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REGIONAL SHIFTS IN NITROGEN FERTILIZER PRODUCTION

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RESUME

Les quelques dernières années ont vu une mutation des régions du monde où la production d'engrais azotés est concentrée. La communication traite de l'ampleur et des raisons possibles qui influent sur cette mutation et examine le prix du gaz naturel comme principal facteur de ces mutations.

La communication montre l'incidence que le prix du gaz naturel a sur le coût de la production de l'ammoniac, principale source d'azote pour les engrais azotés, et décrit les modifications récentes qui sont intervenues dans la technologie de production d'ammoniac pour réduire le coût des engrais azotés. Des tableaux sont inclus indiquant les concentrations régionales de la production et de la consommation d'azote, la fixation des prix du gaz naturel, l'analyse du coût de production de l'ammoniac et les effets des améliorations technologiques sur les coûts de production.

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INTRODUCTION

In order to be better prepared for the future developments in any industry, it is very useful to analyze the past to gain insight. This is particularly important in the fertilizer industry where so many changes in ownership and marketing strategies are taking place worldwide, and even more so in the nitrogen industry which is very capital intensive. In analyzing the recent past of the nitrogen fertilizer industry, it seems important to identify the regional shifts taking place in nitrogen production and to determine the major factors responsible for these shifts.

NITROGEN PRODUCTION BY REGION

Obtaining accurate current regional or worldwide data to analyze trends in the fertilizer industry is difficult. The most complete set of official worldwide fertilizer statistics that includes all countries is published by the Food and Agriculture Organization of the United Nations (FAO), but the latest data available from FAO at the time this paper was prepared were for 1993/94. Although this information is relatively old, we have used it for our analysis because the trends shown are for the most part continuing even though the magnitude may be different.

World nitrogen production increased from 68 million mt of N in 1983/84 to 79 million mt in 1993/94 (**Table 1**). Production of N in Asia during this period increased by about 12 million mt and by about 6 million mt in North America. North America, Asia, and Africa are the only regions where production was at or near record production in 1993/94. Combined production of N in East Europe and the former Soviet Union (FSU) at 12.6 million mt declined about 6.4 million mt during this 10-year period and even more compared to their record production of 22.2 million mt in 1988/89 (**Table 2**). Small gains were registered in Latin America, Africa, and Oceania.

Table 1 - World Nitrogen Production by Region

Region	1983/84	1993/94	Change
	(million mt N)		
North America	11.8	17.9	6.1
Latin America	2.2	2.9	0.8
West Europe	11.6	9.1	-2.5
East Europe	6.1	3.8	-2.3
Former FSU	12.9	8.8	-4.0
Africa	1.5	2.6	1.1
Asia	21.6	33.9	12.3
Oceania	0.2	0.3	0.1
World	**67.8**	**79.5**	**11.7**

Source: Derived from FAO Data.

Table 2 - Maximum Nitrogen Fertilizer Production by Region

Region	Maximum Yearly Production	Year	1993/94	Decline From Record Year
	(million mt N)		(million mt N)	(%)
North America	17.9	1993/94	17.9	same
Latin America	3.3	1989/90	2.9	-12
West Europe	12.3	1984/85	9.1	-26
East Europe	6.6	1988/89	3.8	-42
FSU	15.6	1988/89	8.8	-44
Africa	2.6	1993/94	2.6	same
Asia	34.0	1992/93	33.9	-0.1
Oceania	0.3	1992/93	0.3	same
World	**85.7**	**1988/89**	**79.5**	-7

Source: Derived from FAO data.

North America

Nitrogen fertilizer production in North America has increased from 11.8 million mt in 1983/84 to 17.9 million mt in 1993/94 (**Table 2**). This represents a growth of 52% during the past 10 years. Nitrogen production increased 6.1 million mt during this period, more than in any other region except Asia. The United States is the world's second largest nitrogen producer and Canada is the fifth largest (**Table 3**). The share of world production by North America has been slowly but steadily increasing. Ten years ago 17% of the world's nitrogen fertilizer production was in North America, but today 23% is produced in North America. Production has increased each year since 1990/91.

Table 3 - World: Top 10 Nitrogen Fertilizer Producers

Country	1993/94	World Rank	
	(1,000 mt N)	1983/84	1993/94
China	15533	1	1
United States	14415	2	2
India	7231	3	3
Russia	5000	NA	4
Canada	3489	4	5
Indonesia	2357	15	6
Ukraine	2072	NA	7
Netherlands	1574	7	8
Pakistan	1566	15	9
France	1524	8	10

NA = not available
Source: FAO.

Latin America

Nitrogen fertilizer production in Latin America has increased from 2.2 million mt in 1983/84 to 2.9 million mt in 1993/94. This represents a growth of 32% during the past 10 years. In 1993/94 Mexico was the largest nitrogen producer in Latin America followed by Brazil, Venezuela, and Trinidad/Tobago (**Table 4**). Trinidad/Tobago increased production the most during this period. Total production in Latin America has changed very little since 1986/87. Production has been about 3 million mt since 1986/87. Eleven Latin American countries produced nitrogen in 1983/84. In 1993/94 eight of these had increased production, Guatemala had ceased production, and production in Cuba and Peru had declined. Ten years ago 3% of the world's nitrogen fertilizer production was in Latin America, and today 4% is produced in Latin America.

Table 4 - Latin America: Countries with Largest Increase in Nitrogen Production

Country	1983/84	1993/94	Change
	(million mt of N)		
Mexico	1.0	1.2	0.2
Brazil	0.5	0.7	0.2
Venezuela	0.2	0.4	0.2
Trinidad/Tobago	0.002	0.2	0.2
All Others	0.4	0.4	0
Latin America	**2.2**	**2.9**	**0.8**

Source: Derived from FAO Data.

West Europe

Nitrogen fertilizer production in West Europe has declined from 11.6 million mt in 1983/84 to 9.1 million mt in 1993/94 (**Table 5**). Production peaked in 1984/85 at 12.3 million mt but has declined almost every year since then. Nitrogen production has declined 22% during the past 10 years. Ireland was the only country in West Europe that produced more nitrogen in 1993/94 than 10 years earlier. The Netherlands and France rank 8th and 10th, respectively, in world nitrogen fertilizer production. The main production declines have been in Germany, the United Kingdom, and Italy (**Table 5**). Ten years ago 17% of the world's nitrogen fertilizer production was in West Europe, but today only 12% is produced in this region.

Table 5 - West Europe: Countries With Largest Decline in Nitrogen Production

Region	1983/84	1993/94	Change
	(million mt of N)		
Germany	2.1	1.3	-0.8
United Kingdom	1.4	0.8	-0.6
Italy	1.1	0.7	-0.4
All Others	7.1	6.4	-0.7
West Europe	**11.6**	**9.1**	**-2.5**

Source: Derived from FAO Data.

East Europe

Nitrogen fertilizer production in East Europe has declined from 6.1 million mt in 1983/84 to 3.8 million mt in 1993/94 (**Table 6**). From 1983/84 to 1988/89 production ranged from 6.1 to 6.5 million mt. Production peaked in 1988/89 at 6.6 million mt. Production in 1993/94 was 43% lower. The share of world production has been slowly but steadily declining. Poland is the largest nitrogen-producing country in East Europe with Romania nearly as large. Ten years ago Romania produced 50% more nitrogen than Poland. The main production declines in East Europe have been in Romania, Hungary, and former Czechoslovakia. Ten years ago 9% of the world's nitrogen fertilizer production was in East Europe, but today only 5% is produced in East Europe.

Table 6 - East Europe: Countries With Largest Decline in Nitrogen Production

Region	1983/84	1993/94	Change
	(million mt of N)		
Romania	2.1	1.0	-1.1
Hungary	0.7	0.2	-0.5
Former Czechoslovakia	0.7	0.4	-0.3
All Others	2.6	2.2	-0.4
East Europe	**6.1**	**3.8**	**-2.3**

Source: Derived from FAO Data.

Former Soviet Union

Nitrogen fertilizer production in the former Soviet Union has declined from 12.9 million mt in 1983/84 to 8.8 million mt in 1993/94. Nitrogen production peaked in 1988/89 at 15.6 million mt. Production has declined 43% since the peak production year. The share of world production has been slowly but steadily declining. Currently Russia accounts for 56% of the FSU production and Ukraine accounts for 23%. Russia is the fourth largest nitrogen-producing country in the world and Ukraine ranks seventh. Ten years ago 19% of the world's nitrogen fertilizer production was in the FSU, but today only 11% is produced in the countries comprising the FSU.

Africa

Nitrogen fertilizer production in Africa has increased from 1.5 million mt of N in 1983/84 to 2.6 million mt in 1993/94. This represents an increase of 78% during the past 10 years. Egypt, South Africa, Morocco, Libya, Nigeria, and Tunisia produce 92% of the nitrogen fertilizer in Africa. Morocco and Tunisia do not produce ammonia but contribute to nitrogen production in the form of ammonium phosphate (DAP/MAP) based on imported ammonia. Morocco and Nigeria have realized the most increase in nitrogen production among the 11 countries in Africa that have increased production during the past 10 years. Only 4 countries have decreased production, and these were all very small producers who ceased production. Ten years ago 2% of the world's nitrogen fertilizer production was in Africa, but today 3% is produced or processed in Africa.

Asia

Nitrogen fertilizer production in Asia has increased from 21.6 million mt in 1983/84 to 33.9 million mt in 1993/94, an increase of 57% during the past 10 years. Six countries (China, India, Indonesia, Pakistan, Bangladesh, and Saudi Arabia) account for 90% of this increase (Table 7). Asia's share of world production has been rapidly increasing. Four of the ten largest nitrogen producers in the world are in this region. China is the largest nitrogen-producing country in the world and India ranks third. Indonesia ranks sixth and Pakistan ranks ninth. The Middle East has become a major nitrogen-producing area; it increased its production from 1.8 million mt N in 1983/84 to 3.2 million mt in 1993/94, most of which is exported. The Middle East countries produce nearly as much nitrogen as Eastern Europe and exceed the production of either Latin America, Africa, or Oceania. Ten years ago 32% of the world's nitrogen fertilizer production was in Asia, but today 43% is produced in this region. Nitrogen production in this region increased 12.3 million mt, exceeding the nett world gain of 11.6 million mt. This means nitrogen production in the rest of the world actually declined.

Table 7 - Asia: Countries With Largest Nitrogen Production

Region	1983/84	1993/94	Change
	(million mt of N)		
China	11.3	15.5	4.2
India	3.5	7.2	3.7
Indonesia	1.1	2.4	1.3
Pakistan	1.0	1.6	0.6
Bangladesh	0.3	1.0	0.7
Saudi Arabia	0.3	0.8	0.6
All Others	4.1	5.4	1.2
Asia	**21.6**	**33.9**	**12.3**

Source: Derived from FAO Data.

Oceania

Nitrogen fertilizer production in Oceania has increased from 0.2 million mt in 1983/84 to 0.3 million mt in 1993/94. Australia and New Zealand are the only producing countries in the region.

REGIONAL SHIFTS IN NITROGEN PRODUCTION

The main regional shifts in production of nitrogen fertilizers that are taking place include considerable increases in Asia and North America and considerable decreases in the former Soviet Union, East Europe, and West Europe (**Figure 1**). On a world scale, the other regions have shown only minor changes. There are relatively few countries in the world responsible for the shifts; they are the United States, China, India, Indonesia, Canada, Pakistan, and Saudi Arabia on the positive side and Russia, Ukraine, Romania, Germany, United Kingdom, Hungary, Italy, and the former Czechoslovakia on the negative side. Upon examining the factors behind the changes in the countries that exhibited production increases, we find:

United States

The U.S. increase in nitrogen production has been largely a result of excellent infrastructure, reasonably priced natural gas, inexpensive pipeline and barge transportation, and increased DAP production which has become a very popular export product. The United States has a strong demand for nitrogen because it is the second largest nitrogen consumer in the world and the world's largest exporter of nitrogen products.

China

China's increase is a deliberate policy of the government to increase food production, and fertilizer usage is the main means of accomplishing this. China's nitrogen production increase is not a result of inexpensive natural gas.

India

India's increase in nitrogen production has also been the result of deliberate government policies. Phosphate and potash prices in India have been decontrolled. Nitrogen products are heavily subsidized and nitrogen fertilizer prices are relatively low. As a result, for example, in 1995/96 the price to the farmer for urea is $96/mt and $272/mt for DAP compared with free-market prices of about US$ 225 and US$ 250, respectively. New changes in subsidies announced in July 1996 represent an attempt to get more phosphates and potash used relative to nitrogen.

Indonesia

As in the case of China, Indonesia's increase in production is a deliberate policy of the government to increase food production. Indonesia had a goal to be self-sufficient in rice production which they achieved. Indonesia also has very inexpensive natural gas, which is further subsidized to the fertilizer producer. The fertilizer industry is owned by the government, and exports and domestic allocations are carefully controlled by the government. At one time fertilizer prices were set very low by the government.

Canada

Canada is fortunate to have an ample supply of inexpensive natural gas. The government has encouraged expansion of the fertilizer industry through joint ventures.

Pakistan

Pakistan is fortunate to have an ample supply of inexpensive natural gas. At one time Pakistan subsidized fertilizer very heavily. However, the government has been very instrumental in helping to finance new ammonia/urea plants. The government has been heavily involved in the ownership of much of the industry, but an attempt is now being made to privatize most of the industry, and a strong private sector is being developed.

Saudi Arabia

A plentiful supply of inexpensive natural gas has been responsible for the growth of the industry in Saudi Arabia and other Middle East countries. The government has also been involved in the ownership of much of the industry in these countries. A strong export market in nitrogen has developed due to the reduced production in West Europe.

The main countries responsible for decreases in production of nitrogen fertilizers, as listed previously, belong to the former Soviet Union, East Europe and West Europe. As shown in **Table 8**, most of these countries, including Germany due to the influence of what was East Germany, have decreased their nitrogen fertilizer production when the government subsidies were abandoned, and the production inefficiencies and high production costs became apparent. Two countries, the United Kingdom and Italy, have decreased their production of nitrogen fertilizers because of high natural gas prices and declining consumption.

Table 8 - Summary of Factors for Key Nitrogen Producing Countries

Country	1983/84	1993/94	Change	Major Factors
	(million mt of N)			
United States	9.4	14.4	5.0	Strong demand, free trade
China	11.3	15.5	4.2	Government policies and subsidies
India	3.5	7.2	3.7	Government policies and subsidies
Indonesia	1.1	2.4	1.3	Government policies and subsidies
Canada	2.4	3.5	1.1	Government joint ventures
Pakistan	1.0	1.6	0.6	Government policies and subsidies
Saudi Arabia	0.3	0.8	0.6	Cheap natural gas
Russia	NA	5.0	NA	Inefficiencies
Ukraine	NA	2.1	NA	Inefficiencies, increasing gas prices
Romania	2.1	1.0	-1.1	Inefficiencies
Germany	2.1	1.3	-0.8	Declining consumption, high gas prices Inefficiencies in East Germany
United Kingdom	1.4	0.8	-0.6	Declining consumption, high gas prices
Hungary	0.7	0.2	-0.5	Inefficiencies
Italy	1.1	0.7	-0.4	Declining consumption, high gas prices
Czech Republic	0.7	0.4	-0.3	Inefficiencies

NA = not available.

From the previous analysis, it is clear that government policies, especially subsidies, are by far the main reason for the shifts in regional production of nitrogen fertilizers. Very little can be done to prepare for or even predict the policy actions governments around the world may take regarding the production and consumption of fertilizers. There are documented examples of countries that have changed their policies in opposite ways several times over a short period of time making it difficult for the operation of its fertilizer industry and for its farming community.

The second most important reason detected for the changes in production in the countries that showed major changes was related to the inefficiencies in the production of nitrogen products, particularly in countries of Central/East Europe and the FSU. Inefficiencies in production were responsible for the decrease in production in these countries. This indicates that in countries where government policies do not dictate the operation of the nitrogen industry, production economics become the underlying reason for the establishment or shutdown of nitrogen production facilities.

NITROGEN FERTILIZER PRODUCTION ECONOMICS

Ammonia is the basic and primary chemical used in the production of most nitrogen fertilizers in the world. Presently, at least 95% of the fertilizer nitrogen consumed in the world can trace its origin to ammonia. Because of this and also due to the fact that the cost of ammonia is a very important element in the production cost of other nitrogen fertilizers (for example, about 30% of the production cost of DAP and about 60% of the cost of urea), the production cost of ammonia is the most critical element in the economics of nitrogen fertilizer production.

Although the production of ammonia is fairly widespread, it is concentrated in a few countries. **Table 9** shows the world ammonia production and export statistics for 1995 as prepared by the International Fertilizer Industry Association (IFA), of which the top 10 producing countries are:

Table 9 - Ammonia Production and Export Statistics for 1995, 1'000 mt of N

	Production	Home Deliveries	Exports
Western Europe			
Austria	410.0	410.0	0.0
Belgium	640.0	583.4	56.6
France	1,480.0	1,380.0	96.8
Germany	2,596.7	2,235.9	360.8
Greece	64.9	64.9	7.4
Ireland	407.7	304.1	103.6
Italy	486.6	481.4	0.4
Netherlands	2,450.0	2,010.0	438.3
Norway	289.2	289.2	0.0
Portugal	155.1	118.9	36.2
Spain	423.6	389.1	7.6
Switzerland	33.6	33.6	0.0
United Kingdom	799.3	630.1	186.3
Subtotal	**10,236.7**	**8,930.6**	**1,294.0**
Central Europe			
Albania	0.0	0.0	0.0
Bulgaria	988.4	913.2	90.1
Croatia	310.4	367.2	0.0
Czech Republic	254.0	211.6	42.4
Hungary	307.2	228.3	78.9
Poland	1,889.7	1,796.6	138.5
Romania	1,487.0	1,491.0	1.4
Slovakia	178.4	178.4	0.0
Yugoslavia, Rep. of	150.0	150.0	0.0
Subtotal	**5,565.1**	**5,336.3**	**351.3**
Former Soviet Union			
Byelorussia	668.3	616.5	51.8
Estonia	170.6	58.2	111.0
Georgia	52.3	50.6	1.7
Kazakhstan	48.6	48.6	0.0
Lithuania	363.6	262.1	96.2
Russia	7,938.9	5,439.0	2,648.0
Tadzhikhistan	10.0	10.0	0.0
Turkmenistan	35.0	35.0	0.0
Ukraine	3,109.1	1,973.6	1,135.5
Uzbekistan	905.8	886.0	19.8
Subtotal	**13,302.2**	**9,379.6**	**4,064.0**
North America			
Canada	3,773.0	2,390.0	842.8
USA	13,291.4	12,973.6	317.8
Subtotal	**17,064.4**	**15,363.6**	**1,160.6**
Oceania			
Australia	432.9	398.7	34.1
New Zealand	79.2	79.2	0.0
Subtotal	**512.1**	**477.9**	**34.1**
Latin America			
Argentina	72.0	72.0	0.0
Brazil	992.7	698.2	72.7
Colombia	100.1	77.6	21.5
Cuba	-	-	-
Mexico	1,992.0	1,630.6	249.6
Peru	23.5	23.5	0.0
Trinidad & Tobago	1,696.0	329.1	1,481.2
Venezuela	599.7	512.4	93.2
Subtotal	**5,476.0**	**3,343.4**	**1,918.2**
Africa			
Algeria	176.1	27.0	149.1
Nigeria	170.0	160.0	6.7
South Africa	758.5	707.4	51.4
Zambia	0.6	0.6	0.0
Zimbabwe	42.6	42.6	0.0
Subtotal	**1,147.8**	**937.6**	**207.2**
Middle East			
Abu Dhabi U.A.E.	362.7	301.7	51.2
Bahrain	357.5	0.0	365.1
Egypt	1,095.7	1,091.8	13.2
Iran	715.4	581.8	145.0
Iraq	220.0	220.0	0.0
Israel	53.1	53.1	0.0
Kuwait	492.8	426.5	55.5
Libya	534.3	428.4	106.0
Qatar	653.1	418.9	234.2
Saudi Arabia	1,327.0	978.2	251.9
Syria	63.5	63.5	0.0
Turkey	483.3	437.1	48.1
Subtotal	**6,358.4**	**5,001.0**	**1,270.2**
Asia			
Afghanistan	15.0	15.0	0.0
Bangladesh	1,270.6	1,124.1	141.5
Myanmar (Burma)	66.0	66.0	0.0
China	21,372.0	21,372.0	0.0
India	8,024.4	8,024.4	0.0
Indonesia	3,336.2	3,041.2	305.7
Japan	1,478.0	1,544.0	0.0
Korea, North	700.0	700.0	0.0
Korea, Rep. of	615.8	543.3	0.0
Malaysia	332.8	305.8	27.1
Pakistan	1,492.5	1,490.1	0.0
Taiwan, China	244.8	238.4	0.0
Vietnam	54.0	54.0	0.0
Subtotal	**39,002.1**	**38,518.3**	**474.3**
Total World	**98,664.8**	**87,288.3**	**10,773.9**

Source: Ammonia Statistics 1995 - International Fertilizer Industry Association (IFA), April 1996.

Top 10 World Ammonia Producing Countries - 1995

Country	Annual Production (million mt N)
China	21.4
United States	13.3
India	8.0
Russia	7.9
Canada	3.8
Indonesia	3.3
Ukraine	3.1
Germany	2.6
Netherlands	2.5
Mexico	2.0
Other Countries	30.8
World Total	**98.8**

Source: IFA statistics.

To analyze the ammonia production costs, a single location will be chosen as typical. Because of the difficulty in obtaining information about the production cost elements for ammonia made in China, the top producer, the costs analyzed here are those reported for U.S. production. The United States was the world's second largest producer of ammonia in 1995 and accounted for over 13% of the world production.

In the production of ammonia, substantial amounts of an energy source are required. This energy source is used not only for process energy, but also as a feedstock for the process of generating hydrogen as a basic component of the ammonia molecule. In present-day plants about 60% of the natural gas is used as feedstock and 40% as fuel. Several energy sources are used throughout the world as feedstock and fuels for ammonia production. Comparative consumptions of the different energy sources per mt of end product ammonia are:

Feedstock and Fuel	Requirements Per mt of Ammonia
	Energy
Natural Gas	8.6 MM kcal
Naphtha	9.4 MM kcal
Fuel Oil	9.7 MM kcal
Coal	12.5 MM kcal

Source: *International Fertilizer Development Center. 1979. Fertilizer Manual. IFDC-R-1 (also available from the United Nations Industrial Development Organization, Vienna, Austria), Muscle Shoals, Alabama 35662, U.S.A.*

As can be seen, the most efficient energy source is natural gas. This is so not only on an energy basis, but also on a cost basis after considering the relative unit prices of the different fuel, and the larger capital investment required for producing ammonia from energy sources other than natural gas. An IFDC study gave the following relative capital investments for ammonia plants using different fuels as compared to using natural gas as feedstock:

Feedstock	Comparative Capital Investment
Natural Gas	100%
Naphtha	114%
Fuel Oil	147%
Coal	187%
Electrolytic Hydrogen	190%

Source: *Mudahar, M. S., and T. P. Hignett. 1982. Energy and Fertilizer - Policy Implications and Options for Developing Countries, Tech. Bull. No. T-20, International Fertilizer Development Center, Muscle Shoals, Alabama 35562, U.S.A.*

Because of these considerations, natural gas is presently used to produce more than 75% of the world's ammonia, and most plants being built in the future (with perhaps the exception of China) will use natural gas as the energy source.

In the production of ammonia, the cost of natural gas represents a very large component. In the United States, the cost of natural gas represents about 63% of the total production cost of ammonia ex-plant (**Figure 2**). The capital recovery costs are very low for existing U.S. plants. In a new plant, gas cost would be about 10%-20% of the production cost. The high incidence of the cost of natural gas in the production cost of ammonia has stimulated a drive towards decreasing the unit consumption of natural gas. This consumption has been decreased through technological innovations and through the increase of production efficiency. Such decreases are apparent in the values shown in **Table 10** for the United States.

Table 10 - Natural Gas and Energy Used in the United States for Ammonia Production

Year	Natural Gas	Electricity	Total Energy Used
	MM kcal	M kWh	MM kcal
1980	10.13	0.209	10.64
1981	10.20	0.193	10.68
1982	10.24	0.198	10.73
1983	10.07	0.176	10.50
1984	10.02	0.193	10.49
1985	9.92	0.154	10.30
1986	9.75	0.193	10.23
1987	9.81	0.175	10.24
1988	9.58	0.193	10.06
1989	9.57	0.149	9.94
1990	9.61	0.152	9.99
1991	9.45	0.175	9.88
1992	9.40	0.212	9.92
1993	9.46	0.190	9.92
1994	9.40	0.196	9.88
1995	9.46	0.188	9.93

Source: TFI Production Cost Survey.

A graph of these unit consumptions of energy in ammonia production in U.S. plants is shown in **Figure 3**. From this figure we can see that the unit consumption decrease, which was very apparent in previous years, has reached a plateau since the early 1990s indicating that the plants have probably reached the maximum economic decrease in energy consumption with the presently available technology. **Appendix A** lists the most common technological improvements for existing ammonia and urea plants. To decrease the production cost, it will now be necessary to either decrease the capital investment for new plants or build the new ammonia plants (nitrogen complexes) in locations where the price of natural gas offers a comparative advantage over other locations.

NATURAL GAS SITUATION

As indicated earlier, it may now be necessary to locate the new ammonia-urea complexes in places where the price of natural gas has a comparative advantage over other locations. This can already be seen taking place in the several new plants that have been announced to be built in Trinidad/Tobago, Venezuela and the Middle East where the price of natural gas is very low compared with that of other locations. In an effort to determine the locations that offer the best cost advantage, we have attempted to clarify the gas pricing situation in selected countries. It has been difficult to obtain such information because there is no single source for natural gas price information around the world and the situation is further confused by government-dictated pricing scenarios.

The full correctness of the information obtained from such diverse sources cannot be guaranteed although the sources used are thought to be reliable and current. In any case the order of magnitude of the values given are correct, and they can be compared with one another to determine general areas where the possibilities for locating new nitrogen plants are high or low. Prices are given for countries that have important ammonia production units. In assembling this database of natural gas prices, much help was obtained from the U.S. company J.W. Foster Associates of Tulsa, Oklahoma, to whom we want to give recognition and credit.

Due to the current relatively high prices of fertilizer throughout the world and to the elevated profit levels of the industry, some countries are beginning to tie the prices of their natural gas to the price of urea, while others are taking another look at taxation of natural gas. Because of this, some prices indicated below may change as the pricing method or taxation structure changes. All prices are given in US $/MM Btu. To convert to US $/MM kcal multiply the price by 3.968.

Bangladesh

Natural Gas	$1.03/MM Btu	After tax (current producers)
	$2.18/MM Btu	Before tax (new producers) estimated to be about $2.75/MM Btu after tax

It is reported that Bangladesh government officials are studying the possibility to drastically overhaul the taxation on its natural gas consumption, especially on its two largest users, electric power (52%) and fertilizer (26%). They are looking at three rate structures, a domestic rate, a general industrial rate, and a fertilizer rate. The fertilizer rate may have a base with a charge tied to urea prices. Apparently Kafco, an important fertilizer plant, already pays this urea pricing charge.

Canada

Natural Gas	$0.90 + $0.97/MM Btu

There is a glut of natural gas in Canada. It is expected that with the differential between Canadian and U.S. gas prices, there will be a rash of pipeline expansions to the United States.

China

Natural Gas	$0.50 + $1.00/MM Btu	At wellhead plus gas transmission estimated at an additional $0.70 + $0.80/MM Btu
Naphtha	$3.40 + $3.90/MM Btu	
Oil	$2.75 + $3.00/MM Btu	

China is beginning to develop its gas fields, but the infrastructure to deliver natural gas is lacking. Most of China's fertilizer plants are operating on coal or liquids and the new plants being built are using these feedstocks. It is reported that retrofits are being installed so that plants can switch between feedstocks and use gasification more efficiently. The Hainan offshore natural gas reserves are large, and it is reported that a 575,000-mtpy urea complex is currently under development based on this feedstock. A Chinese press report indicated that three additional 450-mtpy ammonia plants are being planned using Hainan gas as feedstock. Natural gas sales to Hong Kong are still reported at about $2.60/MM Btu with transportation estimated at an additional $0.70-$0.80/MM Btu.

Eastern Europe and Balkans

Natural Gas	$2.50 + $2.75/MM Btu	Plus an additional (but unknown) transportation fee

Egypt

Natural Gas	$0.75 + $0.80/MM Btu	Existing plants
	$1.00/MM Btu	New plants

Germany/Netherlands

Natural Gas	$2.50 + $2.75/MM Btu

India

Natural Gas	$2.50 + $2.75/MM Btu
Naphtha	$3.40 + $3.80/MM Btu
Oil	$2.75 - $3.00/MM Btu

India is short of natural gas and a good portion of the plants operate on naphtha and oil. Efforts are being pursued to obtain gas from Oman via an undersea pipeline although there has been some indication from Pakistan that it would allow a pipeline through Pakistan to deliver natural gas to India.

Indonesia

Natural Gas	$1.00 + $1.05/MM Btu	Delivered to old plants
	$1.50 + $2.00/MM Btu	Delivered to new plants

Gas price to electric power plants is in the range of $3.00/MM Btu

Iran

Natural Gas $0.20 + $0.50/MM tu

Iraq

Natural Gas $0.20 + $0.50/MM Btu

Malaysia

Natural Gas $1.00/MM Btu

Mexico

Natural gas is based on the southern Texas price, which is now about $2.30/MM Btu, but a new pricing policy will somehow tie this price to the South Louisiana producers' gas price, over time, and eventually the price of natural gas paid by the Mexican producer will be competitive with that paid by the Louisiana producer.

Morocco

Natural Gas $0.40 + $0.50/MM Btu

Nigeria

Natural Gas $0.35/MM Btu

Pakistan

Natural Gas	$1.10 + $1.15/MM Btu	For feedstock
	$2.40 + $2.50/MM Btu	For electric power and steam production

In addition to the above prices, the government taxes natural gas, which appears to be about $0.11/MM Btu; this tax changes on a regular basis. The natural gas from the two fields in Pakistan is of low heating value. It appears to be part coal seam gas. At one time, Pakistan was discussing with Iran about furnishing natural gas through a major overland pipeline system, but this has not been implemented.

Saudi Arabia

Natural Gas $0.40 + $0.60/MM Btu

Trinidad

Natural Gas	$1.00/MM Btu	Old gas nitrogen plants
	$1.00/MM Btu	Plus an additional charge that is tied to the price of urea

Ukraine

Natural Gas $2.25 + $2.75/MM Btu

United States

Natural Gas	$2.30 + 2.50/MM Btu	Midwest About $0.10/MM Btu higher to Gulf Coast ammonia producers
	$1.40 + $1.60/MM Btu	For producers in the Northwestern border states who have access to Canadian gas

With the severe winter of 1995/96 the northwestern United States experienced a drain on natural gas storage; it appears that the current price is being somewhat manipulated because of the natural gas going back into storage.

CONCLUSIONS

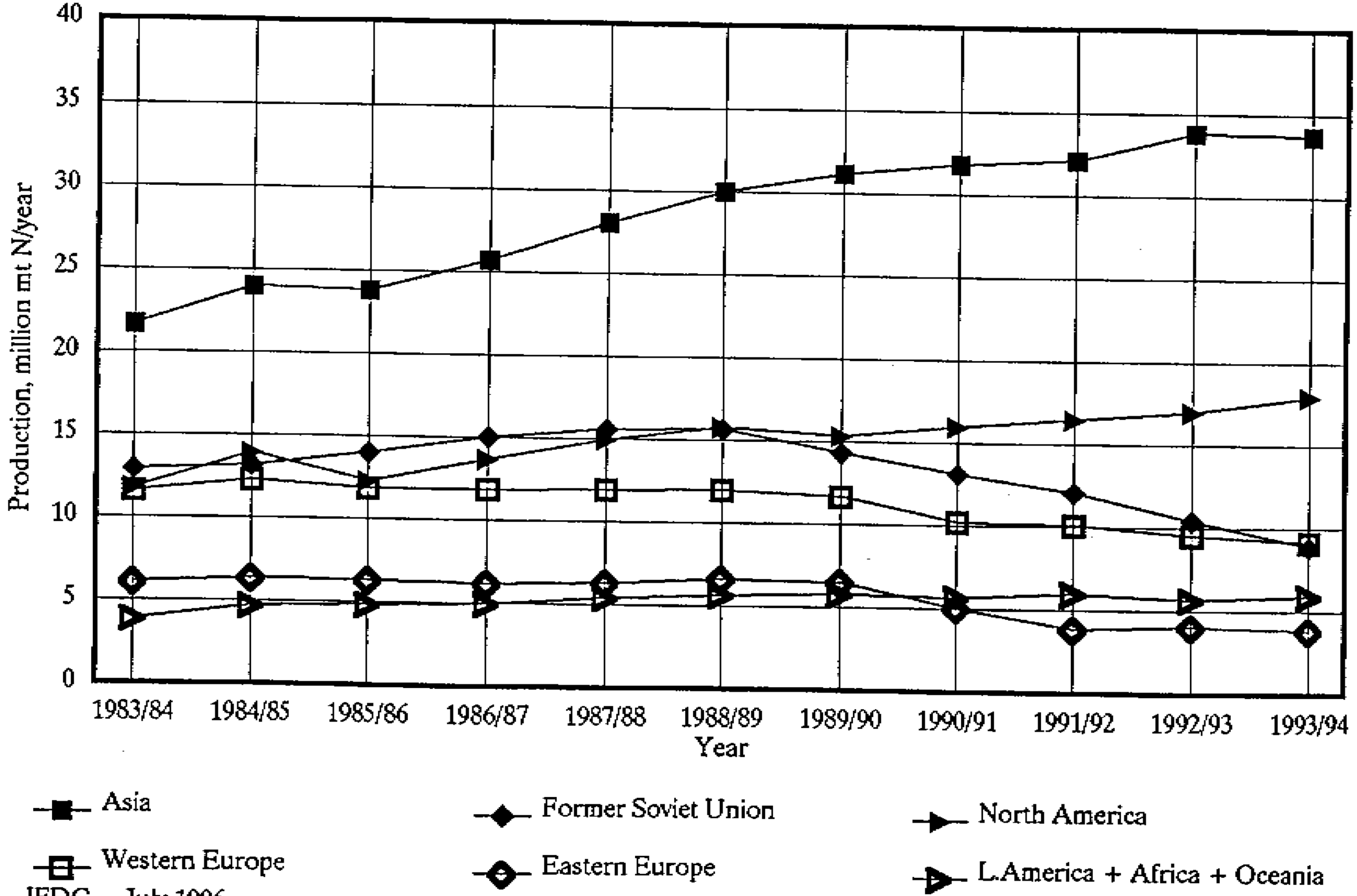
There are already many announcements of intentions to construct new nitrogen facilities throughout the world. IFDC updates a monthly publication entitled « Recent Fertilizer Project Announcements », which maintains a current list of these announcements. In the latest edition of this publication, there were announcements for constructing new ammonia production capacity in 45 countries. Many of these announced capacity increases will probably not take place for one reason or another, but the ones that do materialize will probably be the ones located in places that offer comparative economic advantages.

The competition between nitrogen fertilizer producers has become tense, and will probably become even more fierce when the new capacity becomes a reality. The production economics will become a more critical issue, particularly now that governments are leaving the production arena. The importance of ammonia as the major cost element in the production cost of nitrogen fertilizers makes it very important to find ways to lower this cost. The high incidence of the cost of natural gas in the production cost of ammonia led the process licensors on a search for ways to lower the unit consumption of natural gas in ammonia production. Great strides were made in this respect, and a battery of retrofits were developed to optimize the older plants. The fact that the unit consumption of natural gas is now more or less steady from year to year seems to indicate that decreases in production cost will now have to come from a lower investment cost or from installations using lower priced natural gas.

It seems that the industry should be abreast of natural gas prices to try to pinpoint the locations where nitrogen complexes should or will probably be built. We found no single source of natural gas price information. With the importance this appears to have, perhaps organizations like IFA, the European Fertilizer Manufacturers' Association (EFMA), or the like could develop a natural gas supply and price data base as a service to their members.

One word of caution should be given to those looking for sites to locate new ammonia production facilities. The idle capacity in the former Soviet Union and Eastern European countries is still in existence, and these plants could return to operation if the conditions are right or if the respective governments once again deem nitrogen fertilizer production to be a national priority.

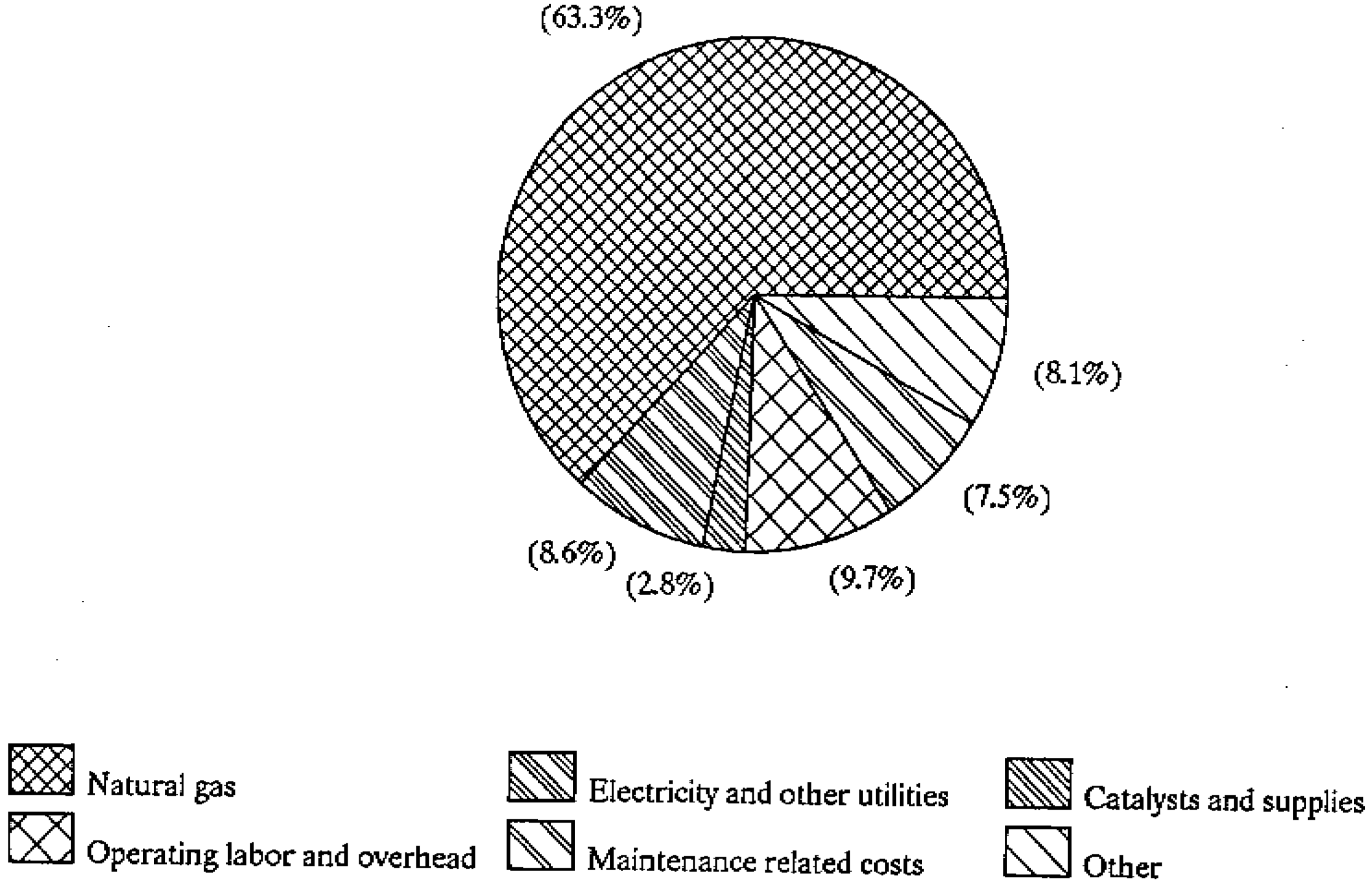
Figure 1. Regional Production of Nitrogen Fertilizers



IFDC – July 1996
Source: Food and Agriculture Organization (FAO) data

Figure 2. Distribution of Ammonia Production Cost

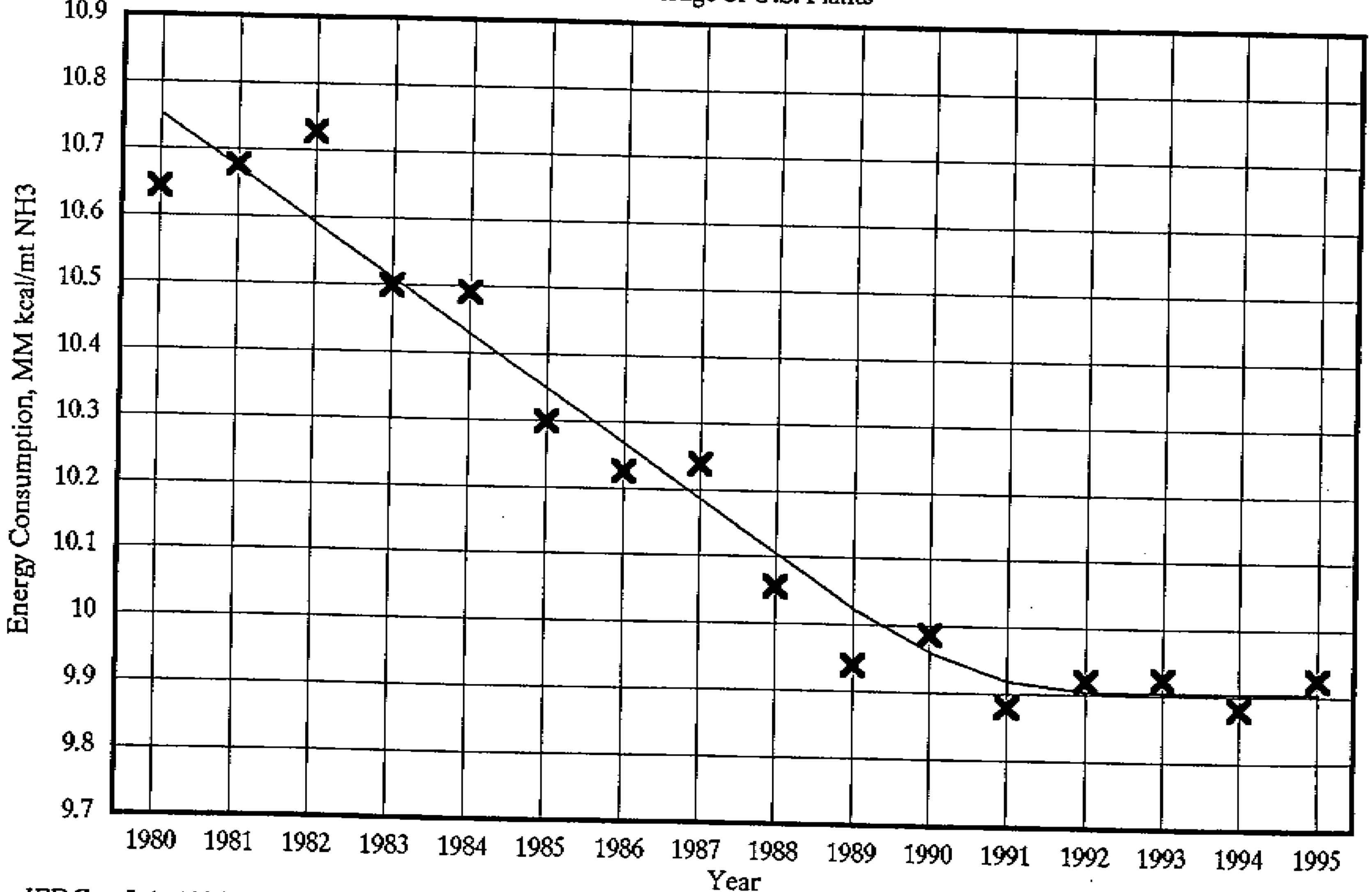
For an Average U.S. Plant in 1995



IFDC – July 1996
Source: The Fertilizer Institute (TFI) Production Cost Survey

Figure 3. Energy Consumption in NH3 Production

Average of U.S. Plants



IFDC – July 1996

Source: The Fertilizer Institute (TFI) Production Cost Survey.

MAJOR TECHNOLOGICAL IMPROVEMENTS FOR EXISTING AMMONIA AND UREA PLANTS

Although technology is available to decrease the natural gas consumption in most existing plants to levels of about 9 MM kcal/mt (or about 32 MM Btu/st), and new plants are presently being designed for consumptions of 7.2-7.8 MM kcal/mt (or 26-28 MM Btu/st) scattered data indicate that there are plants, particularly in the developing world, with much larger consumption. These could be in many cases considerably reduced by improving their capacity utilization. It has been indicated that a decrease of about 25% of the energy used in an ammonia-urea complex operating at a 60% capacity utilization could be obtained by reaching full capacity after implementing an effective preventive maintenance system and eliminating frequent shut-downs.

Retrofit Possibilities of an Existing Ammonia Plant

Most of the ammonia plants built 30 or even 20 years ago were of « conventional » design, which assumed a low cost for natural gas and, therefore, were not built to minimize the use of energy in general. Many of the energy-saving features of the new plants can be adapted to the older plants as modifications. Depending on the modifications chosen, referred to as « retrofits », overall energy consumption reductions in the order of about 15%/mt of ammonia can be achieved. At the same time, the adoption of specific retrofits usually allows an increase in plant capacity of up to 25% as compared to design. The costs of these retrofits are usually in the order of US $8 to $25 million.

Prior to performing the modifications, feasibility and characterization studies need to be performed on the particular unit to help select the retrofits that will yield economically attractive results and determine the extent of the retrofits and their integration to the rest of the plant. These studies will also generate information about the required investment costs for the different options considered. The main retrofits usually considered for an existing ammonia plant are as follows:

Installation of a Feed-Gas Saturator - A mixture of steam and natural gas with a volumetric ratio of steam to carbon of about 3.5:1 is reacted in the primary reformer of reforming ammonia plants. Most of the steam is generated from heat sources within the plant, but the balance of steam has to be produced in auxiliary boilers. This retrofit permits the use of low-level heat from the flue gases, which would otherwise be lost, to be used in saturating the feed natural gas with water. This generates extra steam which replaces some of the steam externally generated in the boiler, resulting in an energy saving of about 0.25 MM kcal/mt ammonia.

Modification of Convection Coils - As a result of other modifications, the temperature profile of the flue gases may change considerably in the cold-leg section of the primary reformer. This change can be compensated for by replacing the low steam superheat coil with a new one with additional rows of tubes and heavier fins on all tubes. When properly integrated with other plant modifications, energy savings in the order of about 0.22 MM kcal/mt ammonia can be achieved.

Boiler Feed Water Economizer - If the plant capacity is to be increased, improved control of the inlet temperature to the low temperature shift converter is essential to preserve catalyst life and optimize the process. This is obtained by the addition of a boiler feed water preheater exchanger upstream of the low temperature shift converter. Although this retrofit is basically needed for capacity increases, it will result in an energy saving of about 0.1 MM kcal/mt ammonia.

Low-Heat Removal of Carbon Dioxide - The traditional systems used for removal of carbon dioxide (CO_2) from the process stream uses hot potassium carbonate which requires heat for regeneration. This heat comes from process heat but needs to be supplemented with external steam. A new low-heat removal system is now available, which uses flashing for part of the regeneration process, and requires less external heat. When a proper integration of this system with the rest of the process is done, a potential savings of about 0.26 MM kcal/mt ammonia can be achieved.

Ammonia Converter Retrofit - The vertical quench-type converters are changed from axial flow to radial flow, greatly decreasing the pressure drop across the converter which in turn allows the use of smaller size catalyst with a larger surface area. This improved catalyst yields a higher conversion per pass, generating a lower recycle volume. The lower recycle volume and the lower pressure drop result in reduced energy requirements. This modification yields an increased effective capacity of the ammonia converter of about 35% and may represent an energy savings of about 0.25 to 0.40 MM kcal/mt ammonia.

Hydrogen Recovery From the Purge Gas - Inert gases must be purged from the plant to avoid their buildup in the system. This purge is carried out by removing a side stream of the synthesis gas after recovering the ammonia. By installing the proper recovery system, the hydrogen in this gas mixture can be recovered decreasing the energy requirements of the process by about 5% or permitting an increase of about 5% in production capacity.

Increased Supply of Process Air - By implementing the series of retrofits identified in the feasibility and characterization studies, an increase in capacity will very likely be achieved. This increase in capacity will require more process air to be fed to the plant. This additional air can be provided by either installing an additional small compressor in parallel with the main compressor, by modifying the internals of the main compressor, or by installing a booster compressor ahead of the main compressor. A comparative economic analysis of the three alternatives is required to determine the best option.

Addition of Process Computer - A dedicated process computer can be installed along with other online analysis and control systems to monitor and control key variables. With this system, continuous setpoint changes are possible to optimize the operation of several plant areas such as hydrogen/nitrogen ratio, steam/carbon ratio, synthesis loop purge, methane leakage, converter control, and refrigeration purge. A saving of about 0.15 MM kcal/mt ammonia is possible.

Retrofit Possibilities of an Existing Urea Plant - Most retrofits to urea plants are geared towards decreasing ammonia consumption, optimizing use, improving product quality, and decreasing emissions to the environment. As in the case of the ammonia plants, feasibility and characterization studies should be conducted to help select the modifications that will yield economically attractive results and to determine their integration into the rest of the process. Capital investments for revamping urea facilities are generally about US $6 to $25 million.

Increase in CO_2 Compressor Capacity - Probably one of the most expensive pieces of equipment in a urea plant is the CO_2 compressor. Because of this, the modification of this compressor or its replacement with a new unit of higher capacity and greater reliability will be one of the most expensive items in the revamping of a urea plant.

High Performance Reactor Trays - An improved design of the reactor trays, presently offered by several companies, can increase the plant capacity if complimentary capacity-related changes are performed in other equipment throughout the plant. It is conceivable that such a modification may lead to a capacity increase of about 35%. A decrease in ammonia consumption in the order of about 2% can generally be obtained.

High-Pressure Add-On System - This method removes the process limits in the high-pressure stripper and high pressure condenser by the installation of a parallel stripper and/or by installing additional reactor volume. This method allows for a capacity increase of up to 50% above the original plant capacity.

Additional Granulation Capacity - The extra urea synthesis plant capacity will have to be turned into a final product. If the extra synthesis capacity generated can be turned into a liquid solution (urea-ammonium nitrate [UAN], for example), no additional prilling or granulation capacity is required. If this is not the case, then the use of new technology prilling buckets of increased capacity or the installation of additional fluidized bed granulation equipment will have to be made.

Other Retrofits - Other common retrofits for urea plants include installation of ammonia/CO_2 ratio control systems; recovery of low-level heat; addition of hydrolyzer/stripper for recovery of condensate and to reduce pollution; and installation of a computer system for process control.