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INDUSTRIAL DEVELOPMENT OF THE NORTH-WEST REGION

DP/ARG/71/546

ARGENTINA

Technical report:
FEASIBILITY STUDY OF THE ESTABLISHMENT OF AN AMMONIA/UREA FERTILIZER PLANT

Prepared for the Government of Argentina by the
United Nations Industrial Development Organization,
executing agency for the
United Nations Development Programme

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Technical report: Feasibility study of the establishment of an ammonia/urea fertiliser plant

Prepared for the Government of Argentina
by the United Nations Industrial Development Organisation,
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Based on the work of Karl Kieldgaard, chemical engineer

United Nations Industrial Development Organisation
Vienna, 1977

Explanatory notes

A full stop (.) is used to indicate decimals.

A comma (,) is used to distinguish thousands and millions.

References to "tons" are to metric tons, unless otherwise specified.

References to dollars ($) are to United States dollars, unless otherwise stated.

The monetary unit in Argentina is the peso ($a). During the period covered by the report, the value of the $a in relation to the United States dollar was $US 1 = $a 250. The conversion rate used by the expert in this report is $US 1 = $a 217.

The following abbreviations are used in this report:

DAP	Diammonium phosphate
MAP	Monoammonium phosphate
Nm^3	Normal cubic meter
NOA	Noroeste Argentino (North-west Argentina)
NPV	Net present value
ppm	Parts per million
psig	Pounds per square inch guage
PVC	Polyvinyl chloride
PVI	Present value of investment
scf	Standard cubic feet
t/a	Tons per annum
t/d	Tons per day

ABSTRACT

The project entitled "Industrial Development of the North-west Region" (DP/ARG/71/546) forms part of a series of projects designed to promote the regional development of North-west Argentina. It originated in a request for UNDP assistance submitted by the Government of Argentina in December 1970 and approved in January 1972, with the United Nations Industrial Development Organization (UNIDO) designated as executing agency and the Ministry of Industry and Mining in co-ordination with the Dirección General de Fabricaciones Militares as government counterparts.

Within the framework of the overall project, the three-month mission covered by this report began in late September 1976. Its objective was to make a thorough study of the economic and technical feasibility of establishing a nitrogenous fertilizer plant in the north-west region. Its conclusions include the following:

1. In order to be viable and competitive, a nitrogenous fertilizer plant should have access to reliable supplies of local or imported raw materials and utilities at competitive prices, the best modern technology, highly skilled labour, and a reliable and efficient transport system ensuring a smooth flow of finished products to their markets.

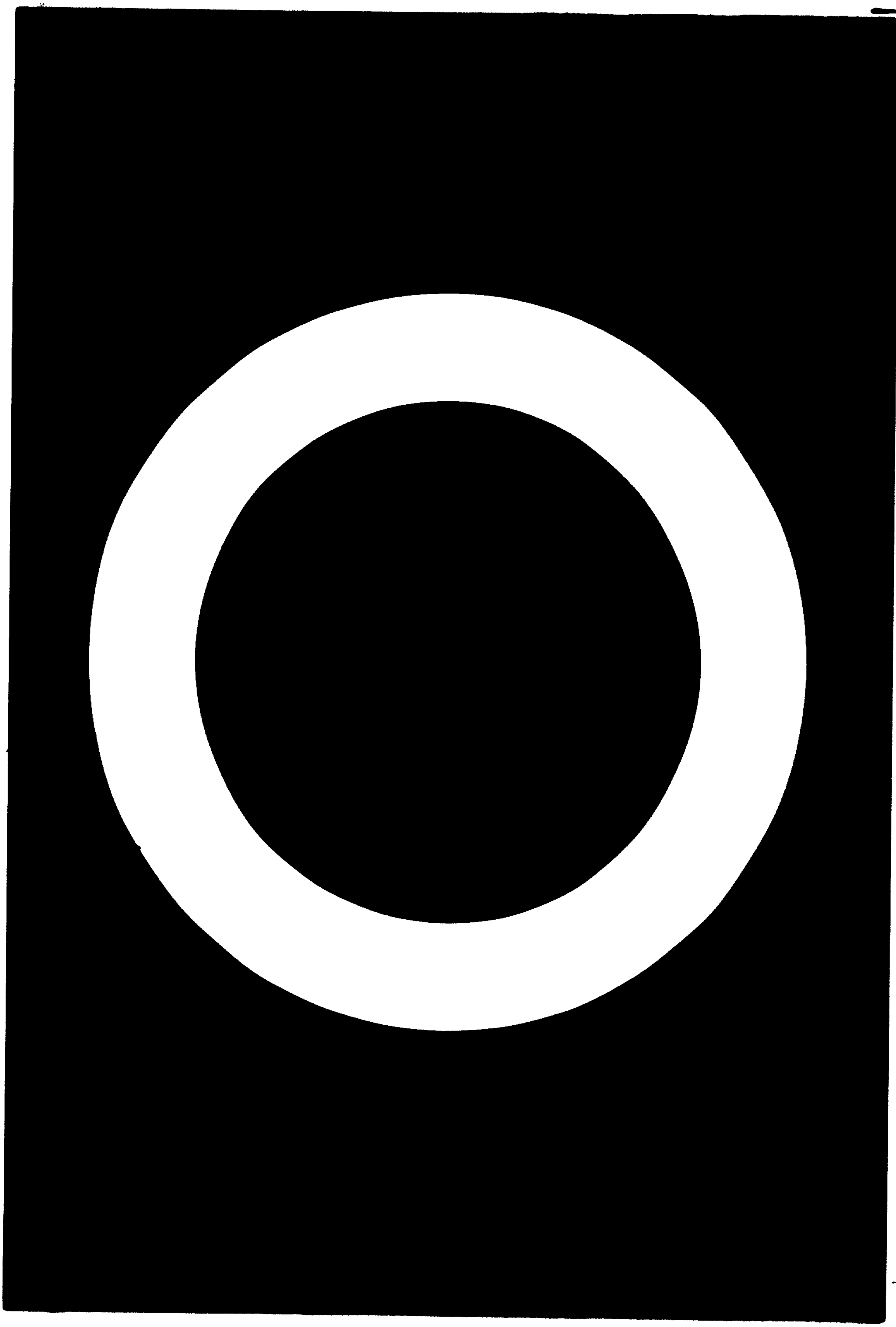
2. A large nitrogenous fertilizer plant based on a reasonably-priced natural gas and built by a reputable and experienced international contractor can be a sound and profitable business in Argentina, provided the market is big enough to justify the plant operating near its design capacity throughout the year, except during the normal annual overhaul and repair period of about one month.

3. Despite the potential availability of domestic and imported fertilizers at competitive prices in Argentina, fertilizer costs will remain significant, especially during poor harvest years caused by bad weather, plant diseases or pests. However, in a rich agricultural country like Argentina, the gains from using fertilizers should be much bigger than any profits arising from the domestic production of fertilizers.

The following recommendations are noteworthy:

1. In order to ensure the best competitive fertilizer prices to Argentine farmers and to safeguard the interests of both agriculture and the ordinary consumer, the development of domestic fertilizer production should be promoted together with the maintenance of a significant degree of freedom to import fertilizers.

2. The purchase and construction of the proposed ammonia/urea plant should be carried out following international competitive bidding by a limited number of highly qualified and reputable contractors. It is strongly recommended that financing institutions, including the World Bank, should be invited to review the preinvestment study before tenders are requested, in order to make sure that adequate financing will be provided under clearly defined terms. Prior to bidding, tender papers should also be prepared by consulting engineers and experts in order to ensure maximum competitiveness, the fullest use of modern technology, engineering and organizational methods, and the extensive use of domestic companies in the execution of the project.



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INTRODUCTION

The north-west region is a less developed part of Argentina with a potential for industrial development based on the availability of mineral resources such as natural gas, charcoal and sulphur. In August 1970 the Government of Argentina established a new programme for the industrialization of the area, and in December 1970 formally requested UNDP assistance in carrying out this programme. The request was approved in January 1972, and the long-term project entitled "Industrial Development of the North-west Region" (DP/ARG/71/546) (NOA IV - Industrial) was initiated in April 1972, with the United Nations Industrial Development Organization (UNIDO) designated as the executing agency and the Ministry of Industry and Mining in co-ordination with the Direción General de Fabricaciones Militares as the government counterparts. The project budget initially provided for a contribution of $715,200 by UNDP and $1,102,650 by Argentina. The purposes of the project were to study the feasibility and viability of new industries in north-west Argentina, with a view to producing a substantial increase in the employment opportunities and wealth of the region. NOA IV - Industrial forms part of a series of projects designed to promote the development of the north-west region. The other UNDP-financed projects are NOA I - Mining, NOA II - Forestry, and a general co-ordinating project, NOA - General.

Within the framework of NOA IV - Industrial a number of technical and economic studies have been undertaken, including the study contained in the present report on the economic and technical implications of establishing a nitrogenous fertilizer plant in the north-west region. The three-month mission covered by the report began in late September 1976.

In Argentina, as in other countries, there is considerable interest in the feasibility of using chemical fertilizers to increase agricultural production and farm earnings and to promote, as a result, a general improvement in economic conditions at both regional and national level. Serious consideration is being given to the possibility of establishing a competitive and reliable fertilizer manufacturing industry so as to increase the present, small amount of domestic fertilizer production, 1/ to enable Argentine farmers to meet their fertilizer requirements at the lowest possible cost, and to keep future fertilizer imports from reaching levels which could threaten the achievement and maintenance of competitive fertilizer prices on the local market. Fertilizer consumption in Argentina has been surprisingly low compared with that of the developed countries and given the great importance and large output of Argentine agriculture, 2/ which is one of the world's major foodstuff suppliers. Total annual fertilizer consumption throughout the country hardly exceeds 100,000 tons. A certain portion of these fertilizers is used in the Pampas and Mesopotamia regions, the main farmlands in Argentina, with relatively plentiful and regular rainfalls throughout the year, and with a temperate or subtropical climate. These two regions have great potential as sources of future fertilizer demand.

A major part of the present small total consumption of fertilizers is accounted for by the north-west (NOA 3/), Andina and Patagonia regions, and is mainly used for specialty crops such as tobacco, sugar cane, tomatoes, green beans, citrus and other fruits, and wine. However, owing to a scarcity of rainfall or drought during most of the year in many areas, and also

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1/ The annual domestic production, import, total consumption and regional distribution of fertilizers in Argentina during the years 1970-1975 are given in annex IV.

2/ Statistical data on the amount and distribution of agricultural land and cultivated areas, crop yields and agricultural commodity prices are on file at UNIDO and may be consulted upon request.

3/ NOA will be used in this report to designate North-west Argentina.

to cold weather in the South, these three regions, as fertilizer markets, will not be as large as the Pampas and Mesopotamia regions in the future.

The regional distribution of cultivated areas and pasture-lands in Argentina is shown in table 1 (census of 1960).

Table 1. Cultivated areas and pasture-land

Region	Cultivated areas (millions of hectars)	Pasture-land (millions of hectares)
Pampas and Mesopotamia	11.5	50
All other regions	1.9	75

On the other hand, the NOA region has a very intensive cultivation of specialty crops, some of which are used as raw materials for industry or exported. These include the following (with 1974/75 figures for areas under cultivation).

Crop	Area under cultivation (in hectares)
Sugar cane	316,000
Tobacco	37,000
Green beans	123,000
Vegetables	70,000
Citrus fruits	25,000
Total	571,000

In view of the importance of these crops in the NOA region, the increasing need for fertilizers must be assessed carefully by agronomists and experts, and the growers must be ensured adequate and competitive fertiliser supplies.

A summary of basic information about the present small domestic fertilizer production is given below:

1. Petrosur plant, Campana, Bueños Aires province, started in 1968. Process feedstock and fuel: natural gas. Fertilisers produced: urea, ammonium sulphate, liquid ammonia (excess not used for production of the first two products). Plant capacities:

Type of plant	Capacity
Ammonia	200 metric tons per day (t/d) of ammonia
Sulphuric acid	117 t/d of sulphuric acid
Ammonia sulphate	147 t/d of ammonium sulphate
Urea	162 t/d of urea

2. Petrosur granulation plant, Rosario of Santa Fé, started in 1968.

Raw material sources: Petrosur plant, Campana, Zapla plant, and imports

Fertilizers produced: NPK compounds

Plant capacity: 30,000 metric tons per annum (t/a) of NPK

3. Plant of the Dirección General de Fabricaciones Militares, Río Tercero, Córdoba province, started before 1955.

Process feedstock and fuel: coal and charcoal

Fertilizer produced: ammonium sulphate

Plant capacities:

Type of plant	Capacity
Ammonia	20 t/d of ammonia
Sulphuric acid	40 t/d of sulphuric acid
Ammonium sulphate	60 t/d of ammonium sulphate

4. Plant of the Dirección General de Fabricaciones Militares, Altos Hornos Zapla, Palpala, Jujuy province.

Type and amount of fertilizer produced: approximately 13,000 t/a of Thomas phosphate slag (16% P_2O_5).

5. Sociedad Mixta Siderúrgica, San Nicolás, province of Buenos Aires;

Fertilizer produced: 6,000 t/a of ammonium sulphate as by-product from coke-oven operation.

SUMMARY

An introduction to the three main fertilizer nutritional elements, nitrogen (N), phosphorus (P) and potassium (K), and some of the micronutrients required for plant growth is given in chapter II. It is pointed out that intensive farming requires the addition of the major elements and the micronutrients to the soil in the form of chemical fertilizers, taking into account soil characteristics, soil virginity, crops, crop rotation, climatic conditions etc. Fertilizers must be added, for example, to improve crop yields in areas or countries where cultivation has taken place for many years.

Finally, chapter II lists the many grades of fertilizers and fertilizer intermediates available on the world market.

The fertilizer manufacturing industries and various technologies developed in the past or which are currently feasible are outlined in chapter III. The development and improvement of the technology of ammonia production in the early 1960s is explained. These technological innovations are valid only for plants of a capacity of at least 600 tons of ammonia per day. Recent developments in the design of ammonia synthesis-gas centrifugal compressors may have made it possible to lower this minimum limit to approximately 500 t/d. However, this design change makes large-capacity ammonia plants appreciably more economic in terms of manufacturing cost than smaller-size plants.

Chapter III refers to the many large ammonia plants constructed throughout the world during the past ten years and which use natural gas as process feedstock and fuel. Under special circumstances, a few large ammonia plants using naphtha, fuel oil or carbon have also been built within the past ten years. Most plants built during the same period for conversion of liquid ammonia into solid fertilizer use the urea process.

Chapter III also states that most phosphate rock treatment plants established in recent years produce phosphoric acid, MAP, DAP etc., to be sold as intermediates to other fertilizer industries for manufacturing NPK compound fertilizers or to be sold as straight fertilizers. NPK compounds are [illegible] over to straight fertilizers, and are produced in order to simplify and economize application work in the fields. It is noted that there is at present a clear tendency to integrate the mining operation with the processing of phosphate rock into intermediates. Finally, chapter III also describes [illegible] granulation, bulk-blending and liquid-mix plants for the manufacture of NPK compound formulations, and outlines the development of this branch of industry in the United States during the past decade.

The import of fertilizers provides an alternative to domestic production. Chapter IV describes how fertilizers are purchased on the world market and how savings in the overseas shipment of commodities can be effected. The changes in the world market price of ammonia and urea during recent years and the causes of these changes are surveyed.

Chapter V deals with the infrastructure required for the satisfactory transport, storage and distribution of locally-produced or imported fertilizers to farmers within the short fertilizing season. The fertilizer grades supplied must of course respond to agricultural demand, which will depend upon many factors.

In chapter VI it is pointed out that experimental fertilizer field trials should be carried out in experimental stations operated by the Government and by farmers' co-operatives, and that agricultural advisors are needed to render consultancy services to farmers and ensure optimal fertilizer use. The

fertilizer types supplied will have to comply with certain practical guidelines and methods of application discussed in chapter VI, which also reviews the implications of the biuret by-product of urea. Finally, chapter VI stresses the importance of suitable mechanical applicators, lorries, and tractors for fertilizer application.

Chapter VII contains an economic evaluation of the capital and production costs of an ammonia/urea plant. In each case considered in chapter VII the urea plants are big enought to convert all the ammonia produced into urea, assuming that no liquid ammonia will be sold directly to the farmers. This may not at all be true for a future ammonia/urea plant in Argentina, so that correspondingly less capital will be needed. The capital costs for four alternative process feedstocks and fuels (natural gas, naphtha, fuel oil and carbon or charcoal) and four sets of plant capacities are detailed in table 6 of chapter VII. The figures for the two larger plant sizes have been evaluated by UNIDO, while the capital costs for the two smaller plant sizes are indicative and have been only roughly estimated. The figures assume an ample supply of make-up water for process and cooling purposes in a warm climate, that is, about 6,000 m^3/d throughout the year for a 600 t/d ammonia and 1,030 t/d urea plant. They do not include any extras, should the supply of water be scarce or impure, for investments in air coolers and water recovery. As the temperature of the circulated cooling water from the atmospheric cooling towers depends on atmospheric conditions, the cooling water will become colder in a colder climate and involve substantial savings in the capital cost of compressors, ammonia synthesis units etc. A reduction of the cooling water temperature by 5°-$10^\circ C$ could mean a decrease in overall investments by up to 10%, assuming that there is enough pure make-up water. On the other hand, if the make-up water supply is scarce, but must still remain above an absolute minimum of about 2,000 m^3/d for the above-mentioned plant size to allow the plant to operate, up to 20% in extra investments will be required for air coolers, which are large consumers of electricity.

The capital costs are based on the process equipment price level of December 1975, and do not include any subsequent price escalation. Nor do the capital costs contain any contingencies for ex-battery-limit off-sites, such as natural gas pipelines, booster compressors, electricity supply lines, water supply lines and pumps, chemical treatment of make-up cooling water, biological treatment plant and lagoon for effluents, roads, railway connections etc., for which millions of dollars in extra investments may have to be added.

The total capital costs for the process and utilities plant units within battery limits are summed up in table 2.

Table 2. Capital cost estimates

Capacity (t/d)		Capital costs within battery limits at December 1975 prices (in millions of $US)			
Ammonia	Urea	Natural	Naphtha	Fuel oil	Coal for charcoal
1,000	1,720	179	199	221	274
600	1,030	124	137	153	202
300	515	87	95	105	134
150	257.5	55	60	66	84

The annual urea production of plants operating at stream factors of 90% or 84% is given in table 3.

Table 3. Annual production estimates

Capacity (t/d)		Annual production of urea for each process (in thousands of tons)			
		90% stream factor			84% stream factor
Urea	Ammonia	Natural gas	Naphtha	Fuel oil	Coal or charcoal
1,000	1,720	516	516	516	483
600	1,030	310	310	310	290
300	515	155	155	155	145
150	257.5	77.5	77.5	77.5	72.5

The slightly lower stream factor given in table 3 for coal-based plants is due to the longer shut-down and repair periods required by such plants.

The specific production costs in dollars per ton of urea have been calculated for the four alternative process feedstocks and fuels, and the four sets of plant capacities on the basis of fuel prices and production and marketing ratios. These production costs are detailed and listed in tables 6, 7 and 8 of chapter VII.

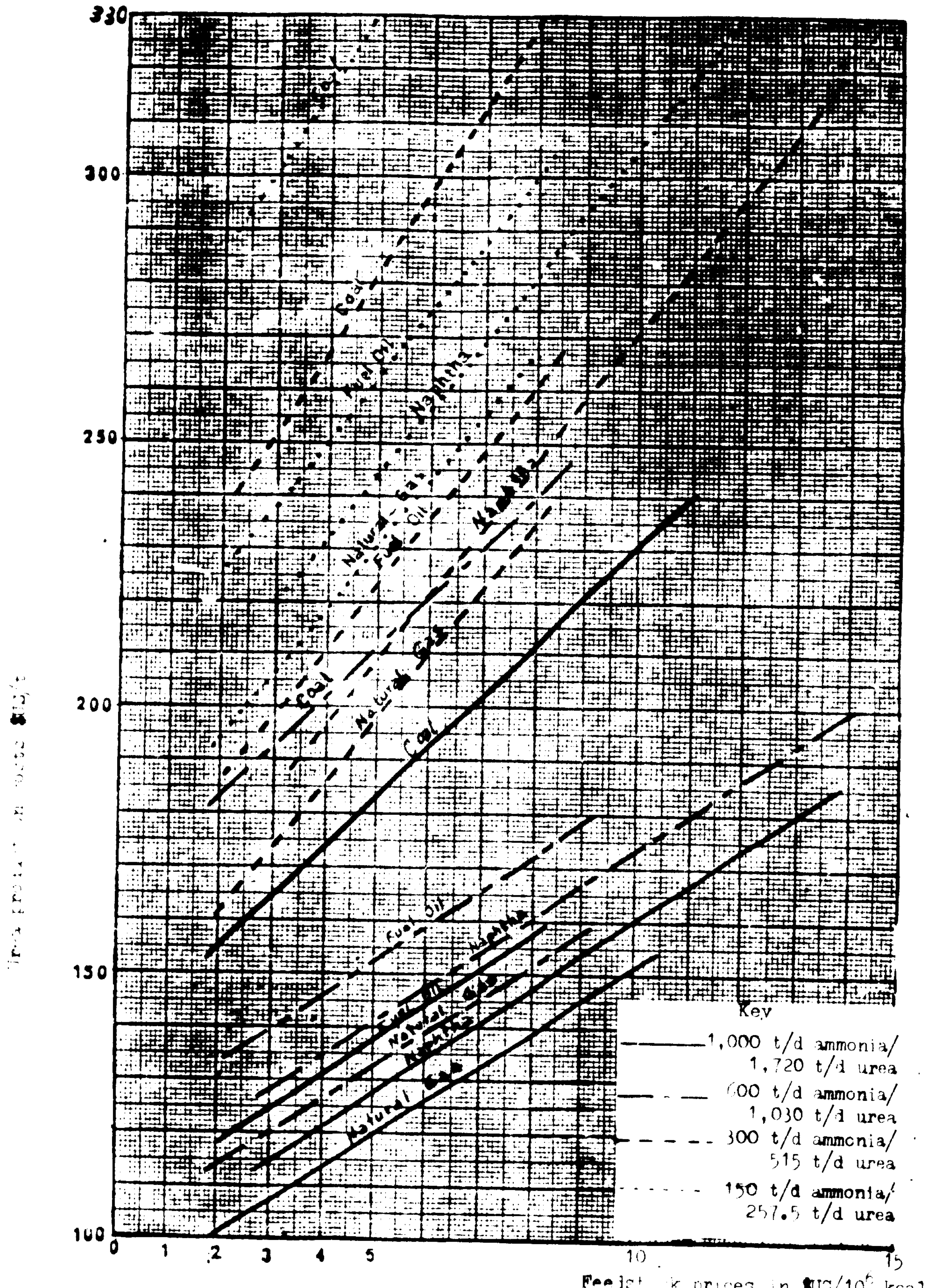
Table 9 of chapter VII gives the prevailing prices of the four raw materials in Argentina at the beginning of November 1976. Table 10 of chapter VII shows the total and the breakdown of the energy consumption figures on the basis of the four alternative raw materials and the four sets of plant capacities. Compared with typical world prices, the domestic natural gas price is at about the same level, whereas the prices of naptha and fuel oil are very low, and that of charcoal is extremely high.

The specific electricity consumption of the two smaller plants will always be much higher than that of the two larger plants, as reflected in table 10 of chapter VII. Some electricity may be saved by using steam-turbine air drive and refrigerant ammonia centrifugal compressors, but this would require larger package steam boilers and more fuel for the boilers. Steam turbine drive through reduction gears of reciprocating synthesis gas and recycle compressors have very rarely been used, but might be feasible. It would however require a big investment for the reduction gears and additional package boilers.

To supplement the above-mentioned tables 6, 7 and 8 the production costs in dollars per ton of urea are shown in figures I and II as a function, on the one hand, of plant capacity, a fixed 90% (or 84% for coal) stream factor and feedstocks and feedstock costs in $/10^6 kcal, and on the other hand, of plant production (plant capacities multiplied by varying stream factors) and feedstocks at fixed feedstock prices in $/10^6 kcal.

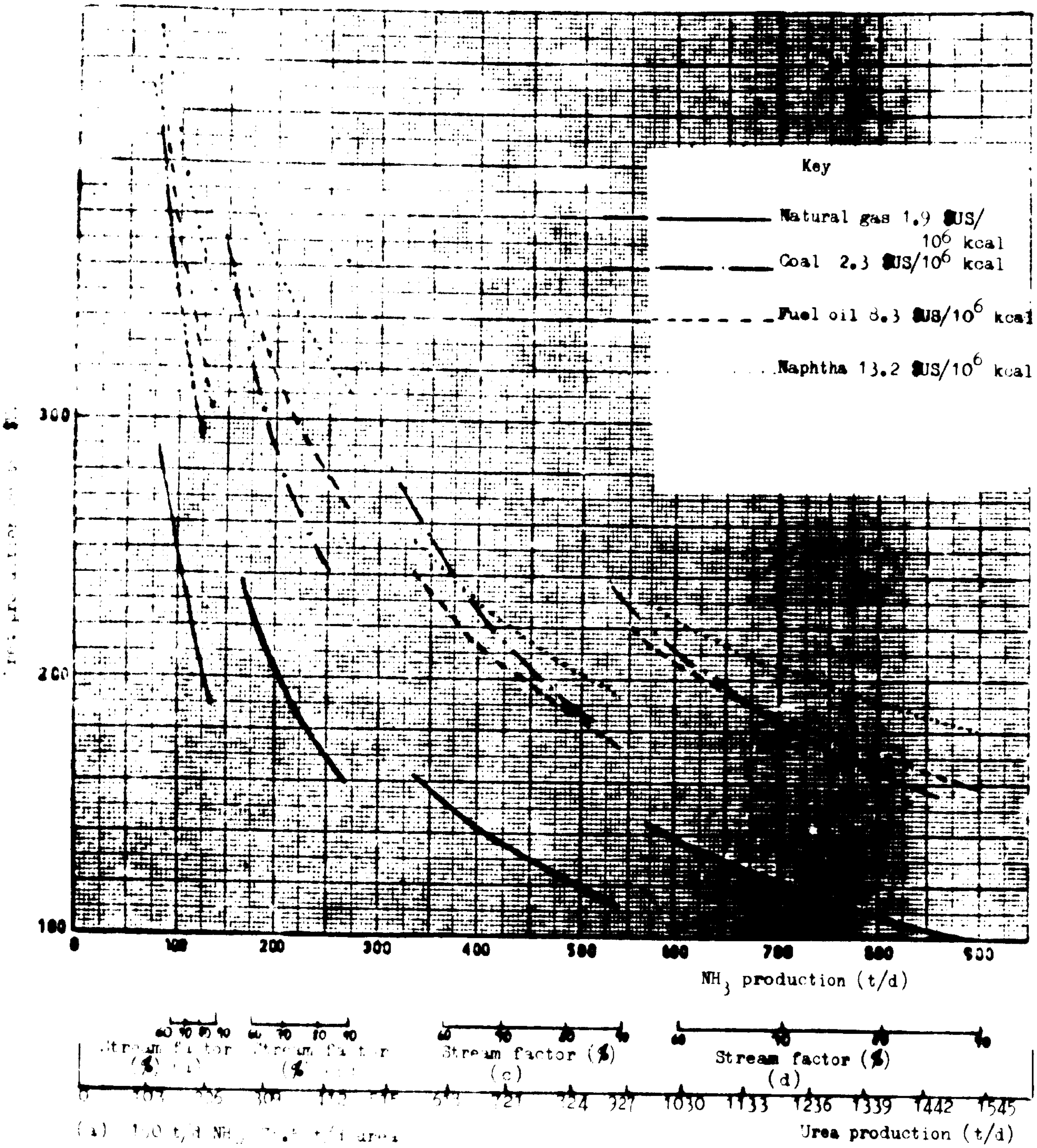
Production costs as a function of stream factors and feedstock prices prevailing in early November 1976 are given in table 4 below.

Figure I. Urea production costs in relation to feedstock costs



Stream factor: [illegible]% for natural gas, naphtha, fuel oil and [illegible]4% for coal

Figure 11. Urea production costs in relation to feedstock capacity



(a) 100 t/d NH_3/[illegible] t/d urea

(b) 300 t/d NH_3/[illegible] t/d urea

(c) 500 t/d NH_3/[illegible] t/d urea

(d) 1,000 t/d NH_3/[illegible] t/d urea

Table 4. Production costs as a function of stream factors and feedstock prices

Plant capacities[a] (t/d)	Production costs ($/ton of urea)			
	Natural gas ($4.7/10[6] kcal) (north of the Rio Colorado)	Naptha ($3.4/10[6] kcal)	Fuel oil ($2.6/10[6] kcal)	Coal or charcoal ($9.6/10[6] kcal)
		Stream factor: 90% (84% for coal)		
A	118	118	122	227
B	131	131	138	256
C	195	138	194	356
D	228	224	233	406
		Stream factor: 80% (74% for coal)		
A	128	129	134	244
B	142	143	152	277
C	211	205	212	382
D	248	246	257	439
		Stream factor: 70% (64% for coal)		
A	140	142	149	270
B	156	159	170	304
C	231	227	237	416
D	274	273	288	482
		Stream factor: 60% (54% for coal)		
A	157	160	169	301
B	175	180	193	341
C	158	256	269	463
D	308	309	329	541

a/ Four plant capacities are considered: 1,000 ammonia/1,720 urea (case A); 600 ammonia/1,030 urea (case B); 300 ammonia/515 urea (case C); 150 ammonia/257.5 urea (case D).

In table 11 of chapter VII a series of cash flows have been calculated for a complete 600 t/d ammonia and 1,030 t/d natural-gas-based urea plant, in order to determine profits before tax and profits after tax at high and at low tax discount rates, assuming urea ex-factory sales prices and maximum stream factors of respectively $160/ton and 90%, $180/ton and 90%, and $200/ton and 90% or 65%. The calculations also include the respective pay-back periods, present value of the investment (PVI), net present value (NPV), NPV/PVI and internal rate of return.

In all cases, straight-line depreciation over 12 years, cash investment during the 3 years' delivery and construction period, a 12 years' operation period and a present worth factor of 10% per annum have been envisaged. A natural gas price of $0.043/Nm^3 for a heat value of 9,300 kcal/Nm^3, or $4.6/10^6 kcal, is entered in the calculations. The results and calculating procedures are apparent from table 11 of chapter VII.

As a supplement to table 11, the calculated results are shown in the figures III and IV.

The results of the cash flow calculations for a present worth investment of $104.2 million are summed up in table 5.

Table 5. Cash flow estimates

Profits 1/	Pay-back period (years)	Present worth net value (10%) (in millions of $)	PWNV (10%) /PWI	Internal rate of return (% per annum)
Urea sales price: $160/ton; maximum stream factor: 90%				
A	8.1	35.6	0.34	14.6
B	8.1	29.0	0.28	13.9
C	11.8	8.8	0.08	11.2
Urea sales price: $180/ton; maximum stream factor: 90%				
A	6.5	63.1	0.61	17.7
B	6.5	54.8	0.53	16.8
C	8.0	34.0	0.33	14.0
Urea sales price: $200/ton; maximum, stream factor: 90%				
A	5.5	91.1	0.87	18.0
B	5.5	80.9	0.78	17.0
C	6.8	49.4	0.47	16.5
Urea sales price: $200/ton; maximum stream factor: 65%				
A	7.5	40.3	0.38	15.5
B	6.7	34.4	0.33	15.0
C	9.7	14.2	0.14	12.1

1/ Three cases are considered: profits before tax (case A); profits after low tax (case B); profits after high tax (case C).

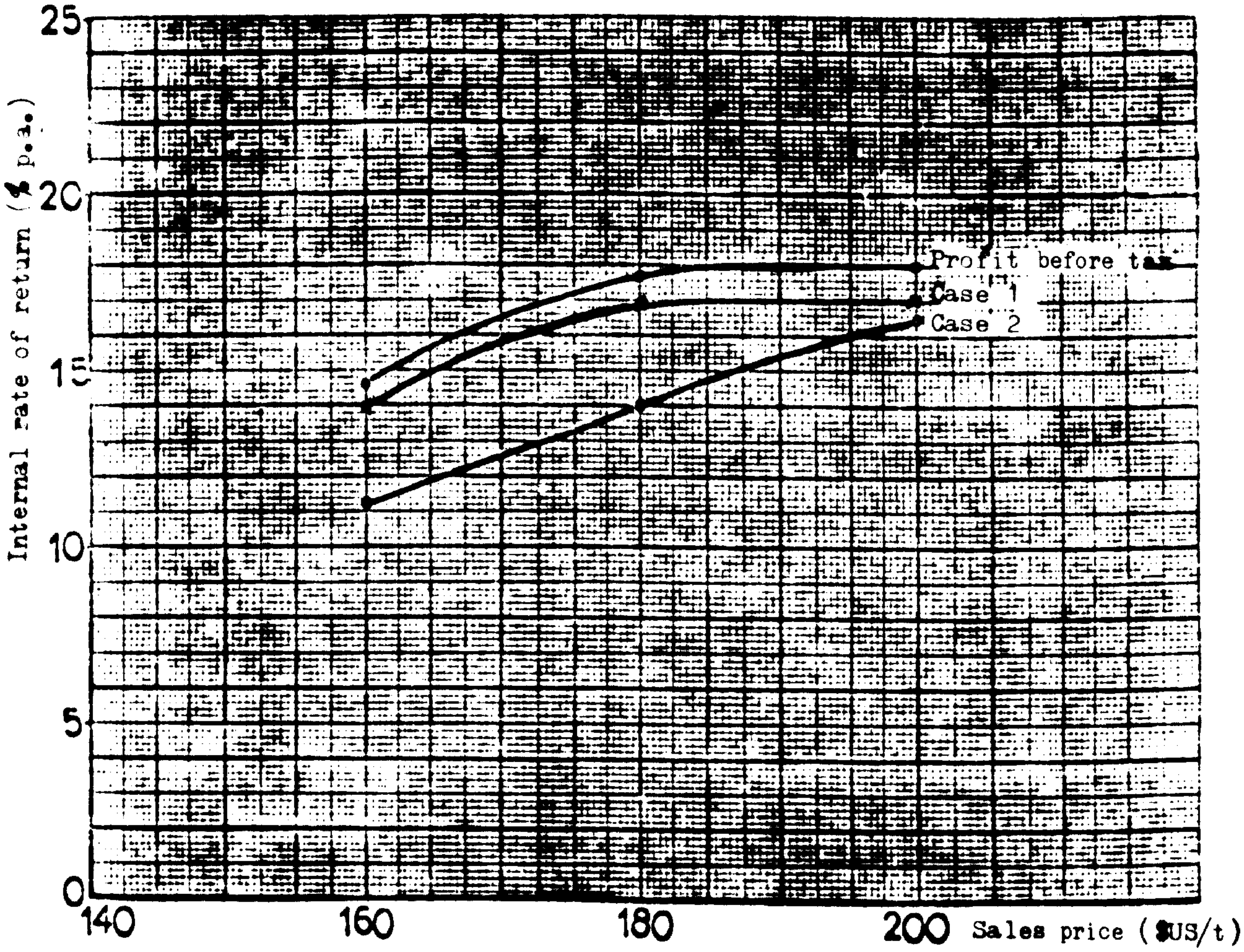
The required raw materials, utilities, climatic conditions and site for the design, are defined in chapter VIII.

The codes and standards for the design and construction of an ammonia/urea plant are discussed in chapter IX, with particular emphasis on its economic aspects and its relationship with the domestic manufacture of equipment and spare parts.

Chapter X contains an introduction to the environmental aspects of the design and operation of an ammonia/urea plant. The sources of aqueous effluents, gaseous exhausts and noise, and the sewer system of such a plant are explained. The sensitivity of effluent recipients is discussed. In addition, the limits to the contents of impurities in effluents sent to biological treatment plants or discharged into rivers and lakes and the general tolerance levels of biological treatment plants are considered.

Chapter XI describes in some detail the steps involved in the planning and implementation of the programme of preinvestment studies, tendering, design, delivery, construction, and operation of an ammonia/urea plant.

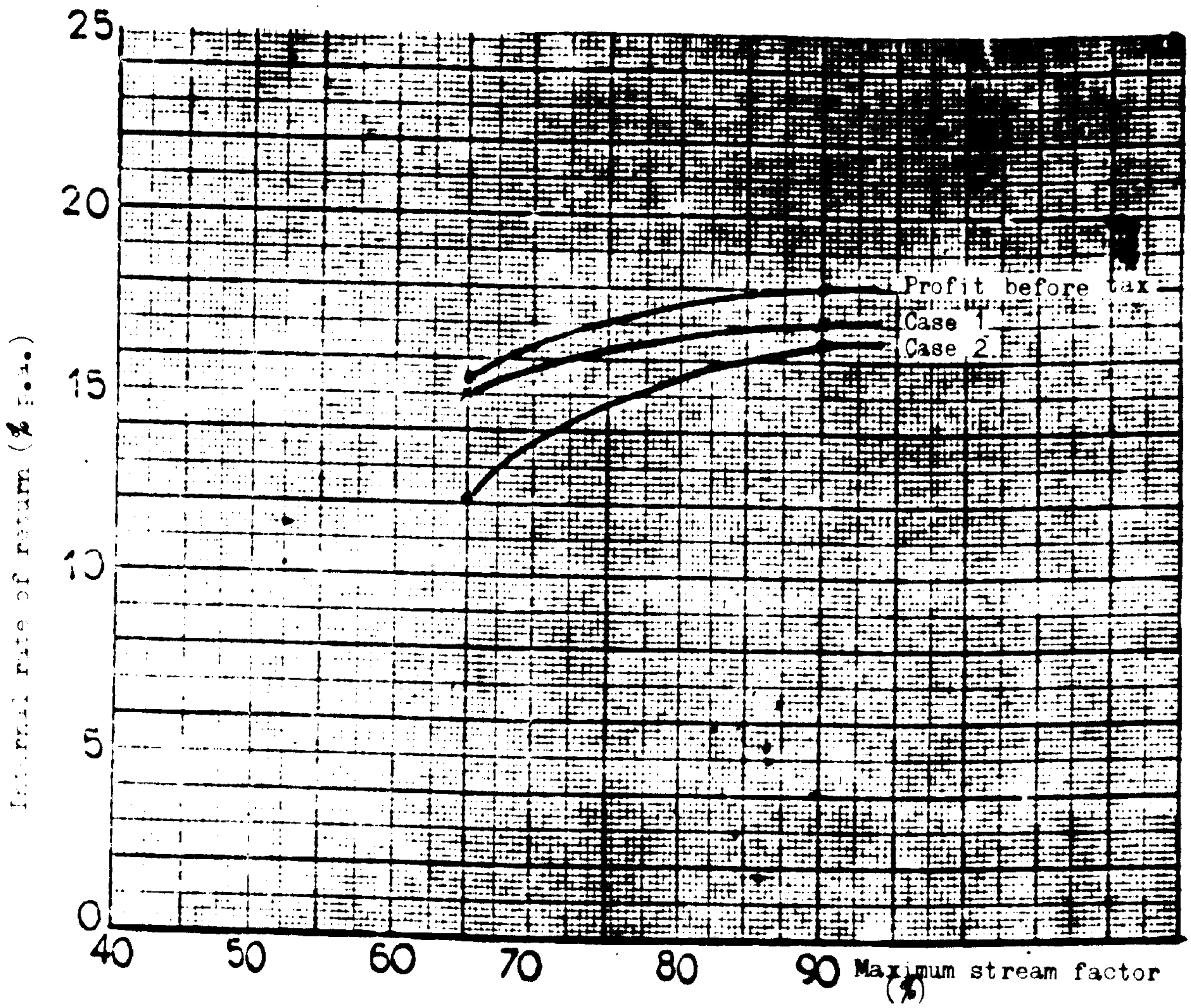
Figure III. Internal rate of return in relation to sales price



Maximum stream factor: 90%

Plant size: 600 t/d ammonia/1,030 urea

Figure IV. Internal rate of return in relation to maximum stream factor



Sales price: $US 200/t

Plant size: 600 t/d ammonia/1,030 t/d urea

I. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Despite the potential availability of domestic and imported fertilizers in Argentina at competitive prices, fertilizer costs will remain significant, especially during poor harvest years caused by bad weather, plant diseases or pests. However, in a rich agricultural country like Argentina, the gains from using fertilizers should be much bigger than any profits arising from the domestic production of fertilizers. Such considerations should be borne in mind in the taxation of agricultural earnings. In particular, the direct taxation of sales revenues before allowances for operational costs such as fertilizer purchases will deter farmers from making the optimal use of fertilizers, and therefore restrict the possibilities for agricultural development and increased production. The degree of fertilization will ultimately depend on crop yields, fertilizer prices and net agricultural earnings.

2. In order to promote agricultural production through the use of fertilizers in Argentina, farmers must be provided with reliable and easily comprehensible experimental data based on fertilizer field trials, which would help them to evaluate the possible advantages of fertilizer use. Numerous government experimental stations are already established in Argentina under the authority of the Instituto Nacional de Tecnología Agropecuaria (INTA) (National Institute of Agricultural Technology), and other stations may be set up by farmers' co-operatives, which should also be represented in the government stations.

3. Despite the very high fertilizer price levels reached on the world market in 1974, there are several reasons to believe that the fertilizer prices of late 1976, possibly with a slow increase, will be typical of the next few years. During the months shortly before the drafting of this report, both ammonia and urea were quoted on the world market as low as $130 per ton, ex factory or f.o.b. Shipment to Argentina might therefore cost no more than $20 to $30 per ton of fertilizer.

4. Increasing fertilizer consumption in Argentina will require investment in transport infrastructure and storage facilities to ensure the timely and reliable transfer of fertilizers from domestic producers or ports of arrival to storehouses and their subsequent distribution to farmers prior to and during the short fertilizing season. It will also provide a powerful stimulus to the domestic mechanical industry in the development, design and manufacture of fertilizer application equipment. This is but one example of how a developed and prosperous agricultural sector can create business and employment for the domestic manufacturing industry, which, besides supplying the home market, may become exporters of the equipment and machinery involved.

5. Fertilizer types, the required nutrients, fertilizer prices per ton of each nutrient, and conditions of delivery are important factors to consider in the selection of fertilizers, and will depend upon soil characteristics, climate, fertilizing efficiency, ease and economy of application, spreading equipment etc.

6. In the design of an ammonia/urea plant it is very important to know whether all the ammonia produced is to be converted into urea, or a part of the ammonia is to be sold directly to the farmers, with a corresponding reduction in the capacity and capital cost of the urea plant. It must also be considered whether a portion of the urea has to be low in by-product biuret for special fertilizing purposes, since this would imply in the design of the urea plant a substantial increase in capital cost (possibly $5 million or more).

7. A modern nitrogeneous fertilizer industry will produce ammonia and urea in accordance with production practice followed in most countries during the past 10 years. In this connection, a few plants in the United States have been producing both urea (U) and ammonium nitrate (AN) for UAN solutions as intermediates and raw materials for the large number of liquid-fertilizer mix plants in the United States. However, the simultaneous production of ammonium nitrate and urea may not be feasible in Argentina. On the other hand, an ammonia/urea plant in Argentina could deliver all its products directly to the farmers, or a part of them to granulation plants, bulk-blending plants, or liquid mix plants for the manufacture of NPK compound fertilizers.

8. In order to be viable and competitive, a nitrogenous fertilizer plant should have access to reliable supplies or local or imported raw materials and utilities at competitive prices, the best modern technology, highly qualified skilled labour and a reliable and efficient transport system ensuring a smooth flow of finished products to the marketing outlets.

9. A nitrogeneous fertilizer industry should have an adequate size, be well-sited and make use of modern technology and the most suitable raw material, which in the case of Argentina is natural gas, supplies of which must reach the plant at acceptable pressure and purity levels. Alternative raw materials are naptha, fuel oil, and carbon or charcoal. Although the domestic prices of naptha and fuel oil in Argentina are very low compared with international market prices in general, neither of these two raw materials would lead to lower manufacturing costs of nitrogeneous fertilizers than natural gas. Moreover, even at low coal or charcoal prices, the manufacturing of nitrogeneous fertilizers on the basis of these raw materials would result in unacceptably high production costs.

10. In addition to the choice of the raw material, the manufacturing cost of nitrogeneous fertilizers depends largely on the size or capacity of the fertilizer plant. Only large capacity plants will be able to produce competitively by world market standards. On the other hand, a large nitrogenous fertilizer plant based on a reasonably-priced natural gas and built by a reputable and experienced international contractor can be a sound and profitable business in Argentina, if a sufficiently big market can be secured to make the plant operate near its design capacity throughout the year, except during the normal annual overhaul and repair period of about one month. Owing to the high capital cost of the plant, it cannot be operated economically at a low utilization rate of its capacity. A minimum of 60% to 80% of its production capacity must be sold on the domestic market, but the income of the plant may be improved by selling marginal production on the world market at an ex-factory price, which should be well above the variable manufacturing costs, without necessarily including all the fixed operating and capital costs.

11. In selecting the plant site, the cost of transporting huge quantities of fertilizers from factory to marketing centres must be the subject of a detailed logistic analysis. For instance, a $5 per ton difference in transport for an annual total of 300,000 tons would amount to $1.5 million a year. The plant site must have reliable large-capacity rail and road connections to all potential markets. It should be noted that there may be no alternative to the transport of liquid ammonia by rail over long distances, since the long-distance transport of liquid ammonia by road may be prohibited.

12. Farmers would be extremely reluctant to buy NPK compound fertilizers at a price which would largely offset the saving arising from the simplified method of application. NPK compound granulation plants can meet this price constraint only if they are big enough to supply a large market area. On the other hand,

small bulk-blending or liquid mix plants producing NPK formulations can be established in market areas with a radius of up to 30 km, provided the NPK formulations are in extensive use among farmers in the local districts concerned. The selection between the three categories of NPK production plants and products must take into account formulating and manufacturing costs, marketing and distribution problems, and methods of application. Transport costs in local districts will be small, and the farmers' choice of fertilizers will chiefly depend on the ex-factory prices and the methods of application.

13. Liquid ammonia will be used in granulation or liquid mix plants to the extent that an equivalent amount of phosphoric acid is applied as raw material in the formulation process. A granulation plant is most suitably placed adjacent to the ammonia/urea plant to ease the transport of the liquid ammonia and urea melt raw materials for granulation. Liquid mix plants established in local districts will receive urea in solid form for dissolution and formulation. However, for this purpose the quantities of urea involved do not need to be delivered as prills, but can be supplied as crystals. This implies a cheaper solidification process and a corresponding reduction in the capacity and capital cost of the prilling section of the urea plant.

Recommendations

1. In order to ensure the best competitive fertilizer prices to Argentine farmers and to safeguard the interests of both agriculture and the ordinary consumer, the development of domestic fertilizer production should be promoted together with the maintenance of a significant degree of freedom to import fertilizers, possibly through the initiative of farmers' co-operatives.

2. In each local district, the farmers' co-operatives should seek the services of a highly qualified agricultural advisor or agronomist to visit the farms, carry out demonstrations in the fields, and convey and explain the test results from the experimental stations.

3. Highly qualified experts should be appointed to study the plant design and construction codes and standards applied by most international chemical industry companies, and the specific codes and standards required by the proposed project and future plants or installations in Argentina should be selected.

4. In addition to the measures taken to ensure the environmental protection of rivers or lakes used as recipients of the aqueous effluents of the ammonia/urea plant, adequate washing equipment should be installed at the top of the urea prilling towers to prevent the discharge into the atmosphere of a fume containing urea dust which may be carried by the wind and cause considerable inconvenience to villages and towns many kilometres away.

5. It is highly recommended that the proposed ammonia/urea plant should have its own electric power station, unless an external electricity supply of 100% reliability can be secured for the plant. Even one short failure once a month of an external electricity source should be regarded as unacceptable. Moreover, even if the plant has its own electric power station, it (the plant) should also be connected to an external system if possible, so as to minimize the risk of plant shut-downs due to electricity failure.

6. The purchase and construction of the proposed ammonia/urea plant should be carried out following international competitive bidding by a limited number of highly qualified and reputable contractors. It is strongly recommended that

financing institutions, including the World Bank, should be invited to review the preinvestment study before tenders are requested, in order to make sure that adequate financing will be provided under clearly defined terms. Prior to bidding, tender papers should also be prepared by consulting engineers and experts in order to ensure maximum competitiveness, the fullest use of modern technology, engineering and organizational methods, and the extensive use of domestic companies in the execution of the project.

II. PLANT NUTRIENTS AND FERTILIZERS

A. Nutritional elements of plants

Some fifteen elements are known to be essential for plant growth. Except for oxygen, carbon and hydrogen, which are supplied mainly from air and water and converted by the plants through photosynthesis of carbon dioxide and water into carbohydrates and fats etc., these elements are obtained through the plant roots from the organic and material substances in the soils. The three elements having the greatest effect on plant growth are nitrogen (N), phosphorus (P), and potassium (K). All three elements are essential to plants, but nitrogen is the most important one. Depending upon the characteristics of the soil these elements are slowly liberated as soluable chemical compounds from the organics and minerals of the soil. Part of the soluble components will remain chemisorbed by the soil and become available to the plant roots, and part of the liberated components will be depleted from the soil through the flow and action of rainwater and removed with the surface and ground water.

Virgin land where cultivation is initiated may be rich in nutritional components and may yield satisfactory harvests for a number of years. When previously cultivated land is lying fallow, the gradual and slow liberation of the nutritional components will go on and the components will start to accumulate in the soil. After some years in fallow, cultivation of the land may be resumed for a limited number of years until a new fallow period becomes necessary.

The nitrogenous nutrients in virgin soil originate partly from inorganic components formed in the atmosphere and brought to the soil with the rain and from biochemical conversion of the nitrogen of the air in the cavities of the soil. The enrichment goes on eternally, but is a slow process. The nutrients will be absorbed by the vegetation, and to some degree return to the soil through putrefaction of dead plants. Depending upon the climatic conditions, virgin soils may become rich in nitrogen, but will gradually be depleted through cultivation. Additional nitrogenous nutrients will be formed in the soil during cultivation or crop rotation with leguminous plants (such as lucerne). The nutritional components of phosphorus and potassium existing in virgin soil all originate from the degradation of the minerals of the soil, and the contents of those components will depend upon the soil and mineral characteristics.

When the land is continuously cultivated it is necessary to add nutritional elements to the soil in the form of manure and chemical fertilizers in order to secure an adequate supply of the elements necessary to meet production requirements. As livestock manure contains only a very reduced portion of the original fodder nutrients, the addition of manure will not be sufficient. Artificial fertilizers must also be used. Normally, nitrogen-containing fertilizers will be required first, unless the soil is poor in phosphorus and potassium. After the soil has been cultivated or lain fallow for a few years phosphorus-containing fertilizers will also be necessary. After about 25 years of continuous cultivation the addition of potassium-containing fertilizers may have an impact on crop yields. Many soils contain relatively high amounts of potassium and may not need the addition of potassium even after a prolonged crop production period.

Besides the three major elements, plants need micronutrient elements such as calcium, magnesium, sulphur, copper, manganese, boron, zinc, iron, selenium etc., which may have to be added through fertilization to cultivated soil. Certain tree crops need appreciable quantities of magnesium.

Regulation of the acidity of the soil may become feasible and necessary, and is done by spreading marl, limestone etc., if the soil is acidulous, or sulphur or sulphur-containing fertilizers (sulphates) if the soil is alkaline.

As mentioned above, both calcium and sulphur are important micronutrients. For instance, sulphur availability may ensure or limit the full utilization of nitrogen by the plants, and a deficiency in sulphur may restrict the plants in such a manner that they produce plant proteins of less biological value to animals and humans.

B. Fertilization

Fertilization should be carried out at rates which are economically advantageous. The increased yields must more than compensate the cost of the fertilizers. Fertilization ought not to be done beyond rates at which the costs of the fertilizer rate differentials surpass the yield increase differentials. Excessive fertilization may even decrease crop yields. Some of the micronutrients which are essential in small concentrations may in fact become toxic to the plants if introduced in excess. The optimal application of fertilizers will depend upon soil characteristics, soil virginity, climatic conditions, crops, crop rotation etc. Thus the optimal application rates may vary very much from one country or region to another.

Fertilizers are greatly needed in the developed countries, which are densely populated and where continuous cultivation has taken place during decenniums or hundreds of years. Some of the developing countries such as those of Western Asia, China, India, Indonesia etc., where huge populations and intensive agriculture exist, are in great need of fertilizers. In developing countries with a scattered population and an abundance of arable land the consumption of fertilizers may grow slowly as the population increases and becomes urbanized.

On a world-wide scale fertilizer consumption in 1972/73 was as follows:

Fertilizer		Consumption (in millions of tons)
N		36.1
P_2O_5		22.6
K_2O		18.7
	Total	77.4

C. Fertilizer grades

The most important fertilizer grades currently sold on the world market are listed below.

Nitrogen

Liquid ammonia (82% N). Large quantities of liquid ammonia are used by farmers in temperate climate zones in the United States and Europe, where the soil is cold and humid in spring. The application of liquid ammonia may not be feasible in subtropical and tropical climates owing to excessive evaporation loss, as the soil may be warm and inadequately humid at the fertilizing season.

Urea (46% N). Urea is the highest concentrated, nitrogenous solid fertilizer which involves low transportation costs. It has a reliable fertilizer effect, and per ton of nitrogen it has the lowest manufacturing costs as compared with other nitrogenous fertilizers produced by plants comparable in size and start-up time. Nearly all the fertilizer plants built throughout the world during the last ten years for the conversion of liquid ammonia into a solid, straight nitrogenous fertilizer have been based upon urea.

Ammonium nitrate (34% N). Ammonium nitrate (AN) with a 1% coating agent is used as a raw material for explosives, but is prohibited for use as fertilizer because of explosion risk during storage, handling and shipment. However, a diluted form of AN is the main ingredient in some NP or NPK compound fertilizers).

Calnitro (26% N). Calnitro is AN with limestone powder in combined prills or granules.

Ammonium sulphate (21% N). This is one of the oldest fertilizers manufactured on a large scale. It has excellent, low hygroscopic properties and is still in great use among farmers in many countries in spite of its low concentration of N. Ammonium sulphate (AS) is advantageously used where the soil is deficient in sulphur, and was formerly a by-product of coal-based gas plants. Other straight nitrogenous fertilizers with even lower percentage of N, such as calcium nitrate, sodium nitrate (natural Chile salpeter) etc., are also available on the world market.

Phosphorous and nitrogen phosphorous

Rock phosphate (30-36% P_2O_5). Since its phosphate content is insoluble, and therefore becomes only very slowly available to the plants, rock phosphate is used only for particular crops.

Single superphosphate (20% P_2O_5). In single superphosphate, as in the following grades, it is rock phosphate which has been treated with sulphuric acid, so that its phosphate content has become soluble and directly accessible to plants.

Triple superphosphate (45% P_2O_5)

Phosphoric acid. This is not directly applied as fertilizer, but is shipped as a highly concentrated phosphorus source for manufacture of any of the next phosphate compounds. Phosphoric acid is produced in either of the following two grades:

(a) Superphosphoric acid (65-72% P_2O_5). This has a high viscosity and cannot be pumped conveniently at room temperatures. To solve this problem, superphosphoric acid is usually loaded and shipped at high temperatures (65°C-93°C). Consequently, shipping containers must be insulated, and, for transportation over long distances, be provided with heating coils. Container cars are either rubber-lined carbon steel or stainless steel, both types being heat-insulated. The same holds true for storage vessels or tanks. Superphosphoric acid sold in the United States is usually supplied in one of two types. The older conventional superphosphoric acid contains about 45-50% of its P_2O_5 in the polyphosphate form, and the newer low polyphosphate superphosphoric acid usually contains from 20% to 30% of its P_2O_5 as polyphosphate. The newer type has a significantly lower viscosity, and is cheaper and less corrosive than the older type. However, all superphosphoric acids are high in viscosity and need to be handled and shipped as described above;

(b) Orthophosphoric acid (52-54% P_2O_5). Most orthophosphoric acid is shipped in the United States in uninsulated, standard, rubber-lined, carbon-steel tank cars, and is unloaded from the cars through 3"-6" outlet pipes or 2" dip pipes, either by applying air pressure or by pumping. Orthophosphoric acid can be pumped with conventional pumps and handled in relatively low-cost PVC piping.

Diammonium phosphate (18-21% N, 46-50% P_2O_5) (DAP)

Monoammonium phosphate (11-12% N, 48-50% P_2O_5) (MAP)

Nitrophosphate

Potassium

Potassium chloride (48-62% K_2O) (Muriate of potash)

Potassium sulphate (48-52% K_2O) (sulphate of potash). This fertilizer is produced from potassium chloride and is used for chlorine sensitive crops, such as potatoes, tobacco, tomatoes, citrus fruits etc.

Binary and tertiary compounds: NP, NPK, PK

In addition to the binary NP compounds referred to above, binary and tertiary compounds or blends are available on the world markets. NPK compounds in particular are getting a bigger share of the fertilizer market, as their application in the fields is easier, cheaper and requires less labour. The binary and tertiary compounds can be delivered in the following three forms in the United States:

(a) Chemical blends. In the manufacture of chemical blends the straight components are reacted or mixed as solutions, sludges or melts, with subsequent drying and prilling or granulation. Chemical blends are therefore uniform, as all fertilizer particles are identical in composition;

(b) Physical or bulk blends. Physical or bulk blends are mixtures of different fertilizer grades made by blending the granules of the grades involved. Although fertilizer grades of nearly uniform particle size are used for the blends, in practice the particles of the different compositions will vary. Physical blends must therefore be treated with great care during handling, shipment, and application, in order to avoid a segregation into the basic components and uneven and unsatisfactory fertilization of the fields. This means that physical blends should not be transported over long distances.

In the United States bulk-blending plants are relatively small and are located in considerable number near the marketing areas, each plant serving an area with a radius of up to about 30 km. Bulk blending plants can mix formulations according to the specific needs of each farmer;

(c) Liquid, aqueous solutions or suspensions. The solutions or suspensions are lower in concentrations of nutrients in the solid blends and are thus more costly to transport. In the United States liquid mix plants are relatively small and are located in considerable number near the marketing areas, each plant serving an area with a radius of up to about 30 km. Liquid mix plants can mix formulations according to the specific needs of each farmer.

Micronutrients

Magnesium. Obtainable from kieserite, $MgSO_4 \cdot x H_2O$ (26% MgO).

Calcium. As chalk, calcium nitrate or limestone powder in calnitro.

Sulphur. As sulphur or in ammonium sulphates and superphosphates.

III. FERTILIZER MANUFACTURE

The establishment of a viable fertilizer manufacturing plant represents a major effort in a large-scale chemical industry, and therefore requires the fulfilment of a number of essential conditions, in particular those enumerated below.

1. Raw materials must be available in adequate quantities at acceptable and competitive prices. The raw materials may be either indigeneous or imported.

2. There must be adequate and reliable supplies of utilities such as electricity, water etc., at acceptable and competitive prices. In developing countries a fertilizer plant should have its own electric power station.

3. Capital requirements are extremely high, which means that the operation of the plant must be reliable, continuous and as near the design capacity as possible, otherwise even a viable modern plant may incur severe economic losses.

4. The plant must be provided with the best modern technology in order to ensure its efficient operation and competitiveness.

5. The management, operations and maintenance personnel must be highly qualified, skilled and experienced, in order to ensure reliable plant operations, production and maintenance.

6. The fertilizer market must be large enough to absorb the entire production of the plant at competitive sales prices.

7. Freight costs for raw materials and fertilizers must be reasonable and within acceptable limits with regard to competition from other plants and importers, and to the world market in general.

8. A fertilizer plant should not have a monopoly of the national market, as this could place a serious economic burden on farmers or consumers of agricultural products, or retard the use of fertilizers and the growth of agricultural production.

A. Raw materials and process routes

The raw materials and process routes used in the production of fertilizer components containing nitrogen, phosphorus and potassium are described below.

Nitrogen

All nitrogenous fertilizers are produced from ammonia as an intermediate product. The manufacturing cost of ammonia forms the greater part of the manufacturing cost of any other nitrogeneous fertilizer. Ammonia is made from either of the following alternative raw materials: natural gas or refinery off-gas (if available in sufficient quantity); naphtha; fuel oil (bunker C); lignite, coal or charcoal; electricity through electrolysis of water (this method is no longer used by the industry).

The modern process route for the production of ammonia based upon natural gas is desulphurisation, steam reforming, secondary reforming, steam production from process waste heat, carbon monoxide conversion into carbon dioxide, carbon dioxide removal, methanization of traces of carbon oxides, high pressure compression, and ammonia synthesis.

In fuel-oil-based ammonia plants the fuel oil is gasified through reaction with oxygen and steam at high pressure, followed by soot removal and regeneration. The next process steps are steam production from process waste heat, desulphurization, carbon monoxide conversion into carbon dioxide, carbon dioxide removal, nitrogen wash for removal of carbon oxide traces and methane, and for nitrogen enrichment, high pressure compression and ammonia synthesis. The oxygen and nitrogen is produced in an air separation plant.

Lignite- or coal-based ammonia plants have the same principle process scheme as the fuel-oil-based plants, except that the gasification usually takes place at atmospheric pressure, so that raw synthesis gas compressors are needed after the carbon ash washing and removal unit at the exit end of the gasifiers. In addition, a lignite or coal grinding, drying and storing unit is installed, and special equipment for feeding the lignite dust with the oxygen and steam into the gasifiers is required. Alternatively, coal can be gasified at high pressure, which is considered a less suitable procedure, although the raw synthesis gas compressors can be omitted. Thus more steam, and therefore also more oxygen, needs to be added to the gasifiers, and as a result of the high pressure and greater steam flow to the gasifiers, methane is formed during gasification and has to be removed in the liquid nitrogen wash. The air separation and nitrogen wash units must be bigger than in the case of gasification at atmospheric pressure. Atmospheric pressure gasification can handle a broad spectrum of lignite and coal qualities as well as fuel oil (if desired), while high pressure gasification is possible only with a specific high-quality coal.

Alternatively, ammonia can be produced using electrolytic hydrogen. The hydrogen for the synthesis gas mixture of $3H_2:N_2$ can be produced from water by electrolysis, and the nitrogen obtained by an air separation process. This method uses very large amounts of electric power, about 11,000 kWh per ton of ammonia compared with 25 to 30 kWh per ton in a large, natural-gas-based ammonia plant. The process is economic only when power is very cheap, for example $0.001 to $0.003 per kWh. The capital cost is high because there is a limitation on the size of the cell used for hydrogen production. Large numbers of cells are required and the capital cost per ton of ammonia does not show as large a decrease when the size of the plant increases as with other processes. Both electrolysis and air separation produce oxygen as a by-product. If this can be sold the economics of the processes are of course improved. If a solid fertilizer salt were produced in conjunction with the electrolytic process, it would be calnitro (26% N), which is composed of ammonium nitrate mixed with limestone. Urea cannot be produced owing to the absence of carbon dioxide.

Only one ammonia plant, to the expert's knowledge, has been built using electrolytic hydrogen feed-stock in recent years. Where cheap and abundant electricity is available, other electric or electrolytic industries, such as electric steel furnaces, aluminium works (possibly using imported bauxite) etc., have been established instead. Moreover, it should be borne in mind that the establishment of an ammonia industry is a long-term investment extending over a period of about 20 years, and the electricity may not be as cheap after a number of years as it had originally been.

For the production of urea, ammonia is reacted with carbon dioxide at high pressure. Carbon dioxide is a by-product of any ammonia plant. A urea plant must therefore be sited near an ammonia plant.

Ammonium nitrate is made through reaction of ammonia with nitric acid. The nitric acid is formed in a separate unit by catalytic burning of ammonia with air. Ammonia is therefore the major raw material. Cheap limestone must be available for admixture with AN to form calcium ammonium nitrate.

Ammonium sulphate is produced from ammonia and sulphuric acid. The sulphuric acid is made in a separate unit on the basis of sulphur or pyrite as raw materials. Previously, gypsum was sometimes used as a sulphate source, but this is now considered an obsolete route.

Phosphorus

Rock phosphate is the raw material of all phosphatic fertilizers. It is found in rich deposits in Brazil, Morocco, Peru, Senegal, Togo, Tunesia, the Union of Soviet Socialist Republics and the United States etc.

Rock phosphates from some of these deposits have been used for years in the phosphate fertilizer industry, and their properties are well known and taken into account in the design of new plants. Rock phosphates from new deposits have to be carefully analysed by experienced contractors to determine whether they can be adequately and economically used. The properties to be analysed include grindability, reactivity to acid, contents of P_2O_5, SiO_2, Fe, and Cl (high chloride content is not acceptable in the hemihydrate process) etc.

In a few instances, for example in the cultivation of tree crops, rock phosphate is applied directly as a fertilizer. However, for all other crops, in particular rice, grain etc., insoluble rock phosphate must be converted into water-soluble phosphate, which can be easily and directly absorbed and used by the plants. For this purpose, the rock phosphate is reacted in special process plants with sulphuric acid. The sulphuric acid is produced in a separate unit, with sulphur or pyrities as raw materials. The acidulated products will be either single or triple superphosphate or phosphoric acid. Phosphoric acid will be neutralized with ammonia into monoammonium or diammonium phosphate fertilizer.

The manufacture of phosphoric acid using sulphuric acid accounts for about one third of total world sulphur consumption. During the period 1967-1969 sulphur prices escalated rapidly on the world market, and this led the fertilizer industry to seek alternative routes for acid attack of phosphate rock. Some plants using hydrochloric acid were built. Moreover, some rock phosphate treating plants, which, instead of sulphuric acid, use nitric acid, were built for the manufacture of nitrophosphates as a combined fertilizer, or nitrate and water-soluble phosphates as individual fertilizers.

In the meantime, sulphur has come to be in abundant supply on the world market, mostly because of the large quantities of sulphur being recovered through hydrotreating of petroleum in recent years. As a result, the nitrophosphate route is no longer considered a good choice, except in remote areas where sulphur is not available at reasonable prices. In some cases plants have been built to react the phosphate rock with both sulphuric acid and nitric acid in combination for the production of particular fertilizers.

All phosphate and phosphoric acid plants built since about 1969 use sulphuric acid and apply the so-called wet processes. Within the definition of these processes a distinction is made between the dihydrate process, the demihydrate process, and the anhydrite process, the former being the more common one. Three different processes exist for concentration of the acid and the separation of impurities. Either superphosphoric acid or orthophosphoric acid may be produced, the highly concentrated acid requiring more energy in the concentration process. In the United States, for example, there are phosphoric acid plants using the thermal process, in which phosphate rock is admixed with coal and reduced in a closed electrical furnace at about 1500°C. In this way, phosphorus is formed, volatilised, and subsequently recovered. Electrical energy requirements of the furnace are about 13,000 kWh per ton of phosphorus produced. In a second process stage the phosphorus is transformed into superphosphoric acid. New thermal process plants have not been built in recent years, and will probably never be built owing to the high energy consumption and cost.

Potassium

Muriate of potash and sulphate of potash are produced from potash-bearing minerals, such as sylvite, carnallite etc., which are found in large underground deposits in many countries, for example in Africa, Europe and North America. The deposits vary greatly in concentration. The ore in Canada is high-grade and contains 26% to 28% K_2O, whereas some of the low-grade Carlsberg, New Mexico, ores contain only 12% to 14% K_2O.

The exploitation of a potash deposit is a large-scale and high-investment operation, involving mining and shaft-sinking, underground recovery, ore-hoisting, separation and waste disposal, and further refining and concentration of the product. This makes possible lower freight costs, and the purity and quality of the product becomes suitable for its use as fertilizer.

A source of natural gas or fuel oil for the electric power plant and steam production must be available for the potash-mining operation, and the water supply must be abundant.

B. Modern ammonia plant design

The modern design of ammonia plants involves the use of centrifugal compressors for the high pressure compression and recycling of the synthesis gas, instead of the reciprocating compressor, which much more expensive, requires much more space, and is much more costly and troublesome to maintain. Centrifugal-compressor ammonia plants did not exist until the beginning of the 1960s, and their design has been improved in recent years. Only a very limited number of companies are specialized in and capable of handling the design and manufacture of the centrifugal-compressor ammonia plant. Formerly, the reciprocating compressor was almost exclusively applied in ammonia plants.

The modern centrifugal-compressor plant is driven by a steam turbine, which makes it possible to exploit waste heat in the ammonia plants by raising steam of adequately high pressure to the large steam turbine. This means a very substantial economy in the consumption of electricity as compared with ammonia plants using the reciprocating compressor, which cannot be driven by a steam turbine, and requires an electrical motor instead. However, for technical reasons the centrifugal compressor can be used only in ammonia plants having a capacity of not less than approximately 600 tons of ammonia per stream day, while smaller ammonia plants will still have to use the reciprocating compressor.

One large ammonia plant will not need more personnel and workers than a smaller plant. Therefore, in addition to the decreasing specific investment cost per ton of ammonia produced, a modern ammonia plant with a capacity of above 600 t/d will have substantially lower production costs than smaller-capacity plants, for the reasons stated above.

At present, small reciprocating-compressor ammonia plants with a capacity of less than 600 t/d would be viable only in a limited number of cases, for example in an old fertilizer or petrochemical complex, or where a very protected ammonia market is available, or where the ammonia is to be used as process feedstock in a small petrochemical plant.

C. Nitrogenous and phosphate fertilizer industries

Nitrogenous fertilizer industries in various countries

The growing need for nitrogeneous fertilizers, especially during the past 15 years, has led to a rapid expansion of the nitrogenous fertilizer industry all over the world. Technological improvements at the beginning of the 1960s made it profitable to centre the production of nitrogeneous fertilizers on large capacity plants because of low production cost as compared with smaller plants. Many large nitrogenous fertilizer plants have therefore been built around the world during the last 10 to 12 years. These include liquid ammonia plants with or without adjacent plants for conversion of the liquid ammonia into solid fertilizers. The ammonia plants built during this period all had a capacity of from 600 to 1,750 t/d.

Most solid nitrogenous fertilizers were formerly made as ammonium sulphate (21%N) or calnitro (26%N), which consists of ammonium nitrate mixed with limestone powder. Ammonium nitrate (34.5%N) is an explosive and is not distributed and used as a fertilizer in most countries for safety reasons. The ammonium sulphate route has been regarded as obsolete for the past 10 to 15 years, and this product is currently made almost entirely in old plants. Only a few small ammonium sulphate plants have been established in recent years, in most cases probably to meet the requirements of soils or crops needing both nitrogen and sulphur as nutrients.

Urea (46%N) is the solid fertlizer with the highest content of nitrogen, and involves less transportation cost than other solid fertilizers. The first urea plants were built many years ago, but suffered in many cases from corrosion and other operational problems. However, from about 1960 the designers and contractors of urea plants succeeded in solving the corrosion problems and improving the manufacturing performance of urea plants. As a result, nearly all the solid nitrogenous fertilizer plants built during the last 10 years or currently under construction around the world have been based upon the urea process, involving an output of up to 1,750 tons of urea per day. However, a few nitric acid and ammonium nitrate plants have been built in recent years or are under construction in the United States, where a big market for aqueous solutions or suspensions of urea-ammonium nitrate exists. Moreover, the ammonium nitrate process has to be used for making a solid fertilizer from imported or pipelined ammonia, since urea must be made in a plant adjacent to an ammonia plant, as it requires for its formation both ammonia and cheap carbon dioxide, the latter produced as a by-product in the ammonia plant. Furthermore, according to the Tennessee Valley Authority in the United States, companies that produce urea and urea-ammonium nitrate solution report that they have less difficulty meeting environmental regulations with urea than they do in the production of urea-ammonium nitrate solution. Therefore, most new ammonia plants will be producing urea in preference to ammonium nitrate and urea-ammonium nitrate solution.

From the beginning of the ammonia industry in the 1920s natural gas was available as the preferred raw material in the United States. All existing or planned ammonia plants in the United States are using or will use natural gas. In Europe, Japan and elsewhere no natural gas at all was formerly available, and, with certain exceptions, there is still none available. The old ammonia plants in Europe, Japan etc., were therefore based upon coke-oven gas from atmospheric gasification of coal. At present, the cost of using coal for the production of ammonia is regarded as prohibitive in most countries, including those of Western Europe.

During the 1920s some ammonia plants were built to make ammonia from electrolysis of water and air separation where electricity was in surplus and very cheap, for instance in Norway. These plants are now obsolete, and in most if not all cases have probably been dismantled. In the middle of the 1960s a number of large ammonia plants were built in Western Europe on the basis of naphtha, since technological developments around 1960 made this route possible, and since naphtha was at that time still available in abundant quantities at relatively low prices. From the end of the 1960s naphtha has become too expensive to use for the production of ammonia in most countries because of the growing number of automobiles, and because great quantities of naphtha are needed and consumed as process feedstock by the petrochemical industry for, among other things, naphtha cracking in the production of ethylene, propylene, etc., in which natural gas cannot be used as the basic material.

In the Federal Republic of Germany the latest large ammonia plants built or under construction are based on fuel oil, which is relatively cheap. A few large ammonia plants based on fuel oil are also under construction in India. In addition, India is currently constructing three ammonia plants, each with a capacity of 900 t/d on the basis of domestic coal, which will be gasified in Koppers gasifiers at atmospheric pressure. The decision to build these plants was taken after the world oil crisis in 1973, in order to make the production of nitrogenous fertilizers in India less dependent upon derivative fractions of imported crude oil. Although the domestic coal will be cheap, these plants will nevertheless involve a relatively high production cost owing to the large capital costs of these plants. The decision to use coal in these new plants was no doubt taken because of the severe problem of providing sufficient domestic food to feed India's huge population, and of the need to apply fertilizers to the Indian soil, which has been cultivated intensively for thousands of years. Another aim was to avoid or reduce imports of costly agricultural products and crude oil, which would mean substantial savings in foreign exchange. It should be noted that India has no reserves of crude oil and only very limited reserves of natural gas.

Since the beginning of the 1960s or somewhat earlier, huge reserves of natural gas have been discovered in Western Asia and in Algeria, China, Indonesia, Libya, Mexico, Nigeria, Poland, Romania, Trinidad and Tobago, the Union of Soviet Socialist Republics and Venezuela. The reserves are being exploited to an increasing extent, for example in the production of ammonia, urea etc. A substantial number of large ammonia/urea plants using natural gas have been built in the above-mentioned countries since the end of the 1960s, or are currently under construction. Moreover, China is building some large ammonia plants based on naphtha, which it has in cheap and abundant supplies.

Most of the nitrogenous fertilizer plants built or under construction around the world are meant for domestic consumption. However, the ammonia/urea plants built in recent years in Western Asia, Algeria, Mexico, Trinidad and Tobago, and Venezuela are definitely producing mainly for export markets.

Recent developments in the phosphate fertilizer industry

Most phosphate fertilizer plants built in recent years produce, using rock phosphate as the raw material, intermediate fertilizer products such as phosphoric acid, monoammonium phosphate (MAP), diammonium phosphate (DAP), and NPK or NP or PK compounds. In some cases the new plants were built by rock phosphate miners, are integrated with the mining operation (for instance in Morocco), and deliver their products as intermediates to fertilizer granulation, blending or mixing plants in other areas or countries, as the transportation of highly concentrated intermediates costs less than that of rock phosphate.

D. Granulation, blending or mixing plants

Fertilizer granulation plants, bulk-blending plants and liquid mix plants manufacture complex fertilizers, which make possible the easier, combined application and spreading of the products, since the alternative use of straight fertilizers, each containing one of the three main nutrients, requires three separate spreading operations by the farmer.

Granulation of compound fertilizers is one of the major technological developments of the past 25 years. Fertilizers are granulated in rotary horizontal cylinders, blungers, pug mills, inclined or horizontal pans, prill towers and roll compactors. The granulation process is followed by drying, cooling, screening and recycling of rejected material to the granulator. So far no one granulation process has proved clearly superior to others. The choice of a granulation process is often influenced by the character of the materials to be granulated. A typical granulation plant is complex and expensive. It involves one or more dryers (often very large), a cooler, screens, crushers, and a series of conveyors and elevators. Each stage generates dust or fumes, and numerous dust collectors, scrubbers etc., are required to recycle the collected dust and liquid. A granulation plant is usually a dusty place. Even in plants where dust and fumes are well controlled, deposits on beams and railings usually show that dusty conditions occur at least occasionally.

A modern granulation plant produces 20 to 40 tons per hour of granules, each of them must be well shaped, dry and homogeneous in order to ensure adequate storage properties and even fertilizer distribution in the fields. The complicated granulation process requires large plants to be economic and competitive. As the plants are large and operation is continuous during certain periods, they cannot produce a wide variety of grades and special mixes, and they are too large to dispose of in a typical retail area. Nevertheless, the complex fertilizer granulation industry is an important branch of fertilizer manufacture in many developed countries.

Alternative systems have been evolved in the United States to take full advantage of the economics of large-scale manufacture while permitting flexibility in the formulation of compound fertilizers. These systems are based upon manufacture of straight fertilizer intermediates in giant plants located where raw materials are cheap and low-cost transport facilities available, minimizing transport, storage and handling costs by maximizing the concentrations of the intermediates, with final blending or mixing and formulation in small inexpensive plants to serve local markets. The small plants serve an area of up to 30 km in radius. They combine the functions of manufacturing and retailing, and carry out prescription mixing, custom formulation, soil sampling analysis, and various other services.

It should be stressed that conditions in the United States are favorable to systems involving the transport of intermediates. The country is large, intermediates may be shipped long distances without the handicap of crossing national borders, and very efficient freighting systems and special design vehicles are available. Low-cost sources of raw materials for all the major fertilizer intermediates are available within the country. The level of fertilizer use makes giant plants feasible, and the use of fertilizers in many areas is sufficiently intensive to support the small local plant that receives the intermediates and makes the final product. Finally, farmers in the United States generally are receptive to new forms of fertilizers and new marketing systems when they can see how the new developments may help them increase their profits.

In 1969, there were over 4,000 bulk blending plants in the United States, each serving a local retail area and blending and producing their products from solid intermediates. In 1974, the United States had 2,300 liquid fertilizer plants, 75% of them being located in the Midwest. The liquid fertilizer plants include both the hot-mix and the cold-mix type. About 40% of the total number are hot-mix plants. Nearly all the liquid fertilizer plants are batch operated. Only about 100 plants in the United States are of the continuous operation type, and these are all hot-mix plants, in which ammonia is mixed with phosphoric acid and neutralization heat is developed, whereas the cold-mix plants handle exclusively neutral intermediates.

Liquid fertilizers are produced either as clear solutions or suspensions. The latter are a means of overcoming the disadvantage of low-concentration solutions. They can be added to both soluble or insoluble micronutrients and are compatible with most pesticides. The suspensions are treated to minimize settling by inclusion of 1% to 3% of a gelling-type clay in their formulation. Liquid fertilizers are often simultaneously applied during sowing in a band beside the seeds by means of a planter attachment. Liquid solutions are well adapted for foliar application, as they need only to be diluted to a concentration that will not damage the leaves. Foliar application is used mainly for supplemental fertilization of specialty crops or for correction of micronutrient deficiencies. In pineapple cultivation, however, foliar application often is the main or only means of fertilization.

IV. FERTILIZER IMPORTS

As fertilizer consumption may exceed domestic production, fertilizers might have to be imported from abroad at competitive prices, on the best terms, and in the quantities and qualities required by the domestic market. Even if domestic production is big enough to satisfy internal market demand, the alternative of importing fertilizers from abroad should always be open, in order to control domestic fertilizer prices and keep them down to a reasonable level in relation to prices on the international market. Imported fertilizers should be free of customs duties in order to ensure such control. It may be desirable to import a certain amount of fertilizers or to arrange to do so at reasonably short notice by farmers' co-operatives, so as to serve and protect the interests of agriculture.

A. World market prices

Fertilizer prices on the world market depend of course upon the delivery terms, but they fluctuate according to actual world market demand for the respective products. These fluctuations have been very drastic in recent years. For example, the ex-factory prices of ammonia and urea, which cost about the same per ton, have varied as follows:

Period	Variation in the cost of ammonia and urea (in $/ton)
1973 and preceding years	40–100
1974 and spring of 1975	300–350
Summer of 1975 to autumn of 1976	120–150

The drastic price peak during 1974 was undoubtedly caused by a shortage of fertilizers owing to large purchases of fertilizers on the world market by China and the Union of Soviet Socialist Republics. However, in those two countries and elsewhere, construction has been completed of about 25 to 30 large nitrogenous fertilizer plants, each with a yearly capacity of from 400,000 to 600,000 tons, and operations have been started. Still more large ammonia-urea plants are under construction, and large phosphate fertilizer plants have been built in recent years, for example in Morocco.

Fertilizer prices on the world market may therefore show stability during the coming years or possibly a slow escalation in response to increases in the cost of raw materials such as crude oil, rock phosphate, and muriate of potash.

B. Purchasing

Fertilizers imported into Argentina may be purchased at either ex-factory prices or c.i.f. prices to the Argentine port of arrival. In the former cases the shipment and insurance charges must be paid separately by the purchaser and determined through consultations between the purchaser and the supplier. The problems of shipment are dealt with in the next chapter.

Ex-factory fertilizer prices normally involve a discount for the purchase of large quantities. For instance, the price per ton for a lot of 1,000 tons will be a few percent less than for a lot of 50 to 100 metric tons. Moreover, regular purchases from the same manufacturer may lead to additional discounts.

Bagged products are more expensive than products in bulk, owing to the extra cost of bagging and bagging materials. The difference is about $10 to $20 per ton.

Purchases of both small and large lots of fertilizers ought to take place on the basis of competitive bidding from several alternative suppliers. Large-scale buyers of fertilizers ought to keep in frequent touch with the export manufacturers and international dealers and brokers, obtaining their price lists on a regular basis, and receiving bids from them before a major purchase is made.

Although farmers and planters may prefer to use their traditional types of fertilizers because they are familiar with their application and benefits, it should be considered that the prices of the various fertilizer qualities on the world market do not fluctuate simultaneously and to the same extent. An effort should therefore be made to purchase the required types at the cheapest price.

Short-term fertilizer buying gives the purchaser a saving when prices are low on the free world market, but involves the risk of large expenditures when the free world market prices are high. Long-term supply contracts may be more beneficial to both the large-scale purchaser and the supplier of fertilizers, because they ensure the purchaser a reliable supply at reasonable prices, and they provide the supplier with a safe outlet for his goods at a fixed profit. Most probably, a long-term supply contract will have a clause stipulating a certain adjustment of the actual delivery prices in relation to the prevailing free market prices, on the basis, for instance, of an international commodity price index.

C. Exporters and brokers

Fertilizers are being exported from the United States and several Western European countries. Algeria, Mexico, Morocco, Poland, Romania, Spain, Trinidad and Tobago and Venezuela, are also important exporters of fertilizers, and Nigeria may become an exporter in future. Fertilizers may be bought through the import agents of foreign fertilizer houses or directly from the foreign manufacturers, or through international fertilizer brokers, who may be owners of mines, manufacturers, and even transporters. A list of some international fertilizer brokers and exporters is given solely for reference purposes in annex II. Other possible suppliers are the large fertilizer manufacturers and exporters in various European countries, such as Belgium, France, the Federal Republic of Germany, Italy, the Netherlands, Norway, Poland, Romania, Spain, the United Kingdom. The manufacturers of fertilizers in Western Europe are members of the Europe Fertilizer Cartel, which takes decisions on export prices and other matters. Some of the broker associations referred to above are members of the Cartel. Fertilizer export cartels also exist in the United States (Rockphos).

The names of some fertilizer exporters in Africa and South America and the type of fertilizers supplied are listed in annex II solely for reference purposes.

D. Shipment

Most reputable ship freighting companies are members of one or more conferences, and they carry freight at tariffs and on terms jointly agreed upon by the conference members. Non-conference members are few in number and have small ships which call at harbours at irregular intervals as their freight business dictates. The terms of ship conferences for freight services to and from Argentine harbours should be carefully studied in order to use them to the best advantage.

Basic freight prices are calculated as follows:

(a) The unit price or tariff is multiplied by the weight in tons or by the volume in m^3, whichever is highest, in order to obtain the weight or volume figure;

(b) The unit price or tariff is multiplied by the weight in long tons or the volume in units of 40 ft^3, whichever is highest, in order to obtain the weight or volume figure.

The unit tariff will depend upon the commodity code of the cargo, its packing, freight distance, the harbours concerned etc.

In principle, ship owners charge on the basis of the space occupied by the stowed cargo if its density does not exceed 1.0 ton/m^3, which is equal to the specific buoyancy of sea water on the ship. This means that a cargo which can be stowed at a density of for example 0.7 ton/m^3 costs as much in freight as a cargo of the same volume but of 1.0 ton/m^3 density, other things being equal. On the other hand, as ships are not allowed to be loaded to the point where they sink below their load line (Plimsoll mark), a cargo with a density above 1.0 ton/m^3 will require reserving a free space corresponding to the density in excess of 1.0 ton/m^3 multiplied by the volume of the cargo and cannot be stowed outside the hold of the ship unless other cargoes of sufficient volume and density below 1.0 ton/m^3 are being freighted at the same time.

The total freight cost will depend on conditions in particular the following:

Basic freight rate in accordance with the conference tariff;

Additional bunker surcharge to cover fuel cost increases;

Congestion rates to cover waiting time in ports before reaching quayside;

Demurrage charge;

Loading and unloading charges, which may be at the expense of the parcel owner, or the ship owner may pay all expenses (including port charges, pilotage, tug boats, dockage etc.) from hook-on to hook-off of the cargo. Harbour dues and handling charges may cost up to a few United States dollars per ton or per m^3;

Larger consignments, for example from 5,000 to 10,000 tons of fertilizer, will result in a discount, which may be up to between 25% and 30% of the basic tariff;

Chartering arrangements, which may take the form of a hatch or compartment charter, under which a parcel would fill one hatch or compartment of the ship, or an agreement that regular shipments of parcels of a specific size, for example between 500 and 600 tons of bagged fertilizers, would involve lower freight rates on the basis of current freight market conditions.

Some freight savings might be effected if fertilizers are shipped in bulk instead of in bags. This is because the overall density of piled bags is lower, owing to the gaps at the sides of the bags, than the bulk density, which may still not exceed 1.0 ton/m^3. However, general cargo ships are not equipped for loading and unloading of materials in bulk. Therefore, if bulk shipment is considered, the parcel owner must arrange for the loading and unloading of the cargo. Bulk loading facilities are frequently available at harbour terminals of fertilizer manufacturers and exporters, while the cargo owner must provide the unloading facilities and storage at the port of arrival. The cargo owner would have to pay a penalty to the ship owner if the stipulated unloading facilities were not ensured. Typical harbour unloading facilities for bulk consignments would include, for a capacity of 60 to 65 tons per hour, one or two cranes and one or two hoppers at quay, and trucks or railway cars below the hoppers. The unloading and conveyance of fertilizers in bulk from the ships to the storage buildings must of course take place under dry conditions in order to avoid humidification and caking of the fertilizers, or even fertilizer loss through leaching and washing away by rain water. The proper precautions must therefore be taken in rainy seasons.

Freight reductions might be possible through arrangements with ships freighting export goods from Argentina to foreign countries, under which the return trip, instead of being just a ballast voyage, would involve the shipment of some of the Argentine exports. In fact, it may be worthwhile considering jointly chartered vessels for freighting export goods from Argentina and importing large quantities of products into Argentina.

In general, conference member ships seem to give the best long-term service. Non-conference ships can usually be advantageous only for a single or short-term deal. Should a non-conference member offer favourable freight terms over a longer period, the conference members might request the conference's permission to lower freight rates. This would normally be admitted by the conference, which may even be prepared to offer a low "fighting" rate, although most non-conference members would object to this as a means of keeping them out of the traditional freight market of the conference members. Only if a large reputable ship owner put his ships in a new market not yet covered by conference members might it become worthwhile to consider long-term co-operation with a non-conference member.

V. TRANSPORT, STORAGE AND DISTRIBUTION

At the beginning of each crop or growth season the fertilizers must be readily available for distribution in the proper qualities and quantities to farmers and plantations at short notice as weather conditions, sowing, growth of plants and trees etc., dictate. Depending on market demand, the fertilizers may be distributed in 50-kg bags, as liquid ammonia in pressure tanks, as solid fertilizer prills or granules in bulk, and as liquid aqueous solutions or suspensions. The transport means, storage, and distribution of the various physical categories of fertilizers will be different, and will have to be established independently in accordance with market developments.

A. Bagged fertilizers

Solid fertilizers must be distributed to farmers and plantations either in bulk or in waterproof bags, not heavier than 50 kgs, which could be taken to the fields in humid weather, if required, and handled by one person. The bagging material will consist of PVC, polyethylene or woven polypropylene.

The fertilizers produced domestically or imported from abroad during the months preceding each fertilizing season must be piled up in the central, intermediate and local stores. The total capacity of the stores must be sufficient to cover demand for at least one fertilizing season. The intermediate and local stores must be located at railways or main roads in the market area, and the storage buildings filled with fertilizers in such a manner as to permit distribution and transportation to the farmers and plantations as and when required, with the use of a reasonable number of moderately-sized transport vehicles.

In order to economize on storage space and investment in intermediate and local transport vehicles, farmers and plantations may be offered a price discount if they agree to receive the bags of fertilizer before the season and store them in their own barns or storage buildings.

The transport vehicles must be available in adequate numbers and sizes to convey the fertilizer bags from the central through the intermediate and local stores to the farmers and the plantations. Transport costs from the local stores to the farmers and plantations should be charged separately from the fertilizer prices. Some farmers and planters may wish to pick up the fertilizers at the local or even the intermediate stores in their own carriages or vehicles.

The imported fertilizers will arrive from abroad at the central stores in the ports according to the purchasing and shipping possibilities. Purchasing and shipment from abroad may be arranged in order to facilitate transport and distribution and to optimize domestic returns on the investments and operating costs of the storage buildings and the means of transport. The storage buildings and transport vehicles may be used between fertilizing seasons for other commodities, such as bagged harvest product. However, joint storage buildings for fertilizers and agricultural produce must only be established if precautions are taken against the risk of contamination of the agricultural produce which is usually packed in jute bags capable of penetration by fertilizer dust. Even though fertilizers are kept in waterproof bags, such dust may be released from defective bags or as a result of damage to the bags during handling.

Before or as soon as fertilizer consumption in Argentina becomes substantial, a logistics analysis should be made, preferably by experts, on the planned imports, storage arrangements, transport and distribution of the fertilizers. This analysis should be integrated with a similar logistics analysis for the agricultural produce. Such analyses would make it possible to achieve optimum investment returns, to establish the most effective plans for construction, the provision of supplies and the organization of personnel and workers, and to cover the operating costs of stores and transport vehicles.

B. Liquid ammonia

A very substantial market for liquid ammonia to be used for direct injection into the soil may develop in response to certain soil characteristics and climatic conditions. Prior to distribution and application the imported or domestically-produced liquid ammonia may be refrigerated at a temperature of -34°C in central tanks at atmospheric pressure. These tanks will need refrigeration compressors and water condensers. The liquid ammonia will eventually have to be transported, most probably in railway pressure tank cars rather than in trucks, to intermediate and local tanks, and kept there either under refrigeration at, for example, a temperature of +5°C and 4 kg/cm^2 gauge pressure or at ambient temperature and up to 20 kg/cm^2 gauge pressure. In the former case the tanks will need refrigeration compressors and water condensers in order to cool down the ammonia at unloading from the tank cars, if necessary, and to absorb the flow of heat to the insulated tanks from the surroundings.

The final distribution to the farmers will take place in pressure vessels carried on trucks or tractors. Application is by harrow injection into the soil, and it may be done directly from the pressure vessels on the trucks or tractors, without requiring intermediate holding tanks on the farms. The tractors and equipment may be owned by the farmers, or, in view of the high cost of the pressure vessels and equipment, by the dealer, or a particular machinery station may supply the ammonia and apply it in the fields as a package deal.

In order to promote a market in a particular area, the ammonia factory or importer and the storage tank owner may offer the dealers or farmers the liquid ammonia in 30-kg steel bottles which can be mounted directly on the farm tractors and returned to the wholesale company for refills. In this way, the local dealers or farmers will only have to invest in the harrow injection applicators.

In the United States and some other countries with intensive agriculture large quantities of liquid ammonia is distributed to the farmers. In the United States liquid ammonia pipelines have been installed to transfer the product from ammonia plants located in states along the Gulf of Mexico, which are rich in natural gas reserves, to the extensive farmlands of the Middle West.

Safety and environmental regulations will have to be established by the authorities in line with similar regulations in other countries, in order to define and regulate the design and minimum permissible distances of the storage tanks from urban areas, the design and permissible transport routes of the tank cars and other transport vehicles, and the design of the tractors with pressure vessels and injection equipment. An analysis of storing, transportation, and distribution logistics should be made in order to ensure the maximum return on investments and the most efficient project implementation.

C. Bulk fertilizers

Bulk fertilizers, in particular complex fertilizers, are sold and distributed in large quantities to farmers in the United States and some other developed countries. Distribution often involves immediate application in the fields by the dealer as one package deal. The bulk fertilizers may be delivered from the storage buildings of fertilizer manufacturers. Alternatively, large quantities of bulk-blended products are sold and distributed in the United States by truck directly from small local bulk-blending plants to farmers, possibly including the application operation. In each case the formulation and quantity to suit individual purposes will be agreed upon between the farmer and the blending plant.

In the United States bulk-blending plants may sell fertilizers intermixed with pesticides. However, it is pointed out that the trading of fertilizers with an admixture of pesticides is prohibited in some countries owing to the danger and risks involved.

D. Liquid, aqueous solutions or suspensions

Fertilizers in liquid, aqueous solutions or suspensions are usually sold in containers and distributed by truck during the fertilizer season in the United States directly from small liquid-mix plants situated in the market areas to the farmers, in the quantities and formulations agreed upon in each case by the farmer and the liquid-mix plant in order to meet the specific requirements of the farmer. The liquid solutions or suspensions could be applied to the field directly from the container on the truck by either broadcasting or harrow injection, or the farmer might have his own equipment for storage and application.

In the United States it has been found advantageous to apply herbicides and insecticides simultaneously with the fertilizer solutions or suspensions, thus saving the cost of one application. Experience has shown that these pesticides can be safely added and mixed in fluid after they have reached the farm. Therefore, the dangers involved in transporting pesticide-fertilizer mixtures by road can be avoided. The authorities ought to work out and issue appropriate regulations against such dangers and risks at the proper time.

E. Railway transport in Argentina

Argentina has railway lines with the following three rail gauges: 1.676 m wide gauge, 1.435 m medium gauge, and 1.000 mm narrow gauge. The medium gauge railway system is found in the north-eastern provinces of Entre Ríos, Corrientes and Misiones. It reaches Buenos Aires city and Rojas south of the Paraná river. The narrow gauge railway system is located in the NOA region, the Andina region, the Chaqueña region and the provinces of Santa Fe and Córdoba. It reaches Buenos Aires city, and one line goes down from Buenos Aires city south-west to Carhué in the province of Buenos Aires. The wide gauge railway system is found in the provinces of Buenos Aires, La Pampa, San Luis, Mendoza, Neuquén, and Río Negro, and in the north it is connected to San Miguel de Tucumán in the NOA region.

The southern provinces of Chubut and Santa Cruz have no railway connection with the main part of Argentina. The largest waggon size of the wide gauge system can load a maximum of 45 tons, while in the narrow gauge system the largest waggon size can load a maximum of 30 tons. The railway tariffs given below for bagged chemical fertilizers were provided by the Salta station of Ferrocarriles de Argentina (Argentine Railways).

Tariff of 6 June 1976 for transport (1,159 km) by narrow gauge lines of a full car load of 30 tons from San Miguel de Tucumán to Buenos Aires (Retiro): $a 2,239 per ton, or $US 8.96 per ton (excluding loading and unloading), at a conversion rate of $a 250 = $US 1. Tariff of 6 June 1976 for transport (1,236 km) by wide gauge lines of a full car load of 30 or 45 tons from San Miguel de Tucumán to Buenos Aires (Retiro): $a 2,471 per ton, or $US 9.88 per ton (excluding loading and unloading).

Tariff for transport (1,631 km) of a full car load of 30 or 45 tons from San Miguel de Tucumán to Bahía Blanca: $a 3,334 per ton, or $US 13.34 per ton (excluding loading and unloading).

Tariff of 6 June 1976 for one loading or unloading operation: $a 156 per ton, or $US 0.62 per ton.

Fertilizer bulk transport by rail will require specially designed, covered, hopper-bottom cars with emptying through bottom outlets, and other tariffs will be valid for this type of transport. Argentinian Railways is able to handle piggyback transport or truck trailers over long distances. After unloading at the railway terminals, the trailers are hauled by trucks to the final destinations.

Argentina has a highly developed system of highways and roads but transport by lorry is in general appreciably more expensive than by rail.

VI. AGRONOMIC ASPECTS OF FERTILIZER APPLICATION

The economic and practical assessment of fertilizer consumption, taking into account prices, qualities and quantities, should be carried out in advance by means of comprehensive, experimental fertilizer field trials. Before fertilizer use begins the experimental stage must be completed and the basic information and conclusions must be available, so that the farmers can know in advance, for the varying climatic conditions in their regions, the harvest yields and economic results to be expected from the fertilizers they are going to use. This requires the prompt communication of test results to the farmers and the provision of the advisory assistance required to enable the farmers to make the best use of the results in cultivating their land. Moreover, a continuing experimental programme of tests and economic analysis of fertilizer types would enable the farmers quickly to modify their crops and fertilizer consumption in response to price and market changes.

The fertilizers used and their distribution patterns must be suited to the type of crops, the farming methods and the climatic conditions of the areas concerned. This means that the fertilizer types and distribution methods may vary from some areas or regions to others. It should also be borne in mind that the application of fertilizers requires carriages and spreading devices, hence equipment investments by the farmers or the fertilizer dealers.

A. Experimental field trials, advisory services and training

Experimental fertilizer field trials should be carried out by organizations which serve and operate in the direct interest of agriculture, such as government experimental stations for agricultural technology, or experimental stations managed and operated by farmers co-operative. The field trials ought to be comprehensive and continuous. They should not be confined to measuring improvements in the yields of certain standard crops as a result of fertilizer use, but should include an investigation of the possible effect on agriculture of changing market conditions, technological developments etc.

Some of the factors and conditions to be considered are listed below.

(a) Effect on various crop yields of different fertilization patterns using straight or complex fertilisers containing N, P or K;

(b) Economic evaluation of yield responses in function of the prices of fertilizers, agricultural products etc.;

(c) Advisability or necessity of harrowing or drilling the soil after broadcasting or spraying fertilisers, depths of injection, distances between shares etc.;

(d) Sensitivity of crops to fertilizer overdosing, particularly of N;

(e) Micronitrient requirements and sensitivity of crops to micronutrient overdosing;

(f) Liming requirements;

(g) Sulphur enrichment requirements: the presence of sulphur in the soil is important for deriving the full benefits of added nitrogen; the question of sulphur deficiency may arise in connection with soils which have never been fertilized with superphosphate in the past;

(h) Development of crop varieties with improved yields, better resistence to climatic variations and pests etc., larger and improved ears, stronger stalks which can resist couching before harvesting etc.;

(i) Pesticide uses and application.

The test results should make it possible for farmers to optimize their operations and earnings. They must be presented and their practical application explained through publications. It is essential that the information provided can be understood and is of practical value to farmers of different training, education and backgrounds. A scientific presentation of the information would not be useful.

Field trials must be planned and supervised by highly qualified experts who can maintain close co-operation with the scientific, agricultural, commercial and industrial communities. The farmers' co-operatives should have representatives on the board of directors of the experimental stations. The co-operatives should employ agricultural advisors with the highest theoretical and practical qualifications to assist farmers in the application of the most up-to-date and suitable technology and the test results from the experimental stations. An agricultural advisor should be assigned to each locality and be available for visits and consultation at the farmer's request. The advisor may also assume responsibility for any field trials in the district. The employment of an adviser should depend upon the achievement of improved earnings and yields and the satisfactory performance of his work.

Fertilizer and pesticide manufacturers. importers and dealers usually employ agricultural advisors and agronomists to follow market trends and demand. These companies may also carry out field trials in order to test the performance of their products and provide basic information in sales campaigns. The test results and consulting services should of course be appreciated by agriculture, but this channel of information can hardly be regarded as impartial and sufficient.

B. Methods of application

Fertilizer application is usually evaluated from the following three main points of views: price of the fertilizers; effectiveness of the fertilizers, which must be reliable and constant, and with the minimum dependence upon climatic variations; work of application. The following factors should also be taken into account in assessing the work of application: hours of labour; fuel consumption of tractors and spreading equipment; investment in spreading equipment and any special tractor or labour requirements; possibility of simultaneous fertilizer application and sowing, or fertilizer application out of sowing season. In this connection, it should be noted that equipment does exist which can sow and apply fertilizers at the same time.

Some practical guidelines or limitations have to be followed in the application of fertilizers, for example the following:

(a) Nitrogen-containing fertilizers have to be applied shortly before, simultaneously with, or soon after sowing, otherwise the nitrogen components are easily depleted from the soil by rain;

(b) P, K or PK fertilizers can be applied to the soil, if convenient, well ahead of sowing, as the risk of depletion of these components is small;

(c) Application of liquid ammonia must take place by harrow injection. The soil must have a certain humidity, not too little and not too much. If too little, the ammonia will be lost to the atmosphere. This means that liquid ammonia is not a suitable fertilizer in warm and dry areas. If the humidity is too high, the ammonia will not distribute evenly enough in the soil to ensure its efficient utilization by the plants;

(d) Urea, either as solid prills or in liquid solutions, should be harrowed or drilled into the soil after broadcasting, otherwise ammonia formed by hydrolysis of the urea will be lost to the atmosphere;

(e) Liquid solutions may be spread by broadcasting or harrow injection. Harrow injection is considered a more efficient method, since the fertilizers are placed at the roots of the plants;

(f) Harrow injection of solid fertilizers can also be practiced;

(g) Sowing and harrow injection requires the soil to be suitable for penetration of the sowing nozzles and harrows. Some clayey soils are suitable for sowing during only a few days. If sowing is attempted earlier the soil may be too wet to carry the weight of the heavy tractor and the sowing machine. In such cases, the farmers may not have enough time after sowing the fields to carry out harrow injection of liquid fertilizers. Simultaneous sowing and harrow injection of fertilizers will require more complicated and heavier equipment (one container for the seeds and another for the fertilizers) and may not be practicable;

(h) Harrow injection cannot take place after the seed or grains have started to sprout and develop roots, although it is possible for a while in the case of crops sowed or planted at some distance between the shares or furrows, for example root crops or potatoes, where the distance is big enough for tractor applicator wheels;

(i) Fertilizer broadcasting or spraying can still take place after the sprouting of the cereals, however not so late that the plants trampled by the wheels of the tractor and applicator will be unable to rise again;

(j) Fertilizer broadcasting or spraying in fields with crops sown or planted at some distance between the shares or furrows can be carried out until the shares have been closed by the growing plants;

(k) Fertilizer spraying should be done only if it will not scorch the plant leaves;

(l) Foliar spraying (see below) is done with diluted solutions of, for example, urea or diammonium phosphate;

(m) The maximum acceptable salt-out temperatures of liquid, aqueous fertilizer solutions or suspensions, if they are used, should be stipulated, due account being taken of climatic conditions in the various parts of Argentina, where in some regions the weather may be milder at sowing time than in the United States, which has salt-out temperatures falling typically in the range of -7°C to +6°C (20°F to 43°F);

(n) The spreading of herbicides may be carried out simultaneously with or separately from fertilizer spreading. Simultaneous spreading will mean a saving in the work of application. However, the right timing for the spreading of herbicides may not coincide with the schedule of fertilization, and simultaneous spreading may entail increased loses of expensive herbicides. A separate application of the herbicides may therefore be preferable.

It is clear from the foregoing that the suitability of fertilizers and methods of application depends to a large extent on soil characteristics, climatic conditions, crops etc., and should be determined on the basis of the recommendations of the agronomists and the practical demands of the farmers. In particular, it must be stressed that a simultaneous application of all the N, P, and K nutrients requires a rapidly functioning distribution system, since the fertilizers must be spread within a very short period. A separate spreading of PK fertilizers and liquid ammonia or urea is much less demanding on the distribution system and the time and skill of the farmers.

C. Biuret content of urea

Industrially-produced urea will always have a small content of biuret, which occurs as a by-product of the urea process. Normally the biuret content (NH_2-CO-NH-CO-NH_2) of urea is from 0.8% to 1.0% by weight, but a urea plant can be designed at substantially increased investment cost to produce urea with a biuret content as low as approximately 0.3% by weight. This quality of urea has a lower density than the above-mentioned urea grade. Consequently, the urea process resulting in the relatively high biuret content is often called the high-density process, and the other process, the low-density process. The urea prills from the two processes have different particle sizes. When the biuret content is selected, the corresponding particle size specification must be given.

Fertilizers are normally applied to the soil for absorption by cultivated plants through the roots. However, unlike all other fertilizers, urea can be absorbed by plants through the foilage, if it is sprayed as a diluted aqueous solution. The spraying must of course take place in dry weather. The fertilizing effect and growth rate of plants is much faster as a result of spraying with a urea solution than through the application of urea prills.

The urea used for foliar spraying must not contain more than about 0.3% by dry weight of biuret, as a higher biuret content may harm the plants. On the other hand, agronomists do not all agree on the maximum permissible biuret content required for certain crops, and some agronomists in the United States even consider that a biuret content of between 1.0% and 1.5% by dry weight has little harmful effect on hardy crops like corn. Even though the biuret compound does have a toxic effect on plant growth, urea with the above-mentioned percentages of biuret, if properly applied, will be no hazard. Nevertheless, pineapples and citrus fruits are sensitive to more than 0.3% biuret in urea.

Urea is often used as a component in animal feed mixtures. For this purpose it is considered an advantage that the urea has a fairly high biuret content. Biuret is non-toxic if used as cattle feed, and in some countries it is even produced commercially for that purpose. As cattle feed, urea is a hazardous material which has to be fed with great caution and only to ruminants. It is considered safe if these animals consume up to 30% of their daily protein intake as urea sprayed on low-value roughage such as maize stalks, grain straws, or degraded hay. The volume of dry plant material and the quantity and concentration of the sprayed urea solution must be in a well-balanced preparation in order to avoid the danger of ammonia-poisoning of the ruminants. Non-ruminants must not be fed with urea-containing fodder. Useful reference material in this connection is the FAO publication, Non-Protein Nitrogen in the Nutrition of Ruminants.

The agronomic and marketing aspects of urea consumption must be carefully studied before final urea specifications and plant designs are established. In general, urea with a 0.8% to 1.0% biuret content will be suitable in most cases. However, this excludes the application of urea for pineapples, citrus fruits, and certain other crops for which a biuret content of over 0.3% is not acceptable.

D. Application equipment

Fertilizer application requires mechanical applicators and tractors suited to the types of fertilizers, their corrosion properties (if liquid), and the application methods and schedules. The equipment will have to be either imported or designed, developed and manufactured by domestic industry. In either case provision must be made to cover the necessary investment and financing requirements.

VII. ECONOMIC EVALUATION OF AMMONIA/UREA PLANTS

This chapter contains an economic analysis of the capital and manufacturing costs of ammonia/urea plants, taking into account plant capacities, level of output as a percentage of plant capacity, raw materials and fuel, fertilizer prices, reliability of markets, and the tax laws to which fertilizer enterprises are subject. The method used to estimate capital and manufacturing costs is explained, and the results of the evaluation are submitted.

A. Capital and production costs

The break-down of capital and production costs of ammonia/urea plants is given in table 6 for 4 different combustibles (natural gas, naphtha, fuel oil and coal or charcoal) and for four different plant sizes in the case of each combustible. It is stressed that a charcoal-based fertilizer plant will require the same investment as a similar plant using coal.

In each case the combined plant will comprise the following: an ammonia plant; a urea plant, where all the ammonia produced in the ammonia plant will be converted into the equivalent of urea, using the by-product carbon dioxide of the ammonia plant for the urea formation; utility units, such as a cooling water system, boiler feed-water preparation unit etc.; an electric power plant producing all the electricity consumed by the combined plant, and using the same combustible as the ammonia plant.

In each case the production costs in $/ton of urea and all the variable and fixed operating and capital costs have been calculated as stated in the table 6. As a basis for the calculations contained in table 6, each combustible is assumed to have typical world prices.

In table 7 the production costs have been calculated for four different prices of the respective combustibles in each of the 16 cases involving different combustibles or plant sizes, including the prices assumed in table 6.

The production costs in tables 6 and 7 have been calculated assuming a stream factor of 90% for the three cases of natural gas, naphtha and fuel oil, and 84% in the case of coal. This lower stream factor reflects the lower production efficiency of a coal-based plant due to coal ash and dust problems, which imply longer and more frequent shut-down and repair periods.

A 90% to 84% stream factor corresponds to a high performance which may not be achieved in a new plant with unexperienced personnel, in particular during the first years of operation. Thus, in table 8 the production costs have been calculated for four different sets of stream factors for the 16 different cases covered in table 6, including the high stream factors assumed in table 6.

Prices of combustibles in Argentina

For purposes of comparison, table 9 shows the prevailing prices of natural gas, naphtha, fuel oil, and charcoal paid by industrial consumers in Argentina. These prices fall within the range of prices used in table 7. It is noteworthy that Argentine prices of natural gas are of the same order as typical prices in other countries where natural gas is available, while Argentine prices of naphtha and fuel oil are very low as compared with typical world market prices. On the other hand, Argentine charcoal prices are extremely high as compared with typical coal prices.

B. Capital cost estimates

The method used to derive the capital costs shown in tables 6, 7 and 8 is described below.

Large plants

1. The capital costs for ammonia/urea plants with capacities of 1,000 t/d of ammonia and 1,700 t/d of urea, and of 600 t/d of ammonia and 1,030 t/d of urea, and using centrifugal ammonia synthesis compressors, have been estimated by UNIDO at the equipment price level of December 1975.

2. The plants referred to are located in developing countries on a green field site, where plants cost 25% to 35% more than similar plants in developed countries.

3. The capital cost division between ammonia and urea is a little arbitrary since the two plants use a common site and facilities. The ammonia plant costs include a 10 MW to 15 MW power station to make the plants independent of external power supplies.

4. No allowance is made for inflation or for interest charges during plant construction. During 1973-1975, equipment prices increased sharply.

5. It is assumed that comparatively warm cooling water from the atmospheric cooling water towers of the plant will be used, while air cooling will not be used to any appreciable extent.

6. Included in the calculations is storage capacity for one month's supply of raw materials and fuel for 1,000 tons of ammonia, and for 75,000 tons of bulk urea and 10,000 tons of bagged urea. All the urea production is prilled and bagged.

7. Road and rail connections to the plant site, water supply and effluent disposal outside the plant site boundaries are not included.

Small plants

The capital costs of the 300 t/d ammonia and 515 t/d urea plant have been estimated in the manner described below.

1. The capital costs of the 600 t/d ammonia and 1,030 t/d urea plant were multiplied by the factor (300/600) 0.65 = 0.637, and $8 million were added to cover the changeover to reciprocating compressors driven by electric motors and the increase in power plant capacity to nearly 40 MW from approximately 10 MW for the 600 t/d ammonia and 1,030 t/d urea plant, with a certain reduction in heat exchange surfaces.

2. The capital costs of the 150 t/d ammonia and 257.5 t/d urea plant were obtained by multiplying the above-mentioned capital cost of the 300 t/d ammonia and 515 t/d urea plant by the factor (150/300) 0.65 = 0.637.

Possible savings or additional capital costs

The possible savings or additional capital costs described below should be borne in mind.

1. Some of the ammonia produced in the ammonia plant may have to be sold as liquid ammonia to the farmers or used as feedstock in a granulation plant or in a liquid fertilizer mix plant. The urea plant would therefore be smaller and cheaper.

2. If some portion of the urea is used as melt for granulation or as crystals for liquid mixtures, the urea prilling section, urea bulk storage and the urea bagging plant can be reduced accordingly.

3. The plant may be located where the climate is colder, which would mean lower cooling water temperatures and up to 10% lower fixed capital cost.

4. If, on the other hand, the plant is located in a region with very warm weather and a shortage of make-up water for processing and cooling, electri. motor-driven air coolers will have to be installed, which might increase the fixed capital cost by up to 20%. If the water supply could become critical, such a location would not be feasible at all.

C. Production cost estimates

Total production costs in dollars per ton of urea have been found to be the total of the variable and fixed costs given below.

Variable operating costs

Feedstock and fuel for the ammonia plant and fuel for the steam boilers and the electrical power plant, depending on fuel prices.

Other variable operating costs are the following:

		$/ton of urea
Catalysts, chemicals		0.6
Cooling water make-up		1.1
Boiler feed water make-up		0.6
Bags for urea fertilizer		6.9
Expenses of selling to dealers		2.0
	Total	11.2

Fixed operating costs

		Percentage per annum of fixed capital
Maintenance		3.0
Insurance		1.0
Personnel		0.5
	Total	4.5

Fixed capital costs

Depreciation over 12 years corresponding to 8.33% per annum of the fixed capital.

Profit or compound interest factor at 10% per annum of the total fixed and working capital, which factor is low for any normal commercial operation.

Total energy consumption

The figures for total energy consumption in the 16 combinations of different plant sizes and raw materials covered by tables 6, 7 and 8 are given in table 10.

D. Stream factors

The stream factor means real annual production as a percentage of design capacity over a period of, for example, 333 days a year, the remaining days of the year being for normal overhaul and repair operations. Under favourable circumstances, an output corresponding to a 100% stream factor may be achieved, but most plant operators find that the achievement of even a 90% stream factor, for instance operation at design capacity during 300 days a year, is a different task.

The performance of such a complicated and large industrial enterprise as a fertilizer plant may fall short of its potential especially during the first years of operation, for several reasons, such as the following: limited market outlets; natural gas, electricity or water supply failures; operational troubles and prolonged or frequent shut-downs due to inexperienced staff or equipment failures; lack of spare parts and long delivery term obstacles to the transport of products by rail or road.

Listed below are the realistic stream factors recommended by UNIDO, FAO and the World Bank for the economic evaluation of nitrogenous fertilizer plants in developing countries.

Year of operation	Stream factor
1	35%
2	70%
3	80%

As already mentioned, a fertilizer plant in a developing country or in a remote region of a developed country without a 100% reliable electricity supply network must have its own electric power station. Any electricity failure would provoke an immediate and automatic shut-down of an ammonia/urea plant, and depending upon the length of the failure it may be several hours or even days before full production can be resumed. Even a short electricity failure once a month by the public electricity network would be unacceptable, since even this low frequency of failure could reduce the stream factor by 10% for the whole year. Failure in natural gas and water supplies would have still worse effects.

Beside the loss of production resulting from such failures, catalysts, equipment etc., may be damaged or destroyed and call for costly replacements or repairs. For the same reasons, the ammonia unit and the urea plant should not be integrated in the process design, even though it would make possible some saving in capital cost, as such an integrated plant may involve more frequent shut-downs, even where operators with many years of experience in other plants can be hired for the start-up and operation of the new plant.

In summary, operation at reduced stream factors means reduced sales revenues, while the fixed operating and capital costs will remain unchanged or become larger due to more repair work caused by shut-downs, thus leading to higher specific manufacturing costs and substantially lower profits or losses, even in the case of a large plant of modern design.

E. Cash flows of large natural-gas-based ammonia/urea plant

The cash flows of a natural-gas-based 600 t/d ammonia and 1,030 t/d urea plant, as shown in table 11 assume a three-year delivery and construction period, 12 years of operation and the cash payment of working capital prior to start-up and operation.

Table 6. Capital and production costs of ammonia/urea plants in developing countries based on plant sizes and feedstock and fuel costs

	Natural gas b/ ($0.5/1,000 scf = $1.9/10^6 kcal)				Naphtha b/ ($140/ton = $13.2/10^6 kcal)				Fuel oil b/ ($80/ton = $8.3/10^6 kcal)				Coal c/ ($12.5/ton = $2.3/10^6 kcal)			
Output: ammonia/urea (t/d) a/	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Capital costs (in millions of $):																
Ammonia	103	72	54	34	115	80	59	37	140	98	70	44	195	146	100	63
Urea	67	47	30	19	67	47	30	19	67	47	30	19	67	47	30	19
Total fixed capital	170	119	84	53	182	127	89	56	207	145	100	63	262	193	130	82
Working capital	9	5	3	2	17	10	6	4	14	8	5	3	12	7	4	2
Total	179	124	87	55	199	137	95	60	221	153	105	66	274	200	134	84
Variable operating costs ($/ton of urea):																
Feedstock and fuel	12.1	12.1	23.3	23.3	86.2	86.2	165.0	165.0	53.8	53.8	103.0	103.0	21.5	21.5	35.2	35.2
Miscellaneous	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
Subtotal	23.3	23.3	34.5	34.5	97.4	97.4	176.2	176.2	65.0	65.0	114.2	114.2	32.7	32.7	46.4	46.4
Fixed operating costs (4.5% on fixed capital)	14.8	17.3	24.4	30.8	15.8	18.4	25.8	32.5	18.0	21.0	29.0	36.6	22.8	28.0	37.7	47.6
Depreciation (8.33% on fixed capital)	27.5	32.0	45.1	57.0	29.5	34.2	47.8	60.2	33.4	39.0	53.7	67.7	45.4	55.5	69.9	88.1
Profit (10% on total capital)	34.7	40.0	56.1	71.0	38.7	44.2	61.3	77.4	42.8	49.4	67.7	85.2	56.7	69.7	86.5	108.4
Subtotal	77.0	89.3	125.6	158.8	84.0	96.8	134.9	170.1	94.2	109.4	150.4	189.5	124.9	153.2	194.1	244.1
Total production costs	100	113	160	193	181	194	311	346	159	174	265	304	158	186	241	291

a/ Four plant capacities are considered: 1,000 ammonia/1,720 urea (case A); 600 ammonia/1,030 urea (case B); 300 ammonia/515 urea (case C); and 150 ammonia/257.5 urea (case D).

b/ Stream days per year: 300; stream factor: 90%.

c/ Stream days per year: 280; stream factor: 84%.

Table 7. Production costs of ammonia/urea plants in developing countries based on feedstock and fuel prices

	Natural gas b/				Naphtha b/				Fuel oil b/				Coal c/			
Output: ammonia/urea (t/d) a/	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Feedstock and fuel price ($/unit)	0.5/1,000 scf = 1.9/10^6 kcal				35/ton = 3.3/10^6 kcal				20/ton = 2.1/10^6 kcal				12.5/ton = 2.3/10^6 kcal			
Production costs ($/ton of urea):																
Feedstock and fuel	12.1	12.1	23.3	23.3	21.6	21.6	41.3	41.3	13.5	13.5	25.8	25.8	21.5	21.5	35.2	35.2
Other operating and capital costs	88.2	100.5	136.8	170.0	95.2	108.0	146.1	181.3	105.4	120.6	161.6	200.7	136.1	164.4	205.3	255.3
Total	100	113	160	193	[illegible]	130	187	223	119	134	187	227	158	186	241	291
Feedstock and fuel price ($/unit)	1.0/1,000 scf = 3.8/10^6 kcal				70/1,000 scf = 6.6/10^6 kcal				40/ton = 4.1/10^6 kcal				30/ton = 5.5/10^6 kcal			
Production costs ($/ton of urea):																
Feedstock and fuel	24.1	24.1	46.7	46.7	43.1	43.1	82.5	82.5	26.9	26.9	51.5	51.5	51.6	51.6	84.5	84.5
Other operating and capital costs	88.2	100.5	136.8	170.0	95.2	108.0	146.1	181.3	105.4	120.6	161.6	200.7	136.1	164.4	205.3	255.3
Total	112	125	184	217	138	151	229	264	132	148	213	252	188	216	290	340
Feedstock and fuel price ($/unit)	1.5/1,000 scf = 5.7/10^6 kcal				105/1,000 scf = 9.9/10^6 kcal				60/ton = 6.2/10^6 kcal				45/ton = 8.2/10^6 kcal			
Production costs ($/ton of urea):																
Feedstock and fuel	36.2	36.2	70.0	70.0	64.7	64.7	123.8	123.8	40.4	40.4	77.3	77.3	77.4	77.4	126.7	126.7
Other operating and capital costs	88.2	100.5	136.8	170.0	95.2	108.0	146.1	181.3	105.4	120.6	161.6	200.7	136.1	164.4	205.3	255.3
Total	124	137	207	240	160	173	270	305	146	161	239	278	214	242	332	382
Feedstock and fuel price ($/unit)	2.0/1,000 scf = 7.6/10^6 kcal				140/ton = 13.2/10^6 kcal				80/ton = 8.3/10^6 kcal				60/ton = 10.9/10^6 kcal			
Production costs ($/ton of urea):																
Feedstock and fuel	48.2	48.2	93.4	93.4	86.2	86.2	165.0	165.0	53.8	53.8	103.0	103.0	103.2	103.2	168.9	168.9
Other operating and capital costs	88.2	100.5	136.8	170.0	95.2	108.0	146.1	181.3	105.4	120.6	161.6	200.7	136.1	164.4	205.3	255.3
Total	136	149	230	263	181	194	311	346	159	174	165	304	239	268	374	424

a/ See table 6, footnote a/.

b/ See table 6, footnote b/.

c/ See table 6, footnote c/.

Table 8. Production costs of ammonia-urea plants in developing countries based on stream factors

	Natural gas ($0.57/1,000 scf = $1.9/10⁶ kcal)				Naphtha ($140/ton = $13.2/10⁶ kcal)				Fuel oil ($80/ton = $8.3/10⁶ kcal)				Coal ($12.5/ton = $2.3/10⁶ kcal)			
Output: ammonia/urea (t/d) a/	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Production costs ($/ton of urea)																
Case 1: 300 stream days per year (280 for coal), 90% stream factor (84.1% for coal)																
Variable operating costs	23.3	23.3	34.5	34.5	97.4	97.4	176.2	176.2	65.0	65.0	114.2	114.2	32.7	32.7	46.4	46.4
Fixed operating and capital costs	77.0	89.3	125.6	158.8	84.0	96.8	134.9	170.1	94.2	109.4	150.4	189.5	124.9	153.2	194.1	244.1
Total	100	113	160	193	181	194	311	346	159	174	265	304	158	186	241	291
Case 2: 266 stream days per year (246 for coal), 80% stream factor (73.9% for coal)																
Variable operating costs	23.3	23.3	34.5	34.5	97.4	97.4	176.2	176.2	65.0	65.0	114.2	114.2	32.7	32.7	46.4	46.4
Fixed operating and capital costs	86.6	100.4	141.3	178.6	94.5	108.9	151.7	191.3	106.0	123.1	169.2	213.2	146.1	174.3	220.8	277.7
Total	110	124	176	213	192	206	328	368	171	188	283	327	179	207	267	324
Case 3: 233 stream days per year (213 for coal), 70% stream factor (64.0% for coal)																
Variable operating costs	23.3	23.3	34.5	34.5	97.4	97.4	176.2	176.2	65.0	65.0	114.2	114.2	32.7	32.7	46.4	46.4
Fixed operating and capital costs	99.0	114.7	161.5	204.1	108.0	124.5	173.4	218.6	121.1	140.7	193.4	243.7	168.7	201.3	255.0	320.7
Total	122	138	196	239	205	222	350	395	186	206	308	358	201	234	301	367
Case 4: 200 stream days per year (180 for coal), 60% stream factor (54.1% for coal)																
Variable operating costs	23.3	23.3	34.5	34.5	97.4	97.4	176.2	176.2	65.0	65.0	114.2	114.2	32.7	32.7	46.4	46.4
Fixed operating and capital costs	115.5	133.8	188.4	238.2	126.0	145.3	202.3	255.1	141.3	164.2	225.7	284.4	199.6	238.2	301.8	379.5
Total	139	157	223	273	223	243	379	431	206	229	340	399	232	271	348	426

a/ See table 6, footnote a/.

Table 9. Fuel prices in Argentina

Fuel	Place of delivery	Minimum consumption	Price					
			$a ton	$US ton	$a 9,300 kcal	$US 9,300 kcal	$ 10^6 kcal	$US 10^3 scf
Natural gas (LHV = 9,300 kcal/Nm^3)	Location north of Río Colorado	200,000			9.48	0.0436	4.688	1.303
	Locations south of Río Colorado, except	500			9.48	0.0436	4.688	1.303
	Comodoro Rivadavia, Río Grande and the Province of Santa Cruz	-			4.86	0.0223	2.397	0.598
Naphtha (LHV = 11,000 kcal/kg)	**San Lorenzo-Rosario, Province of Santa Fe**	-	8,100	37.327			3.393	
	La Plata-Campana Province of Buenos Aires	-	7,200	33.179			3.016	
Fuel oil (LHV = 10,500 kcal/kg)	**Ex tank yard**	-	6,000	27.649			2.633	
Charcoal (LHV = 6,200 kcal/kg)	**Dirección General de Fabricaciones Militares-Altos Hornos Zapla, Province of Jujuy**	-	12,960	59.723			9.632	

Source: Ministry of Economy Resolutions No. 494 of 25 August 1976 and No. 502 of 1 September 1976; Salta Forestal S.A., November 1976.

Table 10. Total energy consumption per ton of urea

	Natural gas	Naphtha	Fuel oil	Coal
Large plants[a]				
Cases A and B				
Reformer feedstock and fuel (kcal)	5.2×10^6	5.4×10^6	5.4×10^6	8.2×10^6
Electricity				
Consumption (kWh)	140	150	150	208
Equivalent fuel (kcal)	0.4×10^6	0.4×10^6	0.4×10^6	0.5×10^6
Steam				
Consumption (tons)	1.0	1.0	1.0	1.0
Equivalent fuel (kcal)	0.8×10^6	0.8×10^6	0.8×10^6	0.8×10^6
Total fuel (kcal)	6.4×10^6	6.6×10^6	6.6×10^6	9.5×10^6
Small plants[a]				
Cases C and D				
Reformer feedstock and fuel (kcal)	6.8×10^6	7.0×10^6	7.0×10^6	9.8×10^6
Electricity				
Consumption (kWh)	1,700	1,710	1,710	1,768
Equivalent fuel (kcal)	4.7×10^6	4.7×10^6	4.7×10^6	4.9×10^6
Steam				
Consumption (tons)				
Equivalent fuel (kcal)	0.8×10^6	0.8×10^6	0.8×10^6	0.8×10^6
Total fuel (kcal)	12.3×10^6	12.5×10^6	12.5×10^6	15.5×10^6

a/ See table 6, footnote a/.

Cash flows of a natural-gas-based 600 t/d ammonia and 1,030 t/d urea plant are shown in table 11, which is based on the assumptions listed below.

Annual production

Operating at design capacity or a 100% stream factor for 333 days a year, the plant will have an annual production of 343,000 t of urea.

Sales revenues at 100% stream factor

Sales price, ex factory, in $/ton of urea:	160	180	200
Sales revenues (million $/a):	54.9	61.7	68.6

Fixed capital

Payments:

	Year	Fraction of total (%)	Amount (Million $)
	1	35	41.7
	2	51	60.7
	3	14	16.6
	Total	100	119
Working capital:			5
	Total capital		124

Fixed operating costs per year

	Fixed capital (%)
Maintenance	3.0
Insurance	1.0
Personnel	0.5
Total	4.5

Total fixed operating costs (million $/a): 119 x 0.045 = 5.4.

Variable operating costs

	$/t of urea
Fuel, 6.4 x 10^6 kcal at $4.6/$10^6$ kcal (assumed natural gas price, $0.043/$Nm^3$ for fuel with a heat value of 9,300 kcal/Nm^3)	29.4
Catalysts, chemicals	0.6
Cooling water make-up	1.1
Boiler feed water make-up	0.6
Fertilizer bags	6.9
Expenses of selling to dealers	2.0
Total	40.6

Annual costs at 100% stream factor: 343,000 x $40.6/t = $13.9 million.

Taxation of fertilizer enterprise

Taxation rate:
35% of profit before tax minus depreciation minus tax discount

Depreciation per year:
Straight-line depreciation over 12 years of operation will apply at a rate of 8.33% of fixed capital, or 0.0833 x $119 million = $9.9 million, per year

Tax discount rates on profit before taxes minus depreciation:

Year	Case 1 (%)	Case 2 (%)
1	100	75
2	100	50
3	100	50
4	100	25
5	100	25
6	100	0
7	100	0
8	80	0
9	70	0
10	50	0
11	0	0
12	0	0

Table 11. Cash flows[a] of a natural-gas-based 600 t/d ammonia and 1,030 t/d urea plant

(a) Sales price: $160/t of urea, ex factory; stream factor: 90% maximum

(i) Profit before taxes

Year	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12
Stream factor (%)	-	-	-	35	70	80	90	90	90	90	90	90	90	90	90
Revenue (million $)															
Sales				19.2	38.4	43.9	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4
Recuperation of working capital															5.0
Total				19.2	38.4	43.9	49.4	49.4	49.4	49.4	49.4	49.4	49.4	49.4	54.4
Expenditures (million $)															
Fixed capital	41.7	60.7	16.6												
Working capital			5.0												
Fixed operating costs				5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Variable operating costs				4.9	9.7	11.1	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Total	41.7	60.7	21.6	10.3	15.1	16.5	17.9	17.9	17.9	17.9	17.9	17.9	17.9	17.9	17.9
Profit before taxes (million $)	(41.7)	(60.7)	(21.6)	8.9	23.3	27.4	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	36.5
Present value factor (10%)	0.909	0.826	0.751	0.683	0.621	0.565	0.513	0.467	0.424	0.386	0.351	0.319	0.290	0.263	0.239
Present value (10%) (million $)	(37.9)	(50.1)	(16.2)	6.1	14.5	15.5	16.2	14.7	13.4	12.2	11.1	10.0	9.1	8.3	8.7

a/ Parentheses around a figure indicate a minus amount.

Results before taxes

Pay-back period: 8.1 years

Present value of investment: $104.2 million

Net present value (10%): $35.6 million

NPV (10%)/PVI: 0.34

Internal rate of return: 14.6% per annum

Table 11 (continued)

(ii) Profit after taxes (case 1)

Year	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12
Profit before taxes (million $)	(41.7)	(60.7)	(21.6)	8.9	23.3	27.4	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	36.5
Depreciation (million $)	-	-	-	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Balance (million $)	-	-	-	-	13.4	17.5	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	26.6
Tax discount rate (%)	-	-	-	100	100	100	100	100	100	100	80	70	50	0	0
Taxable amount (million $)	-	-	-	-	-	-	-	-	-	-	4.3	6.5	10.8	21.6	26.6
Tax (35%) (million $)	-	-	-	-	-	-	-	-	-	-	1.5	2.3	3.8	7.6	9.3
Profit after taxes (million $)	(41.7)	(60.7)	(21.6)	8.9	23.3	27.4	31.5	31.5	31.5	31.5	30.0	29.2	27.7	23.9	27.2
Present value factor (10%)	0.909	0.826	0.751	0.683	0.621	0.565	0.513	0.467	0.424	0.386	0.351	0.319	0.290	0.263	0.239
Present value (10%) (million $)	(37.9)	(50.1)	(16.2)	6.1	14.5	15.5	16.2	14.7	13.4	12.2	10.5	9.3	8.0	6.3	6.5

Results after taxes

Pay-back period: 8.1 years

Present value of investment: $104.2 million

Net present value (10%): $29.0 million

NPV (10%) PVI: 0.28

Internal rate of return: 13.9% per annum

Table 11 (continued)

(iii) Project after taxes (case 2)

Year	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12
Profit before taxes (million $)	(41.7)	(60.7)	(21.6)	8.9	23.3	27.4	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	36.5
Depreciation (million $)	-	-	-	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Balance (million $)	-	-	-	-	12.4	17.5	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	26.6
Tax discount rate (%)	-	-	-	75	50	50	25	25	0	0	0	0	0	0	0
Taxable amount (million $)	-	-	-	-	6.2	8.8	16.2	16.2	21.6	21.6	21.6	21.6	21.6	21.6	26.6
Tax (35%) (million $)	-	-	-	-	2.2	3.1	5.7	5.7	7.6	7.6	7.6	7.6	7.6	7.6	9.3
Profit after taxes (million $)	(41.7)	(60.7)	(21.6)	8.9	21.1	24.3	25.8	25.8	23.9	23.9	23.9	23.9	23.9	23.9	27.2
Present value factor (10%)	0.909	0.826	0.751	0.683	0.621	0.565	0.513	0.467	0.424	0.386	0.351	0.319	0.290	0.263	0.239
Present value (10%) (million $)	(37.9)	(50.1)	(16.2)	6.1	13.1	13.7	13.2	12.0	10.1	9.2	8.1	7.3	6.7	6.0	6.5

Results after taxes

Pay-back period:	11.8 years
Present value of investment:	$104.2 million
Net present value (10%):	$8.8 million
NPV (10%)/PVI:	0.08
Internal rate of return:	11.2% per annum

Table 11 (continued)

(b) Sales price: $180/t of urea, ex factory; stream factor: 90% maximum

(i) Profit before taxes

Year	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12
Stream factor (%)	-	-	-	35	70	80	90	90	90	90	90	90	90	90	90
Revenue (million $)															
Sales				21.6	43.2	49.4	55.5	55.5	55.5	55.5	55.5	55.5	55.5	55.5	55.5
Recuperation of working capital															5.0
Total				21.6	43.2	49.4	55.5	55.5	55.5	55.5	55.5	55.5	55.5	55.5	60.5
Expenditures (million $)															
Fixed capital	41.7	60.7	16.6												
Working capital			5.0												
Fixed operating costs				5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Variable operating costs				4.9	9.7	11.1	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Total	41.7	60.7	21.6	10.3	15.1	16.5	17.9	17.9	17.9	17.9	17.9	17.9	17.9	17.9	17.9
Profit before taxes (million $)	(41.7)	(60.7)	(21.6)	11.3	28.1	32.9	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6	42.6
Present value factor (10%)	0.909	0.826	0.751	0.683	0.621	0.565	0.513	0.467	0.424	0.386	0.351	0.319	0.290	0.263	0.239
Present value (10%) (million $)	(37.9)	(50.1)	(16.2)	7.7	17.5	18.6	19.3	17.6	15.9	14.5	13.2	12.0	10.9	9.9	10.2

<u>**Results before taxes**</u>

Pay-back period:	6.5 **years**
Present value of investment:	**$104.2 million**
Net present value (10%):	**$63.1 million**
NPV (10%)/PVI:	0.61
Internal rate of return:	17.7% **per annum**

Table 11 (continued)

(ii) Profit after taxes (case 1)

Year	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12
Profit before taxes (million $)	(41.7)	(60.7)	(21.6)	11.3	28.1	32.9	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6	42.6
Depreciation (million $)	-	-	-	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Balance (million $)	-	-	-	1.4	18.2	23.0	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	32.7
Tax discount rate (%)	-	-	-	100	100	100	100	100	100	100	80	70	50	0	0
Taxable amount (million $)	-	-	-	-	-	-	-	-	-	-	5.5	8.3	13.9	27.7	32.7
Tax (35%) (million $)	-	-	-	-	-	-	-	-	-	-	1.9	2.9	4.9	9.7	11.4
Profit after taxes (million $)	(41.7)	(60.7)	(21.6)	11.3	28.1	32.9	37.6	37.6	37.6	37.6	35.7	34.7	32.7	27.9	31.2
Present value factor (10%)	0.909	0.826	0.751	0.683	0.621	0.565	0.513	0.467	0.424	0.386	0.351	0.319	0.290	0.263	0.239
Present value (10%) (million $)	(37.9)	(50.1)	(16.2)	7.7	17.5	18.6	19.3	17.6	15.9	14.5	12.5	11.1	9.5	7.3	7.5

<u>Results after taxes</u>

Pay-back period:	6.5 years
Present value of investment:	$104.2 million
Net present value (10%):	$54.8 million
NPV (10%) PVI:	0.53
Internal rate of return:	16.8% per annum

Table 11 (continued)

(iii) Profit after taxes (case 2)

Year	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12
Profit before taxes (million $)	(41.7)	(60.7)	(21.6)	11.3	28.1	32.9	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6	42.6
Depreciation (million $)	-	-	-	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Balance (million $)	-	-	-	1.4	18.2	23.0	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	32.7
Tax discount rate (%)	-	-	-	75	50	50	25	25	0	0	0	0	0	0	0
Taxable amount (million $)	-	-	-	0.4	9.1	11.5	20.8	20.8	27.7	27.7	27.7	27.7	27.7	27.7	32.7
Tax (35%) (million $)	-	-	-	0.1	3.2	4.0	7.3	7.3	9.7	9.7	9.7	9.7	9.7	9.7	11.4
Profit after taxes (million $)	(41.7)	(60.7)	(21.6)	11.2	24.9	28.9	30.3	30.3	27.9	27.9	27.9	27.9	27.9	27.9	31.2
Present value factor (10%)	0.909	0.826	0.751	0.683	0.621	0.565	0.513	0.467	0.424	0.386	0.351	0.319	0.290	0.263	0.239
Present value (10%) (million $)	(37.9)	(50.1)	(16.2)	7.6	15.5	16.3	15.5	14.2	12.8	11.	10.6	9.7	8.8	8.0	7.5

<u>Results after taxes</u>

Pay-back period:	8.0 **years**
Present value of investment:	**$104.2 million**
Net present value (10%):	**$34.0 million**
NPV (10%)/PVI:	0.33
Internal rate of return:	14.0% **per annum**

Table 11 (continued)

(c) **Sales price: $200/t of urea; stream factor: 90% maximum**
(i) Profit before taxes

Year	-2	-1	0	1	2	3	4	5	6	7	3	9	10	11	12
Stream factor (%)	-	-	-	35	70	80	90	90	90	90	90	90	90	90	90
Revenue (million $)															
Sales	-	-	-	24.0	48.0	54.9	61.7	61.7	61.7	61.7	61.7	61.7	61.7	61.7	61.7
Recuperation of working capital															5.0
Total				24.0	48.0	54.9	61.7	61.7	61.7	61.7	61.7	61.7	61.7	61.7	66.7
Expenditures (million $)															
Fixed capital	41.7	60.7	16.6												
Working capital			5.0												
Fixed operating costs				5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Variable operating costs				4.9	9.7	11.1	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Total	41.7	60.7	21.6	10.3	15.1	16.5	17.9	17.9	17.9	17.9	17.9	17.9	17.9	17.9	17.9
Profit before taxes (million $)	(41.7)	(60.7)	(21.6)	13.7	32.9	38.4	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	48.8
Present value factor (10%)	0.909	0.826	0.751	0.683	0.621	0.565	0.513	0.467	0.424	0.386	0.351	0.319	0.290	0.263	0.239
Present value (10%) (million $)	(37.9)	(50.1)	(16.2)	9.4	20.4	21.7	22.5	20.5	18.6	16.9	15.4	14.0	12.7	11.5	11.7

Results before taxes

Pay-back period:	5.5 years
Present value of investment:	$104.2 million
Net present value (10%):	$91.1 million
NPV (10%)/PVI:	0.87
Internal rate of return:	18.0% per annum

Table 11 (continued)

(ii) Profit after taxes (case 1)

Year	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12
Profit before taxes (million $)	(41.7)	(60.7)	(21.6)	13.7	32.9	38.4	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	48.8
Depreciation (million $)	-	-	-	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Balance (million $)	-	-	-	3.8	23.0	28.5	33.9	33.9	33.9	33.9	33.9	33.9	33.9	33.9	38.9
Tax discount rate (%)				100	100	100	100	100	100	100	80	70	50	0	0
Taxable amount (million $)	-	-	-	-	-	-	-	-	-	-	6.8	10.2	17.0	33.9	38.9
Tax (35%) (million $)	-	-	-	-	-	-	-	-	-	-	2.4	3.6	6.0	11.9	13.6
Profit after taxes (million $)	(41.7)	(60.7)	(21.6)	13.7	32.9	38.4	43.8	43.8	43.8	43.8	41.4	40.2	37.8	31.9	35.2
Present value factor (10%)	0.909	0.826	0.751	0.683	0.621	0.565	0.513	0.467	0.424	0.386	0.351	0.319	0.290	0.263	0.239
Present value (10%) (million $)	(37.9)	(50.1)	(16.2)	9.4	20.4	21.7	22.5	20.5	18.6	16.9	14.5	12.8	11.0	8.4	8.4

<u>Results after taxes</u>

Pay-back period: 5.5 **years**

Present value of investment: $104.2 **million**

Net present value (10%): $80.9 **million**

NPV (10%)/PVI: 0.78

Internal rate of return: 17.0% **per annum**

Table 11 (continued)

(iii) Profit after taxes (case 2)

Year	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12
Profit before taxes (million $)	(41.7)	(60.7)	(21.6)	13.7	32.9	38.4	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	48.8
Depreciation (million $)	-	-	-	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Balance (million $)	-	-	-	3.8	23.0	28.5	33.9	33.9	33.9	33.9	33.9	33.9	33.9	33.9	38.9
Tax discount rate (%)				75	50	50	25	25	0	0	0	0	0	0	0
Taxable amount (million $)	-	-	-	1.0	11.5	14.2	25.4	25.4	33.9	33.9	33.9	33.9	33.9	33.9	38.9
Tax (35%) (million $)	-	-	-	0.3	4.0	5.0	8.9	9.9	11.9	11.9	11.9	11.9	11.9	11.9	13.6
Profit after taxes (million $)	(41.7)	(60.7)	(21.6)	13.4	28.9	33.4	34.9	34.9	31.9	31.9	31.9	31.9	31.9	31.9	35.2
Present value factor (10%)	0.909	0.826	0.751	0.683	0.621	0.565	0.513	0.467	0.424	0.386	0.351	0.319	0.290	0.263	0.239
Present value (10%) (million $)	(37.9)	(50.1)	(16.2)	9.2	18.0	18.9	17.9	16.3	13.5	12.3	11.2	10.2	9.3	8.4	8.4

Results after taxes

Pay-back period:	6.8 years
Present value of investment:	$104.2 million
Net present value (10%):	$49.2 million
NPV (10%)/PVI:	0.47
Internal rate of return:	16.5% per annum

Table 11 (continued)

(d) Sales price: $200/t of urea; stream factor: 65% maximum

(i) Profit before taxes

Year	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12
Stream factor (%)	-	-	-	35	65	65	65	65	65	65	65	65	65	65	65
Revenue (million $)															
Sales				24.0	44.6	44.6	44.6	44.6	44.6	44.6	44.6	44.6	44.6	44.6	44.6
Recuperation of working capital															5.0
Total				24.0	44.6	44.6	44.6	44.6	44.6	44.6	44.6	44.6	44.6	44.6	49.6
Expenditures (million $)															
Fixed capital	41.7	60.7	16.6												
Working capital			5.0												
Fixed operating costs				5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Variable operating costs				4.9	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Total	41.7	60.7	21.6	10.3	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4
Profit before taxes (million $)	(41.7)	(60.7)	(21.6)	13.7	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	35.2
Present value factor (10%)	0.909	0.826	0.751	0.683	0.621	0.565	0.513	0.467	0.424	0.386	0.351	0.319	0.290	0.263	0.239
Present value (10%) (million $)	(37.9)	(50.1)	(16.2)	9.4	18.8	17.1	15.5	14.1	12.8	11.7	10.3	9.6	8.8	8.0	8.4

Results before taxes

Pay-back period: 7.5 years

Present value of investment: $104.2 million

Net present value (10%): $40.3 million

NPV (10%)/PVI: 0.38

Internal rate of return: 15.5% per annum

Table 11 (continued)

(ii) Profit after taxes (case 1)

Year	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12
Profit before taxes (million $)	(41.7)	(60.7)	(21.6)	13.7	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	35.2
Depreciation (million $)	-	-	-	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Balance (million $)	-	-	-	3.8	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	25.3
Tax discount rate (%)				100	100	100	100	100	100	100	80	70	50	0	0
Taxable amount (million $)	-	-	-	-	-	-	-	-	-	-	4.1	6.1	10.2	20.3	25.3
Tax (35%) (million $)	-	-	-	-	-	-	-	-	-	-	1.4	2.1	3.6	7.1	8.9
Profit after taxes (million $)	(41.7)	(60.7)	(21.6)	13.7	30.2	30.2	30.2	30.2	30.2	30.2	28.8	28.1	26.6	23.1	26.3
Present value factor (10%)	0.909	0.826	0.751	0.683	0.621	0.565	0.513	0.467	0.424	0.386	0.351	0.319	0.290	0.263	0.239
Present value (10%) (million $)	(37.9)	(50.1)	(16.2)	9.4	18.8	17.1	15.5	14.1	12.8	11.7	10.1	9.0	7.7	6.1	6.3

Results after taxes

Pay-back period:	6.7 years
Present value of investment:	$104.2 million
Net present value (10%):	$34.4 million
NPV (10%)/PVI:	0.33
Internal rate of return:	15.0% per annum

Table 11 (continued)

(iii) Profit after taxes (case 2)

Year	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12
Profit before taxes (million $)	(41.7)	(60.7)	(21.6)	13.7	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	30.2	35.2
Depreciation (million $)				9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9
Balance (million $)				3.8	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	25.3
Tax discount rate (%)				75	50	50	25	25	0	0	0	0	0	0	0
Taxable amount (million $)				1.0	10.2	10.2	15.2	15.2	20.3	20.3	20.3	20.3	20.3	20.3	25.3
Tax (35%) (million $)				0.3	3.6	3.6	5.3	5.3	7.1	7.1	7.1	7.1	7.1	7.1	8.9
Profit after taxes (million $)	(41.7)	(60.7)	(21.6)	13.4	26.6	26.6	24.9	24.9	23.1	23.1	23.1	23.1	23.1	23.1	26.3
Present value factor (10%)	0.909	0.826	0.751	0.683	0.621	0.565	0.513	0.467	0.424	0.386	0.351	0.319	0.290	0.263	0.239
Present value (10%) (million $)	(37.9)	(50.1)	(16.2)	9.2	16.5	15.0	12.8	11.6	9.8	8.9	8.1	7.4	6.7	6.1	6.3

Results after taxes

Pay-back period: 9.7 years

Present value of investment: $104.2 million

Net present value (10%): $14.2 million

NPV (10%)/PVI: 0.14

Internal rate of return: 12.1% per annum

VIII. REQUIREMENTS OF A NATURAL-GAS-BASED AMMONIA/UREA PLANT

A. Natural gas

The battery limit conditions for natural gas should be given in the following form:

Pressure at battery limit			______	kg/cm^2 gauge
Temperature at battery limit			______	^{o}C
Composition at battery limit:			______	
N_2	mole %:		______	
CO_2	mole %:		______	
O_2	mole %:	maximum	______	
CH_4	mole %:		______	
C_2H_6	mole %:		______	
C_3H_8	mole %:		______	
n-C_4H_{10}	mole %:		______	(maximum)
iso-C_4H_{10}	mole %:		______	(maximum)
n- and iso-C_5H_{12}	ppm:		______	(maximum)
C_5	ppm:		______	(maximum)
		Total (dry)	100.00	
H_2S	ppm:	(measured as S)	______	
Organic S	ppm:	(measured as S)	______	
Total sulphur	ppm:	(measured as S)	______	
Dew points:				
Water	maximum ______	^{o}C at	______	kg/cm^2 gauge
Hydrocarbon	maximum ______	^{o}C at	______	kg/cm^2 gauge
Filtration of natural gas:				
Particle cut-off size			______	micrometres
Lower heating value $kcal/Nm^3$			______	
or, Btu/scf, $60^{o}F$			______	

Natural gas is usually, or preferably, delivered to the battery limit of ammonia plants at a pressure of about 40 kg/cm^2 gauge (570 psig). If the pipeline pressure of the natural gas is appreciably lower, natural gas booster compressors should be installed in front of the ammonia plant in order to reduce compression energy requirements, as the standard volume of the natural gas is only about one fourth that of the hydrogen contained in the equivalent synthesis-gas volume ($3H_2:N_2$) for the same quantity of ammonia to be produced.

As a guideline, all C_1 to C_3 compounds of hydrocarbons can be readily reformed over normal natural gas reforming catalysts, but appreciable quantities of C_4 and higher hydrocarbons can give carbon deposition problems in the reformer. Thus, the above specification must state the maximum values of C_4 and $> C_5$. If, however, substantial concentrations of $C_4 > C_5$ appear in the natural gas, the plant will need a special reforming catalyst which is resistent to the cracking of these compounds, and it may also have to introduce certain alterations in the ammonia plant design required by the departure from the use of normal natural gas reforming catalysts. It should be noted that since a natural gas is low in or free of hydrocarbons higher than C_3, there will be a longer reforming catalyst lifetime and a lower catalyst cost.

B. Electric power

It is highly recommended that an ammonia/urea fertilizer plant in a developing country or a remote region of a developed country should have its own electric power plant so that the ammonia/urea plant will not become idle because of power failures of an external source. It is emphasized that the electric power plant will cost only a small percentage (a maximum of 5%) of the total investment required to construct a 600 t/d ammonia/1,030 t/d urea plant.

In industrialized countries petrochemical plants are often supplied with electricity from the public electricity networks. These are always interlinked with other nets and sustained and secured from a number of electric power stations, thus making a power failure very improbable. This will hardly be the case with the public electricity nets in any areas in Argentina where the ammonia/urea plant will be located.

Meanwhile, even if the fertilizer plant has its own electricity power station, it should be connected to the public net for increased safety in the electricity net, in such a manner, however, that no failures or disturbances in the public net can influence the operation of the fertilizer plant as long as its own electric power station is in service.

C. Water

The battery limit or design conditions of the make-up water should be given in the following form.

Make-up water for processing and cooling

Source:

Location of source (may be shown on drawing):

Maximum amount of make-up water available in m^3/h on any day and at any time of the year:

Temperatures in $^{\circ}C$:

- Maximum
- Average
- Minimum
- Design basis (weighted average of the above)

Water analysis (limits):

- Suspended solids (mg/l)
- Filtered water

Ignition residue (mg/l):

Specific conductivity (micro Siemens/cm):

Total hardness (German degrees):

Permanent hardness (German degrees):

Temporary hardness (German degrees):

Chemical composition (in mg/l):

CaO
MgO
Fe_2O_3
SiO_2
Cl
SO_4
P
NH_3 (mg N/l)
Nitrate (mg N/l)
Nitrate (mg N/l)
O_2
Permanganate consumption (mg/l)
pH

The temperature increase of circulating cooling water must not exceed ___ oC, in order to limit scale deposits in the water coolers.

Normally, an ammonia/urea fertilizer plant will be equipped with a circulating cooling water system with atmospheric cooling water towers where the hot cooling water returning from the water coolers is cooled down again by evaporation of a small quantity of the water into the atmosphere. In order to cover the loss of water through evaporation a relatively small percentage of the circulating water will have to be added constantly to the system. The total amount of make-up water for both cooling and process purposes will be in the order of 6,000 m^3/day for a 600 t/d ammonia/1,030 t/d urea plant.

The circulating cooling water system is usually the cheapest and most satisfactory solution compared to other cooling alternatives. On the basis of an actual analysis of the make-up water, possibly supplemented by a laboratory examination, the maximum permissible temperature increase of the circulating cooling water in the coolers should be specified in order to avoid excessive scale deposits in the coolers.

An alternative to cooling by a circulating cooling water system is cooling by passing river water of sufficient purity once through the coolers. This would save the cooling towers, and does not involve a loss of water through evaporation to the atmosphere. The hot cooling water would be returned to the river. On the other hand, this would require from 20 to 30 times as much river water to be pumped to the plant as in the case of a circulating cooling water system. Large pipes and pumps and a big consumption of electric energy would therefore be needed to pump the water from the river to the plant and back to the river. This alternative would presuppose that the river would always have a steady current, so that hot water could never be pumped back to the plant. It would also require that the current of the river would be big enough to prevent the hot cooling water from causing ecological problems.

Only in rare cases would this alternative be economic and feasible. A third alternative would be air cooling replacing water cooling partly or wholely. However, air coolers are much more expensive than water coolers, and the cooling air fans require much more electric energy than the water pumps. The entire application of air cooling instead of water cooling would increase the required investments by up to 20%. Air cooling is therefore not attractive and is used only where soft cooling water in sufficient quantity is not available.

Nevertheless, the need for process make-up water is still substantial and can never be reduced below a certain level, although a certain saving of the process make-up water can be achieved at extra investment cost.

The type, material, sizes, prices and other details of urea bags should be carefully considered before deciding which to procure.

D. Meteorological data

Atmospheric air

Design figures (weighted averages):

Barometric pressure (mm Hg): __________
Temperature (°C): __________
Relative humidity (%): __________

It must be specified if the plant is to be built in a region with a dry season during which the air may contain dust.

The following meteorological and climatic data will be necessary:

Air temperature: average monthly temperatures each month for one or more years; temperature extremes each month for one or more years, maximum, minimum, and maximum daily variation.

Rain: mm of rain each month for one or more years; annual rainfall for one or more years.

Relative humidity: average relative humidity each month for one or more years; maximum and minimum relative humidities each month for at least two or more years.

It is essential to know whether the relative humidity ever reaches 100% or nearly 100%, because such an extreme humidity would cause the cooling tower to stop functioning and lead to a complete shut-down of the entire plant.

Wind: wind frequencies in terms of number of days, directions, and velocities in m/sec each month for one or more years.

Barometric pressure: average barometric pressure each month for one or more years; maximum and minimum barometric pressures each month for at least two years.

The performance of the atmospheric cooling water towers depends very much on the humidity and temperature of the ambient air. The temperature of the make-up water has only a slight or no influence. The performance of the towers is characterized by the decrease in water temperature achieved at the normal rate of circulation of cooling water through the towers. The performance of the process air compressor of the ammonia plant will depend upon the barometric pressure and the cooling water temperature, which again will influence the production of ammonia and urea. Moreover, the performance of the synthesis and recycle gases compressor of the ammonia plant and the CO_2 compressors of the urea plant will depend upon the cooling water temperature, which will also influence the production of ammonia and urea.

Before the request for bids a calculation of the weighted averages of make-up water temperature, barometric pressure and relative humidity and temperature of ambient air should be made on the basis of the meteorological and climatic data for the site. This calculation will be used as the design basis in order to ensure that the average production of ammonia and urea throughout the year will be equal to the design capacities. It must be stressed that the use of arithmetric averages of the above climatic data as the design basis would be a mistake.

E. Plant site

The request for bids for the construction of the plant should at least include a guide map, a topographical map, preliminary soil investigation data, including the ground water level, flooding risks etc. The final detailed site data may be given later than the request for bids on construction etc.

The minimum soil bearing capacity or loading factor of the site should be 2.0 kg/cm^2 or more, as otherwise expensive building and foundation piling will be necessary.

Seismic data

If necessary, a table of earthquakes should contain a record of the number and intensity of earthquakes, measured on a standard scale of intensity, which have occurred over a number of years. Attention must then be drawn to the appropriate regulations which set forth in detail the antiseismic design requirements and procedures.

IX. CODES AND STANDARDS FOR PLANT DESIGN AND CONSTRUCTION

Codes and standards of, among others, mechanical, electrical and civil engineering designs must be selected and issued by the Argentinian authorities and entrepreneurs before the request for bids on an ammonia/urea plant. Codes and standards are available for designs and items which are manufactured and used repeatedly, whereas apart from standardization of some general features, norms on specialized and complicated machinery are seldom issued or available.

Adequate codes and standards provide a number of advantages, such as the following:

(a) Mechanical and electrical machinery, equipment and other items, buildings etc., will have a definite minimum satisfactory design, quality, standard, and service life;

(b) Items with similar functions and purposes, such as vessels, electrical motors, switchgears, cables, pipes, flanges, bolts, nuts, valves etc., will be standardized;

(c) Most leading manufacturers will be able to comply with any alternative codes and standards selected by their clients. Thus, manufacturers in the Federal Republic of Germany and the United States, for instance, will be able to comply with the codes and standards applicable in either of their respective countries. The specification of a set of standards means that particular designs of individual manufacturers are ruled out. In practice, however, all leading manufacturers apply as great a degree of standardization on the basis of international codes and standards as possible;

(d) The selection and specification of reasonable, well-known and internationally applied codes and standards does not mean that the number of competitive manufacturers becomes too narrow and the acquisition of equipment more costly;

(e) The standardization of common items means that the stock of spare parts can be maintained with a great saving in capital and operating costs, and that any piece of machinery, equipment, or other item can be easily replaced, without the plant having to rely solely on the original manufacturer of the replaced part, which could result in substantial savings;

(f) Standardization would also make it possible to ensure maintenance, repair, and replacement work more rapidly, easily, safely and economically with a smaller maintenance and repair crew, to shorten the annual overhaul period, and to minimize production losses during shut-down, repair and annual overhaul periods.

Most international chemical industry companies follow specific sets of codes and standards for the design and construction of their plants because of the obvious advantages and savings they entail. The Argentinian authorities and entrepreneurs should appoint highly qualified experts to study this subject and submit recommendations, and specific codes and standards should be selected for the project and for future plants or installations. In view of the great advantages and savings involved, this matter ought to be dealt with as soon as possible.

The design codes and standards of the plant ought to be discussed with and approved by the insurance company which will provide insurance for the plant. In the selection of codes and standards all due consideration should be given to promoting the participation of domestic manufacturers and subcontractors in the bidding for the delivery, construction, and maintenance of the plant.

Examples of some of the relevant plant equipment codes and standards currently applied in the United Kingdom and the United States are given in annex III.

X. ENVIRONMENTAL PROTECTION

A. Sources of pollution

For protection of the environment and operating personnel, the sources of effluents, exhausts and noise described below must be controlled as far as possible through proper designing and careful operation.

Leakage of solution from CO_2 wash unit in the ammonia plant

During normal operation effluents from this plant will not take place, as leakages from the glands of circulating pumps are recovered. However, leakages of effluents to the sewer system may occur as a result of, for example, corrosion attack, and if such a leakage occurs from a tower or pipe under pressure, or should an explosion take place, the solution could be spread to the surrounding area. The use of poisonous activators in hot pot solutions should therefore be avoided. For this reason, the Giammanon-Vetrocoke CO_2 removal process with an arsenic compound as activator of the potassium carbonate solution should not be used. Possible effluents may be discharged into either the inorganic or the organic sewer system.

Boiler blow-down

Blow-down from all boilers takes place either continuously or intermittently in order to control and limit the salt content in the boiler water. When ejected from boilers, the blow-down water is hot and boiling, but is usually sent to boiler blow-down drums for deboiling and mixing with cooling water before the mixture of boiler blow-down water and cooling water is sent to the inorganic sewer system. Because boiler water is kept at a pH of 9-10, the effluent mixture will be alkaline, and will also contain phosphate, hydrazine, and the chemicals from the cooling water.

Oil leakages from compressors

Oil discharge from the lubricating oil and grease system ought not to take place, but it may happen by accident. Water condensate containing oil accumulates regularly in compressor knock-out drums which are drained continuously or intermittently into oil separator drums. The overflows from the oil separators will flow into the organic sewer system. Careless operation may result in oil from the oil separators or from oil spills being discharged into the organic sewer as well.

Leakage from circulating cooling water systems

In addition to the cooling water discharged steadily to the inorganic sewer through the boiler blow-down drums, more cooling water will usually have to be drained from the circulating cooling water system in order to limit the content of chloride to 150-200 ppm in the water, and therby limit the corrosiveness of the water. The drainage required will depend upon the content of chloride in the make-up cooling water. In most circulating cooling water systems there are installed a number of parallel water catch-filters for sediments. At frequent intervals, these filters will have to be cleaned through back-flow of cooling water into a sedimentation pond which discharges into the inorganic sewer. The amount of back-flow cooling water may be considerable, depending upon, among other things, the hardness of the make-up water, and may carry most of the effluent discharged during a full operation day. At high hardness, the back-flow drainage may be sufficient to control the chloride content of the circulating water.

For further control of corrosiveness, sedimentation and algae growth, the following chemicals are added to the circulating cooling water:

Sulphuric acid to keep pH between approximately 5.8 and 6.3 and to avoid excessive sedimentation due to temperature increase during passage of the water through the coolers

Chromate and/or zinc derivates to maintain approximately 20 to 30 ppm Cr, or, alternatively, about 3 ppm Zn to control corrosion. Chromate will gradually be reduced to Cr^{+++}, which, like Zn^{++}, precipitates in alkaline solutions

Polymer disperse agent to counteract sedimentation

Biocides (for instance methylene dicyanate) and amines to control algae growth

Chloride, also to control algae growth, added either continuously or intermittently to maintain about 1 ppm of Cl_2 in the water

Thus the drain or back-flow water may contain ca. 20 to 30 ppm Cr or 3 ppm Zn.

<u>Back-flow of water from make-up water catch filters for boiler feed water system</u>

This water will flow into the inorganic sewer system, and the frequency and quantity of the back-flow will depend upon the content of suspended particles in the make-up water at the filter inlets.

<u>Salt solutions, acids or bases from regeneration of the ion-exchange filter of the boiler feed water preparation unit</u>

Salt solutions and acids or bases, after passage through neutralisation pits from the intermittent regeneration of the ion-exchange filters of the boiler feed water preparation unit, will be discharged into the inorganic sewer system.

<u>Gland cooling water from circulating pumps of urea plant</u>

Cooling water for temperature control of the circulating pump glands will contain urea and ammonia leaked through the glands from the pumps. This water will be discharged into the organic sewer. The contents of urea and ammonia will largely depend upon the maintenance of the pumps. Because of the ammonia content, this effluent water will be alkaline. If water drained from the circulating cooling water is used, precipitates of hardness and chromium hydroxide may clog the sewer. As the quantity of gland cooling water is comparatively small, it is recommended to use instead cooled steam condensate in order to avoid clogging.

<u>Process water from urea plant</u>

It has been noted that water is formed during the urea reaction and some steam is added to the process. This process water has to be removed. The removal takes place in the urea crystallizers in which the water is boiled off under vacuum and subsequently condensed in the vacuum condenser installed in one or two stages. The process condensate will be discharged into the organic sewer.

After one stage of vacuum evaporation and condensing the process water will contain 1,500 to 2,000 ppm. of ammonia and some traces of urea.

After two stages of vacuum evaporation and condensing the primary condensate will be returned to the process, while the secondary condensate containing only 100 to 300 ppm. of ammonia and traces of urea will be sent to the organic sewer.

Inadvertent discharge of carbamate and urea solution from the urea plant

Upon shutting down the urea plant, the hot carbamate and urea solutions in the process reactors, vessels, pipes, and pumps must be pumped and displaced into the large carbamate tank and the large urea surge tank, otherwise the solution would solidify in the equipment with the decreasing temperature and cause a serious problem. Upon restarting the plant, the solutions in these tanks must be eventually recovered for processing. In case of frequent shut-downs or malfunctioning, the tanks may already be full when a shut-down takes place, so the operators would have no other choice than to discharge large amounts of concentrated ammonia carbamate and urea solutions into the organic sewer system. If discharged directly into a lake or river, they would have a disastrous effect on biological life in the recipient waters.

Exhaust flue gases

Exhaust of flue gases takes place from the primary reformer furnace, the package steam boilers and the electricity plant, and the gases do not cause any problem.

Exhaust air of urea prilling towers

Adequate washing equipment should be installed for cleaning the exhaust air at the top of the urea prilling towers, otherwise the towers may exhaust a fume containing urea dust, especially when operational disturbances occur. This fume may be carried by the wind and can cause considerable inconvenience to villages or towns situated many kilometers away.

Noise

Noise will be made by the compressors, turbines, burners of the primary reformers etc., and adequate noise control measures should therefore be taken.

B. Sewers, recipients and general tolerance limits

Sewer systems

A complete sewer system could include one sewer for inorganic and another for organic process effluents, a sanitary sewer, and rainwater canals.

Sewers where there may be sedimentation of hardness or other salt should be open canals, in order to be able to clean the sewers and avoid their clogging and obstruction. In particular, this will be necessary where water from the circulating cooling water system will be discharged and mixed with alkaline effluent water, for example boiler blow-down water, urea process condensate or gland cooling water of circulating pumps in the urea plant.

Recipients

In most countries the sanitary effluent will require biological treatment before discharge into any recipient. In some cases the inorganic process effluents can be discharged directly into the recipient, or they may first have to pass through a lagoon. However, it is pointed out that some countries have very strict regulations concerning the quantities of Cr and Zn which can be discharged into rivers or lakes. In such cases, costly special measures must be taken with regard to the circulating cooling water. For instance, air cooling may to a certain extent replace chemical treatment of cooling water make-up or water cooling.

With respect to the organic process effluents, they will have to undergo biological treatment before being discharged into sensitive recipients like rivers and lakes.

General tolerance limits on process effluents discharged into lakes or rivers

	Organic process effluents subjected to biological treatment before discharge into lake	Inorganic process effluents directly discharged through lagoons into lake
Suspended material	0	1,500 mg/l
Particle size	1.2 cm	1.27 cm
Asphalt, pitch, catalysts, slags, iron or metal chips, mud, mortar etc.	0	0
Grease, fat, oil	200 mg/l	0
Chemical oxygen demand	Daily average: 10,000 mg/l	Monthly average: 200 mg/l Maximum at any given time: 600 mg/l
Temperature	54°C	54°C
pH range	5.5-9.5	6.0-9.0
Toxic substances	0	0
Radioactive substances	0	0

General tolerance limits required for biological treatment

Suspended solids	125 mg/l
Oil and grease	50 mg/l
Heavy metals (Cr, Zn etc.)	1-10 mg/l
Acids	No free mineral acids
Variation of organic load (based on 4 consecutive hours)	4:1
Sulphur compounds	100 mg/l
Chlorine compounds	8,000-15,000 mg/l
Phenols	70-160 mg/l
Ammonia (during start-up of biological treatment plant and formation of activated biological sludge)	100-200 mg/l
Ammonia (during normal operation of biological treatment plant)	1,600 mg/l
Dissolved salts	20,000 mg/l

XI. ESTABLISHMENT OF AN AMMONIA/UREA PLANT

A. Preliminary steps

A non-comprehensive list of the preliminary steps involved in the establishment of a fertilizer plant is given below. More steps may be needed, and the order in which they are taken may be changed according to circumstances.

Pre-feasibility study

Quotations from suppliers and transporters of raw materials and utilities

Study of domestic and export markets and prices of finished products

Quotations for the shipment of finished products

Appointment of experts and consulting engineers

Study of the shipment, storage and distribution of raw materials and finished products

Study of alternative plant sites and selection of final site

Study of roads, railways, off-sites, electric power supplies, water for process and cooling purposes etc.

Study of climatic conditions, preferably on the basis of metereological data covering a number of years

Study of regulations, codes and standards of plant construction and operation, environmental protection, health, safety, equipment inspection etc.

Study of staffing requirements and the relevant labour laws;

Study of housing requirements of expatriates and nationals during plant construction and operation

Study of the experience, capabilities, financial reliability etc. of domestic manufacturers and suppliers, engineering firms, subcontractors etc.

Study of the availability of domestic workshops etc., for plant maintenance and repairs

Preparation of tender papers for the establishment of the plant

Study of alternative plant financing

Study and selection of possible bidders

Submission of tenders

Evaluation of bids

Signing of letters of intent and subsequently contracts for raw material supplies, utilities and marketing of finished products

Purchase of plant site

Selection of successful bidder and final contract negotiations;

Signing of contract on financing

Signing of contract with an inspection agency for inspection and approval of equipment prior to shipment

Recruitment by purchaser of staff for contract review and verification of fulfilment of purchaser's contractual obligations

Bidding and signing of contracts with: domestic manufacturers and suppliers, civil engineering firms and building subcontractors, plant security agencies and industrial insurance companies

Bidding, and contracting for harbour facilities, public utilities, site preparation, sewers, housing etc.

Employment, housing and training of staff and labour for plant construction, management, operation and maintenance, including marketing and sales, financing and administration, employment and staff welfare, medical services, security guards etc.

B. Consultancy services and assistance

The type of consultancy services and assistance required will depend upon the various phases of the project, namely: phase 1 - feasibility and pre-investment study; phase 2 - request for and evaluation of bids and signing of contracts; phase 3 - plant construction; phase 4 - start-up and operation of plant.

The consulting engineering company should be paid per diem rates on the basis of the number of foreign experts actually made available, because the amount of consultancy work can only be very roughly estimated in advance. An alternative agreement based upon a lump sum fee would be substantially more expensive and less advantageous from a legal point of view. For instance, the purchaser, even if he deemed it necessary and desirable, would not be able to withdraw from the agreement prior to its expiration unless the full fee was paid.

The consultancy services which may be needed during phases 2, 3 and 4 will to a certain extent depend upon the capability and size of the staff formed by the purchaser for the project.

However, the consulting company engaged for the feasibility study must be able to carry out consultancy services relating to phases 2, 3 and 4 if requested to do so. As the latter services cannot be evaluated beforehand in terms of the amount required or the time they take, it is essential that the consulting company should be paid per diem rates on the basis of the number of foreign personnel actually made available, as in the case of the feasibility study. Special care should be taken to avoid duplication by the consulting engineering company or any other consultants of work which would be part of the obligations of the contractor, such as training operating personnel, participation in construction, start-up and operation etc., as this would dilute the contractual obligations of the contractor and give him excuses and loopholes if any delays, damage to equipment, or similar incidents occurred during construction, start-up and operation.

High level consultancy will be needed on the following subjects: preparation of tender papers and preinvestment studies, evaluation of bids from contracting companies and selection of financing methods, contract negotiations and drafting of contracts.

During the construction, start-up and operation phases, the consultancy services should be confined to assisting in the implementation of the purchaser's obligations and in checking the contractor's fulfilment of his obligations.

Annex II contains, solely for reference purposes, a list of some impartial consulting companies and consultants which are able to render consulting services and assistance in the preparation of feasibility and preinvestment studies, tender papers etc., for an ammonia/urea fertilizer plant.

C. Tender papers and contractors

A summary list of the items normally dealt with in tender papers for the design, construction, and initial operation of a fertiliser plant is given below. Such tender papers will have to be worked out by experts and consulting engineers.

Project background

Plant capacities and product specifications

Process and utility units and off-sites

Basic design data on raw materials, utilities, climatic conditions codes and standards for equipment, installations, construction, etc.

Unit costs of raw materials, utilities and labour, and design and calculating basis for determining the optimal design and minimizing the sum of variable costs and fixed costs;

Plant site, location, map and dimensions, heights, soil investigation data, ground-water levels, anti-flooding measures, road connections etc.;

Presentation and approval of designs and specifications of various processes, utilities, equipment and basic civil engineering work;

Detailed list of all required equipment, materials, normal first-year spare parts etc.

Rules and procedures for the inspection of equipment and materials in manufacturers' workshops prior to shipment

Quoted prices of equipment, materials and spare parts, including delivery terms ex works, f.o.r., f.o.b., or c.i.f., cash payment terms and currencies

Travelling expenses, remunerations and living allowances of construction workers and supervisory staff and of operation and maintenance staff during the plant's first year in service, including estimated manpower requirements in each category

Payment, financing and insurance terms applied to quoted prices, remunerations etc.

Financing provided by purchaser from his own resources;

Purchaser's right to approve or reject contractor's foreign personnel in advance

Rules for payment and approval of living allowances to contractor's foreign personnel

Terms of employment of local staff and labour

Role of selected consulting engineers

Terms of transport, insurance, and ownership transfer of equipment and materials

Staff training plans

Purchaser's obligations, such as site preparation and protection of off-sites, roads and utility supplies, staff employment, housing, obtaining the necessary permits from the authorities, the procurement of equipment, raw materials and utilities

Contractor's guarantees with regard to the reliability and operation of equipment during the first year of service, performance, consumption figures, product specifications, the regulation of effluents for environmental protection purposes, and test-run procedures;

Guidelines for the replacement of unsatisfactory equipment and materials and procedures to be followed in case of non-fulfilment of the contractor's guarantees and repeated test-runs

Time schedules and penalties in case of non-comliance

Financial securities, including letters of credit or bonds held by purchaser, and advance payment and performance guarantees certified by reputable banks

Contractor's liabiity, royalty and patent clauses, language of the contract, arbitration and adjudication rules, the applicable laws, secrecy provisions

Bidding schedule and procedures, security, evaluation and forfeit of bids, selection of successful bidder, negotiation and signing of contract.

The tender papers should ask the bidders to submit binding bid prices (firm or with escalation clauses) on engineering and supplies and binding fees or remunerations for supervisory services related to transport, civil engineering, construction, start-up, and initial operation. On the other hand, only estimated prices should be called for from the bidders on detailed civil engineering design, civil engineering works, construction works etc., as these tasks are to be carried out under the supervision and responsibility of the contractor, subject to approval by domestic firms, sub-contractors, personnel and workers. In this manner, the bidders will not be responsible for any economic risks involving the domestic firms, sub-contractors, personnel and workers, the prices and salaries of which the purchaser much better than any foreign contractor, will be in a position to control in accordance with the terms of the tender papers.

The project guidelines embodied in well-prepared tender papers should make possible the achievement of the lowest investment costs. The tender papers should provide for the contractor's assignment of more foreign personnel to the plant site during the construction period, if the capabilities and manpower of domestic companies are insufficient to ensure the satisfactory completion of the construction works.

The contracting companies invited to bid for the delivery and construction of an ammonia/urea plant on a turn-key basis must be experienced and specialized in this difficult field. In order to avoid discouraging qualified companies from participating in the bidding, no other companies should be asked to bid. Moreover, the bidding should not be called for before the feasibility and financing of the project have been examined and cleared. At the request for bids, the contracting companies should be told about the feasibility and the pre-arranged or contemplated financing scheme of the project, as they may not want to bid unless they feel convinced that the project can and will be carried out. In this connection, it should be noted that it would cost a contracting company approximately $100,000 to $300,000 to prepare its bid in the required form.

Suppliers of large ammonia/urea plants

Annex II contains, solely for reference purposes, a list of some contracting companies which have constructed in recent years or are in the process of constructing large ammonia/urea plants of modern design, and are able to carry out a complete turn-key operation.

The major concern of the purchaser should not be to satisfy particular bidders or to comply with domestic regulations relating to open and unrestricted bidding which may apply in the case of standardized commodities. On the contrary, in the present case involving an extremely complex, integrated, large petrochemical plant the major concern of the purchaser must be to attract the limited number of highly-qualified, experienced, and competitive international contracting companies in this particular field to participate in the bidding. In this broad context, competitive ability will mean satisfactorily low investments and operating costs (not necessarily the lowest), experience in process technology and construction, the capability to execute a turn-key contract, to terminate construction within agreed time limits, to organize and initiate production, to train client's personnel and workers etc.

Suppliers of small ammonia/urea plants

A list of some engineering and contracting firms which are able to supply small ammonia/urea fertilizer plants, i.e. plants with an ammonia capacity of less than 600 t/d, is included solely for reference purposes in annex II.

Before tenders are called for, the feasibility of the project should be ascertained. No reputable engineering and contracting firm would bid on unfeasible projects requiring between $100,000 and $300,000 to prepare a detailed bid with a possibility of success under competitive bidding conditions. Moreover before tendering is opened, the bidders contemplated by the purchaser should be contacted and given information on the project in order to convince them of its feasibility. It should be noted that small ammonia/urea fertiliser plants are not generally considered feasible at present. Bidding may therefore have to be limited to a certain number of specific companies, and the purchaser may have to offer special advantages to the two top bidders and perhaps also to the third highest bidder, in accordance with the adjudication and evaluation rules stipulated by a neutral committee, in order to encourage reputable companies to participate in the bidding.

D. Domestic manufacturers and suppliers

Before the final issue of the main tender papers, experts should thoroughly examine the extent to which domestic manufacturers and suppliers may be able and qualified to act as subcontractors or subsuppliers of the main contractor. The domestic manufacturers and suppliers must be able to comply with the selected codes and standards and the usual engineering and business standards and requirements of reputable international contractors.

The experience, capabilities, financial reliability etc., of domestic manufacturers and suppliers of various categories of equipment should be examined, and data on the domestic companies acceptable to the purchaser should be included in the tender papers for the main contract. The purchaser should specify in the tender papers that domestic manufacturers and suppliers are preferred to foreign companies in so far as they are competitive, responsible, reliable and capable of acting as subcontractors or subsuppliers to the main contractor. Under no circumstances should the main contractor be asked or required to deal with domestic manufacturers and suppliers if this might involve the following consequences and risks: increase in plant capital cost and consumption figures; lower plant quality and mechanical and operational reliability; increase in delivery and construction time limits and delay in the start-up and operation of the plant; lessening the main contractor's overall responsibility for the design, delivery, construction and initial operation of the plant, as this could prove to be very expensive and detrimental to the interests of the purchaser.

E. Transport means

The transport means for conveying machinery, equipment etc., from the Atlantic harbour by railway, road or river to the plant site must be carefully scrutinized to ensure adequate carrying capacity, dimensions etc. This inspection should include waggons, trails, bridges, railway traffic, barges, river navigation, loading and unloading cranes etc. The following data may be tentatively accepted as characteristic for the machinery, equipment etc., to be transported for a 600 t/d ammonia/1,030 t/d urea plant. Total weight of machinery and equipment: approximately [illegible],000 tons. Heaviest piece of equipment (urea converter): approximately 150 to 200 tons. Largest piece of equipment (CO_2 stripper): approximately 4 m in. diameter x 40 m in length.

F. Purchaser's staff

During the construction of the ammonia/urea fertilizer plant, the purchaser will have to set up a competent staff with the following responsibilities:

To perform the tasks of the purchaser under the agreement with the contractor, with the help of the consulting engineering company

To check and approve the design submitted by the contractor, with the help of the consulting engineering company

To approve the tendering by forwarding agents and select the forwarding agent on the basis of the contractor's recommendations

Together with contractor's personnel, to receive and check against the contractor's and vendors' packing lists etc., the machinery, equipment etc., upon arrival at plant site

To approve the contractor's selection of domestic design firms to work out the detailed civil engineering design

To check the detailed civil engineering design drawings, specifications, and static calculations prepared by domestic design firms with regard to compliance with domestic regulations etc.

To approve the temporary plant site installations suggested by the contractor

To approve the tendering by domestic civil engineering subcontractors and select the domestic civil engineering subcontractors on the basis of the contractor's recommendations

To co-operate with the contractor in the supervision, approval and acceptance of civil engineering works

To approve the selection of domestic construction firms and the employment of domestic construction personnel and workers recommended by contractor

To co-operate with the contractor in the inspection and testing of finished installations

To provide work for every staff member and worker in the management, operation, and maintenance of the ammonia/urea fertilizer plant

To co-operate with the contractor in carrying out and checking the various performance test-runs, with the help of the consulting engineering company

To pay contractual prices to the contractor

To reimburse the contractor foreign exchange or local currency paid by him.

The purchaser's staff during construction, excluding domestic personnel and workers employed in the completed plant, will include chemical, mechanical, civil and electrical engineers, accountants, functional administrative staff, secretaries etc. The staff should probably include from 50 to 75 members.

G. Domestic participation

Domestic companies

Domestic companies, personnel, and workers should be expected to participate to a considerable extent in the construction of the plant. It is essential for the purchaser carefully to check, before bids from foreign contracting companies are requested, the capabilities of the domestic companies to ensure the satisfactory execution, within reasonable time limits, of the various tasks assigned to it. The availability of sufficient numbers of suitable domestic personnel and workers for the construction works and of construction materials for the plant site must also be checked in advance by the purchaser.

This checking should be based on the following tentative and approximate figures for a 600 t/d ammonia/1,030 t/d urea plant.

Detailed civil engineering designs

Total combined man-hours of civil engineers and draughtsmen: approximately 50,000

Civil engineering works

m^3 of concrete to be poured: approximately 25,000 (from this figure the quantities of cement, gravel, sand, and reinforcement iron can be roughly estimated). The checking of civil engineering subcontractors must include civil engineers, workers, machinery and equipment such as lorries scrapers, digging machines, concrete mixers, cranes, scaffolding etc.

Manpower

The construction force will consist of approximately 1,100 men at its peak and 650 men on the average, and approximately 80 expatriates may be needed. The force will be divided into categories and man-hours as indicated below.

Type of workers		Approximate man-hours
Boilermakers		470,000
Bricklayers		90,000
Carpenters		400,000
Electricians		270,000
Labourers		760,000
Operating engineers		320,000
Millwrights		50,000
Painters		90,000
Pipe fitters		1,700,000
Ironworkers		340,000
Cement finishers		50,000
Truck drivers		50,000
	Total	4,590,000

Construction materials

Satisfactory and reliable suppliers of cement and reinforcement iron, and adequate deposits and qualities of gravel and sand must be found. Suitable machinery for excavating, crushing, sieving, loading etc., must be available or procured in due time for the quarries and deposits of gravel and sand. Roads must be available and permanently maintained in a good state of repair, and lorries are required for the heavy transport of cement, gravel, sand, and reinforcement iron to the plant site.

Time schedule

The typical time schedule for delivery and construction of a large ammonia/urea plant is outlined below.

Stage of project	Months from signature of contract
Delivery f.o.b.	30
Civil engineering works	14
Construction	12
Commissioning and start-up	6
Total time	38

H. Operation and staff of an ammonia/urea plant

The ammonia/urea fertilizer plant should be run as an autonomous company. The marketing of urea may be under the responsibility of the same company, or partly or wholly transferred to an independent marketing company. The organization chart of the ammonia/urea fertilizer plant should be discussed and agreed upon with the contractor. Tentatively, the composition of the plant staff would be as follows:

Managing director	1
Director of administration	1
Secretaries, personnel office, security guards, cafeteria and cleaning personnel etc.	20
Finance manager	1
Accountants, internal auditor	6
Chief statistician	1
Statistician	1
Purchasing supervisory	1
Purchase clerks, storage personnel	10
Production manager	1
Manager of ammonia plant	1
Supervisors for 4 shifts (3 eight-hour shifts, plus one extra shift to cover holidays, vacations, resignations, retirements etc.)	4
6 operators for each shift	24
Manager of urea plant	1
Supervisors for 4 shifts	4
4 operators for each shift	16
Shipment workers (assuming movable loading conveyors)	24

Manager of power plant, electrical distribution system, water preparation and cooling water towers and pumps	1
Supervisors for 4 shifts	4
6 operators for each shift	24
Chemical engineers	3
Safety engineer	1
Laboratory and data logging personnel	6
Maintenance and repair manager	1
Engineers (mechanical and electrical)	4
Workshop personnel	30
Instrument shop personnel	6
Purchasing officer and clerks	4
Manager of engineering department	1
Engineers (civil, mechanical and electrical)	4
Draughtsmen	2
Marketing manager (possibly in an independent company)	1
Miscellaneous (depends largely on marketing agreement)	20
Total	229

In order to achieve the required economic results of the ammonia/urea fertilizer plant, it should be operated near capacity throughout the year, except during the annual overhaul period of three to four weeks. To ensure satisfactory and continuous operation, the operation and maintenance personnel must be highly qualified, satisfied with their social and working conditions, and recognized as the key personnel of the plant. During the training and employment of the operating and maintenance personnel, strict selection standards should be applied to ensure that no unqualified personnel is allowed to participate in and be responsible for plant operation and maintenance. The salaries of operating and maintenance personnel represent only an insignificant share of total production costs. These staff members should therefore be well paid and offered conditions attractive enough to make it worthwhile for well-qualified persons to join the staff and to rule out strike threats or other personnel problems.

In order to ensure satisfactory continuous operation and personnel safety, and to avoid equipment losses through wear and tear a set of strict plant regulations governing working conditions, standards of behaviour etc., must be established. It must be at the entire discretion of the plant management to sanction any breach of plant regulations by the immediate dismissal of the staff member concerned.

The managing director of the plant and the managers of the individual departments must all possess the highest qualifications as chemical, mechanical, electrical or civil engineers, and have many years of experience as successful managers in the fertilizer industry before they join the staff of the proposed ammonia/urea fertilizer plant. Inexperienced and unproven young people, regardless of their university degrees, should not be appointed to any of these key posts. If sufficiently qualified nationals are not available for these posts, foreigners must be sought for and employed.

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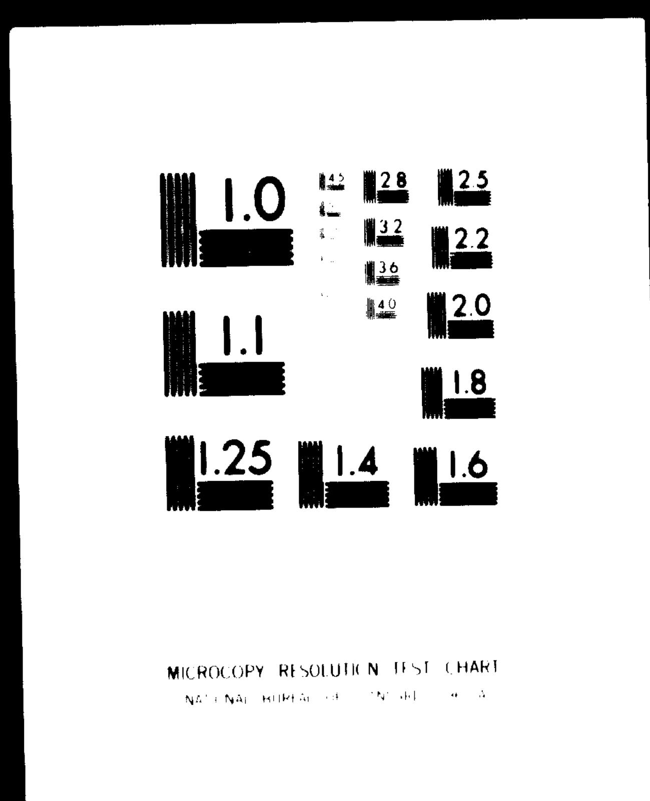

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Annex I

PROJECT PERSONNEL

A. International staff

Remigio D. Gabin, UNIDO Project Manager
Mauricio Jelen, UNIDO Project Evaluator

B. Host country staff

Julián Enrique Finetti, Co-director of SEDI
Héctor Solá, Chemical engineer

Annex II

INTERNATIONAL FERTILIZER BROKERS, EXPORTERS, CONSULTANTS AND CONTRACTORS

A. International fertilizer brokers and exporters

Agricultural and Industrial Corporation
866 United Nations Plaza
New York, New York 10017
United States of America

Beker International Corporation
124 West Putnam Avenue
Greenwich, Connecticut 06830
United States of America

International Minerals and Chemical Corporation (IMC)
United States of America

Kaiser Aluminium and Chemicals, Inc.
Oakland, California
United States of America

Occidental Petroleum Corporation
(INTERORE)
10889 Wiltshire Boulevard
Los Angeles, California 90024
United States of America

Nitrex A.G.
Bleicherweg 33
CH-8027 Zurich
Switzerland

Société Complexport
12 Avenue de la Grande Armée
Paris
France

B. Fertilizer exporters in Africa and South America

Exporter	Fertilizer supplied
Chérifien des Phosphates Rabat Morocco	Phosphatic fertilizers
Federation Chemicals Ltd Trinidad and Tobago	Nitrogenous fertilizers
Nitrogen Venezolana del Nitrógeno, C.A. Maracaibo Venezuela	Nitrogenous fertilizers

Exporter	Fertilizer supplied
Pemex Mexico	
Sonatrach Alger Algeria	Nitrogenous fertilizers

C. International consulting firms and experts

Battle Memorial Institute
505 King Avenue
Columbus, Ohio 43201
United States of America

Cremer and Warner
Consulting Engineers
140 Buckingham Palace Road
London, SW1W 9SQ
United Kingdom of Great Britain and
Northern Ireland

Imhausen International Company mbH
Kaiserstrasse 95
D-7630 Lahr/Schwarzwald
Federal Republic of Germany

James Chemical Engineering
4 Seymour Place
West Armonk, New York 10504
United States of America

Japan Consulting Institute
Hibiya Park Building
No. 1, 1-chome, Yuraku-cho
Chiyoda-ku, Tokyo 100
Japan

Karl Kjeldgaard
Consulting Engineer
Trongaardsrej 37B
Copenhagen
Denmark

L.H. Manderstam and Partners Limited
Consulting Engineers
38 Grosvenor Gardens
London SW1
United Kingdom of Great Britain and
Northern Ireland

Scientific Design Company Limited
Bush House
Aldwych
London WC2B 4QB
United Kingdom of Great Britain and
Northern Ireland

D. Contracting companies

Bechtel Inc.
50 Beale St.
P.O. Box 3965
San Francisco, California 94119
United States of America

CHEMICO
Chemical Construction Corporation
320 Park Avenue
New York, New York 10022
United States of America

C.F. Braun and Co.
Alhambra, California
United States of America

Davy Power Gas Limited
P.O. Box 21
Stockton-on-Tees
Teeside
United Kingdom of Great Britain and
Northern Ireland

E.N.S.A.
Paris
France

Fluor Corporation
2500 South Atlantic Boulevard
Los Angeles, California 90040
United States of America

Friedrich Uhde GmbH
Deggingstrasse 10
46 Dortmund
Federal Republic of Germany

Heurtey S.A.
Paris
France

Humphreys and Glasgow Limited
22 Carlisle Place
London SW 1P 1JA
United Kingdom of Great Britain and
Northern Ireland

M.W. Kellogg Company
1300 Three Greenway Plaza East
Houston, Texas 77046
United States of America

SNAM Progettj S.P.A.
20097 San Donato Milanese
P.O. Box 4172
Milan
Italy

Toyo Engineering Corporation
Kasumigaseki Building, 2-5, 3-chome
Kasumigaseki
Chiyoda-ku
Tokyo
Japan

E. Contracting companies able to supply small plants

Chiyoda Chemical Engineering and Construction Company, Japan

Chemico, United States of America

Coppee-Rust, Belgium

Davy - Powergas, United Kingdom of Great Britain and Northern Ireland

Friedrich Uhde GmbH, Federal Republic of Germany

N-Ren Corporation, United States of America and Belgium

Simon - Carves Ltd., United Kingdom of Great Britain and Northern Ireland

SNAM Progetti, Italy

Voest - Alpine, Austria

Annex III

EXAMPLES OF FERTILIZER PLANT EQUIPMENT CODES AND STANDARDS CURRENTLY APPLIED IN THE UNITED KINGDOM AND THE UNITED STATES

United Kingdom

British Standards Institution
2 Park Street
London W1A 2BS

BS 4741: 1971
Specification for vertical cylindrical welded steel storage tanks for low-temperature service: single-wall tanks for temperatures down to -50°C

United States

American Petroleum Institute
Division of Refining
1801 K Street NW
Washington DC 20006

API RP 550
Manual on installation of refinery instruments and control systems
Part I - Process instrumentation and control
Part II - Process stream analyzers

API standard 610
Centrifugal pumps for general refinery services

API standard 611
General-purpose steam turbines for refinery services

API standard 612
Special-purpose steam turbines for refinery services

API standard 614
Lubrication, shaft-sealing and control oil systems for special-purpose applications

API standard 617
Centrifugal compressors for general refinery services

API standard 620
Recommended rules for design and construction of large, welded, low-pressure storage tanks

API standard 665
API fired heater data sheet

The American Society of Mechanical Engineers
United Engineering Center
345 East 47th Street
New York, New York 10017

ASME boiler and pressure vessel code
Section I: Rules for construction of power boilers

ASME boiler and pressure vessel code
Section VIII: Rules for construction of pressure vessels
Division 1

ASME boiler and pressure vessel code
Section VIII: Rules for construction of pressure vessels
Division 2: Alternative rules

ANSI B313 - 1973
American national standard code for pressure and petroleum refinery piping

Tubular Exchanger Manufacturers Association, Inc.
331 Madison Avenue
New York, New York 10017

TEMA Specification, fifth edition 1968
Standards of the Tubular Exchanger Manufacturers Association

Annex IV[a/]

ANNUAL DOMESTIC PRODUCTION, IMPORT, TOTAL CONSUMPTION AND REGIONAL DISTRIBUTION OF FERTILIZERS IN ARGENTINA DURING THE YEARS 1970-1976

A. Domestic production and import of fertilizers

Fertilizer	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76
	Domestic production from 1970 to 1976					
Ammonium sulphate	49,533	49,361	56,821	50,834	29,031	
Urea	37,717	45,765	36,330	39,783	18,414	
Liquid ammonia	3,812	4,778	.878	4,068	1,350	
NPK compound	18,821	19,624	...	...	...	
NP compound (bone meal)	-	-	7,002	3,905	436	
Thomas phosphate slag	7,236	10,000	9,083	4,080	3,459	
	Imports from 1970 to 1976					
Ammonium sulphate	-	-	9,934	-	3,500	
Urea	-	-	7,000	10,000	22,024	
Liquid ammonia	-	-	2,000	-	-	
Sodium nitrate	16,172	6,990	14,600	14,268	8,156	
Other nitrogenous fertilizers	1,840	1,630	2,901	5,665	5,557	
Simple superphosphate	-	120	1,000	-	4,013	
Triple superphosphate	11,998	16,606	31,520	11,310	15,344	
Thomas phosphate slag	-	-	-	-	700	
Phosphate rock	8,300	13,262	16,750	19,820	29,840	
Other phosphates	170	100	-	-	-	
Potassium nitrate	-	-	1,220	2,875	5,103	
Potassium chloride	5,226	7,909	6,511	12,872	6,171	
Potassium sulphate	1,256	2,698	2,559	3,418	2,163	
Potassium magnesium sulphate	-	-	4,132	6,009	2,241	
Potassic rock	1,695	2,315	-	-	-	
NP and NK compounds	62,359	26,040	55,490	30,068	29,087	

a/ The data contained in the tables are based on the statistical publications of the Ministerio de Agricultura y Ganadería, the Instituto Nacional de Tecnología Agropecuaria, and the Centro de Investigaciones de Recursos Naturales, and on information obtained during visits to the Ministry of Agriculture.

B. Total and regional distribution of fertilizer consumption

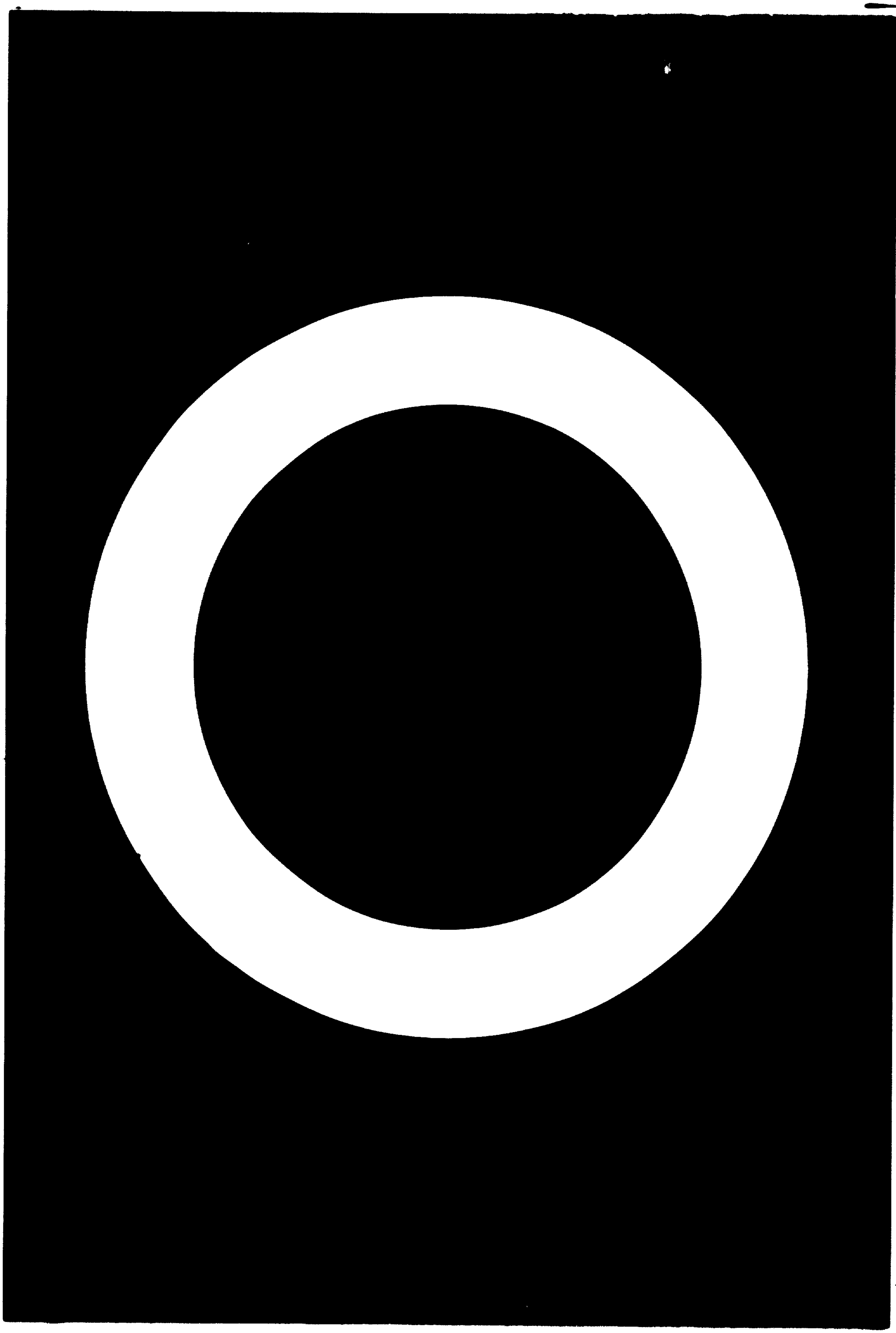
Year	Total	Pampeana	Andina	Noroeste	Mesopotamia	Patagonia	Chaqueño
				Straight nitrogenous fertilizers			
				Ammonium sulphate			
1970/71	43,420	4,677	18,874	10,449	103	7,483	1,834
1971/72	32,525	637	15,956	8,338	79	7,515	-
1972/73	49,053	7,306	22,144	10,245	198	9,160	-
1973/74	47,787	7,168	18,783	12,089	59	9,663	25
1974/75	30,065	15,899	5,125	4,320	204	4,517	-
1975/76							
				Urea			
1970/71	34,695	7,524	4,144	19,125	657	2,685	560
1971/72	31,949	7,437	2,748	19,234	505	1,998	27
1972/73	32,721	7,306	2,931	19,877	1,010	1,517	80
1973/74	39,633	9,252	2,255	25,685	911	1,430	100
1974/75	30,779	14,889	1,391	13,714	577	208	-
1975/76							
				Liquid ammonia			
1970/71	4,449	4,449	-	-	-	-	-
1971/72	859	859	-	-	-	-	-
1972/73	3,631	3,631	-	-	-	-	-
1973/74	4,068	4,068	-	-	-	-	-
1974/75	1,350	1,350	-	-	-	-	-
1975/76							
				Sodium nitrate			
1970/71	9,120	943	1,156	587	6,168	263	3
1971/72	8,098	1,339	1,920	739	3,559	534	7
1972/73	11,846	2,392	890	538	7,932	85	9
1973/74	5,335	1,647	804	519	2,300	59	6
1975/75	5,724	1,481	1,002	164	3,071	6	-
1975/76							

Year	Total	Pampeana	Andina	Noroeste	Mesopotamia	Patagonia	Chaqueño
				Other straight nitrogenous fertilizers			
1970/71	1,817	626	786	380	20	5	-
1971/72	1,475	312	667	431	63	2	-
1972/73	2,678	643	1,101	907	9	18	-
1973/74	3,595	608	549	2,285	2	151	-
1974/75	3,844	1,793	476	1,296	225	54	-
1975/76							
				Straight phosphatic fertilizers			
				Thomas phosphate slag			
1970/71	7,406	3,415	-	-	2,726	1,235	30
1971/72	....	...	...	...	...	...	...
1972/73	9,083	2,900	100	500	4,883	700	-
1973/74	4,080	1,300	-	-	2,450	330	-
1974/75	475	475	-	-	-	-	-
1975/76							
				Simple superphosphate			
1970/71	-	-	-	-	-	-	-
1971/72	2,946	1,672	1,240	12	2	20	-
1972/73	- 1	-	-	-	1	-	-
1973/74	-	-	-	-	-	-	-
1974/75	-	-	-	-	-	-	-
1975/76							
				Triple superphosphate			
1970/71	5,345	2,628	685	295	255	1,435	47
1971/72	10,075	6,586	1,176	755	448	1,110	-
1972/73	16,645	12,840	730	387	1,712	941	35
1973/74	14,993	11,682	412	1,084	1,789	26	-
1974/75	13,834	7,015	4,222	164	1,926	207	-
1975/76							

Year	Total	Pampeana	Andina	Noroeste	Mesopotamia	Patagonia	Chaqueño
				Phosphate rock			
1970/71	9,284	8,349	40	15	870	-	10
1971/72	15,809	12,619	25	10	3,090	25	40
1972/73	16,750	13,755	27	13	2,895	17	43
1973/74	19,306	15,640	35	22	3,529	28	52
1974/75	22,579	17,184	77	89	4,892	262	75
1975/76							
				Other straight phosphate fertilizers			
1970/71	-	-	-	-	-	-	-
1971/72	-	-	-	-	-	-	-
1972/73	40	19	-	20	1	-	-
1973/74	-	-	-	-	-	-	-
1974/75							
1975/76							
				Straight potassic fertilizers			
				Potassium chloride			
1970/71	2,046	459	310	353	623	301	-
1971/72	2,037	427	324	107	762	417	-
1972/73	1,566	367	309	20	743	127	-
1973/74	2,024	437	597	14	901	75	-
1974/75	2,191	1,076	321	5	695	94	-
1975/76							
				Potassium sulphate			
1970/71	1,039	254	202	170	200	213	-
1971/72	782	125	290	243	19	105	-
1972/73	3,644	506	325	183	2,563	67	-
1973/74	1,198	309	154	572	23	140	-
1974/75	783	163	-	540	50	9	21
1975/76							

Year	Total	Pampeana	Andina	Noroeste	Mesopotamia	Patagonia	Chaqueño
				Potassium magnesium sulphate			
1970/71	-	-	-	-	-	-	-
1971/72	-	-	-	-	-	-	-
1972/73	2,694	124	-	5	2,565	-	-
1973/74	3,455	135	-	61	3,259	-	-
1974/75	2,241	873	-	51	1,317	-	-
1975/76							
				Potassic rock			
1970/71	1,116	16	-	-	1,100	-	-
1971/72	2,810	110	-	-	2,700	-	-
1972/73	-	-	-	-	-	-	-
1973/74	-	-	-	-	-	-	-
1974/75	-	-	-	-	-	-	-
1975/76							
				Complex fertilizers			
				NPK and NPK compounds			
1970/71	24,588	2,855	5,329	6,863	5,587	3,763	191
1971/72	15,942	2,291	3,962	4,171	4,144	1,374	-
1972/73	58,771	6,865	13,243	10,716	16,373	10,973	601
1973/74							
1974/75							
1975/76							
				NP compounds			
1970/71	32,907	21,328	8,399	1,313	564	1,185	118
1971/72	18,392	13,103	3,808	817	565	99	-
1972/73	42,529	30,022	8,569	1,268	990	1,652	28
1973/74							
1974/75							
1975/76							

Year	Total	Pampeana	Andina	Noroeste	Mesopotamia	Patagonia	Chaqueño
				NK compounds			
1970/71	1,187	150	593	163	37	244	-
1971/72	2,432	74	862	1,210	8	278	-
1972/73	2,989	244	676	1,843	128	98	-
1973/74							
1974/75							
1975/76							
				PK compounds			
1970/71	160	-	-	160	-	-	-
1971/72	3	3	-	-	-	-	-
1972/73							
1973/74							
1974/75							
1975/76							
				Foliar fertilisers			
1970/71	276	91	57	51	50	25	2
1971/72	370	126	151	43	22	27	1
1972/73							
1973/74							
1974/75							
1975/76							
				Organic-chemical fertilisers			
1970/71	22	2	4	3	2	11	-
1971/72	19	1	5	4	2	7	-
1972/73							
1973/74							
1974/75							
1975/76							



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