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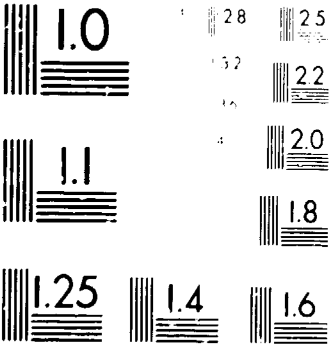

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INVESTMENT AND PRODUCTION COSTS FOR FERTILIZERS*

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SUMMARY AND CONCLUSIONS

This is the fourth paper in a series of papers on fertilizer costs presented by the World Bank to the FAO Commission on Fertilizers. The previous papers updated the investment cost data for the principal nitrogenous, phosphate and potash fertilizers, particularly those which form the basis for the fertilizer export market, and they also considered the special case of superphosphate manufacture. In this fourth paper the range of materials considered has been extended to include nitrophosphates. Both the investment and production cost data have been reviewed and brought up to date for the main fertilizer materials, taking into account inflation in different countries and international currency realignments up to mid-1982. Also the effect of energy use and costs has been considered in more detail.

The two main factors in determining fertilizer costs, the costs of raw materials and investment, can vary significantly for different site locations and it is important to take these into account when projecting fertilizer costs and prices. Sometimes, raw materials may be available cheaply, but this advantage can be offset by higher investment costs and lower operating rates, if plants have to be built in remote locations.

In order to appreciate more fully the factors which influence fertilizer costs and enable more realistic projections of future fertilizer prices, cost estimates have been calculated for a range of conditions and different fertilizer materials. Bearing in mind that prices of raw materials and fertilizers can fluctuate considerably, the main object of the exercise has been to provide a "cost envelope" which can be easily used to assess fertilizer investment and production costs for any situation. The comparisons have been made using "realization price"; this is the price which would be required to

justify new investment for an assumed situation and three main variables, (feedstock cost, utilization rate and capital charge) have been evaluated. It is emphasized, however, that "realization price" as used in this paper is basically a total cost figure and does not necessarily reflect future fertilizer export prices which depend on many other factors not covered in the paper.

Site Location and Investment Costs: In this study three different scenarios were considered in order to represent a wide range of possible site locations. The first is for a site with available supporting infrastructure. Normally this would be in a developed country but it could also occur in a developing country which already has a well developed fertilizer industry. The second scenario covers a site which has some facilities but where some infrastructure would have to be provided, and the third scenario is a site at a remote location without any existing infrastructure. These two latter situations are most likely to occur in a developing country. In the case of potash, only Canada has been considered, as the prospects for building significant new capacity outside of Canada or the USSR are believed to be limited.

Capital Charges and Operating Rates: In order to assess and compare the different scenarios, a capital charge has been used to cover the requirements of return on investment, interest payments, etc. A series of tables has been prepared to show how realization prices vary for different capital charges and operating rates.

Raw Materials Costs: Feedstock costs vary considerably from site to site for fertilizers, particularly phosphates, depending on the nature of raw material, freight, etc. Although certain typical costs have been assumed these are basically to demonstrate the methodology and for specific cases it will be necessary to adjust the data. Tables have been prepared which in the case of nitrogen fertilizers relate realization prices to gas prices, and in the case of phosphate fertilizers to sulphur and phosphate rock prices which allow these adjustments to be made.

Nitrogen Fertilizers: The study shows that for urea production, the cost of energy and capital related costs are equally important and other costs are relatively small. Until recently many developed countries had both the advantage of cheap energy and low investment costs, but this advantage is disappearing as natural gas prices in these countries rise to the level of fuel oil equivalent energy prices, and also as it becomes relatively cheaper to build, and easier to operate plants in developing countries. Undoubtedly the effect of increasing energy prices will eventually favor those countries where there is cheap natural gas.

Phosphate Fertilizers: The cost of raw materials is much more important than investment costs compared with nitrogen fertilizers, and in some cases the cost of raw materials can be as high as 70% of the realization price. Taking into account that raw materials tend to be more concentrated in a few specific locations than is the case for natural gas and nitrogenous fertilizers, this gives producers of phosphate raw materials an advantage, both with regard to the sale of the raw materials and to the local production of phosphate fertilizers. New phosphate fertilizer plants, particularly those designed for the export business, are therefore most likely to be built near the rock mine where rock is cheapest or perhaps near a cheap source of sulphur or sulphuric acid.

Nitrophosphate Fertilizers: Nitrophosphate fertilizers show very significant savings in sulphur consumption which is becoming increasingly important. This main advantage, however, has to be set against higher investment costs and when rock is imported, higher relative freight costs. The overall advantage of the nitrophosphate process will depend very much on specific cases of sulphur and freight costs and also the type of fertilizer and product mix required. The report gives comparative cost data for nitrophosphate and alternative process routes.

Phosphate Rock: The high investment costs and investment related charges, particularly for infrastructural facilities, remains the main cost component for phosphate rock production, particularly in developing countries. Phosphate rock realization prices vary widely for different locations. However, rock prices have not fallen as much as phosphate fertilizers and for some locations export prices are still high enough to attract new investment. This is particularly so when the freight costs to the major growing markets are relatively low.

Potash: Future potash prices will depend on the cost of producing potash in Canada and the USSR. These costs are mainly related to investment and transport and in the case of Canada, to taxes also. There appears to be no constraint on the availability of potash ore, particularly in Canada.

Taking into account the relationship between raw material costs and investment costs and the most likely locations for new plants, it is judged that the realization price range to justify new fertilizer plants on new sites would have to be as follows:

	Realization Price Range* mid-1982 US$/Metric Ton
Urea (bagged)	260-290
Phosphoric Acid (as 100% P_2O_5)	425-450
Triple Superphosphate (bulk)	200-220
Diammonium Phosphate (bulk)	300-320
Phosphate Rock (70 BPL)	38- 48
Potash (FOB Vancouver)	120-130

* These do not allow for a real increase in energy costs which would affect future production costs.

Basically, these realization prices represent the export price levels which would be sufficient to entice new investment from the more favorably situated producers, usually those who can expand on existing developed sites or who have significant advantages in raw material costs.

This situation will prevail so long as there are no constraints in meeting an increasing fertilizer demand from these cheap sources. In the event, however, that demand outruns the supply capability of these locations, prices will rise, permitting more costly producers to enter the market. In this situation, the export prices would be determined by the total cost or realization price of the marginal producers. This could happen particularly in the case of phosphate fertilizers where the number of developed sites with raw material advantages is limited and where demand considerations may require other and more expensive producers to enter the market.

Generally, fertilizer prices have fallen considerably in the last two years and most of them in real terms are well below the average of their historical prices over the past twenty years or so. Prices will have to rise very significantly in most cases to justify new investment.

INVESTMENT AND PRODUCTION COSTS FOR FERTILIZERS

1.0 INTRODUCTION AND BASIS FOR COST ESTIMATES

Investment and production costs for fertilizers can vary widely depending on site location, cost of raw materials, financial charges on the project, etc., and it is extremely difficult and may be misleading to represent such data in a single simple generalized form. Also, many surveys on fertilizer costs fail to realize the extent to which the need for, and cost of infrastructure can influence fertilizer costs, particularly in developing countries. Some major surveys in the past have estimated fertilizer production costs based only on battery limit estimates of investment costs provided by engineering companies, and although such procedure may have advantage on occasion from a producer's point of view in evaluating expansion programs on existing sites, it must be appreciated that in the longer term and on an aggregated basis, the cost of producing fertilizers must include the cost of the associated infrastructure and working capital.

Another important factor influencing the investment and production of fertilizers is the size of the operation. In most cases, production costs are reduced with increasing scale but it is important that this comparison must not be limited to the plant costs alone but must include total investment costs including infrastructure. Sometimes equipment costs may only amount to 40% or less of the total investment cost and, in some cases, the disadvantage of additional investment cost and operating costs incurred by using two large rather than one very large unit may be outweighed by the benefits of flexibility and reliability.

Operating rate is another very important factor - perhaps the most important - that must be taken into account in calculating production costs. The fixed charges in many large fertilizer complexes are the most important single cost item, and increases in this because of low operating efficiencies can soon outweigh advantages in material costs. Although most appraisals of fertilizer projects are based on obtaining a plant utilization of 90%, experience indicates that in many developing countries such high utilizations are difficult to obtain, particularly in the early years of operation. Estimates of investment cost must also include sufficient technical and management assistance to ensure that the plant can be started up efficiently and achieve the desired utilization within an acceptable time period.

In making comparisons of production costs in different locations, it must also be appreciated that many of the cost factors involved are dynamic and comparative values might well change over the life of the project. For example, although a plant in a developing country may have a low utilization in its early years because of inexperienced operators and lack of supporting facilities, these factors normally improve with time and recent experience indicates that many plants in developing countries after a poor start are achieving operating rates comparable with rates in developed countries. Also, it seems likely that the relative value of some feedstock and energy sources may well change over a project's life. The last few years for example have seen some major changes in energy costs which have had serious implications on the cost of producing nitrogen fertilizers.

It is important therefore in presenting data on fertilizer costs that both the effect of the major factors and the relative effect of change in these factors can be easily seen. The object of this report has been to calculate both investment and operating costs for a range of conditions for manufacturing fertilizer materials. Although the best data available on absolute costs have been used, as these costs do change constantly, due to inflation and other factors, a major emphasis has been placed on maintaining proper relative costs. Also, by providing additional information on the effect of the various parameters, it is possible to interpolate the data for a specific situation.

The figures on investment costs presented to the Fertilizer Commission in the previous papers in this series were based on a detailed analysis of World Bank projects, and on prices and costs prevailing in mid-1980. In mid-1982 because of the major changes in relative international currency values and the need to update its figures on fertilizer production costs, the Industry Department of the World Bank established a new investment data base. Discussions were held with several major engineering contractors representing different countries on current cost levels and trends. In addition, investment and production cost data have been reviewed for several major new nitrogen and phosphate projects. New investment data were obtained on nitrophosphate process investment and production costs which are presented in this series for the first time.

Equipment item costs, of course, can still vary widely depending on source of manufacture, the desire to get new work, and sometimes on government assistance, so it is difficult to build up consistent plant costs based on a few detailed equipment lists, particularly as cost data are not always presented in a readily comparable form. Careful consideration was given to the best way to build up total investment costs which on previous occasions had been made up from the major components of engineering costs estimated for different types of locations. In this study the costs are made up by adding together battery limit costs of plants plus offsite requirements plus the infrastructure for different locations.

Comparisons of many project costings show that even for fertilizer projects based on similar plant and production rates, there are usually significant differences in the investment costs depending on site location, scope of project, etc. In order to try to categorize the projects into major headings, it can be assumed that in general a project will fall roughly into one of the following areas:

(a) A site with existing infrastructure. In these cases, most of the supporting facilities will already exist, for example, there will be roads, a port, railroad, a social infrastructure that will provide people to build and work in the plant, schools, hospitals, etc. Equipment can often be provided from local sources and can sometimes be maintained using local facilities. In this paper, this situation is referred to as a developed site.

(b) A site with some infrastructure. In this case, there will be some fertilizer and social infrastructure already existing which can usefully contribute towards the project but not as much as for case (a). Labor for building the plant will be available locally and so will some of the materials. Local specialized services will be limited. Typical countries in this case would be Indonesia, Brazil, India, Pakistan, etc. This is referred to later as a developing site.

(c) A plant in a remote location with no infrastructure such as certain Middle East or African countries. In this case, there would be no supporting facilities of any sort available and all roads, ports, railways, civil works amenities, etc., would have to be provided as part of the project cost. All equipment will have to be imported. Most of the labor to build and operate the plant will also have to be brought in from outside. There would be no supporting technical infrastructure. This is referred to later as a developing site - remote location.

In specifying these categories, it is intended that they be used basically as a guide. For example, some projects in developing countries with developed fertilizer infrastructure might well fall into category (a), for example India and Brazil. Similarly, there may be plants in remote locations in developed countries which would require extensive and expensive infrastructure, for example Australia. In other cases, it might be judged that a particular situation may fall between two categories.

Another important consideration for case (c) is that whereas a first plant may be expensive, as it will have to support the initial infrastructure, the cost of subsequent facilities may be very much reduced. In some cases, such as Saudi Arabia for example, the provision of industrial estates which will spread the cost of infrastructural facilities over a number of chemical plants, including fertilizer plants, is already having the effect of reducing investment costs. Certain site locations which would previously have been classified as "remote" and fallen within category (c) would now more appropriately fall within category (b) because of the development of infrastructural facilities.

Investment costs are all for plants on new sites and are on the basis of prices prevailing in mid-1982. The average realization prices which would be required to give an acceptable return on investment for a plant contracted in 1982 and coming on-stream in three or four years time have been calculated. In order to cover such items as interest payments on loans and return on investment and to simplify the calculations, a capital charge has been included as a cost component. As the exercise does not cover the financing plan or the cash flow situation, interest during construction has not been included within the total financing required.

Energy Requirements to Produce Chemical Fertilizers

In order to assess more accurately the effect that energy costs will have on future fertilizer production costs, a detailed review has been made of the energy requirements for new plants. Much of the published information on this subject is based on information released by engineering companies estimate from battery limit requirements during equilibrium operating conditions. Usually under these conditions, energy needs are much lower than they are in practice where allowance has to be made also for the cost of operating infrastructure or for transient operating conditions when a plant is starting up or closing down or periods of malfunctioning.

In 1980 The Fertilizer Institute (T.F.I.) of the U.S. carried out a very useful survey of its members[1] which provided the following information on energy requirements for fertilizer. In order to be consistent with other information in this paper, T.F.I. information has been converted from short to metric ton of product.

Average Requirement per Metric Ton of Product - 000's BTU's

	Nitrogen (Urea-46%N)[a]	Phosphate ($TSP-46\%P_2O_5$)[b]	Potash ($KCI-60\%K_2O$)[c]
Natural Gas	30,552	920	1,356
Electricity	2,334	2,600	1,063
Fuel Oil	26	730	1
Imported Steam	6,152	360	-
Total	39,064	4,610	2,420

a/ Based on ammonia plants using centrifugal compressors.
b/ Total estimated energy including rock production and energy recovery from sulphuric acid manufacture.
c/ Based on shaft mining.

All energy estimates have been expressed in terms of equivalent fuel requirements and electrical and mechanical power and steam have been converted into the amount of fuel required to generate them. It is assumed that a new major project would use an integrated energy scheme, and as far as economically possible all energy saving devices would be incorporated. Nevertheless the energy consumptions estimated for each fertilizer are those considered reasonably attainable rather than based on theoretical considerations. In most cases it is assumed that a new plant will do significantly better than the average figures from the T.F.I. Survey. Where no other data are available the T.F.I. consumption figures have been used.

1/ Energy Use Surveys CY 1978 The Fertilizer Institute U.S.A. 1980.

Realization Prices

Realization prices have been calculated for a range of capital charges, as it is appreciated that the level of return on investment perceived as satisfactory may vary in different situations. For example, at the present time, energy rich countries with surplus funds for investment may well be prepared to accept a lower rate of return than perhaps a commercial company in the U.S. or Europe. The use of a simple annual capital charge must be used with caution as it cannot measure the effects of financial leverages, tax advantages, project implementation time and many other factors. Obviously a more detailed financial analysis using discounted cash flow would need to be made to give a fuller appreciation of the viability of a project. However, in order to confirm the validity of using a simple capital charge and assess it against other financial yardsticks, an exercise was carried out using the cost data prepared for the production of urea in the three locations.

Capital charges and internal rates of return were compared for similar realization prices. The comparison incorporated the assumption that the profiles for investment expenditure would be similar for the different site locations considered. It was assumed that the plant was built over a three year period and then took a further three years to build up to a r ilization of 90%. Allowance was made at the end of the sixteenth year er working capital and 10% of the initial plant investment. The differences between the capital charge and internal rates of return were relatively small and confirm that the capital charge method represents a simple but adequate method of asssessing and comparing the different scenarios. In the report, it has been assumed that generally a 15% capital charge would represent a satisfactory return on the investment.

2.0 THE MANUFACTURE OF UREA

General

Up to about 1979 more than 70% of the world's ammonia capacity was based on natural gas, with about 15% based on naphtha and the remainder from oil and several other sources. The energy crisis of 1979 which resulted in disproportionate increases in naphtha prices meant that many plants based on naphtha, particularly in Europe and Japan, were no longer competitive and had to close down or change to natural gas. Although serious consideration is now being given to coal as a feedstock for nitrogen fertilizer production and some new plants will be built using improved coal gasification technology, it seems almost certain, and particularly for nitrogen fertilizers, for the export market, that natural gas will remain the main feedstock during the next decade and beyond. The export prices for nitrogen fertilizers will therefore depend mainly on the cost of producing ammonia and urea in different parts of the world based on natural gas and the basis for the investment and production costs is on this premise. It is anticipated that urea will remain the dominant "finished" nitrogen fertilizer in international trade and that the annual percentage growth rate for world urea will be more than three times the growth rate of capacity for the production of other types of finished nitrogen fertilizers.

Another important factor influencing the investment and production costs of urea is the size of the operation. Although urea plants up to 2000 tpd have been built, as have 1500 tpd ammonia plants, the complex comprising plants to produce about 1000 tpd ammonia and 1700 tpd urea is probably still the most popular combination, although in cases where additional ammonia is required, the ammonia plant may be sized correspondingly higher. The economies of scale in using much larger ammonia and urea plants at the present time seems rather limited although there are, however, advantages in building several large plants on one site in order to share infrastructural costs.

Site Location

Three scenarios have been considered as previously outlined. The first is for a site with existing infrastructure (developed site), the second is for a site with some infrastructure (developing site) and the third for a site in a remote location without any infrastructure (developing site - remote location).

Investment Costs

The following investment costs have been estimated for an ammonia/urea complex based on mid-1982 US$ million to produce 1,670 tpd urea:

	US$ Million
Battery limit costs - developed site	140
Total investment costs	
Developed site	231
Approximate range of costs	200-250
Developing site (some infrastructure)	323
Approximate range of costs	250-350
Developing site (remote location)	405
Approximate range of costs	350-450*

* Where a major port or railroad is required this figure could be larger.

Fuel and Feedstock Costs

The cost of natural gas, used both as a fuel and feedstock for ammonia and urea production, is becoming increasingly important in determining the economics and location of future nitrogen fertilizer plants. For example, until recently, gas has been relatively cheap in some developed sites such as the USA and to a lesser extent in Europe, and both of these regions were major exporters of nitrogen fertilizers. In calendar year 1981, according to The Fertilizer Institute, the average price of gas to US ammonia producers was still only US$2.33 M.M. BTU.

In considering the scenario for a developed site, it is assumed that gas prices will increase significantly in the next few years but, on average, will still tend to be lower than equivalent oil energy prices by 1985. A gas price of 1982 US$3.0/M.M. BTU has been assumed to be typical of the lower end of the gas price range. It is also assumed, however, that eventually and particularly at those developed sites where energy as gas or oil is or will be imported, the price of gas to nitrogen fertilizer plants must also rise to an equivalent oil energy level. On this basis, an alternative gas price of US$5.0/M.M. BTU has also been considered.

Opportunity costs for ammonia manufacture in many developing areas would vary between $1.0 and 2.0 per M.M. BTU. In some cases particularly where gas is being flared and has no apparent alternative immediate use, the opportunity cost of the gas is basically that of collection and sweetening which would usually be less than $1.0/M.M. BTU. Where gas can be used to produce LNG the net-back value of the gas is about $2.0/M.M. BTU depending on location of deposit and market. Adjustments in the urea production costs can be made as desired by varying gas prices by reference to Annex 2.

In a fully integrated energy plant for the production of ammonia and urea, gas is used to supply total energy such as electricity, steam and fuel, as well as feedstock for the production of urea. An analysis of plant performances of existing plants in 1980 as well as theoretical considerations indicated that an average figure of about 35 M.M. BTU of gas per ton of urea produced was a reasonable figure to assume for plants being built at that time.

The Fertilizer Institute Survey indicated that the average energy consumption for all plants to produce one metric ton of urea is about 39 M.M. BTU which is in good agreement with the assumption of 35 M.M. BTU. for a new plant in 1980. As significant savings are claimed since then for energy savings, in this paper it is assumed that the energy consumption will be 32 M.M. BTU per metric ton of bagged urea. If however it is considered more appropriate to use 35 MM BTU per metric ton of bagged urea it will be necessary to add $3 for each dollar in the gas price per MM BTU, to the realization cost per ton for urea.

Other Variable Costs

Analysis of several projects both in developed and developing countries show that in terms of total operating costs, changes in the costs of variables other than feedstock and fuel are not very significant from one site to another. The main variable costs are for bags which range from $10-15 per ton of product depending on size of bag and specification. Catalyst and chemicals average about $2-3 per ton of product and boiler and cooling water is usually less than $1 per ton. In the comparative costs, the same "other variable" cost of $18 per ton of urea has been assumed for all sites and although it is appreciated that in developing countries generally these costs may be slightly higher than in developed countries, it is not a significant difference. No special additional allowance has been made in the cost of urea for electric power as it has been assumed that in all cases power would be produced on site from gas and an appropriate allowance has been made in the investment costs for a 20 MW power station and also in the overall gas requirements.

Fixed Costs

(a) Labor and Overheads: These are also found to vary little from one site to another. To some extent, the cheap cost of local labor in developing countries is counteracted by greacer numbers employed and sometimes by expensive expatriate labor. In some countries such as India, Pakistan, etc., where both skilled and unskilled labor is available, labor costs are likely to be cheaper but in certain Middle East Countries, where most labor is expatriate, costs may be higher. In any case, the differences are only likely to amount to a few dollars, so it has been assumed that labor and overheads would be the same in each case. Labor costs are based on a survey of operating costs for several large plants covering operations in both developed and developing countries. Overheads to cover administration and supervision have been taken as 150% of labor costs.

(b) Investment Related Charges: The operating life of the plant has been taken as 12 years (8-1/3% depreciation rate). Annual maintenance material costs have been taken as 3% of the total plant investment cost and annual insurance costs at 2/3% of total plant investment cost. In some cases i tmay be possible to depreciate the infrastructure over a longer period than the plant itself, particularly for such items as port and railroad facilities. If this is appropriate it would reduce the cost of producing urea on a developing site by up to about $10/ton and for developing site at a remote location by up co $20/ton.

Capital Charge

In order to cover such items as interest on loans, return on equity, etc., a capital charge based on total investment has been included.

Operating Rate

Most present day ammonia/urea complexes are designed to operate 330 days per annum. If these plants fail to perform at full design capacity, production costs escalate very rapidly. Fixed costs per unit of output vary inversely with production rates. Thus, production costs of urea in plants in developing countries where capital costs are higher, are most adversely affected by a reduction in the operating rate.

Production Costs and Realization Prices

Comparative investment and production costs and realization prices for urea are given in Table 1 for a range of conditions for four scenarios covered. Annex 1 shows the effect of capital charges and operating rates on realization price. The effect of gas price is shown in Annex 2.

Discussion of the Results

The results in Table 1 and Annexes 1 and 2 demonstrate the importance of the three main variables, feedstock cost, investment cost and operating rate, on production costs and realization prices for urea. They also show that the cost of producing urea and the realization prices to give acceptable returns on investment could vary considerably from site to site and even for each site itself depending on the parameters assumed. Comparison between sites shows that the advantages of cheap natural gas, which may be available in remote locations, can soon be outweighed by higher investment costs and lower operating rates.

Realization prices have been calculated using a range of capital charges. Generally, however, it is assumed that a project would require at least a 15% internal rate of return and, as indicated earlier, this is approximately equal to a capital charge of 15% in the cases considered.

On this basis, therefore, assuming an operating rate of 90%, it is judged that the average realization price for urea for a project contracted in 1982 and coming on-stream three or four years later would have to be about (1982) US$260-290/ton to give the project an adequate return. The relationship between these estimated realization prices and projection of future fertilizer prices is one of judgement and has to be assessed carefully in view of the many possible variations that can exist for production costs. For example, on a developed site with a very favorable gas contract, say $2.5/M.M. BTU, it should still possible to sell urea profitably at about $245 per ton. In certain developing countries, where gas is very cheap and a plant can be built to use existing infrastructure, the realization price to give an adequate return might be as low as $220 per ton. These situations, however, would tend to be the exception rather than the rule and it is expected that for most scenarios and certainly the most important, urea prices will have to fall within the range of $260-290 per ton to justify new investment. This assumes that energy prices remain constant for a plant coming on-stream in 1985. These prices are based on 1982 energy costs. Two factors, however, are likely to increase this range in real terms. The first will be the trend for gas prices to ammonia plants to approach equivalent oil energy values particularly for the developed sites where energy has to be imported. The second factor is for energy costs themselves to increase in real terms. To some extent, however, these factors will be offset by improved energy efficiencies in ammonia and urea plants.

TABLE 1

ESTIMATED INVESTMENT AND PRODUCTION COSTS FOR UREA
(1982 US$/Metric Ton)

Basis : 1,650 tpd bagged product
Capacity Utilization: 90%
Capacity : 330 days/year
544,500 tons urea/year
Production: : 490,050 tons/year

Site	Developed Site	Developed Site	Developing Site (Some Existing Infrastructure)	Developing Site (Remote Location)
Plant Investment US$ Million	231	231	323	405
Working Capital US$ Million	18	24	32	38
Total Investment US$ Million	249	255	355	443
Raw Materials	Gas @ $3.0/M.M. BTU	Gas @ $5.0/M.M. BTU	Gas @ $2.0/M.M. BTU	Gas @ $1.0/M.M. BTU
Natural Gas including Fuel and Gas for Steam and Power Generation	96.0	160.0	64.0	32.0
Other Variable Costs US$/Ton	18.0	18.0	18.0	18.0
Fixed Costs US$/Ton	70.9	70.9	93.3	113.2
Production Costs US$/Ton	184.9	248.9	175.3	163.2
Capital Charge (15%) US$/Ton	76.2	78.0	108.6	135.6
Realization Price US$/Ton (ex-factory)	261.1	326.9	283.9	298.8

3.0 THE MINING AND BENEFICIATION OF PHOSPHATE ROCK

General

Very little information has been available in the literature until recently on cost analysis for the mining and beneficiation of phosphate rock. Changing trading patterns in the industry have stimulated increasing interest and several major client studies are being carried out. Rock mining costs, however, tend to be very specific so it is difficult to present data of this type without disclosing proprietary information.

To overcome this difficulty, it has been necessary to present the data in a generalized model form which allows the reader, according to his own requirements, to interpolate approximate production and investment cost data for particular situations.

In order to build up the cost model, considerable work has been carried out in assessing the phosphate mining operations in the following countries: USA, Morocco, Tunisia, Togo, Jordan and Senegal, who are the main phosphate rock producers and exporters. Insufficient information was available on phosphate mining in the USSR to include this country as a data source.

Phosphate Rock Mining

The method of mining depends on the nature of the deposit but approximately 80% of world production comes from opencast workings and about 20% from underground mining. Opencast mining, which is usually cheaper than underground mining, is used exclusively in Florida, for about half the production in Morocco, and in Senegal and Togo. Underground mining is used in Morocco, the Western USA, Tunisia, Jordan, Egypt and some deposits in the USSR. The opencast mining operation includes site preparation which is usually carried out with bulldozers. Stripping and mining operations are done concurrently with large electric draglines. Pumping, which involves the transfer of the rock matrix to the beneficiation plant as a slurry, can often be an expensive item in the mining process.

With some new mines, the need for handling large amounts of overburden and ore to produce a ton of product will increase, requiring larger and more expensive equipment and also higher production costs.

Beneficiation

For a good rock which does not require a wet classification, beneficiation may involve a simple drying and grinding operation. More often, however, it is necessary to carry out a wet classification in order to take out the impurities from the matrix. In some cases, when separation of the impurities cannot be carried out by simple physical methods, it is necessary to treat all, or part of the ore with reagents and pass it through a flotation process. For certain rocks, calcination is carried out to reduce organic carbon or break down the apatite structure to make the ore more amenable to chemical processing. Calcination is expensive and is normally used only where there is no other alternative to ensure a satisfactory up-grading of the ore. Magnetic separation is often used to remove iron-based minerals.

Beneficiation processes are becoming more complex and expensive as ore grades become lower and less amenable to treatment. The simple dry classification processes are usually not applicable and flotation is required more frequently. The need for washing processes usually places demands on water supply, waste disposal and water recovery, which increases investment costs.

The presence of certain impurities in the rock such as M_gO can cause serious processing problems during the production of phosphoric acid and these impurities must be removed as far as possible during beneficiation.

Investment Costs

Investment costs for phosphate rock can vary widely. For a good quality rock with simple beneficiation needs and high recovery rates, the investment requirements can be below $50/per annual ton of product capacity. For a new mine at a remote location where all infrastructure has to be provided, the cost of investment can rise to more than $200 per annual ton of product capacity. Phosphate rock deposits are often located in remote and difficult environments requiring new town-sites, power plants, water supply systems and other support facilities such as transportation and parts.

Site Location

This factor is usually the most important in determining phosphate rock mining investment costs, as infrastructural costs for mining, particularly in remote locations can be very expensive. In estimating the investment costs it has been assumed that the size of mine would be 3 million tons of product per year and this material would be exported, thus requiring both port and rail facilities if not already available. Two types of rock have been considered; a high grade rock requiring a minimum of beneficiation and the other, a low grade rock requiring extension beneficiation which increases both investment and production costs.

(a) Developed Site

Florida falls in this category with a well developed phosphate rock mining industry. Based on several recent independent studies for new projects, the investment costs for mining falls between about \$50 and \$65 per annual ton of capacity, the larger investments would be required for mines in South Florida and the lower end of the scale for new mines in Central Florida. In North Carolina it is estimated that a new mine for 3 million tons per annum would cost about \$80 per annual ton capacity.

Morocco, because of its well-developed industry, is also considered a developed site. It is estimated that the overall cost of providing new mining capacity in Morocco in its current expansion program will be about \$50-55 per annual ton capacity. It has therefore been assumed that the average investment cost for a developed site will be of the order of \$58 per annual ton capacity for a high quality rock, and for a lower quality rock it will be about \$62.

(b) Developing Site

This case would require some infrastructure, perhaps extension of port and rail facilities. Engineering costs would be rather high and on average it is assumed that additional infrastructural costs compared with the developed site would be about \$100 million for a 3 million ton per year mine. Based on these assumptions, it has been estimated that on a developing site a 3 million ton per year mine would cost about \$300 million or \$100 per annual ton of capacity. For a lower grade rock the investment cost is assumed to be \$105 per annual ton of capacity.

(c) Developing Site (remote location)

In this particular case it is assumed that all infrastructure must be provided, including water supply. Based on projects studied by the World Bank, the cost of providing these facilities can be extremely high, in particular when the mine is a long way from the port. For example, a 200 mile railroad could cost $150 million or more. It has been assumed for the case considered that a typical infrastructural cost would be about $250 million and the total mine cost would be about $480 million, equivalent to $160 per annual ton of capacity.

The investment figures for the developing sites are a little lower than those assumed in the previous papers because of improving infrastructural facilities.

Mining Costs

The make-up of mining costs can vary significantly from mine to mine depending on the type of mining and process used and also on the relative cost of labor in different countries. For example, production costs for Florida and Morocco rock are currently believed to be similar but the nature of the ore and the processing required are different. In presenting the model costs, judgement has been used in apportioning the various elements of production costs, but generally in total it is believed they are representative of the production costs that would be required for new mines.

Labor and Overheads

It is estimated that the average cost for labor operation and maintenance plus overheads will be about $5/ton of product.

Energy

According to The Fertilizer Institute Survey, the average energy requirements for the unit operations used in phosphate rock mining in the USA are as follows:

Operation	Energy Required Million BTU per Metric Ton
Mining and reclamation	0.29
Beneficiation (wet)	0.39
Rock drying	0.44

Florida is a relatively high cost energy user compared with many other large producers because of the relatively lower quality of the crude ore and more extensive beneficiation required. The average energy consumption in the USA to produce one metric ton of rock varies from about 0.8 M.M. BTU up to about 1.6 M.M. BTU with an average of about 1.1 M.M. BTU. In Florida most of this energy is required as electric power, in Morocco more than half is required as diesel fuel. It is estimated that energy requirements would range between $4/ton for a high grade rock to about $8/ton for a low grade quality rock.

Supplies

This covers supplies for operating and maintenance including chemicals and would vary between $2-3/ton. Flotation agents for example may cost $1-2/ton of rock product.

Other Costs

These include handling and storage, laboratory, commercial and administration. In all cases a cost of $3.5/ton of product has been included.

Transportation

Phosphate rock prices are usually quoted and compared on an FOB basis and transport to the ship from the mine can be an important part of the cost. The loading and transport costs used in the model are based on current transport costs which are known to prevail in rock producing countries.

Discussion of Results

The results of the model costs are given in Table 2. These show a breakdown of production costs and capital charges that might apply to a range of phosphate rock mining projects for differing rock quality and site location. In these estimates, it is assumed that the cost of rock in the ground is included as part of the initial investment costs. As for similar exercises on fertilizer costs, they demonstrate the large influence of investment related costs on the required realization price. Even for a high quality rock on a well developed site, investment related charges may account for about 40% of the realization price whereas in a remote location for a high quality rock, these charges could be more than 60% of the realization price.

It becomes increasingly difficult, therefore, for new mining operations to be justified in remote locations that require very expensive infrastructural facilities even though there may be large deposits of good quality ore. The cost of producing rock in the future will depend mainly on the new investment cost per annual ton of capacity, and producers with existing infrastructure such as Florida, Morocco and other West African and North African countries will retain a major advantage over new producers in expanding their production facilities. Taking into account that the quality of rock available for exploitation in the future is likely to deteriorate as the better quality reserves are depleted, there will be a trend towards Case B as indicated in the model costs.

Most known rock reserves are in those countries exploiting rock and where there is already a basis of infrastructure and technical knowledge. Even so, the estimates indicate a wide range of realization prices for different cases required to justify new investment, for example between $30-50/ton. As the lower end of this range represents an optimum situation for which there is probably limited scope for major increased capacity, it is more likely that rock prices for a new project on a developed site will have to be in the range of $38-48/ton to justify new investment.

TABLE 2

ESTIMATED INVESTMENT AND PRODUCTION COSTS FOR PHOSPHATE ROCK
(1982 US$/Metric Ton)

Basis - 3.0 Million Tons/Year Product [Dry Basis]
Rock A - High grade. High recovery and low processing requirements.
Rock B - Low grade. Low recovery and high processing requirements.

Site	Developed Site		Developing Site		Developing Site	
	New Site:		New Site: Some Infrastructure		New Site: Remote Location	
Rock Type	Rock A	Rock B	Rock A	Rock B	Rock A	Rock B
Mine Investment US$ Annual Ton	58.0	62.0	100.0	105.0	160.0	167.0
Working Capital US$ Annual Ton	3.0	4.0	3.0	4.0	3.0	4.0
Total Investment US$ Annual Ton	61.0	66.0	103.0	109.0	163.0	171.0
Operating Costs:						
Labor and Overheads	5.0	7.0	5.0	7.0	5.0	7.0
Energy (Electricity & Fuel)	4.0	8.0	4.0	8.0	4.0	8.0
Chemicals and Supplies	2.0	3.0	2.0	3.0	2.0	3.0
Other Costs	3.5	3.5	3.5	3.5	3.5	3.5
Sub-Total	14.5	21.5	14.5	21.5	14.5	21.5
Depreciation (5%)	2.9	3.1	5.0	5.2	8.0	8.3
Total Production Costs	17.4	24.6	19.5	26.7	22.5	29.8
Transport and Loading	4.0	4.0	5.5	5.5	7.0	7.0
Total	21.4	28.6	25.0	32.2	29.5	36.8
15% Capital Charge	9.1	9.9	15.4	16.3	24.4	25.6
Realization Price: At 15% Capital Charge	30.5	38.5	40.4	48.5	53.9	62.4

4.0 THE MANUFACTURE OF PHOSPHATE FERTILIZERS

A. PHOSPHORIC ACID BASED FERTILIZERS

General

The cost of producing phosphatic intermediates and phosphate fertilizers are dependent mainly on the cost of raw materials such as phosphate rock and sulphur. Plant investment and utilization of plant are also very important in determining production costs, particularly on remote sites in developing countries where infrastructure requirements can be very expensive.

The estimation of both investment and operating costs for phosphate fertilizers is more difficult than in the case for nitrogenous fertilizers because of the wide variation in the cost and quality of phosphate rock, both of which, affect investment and operating costs. However, the production cost information is produced as far as possible in a parameterized form which shows the effect of the main variables. Also, several different cases for the production of phosphate fertilizers have been considered to show the effect that site location can have on production costs.

Basis for Cost Comparisons

Phosphoric acid, triple superphosphate and ammonium phosphates are made in many places throughout the world, although in the last few years there has been a strong trend to manufacture phosphatic intermediates at, or near, the source of the phosphate rock mine. There are two main advantages of this: firstly, that significant savings in freight can be derived from shipping a concentrated fertilizer intermediate or product rather than phosphate rock, and secondly, it allows the utilization of lower grade rocks. In many cases, effluent disposal is also easier and less costly. These rocks, which would have relatively low export market value can be converted into high grade product at the mine site, in large plants specially designed to deal with a single type of lower grade feed. The use of wet-grinding in the phosphoric acid plants situated near the mine also results in reduced operating costs. An analysis of new plants that have recently been built or are planned within the next five years, indicates that the majority of these plants will be rock producing sites and that the average size of new plants is between 500-1,200 tpd P_2O_5.

In the cost basis therefore, it is assumed that the most likely place for a new phosphoric acid plant would be at a rock producing site and based on both economic and technical considerations, the capacity of the plant would be 1,000 tpd P_2O_5, although this could be in the form of two lines each of 500 tpd. One general exception to this situation would be at a site where rock is imported but where by-product sulphuric acid is available cheaply from a smelting operation or perhaps where cheap pyrites is available.

Three different scenarios have been considered:

(a) Phosphate fertilizer plant in developed site: This would apply mainly to new phosphoric acid plants built in the USA (Florida), Europe or North Africa (Morocco and Tunisia), and where there is existing infrastructure which can be used for the production, storage and transport of phosphate fertilizers. For example, it assumes existing port and rail facilities and the availability of fresh water for process and cooling, and also an existing source of power.

(b) Phosphate fertilizer plant on site where there is some infrastructure: It is assumed in this case that local labor would be available to help with plant construction and that there would be some port and rail facilities, although these would have to be extended for the new plant. It also assumes availability of fresh water, but an allowance has been made to increase availability of power.

(c) Phosphate fertilizer plant in remote location with no infrastructure: The most likely case is an inland desert area where all transport facilities such as rail, road, conveyer, and ports (or jetty) at the coast, would have to be provided. There would be no local labor to assist with construction and all amenities such as housing, etc., would have to be provided. The provision of fresh water and power could be a major cost.

Investment Costs

Investment costs for a 1,000 tpd phosphoric acid plant and corresponding sulphuric acid plant have been estimated on the same basis as for nitrogen fertilizers in developed and developing countries. Once again, cost estimates prepared for appraisals of several World Bank projects have been used as well as information received from industry and engineering companies. All of this data were received and updated in 1982. In the case of triple superphosphate plants, it is assumed that a 50 tph granulation plant is erected on the same site as the phosphoric acid plant so that the investment costs for TSP are mainly the plant costs with some associated equipment plus storage.

A 50 tph diammonium phosphate plant has also been assumed. Generally granulation plants which make TSP can also make DAP, although it is necessary to provide equipment for the ammoniation reaction, ammonia scrubbing and ammonia storage. It is assumed in this case that anhydrous ammonia will be imported and stored in a 15,000 ton atmospheric storage tank at low temperatures.

Working Capital

In the case of phosphoric acid, the working capital has been calculated on the basis of 4 days' rock stock (on the basis that the plant is near the rock mine), 40 days' sulphur stock and phosphoric acid equivalent to 40 days' sales at cost. For TSP, working capital requirements have been taken as 4 days' stock of rock, 10 days' stock of phosphoric acid and 40 days' sales of TSP at cost. For DAP, working capital requirements have been taken as 10 days' stock of phosphoric acid, 30 days' stock of ammonia and 40 days' sales of DAP at cost.

Feedstock Costs

Phosphate rock and sulphur are the two main raw materials used for the production of phosphoric acid, and phosphatic fertilizers although sulphuric acid produced from smelter gases or pyrites can be used as an alternative to elemental sulphur. Raw material costs normally account for about 60-70% of the production costs.

Phosphate Rock

For most producers, phosphate rock represents the largest cost item. However, phosphate rock quality varies significantly from source to source and these differences in quality can have a major impact on both production costs and investment requirements. All phosphate rock contains impurities which usually have adverse effects upon their use in the phosphate industry. For example, iron, aluminium and magnesium can cause troublesome sludge formation, fluorine tends to cause liquid and gaseous effluent problems, chlorine serious corrosion, carbonates excessive sulphuric acid consumption and, in conjunction with organic matter, foaming problems. In addition to the chemical composition of a rock, its physical condition, hardness, porosity, etc., also affect its suitability for phosphoric acid manufacture.

Although phosphate rock is generally sold according to its P_2O_5 content, the other factors mentioned above must also be taken into account in assessing overall rock costs. Generally, however, only the best quality high grade rocks are exported to produce phosphoric acid and triple superphosphate and it is becoming increasingly more common for low grade phosphates to be processed at their source. In these cases, a lower value is attributed to the rock, although normally due to the lower quality, additional investment costs are required. In the cost data in Table 3, it was assumed that rock would cost $35 per ton. Although rock production costs will vary widely for new phosphate rock projects, it was felt that this price would be a typical average realization price for a new mine for a reasonable quality rock on a developing site as indicated in Table 2. It is assumed in this case that the phosphoric acid plant would be adjacent to the mine.

Sulphur

Sulphur is shipped in bulk either as a liquid melt or as a solid powder or flake. As such, it is relatively pure material of constant quality and offers no major processing problems. Sulphur is burned to produce sulphuric acid which is subsequently reacted with phosphate rock to produce phosphoric acid. During the production of sulphuric acid, heat is generated which is used to produce steam and electricity which can be credited to the process.

In the costings, the price of sulphur at plant has been taken as $160 per ton. CIF sulphur prices reached these levels in 1980/81 although these prices have fallen well below this level in 1982 due to very low freight rates and a depressed phosphate market. When the phosphate market recovers it is predicted that sulphur prices will also firm-up again to their 1980 levels. Adjustments to realization prices, however, can be made for any particular sulphur price using the factor below Tables 3, 4 and 5. The quantity of sulphuric acid required to acidulate phosphate rock varies according to rock composition and process efficiency. In the following costs, an overall efficiency for the sulphuric acid plant of 98% has been taken and for the phosphoric acid plant based on rock, an efficiency of 95% has been assumed. Specific sulphuric acid consumption per ton of P_2O_5 may vary from about 2.4 to 3.0 depending on grade of rock. In this case, a 68/69 BPL rock is considered with a consumption of 2.9 tons of sulphuric acid per ton of P_2O_5.

Ammonia

Diammonium phosphate is often one of the main phosphatic fertilizer products from a phosphate fertilizer complex, but as there are few areas where the feed materials for ammonia and phosphoric acid manufacture occur together, it is usual to import ammonia to the phosphoric acid site. Ammonia is shipped as an anhydrous liquid and for storage above about 2,000 tons, it is normal to use refrigerated non-pressure storage.

The price of anhydrous ammonia has varied widely over the last few years but the average FOB price today is at a very low level and much lower than that required to justify new investment. Long-term equilibrium prices for ammonia will probably rise well above these levels as energy prices increase in real terms. This is very much higher than present prices which do not reflect the true cost of energy. Ammonia prices are likely to rise significantly in the future to reflect increasing energy prices and in some cases could be well above $200/ton. The effect of varying ammonia prices on DAP realization prices can be calculated from the factor below Table 4. In the costings exercise, $200 per ton at the plant has been assumed for ammonia in the base case.

In the process, an ammonia efficiency of 97% is assumed. The ammoniation of phosphoric acid usually causes some reversion of water soluble P_2O_5 to insoluble P_2O_5. To cover this factor and other losses, a P_2O_5 efficiency of 98% has been assumed in the manufacture of DAP.

<u>Other Variable Costs</u>

Other variable costs are not a major cost item and variation from one site to another, either as items or in aggregate, with the exception of gypsum disposal which is referred to later, does not significantly affect the total production cost. Other variables are mainly water, electricity, steam and chemicals.

<u>Energy Costs</u>

<u>Phosphoric Acid</u>

Although the average energy requirement per ton of P_2O_5 in the USA, according to The Fertilizer Institute Survey in 1980 is about 9 M.M. BTU, some plants in the USA do much better as can be seen from the lower interquartile TFI figures given below:

Operation	Energy Required Million BTU per Metric Ton P_2O_5
Filter Grade Acid	2.5
Concentration to Merchant Grade	4.4
Energy Recovered	-5.7
Net Energy Required	1.2

In the cost estimates it is assumed that the energy consumption for new plants should not be in excess of about 2.0 M.M. BTU which at present oil-equivalent energy prices of \$5.0 per M.M. BTU would result in an energy cost in \$10 per ton of P_2O_5 when starting with wet rock and sulphur.

Triple Superphosphate

The main energy costs for TSP production are for electricity for the granulation and drying plant and gas or fuel oil to dry the product. According to The Fertilizer Institute Survey, about 1.6 M.M. BTU are required per metric ton TSP with an interquartile range of about 1.2-3.0 M.M. BTU. For a new plant it has been assumed that it should be possible to reduce this to about 1.2 M.M. BTU equivalent to an energy cost of \$6.0 of which about one-third would be required for electricity and the remainder as gas or oil for drying.

Diammonium Phosphate

The energy requirements for granular diammonium phosphate are similar to those for granular triple superphosphate except that less energy is required for the drying process because part of the heat of ammoniation can be used for this purpose. The average energy use to produce one metric ton of DAP in the TFI Survey is on average 1.1 M.M. BTU of which about half would be required as electricity and the other as gas or oil for drying. An energy cost of $5 has been assumed.

Gypsum Disposal

No extra costs have been taken into account to remove the by-product gypsum (5 tons $CaSO_4H_2O$ per ton of P_2O_5). It is assumed that the investment includes equipment (pipelines, etc.) for gypsum disposal. The disposal of gypsum from phosphoric acid plants is becoming an increasing problem particularly in developed sites, however, and in many cases today, permission to dump gypsum into estuaries cannot be obtained and gypsum disposal costs can run as high as $20 per ton of P_2O_5.

Fluorine Recovery

The regulations on fluorine emission in the USA and Europe (two large P_2O_5 producing areas) are becoming more severe and are expected to affect the economies of phosphoric acid production in these areas in the future. In this paper, it is assumed that fluorine recovery will not cause major additional phosphoric acid costs.

Uranium Recovery

In some phosphoric acid plants, uranium is recovered as "yellow cake" from the weak acid before concentration. The uranium content of phosphate rock varies considerably from deposit to deposit, and as the practice of uranium recovery is still fairly limited and is not generally an overriding economic factor in phosphoric acid production, it has not been included in this cost data.

Fixed Costs

Labor and Overheads: The cost of labor and overheads for producing sulphuric and phosphoric acid should not vary greatly from site to site or even over a range of phosphoric acid plant capacity. To some extent, the cheap cost of local labor in developing countries is counteracted by greater numbers employed and sometimes by expensive expatriate labor. Generally, however, the cost in developing countries should be a little less than developed countries but not significantly so.

Investment Related Costs: Depreciation has been assumed to be straight line over 12 years. An allowance of 2/3% of total plant investment per year has also been made for insurance. Maintenance materials have been assumed to cost 3% of plant investment per year.

Capital Charge

Realization prices have been calculated for a range of capital charges. This capital charge would be necessary to cover interest on loans and give an adequate return on the equity investment.

Operating Rates

Phosphoric acid plants are much more flexible with regard to output than nitrogenous fertilizers and are usually capable of a much larger turn down ratio. They are also usually capable of operating quite satisfactorily above design capacity although with some sacrifice of materials efficiency. Phosphoric acid plant capacity can also vary a great deal with different qualities of phosphate rock, so producers may compensate to some extent for market constrained situations by processing lower grade and hence, lower cost rocks at reduced outputs.

Comparative Investment and Production Costs and Realization Prices

Cost data for phosphoric acid for various assumed locations are given in Table 3. The cost data for TSP are given in Table 4 and for DAP in Table 5. In the calculations for TSP and DAP, it has been assumed in one case that phosphoric acid would be transferred at the same site to a TSP or DAP plant and the transfer price is based on the capital charge of 10% return on investment from the phosphoric acid plant and a 90% operating rate. This is on the assumption that inter-unit transfers may be made on more favorable conditions than export sales. In the other case, a capital charge of 15% has been assumed. It has also been assumed in the calculations that rock would be $35 per ton and sulphur $160 per ton, but adjustments can easily be made to the production costs and realization prices for differing rock and sulphur prices as indicated previously.

Discussion of Results

The cost of producing phosphate fertilizers varies significantly from site to site depending on investment costs and scale of operation. The most important cost component and one which is becoming more and more important is the cost of raw materials. In some cases feedstock costs can be as much as 80% of the direct production costs and 60-70% of the realization price. Freight is also a very important item particularly when both sulphur and phosphate rock have to be imported.

Because of these factors there is a strong trend for phosphate fertilizers to be produced in integrated units near the mine as this offers advantages in both freight and operating costs.

In order to demonstrate these advantages, total delivered production costs have been calculated for phosphate fertilizers based in one case on vertically integrated production and in the other case on imported phosphate rock. The results are shown in Figure 1.

In the case of the integrated producer it is assumed that the rock does not need to be dried and this together with savings in loading costs is equivalent to about $5/ton of rock. Roughly there is a 50% savings in overall freight costs when importing finished product rather than rock (assuming that sulphur freight is common to both cases).

In practice the savings are likely to be greater than indicated if account is taken of the two-tier price structure of phosphate rock to domestic and export plants and also that a lower grade of rock is usually used in the integrated production.

Based on the assumptions made in estimating production costs, the most likely range of realization prices to justify future investments will be as follows:

Phosphoric Acid	$425-450/ton
Triple Superphosphate	$200-220/ton
Diammonium Phosphate	$300-320/ton

These estimates do not take into account any allowances for an increase in energy in real terms. One important point to make, however, in assessing realization prices for phosphate fertilizers for different scenarios is the relatively large difference in these prices. The ranges given above refer to the more favorable locations, such as an existing developed site, as these will obviously be the most likely to encourage new investment but, at the same time, it is recognized that there may be constraints to meeting adequate supply in the future from these locations. In this event, export prices are more likely to be decided by the realization prices necessary to encourage marginal producers into the market. Certainly in the short-term the excess supply of phosphate fertilizers will depress prices and discourage new investors but this situation is expected to change after 1985/86.

TABLE 3

ESTIMATED INVESTMENT AND PRODUCTION COSTS FOR PHOSPHORIC ACID
(1982 US$/Metric Ton)

Basis : 1,000 tpd (100% P_2O_5)
Capacity Utilization: 90%
Capacity : 330 days/year
330,000 tons/year P_2O_5
Production : 297,000 tons/year

Site	Developed Site	Developing Site (Some Existing Infrastructure)	Developing Site (Remote Location)
Plant Investment US$ Million	132	210	282
Working Capital US$ Million	21	23	25
Total Investment US$ Million	153	233	307
Raw Materials US$/Ton			
Rock Phosphate (3.4 tons at $35/ton)	119.0	119.0	119.0
Sulphur (0.976 tons at $160/ton)	156.8	156.8	156.8
Other Variable Costs US$/Ton	15.0	15.0	15.0
Fixed Costs US$/Ton	66.8	98.3	127.4
Production Costs US$/Ton	357.6	389.1	418.2
Capital Charge (15%) US$/Ton	77.4	117.6	155.1
Realization Price US$/Ton (ex-factory)	435.0	506.7	573.3

For each $1.00/ton increase in rock costs, production costs increase by US$3.4/ton P_2O_5.

For each $1.00/ton increase in sulphur costs, production costs increase by US$0.98/ton P_2O_5.

TABLE 4

ESTIMATED INVESTMENT AND PRODUCTION COSTS FOR GRANULAR TRIPLE SUPERPHOSPHATE
(1982 US$/Ton)

Basis : 1,200 tpd bulk product (46% P_2O_5)
Capacity Utilization: 90%
Capacity : 330 days/year
396,000 tons/year GTSP
Production : 356,400 tons/year GTSP

Site	Developed Site		Developing Site (Some Existing Infrastructure)		Developing Site (Remote Location)	
Plant Investment US$ Million	39		45		48	
Working Capital US$ Million	11		12		14	
Total Investment US$ Million	50		57		62	
Raw Materials US$/Ton	(a)	(b)	(a)	(b)	(a)	(b)
Phosphate Rock (0.44 tons at $35/ton)	15.4	15.4	15.4	15.4	15.4	15.4
Phosphoric Acid - 0.34 tons	139.1	147.9	159.0	172.3	177.3	194.9
Other Variable Costs US$/Ton	7.0	7.0	7.0	7.0	7.0	7.0
Fixed Costs US$/Ton	15.8	15.8	18.0	18.0	19.0	19.0
Production Cost US$/Ton	177.3	186.1	199.4	212.7	218.7	236.3
Capital Charge (15%) US$/Ton	21.0	21.0	24.0	24.0	26.1	26.1
Realization Price US$/Ton	198.3	207.1	223.4	236.7	244.8	262.4

(a) Based on phosphate rock at US$35/ton and sulphur at US$160/ton and capital charge of 10%.
(b) Based on phosphate rock at US$35/ton and sulphur at US$160/ton and capital charge of 15%.

For each $1.00/ton increase in rock costs, production costs increase by US$1.60/ton TSP.
For each $1.00/ton increase in sulphur costs, production costs increase by US$0.33/ton TSP.

TABLE 5

ESTIMATED INVESTMENT AND PRODUCTION COSTS FOR DIAMMONIUM PHOSPHATE
(1982 US$/Metric Ton)

Basis : 1,200 tpd bulk product (18-46-0)
Capacity Utilization: 90%
Capacity : 330 days/year
396,000 tons/year DAP
Production : 356,400 tons/year DAP

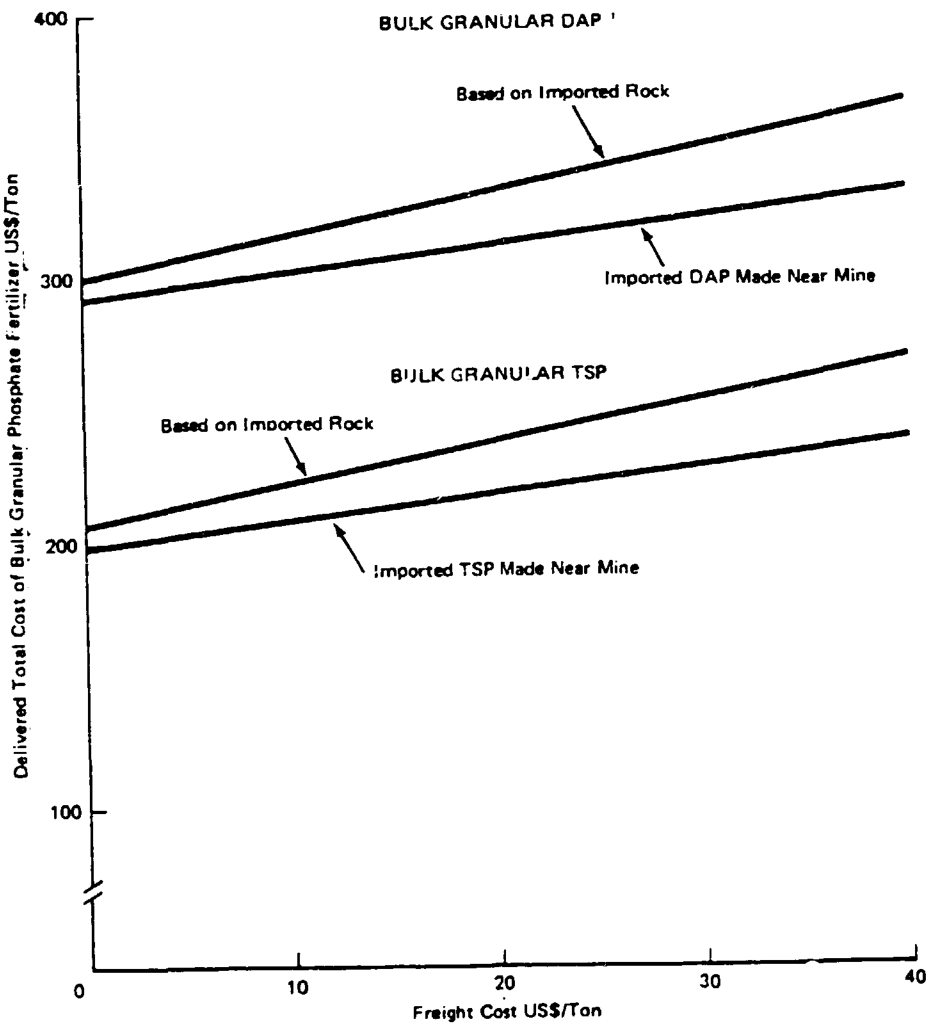
Site	Developed Site		Developing Site (Some Existing Infrastructure)		Developing Site (Remote Location)	
Plant Investment US$ Million	47		53		56	
Working Capital US$ Million	15		17		19	
Total Investment US$ Million	62		70		75	
Raw Materials US$/Ton	(a)	(b)	(a)	(b)	(a)	(b)
Phosphoric Acid - 0.47 tons P_2O_5	192.3	204.4	219.7	238.1	245.1	269.5
Ammonia - 0.225 NH_3	45.0	45.0	45.0	45.0	45.0	45.0
Other Variable Costs US$/Ton	7.0	7.0	7.0	7.0	7.0	7.0
Fixed Costs US$/Ton	18.7	18.7	20.7	20.7	21.7	21.7
Production Costs US$/Ton	263.0	275.1	292.4	310.8	318.8	343.2
Capital Charge 15% US$/Ton	26.1	26.1	29.4	29.4	31.8	31.8
Realization Price US$/Ton	289.1	301.2	321.8	340.2	350.6	375.0

(a) Based on phosphate rock at US$35/ton and sulphur at US$160/ton and capital charge of 10%.
(b) Based on phosphate rock at US$35/ton and sulphur at US$160/ton and capital charge of 15%.

For each $1.00/ton increase in rock costs, production costs increase by US$1.60/ton DAP.
For each $1.00/ton increase in sulphur costs, production costs increase by US$0.46/ton DAP.
For each $1.00/ton increase in ammonia costs, production costs increase by US$0.225/ton DAP.

FIGURE 1

Comparison of Total Costs of Phosphate Fertilizers from Integrated and Non-Integrated Projects



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B. NITROPHOSPHATE FERTILIZERS

General

The term "nitrophosphate" is used to describe processes and products where nitric acid is used to acidulate phosphate rock. Most of today's fertilizer processes use sulphuric acid to produce phosphate fertilizers and nitrophosphate processes are used mainly in Eastern and Western Europe and to some extent in India, Pakistan and China. One of the main advantages of the nitrophosphate process is that it does not require sulphur and when sulphur prices are relatively high, which is the case at the present time, there is always a renewed interest in the nitrophosphate route.

Although the process has been used for many years, particularly in Europe where it was developed, its more general use has been constrained in the past by its relatively low product analysis and degree of water solubility. Recent advances in technology have largely overcome these limitations and there are situations where nitrophosphate processes offer a potential economic advantage over alternative processes. A feature of the basic process which in some cases could be a disadvantage is the fact that the overall nutrient ratio in the products from a nitrophosphate process is about 2:1, N to P_2O_5. The process is therefore more likely to find favor in those areas where there is a strong demand for nitrogen. Generally the process would not be particularly suitable as a method of exporting processed phosphate unless a country possessed both indigenous resources of both rock and natural gas for ammonia production.

The most likely situation for a nitrophosphate process to compete economically with a sulphuric acid based process would be for a country with a relatively large fertilizer use, preferably with a cheap domestic source of ammonia, where ammonium nitrate is the preferred form of nitrogen fertilizer and where there is a seasonally uniform demand for a relatively high $N:P_2O_5$ fertilizer usage.

The main purpose of the exercise in this paper is to assess the economics of producing nitrophosphate materials and also to compare them against alternative methods of producing equivalent quantities of fertilizer nutrients. The assessment is very difficult, however, as it is not possible to chose a comparison which will apply under all conditions of production, composition, plant capacity, etc. as will be discussed later.

Most previous comparisons have been based on a 1:1, $N:P_2O_5$ ratio nitrophosphate with prilled ammonium nitrate as a concomitant product and this ratio and product mix has been used also in this case. A 1,000 tpd ammonia plant has been assumed as the basis for both cases. This would provide for either a large economic sized urea plant or nitrophosphate plant. Carbon dioxide, a by-product of ammonium production, is required for both urea and nitrophosphate production.

The two cases compared are outlined below.

Case A - Nitrophosphate Process

Ammonia plant 1,000 tpd based on natural gas for fuel and feedstock. Nitric acid plant, nitrophosphate plant and prilled ammonium nitrate plant with annual capacity of 554,400 of NP, 22-22-0 and 412,500 tons of (33.5%N) prilled ammonium nitrate. Phosphate rock of 68% BPL either imported or produced locally. It is assumed that the plant is designed to produce a water-soluble phosphate component of 80-85% which would be roughly equivalent in phosphate agronomic availability to the quality of TSP currently traded.

Case B - Sulphuric Acid Route for Processed Phosphate

Ammonia plant 1,000 tpd based on natural gas for fuel and feedstock. Urea plant 1,670 tpd. In this case it is assumed that TSP is either purchased or produced independently. The cost of TSP is based on the production costs outlined in Section 4 plus the cost of freight and bagging in order to compare on a similar basis.

Nitrophosphate Process

There are several different nitrophosphate processes currently in use but they are all essentially based on solubilizing phosphate rock with nitric acid and then removing calcium nitrate usually by deep-cooling, crystallization and filtration. The degree of calcium nitrate removed determines the ultimate water-solubility of the phosphate component. The mother liquor is neutralized with ammonia, concentrated and then either prilled or granulated to give a N/P_2O_5 compound.

The calcium nitrate by-product can be either used in the production of ammonium nitrate or can be converted to calcium ammonium nitrate. In this comparison it is assumed that prilled ammonium nitrate is produced from the calcium nitrate using carbon dioxide by-product from the ammonia plant. More detailed descriptions of the process are available in the technical literature.

Basis for Assessment

In order to compensate for the difference in nutrient content in the products, the cost comparison is based upon the cost of one ton of P_2O_5 in the product. The cost of producing one ton of P_2O_5 by the nitrophosphate route is compared with the cost of either producing or importing one ton of P_2O_5 in the form of granular TSP. To compare TSP with the nitrophosphate product it is also necessary to include the cost of bagging and bags for TSP. The realization prices for TSP calculated in this report, plus freight (if any) plus the cost of bagging has been used as a basis for comparison against the nitrophosphate process. It is assumed that the realization price of one ton of the nitrogen nutrient from the nitrophosphate process would be equivalent to the cost of one ton of nitrogen as urea produced at the same location.

The realization prices of urea for different conditions as calculated in section 1 of this report have been used to value one ton of nitrogen nutrient produced either as an N/P_2O_5 base or as prilled ammonium nitrate in the nitrophosphate complex.

The basis for comparison is a 1,000 tpd ammonia plant but there is a slight but insignificant difference in the products from the two routes due to small differences in processes, yields, etc. The relative economics of phosphate from the sulphuric acid route and nitrophosphate products depend also on the relative costs of freight and sulphur and the effect of these two items has also to be included in the assessment.

Investment Costs

The investment costs have been estimated as for the other fertilizer materials considered in this report for different types of locations and a summary is given in Table 6. The investment cost of a nitrophosphate complex is generally higher than that required for the sulphuric acid route and the extra capital charges incurred have therefore to be set against the savings in sulphur. The investment costs for the ammonia plant and related infrastructure would be common to both process routes considered.

Fuel and Feedstock Costs

Very little data have been published on the fuel and energy costs for nitrophosphate processes although it is relatively easy to calculate theoretical requirements. Usually however there is a significant difference between theoretical and actual usages and allowance has been made for this in estimating production costs. However most of the energy consumption is required for ammonia production. The nitric acid plant is exothermal with net energy recovery.

The total energy required to produce 1 ton of 22:22:0 and concomitent 0.75 tons of by-product ammonium nitrate has been estimated at about 31 M.M. BTU which is almost the same as producing an equivalent amount of nitrogen as urea. Taking into account the relatively small energy requirement for TSP in an integrated phosphate project there appears to be little difference between the total energy required to produce fertilizers by the nitrophosphate route and the sulphuric acid route. About 3.32 tons of rock are required per ton of P_2O_5 in nitrophosphate processes assuming 68 BPL rock. The cost of this rock has been taken as $35/ton exclusive of freight.

Other Variable Costs

The main items under this heading are bags, chemicals, catalysts and water, as all energy costs are accounted for elsewhere. Generally in terms of tons of product, the variable costs by the nitrophosphate route and the sulphuric acid route are similar but as the nitrophosphate products are less concentrated, the other variable costs per ton of nutrient are a little higher in the case of nitrophosphate processes.

Fixed Costs

In order to compare the two process routes on the same basis, similar assumptions have been made for (a) labor and overheads, (b) investment related charges, and (c) capital charges as have been made for urea and TSP and these are described elsewhere in the paper.

Investment and Production Costs for Nitrophosphate Processes

Comparative investment and production costs and realization prices are given in Table 6 and Annex 13 for a range of conditions at different plant locations. Nitrophosphate processes normally produce two products; an N/P_2O_5 base and a straight nitrogen product. In this case the two products are 22:22:0

and 33.5:0:0. The average analysis per ton of product is 26.9:12.6:0 and production costs have been calculated on this basis for the purpose of comparing with other process routes.

Discussions of Results

The comparative cost for nitrophosphate and other process routes are given in Figure 2. Basically. the graphs compare the price of obtaining one ton of P_2O_5 from a nitrophosphate process with one ton of P_2O_5 produced as triple superphosphate. It relates the effect of sulphur prices for TSP production and the freight cost of both rock and TSP in the comparative costings.

The graphs indicate that generally within the current and anticipated range of sulphur and freight prices the nitrophosphate process appears to show an economic benefit when compared with the alternative route. It is appreciated that had the comparison been made with diammonium phosphate rather than TSP the apparent benefit would have been greater.

The choice of nitrophosphate process however will depend mainly on its suitability as a product and its agronomic efficacy. For example in Egypt where there is both natural gas and phosphate rock available and where "nitrate" nitrogen is highly regarded, nitrophosphate processes would appear particularly suitable. The nitrophosphate process would also appear to be suitable for use in other countries with large fertilizer usages such as India, Indonesia, China and the USSR.

In the case of India it is estimated that on present day CIF sulphur prices and freight rates of rock from Jordan, the nitrophosphate route could show a benefit of about \$30/ton of P_2O_5 on an ex-factory basis in India compared with imported TSP.

However, in making this comparison two other factors should be taken into account. The first is that no benefit was assumed for the possibility of using wet-rock for phosphoric acid in TSP production which could reduce the cost of one ton of P_2O_5 from TSP by about $8/ton.

The other factor is that the overall nitrophosphate product and ammonium nitrate product analysis will be about 15% lower than that for a corresponding quantity of nutrients provided as urea and TSP and this will increase the cost of storage and distribution before the fertilizer reaches the farmer. In India for example it is estimated that this would be equivalent to increased costs of about $3 per ton of product or about $6 per ton of P_2O_5.

Even so, the nitrophosphate process offers some inherent economic benefits provided that the product mix and the nature of the product can be easily integrated into a country's fertilizer sector. If the price of sulphur remains relatively high, as seems likely, these benefits will remain.

TABLE 6

ESTIMATED INVESTMENT AND PRODUCTION COSTS FOR NITROPHOSPHATE AND AMMONIUM NITRATE
(1982 US$/Ton)

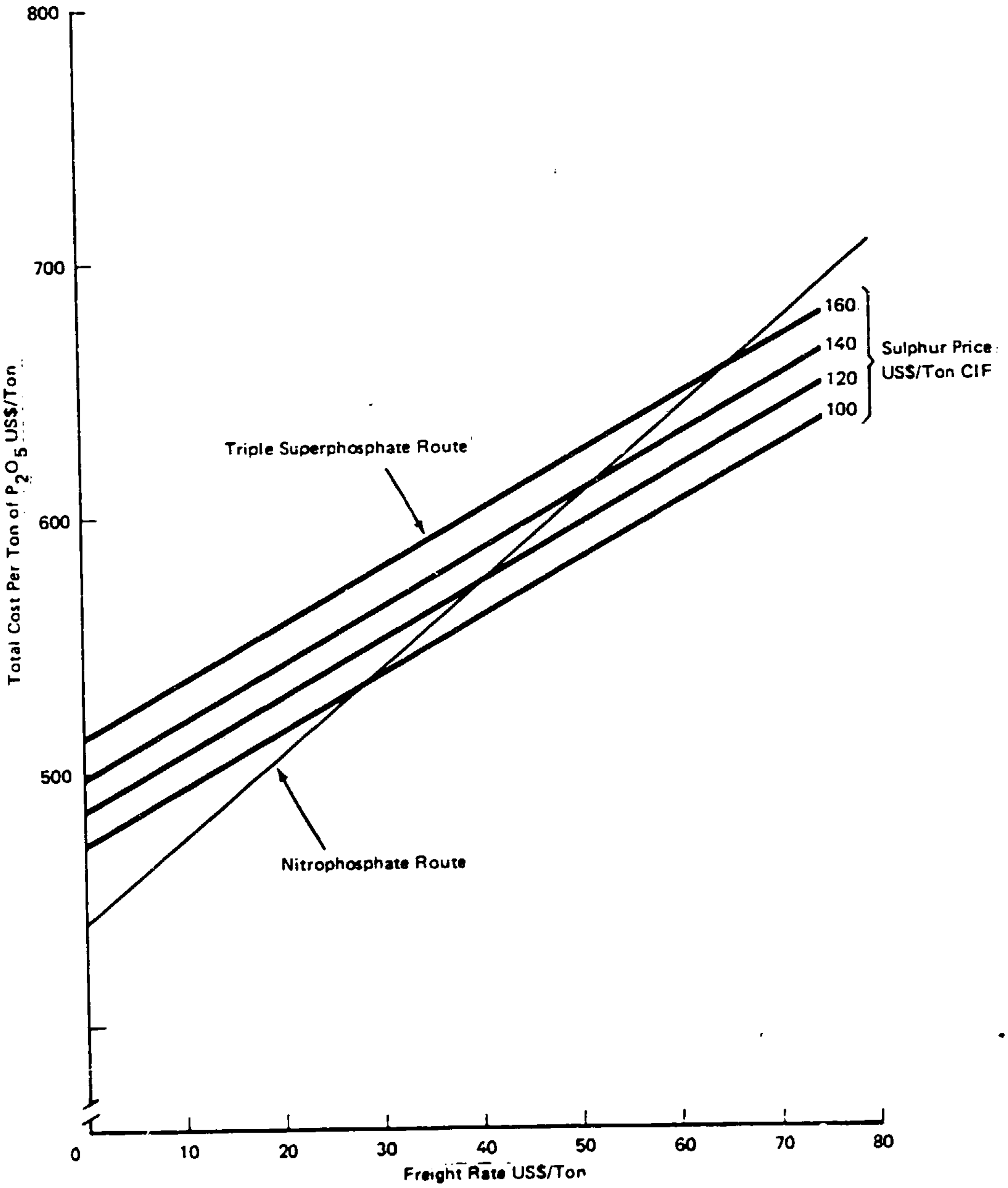
Basis: 1000 Tons/Day Ammonia Plant with downstream nitrophosphate plant complex to match
Capacity Utilization: 90%
Capacity : 330 days/year
554,400 tons/year 22:22:0 (bagged, prilled NP Compound)
412,500 tons/year 33.5:0:0 (bagged, prilled Ammonium Nitrate)
966,900 tons/year total products average analysis 26.9:12.6:0
Production : 498,960 tons/year 22:22:0 (bagged, prilled NP Compound)
371,250 tons/year 33.5:0:0 (bagged, prilled Ammonium Nitrate)
870,210 tons/year total products average analysis 26.9:12.6:0

Site	Developed Site	Developed Site	Developing Site (Some Existing Infrastructure)	Developing Site (Remote Location)
Plant Investment US$ Million	354	354	463	555
Working Capital US$ Million	26	32	47	59
Total Investment US$ Million	380	386	510	614
Raw Materials				
Natural Gas Price US$/M.M. BTU	3.0	5.0	2.0	1.0
Natural Gas Cost US$/Ton Product	53.0	88.3	35.3	17.7
Phosphate Rock US$/Ton Product	14.6	14.6	14.6	14.6
Other Variable Costs US$/Ton	18.2	18.2	18.2	18.2
Fixed Costs US$/Ton	59.1	59.1	74.2	86.9
Production Costs US$/Ton	144.9	180.2	142.3	137.4
Capital Charge (15%) US$/Ton	65.4	66.6	87.9	105.6
Realization Price US$/Ton [1] (bagged ex-factory)	210.3	246.8	230.0	243.0

1) Refers to the average cost of one equivalent ton of product - analysis 26.9:12.6:0

FIGURE 2

Comparative Total Costs of Producing one Ton of P_2O_5 by Triple Superphosphate and Nitrophosphate Routes Including Freight



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5.0 THE MINING AND BENEFICIATION OF POTASH

General

The supply capability of potash in 1982 was approximately as follows:

	Million Tons	%
Eastern Europe	12.0	43.6
North America	9.0	32.7
Western Europe	5.5	20.0
Others	1.0	3.7
World Total	27.5	100.0

Most new potash capacity is expected to be developed in Eastern Europe (mainly the USSR) and in North America (mainly Canada).

Information on the investment and production costs for potash is not so readily available as for other fertilizers particularly for non-North American sources. However, the development of the large potash deposits in Saskatchewan, Canada where conditions are generally uniform and the unit cost data much better defined, represents the most reliable source of cost data on potash. As a significant part of new capacity coming on-stream in the future will be in Canada, the costs there will be important in determining future potash prices. It is also generally accepted that the production costs in Canada where mines are large and modern and the potash seams rich and regular are probably the lowest in the world. This location has therefore been used as the basis for estimating investment and production costs.

Investment Costs

Cost estimates are based on a mine in Canada using underground dry mining with conventional flotation and crystallizer scavenger circuits for beneficiation. As potash mining costs and prices are often given in terms of short tons, the cost information has been calculated for both short tons (2,000 lbs) and metric tons (2,205 lbs). The capacity of the mine is assumed to be 1.5 million short tons of product per annum. The investment costs reflect the complete facilities to produce fertilizer grade material. The mine costs include continuous miners and haulage equipment, underground crushing, ore and service shafts and hoisting facilities. The surface plant also includes offices, laboratories, maintenance and product storage buildings. Although direct operating costs are relatively low in Canada, investment costs are relatively high because of the depth of the deposit, the need for tubbing and the rather difficult climatic conditions.

Item	Specification
Plant production (short tons per year)	1,500,000
Shafts	2 at 3,000 ft.
Product quality	95% KCl
Feed quality	26% K_2O
Rates of concentration	2.7
Recovery	90%

	Item	Investment Cost US$ Million
Mine	Shafts with Hoisting Equipment	93
	Mining Equipment	52
	Subtotal	145
Surface Plant		226
Total Investment Cost		371

Energy Costs

The average energy consumption for potash by shaft mining in the U.S., according to The Fertilizer Institute Survey is:

Energy Required Million BTU per Metric Ton Product

Gas	Electricity	Total
1.36	1.06	2.42

These figures are higher than those reported for Canada but this is due to the fact that the U.S. figures contain some plants with high energy usages. In Canada most new plants will use physical rather than thermal methods of beneficiating potash and will therefore require less energy on average. It has been assumed therefore that the energy usage per metric ton of potash product ex-mine is 1.7 M.M. BTU. At $3.0 per M.M. BTU (the present cost of gas in Canada) this energy would cost about $5.

Direct Operating Costs

Direct operating costs include all direct labor, supervisory and office personnel, administrative expenses, utilities, operating supplies and maintenance.

Item	Canada - Cost US$	
Mine	Short Ton	Metric Ton
Labor and Personnel	4.4	4.8
Materials	3.6	4.0
Energy	1.7	1.8
Other expendables	0.6	0.7
Subtotal: mine	10.3	11.3
Plant		
Labor and Personnel	4.2	4.6
Materials	3.6	4.0
Energy	2.8	3.1
Other expendables	0.9	1.0
Subtotal: mine	11.5	12.7
Total	21.8	24.0

Start-up Costs

The estimates of plant costs contain a component for start-up to cover the contractor's costs during the commissioning of the plant. In view of existing experience in Canada on well-proven processes and ores, it is believed that start-up costs would be minimal. However, an allowance of three months direct operating costs has been allowed for start-up expenses.

Contingency Allowance

A contingency allowance of 10% to cover physical and price contingencies has been taken as appropriate.

Interest During Construction

No direct allowance has been made in the capital costs for interest during construction.

Depreciation

Depreciation has been taken as 20 years (5%) as an average for both the beneficiation plant and mine. Allowance for higher or lower depreciation over 30 years (3-1/3%) would reduce the realization price using 20 years depreciation by about $6/metric ton.

Capital Charge

In order to establish an ex-works realization price, it has been assumed that a commercial company investing in a new mine in Canada would require at least 15% pre-tax return on its equity to cover interest charges and provide adequate profit to justify the project.

Realization Price

The realization price calculated in Table 7 is an ex-works price exclusive of transport costs and taxes. Based on present costs, it would be necessary to add about $24.5/short ton transport to Vancouver plus $3.5/short ton loading.

Discussion of Results

Most of the new capacity for potash will be developed in the USSR and Canada and will be by the dry mining of sylvinite ore. Little is known of the economics of mining potash in the USSR, and it is assumed in this exercise that, to a large extent, future prices for potash will be determined by the cost of mining in Canada and also transport costs in moving the potash to a suitable port for export. The results in Table 7 indicate that the investment cost of a new mine and related facilities in Canada will be about US$285 per annual metric ton of capacity based on mid-1982 dollars. In order to achieve an acceptable return on investment, the ex-works price of potash on such a project would probably have to be about $83/metric ton or about $113/metric ton FOB from Vancouver. It should be noted, however, that this price is exclusive of both Provincial and Federal taxes. The tax situation is complex as it depends on several factors including plant output, profitability, etc. It seems likely that with the changes in provincial government in Saskatchewan there may in time be revisions to the present taxation system on potash production.

Based on the current situation, however, to cover the base tax a figure of $11/per metric ton of product has been added to the realization price.

The FOB price Vancouver to justify the investment would then have to be about $124/metric ton of product.

ESTIMATED INVESTMENT AND PRODUCTION COSTS FOR POTASH

(1982 US$)

Site	Canada
Capacity stpy	1,500,000
Capacity metric tpy	1,364,000
Mine and Plant Investment US$ Million	371
Working Capital US Million	15
Total Investment US Million	386

	Short Ton	Metric Ton
Operating Cost - Mine	10.3	11.3
- Refinery	11.5	12.7
Subtotal	21.8	24.0
Depreciation (5%)	12.3	13.5
Insurance and Local Taxes (1%)	2.5	2.8
Subtotal	14.8	16.3
Total Production Costs	36.6	40.3
(a) Capital Charge (15%)	38.5	42.3
Estimated Realization Price Ex-Works at 15% Capital Charge	75.1	82.6
(b) Capital Charge (10%)	25.7	28.3
Estimated Realization Price Ex-Works at 10% Capital Charge	62.3	68.6
Transport and Loading	28.0	30.8
(c) Estimated FOB Realization Price with Capital Charge of 15%	103.1	113.4
(d) Estimated FOB Realization Price with Capital Charge of 10%	90.3	99.4

ESTIMATED INVESTMENT AND PRODUCTION COSTS FOR UREA

REALIZATION PRICES VERSUS CAPITAL CHARGES

1982 US$/METRIC TON

Capacity Basis 544,500 Tons/Year

Site	Developed Site					Developed Site					Developing Site (Some existing Infrastructure)					Developing Site (Remote Location)				
Plant Investment US$ Million	231					231					323					405				
Working Capital US$ Million	18					24					32					38				
Total Investment US$ Million	249					255					355					443				
Gas Price US$/M.M.BTU	3.0					5.0					2.0					1.0				
Gas Cost US$/Ton Product	96					160					64					32				
Other Variable Costs US$/Ton Product	18					18					18					18				
Utilization Rate %	100	90	80	70	60	100	90	80	70	60	100	90	80	70	60	100	90	80	70	60
Fixed Costs US$/Ton	63.9	70.9	79.9	91.4	106.5	63.9	70.9	79.9	91.4	106.5	84.0	93.3	105.0	120.0	140.0	101.9	113.2	127.4	145.7	169.8
Capital Charge US$/Ton @ 5%	22.9	25.4	28.5	32.7	38.1	23.4	26.0	29.3	33.5	39.0	32.6	36.2	40.7	46.6	54.3	40.7	45.2	50.8	58.1	67.8
10%	45.7	50.8	57.0	65.3	76.2	46.8	52.0	58.6	66.9	78.0	63.2	72.4	81.4	93.2	108.6	81.4	90.4	101.6	116.2	135.6
15%	68.7	76.2	85.5	98.1	114.3	70.2	78.0	87.9	100.5	117.0	97.8	108.6	122.1	139.8	162.9	122.1	135.6	152.4	174.3	203.4
20%	91.6	101.6	114.0	130.8	152.4	93.6	104.0	117.2	134.0	156.0	130.4	144.8	163.8	186.4	217.2	162.8	180.8	302.2	232.4	271.2
25%	114.5	127.0	142.7	163.5	190.5	117.0	130.0	146.5	167.5	195.0	163.0	181.0	203.5	233.0	271.5	203.5	226.0	254.0	290.5	339.0
Realization Price US$/Ton with capital charges of 5%	200.8	210.3	222.4	238.1	258.6	265.3	274.9	287.2	302.9	323.5	198.5	211.5	227.7	248.6	276.3	192.6	208.4	228.2	253.8	287.6
10%	223.7	235.7	250.9	270.8	296.7	288.7	300.9	316.5	336.4	362.5	231.1	247.7	268.4	295.2	330.6	233.3	253.6	279.0	311.9	355.4
15%	246.6	261.1	279.4	303.5	334.8	312.1	326.9	345.8	369.9	401.5	263.7	283.9	309.1	341.8	384.9	274.0	298.8	329.8	370.0	423.2
20%	269.5	286.5	307.9	336.2	372.9	335.5	352.9	375.1	403.4	440.5	296.3	320.1	349.8	388.4	439.2	314.7	344.0	380.6	428.1	491.0
25%	292.4	311.9	336.4	368.9	411.0	358.9	378.9	404.4	436.9	479.5	328.9	356.3	390.5	435.0	493.5	355.4	389.2	431.4	486.2	558.8

ANNEX 2

UREA REALIZATION PRICES - VARIATION WITH GAS PRICES

1982 US$/METRIC TON

90% Utilization; 15% Capital Charge
Capacity : 544,400 Tons/Year Bagged Urea
Production: 490,050 Tons/Year Bagged Urea

Gas Price US$/M.M.BTU	Developed Site	Developing Site (Some Infrastructure)	Developing Site (Remote Location)
0.5	181	236	283
1.0	197	252	299
1.5	213	268	315
2.0	229	284	331
2.5	245	300	347
3.0	261	316	363
3.5	277	332	379
4.0	293	348	395
4.5	309	364	411
5.0	325	380	427
5.5	341	396	443
6.0	357	412	459
6.5	373	428	475
7.0	389	444	491
7.5	405	460	507
8.0	421	476	523

ESTIMATED INVESTMENT AND PRODUCTION COSTS FOR PHOSPHORIC ACID

REALIZATION PRICES VERSUS CAPITAL CHARGES

1982 US$/METRIC TON

Capacity Basis 330,000 Tons/Year P_2O_5

Site	Developed Site					Developing Site (Some existing Infrastructure)					Developing Site (Remote Location)				
Plant Investment US$/Million	132					210					282				
Working Capital US$/Million	21					23					25				
Total Investment US$/Million	153					233					307				
Raw Materials															
Phosphate Rock (3.40 Tons @ US$35/Ton)	119.0					119.0					119.0				
Sulphur (0.98 Tons @ US$160/Ton)	156.8					156.8					156.8				
Other Variable Costs US$/Ton	15.0					15.0					15.0				
Utilization Rate %	100	90	80	70	60	100	90	80	70	60	100	90	80	70	60
Fixed Costs US$/Ton	60.1	66.8	75.1	85.9	100.2	88.5	98.3	110.6	126.4	147.4	114.6	127.4	143.3	163.6	191.1
Capital Charge US$/Ton @ 5%	23.2	25.8	29.0	33.1	38.6	35.3	39.2	44.1	50.4	58.8	46.5	51.7	58.1	66.4	77.5
10%	46.4	51.6	58.0	66.2	77.2	70.6	78.4	88.2	100.8	117.6	93.0	103.4	116.2	132.8	155.0
15%	69.6	77.4	87.0	99.3	115.8	105.9	117.6	132.3	151.2	176.4	139.5	155.1	174.3	199.2	232.5
20%	92.8	103.2	116.0	132.4	154.4	141.2	156.8	176.4	201.6	235.2	186.0	206.8	232.4	265.6	310.0
25%	116.0	129.0	145.0	165.5	193.0	176.5	196.0	220.5	252.0	294.0	232.5	258.5	290.5	332.0	387.5
Realization Price US$/Ton with capital charges of 5%	374.1	383.4	394.9	409.8	429.6	414.6	428.3	445.5	567.6	497.0	451.9	469.9	492.2	521.0	559.4
10%	397.3	409.2	423.9	442.9	468.2	449.9	467.5	489.6	518.0	555.8	498.4	521.6	550.3	587.4	636.9
15%	420.5	435.0	452.9	476.0	506.8	485.2	506.7	533.7	568.4	614.6	544.9	573.3	608.4	653.8	714.4
20%	443.7	460.8	481.9	509.1	545.4	520.5	545.9	577.8	618.8	673.4	591.4	625.0	666.5	720.2	791.9
25%	466.9	486.6	510.9	542.2	584.0	555.8	585.1	621.9	669.2	732.2	637.9	676.7	724.6	786.6	869.4

VARIATION IN PHOSPHORIC ACID REALIZATION PRICES WITH DIFFERENT FEEDSTOCK PRICES FOR DEVELOPED SITE

(1982 US$/Metric Ton)

Plant Investment: US$132 Million
Working Capital : US$ 21 Million
Total Investment: US$153 Million

Capacity Basis 330,000 Tons/Year P_2O_5
Capacity Utilization 90%

Sulphur US$/Ton \ Rock US$/Ton	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
60	252	269	286	303	320	337	354	371	388	405	422	439	456	473	490	507	524	54[illegible]
65	257	274	291	308	325	342	359	376	393	410	427	444	461	478	495	512	529	546
70	262	279	296	313	330	347	364	381	398	415	432	449	466	483	500	517	534	55[illegible]
75	267	284	301	318	335	352	369	386	403	420	437	454	471	488	505	522	539	556
80	272	289	306	323	340	357	374	390	407	424	441	458	475	492	509	526	543	56[illegible]
85	276	293	310	327	344	361	378	395	412	429	446	463	480	497	514	531	548	565
90	281	298	315	332	349	366	383	400	417	434	451	468	485	502	519	536	553	570
95	286	303	320	337	354	371	388	405	422	439	456	473	490	507	524	541	558	575
100	291	308	325	342	359	376	393	410	427	444	461	478	495	512	529	546	563	580
105	296	313	330	347	364	381	398	415	432	449	466	483	500	517	534	551	568	585
110	301	318	335	352	369	386	403	420	437	454	471	488	505	522	539	556	573	590
115	306	323	340	357	374	391	408	425	442	459	476	493	510	527	544	561	578	595
120	311	328	345	362	379	396	413	430	447	464	481	498	515	532	549	566	583	600
125	316	333	350	367	384	401	418	435	452	468	486	503	520	537	554	571	588	605
130	321	338	355	372	389	406	423	440	457	474	491	508	525	542	559	576	593	610
135	325	342	359	376	393	410	427	404	461	478	495	512	529	546	563	580	597	614
140	330	347	364	381	398	415	432	449	466	483	500	517	534	551	568	585	602	619
145	335	352	369	386	403	420	437	454	471	488	505	522	539	556	573	590	607	624
150	340	357	374	391	408	425	442	459	476	493	510	527	544	561	578	595	612	629
155	345	362	379	396	413	430	447	464	481	498	515	532	549	566	583	600	617	634
160	350	367	384	401	418	435	452	469	486	503	520	537	554	571	588	605	622	639
165	355	372	389	406	423	440	457	474	491	508	525	542	559	576	593	610	627	644
170	360	377	394	411	428	445	462	479	496	513	530	547	564	581	598	615	632	649
175	365	382	399	416	433	450	467	484	501	518	535	552	569	586	603	620	637	654
180	370	387	404	421	438	455	472	489	506	523	540	557	574	591	608	625	642	659

VARIATION IN PHOSPHORIC ACID REALIZATION PRICES WITH DIFFERENT FEEDSTOCK PRICES FOR DEVELOPING SITE

(1982 US$/Metric Ton)

Plant Investment: US$210 Million
Working Capital : US$ 23 Million
Total Investment: US$233 Million

Capacity Basis 330,000 Tons/Year P_2O_5
Capacity Utilization 90%

Sulphur US$/Ton \ Rock US$/Ton	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
60	324	341	358	375	392	409	426	443	460	477	494	511	528	545	562	579	596	613
65	329	346	363	380	397	414	431	448	465	482	499	516	533	550	567	584	601	618
70	333	350	367	384	401	418	435	452	469	486	503	520	537	554	571	588	605	622
75	338	355	372	389	406	423	440	457	474	491	508	525	542	559	576	593	610	627
80	343	360	377	394	411	428	445	462	479	496	513	530	547	564	581	598	615	632
85	348	365	382	399	416	433	450	467	484	501	518	535	552	569	586	603	620	637
90	353	370	387	404	421	438	455	472	489	506	523	540	557	574	591	608	625	642
95	358	375	392	409	426	443	460	477	494	511	528	545	562	579	596	613	630	647
100	363	380	397	414	431	448	465	482	499	516	533	550	567	584	601	618	635	652
105	368	385	402	419	436	453	470	487	504	521	538	555	572	589	606	623	640	657
110	373	390	407	424	441	458	475	492	509	526	543	560	577	594	611	628	645	662
115	378	395	412	429	446	463	480	497	514	531	548	565	582	599	616	633	650	667
120	382	399	416	433	450	467	484	501	518	535	552	569	586	603	620	637	654	671
125	387	404	421	438	455	472	489	506	523	540	557	574	591	608	625	642	659	676
130	392	409	426	443	460	477	494	511	528	545	562	579	596	613	630	647	664	681
135	397	414	431	448	465	482	499	516	533	550	567	584	601	618	635	652	669	686
140	402	419	436	453	470	487	504	521	538	555	572	589	606	623	640	657	674	691
145	407	424	441	458	475	492	509	526	543	560	577	594	611	628	645	662	679	696
150	412	429	446	463	480	497	514	531	548	565	582	599	616	633	650	667	684	701
155	417	434	451	468	485	502	519	536	553	570	587	604	621	638	655	672	689	706
160	422	439	456	473	490	507	524	541	558	575	552	609	626	643	660	677	694	711
165	427	444	461	478	495	517	528	546	563	580	597	614	631	648	665	682	699	716
170	431	448	466	482	499	516	533	550	567	584	601	618	635	652	669	686	703	720
175	436	453	470	487	504	521	538	555	572	589	606	623	640	657	674	691	708	725
180	441	458	475	492	509	526	543	560	577	594	611	628	645	662	679	696	713	730

ESTIMATED INVESTMENT AND PRODUCTION COSTS FOR GRANULAR TRIPLE SUPERPHOSPHATE

REALIZATION PRICES VERSUS CAPITAL CHARGES

1982 US$/METRIC TON

Capacity Basis 396,000 Tons/Year

Site	Developed Site					Developing Site (Some existing Infrastructure)					Developing Site (Remote Location)				
Plant Investment US$/Million	39					45					48				
Working Capital US$/Million	11					12					14				
Total Investment US$/Million	50					57					62				
Raw Materials US$/Ton															
Phosphate Rock (0.44 Tons @ US$35/Ton)	15.4					15.4					15.4				
[1] Phosphoric Acid - 0.34 Tons	147.9					172.3					194.9				
Other Variable Costs US$/Ton	7.0					7.0					7.0				
Utilization Rate %	100	90	80	70	60	100	90	80	70	60	100	90	80	70	60
Fixed Costs US$/Ton	14.3	15.8	17.9	20.4	23.8	16.2	18.0	20.2	23.1	27.0	17.1	19.0	21.4	24.4	28.5
Capital Charge US$/Ton @ 5%	6.3	7.0	7.9	9.0	10.5	7.2	8.0	9.0	10.3	12.0	7.8	8.7	9.7	11.1	13.0
10%	12.6	14.0	15.8	18.0	21.0	14.4	16.0	18.0	20.6	24.0	15.6	17.4	19.4	22.2	26.0
15%	18.9	21.0	23.7	27.0	31.5	21.6	24.0	27.0	30.9	36.0	23.4	26.1	29.1	33.3	39.0
20%	25.2	28.0	31.6	36.0	42.0	28.8	32.0	36.0	41.2	48.0	31.2	34.8	38.8	44.4	52.0
25%	31.5	35.0	39.5	45.0	52.5	36.0	40.0	45.0	51.5	60.0	39.0	43.5	48.5	55.5	65.0
Realization Price US$/Ton with capital charges of 5%	191.1	193.1	196.1	199.7	204.6	218.1	220.7	223.9	228.1	233.7	242.2	245.0	248.4	252.8	258.8
10%	197.4	200.1	204.0	208.7	215.1	225.3	228.7	232.9	238.4	245.7	250.0	253.7	258.1	263.9	271.8
15%	203.7	207.1	211.9	217.7	225.6	232.5	236.7	241.9	248.7	257.7	257.8	262.4	267.8	275.0	284.8
20%	210.0	214.1	219.8	226.7	236.1	239.7	244.7	250.9	259.0	269.7	265.6	271.1	277.5	286.1	297.8
25%	216.3	221.1	227.7	235.7	246.6	246.9	252.7	259.9	269.3	281.7	273.4	279.8	287.2	297.2	310.7

1) Based on realization price for phosphoric acid for various sites at 15% capital charge from Annex 3.

VARIATION IN TRIPLE SUPERPHOSPHATE PRICES WITH DIFFERENT FEEDSTOCK PRICES FOR DEVELOPED SITE

(1982 US$/Metric Ton)

Plant Investment: US$39 Million
Working Capital : US$11 Million
Total Investment: US$50 Million

Basis 396,000 Tons/Year
Capacity Utilization 90%

Sulphur US$/Ton \ Rock US$/Ton	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
65	136	144	152	160	168	176	184	192	200	208	216	224	232	240	248	256	264	272
70	137	145	153	161	169	177	185	193	201	209	217	225	233	241	249	257	265	273
75	139	147	155	163	171	179	187	195	203	211	219	227	235	243	251	259	267	275
80	141	149	157	165	173	181	189	197	205	213	221	229	237	245	253	261	269	277
85	142	150	158	166	174	182	190	198	206	214	222	230	238	246	254	262	270	278
90	144	152	160	168	176	184	192	200	208	216	224	232	240	248	256	264	272	280
95	146	154	162	170	178	186	194	202	210	218	226	234	242	250	258	266	274	282
100	147	155	163	171	179	187	195	203	211	219	227	235	243	251	259	267	275	283
105	149	157	165	173	181	189	197	205	213	221	229	237	245	253	261	269	277	285
110	151	159	167	175	183	191	199	207	215	223	231	239	247	255	263	271	279	287
115	152	160	168	176	184	192	200	208	216	224	232	240	248	256	264	272	280	288
120	154	162	170	178	186	194	202	210	218	226	234	242	250	258	266	274	282	290
125	156	164	171	180	188	196	204	212	220	228	236	244	252	260	268	276	283	292
130	157	165	173	181	189	197	205	213	221	229	237	245	253	261	269	277	285	293
135	159	167	175	183	191	199	207	215	223	231	239	247	255	263	271	279	287	295
140	160	168	176	184	192	200	208	216	224	232	240	248	256	264	272	280	288	296
145	162	170	178	186	194	202	210	218	226	234	242	250	258	266	274	282	290	298
150	164	172	180	188	196	204	212	220	228	236	244	252	260	268	276	284	292	300
155	165	173	181	189	197	205	213	221	229	237	245	253	261	269	277	285	293	301
160	167	175	183	191	199	207	215	223	231	239	247	255	263	271	279	287	295	303
165	169	177	185	193	201	209	217	225	233	241	249	257	265	273	281	289	297	305
170	170	178	186	194	202	210	218	226	234	242	250	258	266	274	282	290	298	306
175	172	180	188	196	204	212	220	228	236	244	252	260	268	276	284	292	300	308
180	174	182	190	198	206	214	222	230	238	246	254	262	270	278	286	294	302	310

VARIATION IN TRIPLE SUPERPHOSPHATE PRICES WITH DIFFERENT FEEDSTOCK PRICES FOR DEVELOPING SITE

(1982 US$/Metric Ton)

Plant Investment: US$45 Million
Working Capital : US$12 Million
Total Investment: US$57 Million

Basis 396,000 Tons/Year
Capacity Utilization 90%

Sulphur US$/Ton \ Rock US$/Ton	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
60	164	172	180	188	196	204	212	220	228	236	244	252	260	268	276	284	292	300
65	165	173	181	189	197	205	213	221	229	237	245	253	261	269	277	285	293	301
70	167	175	183	191	199	207	215	223	231	239	247	255	263	271	279	287	295	303
75	169	177	185	193	201	209	217	225	233	241	249	257	265	273	281	289	297	305
80	170	178	186	194	202	210	218	226	234	242	250	258	266	274	282	290	298	306
85	172	180	188	196	204	212	220	228	236	244	252	260	268	276	284	292	300	308
90	174	182	190	198	206	214	222	230	238	246	254	262	270	278	286	294	302	310
95	175	183	191	199	207	215	223	231	239	247	255	263	271	279	287	295	303	312
100	177	185	193	201	209	217	225	233	241	249	257	265	273	281	289	297	305	313
105	179	187	194	203	211	219	227	235	243	251	259	267	274	283	291	299	307	314
110	180	188	196	204	212	220	228	236	244	252	260	268	276	284	292	300	308	316
115	182	190	198	206	214	222	230	238	246	254	262	270	278	286	294	302	310	318
120	183	191	199	207	216	223	231	239	247	255	263	271	279	287	296	303	311	319
125	185	193	201	209	217	225	233	241	249	257	265	273	281	289	297	305	313	321
130	187	195	203	211	219	227	235	243	251	259	267	275	283	291	299	307	315	323
135	188	196	204	212	220	228	236	244	252	260	268	276	284	292	300	308	316	324
140	190	198	206	214	222	230	238	246	254	262	270	278	286	294	302	310	318	326
145	192	200	208	216	224	232	240	248	256	264	272	280	288	296	304	312	320	328
150	193	201	209	217	225	233	241	249	257	265	273	281	289	297	305	313	321	329
155	195	203	211	219	227	235	243	251	259	267	275	283	291	299	307	315	323	331
160	197	205	213	221	229	237	245	253	261	269	277	285	293	301	309	317	325	333
165	198	206	214	222	230	238	246	254	262	270	278	286	294	302	310	318	326	334
170	200	208	216	224	232	240	246	256	264	272	280	288	296	304	312	320	328	336
175	202	210	218	226	234	242	250	258	266	274	282	290	298	306	314	322	330	338
180	203	211	219	227	235	243	251	259	267	275	283	291	299	307	315	323	331	339

ESTIMATED INVESTMENT AND PRODUCTION COSTS FOR GRANULAR DIAMMONIUM PHOSPHATE

REALIZATION PRICES VERSUS CAPITAL CHARGES

1982 US$/METRIC TON

Capacity Basis 396,000 Tons/Year

Site	Developed Site					Developing Site (Some existing Infrastructure)					Developing Site (Remote Location)				
Plant Investment US$/Million	47					53					56				
Working Capital US$/Million	15					17					19				
Total Investment US$/Million	62					70					75				
Raw Materials US$/Ton															
Phosphoric Acid - 0.47 Tons P_2O_5	204.4					238.1					269.5				
Ammonia - 0.225 Tons NH_3	45.0					45.0					45.0				
Other Variable Costs US$/Ton	7.0					7.0					7.0				
Utilization Rate %	100	90	80	70	60	100	90	80	70	60	100	90	80	70	60
Fixed Costs US$/Ton	16.8	18.7	21.0	24.0	28.0	18.6	20.7	23.2	26.6	31.0	19.5	21.7	24.4	27.9	32.5
Capital Charge US$/Ton @ 5%	7.8	8.7	9.7	11.1	13.0	8.8	9.8	11.0	12.6	14.7	9.5	10.6	11.9	13.6	15.8
10%	15.6	17.4	19.4	22.2	26.0	17.6	19.6	22.0	25.2	29.4	19.0	21.2	23.8	27.2	31.6
15%	23.4	26.1	29.1	33.3	34.0	26.4	29.4	33.0	37.8	44.1	28.5	31.8	35.7	40.8	47.4
20%	31.2	34.8	38.8	44.4	52.0	35.2	39.2	44.0	50.4	58.8	38.0	42.4	47.6	54.4	63.2
25%	39.0	43.5	48.5	55.5	65.0	44.0	49.0	55.0	63.0	73.5	47.5	53.0	59.5	68.0	79.0
Realization Price US$/Ton at various capital charges 5%	281.0	283.8	287.1	291.5	297.4	317.5	320.6	324.3	329.3	335.8	350.5	353.8	357.8	363.0	369.8
10%	288.8	292.5	296.8	302.6	310.4	326.3	330.4	335.3	341.9	350.5	360.0	364.4	369.7	376.6	385.6
15%	296.6	301.2	306.5	316.7	323.4	335.1	340.2	346.3	354.5	365.2	369.5	375.0	381.6	390.2	401.4
20%	304.4	309.9	316.2	324.8	336.4	343.9	350.1	357.3	367.1	379.9	379.0	385.6	393.5	403.8	417.2
25%	312.2	318.6	325.9	335.9	349.4	352.7	359.8	368.3	379.7	394.6	388.5	396.2	405.4	417.4	433.0

VARIATION IN DIAMMONIUM PHOSPHATE PRICES WITH DIFFERENT FEEDSTOCK PRICES FOR DEVELOPED SITE

(1982 US$/Metric Ton)

Plant Investment: US$47 Million
Working Capital : US$15 Million
Total Investment: US$62 Million

Capacity Basis 396,000 Tons/Year
Capacity Utilization 90%

Sulphur US$/Ton \ Rock US$/Ton	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
65	217	225	233	241	249	257	265	273	281	289	297	305	313	321	329	337	345	353
70	220	228	236	244	252	260	268	276	284	292	300	308	316	324	332	340	348	353
75	222	230	238	246	254	262	270	278	286	294	302	310	318	326	334	342	350	359
80	224	232	240	248	256	264	272	280	288	296	304	312	320	328	336	344	352	358
85	227	235	243	251	259	267	275	283	291	299	307	315	323	330	339	347	355	360
90	229	237	245	253	261	269	277	285	293	301	309	317	325	333	341	349	357	353
95	231	239	247	255	263	271	279	287	295	303	311	319	327	335	343	351	359	355
100	234	242	250	258	266	274	282	290	298	306	314	321	330	338	346	354	362	367
105	236	244	252	260	268	276	284	292	300	308	316	324	332	340	348	356	364	372
110	238	246	254	262	270	278	286	294	302	310	318	326	334	342	350	358	366	374
115	240	248	256	264	272	280	288	296	304	312	320	328	336	344	352	360	368	376
120	243	251	259	267	275	283	291	299	307	315	323	331	339	347	355	363	371	379
125	245	253	261	269	277	285	293	301	309	317	325	333	341	349	357	365	373	381
130	247	255	263	271	279	287	295	303	311	319	327	335	343	351	360	367	375	383
135	250	258	266	274	282	290	298	306	314	324	330	338	346	354	362	370	378	386
140	252	260	268	276	284	292	300	308	316	324	332	340	348	356	364	372	380	388
145	254	262	270	278	286	294	302	310	318	326	334	342	350	358	366	374	382	390
150	257	265	273	281	289	297	305	313	321	329	337	345	353	361	369	377	384	393
155	259	267	275	283	291	299	307	315	323	331	339	347	355	363	371	379	387	395
160	261	269	277	285	293	301	309	317	325	333	341	349	357	365	373	381	389	397
165	263	271	279	287	295	303	311	319	327	335	343	351	359	367	375	383	391	399
170	266	274	282	290	298	306	314	322	330	338	346	354	362	370	378	386	394	402
175	268	276	284	292	300	308	316	324	332	340	348	356	364	372	380	388	396	404
180	270	278	286	294	302	310	318	326	334	342	350	358	366	374	382	390	398	406

VARIATION IN DIAMMONIUM PHOSPHATE PRICES WITH DIFFERENT FEEDSTOCK PRICES FOR DEVELOPING SITE

(1982 US$/Metric Ton)

Plant Investment: US$53 Million
Working Capital : US$17 Million
Total Investment: US$70 Million

Capacity Basis 396,000 Tons/Year
Capacity Utilization 90%

Sulphur US$/Ton \ Rock US$/Ton	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
65	256	264	272	280	288	296	304	312	320	328	336	344	352	360	368	376	384	392
70	259	267	275	283	291	299	307	315	323	331	339	347	355	363	371	379	387	395
75	261	269	277	285	293	301	309	317	325	333	341	349	357	365	373	381	389	397
80	263	271	279	287	295	303	311	319	327	335	343	357	359	367	375	383	391	399
85	266	274	282	290	298	306	314	322	330	338	346	354	362	370	378	386	394	402
90	268	276	284	292	300	308	316	324	332	340	348	356	364	372	380	388	396	404
95	270	278	286	294	302	310	318	326	334	342	350	358	366	374	382	390	398	406
100	273	281	289	297	305	313	321	329	337	345	353	361	369	377	385	393	401	409
105	275	283	291	299	307	315	323	331	339	347	355	363	371	379	387	395	403	411
110	277	285	293	301	309	317	325	333	341	349	357	365	373	381	389	397	405	413
115	279	287	295	303	311	319	327	335	343	351	359	367	375	383	391	399	407	415
120	282	290	298	306	314	322	330	338	346	354	362	370	378	386	394	402	410	418
125	284	292	300	308	316	324	332	340	348	356	364	372	380	388	396	404	412	420
130	286	294	302	310	318	326	334	342	350	358	366	374	382	390	398	406	414	422
135	289	297	305	313	321	329	337	345	353	361	369	377	385	393	401	409	417	425
140	291	299	307	315	323	331	339	347	355	363	371	379	387	395	403	411	419	427
145	293	301	309	317	325	333	341	349	357	365	373	381	389	397	405	413	421	429
150	296	304	312	320	328	336	344	352	360	368	376	384	392	400	408	416	424	432
155	298	306	314	322	330	338	346	354	362	370	378	386	394	402	410	418	426	434
160	300	308	316	324	332	340	348	356	364	372	380	388	396	404	412	420	428	436
165	302	310	318	326	334	342	350	358	366	374	382	390	398	406	414	422	430	438
170	305	313	321	329	337	345	353	361	369	377	385	393	401	409	417	425	433	441
175	307	315	323	331	339	347	355	363	371	379	387	395	403	411	419	427	435	443
180	309	317	325	333	341	349	357	365	373	381	389	397	405	413	421	429	437	445

ESTIMATED INVESTMENT AND PRODUCTION COSTS FOR NITROPHOSPHATE AND AMMONIUM NITRATE

REALIZATION PRICES VERSUS CAPITAL CHARGES 1982

1982 US$/METRIC TON

Capacity Basis - 554,400 Tons/Year 22:22:0
412,500 Tons/Year 33.5:0:0
966,900 Tons/Year 26.9:12.6

Average analysis of product/ton is 26.9:12.6

Site	Developed Site					Developed Site					Developing Site (Some existing Infrastructure)					Developing Site (Remote Location)				
Plant Investment US$/Million	354					354					463					555				
Working Capital US$/Million	26					32					47					59				
Total Investment US$/Million	380					386					510					614				
Gas Price US$/Million BTU	3.0					5.0					2.0					1.0				
Gas Cost US$/Ton Product	53.0					88.3					35.3					17.7				
Phosphate Rock Cost US$/Ton Product	14.6					14.6					14.6					14.6				
Other Variable Costs	18.2					18.2					18.2					18.2				
Utilization Rate %	100	90	80	70	60	100	90	80	70	60	100	90	80	70	60	100	90	80	70	60
Fixed Costs US$/Ton Product	53.2	59.1	66.5	76.0	88.7	53.2	59.1	66.5	76.0	88.7	66.8	74.2	83.5	95.4	111.3	78.2	86.9	97.7	111.7	130.3
Capital Charge US$/Ton @ 5%	19.6	21.8	24.5	28.0	32.7	20.0	22.2	25.0	28.6	33.3	26.4	29.3	33.0	37.7	44.0	31.7	35.2	39.6	45.2	52.8
10%	39.2	43.6	49.0	56.0	65.4	40.0	44.4	50.0	57.2	66.6	52.8	58.6	66.0	75.4	88.0	63.4	70.4	79.2	90.6	105.6
15%	58.8	65.4	73.5	84.0	98.1	60.0	66.6	75.0	95.8	99.9	79.2	87.9	99.0	113.1	132.0	95.1	105.6	118.8	135.9	158.6
20%	78.4	87.2	98.0	112.0	130.8	80.0	88.8	100.0	114.4	133.2	105.6	117.2	132.0	150.8	176.0	126.8	140.8	158.4	181.2	211.2
25%	98.0	109.0	122.5	140.0	163.5	100.0	111.0	125.0	143.0	166.5	132.0	146.5	165.0	188.5	220.0	158.5	176.1	198.0	226.5	264.0
Realization Prices US$/Ton at various capital charges 5%	158.6	166.7	176.8	189.8	207.2	194.3	202.4	212.6	225.7	243.1	164.3	171.6	184.6	210.2	223.4	160.4	172.5	187.8	207.4	233.6
10%	178.2	188.5	201.3	217.8	239.9	214.3	224.6	237.6	254.3	276.4	187.7	200.9	217.6	238.9	267.4	192.1	207.8	227.4	252.6	286.4
15%	197.8	210.3	225.8	245.8	272.6	234.3	246.8	262.6	282.9	309.7	214.1	230.2	250.2	276.6	311.4	223.8	243.0	267.0	297.8	339.2
20%	217.4	232.1	250.3	273.8	305.3	254.3	269.0	287.6	311.5	343.0	240.5	259.5	283.6	314.3	355.4	255.5	278.2	306.6	343.0	392.0
25%	237.0	253.9	274.8	301.8	338.0	274.3	291.2	312.6	340.1	376.3	267.0	288.8	316.6	352.0	399.4	287.2	313.4	346.2	388.2	444.8