to 8.5 -- 9.0 x 10^6 Kcal, and capacity increased by about 5% when revamping

is implemented, thus making the technological level of the large-sized nitrogen fertilizer plants up to the level of 1980s. We expect that the investment can be amortized in three to five years. Based on the resources in China, the medium-sized nitrogen fertilizer plants will mainly take lump anthracite as the feedstock in a quite long period to come. The proved energy saving measures mentioned above for medium-sized plants should be applied. For those plants where conditions are suitable, it is advisable for them to turn to producing nitro-phosphate fertilizer or ammonia integrated soda ash. Powder coal gasification technique should be developed without delay. This is of great significance as coal resources in China is fairly abundant.

In principle, the small-sized nitrogen fertilizer plants are facing the same problems as medium-sized plants. Technical revamping with energy saving as the main task should be carried out. However, consideration must be taken to raw materials, water, electric power and mangement level of the plants, and revamping priority must be given to those plants where their local conditions are favourable so that best energy saving results will be achieved with less investment. Special attention should be given to the improvement of physical and chemical properties of ammonia bicarbonate product. For some plants where conditions are suitable, it is advisable to turn to producing ammonium phosphate or nitro-phosphate fertilizer.

In some suitable locations direct application of liquid ammonia is also advisable. Based on the present conditions that chemical fertilizers in our country, and most of the phosphate fertilizers have low concentration, great strides should be made in phosphate fertilizer industry.

Single superphosphate and calcium magnesium phosphate will remain the main varieties of phosphate fertilizer in our country for a time to come. First of all, attention should be given to the on-spot enrichment of phosphate rocks so as to provide qualified raw materials and to raise product quality and reduce sulfuric acid consumption and energy consumption. Secondly fluorine pollution should be abated, more varieties of products from fluorine treatment should be manufactured, f.i, producing aluminium fluoride and cryolite from concentrated fluorosilicate solution. Some plants may make triple superphosphate to replace single superphosphate. As to the calcium magnesium phosphate production, proved experiences in feedstock preparation, furnace structure, utilization of waste heat should be spread process and equipment should be improved, coke consumption be reduced, technical level for the treatment of solid, liquid and gaseous wastes be increased. Thirdly,

number of phosphate fertilizer bases must be established, ammonium phosphate units with wet process for phosphoric acid production be built, some nitrogen fertilizer plants which are producing ammonia bicarbonate, ammonium nitrate and ammonium sulfate be modified to produce ammonium phosphate or nitro-phosphate, the proportion of high concentrated phosphate and compound fertilizers must be increased in the total output of chemical fertilizers.

In order to accelerate the step of modernization of phosphate fertilizer industry, a group of key research items for solving practical production problems are being tackled, f,i., enrichment technique of low-and medium-grade phosphate rocks, improving the quality of the old products, developing new processes for nitro-phosphate and ammonium phosphate, commerical demonstration of the technology for solid, liquid and gaseous wastes treatmnet, meanwhile, some key equipments and technologies will be imported.

The foundation of the potash fertilizer industry in China is very weak. However, we should actively expand the existing plant capacity. Our stress should be put on the brine lake in Qinghai Province, which is rich in potash resources. The project for the exploitation of the resources there is now under construction.

In addition to the vigorous development of the chemical fertilizer, we also clearly realize that application of chemical fertilizer is to increase crop yield, and that increasing the output variety and quality of chemical fertilizer and raising its application efficiency are two key links for the chemical fertilizer to contribute its share to the total benifit of national economy.

Much work has been done on systematic study in pedology, plant nutriology, mechanism of fertilizer effect on crops and scientific application of fertilizers, but, generally speaking it is far from enough. In general, the application efficiency of chemical fertilizer in our country is low, it implys that the potential in this area is great. The experiment done by the agricultural research unit has shown that nitrogen utilization rate of ammonium bicarbonate by deep application was much higher than that by surface dressing, and that the granulated ammonium bicarbonate with coating for delayed effect was even better. In future, in addition to increasing chemical fertilizer output, chemical fertilizer departments together with agricultural departments should provide on-spot technical services (including soil analysis, giving directions for applied fertilizer quantity and variety, preparation of various blended fertilizers, and providing scientific application method of fertilizers) for

the peasants, who are in want of scientific knowledge in agriculture after the Responsibility System is practised in the countrysides. Based on soil analysis, Liaoning Province increased N/P ratio from 1 : 0.15 to 1 : 0.35 from 1979 to 1981 over 12 million Mu of land, as a result, nitrogen utilization rate was increased by 20%, and the average output of various crops was increased by 20%. The close cooperation between industry and agriculture will benifit both fertilizer plants and peasants, and also impel chemical fertilizer industry to produce more fertilizers with higher concentration and efficiency, more phosphate and potash fertilizers, more granulated and delay-effect (coated) fertilizers,and to provide blended fertilizers, humate fertilizers and micro-element fertilizers according to different locations, soil analysis and crops. In this way, not only the social and economic benifit of chemical fertilizer will be doubled and redoubled, but also the chemical fertilizer industry itself will march forward vigorously and soundly.