Technical and Economic Evaluation of FERTILIZER INTERMEDIATES for use by Developing Countries

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TECHNICAL AND ECONOMIC EVALUATION OF FERTILIZER INTERMEDIATES FOR USE BY DEVELOPING COUNTRIES

World consumption of fertilizer totaled 55.3 million metric tons (mt) of plant food nutrients ($N+P_2O_5+K_2O$) in 1968 *(1)*. By 1980 consumption has been projected to reach an estimated 135 to 170 million tons of total nutrients *(2)*. In 1969 some 80% of the world fertilizer production capability is located in the highly developed countries, whereas the greatest future fertilizer needs, especially during the next decade, will be in the developing countries *(3)*.

Fertilizer application rates vary widely throughout the world. Table 1 lists these rates for a number of individual countries and areas of the world. The highest application rate is found in the Netherlands where, in 1965-66, over 518 kilograms (kg) of fertilizer was used per hectare (ha) of arable land. This compares with an application rate of only about 11 kg/ha in Latin America and 3.5 kg/ha in India during the same period *(4, 5)*. Although some of the countries have increased their use substantially since these figures were obtained, the potential for greatly increased fertilizer usage in the developing countries is clearly indicated. In order to reap full benefit from increased fertilizer usage, mass educational programs will be needed to train the farmer to develop better farm practices and use improved crop varieties.

Table 1. World Fertilizer Application Rates

Location	Date	Application rate kg of $N+P_2O_5+K_2O$/ha of arable land
The Netherlands	1965-66	518.5
Europe	1965-66	113
North America and Central America	1965-66	43
Oceania	1965-66	39
U.S.S.R.	1965-66	19
South America and Asia	1965-66	11
Africa	1965-66	5
India	1965-66	3.5
World average	1965-66	24
South Vietnam	1966	30

Efforts to meet the increased fertilizer needs will be hampered by shortages of key resources in many of the areas having greatest need for fertilizer. Few of the developing countries have ample supplies of the main raw materials—natural gas, naphtha, sulfur, phosphate rock, and potash. Properly planned import programs will be needed if these countries are to meet their fertilizer needs. Only through a world planning approach is it likely that the problems of fertilizer supply during the next decade can be solved. Even then, transportation difficulties must be overcome and new innovations applied if movement of necessary materials and products throughout the world is to be economical and reliable *(3)*.

One of the greatest problems facing the developing countries in meeting their increased fertilizer demands will be payment of their resulting financial obligations for imported materials and construction of production facilities. Because of their lesser developed agriculture and industrialization, nearly all of these countries are low on foreign exchange. For this reason many of them have in the past stressed the production of fertilizers from any available basic raw materials in an effort to save foreign exchange. In some instances this procedure has resulted in the choice of inefficient fertilizer processes beset by operational problems that tend to offset indicated savings. Foreign exchange will be a decisive factor in planning for the future.

During recent years advances in the technology of fertilizer processes have made possible the construction of very large, efficient plants for production of ammonia, urea, wet-process phosphoric acid, and ammonium phosphates. Recently, facilities for the production of elemental phosphorus on large scale at locations well suited to export were put in operation. The strategic location of such plants near the key raw materials and where low-cost water transportation is available will allow movement of such intermediates to areas of demand throughout the world at relatively low cost *(6)*. In many instances the developing countries can obtain their needed fertilizers more economically in a shorter time by import of intermediates rather than by using the basic fertilizer processes from the start. Import of some finished products will be necessary, particularly in early stages. Proper planning should control foreign exchange requirements at a reasonable level. Because of the indicated importance of intermediates to the developing nations, several individual studies have been made by the Tennessee Valley Authority (TVA) in cooperation with the United States Agency for International Development (AID) *(7, 8, 9, 10)*.

PURPOSES AND OBJECTIVES OF THIS STUDY

In the past, comparatively little emphasis has been placed on the position of fertilizer intermediates in supplying the rapidly growing fertilizer needs of the developing countries. Instead, the development of the basic industry was promoted, using as many indigenous raw materials as possible. In some cases, this approach was slow in developing and in many cases, desired levels of production were not obtained. Import of finished fertilizers was necessary to start the development of a fertilizer use program in smaller countries and to meet urgent needs in larger countries, such as India. Now it appears that intermediates have a good potential to supply such countries with needed fertilizers more quickly and with less impact on foreign exchange than might be expected. The purpose of this study, therefore, is to evaluate economically for the developing countries the prospects for fertilizer intermediates. An effort will be made to rationalize the economic and practical examples by hypothetical planning exercises for the case of a few typical countries with small and large needs for fertilizers.

In some cases, the import of fertilizer intermediates would be only a short-term requirement until a more basic fertilizer industry could be established. A consideration of the alternatives indicates a number of potential advantages of importing intermediates. The needed fertilizers should be made available in shorter time with modest capital investment and the use of less complex processes. Trained personnel, that usually are in short supply, are used more effectively, and the tendency to use outdated, inefficient processes is reduced. Concentration on production of the final products could increase the efficiency and diversification of the fertilizer industry. Economies in transportation and handling are also made possible because the more promising intermediates are concentrated and can be handled as liquids. In many instances, the large fertilizer complex located at its most economic site near the source of raw materials would be much more effectively used in world trade by production and ocean movement of intermediates that would be processed into finished fertilizers near the market.

The shipment of major intermediates from the most economical sites of production offers an opportunity to more effectively avoid a continuation of the overproduction capacity that has built up recently in the United States and other developed areas.

There are also some inherent disadvantages to heavy reliance on the import of fertilizer intermediates by developing countries. The continuing expenditure of substantial amounts of foreign exchange for intermediates will be looked upon with disfavor in many countries; however, with proper planning this expenditure now may not be greatly higher than for the import of basic raw materials. Investment in total fertilizer facilities is much less when using intermediates; consequently, foreign exchange for construction of facilities will be greatly lessened. This will decrease the total impact of the continuing expenditure of foreign exchange. Complete reliance on imports of intermediates as well as raw materials could result in serious difficulties for the developing countries in times of international emergency, when ocean transport would be curtailed.

INTERMEDIATES CONSIDERED

The primary intermediates that show considerable potential for movement in international trade are anhydrous liquid ammonia, low or nonpressure nitrogen solutions, phosphoric acid, and elemental phosphorus. Of these, only liquid ammonia presently stands thoroughly proven in international commerce; low-cost atmospheric storage and ocean transport are dependable established practices. The modern, very large ammonia plants located near low-cost natural gas produce ammonia at very low cost; therefore, this material is in an ideal position for international trade. Ammonium nitrate and nitric acid can be made easily from ammonia; but in most newly developing areas of the world, urea is more desirable. Unfortunately, when ammonia is imported, there is no carbon dioxide available as a byproduct of ammonia production to make urea. Alternative sources of carbon dioxide would be considerably more expensive. This is a major disadvantage to import of ammonia into developing countries.

Low or nonpressure nitrogen solutions containing 32%-37% nitrogen are also suitable materials for international shipment as intermediates; however, the unit cost of these materials, because of their lower concentrations of plant nutrients, is higher than that of ammonia. Some amounts of urea and ammonium nitrate could be imported in this form, but the use and versatility of these materials would be much more restricted than that of the primary intermediates. Only limited ocean transport data are available for these materials; they are somewhat more corrosive than ammonia but should present no undue shipping problems.

Phosphoric acid is available in a range of concentrations, but only the merchant-grade wet-process acid containing about 54% P_2O_5 is being currently planned for large-scale

shipment by ocean transport as an intermediate. This material is likely to present problems in shipment; precipitation of impurities can cause aggravating problems in storage, handling, and shipment. Corrosion also is a factor in ocean shipment. Rubber-lined steel or stainless steel holding tanks must be used to contain the acid. Concentration of wet-process acid to 70%-74% P_2O_5 is now an established commercial practice, but this type of acid might have even greater transport problems; its comparatively high viscosity requires that the acid be heated for unloading and pumping. Electric-furnace superphosphoric acids containing 76%, 80%, or 83% total P_2O_5 are easier to handle and transport than the wet-process acids; however, the cost generally is higher. Phosphoric acid presents an ideal building block for phosphate fertilizers. The variety of products that can be made from phosphoric acid is extensive. Both simple phosphate fertilizers and compound products can be produced by reliable and established processes.

Elemental phosphorus, which contains the equivalent of 229% P_2O_5, is the most concentrated fertilizer intermediate available. Shipping costs on a unit basis are thus low and it can be handled as a fluid. The potential hazards in shipping this combustible material are recognized, and simple and practical safeguards are firmly established by experience in storage and rail shipment. The technology of the conversion of phosphorus to phosphoric acid or superphosphoric acid is comparatively simple and well established. Thermal acid plants require low capital investment and can be built in relatively small size to fit the needs of a particular area. Elemental phosphorus is particularly well suited as a short-term intermediate in areas which later could become self-sufficient in phosphate through the production of elemental phosphorus by the electric-furnace process if economic electrical power becomes available.

Some secondary intermediates which may become important in international fertilizer development in the future are liquid fertilizer base solutions (10-34-0 or 11-37-0), base suspensions (12-40-0 to 14-47-0), granular ammonium polyphosphate (15-62-0), and nongranular monoammonium phosphate (10.5-53-0). These materials are of lesser versatility than the primary intermediates described previously. No appreciable transport difficulties should be experienced with any of the materials. Both the liquids and the suspensions may be stored and shipped in carbon steel containers without difficulty. A variety of N-P-K liquid and suspension fertilizers can be made from the base liquids and suspensions. Granular ammonium polyphosphate also can be used as an intermediate for the production of liquid and suspension fertilizers; it is also suitable for direct application and for use in bulk blends. Nongranular monoammonium phosphate is a practical intermediate for use as a component in formulating compound granular fertilizers; it could be used in many applications that otherwise call for phosphoric acid. Because of their specialized usage these secondary intermediates will not be considered in detail in the economic evaluations of this report which deals primarily with the use of the primary intermediates.

The use of easily pumpable fluid intermediates likely will be preferred, although efficient bulk handling of solids should be practical with proper provisions. Experience in handling of crude oil and petroleum refinery products paves the way for other fluid materials. Ocean transport turnaround time in port is much less for fluids than for solids; consequently, the savings in time and cost could be considerable *(11)*.

SITUATIONS FOR COMPARING THE ECONOMICS OF INTERMEDIATES

In studying the specific potential of using intermediates to supply the growing fertilizer needs in developing countries, it is desirable to present actual comparisons with the use of raw materials and finished products. During the current period of overproduction and deflated pricing in the U.S. fertilizer industry, it is extremely difficult to select realistic prices for finished fertilizers to use in economic comparisons. Therefore, this evaluation will concern primarily comparisons between intermediates and the basic raw materials. A few examples comparing import of finished fertilizers are included. The fertilizer needs of each country are different; however, general economic evaluations can be made to illustrate the potential for intermediates in different areas of the world and in countries of different size and economic status. In this report, these evaluations are intended to indicate the comparative economics and general feasibility of the alternatives (production from imported intermediates vs production from domestic and/or imported raw materials). Estimates are given to indicate the foreign exchange commitments for the various alternatives.

A large part of the detailed background information and specific economic evaluations used in the comparisons made in this report are taken or adapted from the following reports previously prepared for AID by TVA:

*Economic and Technical Evaluation of Overseas Shipment and Utilization of Elemental Phosphorus for Fertilizer Production *(9)*

*Economic Evaluation of Overseas Shipment and Utilization of Phosphoric Acid for Fertilizer Production *(8)*

*Economic Comparison of Overseas Manufacture Versus Importation of Anhydrous Ammonia *(7)*

*Cost Comparison of Ocean Shipment of Anhydrous

Ammonia and Solid Urea Versus Shipment of Urea-Ammonia Solution *(10)*

Some minor changes were made in the estimates taken from these reports to adjust to the objectives of this evaluation. Also an effort was made to standardize certain factors such as interest, depreciation, return on investment, and working capital that had differed in some of the individual evaluations. Additional comparisons that had not been included in any of the previous evaluations have been made, and the study was projected to complete fertilizer manufacturing complexes, with evaluation based on cost of finished fertilizer products.

Battery-limit plant investments were taken from the *Fertilizer Manual* of the United Nations Industrial Development Organization and other publications which are footnoted in tables in the appendix.

The following alternatives were evaluated for providing the nitrogen, phosphate, and potash materials for the countries considered in this study.

Nitrogen Fertilizers

Anhydrous ammonia is the necessary starting point for all of the nitrogen fertilizers. Information comparing cost of production of ammonia with import taken from the previous report *(7)* was used as the main basis. Urea production is included in situations where ammonia is manufactured (CO_2 available). Production of nitric acid and ammonium nitrate is included where ammonia is imported. In some comparisons a part of the nitrogen fertilizer requirement is produced in conjunction with phosphate fertilizer production.

Phosphate Fertilizers

Evaluation of the planning for phosphate fertilizer production in developing countries is not so straightforward and involves more alternatives than for the nitrogen materials. The varying supply-demand situation and corresponding variations in the price of sulfur have further complicated the situation during the past few years. Intermediates that are included in the detailed comparisons in this report are:

*Wet-process phosphoric acid (54% P_2O_5)

*Elemental phosphorus (229% P_2O_5 equivalent)

The 54% wet-process phosphoric acid was selected on the basis of the previous report *(8)* that indicated it as being the most favorable type. Basic cost data were taken from that report. These cost data were arrived at by calculations that assumed appropriate raw materials costs at that time. Reasonable operating costs and financing cost factors were applied and return on investment was included. Recently the price of wet-process acid has deflated severely, and some reported prices appear to be inappropriately low. To allow more latitude in application of this evaluation to a changing price situation, charts are presented (figures 3, 8, and 13) covering a wide range of price from imported wet-process acid. These charts reflect the effect of variation in the imported acid cost on cost of finished fertilizers in which it is used as a major intermediate.

Investment, production, handling, and shipping costs for phosphorus and cost of acid production from phosphorus were modified as necessary from data in the previous report *(8)*.

Import of these intermediates is compared with the production of wet-process acid from imported phosphate rock and sulfur and with importation of granular ammonium phosphates.

The final phosphate fertilizers considered were triple superphosphate and ammonium phosphates including combinations of urea or ammonium nitrate with the ammonium phosphates. In some comparisons the production of ammonium phosphate nitrate products by use of a nitric phosphate approach (nitric acid acidulation process) was included.

Some information is included on the prospects and likely general economics of nongranular ammonium phosphate as an intermediate. Such products (usually monoammonium phosphate [10.5-53-0 grade]) can be produced in a comparatively simple and economical process. Shipping and handling properties should be about the same as for nongranular (run-of-pile) superphosphate and no special type of ship would be needed. Ammonium phosphate of this type should be suitable for supplying the phosphate and part of the nitrogen in formulations for a granulation plant; it could be ammoniated further in the granulation process.

Potash

Fortunately, the cost of potash per unit is considerably less than for nitrogen and phosphate. The projected requirement of potash in developing countries usually is considerably less than for the other nutrients. For these reasons the impact of potash import on foreign exchange is not so severe as for nitrogen and phosphate materials. Plentiful supplies of potash are available to meet projected world requirements for fertilizers for the foreseeable future. Major sources of supply are Canada, the United States, Europe, the Soviet Union, Spain, and North Africa. It is unlikely that potential sources of supply in some of the developing countries will be brought into production for

a number of years; therefore, potash requirements will be imported by many countries. Investment for development of a potash complex is very high, and very large installations are more practical and economical. Such installations usually must rely on broad marketing and export possibilities for the products. The plentiful supply and competitive situation among a number of large producers throughout the world should make prospects for stable prices and dependable supply very good.

Estimates were made of the cost of importing potassium chloride, including storage and handling for inclusion in the final fertilizer processes. Typical examples are included in this report.

TYPICAL COUNTRIES USED IN ECONOMIC COMPARISONS

For the detailed economic studies of this report, typical developing countries in various parts of the world were selected (as examples) on the basis of varying requirements in the amounts of fertilizers needed. Countries selected were:

*Uruguay
*South Vietnam
*India

The requirements for Uruguay and South Vietnam represent small to moderate amounts and those for India make planning for very large amounts of fertilizer appropriate. For South Vietnam and Uruguay the size of fertilizer complex in this study is sufficient to provide most, if not all, of the entire additional projected requirements through the 1975-80 period. For India a large complex that would be one of the several additional units needed in the future was selected as the basis.

The types of fertilizer products to be evaluated were selected on the basis of indications of previous agronomic surveys and evaluations when such information was available.

For the typical cases selected for this evaluation a basis of daily nitrogen production equivalent to 150, 400, and 1000 mt/day of ammonia is used for Uruguay, South Vietnam, and India, respectively. Comparisons are made of the economics of manufacturing the ammonia in the particular country with import of the same amount from the growing number of sources where production cost in large plants is very low. On the basis of general agronomic assessments for the next 10 years, production of nitrogen and phosphate products was based on overall $N:P_2O_5$ ratios of 1:4 for Uruguay and 3:2 for India and South Vietnam. In actual individual cases the proportion would vary above and below these ratios. A complete fertilizer production complex was postulated for each case study based on the selected daily tons of ammonia and the respective $N:P_2O_5$ ratio. Various alternatives among production and import of ammonia and phosphate intermediates and phosphate products are compared.

For Uruguay the end products are granular ammonium phosphates of 13-52-0 to 15-60-0 grade and a prilled ammonium nitrate-granular triple superphosphate blend of 8.7-34.6-0 grade. Use of wet-process phosphoric acid in production of the ammonium phosphate results in a 13-52-0 grade. The acid will be partially neutralized in a tank followed by completion of the ammoniation and simultaneous granulation in either a TVA-type rotary drum ammoniator or a blunger. Use of electric-furnace superphosphoric acid results in a 15-60-0 grade. Ammoniation is done in a pressure reactor and the resulting melt is granulated in a pug mill. The granular triple superphosphate will be produced by reaction of phosphate rock and wet-process phosphoric acid in two tanks and by granulation with recycled fines in a blunger.

For South Vietnam the end products are urea-ammonium phosphate in which the $NH_3:H_3PO_4$ mole ratio is 1:3. Calculations were made on the basis of 28-28-0 and 34-17-0 grades in proportions to give the 3:2 ratio of $N:P_2O_5$. However, when phosphorus is imported as an intermediate, higher grades such as 29-29-0 and 36-18-0 can be made. The melt process as developed by TVA is assumed used in all cases except one. The ammonium phosphate is produced as an essentially anhydrous melt in a tee reactor, scrubbing tower, and vapor disengaging chamber. The ammonium phosphate melt and concentrated urea solution (> 99%) are cogranulated in a pug mill. No drying step is required. In one case granular diammonium phosphate (18-46-0) and prilled urea are produced separately and mixed in blending plants.

For India the end products are urea-ammonium phosphate or ammonium phosphate nitrate. The urea-ammonium phosphates are produced as the same grades, in the same $N:P_2O_5$ proportions, and by the same processes as for South Vietnam. The ammonium phosphate nitrate materials are products of nitric acid acidulation of phosphate rock by either the Odda or the sulfate recycle process. The grade is 28-14-0 in both latter processes.

The magnitude of the total cost and foreign exchange outlay for imported potash for overall $N:P_2O_5:K_2O$

requirements of 3:2:2 and 3:2:1 was estimated as a part of the total fertilizer manufacturing complex in India and South Vietnam. Similar data for Uruguay were based on a $N:K_2O$ ratio of 2:1 and 1:1.

The evaluations of this study are intended to indicate the comparative overall economics and general feasibility of the alternatives (import of intermediates or finished products vs production from raw materials). Also, estimates are given to indicate the foreign exchange commitments for the various alternatives. The individual typical studies for the developing countries selected are somewhat generalized and are not intended to be of sufficient depth and detail to serve as any specific and finalized pattern. Instead, they are expected to indicate prospects for intermediates and to evaluate the main economic and technical factors that are involved in planning for the fertilizer requirements of typical developing countries.

Sources of Intermediates and Raw Materials

There are several prospective sources of raw materials and intermediates for import by developing countries. Some likely sources are the Persian Gulf, U.S. Gulf Coast and Caribbean areas for ammonia and sulfur, United States and North Africa for phosphate rock, and United States and Mexico for wet-process acid.

Phosphorus likely will be available from U.S. and Canadian locations where lower cost electric power may be available and where phosphate ore could be obtained economically. For this evaluation the following sources of the materials and conditions were assumed.

Ammonia would be manufactured in a new, modern 1,000-mt/day plant located in the Persian Gulf area or in Trinidad. The estimated landed costs per mt of ammonia of \$44, \$45, and \$40 for Uruguay, South Vietnam, and India, respectively, were used in the basic evaluations *(7)*. The costs f.o.b. vessel at port of embarkation and the ocean freight were estimated from information given in that report. Curves are included in this current report to show the effect of variations in the cost of imported ammonia on final cost of the finished fertilizers. The estimated costs of operating storage and handling facilities for ammonia are shown in tables A, B, and C of the appendix.

Phosphorus would be produced in a new, modern plant in Florida with a capacity equivalent to 600 short tons (545 mt) of P_2O_5 per day. No such electric-furnace plants now exist in Florida, although some companies are considering construction. The estimated cost of phosphorus f.o.b. vessel in the Gulf Coast area, and the ocean freight were taken from a previous report *(8)*. The phosphorus would be stored in tanks of 12,000-mt capacity and shipped in vessels of 10,000-mt capacity. The estimated cost of operating storage and handling facilities in the developing countries is given in tables A, B, and C of the appendix. The effect of changes in the cost of imported phosphorus on the estimated cost of the finished fertilizer is evaluated.

The wet-process phosphoric acid would be produced in a modern plant in Florida with a capacity equivalent to 600 short tons (545 mt) of P_2O_5 per day *(8)*. A delivered cost of sulfur at Port Tampa of \$39/mt (\$35 f.o.b. vessel) and a cost of \$1/ton for handling the sulfur from the port to the plant were assumed. A sludge of precipitated impurities forms in wet-process phosphoric acid. Acid to be shipped a considerable distance must first be clarified. Contacts with several producers indicate that the total cost for clarification of 54% P_2O_5 acid with a 10% return on investment is about \$5/mt of P_2O_5, provided the facilities are operated on a substantially continuous basis. The estimated cost of phosphoric acid f.o.b. vessel in the Gulf Coast area and the ocean freight were taken from the previous report *(8)*. Curves are given to show the effect of sulfur price on cost of wet-process phosphoric acid f.o.b. at Port Tampa. The acid would be stored in tanks of 24,000-mt capacity and shipped in vessels of 20,000-mt capacity. The estimated cost of operating the storage and handling facilities at the overseas ports is given in tables A, B, and C of the appendix.

The molten sulfur would be stored and handled in facilities similar to those for phosphorus. The storage capacity of the tanks would be 22,000 mt and the shipping vessel would have a capacity of 20,000 mt. The cost of sulfur f.o.b. vessel Gulf of Mexico ports was assumed to be \$35/mt. The price of sulfur has varied above and below the \$35/mt value in recent years. This might be considered as a reasonable "pivotal" price based on past experience. Curves are given in the report to show the effect of higher and lower sulfur prices on cost of production of finished fertilizer products. The ocean freight rate is estimated at \$12/mt for shipment to India; cost for shipment of sulfur to South Vietnam was assumed to be the same, but that for shipment to Uruguay was estimated to be \$7/mt. The estimated cost of operating the storage and handling facilities for sulfur at the overseas port is given in tables A, B, and C of the appendix.

Delivered costs of phosphate rock of \$13/mt in Uruguay and \$21 in South Vietnam and India were taken from previous reports and other source information. Data are given to show the effect of variations in cost of phosphate ore on production cost of the finished fertilizers.

SPECIFICATIONS AND ASSUMPTIONS FOR THE ESTIMATES

A number of standard specifications and assumptions were used in the investment and production cost estimates of this report. The main ones are as follows.

General

The fertilizer plant complexes in each of the developing countries are assumed to be located at a seaport for direct receipt of raw materials or intermediates by ship.

Investment Estimates

1. The battery limits investment cost of various plant units in Uruguay, South Vietnam, and India was assumed to be 1.3 times corresponding U.S. battery limits cost.
2. The cost of auxiliary facilities for the complex (steam, power, water supply, etc.) was assumed to be 25% of the total battery limits cost of all the plant units included in the complex.
3. The cost of supporting facilities for the complex (roads, civil works, office and administrative buildings, etc.) was assumed to be 25% of the total battery limits cost plus 25% of the auxiliary facilities cost.
4. The foreign exchange components of the investment costs were assumed to be as follows:

Uruguay	75% of battery limits cost of plant units
	25% of cost of storage facilities
	50% of auxiliaries
	35% of support facilities
South Vietnam	75% of battery limits cost of plant units
	25% of cost of storage facilities
	50% of auxiliaries
	35% of support facilities
India	60% of battery limits cost of plant units
	20% of cost of storage facilities
	40% of auxiliaries
	28% of support facilities

5. Bulk storage capacity for solid fertilizers was assumed to be one-third of the annual production capacity.
6. The cost of bulk storage buildings for solid fertilizer was assumed to be as follows:
   Dehumidified storage – $16.50/mt of storage capacity (U.S. cost)
   Atmospheric storage – $11.00/mt of storage capacity (U.S. cost)

Production Cost Estimates

(Standard Assumptions Used in TVA Cost Estimates)
Depreciation – 15 years
Interest – 8% on one-half of plant investment
Taxes and insurance – 2% of plant investment
Operating labor – $3/man-hr[1]
Maintenance – 5% of plant investment
Supplies – 20% of maintenance
Analyses – 20% of operating labor
Handling – 4% of operating cost (except in port storage facilities)
Overhead – 100% of operating labor
Utilities
- Electrical power – $0.01/kwh
- Cooling water – $0.02/M gal
- Treated water – $0.10/M gal
- Boiler feed water – $0.40/M gal
- Fuel – $0.08/gal
- Steam – $0.50/M lb

Working capital – Cost of 1 month's raw materials plus 3 months' in-plant value of products
Return on investment – Calculated at 0%, 10%, 15%, and 20%; 10% value used in comparative evaluations emphasized in this report

The type and size of the individual plant units included in the various production complexes for the three countries are listed in tables D through F of the appendix.

[1] In developing countries lower rates likely would apply but larger numbers of personnel would be used. Total cost should be about the same.

RESULTS OF ECONOMIC EVALUATIONS

A number of alternatives were evaluated for each of the countries used in this study. Data giving results of the economic studies of those selected for comparison are shown in the summary table G in the appendix. Values for production costs are based on a 10% return on investment. Individual estimates for each alternative are given in tables J through Y of the appendix. Investment costs for each alternative are itemized in table H of the appendix.

Uruguay Example

For the case study of Uruguay (basis: 150 mt/day of ammonia and overall $N:P_2O_5$ ratio in products of 1:4), four different alternatives were evaluated—two involving import of raw materials for phosphate fertilizer production and two involving phosphate intermediates. In all cases, import of ammonia was assumed because of the very high cost of production for the low requirement of only 150 mt/day. (A previous TVA-AID study *Economic Comparison of Overseas Manufacture and Importation of Anhydrous Ammonia (7)* showed that importation of ammonia is more economical than production at the 150 mt/day use level.

Data in the summary table show the substantially lower investment in facilities for the total complex for the cases involving import of phosphate intermediates. There are also some significant differences in production cost and in foreign exchange requirements. The following tabulation shows some key comparisons from the evaluations in the Uruguay studies taken from the summary table.

	Investment in facilities $ million		Cost of Production[a] $/mt of total nutrients		Cost of Production[a] $ million/yr
	Total	Foreign exchange component	Total	Foreign exchange component	Foreign exchange component
Import of phosphate rock, sulfur, and ammonia (product, ammonium phosphate)	30.5	18.7	136	84	17.0
Import of phosphate rock, sulfur, and ammonia (products, granular triple superphosphate and prilled ammonium nitrate for blending)	42.5	20.5	150	83	17.0
Import of 54% wet-process acid and ammonia (product, ammonium phosphate)	8.1	4.6	139	119	24.0
Import of elemental phosphorus and ammonia (product, ammonium polyphosphate)	12.8	7.4	147	118	24.0

[a]Includes 10% return on total investment.

The investment in facilities is much lower for the cases in which phosphate intermediates are imported. Lowest investment is about $8 million for import of wet-process acid; import of elemental phosphorus increases the investment to about $13 million mainly because of the investment for phosphorus burning plants for acid production. The estimated investment for cases involving import of raw materials (phosphate rock and sulfur) is about $42 million if granular triple superphosphate and prilled ammonium nitrate are produced and about $30 million if granular ammonium phosphate is produced. The separate production units for triple superphosphate and ammonium nitrate (including nitric acid plant) and the cost of blending units require substantially higher investment than a single granulation system for ammonium phosphate. Production of a cogranulated mixture of superphosphate and ammonium nitrate would narrow this difference as compared with production of ammonium phosphate; cost of a prilling tower and the blending plants would be avoided and the ammonium nitrate preparation system would be simpler. The foreign exchange component of the investment in facilities is about 50%-60% of the total investment.

Estimated overall cost of production of plant nutrient for the Uruguay cases and the foreign exchange component as listed in the preceding tabulation provide some important comparisons. Lowest cost of production of $136/mt of $N + P_2O_5$ was for the case of imported rock and sulfur for production of granular ammonium phosphate. Import of the intermediates results in only marginally higher production costs—$139 for wet-process acid import for production of ammonium phosphate and $147 for elemental phosphorus import for production of ammonium polyphosphate. Import of phosphate rock and sulfur for production of granular triple superphosphate and prilled ammonium nitrate for blending gave highest cost of $150/mt of nutrients. This again resulted largely from the higher investment and increased operating costs for the larger number of individual plant units in the complex.

The foreign exchange component in the total production cost is shown to be considerably higher for the cases involving import of the phosphate intermediates. A foreign

exchange requirement of \$83 and \$84/mt of total nutrients is indicated for the cases involving import of the phosphate raw materials and \$118 and \$119 for those involving the intermediates. Foreign exchange requirement for import of elemental phosphorus is indicated to be slightly higher than for import of wet-process acid. These comparisons, that indicate \$34-\$36/mt of total nutrients higher continuing requirement of foreign exchange for import of intermediates, would result in an additional outlay of about \$7 million per year in foreign exchange. On this basis, the \$11 to \$16 million initial savings in foreign exchange for construction of facilities would be offset in the first 2 to 3 years of operation.

In general, the situation illustrated by the Uruguay examples appears to give a good case for production of the phosphatic component from imported raw materials. The low requirement of nitrogen (150 mt/day of NH_3) makes import of ammonia as an intermediate particularly attractive, and this saves substantially on investment. The requirement of phosphate component is high enough (500 mt/day of P_2O_5) to make production from imported rock and sulfur economical. The estimates show lowest cost of production and considerably lower continuing foreign exchange for production of the ammonium phosphate fertilizer using raw materials for the phosphate component. Total investment in facilities for the complex of about \$30 million is moderate. Import of the phosphate intermediates would appear to be more attractive as a short-term approach with planning for later installation of full production facilities.

Consideration of nitric phosphate, that would be expected to be economical for the comparatively large phosphate requirement, does not appear to be feasible because of the indicated planning for a low overall $N:P_2O_5$ ratio of 1:4.

South Vietnam Example

The general situation assumed for the economic studies for South Vietnam would appear to make either production from raw materials or import of intermediates for both the nitrogen and phosphate fertilizer components practical. The quantities used in the evaluations are 400 mt/day of ammonia and 219 mt/day of P_2O_5. However, there is a strong preference for urea as the main nitrogen fertilizer because of its suitability for rice fertilization and high analysis. The uncertainty in technology and lack of information on investment and operating costs for facilities for preparation of carbon dioxide (that would be necessary for use with imported ammonia for urea production) made it advisable to consider only manufacture of ammonia in the alternatives that were evaluated. Also, the previous TVA-AID study *Economic Comparison of Overseas Manufacture an Importation of Anhydrous Ammonia (7)* indicated that countries with ammonia requirements of over about 400 mt/day probably can produce ammonia more economically than they can import it when foreign exchange is considered. This results in an essentially opposite situation to Uruguay where only import of ammonia was evaluated. Data for the four alternatives in the summary provide some interesting comparisons that are summarized in the following tabulation.

	Investment in facilities \$ million		Cost of Production[a] \$/mt of total nutrients		Cost of Production[a] \$ million/yr
	Total	Foreign exchange component	Total	Foreign exchange component	Foreign exchange component
Imported phosphate rock and sulfur and manufactured ammonia (product, urea-ammonium phosphate)	54.5	33.1	177	75	13.5
Imported wet-process acid and manufactured ammonia (product, urea-ammonium phosphate)	40.9	25.0	162	83	15.0
Imported wet-process acid and manufactured ammonia (product, granular ammonium phosphate and prilled urea for blending)	39.5	24.2	161	83	15.0
Imported elemental phosphorus and manufactured ammonia (product, urea-ammonium phosphate)	43.0	26.2	162	81	14.5

[a]Includes 10% return on total investment.

Since production of 400 mt of ammonia is included, the investment in facilities is comparatively high in each case. However, the three alternatives involving import of phosphate intermediates result in considerably lower estimated investment of \$40-\$43 million as compared with about \$55 million when phosphate rock and sulfur raw materials are imported for use in phosphate production.

A considerably lower total cost of production of \$161-\$162/mt of total nutrients is indicated for the three cases involving import of phosphate intermediates as compared with \$177 for production from imported phosphate rock and sulfur. The foreign exchange component of total production cost is indicated to be only marginally higher—\$81-\$83/mt of nutrients for intermediates as compared with \$75 for use of the raw materials. The approximately \$8 million lower foreign exchange for construction of facilities for use of the intermediates would cover 6 to 8 years of additional continuing foreign exchange for their import. The substantially higher cost of production using raw materials for phosphate fertilizer production results mainly from high cost of production of wet-process acid in the comparatively small plant unit of 219 mt/day of P_2O_5 and the longer shipping distance for phosphate rock and sulfur that adds substantially to their delivered cost as compared with the Uruguay evaluation.

In general, the South Vietnam studies appear to provide an attractive situation for import of phosphate intermediates. There appears to be no significant economic difference between the two phosphate intermediates (phosphorus and wet-process acid).

India Example

Because of the very large need for fertilizers in India in the future and the variety of crops and versatility of the market, huge fertilizer manufacturing complexes with individual plant units of the largest practical size of almost any common type could be reasonably postulated. Therefore, a variety of case studies based on either import of raw materials or intermediates or combinations of these would be appropriate in this evaluation. Five alternatives were selected for complete evaluation, and for the three cases involving use of phosphate rock both import and use of domestic material were evaluated. The newly discovered phosphate deposits in Rajasthan make consideration of the domestic material practical. Final realistic price for the domestic phosphate ore is uncertain. For this evaluation a port location near the mine site with direct rail connection is assumed for the complex using the ore. With advanced mining technique and greater volume that would be expected in the future, a delivered price of \$10/mt was assumed. This price is lower than is practical at present or perhaps in the near future but may be reasonable in longer term. Charts are included (figure 11) that show the effect of phosphate ore cost over a wide range. Results of the economic studies are given in summary table G of the appendix.

Some key results of the estimates and evaluations are given in the following tabulation.

	Investment in facilities \$ million		Cost of Production[a] \$/mt of total nutrients		Cost of Production[a] \$ million/yr
	Total	Foreign exchange component	Total	Foreign exchange component	Foreign exchange component
Imported phosphate rock and sulfur and manufactured ammonia (product, urea-ammonium phosphate)	105	51	148	65	29.5
Same except use of potential domestic phosphate rock	105	51	132	38	17.0
Imported wet-process acid and manufactured ammonia (product, urea-ammonium phosphate)	81	39	141	75	33.5
Imported elemental phosphorus and manufactured ammonia (product, urea-ammonium phosphate)	86	42	141	72	32.5
Imported phosphate rock and manufactured ammonia (product, nitric phosphate—sulfate recycle process)	90	43	126	43	17.5
Same except use of domestic phosphate rock	90	43	113	21	8.5
Imported phosphate rock and imported ammonia (product, nitric phosphate—Odda process)	60	28	117	62	25.5
Same except use of domestic phosphate rock	60	28	104	40	16.5

[a]Includes 10% return on total investment.

The estimated total investment in the large fertilizer manufacturing complexes for the various alternatives ranged from $60 million for nitric phosphate produced from phosphate rock and imported ammonia to $105 million for urea-ammonium phosphate produced from phosphate rock, imported sulfur, and manufactured ammonia.

Total cost of production was indicated to be substantially lower for the nitric phosphate products. Lowest cost indicated is $104/mt of total nutrients using domestic phosphate rock and imported ammonia; this is also an alternative with lowest investment in facilities. Next lowest production cost is $113 for domestic phosphate rock and manufactured ammonia; this alternative involves lowest continuing foreign exchange component of production of only $21/mt of total nutrients. Use of the higher cost imported phosphate rock and imported ammonia gave a production cost of $117, and the imported phosphate rock and manufactured ammonia resulted in an estimated production cost of $126/mt of nutrients. The savings in foreign exchange for construction of nitric phosphate production facilities by using imported ammonia was $15 million. This would cover about 2 years of higher continuing foreign exchange using imported ammonia.

Among the alternatives for production of urea-ammonium phosphate, lowest estimated production cost was $132/mt of nutrients using imported sulfur, domestic phosphate rock, and manufactured ammonia. The same alternative using imported phosphate rock gave the highest cost of production of $148. Import of the phosphatic intermediates–wet-process acid and elemental phosphorus–for use with manufactured ammonia gave estimated production costs of $141. Foreign exchange for production was highest ($72 and $75/mt of nutrients) for the import of intermediates for phosphate production. The savings in foreign exchange for construction of production facilities by use of the phosphate intermediates was indicated to be $9 to $12 million; this would cover 3 to 4 years of higher continuing foreign exchange for production using the intermediates than for imported phosphate rock but would cover less than a year for domestic rock.

It is difficult to generalize on the results of the India evaluations. However, the several alternatives illustrate a number of significant points.

*Production of nitric phosphate by one of the processes (Odda or sulfate recycle) that requires little or no sulfur appears to be attractive. Estimated total cost of production is substantially lower, and substantial savings in investment can be effected through use of imported ammonia. However, in terms of foreign exchange, production of ammonia is probably more economical than importation.

*Use of domestic phosphate rock would be very effective in decreasing both production costs and the continuing outlay of foreign exchange. This emphasizes potential importance of the new phosphate discovery.

*For urea-ammonium phosphate production, import of phosphate intermediates–wet-process acid or elemental phosphorus–appears to be attractive as compared with import of phosphate rock and sulfur.

The several cases in the India studies point out the need for thorough and detailed evaluation in selecting import materials and processes for any planned new fertilizer production facilities.

General

The cost comparisons in the summary table and in the previous tabulations were for values that had been estimated to be reasonable for cost of the raw materials and intermediates. Base values used were as follows.

Cost of materials, $/mt Delivered to Plant

	Uruguay	South Vietnam	India
Phosphate rock			
Imported	13	21	21
Domestic	–	–	10
Imported sulfur[a]	44-45	51	49
Imported wet-process acid, 54% P_2O_5[b]	73	80	79
Imported elemental phosphorus[c]	303	313	309

[a]$35.00/mt f.o.b. at port of embarkment.
[b]$114.15/mt P_2O_5 f.o.b. at port of embarkment.
[c]$0.124/lb at producing point.

Any appreciable change in these costs would affect the estimated production costs substantially. Curves showing the effect of a range of costs for the raw materials and intermediates on total production cost are shown in figures 1 through 17. In each figure, individual curves depict the added effect on production cost of 0%, 10%, and 20% return on the total investment. Only the curves for 10% return on total investment are used in the following discussion of the estimates for India.

For instance, as shown in figure 11 a decrease in delivered cost of phosphate rock from the $21/mt used for imported material in the estimate to $16/mt would decrease cost of production of urea-ammonium phosphate from $148 to $140/mt of total nutrients and offset the lower production cost indicated for use of the intermediates. On the other hand, a decrease in cost of imported elemental phosphorus from the standard value of $0.124/lb at the production plant to $0.105/lb (see figure

12) would double the indicated advantage of $7/mt of nutrients over import of phosphate rock and sulfur at the standard prices used in the estimates. A lower f.o.b. sulfur cost of $24/mt instead of the $35 used in the estimates (figure 10) would decrease cost of production from $148 to $143/mt of total nutrients. This would decrease the advantage of intermediates from about $7 to about $2/mt of nutrients over import of sulfur and phosphate rock. A $1/mt increase in naphtha cost (figure 14) would increase the cost of the urea-ammonium phosphate $0.70/mt of nutrient.

Estimated Cost of Imported Potash

Estimates were made to indicate the total cost of imported potash for inclusion in the finished fertilizers. The cost includes purchase price of potash, rail shipment to port, loading on ship, ocean transport cost, off-loading, and handling into the granulation process.

For India and South Vietnam the delivered cost of imported potash as potassium chloride (60% K_2O) is estimated at $36/mt off-loaded from ships into storage. On the same basis, the cost in Uruguay is estimated at $34/mt. With an additional $1/mt for handling into the process and $0.50 for increased capital costs for storage and handling facilities, the total cost of the potash component is:

For Uruguay– $35.50/mt of KCl ($59.00/mt K_2O)

For India and South Vietnam– $37.50/mt of KCl ($62.50/mt K_2O)

The following tabulation shows the estimated annual expenditures for potash for the examples of the three countries used in this evaluation. Also shown is a rough estimate of additional investment for storage facilities for the potash and increased storage space for finished products containing potash.

Country	Annual total expenditures for potash $ million	Additional investment for storage facilities $ million
Uruguay		
K_2O = 1/2 N	1.2	0.2
K_2O = N	2.4	0.4
South Vietnam		
K_2O = 1/2 P_2O_5	2.3	0.35
K_2O = P_2O_5	4.5	0.7
India		
K_2O = 1/2 P_2O_5	5.7	0.8
K_2O = P_2O_5	11.3	1.6

Comparison of Cost of Importing Finished Fertilizers

A realistic evaluation of feasibility and cost of importing finished fertilizers by developing countries is difficult and subject to considerable uncertainties at present because of the generally depressed and unstable price situation in the United States and other exporting countries. Prices selected could be questioned in light of variability of quoted prices and unlisted prices that apparently have prevailed in 1968 and 1969. Prices at times apparently were lower than cost of production and certainly would not allow reasonable return on investment. Despite this rather hectic pricing and marketing situation, a few estimates were made using prices somewhat above current published levels for some finished products. Delivered cost and foreign exchange outlay for the plant nutrients imported as finished fertilizers are compared with some of the more favorable examples in the detailed evaluation of intermediates and raw materials. The following prices of fertilizers (bulk f.o.b. U.S. producing plant) were used. These prices might be expected to be reasonable in a more stabilized market situation. Somewhat higher prices likely would prevail in a completely normal situation allowing reasonable return on investment.

Fertilizer	Price bulk (f.o.b. U.S. mfg. plant) $/mt
Granular diammonium phosphate (DAP) 18-46-0	70
Granular monoammonium phosphate (MAP) 11-55-0 or 13-52-0	74
Prilled urea 45-0-0	66

Other costs assumed for the imported finished fertilizers were:

	$/mt
Bags and bagging (50-kg plastic-lined jute)	10
Freight, mfg. plant to port	4
Handling and loading	2
Estimated tramp rates, U.S. to:	
Uruguay	9
South Vietnam	14
India	16
Off-loading at receiving port	1

Using these figures the delivered costs of the finished fertilizers would be as follows:

	$/mt, delivered
Uruguay	
DAP (18-46-0)	96
MAP (11-55-0 or 13-52-0)	100
Urea (45-0-0)	92
South Vietnam	
DAP	101
MAP	105
Urea	97
India	
DAP	103
MAP	107
Urea	99

Using the above delivered costs for the fertilizers, average plant nutrient costs for $N:P_2O_5$ ratio of 3:2 for Vietnam and India and 1:4 for Uruguay would be as follows:

Country	Fertilizers imported	Delivered cost $/mt of $N + P_2O_5$
Uruguay	MAP (13-52-0)	154
South Vietnam	DAP (18-46-0) and urea (45-0-0)	183
India	DAP (18-46-0) and urea (45-0-0)	187

A 10% return on total investment, including working capital, adds $2/mt to the cost of plant nutrient in Uruguay and South Vietnam and $1/mt in India.

Essentially all of the cost of the imported finished fertilizers would be foreign exchange. Few, if any, developing countries would have their own ships, and only off-loading and handling costs at the receiving plant complex would be in domestic currency.

The following tabulation shows cost and foreign exchange requirement for import of the finished fertilizers as compared with the most favorable raw materials and intermediates examples for the same types of fertilizers.

	Cost of nutrients[a] $/mt $N + P_2O_5$ by import of		
	Finished products	Intermediates	Raw materials
Uruguay	156 (152)[b]	139-147 (118-119)[b]	136 (84)[b]
South Vietnam	185 (181)	161-162 (82)	177 (75)
India	188 (184)	141 (73)	148 (65)

[a]Includes 10% return on investment.
[b]Values in parentheses—estimated foreign exchange component.

Cost of importing finished fertilizer is shown to be substantially higher than for manufacture by use of intermediates or raw materials. Foreign exchange is much higher (more than double in most cases) for import of the finished products.

For Uruguay the $33-$34/mt of nutrients higher foreign exchange for finished products than for intermediates would result in yearly additional outlay of about $7 million. The approximately $6 million in foreign exchange estimated for construction of manufacturing facilities using intermediates (summary table G) would be recovered in the first year. The $68/mt of nutrient higher foreign exchange for import of finished fertilizers than for production from imported raw materials would result in a yearly additional outlay of about $14 million. Thus, the $19 million foreign exchange for production facilities using raw materials would be recovered in about 1-1/3 years.

For Vietnam, the $99/mt of nutrients higher foreign exchange for import of finished fertilizers would result in an additional yearly outlay of about $18 million. Thus, the $25 million foreign exchange for production facilities using intermediates would be recovered in about 1-1/2 years.

For India, the $111/mt of nutrients higher foreign exchange for import of finished fertilizers would result in additional outlay of about $50 million per year. Thus, the $41 million foreign exchange for construction of manufacturing facilities using intermediates would be recovered in less than a year.

These examples indicate clearly that both from total cost and foreign exchange standpoints, the import of finished fertilizers by countries having requirements in the range covered in this study is not attractive. Import of moderate amounts of finished fertilizers in early introduction and market development programs likely will be desirable. For countries with future potential fertilizer requirements too small to allow even marginally economic production, continued import of finished products may be necessary.

Comparison of Cost of Importing Powdered Monoammonium Phosphate

In the last few years, at least three companies have announced processes for production of powdered monoammonium phosphate (MAP) for use as an intermediate or a finished product. This product (approximate grade 10.5-53-0) containing about the same P_2O_5 content as merchant-grade wet-process phosphoric acid likely could be shipped overseas at less cost and with greater convenience than the phosphoric acid. This should be a very versatile material for use as a major component in preparation of finished granular fertilizer. The production processes are reported to be more economical and require

less investment than for granular ammonium phosphates. Plants for producing this product are in operation or under construction. Cost of the MAP intermediate (f.o.b.) should be somewhat lower than for the granular ammonium phosphate such as the presently popular 18-46-0 diammonium phosphate. A price of $65/mt f.o.b. plant in Florida was used as the base price in evaluating the powdered MAP as an intermediate. This price is about the same as the equivalent amounts of phosphoric acid and ammonia at prices used in the other basic estimates. Charts are included to show the effect of a range of prices of the MAP from $50 to $75/mt. Other costs assumed for this material were:

	$/mt MAP	
Freight, mfg. plant to port	2	
Handling and loading	1	
Cost f.o.b. vessel; Fla. port	68	
Estimated tramp rates, U.S. to:		
Uruguay	5	–
South Vietnam and India	–	9
Offloading at receiving port	1	
Delivered cost		
Uruguay	74	–
South Vietnam and India	–	78

For the case in Uruguay, the imported powdered MAP would be ammoniated to raise the $N:P_2O_5$ ratio to 1:4 which results in a 13-52-0 granular grade. To satisfy this added nitrogen requirement, about 32 mt/day of ammonia would be imported in addition to the 928 mt/day of MAP. Using the same landed cost for ammonia used in the detailed estimates and an adjusted refrigerated storage cost of $6/mt, the cost of ammonia delivered to the ammonium phosphate plant in Uruguay would be $50/mt. Ammoniation and granulation would be done simultaneously in a conventional TVA-type granulation plant. Such a plant to produce the required 946 mt/day of product including the port facilities for ammonia and MAP is estimated to cost $6.5 million including the auxiliary and supporting facilities.

Using the above costs for raw materials, the total raw material cost for 13-52-0 would be $114/mt of plant nutrient. The operating cost of the granulation plant is estimated to be $5/mt of plant nutrient and that for auxiliary facilities is $2. A return of 10% on the total investment (including $8 million in working capital) together with 8% interest on one-half of the working capital would be $9/mt of plant nutrient. These costs are itemized below.

	$
Raw materials	114
Capital and operating costs in granulation and for auxiliary facilities	7
Interest on working capital (4%) and return on investment (10%)	9
	130

The foreign exchange component for this case consists of $114 for imported feedstock, $1 for maintenance supplies, and $2 for retirement of plant investment which totals $117/mt of plant nutrient.

For a case in South Vietnam, the powdered MAP would be cogranulated with urea melt (99.8%) to produce fertilizers having an average $N:P_2O_5$ ratio of 3:2. The basis of calculation for this case is an ammonia plant of 400 mt/day capacity as was used in other estimates for this country. Since the import of MAP to produce the 3:2:0 ratio brings in additional nitrogen, the total production capacity in this case is 15% greater than in the other cases in South Vietnam. The granulation would be done in conventional pug mill or rotary drum-type granulation plants having a 1,200 mt/day total capacity. The estimated cost of a 400 mt/day ammonia plant, a 700 mt/day urea plant, port facilities for handling 477 mt/day of MAP, and the granulation plants including auxiliary and supporting facilities for such a complex is $40 million. Using the $46/mt cost of the urea solution calculated in the other South Vietnamese cases and the $78/mt estimated delivered cost for the powdered MAP, the raw material cost is $110/mt of plant nutrient. The operating cost of the granulation plant is estimated to be $5/mt of plant nutrient and that for auxiliary facilities is $9. A return of 10% on the total investment (including $7 million in working capital) together with 8% interest on one-half of the working capital, would be $24/mt of plant nutrient. The total cost per mt of plant nutrient as itemized below is $148.

	$
Raw materials	110
Capital and operating costs in granulation and for auxiliary facilities	14
Interest on working capital (4%) and return on investment (10%)	24
	148

The foreign exchange component for this case is $88/mt of plant nutrient and consists of $71 for imported feedstock, $4 for maintenance supplies, and $13 for retirement of the plant investment.

For a case in India, the powdered MAP would be cogranulated with urea melt (99.8%) to produce fertilizers with an average $N:P_2O_5$ ratio of 3:2. Granulation would be done in three conventional granulation plants having a combined capacity of about 3,000 mt/day. The estimated cost of the complex is $81 million. Included are a 1,000 mt/day ammonia plant, two urea solution plants having a combined capacity of 1,766 mt/day, port facilities for 1,193 mt/day of MAP, and the three granulation plants plus auxiliary and supporting facilities. Using the urea solution cost of $36/mt calculated in the other Indian cases and the $78/mt estimated cost for the powdered MAP, the raw materials cost is $99/mt of plant nutrient. The operating cost of the granulation plant is estimated to be $5/mt of plant nutrient and that for auxiliary facilities is $7. A return of 10% on the investment (including $17 million in working capital), together with 8% interest on one-half of the working capital, would be $20/mt of plant nutrient. These costs are itemized below.

	$
Raw materials	99
Capital and operating costs in granulation and for auxiliary facilities	12
Interest on working capital (4%) and return on investment (10%)	20
	131

The foreign exchange component for this case is $83/mt of plant nutrient and consists of $70 for imported feedstock, $3 for maintenance supplies, and $10 for retirement of the plant investment. The following tabulation shows cost and foreign exchange component for import of the powdered MAP intermediate as compared with raw materials, other intermediates, and finished products.

With the base price of powdered MAP used in this estimate ($65/mt f.o.b. Florida plant), the cost of fertilizer product nutrients in the selected LDCs is generally lower than with the other intermediates. Generally, the foreign exchange costs are slightly higher with the powdered MAP alternative, but total production costs are significantly lower. The lower costs result mainly from lower shipping and handling costs estimated for the MAP and the somewhat lower investment in final production facilities.

Changes in cost of the imported MAP would affect the estimated production cost in each of the three cases considered, and could significantly affect the choice of alternatives. Curves depicting this effect are shown in figures 18-20. These curves are based on a 10% return on investment. In Uruguay, for instance, as shown in figure 18, a decrease in the cost of MAP from the $68 f.o.b. vessel, Florida port, used in the estimate, to $53 would decrease the production cost of 13-52-0 in Uruguay from $131/mt of plant nutrient to $108/mt of plant nutrient. Similar results for South Vietnam and India can be taken from figures 19 and 20.

	Cost of nutrients, $/mt ($N + P_2O_5$) by import of			
	MAP intermediate	Other intermediates	Raw materials	Finished products
Uruguay	130 (117)	139-147 (118-119)	136 (84)	156 (152)[a]
South Vietnam	148 (88)	162 (81-83)	177 (75)	185 (181)
India	131 (83)	141 (72-75)	148 (65)	188 (184)

[a]Value shown in parentheses in foreign exchange.

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11. Young, Ronald D., *The Potential for Fertilizer Intermediates*, presented at Management Seminar for Indian Fertilizer Executives, Tennessee Valley Authority, Muscle Shoals, Alabama (1968).

APPENDIX

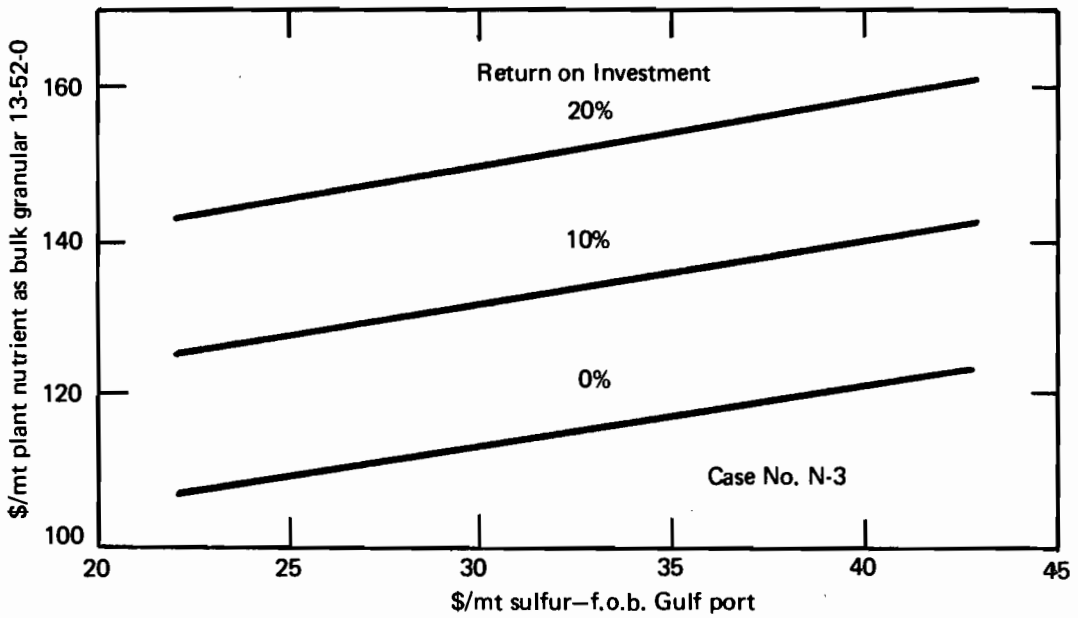

Fig. 1. Effects of Sulfur Cost on Cost of Granular 13-52-0 Ammonium Phosphate in Uruguay

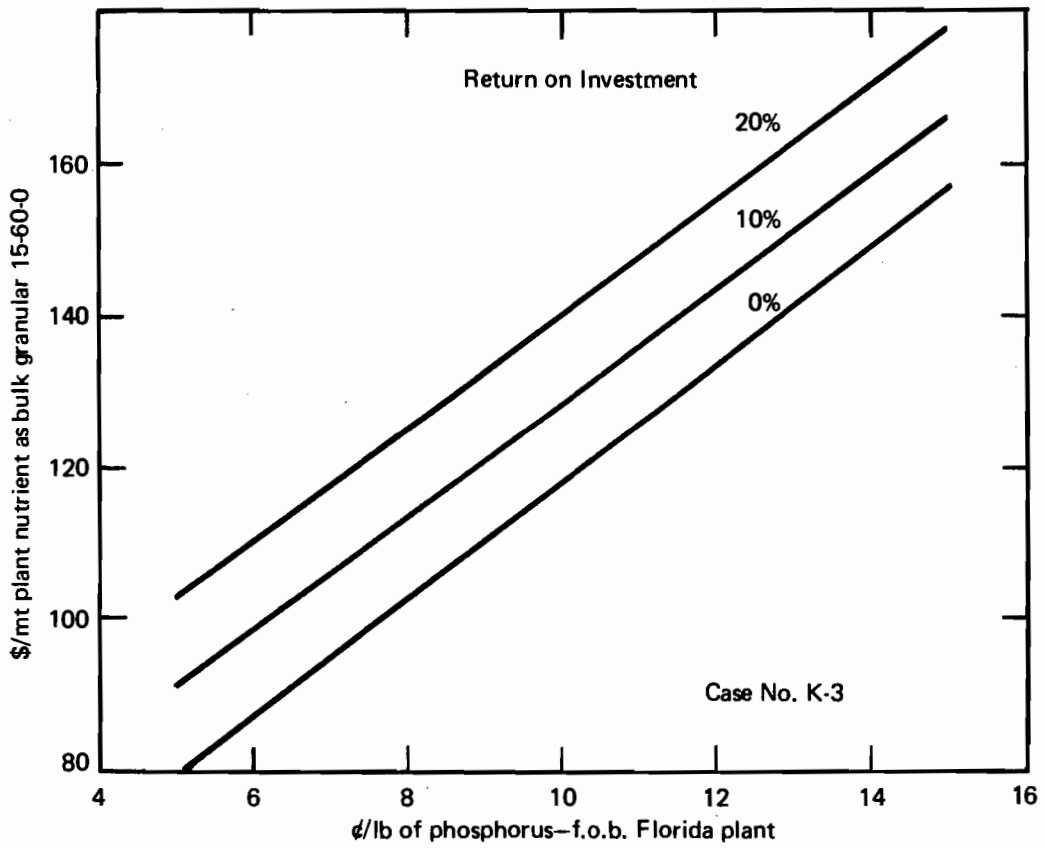

Fig. 2. Effects of Phosphorus Cost on Cost of Granular 15-60-0 Ammonium Polyphosphate in Uruguay

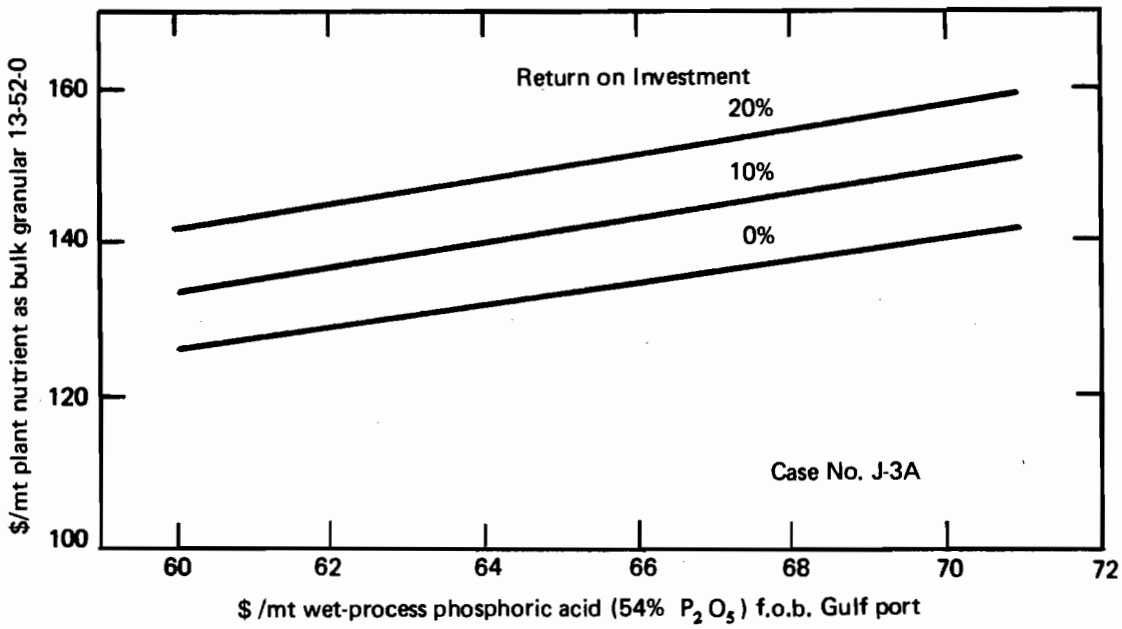

Fig. 3. Effects of Wet-Process Phosphoric Acid (54% P_2O_5) Cost on Cost of Granular 13-52-0 Ammonium Phosphate in Uruguay

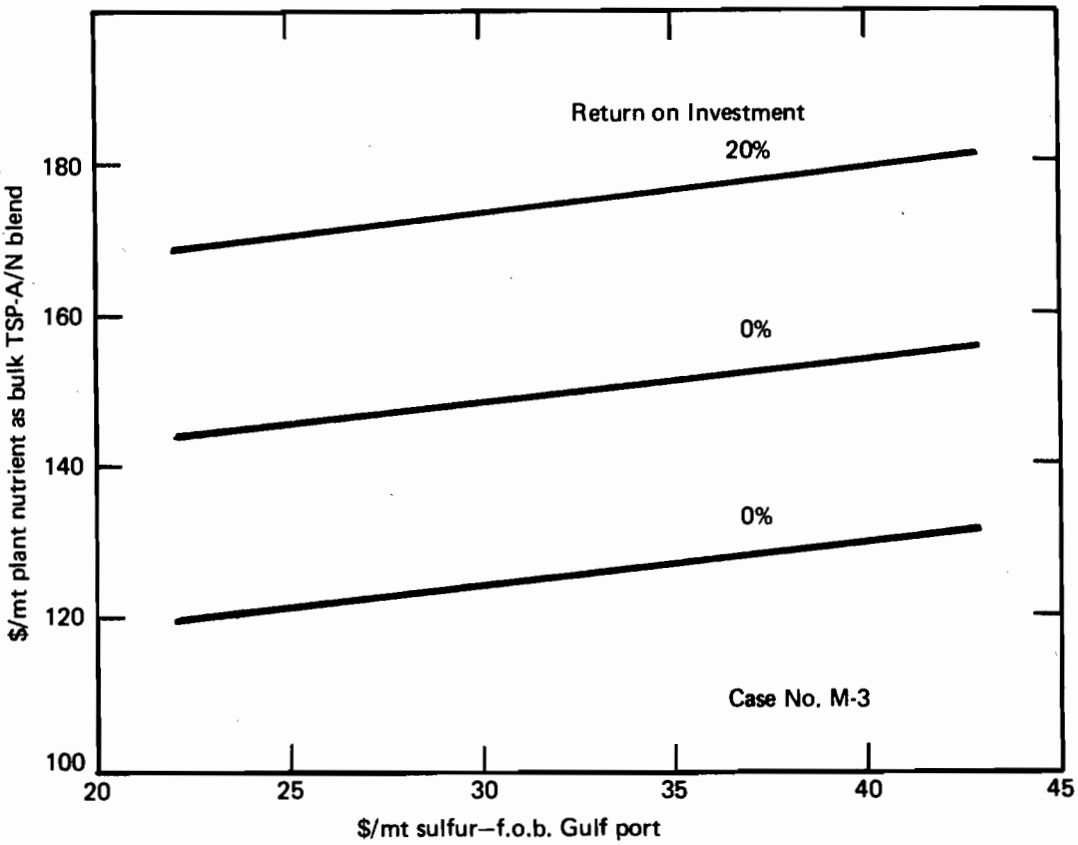

Fig. 4. Effects of Sulfur Cost on Cost of Triple Superphosphate-Ammonium Nitrate Blend in Uruguay

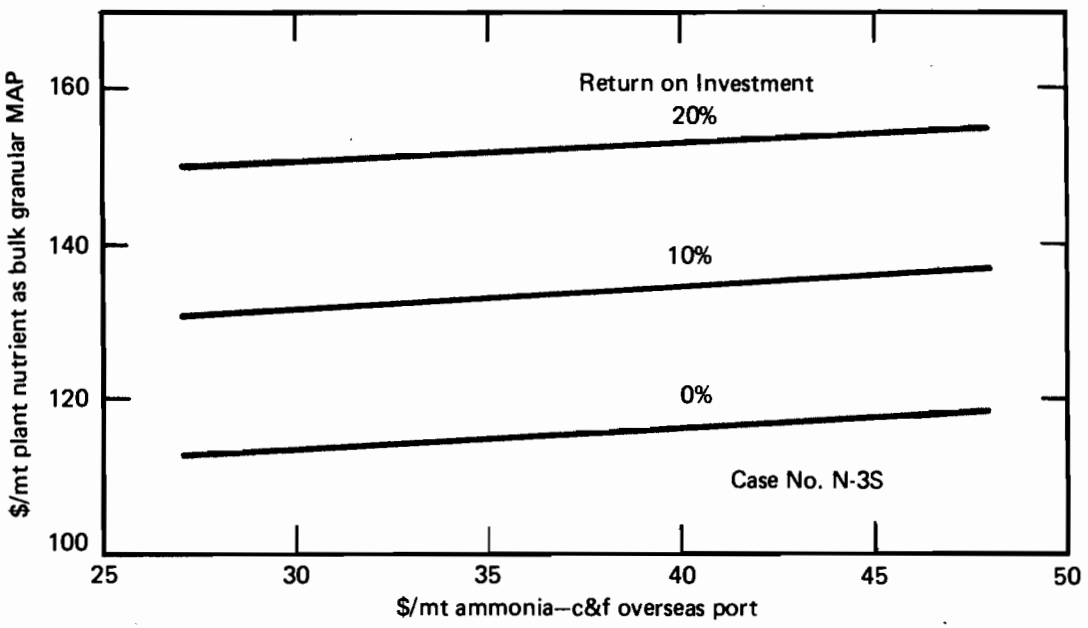

Fig. 5. Effects of Ammonia Cost (Imported) on Cost of 13-52-0 Ammonium Phosphate in Uruguay

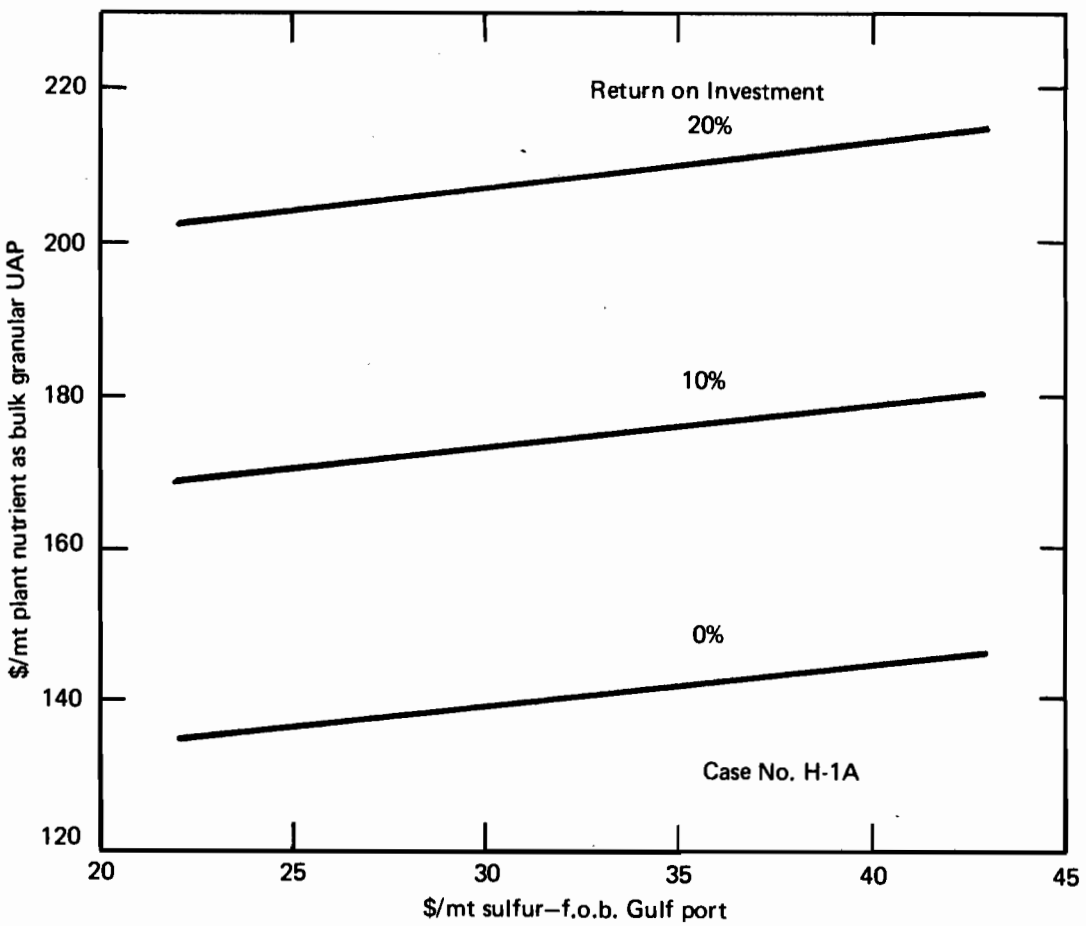

Fig. 6. Effects of Sulfur Cost on Cost of Granular Urea - Ammonium Phosphate by Melt Process in Vietnam

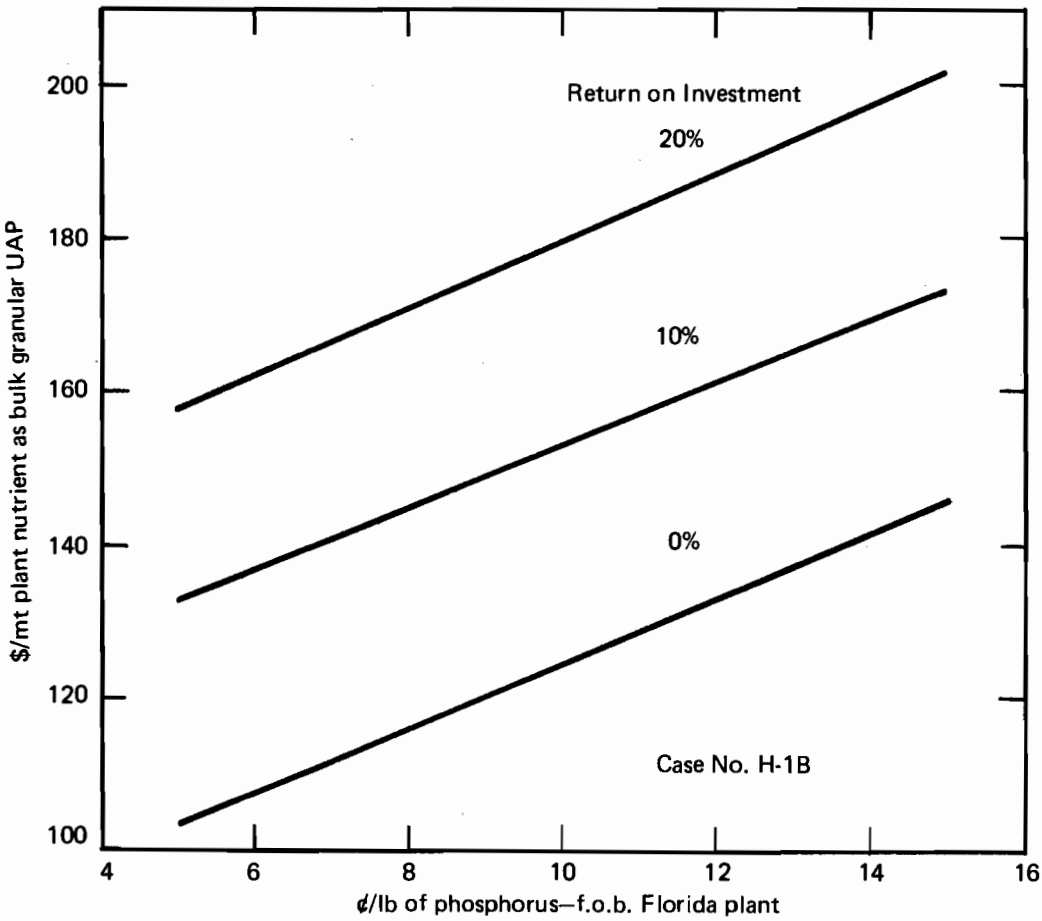

Fig. 7. Effects of Phosphorus Cost on Cost of Granular Urea - Ammonium Phosphate by Melt Process in Vietnam

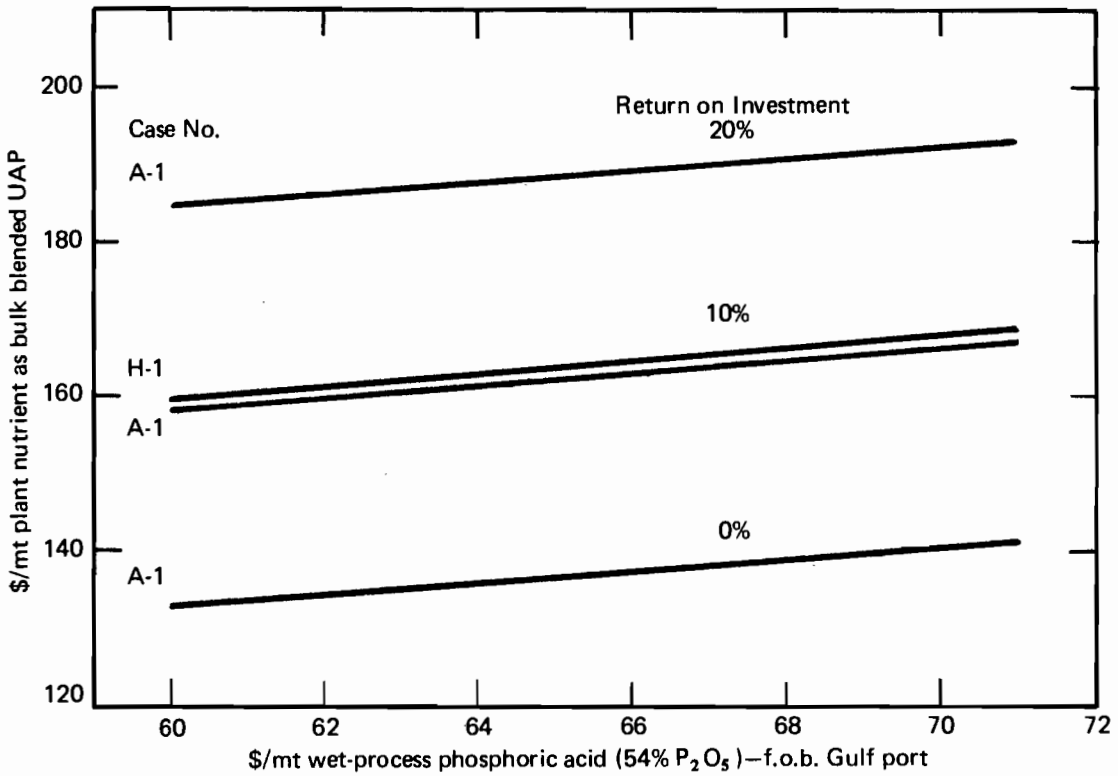

Fig. 8. Effects of Wet-Process Phosphoric Acid (54% P_2O_5) Cost on Cost of Blended Urea - Ammonium Phosphate in Vietnam

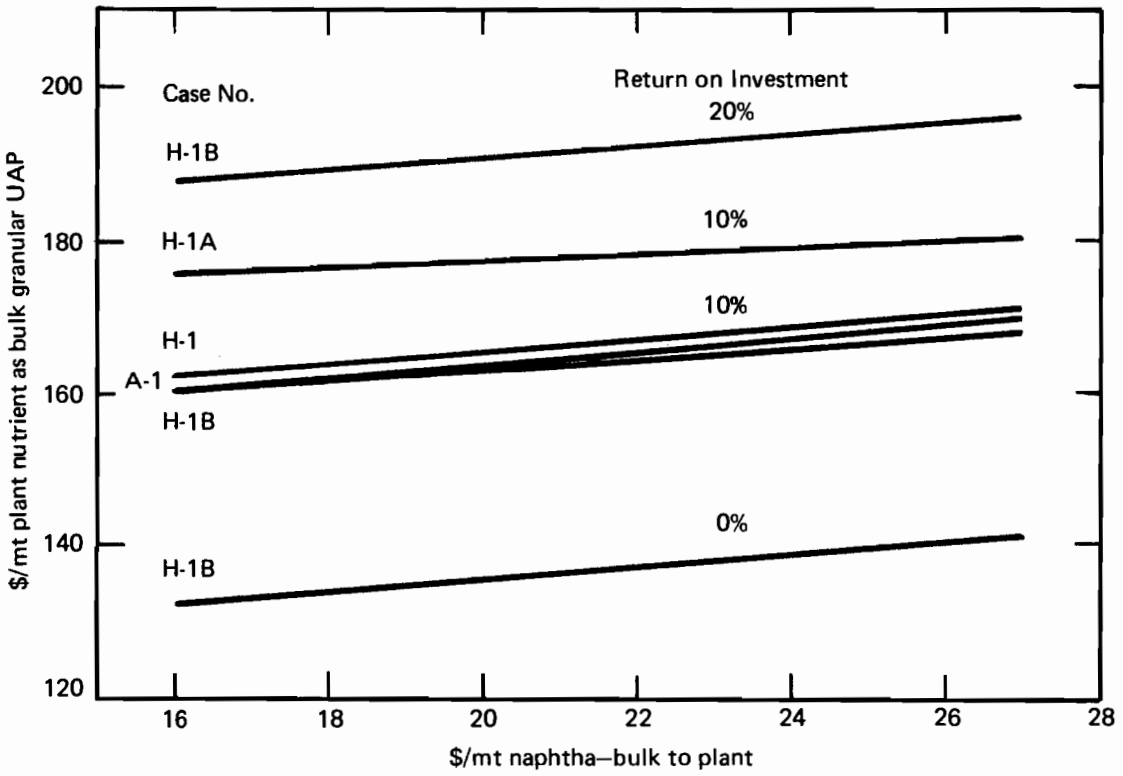

Fig. 9. Effects of Naphtha Cost on Cost of Production of Blended and Granular Urea - Ammonium Phosphate in Vietnam

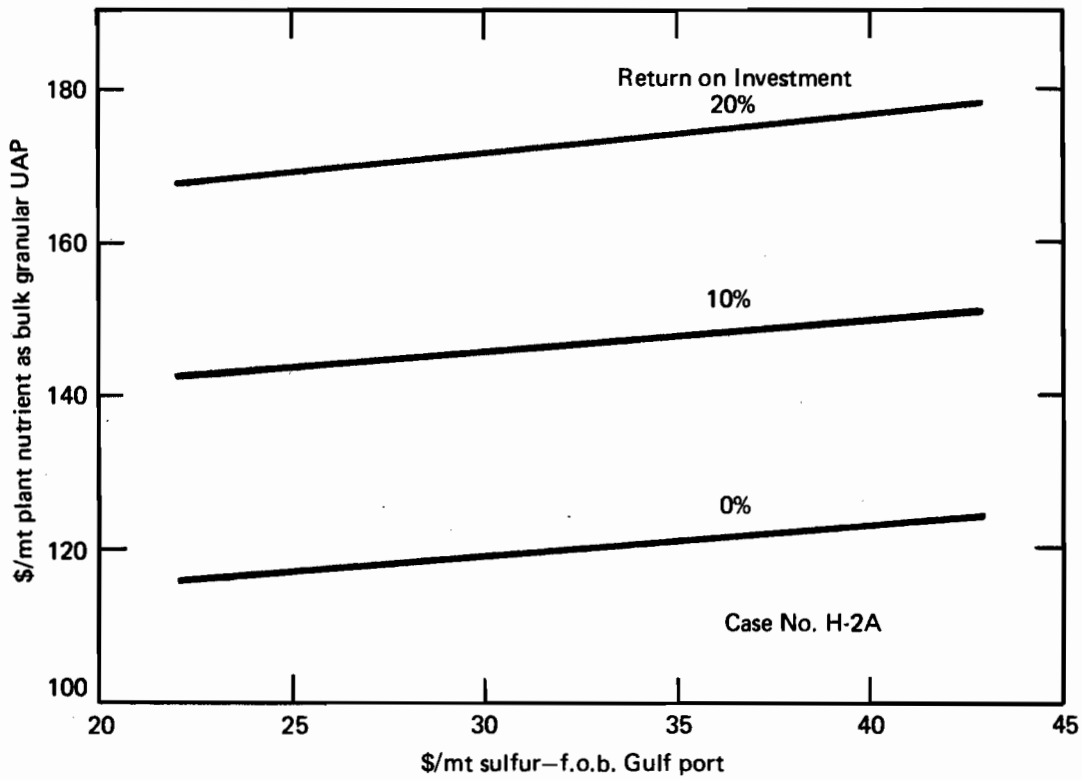

Fig. 10. Effects of Sulfur Cost on Cost of Urea - Ammonium Phosphate by Melt Process in India

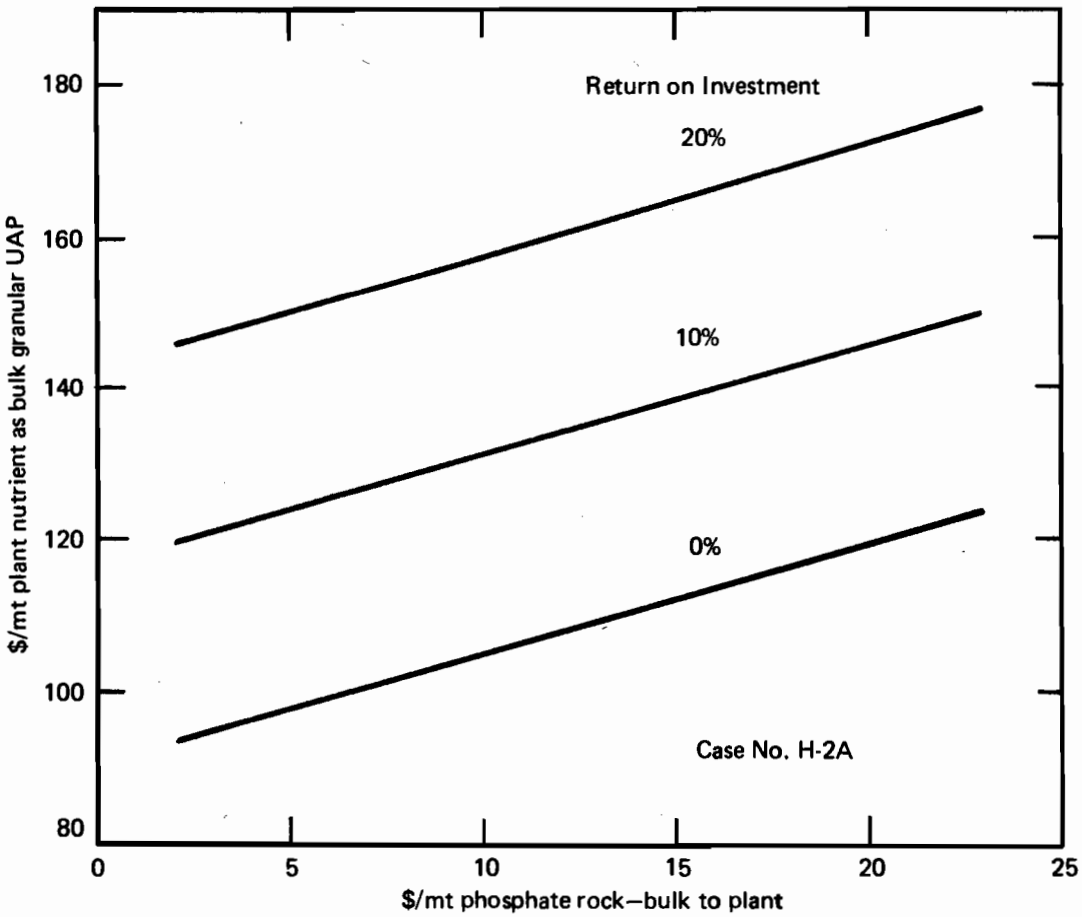

Fig. 11. Effects of Phosphate Rock Cost on Cost of Urea - Ammonium Phosphate by Melt Process in India

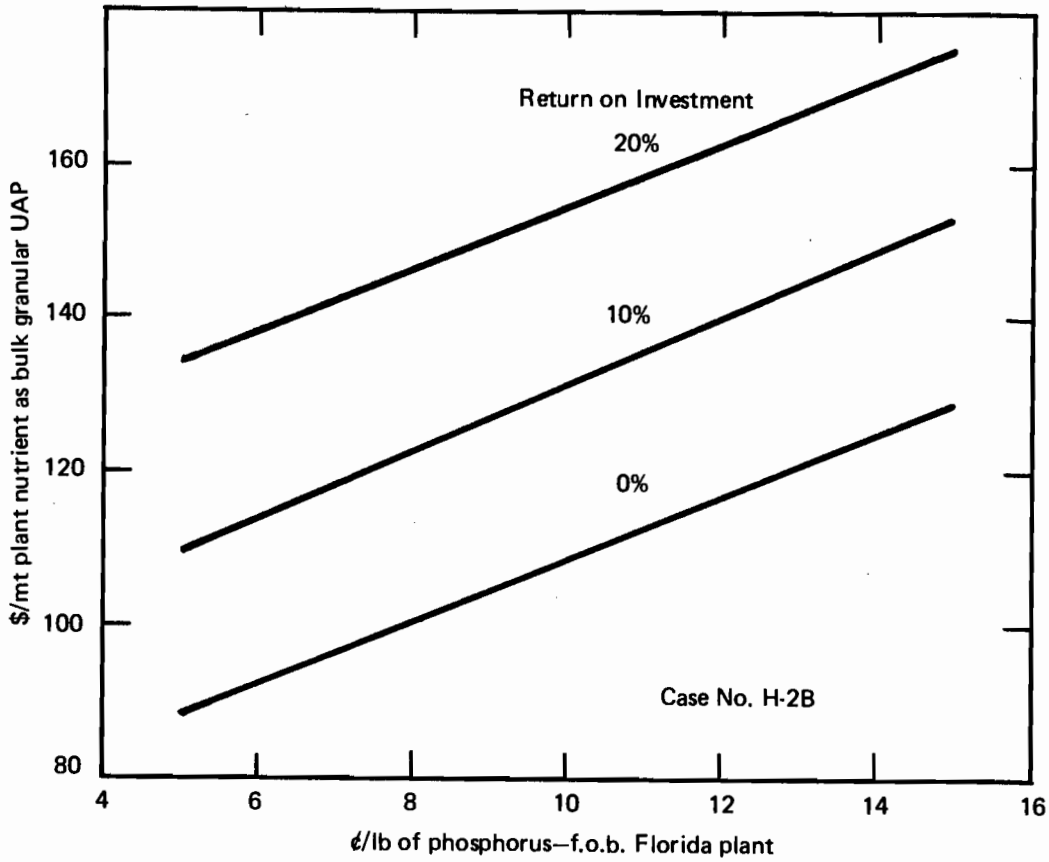

Fig. 12. Effects of Phosphorus Cost on Cost of Urea - Ammonium Phosphate by Melt Process in India

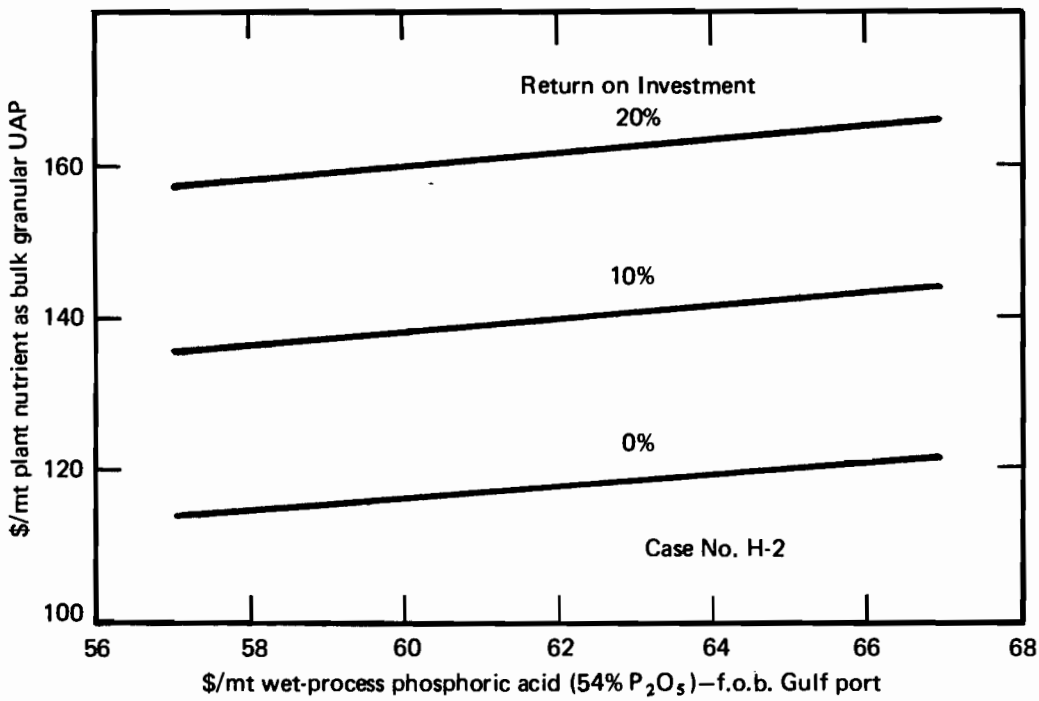

Fig. 13. Effects of Wet-Process Phosphoric Acid (54% P_2O_5) Cost on Cost of Urea - Ammonium Phosphate by Melt Process in India

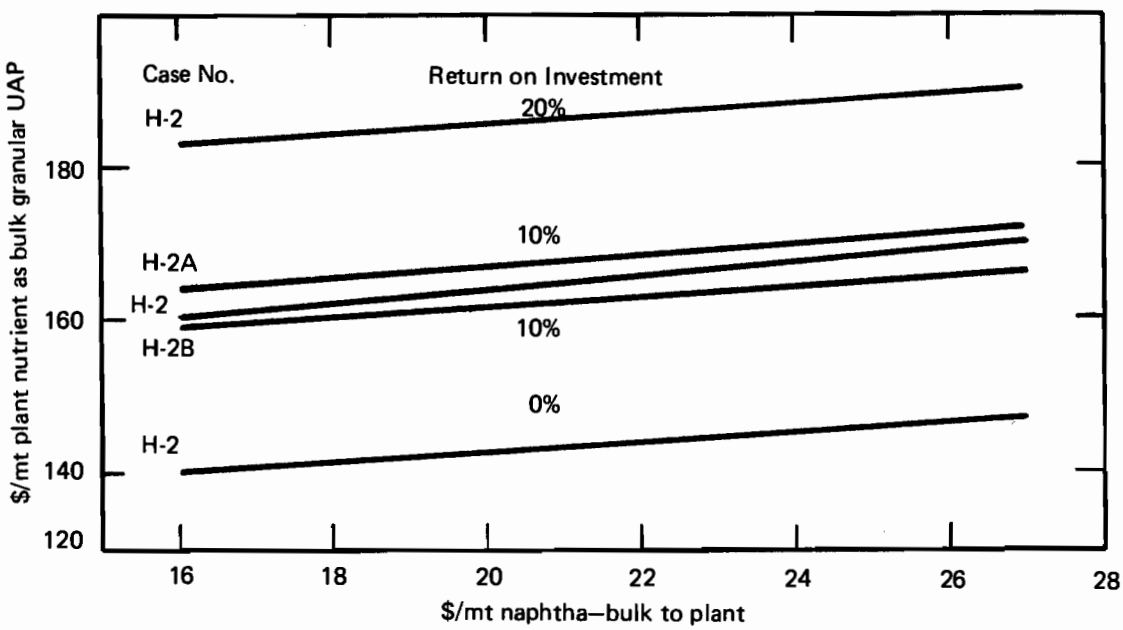

Fig. 14. Effects of Naphtha Cost on Cost of Production of Urea - Ammonium Phosphate by Melt Process in India

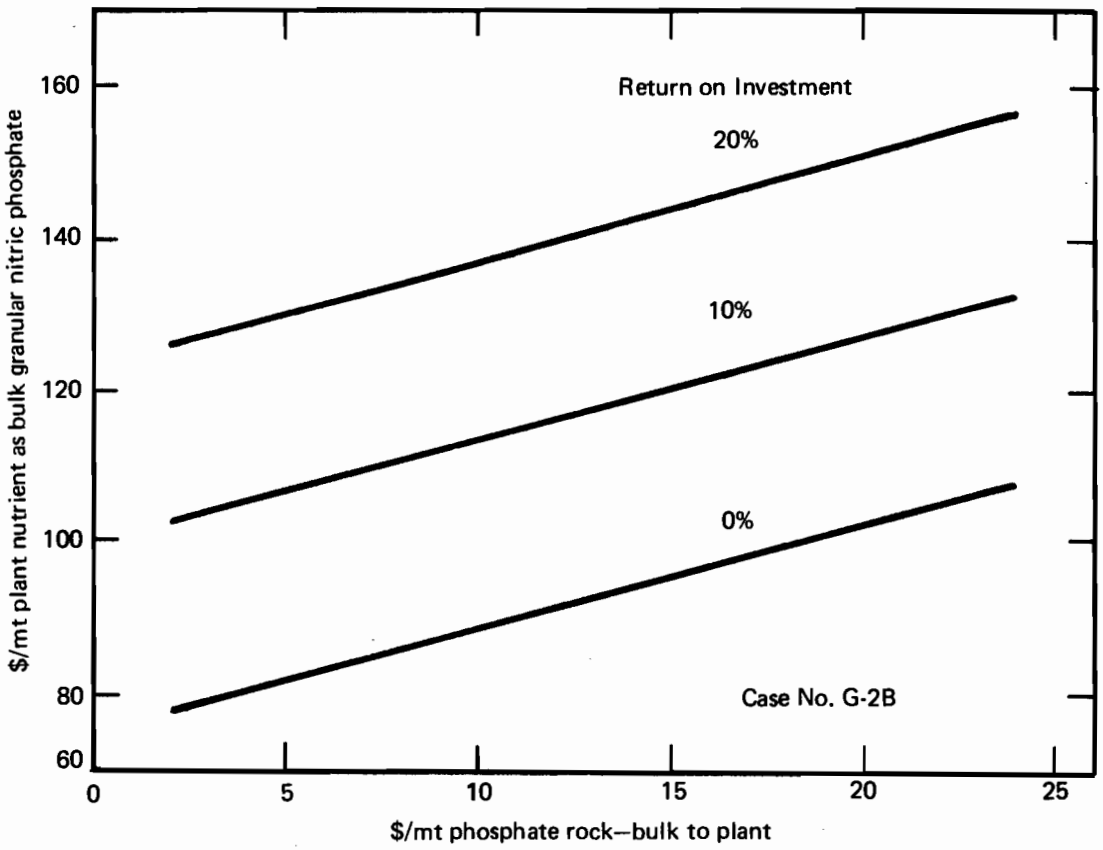

Fig. 15. Effects of Phosphate Rock Cost on Cost of Nitric Phosphate by Sulfate Recycle Process in India

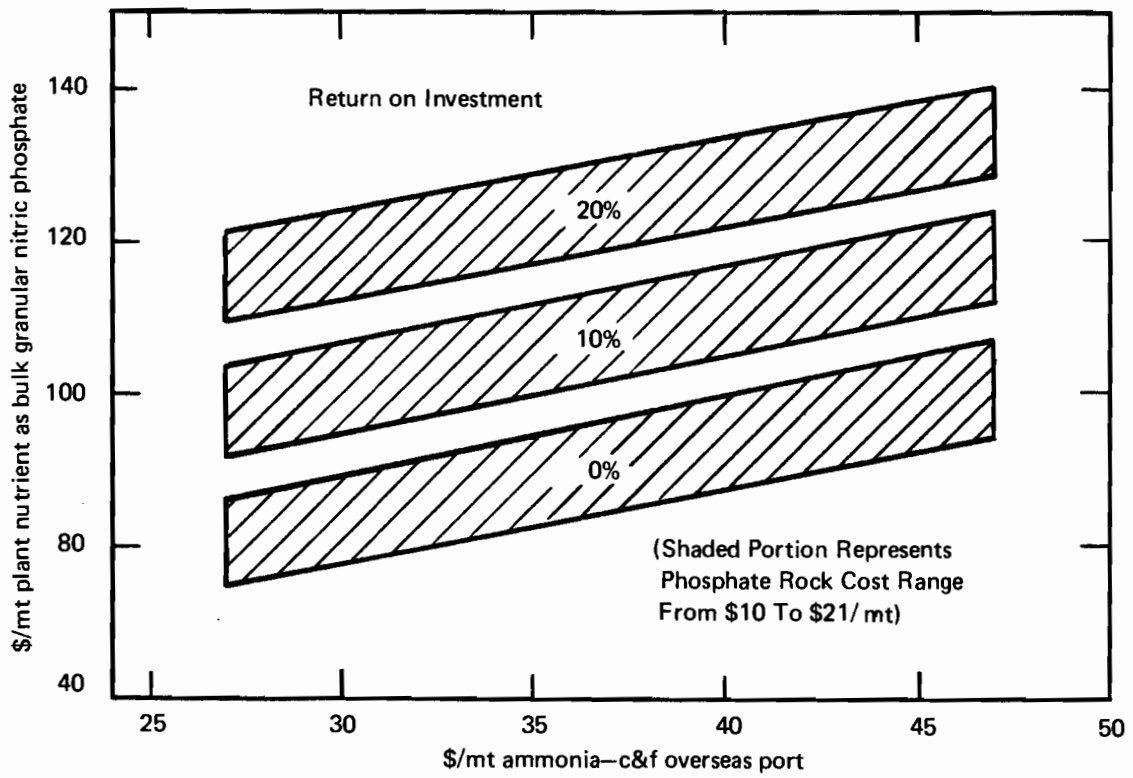

Fig. 16. Effects of Ammonia Cost on Cost of Nitric Phosphate by the Odda Process in India

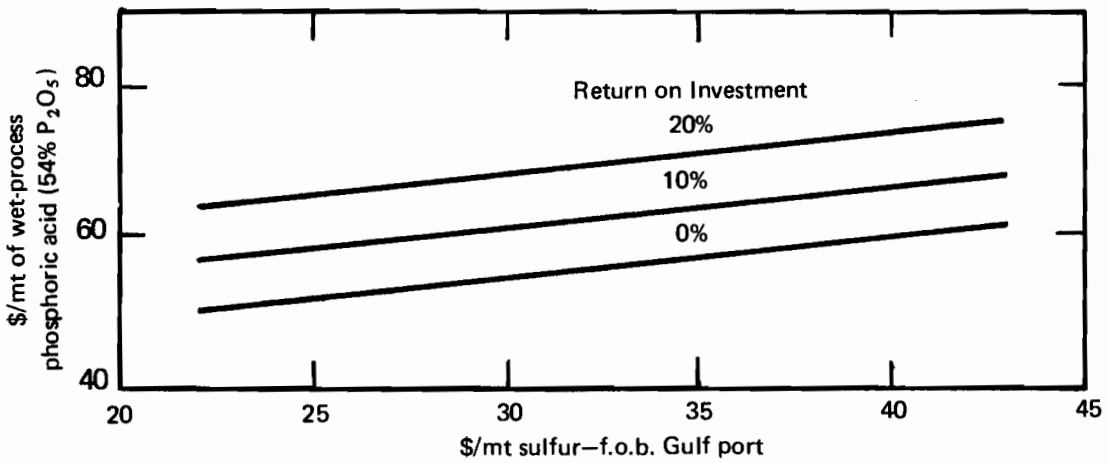

Fig. 17. Effects of Sulfur Cost on Cost of Wet-Process Phosphoric Acid (54% P_2O_5)

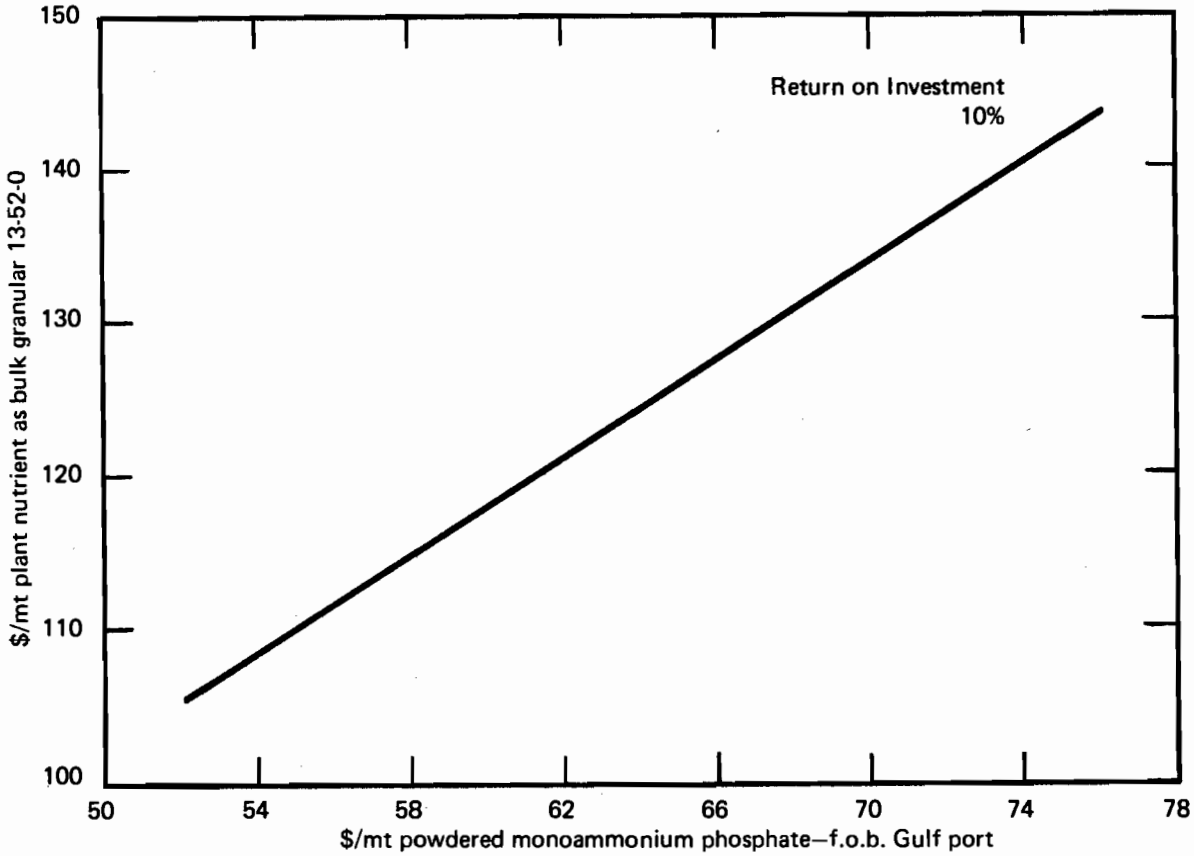

Fig. 18. Effects of Powdered Monoammonium Phosphate Cost on Cost of Granular 13-52-0 Ammonium Phosphate by Conventional Granulation Method in Uruguay

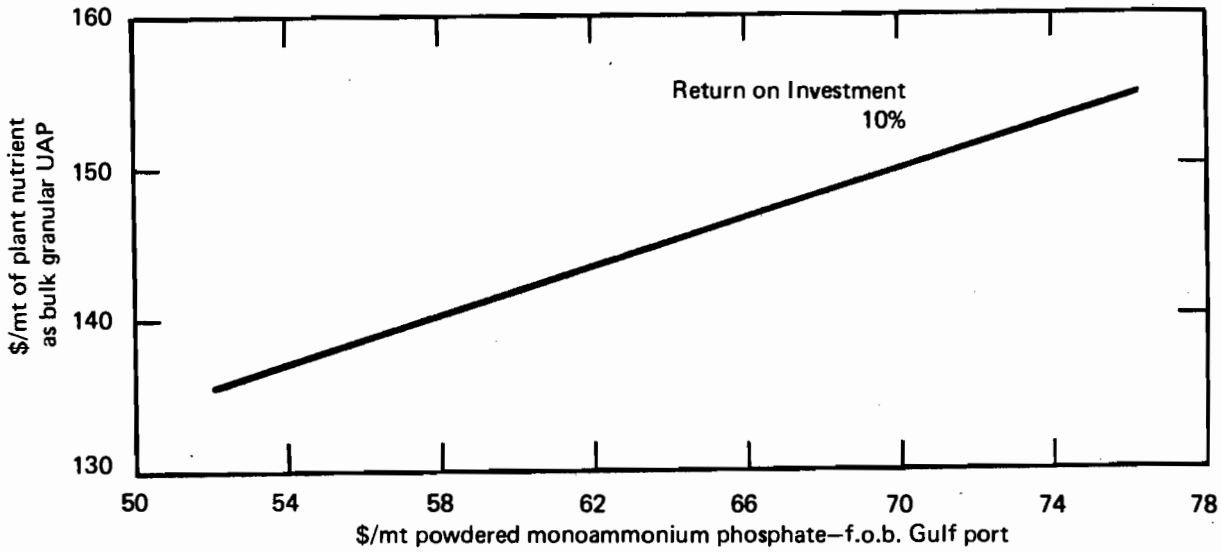

Fig. 19. Effects of Powdered Monoammonium Phosphate Cost on Cost of Urea-Ammonium Phosphate by Conventional Granulation Method in Vietnam

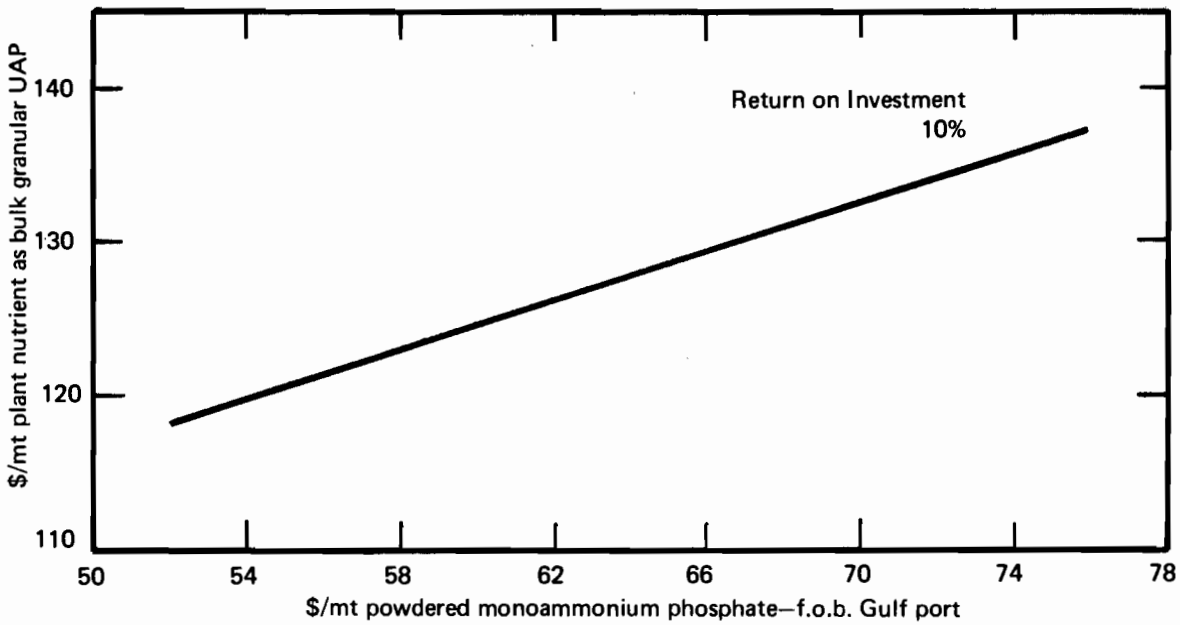

Fig. 20. Effects of Powdered Monoammonium Phosphate Cost on Cost of Urea-Ammonium Phosphate by Conventional Granulation Method in India

Table A. Estimated Costs of Phosphoric Acid, Phosphorus, Sulfur, and Ammonia at Port of Embarkment and Delivered to Uruguay

	Estimated cost, $/mt material				
	Phosphoric acid 54% P_2O_5	Phosphorus	Sulfur 331 ton/day	Sulfur 472 ton/day	Ammonia
Cost f.o.b. vessel at embarkment port	63.65	289.07[a]	35.00	35.00	34.00
Ocean freight	8.00	8.00	7.00	7.00	10.00[b]
	71.65	297.07	42.00	42.00	44.00[c]
Storage and handling at overseas port	1.69	6.11	2.80	2.08	5.61
Total delivered cost to plant, $/mt material	73.34	303.18	44.80	44.08	49.61

[a]Obtained from *Economic Evaluation of Overseas Shipment and Utilization of Phosphoric Acid for Fertilizer Production.*
[b]Estimated ocean freight from Trinidad to Uruguay.
[c]Obtained from *Economic Comparison of Overseas Manufacture and Importation of Anhydrous Ammonia.*

Table B . Estimated Costs of Phosphoric Acid, Phosphorus, Sulfur, and Ammonia at Port of Embarkment and Delivered to South Vietnam

	Estimated cost, $/mt material			
	Phosphoric acid 54% P_2O_5	Phosphorus	Sulfur	Ammonia
Cost f.o.b. vessel at embarkment port	63.65	289.07[a]	35.00	34.00
Ocean freight	14.00	14.00	12.00	11.00[b]
	77.65	303.07	47.00	45.00[c]
Storage and handling at overseas port	2.83	9.78	4.15	4.45
Total delivered cost to plant, $/mt material	80.48	312.85	51.15	49.45

[a]Obtained from *Economic Evaluation of Overseas Shipment and Utilization of Phosphoric Acid for Fertilizer Production.*
[b]Estimated ocean freight from Persian Gulf to Vietnam.
[c]Obtained from *Economic Comparison of Overseas Manufacture and Importation of Anhydrous Ammonia.*

Table C. Estimated Costs of Phosphoric Acid, Phosphorus, Sulfur, and Ammonia at Port of Embarkment and Delivered to India

	Estimated cost, $/mt material			
	Phosphoric acid 54% P_2O_5 1,016 ton/day	Phosphorus	Sulfur	Ammonia
Cost f.o.b. vessel at embarkment port	63.65	289.07[a]	35.00	34.00
Ocean frieght	14.00	14.00	12.00	6.00[b]
	77.65	303.07	47.00	40.00[c]
Storage and handling at overseas port	1.64	5.88	1.86	2.21
Total delivered cost to plant, $/mt material	79.29	308.95	48.86	42.21

[a]Obtained from *Economic Evaluation of Overseas Shipment and Utilization of Phosphoric Acid for Fertilizer Production.*
[b]Estimated freight from Persian Gulf to India.
[c]Obtained from *Economic Comparison of Overseas Manufacture and Importation of Anhydrous Ammonia.*

Table D. Fertilizer Complexes Considered in Uruguay

Basis—150 mt/day of ammonia imported

Case	Quantity or capacity mt/day
N–3: Granular Ammonium Orthophosphate (13-52-0)	
Imports	
Ammonia (123 mt N/day)	150
Sulfur	472[a]
Phosphate rock (72 B.P.L. - 33% P_2O_5; 549 mt P_2O_5/day	1,663[b]
Potassium chloride (60% K_2O)	102 & 205[c]
Manufacturing plants	
Sulfuric acid (100% H_2SO_4)[d]	1,402
Wet-process acid (54% P_2O_5; 492 mt P_2O_5/day)	911
Granular ammonium orthophosphate (13-52-0; 123 mt N/day and 492 mt P_2O_5/day)	946
K–3: Granular Ammonium Polyphosphate (15-60-0)	
Imports	
Ammonia (123 mt N/day)	150
Elemental phosphorus (492 mt P_2O_5/day)	215
Potassium chloride (60% K_2O)	102 & 205[c]
Manufacturing plants	
Thermal acid (76% P_2O_5; 492 mt P_2O_5/day)	647[e]
Granular ammonium polyphosphate (15-60-0; 123 mt N/day and 492 mt P_2O_5/day	820
J–3A: Granular Ammonium Orthophosphate (13-52-0)	
Imports	
Ammonia (123 mt N/day)	150
Wet-process acid (54% P_2O_5; 492 mt P_2O_5/day)	911
Potassium chloride (60% K_2O)	102 & 205[c]
Manufacturing plants	
Granular ammonium orthophosphate (13-52-0; 123 mt N/day and 492 mt P_2O_5/day)	946

Basis—150 mt/day of ammonia imported

Case	Quantity or capacity mt/day
M–3: Prilled Ammonium Nitrate (33.5-0-0) and Granular Triple Superphosphate (0-46-0)[f]	
Imports	
Ammonia (123 mt N/day)	150
Sulfur	331[a]
Phosphate rock (72 B.P.L. - 33% P_2O_5 for wet-process acid; 384 mt P_2O_5/day)	1,163[b]
Phosphate rock (73 B.P.L. - 33.4% P_2O_5 for triple superphosphate; 157 mt P_2O_5/day)	471[g]
Potassium chloride (60% K_2O)	102 & 205[c]
Manufacturing plants	
Nitric acid (100% HNO_3; 62 mt N/day)[h]	277
Prilled ammonium nitrate (35-0-0;[i] 123 mt N/day)	352
Sulfuric acid (100% H_2SO_4)[d]	981
Wet-process acid (54% P_2O_5; 344 mt P_2O_5/day)	637
Granular triple superphosphate (0-46-0; 492 mt P_2O_5/day)	1,070[j]
Bulk blend (8.7-34.6-0)	1,422[k]

[a]Allows for 3% loss of S.
[b]Allows for 11% loss of P_2O_5.
[c]Data are included for importation of potassium chloride at two levels: K_2O = 1/2 N and K_2O = N.
[d]Produced as 93% H_2SO_4.
[e]Two trains at 324 mt/day each.
[f]The two products are manufactured in proportions to give a N:P_2O_5 ratio of 1:4 in the blend; the average grade is 8.7-34.6-0.
[g]Allows for 1% loss of P_2O_5.
[h]Produced as 60% HNO_3.
[i]Produced as 33.5-0-0 grade.
[j]Two trains at 535 mt/day each.
[k]Fourteen trains at 102 mt/day each.

Table E. Fertilizer Complexes Considered in South Vietnam

Basis—400 mt/day of ammonia manufactured

Case	Quantity or capacity mt/day
H–1A: Granular Urea-Ammonium Phosphate (28-28-0 and 34-17-0)[a]	
Imports	
Naphtha	352
Sulfur	210[b]
Phosphate rock (72 B.P.L. - 33% P_2O_5; 244 mt P_2O_5/day)	740[c]
Potassium chloride (60% K_2O)	182 & 365[d]
Manufacturing plants	
Ammonia (329 mt N/day)	400
Urea solution (46.6-0-0;[e] 273 mt N/day)	586
Sulfuric acid (100% H_2SO_4)[f]	624
Wet-process acid (54% P_2O_5; 219 mt P_2O_5/day)	406
Urea-ammonium phosphate (28-28-0 and 34-17-0)[a] granulation (329 mt N/day and 219 mt P_2O_5/day)	1,036[g]
H–1B: Granular Urea-Ammonium Phosphate (28-28-0 and 34-17-0)[a]	
Imports	
Naphtha	352
Elemental phosphorus (219 mt P_2O_5/day)	96
Potassium chloride (60% K_2O)	182 & 365[d]
Manufacturing plants	
Ammonia (329 mt N/day)	400
Urea solution (46.6-0-0,[d] 273 mt N/day)	586
Thermal acid (76% P_2O_5; 219 mt P_2O_5/day)	288
Urea-ammonium phosphate (28-28-0 and 34-17-0)[a] granulation (329 mt N/day and 219 mt P_2O_5/day)	1,036[g]

Basis—400 mt/day of ammonia manufactured

Case	Quantity or capacity mt/day
H–1: Granular Urea-Ammonium Phosphate (28-28-0 and 34-17-0)[a]	
Imports	
Naphtha	352
Wet-process acid (54% P_2O_5; 219 mt P_2O_5/day)	406
Potassium chloride (60% K_2O)	182 & 365[d]
Manufacturing plants	
Ammonia (329 mt N/day)	400
Urea solution (46.6-0-0;[e] 273 mt N/day)	586
Urea-ammonium phosphate (28-28-0 and 34-17-0)[a] granulation (329 mt N/day and 219 mt P_2O_5/day)	1,036[g]
A–1: Prilled Urea (46-0-0) and Granular Diammonium Phosphate (18-46-0)[h]	
Imports	
Naphtha	352
Wet-process acid (54% P_2O_5; 219 mt P_2O_5/day)	406
Potassium chloride (60% K_2O)	182 & 365[d]
Manufacturing plants	
Ammonia (329 mt N/day)	400
Urea prills (46.6-0-0;[i] 243 mt N/day)	521
Diammonium phosphate (18-46-0) granulation (86 mt N/day and 219 mt P_2O_5/day)	476
Urea-ammonium phosphate (28-28-0 and 34-17-0)[a] bulk blend (329 mt N/day and 219 mt P_2O_5/day)	1,036[j]

[a]The two grades are proportioned to give a $N:P_2O_5$ ratio of 3:2; the average grade is 31.7-21.2-0.
[b]Allows for 3% loss of S.
[c]Allows for 11% loss of P_2O_5.
[d]Data are included for importation of potassium chloride at two levels: $K_2O = 1/2\ P_2O_5$ and $K_2O = P_2O_5$.
[e]Prepared as a 98% aqueous solution.
[f]Produced as 93% H_2SO_4.
[g]Two trains at 518 mt/day each.
[h]The two products are manufactured in proportions to give a $N:P_2O_5$ ratio of 3:2 in the blend; the average grade is 31.7-21.2-0.
[i]Prepared as 46-0-0.
[j]Eleven trains at 94 mt/day each.

Table F. Fertilizer Complexes Considered in India

Basis—1,000 mt/day of ammonia

Case	Quantity or capacity mt/day
H–2A: Granular Urea-Ammonium Phosphate (28-28-0 and 34-17-0)[a]	
Feedstock	
Domestic	
Naphtha	880
Imports	
Sulfur	546[b]
Phosphate rock (72 B.P.L. - 33% P_2O_5; 612 mt P_2O_5/day)	1,856[c]
Potassium chloride (60% K_2O)	457 & 915[d]
Manufacturing plants	
Ammonia (823 mt N/day)	1,000
Urea (46.6-0-0)[e] solution (682 mt N/day)	1,464[f]
Sulfuric acid (100% H_2SO_4)[g]	1,620
Wet-process acid (54% P_2O_5; 549 mt P_2O_5/day)	1,017
Granular urea-ammonium phosphate (28-28-0 and 34-17-0;[a] 823 mt N/day and 549 mt P_2O_5/day)	2,594[h]
H–2A: Granular Urea-Ammonium Phosphate (28-28-0 and 34-17-0)[a]	
This case is identical to case H–2A except that domestic Indian phosphate rock is used instead of the imported rock.	
H–2B: Granular Urea-Ammonium Phosphate (28-28-0 and 34-17-0)[a]	
Feedstock	
Domestic	
Naphtha	880
Imports	
Elemental phosphorus (549 mt P_2O_5/day)	240
Potassium chloride (60% K_2O)	457 & 915[d]
Manufacturing plants	
Ammonia (823 mt N/day)	1,000
Urea (46.6-0-0)[e] solution (682 mt N/day)	1,464[f]
Thermal acid (76% P_2O_5; 549 mt P_2O_5/day)	722
Granular urea-ammonium phosphate (28-28-0 and 34-17-0;[a] 823 mt N/day and 549 mt P_2O_5/day)	2,594[h]
H–2: Granular Urea-Ammonium Phosphate (28-28-0 and 34-17-0)[a]	
Feedstock	
Domestic	
Naphtha	880
Imports	
Wet-process acid (54% P_2O_5; 549 mt P_2O_5/day)	1,016
Potassium chloride (60% K_2O)	457 & 915[d]
Manufacturing plants	
Ammonia (823 mt N/day)	1,000
Urea (46.6-0-0)[e] solution (682 mt N/day)	1,464[f]
Granular urea-ammonium phosphate (28-28-0 and 34-17-0;[a] 823 mt N/day and 549 mt P_2O_5/day)	2,594[h]

Basis—1,000 mt/day of ammonia

Case	Quantity or capacity mt/day
G–2B: Granular Nitric Phosphate (28-14-0)–Sulfate Recycle Process[i]	
Feedstock	
Domestic	
Naphtha	880
Gypsum	353
Imports	
Phosphate rock (72 B.P.L. - 33% P_2O_5; 532 mt P_2O_5/day)	1,308[j]
Potassium chloride (60% K_2O)	457 & 915[d]
Manufacturing plants	
Ammonia (823 mt N/day)	1,000
Nitric acid (100% HNO_3;[k] 374 mt N/day)	1,683[l]
Granular nitric phosphate (28-14-0; 823 mt N/day and 411.5 mt P_2O_5/day)	2,939[m]
G–2B–1: Granular Phosphate (28-14-0)–Sulfate Recycle Process[i]	
This case is identical to case G–2B except that domestic Indian phosphate rock is used instead of the imported rock.	
G–2C: Granular Nitric Phosphate (28-14-0)–Odda Process[i]	
Imports	
Ammonia (823 mt N/day)	1,000
Phosphate rock (72 B.P.L. - 33% P_2O_5; 432 mt P_2O_5/day)	1,308[j]
Potassium chloride (60% K_2O)	457 & 915[d]
Manufacturing plants	
Nitric acid (100% HNO_3;[k] 374 mt N/day)	1,683[l]
Granular nitric phosphate (28-14-0; 823 mt N/day and 411.5 mt P_2O_5/day)	2,939[m]
G–2C–1: Granular Nitric Phosphate (28-14-0)–Odda Process[i]	
This case is identical to case G–2C except that domestic Indian phosphate rock is used instead of the imported rock.	

[a] The two grades are proportioned to give a N:P_2O_5 ratio of 3:2; the average grade is 31.7-21.2-0.
[b] Allows for 3% loss of S.
[c] Allows for 11% loss of P_2O_5.
[d] Data are included for importation of potassium chloride at two levels; K_2O = 1/2 P_2O_5 and K_2O = P_2O_5.
[e] Prepared as a 98% aqueous solution.
[f] Two trains at 732 mt/day each.
[g] Produced as 93% H_2SO_4.
[h] Five trains at 519 mt/day each.
[i] These four complexes are based on the natural 2:1 ratio of N:P_2O_5 for nitric phosphate rather than the 3:2 ratio used in the remaining four cases; therefore, the data in these four cases are not directly comparable with those of the four cases based on the 3:2 ratio of N:P_2O_5. The four complexes based on the 2:1 ratio require 137.5 mt/day less of P_2O_5 than do the complexes based on the 3:2 ratio.
[j] Allows for 5% loss of P_2O_5.
[k] Produced as 60% HNO_3.
[l] Two trains at 842 mt/day each.
[m] Two trains at 1,470 mt/day each.

Table G. Summary of Economic Evaluation (Includes 10% return on investment)

Case	Cost, $/mt		Capital requirement for complex, $ million			Foreign currency for Production $/mt		
	Product	Plant nutrient	Fixed capital	Working capital	Total	Fixed capital $ million	Product	Plant nutrient
150 mt/day Ammonia–Uruguay								
N–3: Imported phosphate rock, sulfur, and ammonia to produce granular ammonium orthophosphate (13-52-0)	88.18	135.66	30.5	7.3	37.8	18.7	54.40	83.69
K–3: Imported phosphorus and ammonia to produce granular ammonium polyphosphate (15-60-0)	110.43	147.24	12.8	8.9	21.7	7.4	88.41	117.88
J–3A: Imported wet-process acid (54% P_2O_5) and ammonia to produce granular ammonium orthophosphate (13-52-0)	90.37	139.03	8.1	8.7	16.8	4.6	77.41	119.09
M–3: Imported phosphate rock, sulfur, and ammonia to produce granular triple superphosphate (0-46-0) and prilled ammonium nitrate (33.5-0-0) for blending[a]	65.08	150.30	42.5	7.6	50.1	20.5	35.88	82.86
400 mt/day Ammonia–South Vietnam								
H–1A: Imported phosphate rock and sulfur and manufactured ammonia to produce granular urea-ammonium phosphate (28-28-0 and 34-17-0)[b]	93.55	176.84	54.5	7.4	61.9	33.1	39.42	74.52
H–1B: Imported phosphorus and manufactured ammonia to produce granular urea-ammonium phosphate (28-28-0 and 34-17-0)[b]	85.94	162.46	43.0	7.1	50.1	26.2	42.75	80.81
H–1: Imported wet-process acid (54% P_2O_5) and manufactured ammonia to produce granular urea-ammonium phosphate (28-28-0 and 34-17-0)[b]	85.85	162.29	40.9	7.2	48.1	25.0	43.93	83.04
A–1: Imported wet-process acid (54% P_2O_5 and manufactured ammonia to produce granular diammonium phosphate (18-46-0) and prilled urea (46-0-0) for blending[b]	85.44	161.51	39.5	7.2	46.7	24.2	43.78	82.76
1,000 mt/day Ammonia–India								
H–2A: Imported phosphate rock and sulfur and manufactured ammonia to produce granular urea-ammonium phosphate (28-28-0 and 34-17-0)[b]	78.19	147.81	105.2	16.0	121.2	51.4	34.57	65.35
H–2A–1: Domestic Indian phosphate rock, manufactured ammonia, and imported sulfur to produce granular urea-ammonium phosphate (28-28-0 and 34-17-0)[b]	69.80	131.95	105.2	13.7	118.9	51.4	19.99	37.79
H–2B: Imported phosphorus and manufactured ammonia to produce granular urea-ammonium phosphate (28-28-0 and 34-17-0)[b]	74.58	140.98	86.1	15.9	102.0	41.7	37.83	71.51

Table G (continued)

Case	Cost, $/mt		Capital requirement for complex, $ million			Foreign currency for		
						Fixed capital $ million	Production $/mt	
	Product	Plant nutrient	Fixed capital	Working capital	Total		Product	Plant nutrient
H–2: Imported wet-process acid (54% P_2O_5) and manufactured ammonia to produce granular urea-ammonium phosphate (28-28-0 and 34-17-0)[b]	74.70	141.21	81.2	16.2	97.4	39.3	39.42	74.52
G–2B: Imported phosphate rock and manufactured ammonia to produce nitric phosphate (28-14-0) by sulfate recycle process[c]	52.75	125.60	89.7	11.6	101.3	43.3	18.04	42.95
G–2B–1: Domestic Indian phosphate rock and manufactured ammonia to produce granular nitric phosphate (28-14-0) by sulfate recycle process[c]	47.48	113.15	89.7	10.0	99.7	43.3	8.70	20.71
G–2C: Imported phosphate rock and ammonia to produce nitric phosphate (28-14-0) by Odda process[c]	49.06	116.81	59.7	12.0	71.7	28.2	26.19	62.36
G–2C–1: Domestic Indian phosphate rock and imported ammonia to produce nitric phosphate (28-14-0) by Odda process[c]	43.89	104.50	59.7	10.4	70.1	28.2	16.85	40.12

[a]Proportioned to give 1:4 ratio of $N:P_2O_5$; total plant food 43.3% ($N + P_2O_5$).
[b]Proportioned to give 3:2 ratio of $N:P_2O_5$; total plant food 52.9% ($N + P_2O_5$).
[c]These four complexes are based on the natural 2:1 ratio of $N:P_2O_5$ for nitric phosphate rather than the 3:2 ratio used in the remaining four cases; therefore, the data in these four cases are not directly comparable with those of the four cases based on the 3:2 ratio of $N:P_2O_5$. The four complexes based on the 2:1 ratio require 137.5 mt/day less of P_2O_5 than do the complexes based on the 3:2 ratio.

Table H. Itemized Capital Costs for Complexes, $ million

Country	Uruguay				Vietnam				India				
Case No.	N-3	K-3	J-3A	M-3	H-1A	H-1B	H-1	A-1	H-2A H-2A-1	H-2B	H-2	G-2B G-2B-1	G-2C G-2C-1
Port facilities for raw materials and intermediates[a]	2.0	1.6	1.9	2.0	0.9	0.7	0.9	0.9	0.9	0.6	0.9	–	2.5
Auxiliaries for port facilities	0.5	0.5	0.5	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	–	0.6
Battery limits for manufacturing plants	16.7	5.4	2.4	23.2	32.5	25.4	23.8	23.2	62.7	50.8	47.4	53.2	31.6
Auxiliaries for manufacturing plants	4.1	1.3	0.6	5.8	8.1	6.3	6.0	5.8	15.7	12.7	11.9	13.3	7.9
Fertilizer storage	1.1	1.4	1.1	2.5	1.9	1.8	1.8	1.5	4.6	4.6	4.6	5.2	5.2
Auxiliaries for overall complex	6.1	2.6	1.6	8.5	10.9	8.6	8.2	7.9	21.1	17.2	16.2	18.0	11.9
Total	30.5	12.8	8.1	42.5	54.5	43.0	40.9	39.5	105.2	86.1	81.2	89.7	59.7

[a]The port facilities for handling phosphate rock and potassium chloride are not included in these costs.

Table J. (N-3) Estimated Cost of Granular Ammonium Orthophosphate (13-52-0) Produced from Phosphate Rock, Sulfur, and Ammonia Imported to Uruguay

Basis—150 mt/day ammonia imported and 492 mt/day P_2O_5 manufactured to produce 312,180 mt/yr of granular ammonium orthophosphate: 330 operating days/yr. Estimated plant cost—$30,548,000.

I. Ammonia port (49,500 mt/yr)	*Est. cost*
Facilities plant cost—$1,250,000	*$/mt*
Ammonia (1.00 mt @ $44)	44.00
Labor (0.10 man-hr @ $3.00)	0.30
Maintenance (5% of plant cost)	1.26
Electricity (13.8 kwh @ $0.01)	0.14
Steam (0.265 M lb @ $0.50)	0.13
Supplies (20% of maintenance)	0.25
Insurance and taxes (2% of plant cost)	0.51
Depreciation (6-2/3% of plant cost)	1.68
Overhead (100% of labor)	0.30
Interest (8% of 1/2 plant cost)	1.01
Product loss (0.5% of storage output cost)	0.03
Total production cost	49.61

II. Molten sulfur port (155,760 mt/yr)	*Est. cost*
Facilities plant cost—$1,175,000	*$/mt*
Molten sulfur (1.00 mt @ $35.00)	35.00
Ocean freight (1.00 mt @ $7.00)	7.00
Labor (4 men/yr @ $6,240)	0.16
Maintenance (5% of plant cost)	0.38
Electricity (1 kwh @ $0.01)	0.01
Fuel (5.25 gal @ $0.08)	0.42
Insurance and taxes (2% of plant cost)	0.15
Depreciation (6-2/3% of plant cost)	0.50
Overhead (100% of labor)	0.16
Interest (8% of 1/2 plant cost)	0.30
Total production cost	44.08

III. Sulfuric acid section (463,000 mt/yr)	*Est. cost*
Plant cost—$5,253,000	*$/mt*
Sulfur (0.337 mt @ $44.08)	14.85
Labor (0.034 man-hr @ $3.00)	0.10
Maintenance (5% of plant cost)	0.57
Electricity (30 kwh @ $0.01)	0.30
Water, cooling (24 M gal @ $0.02)	0.48
Water, filtered (0.14 M gal @ $0.10)	0.01
Steam, export (2.2 M lb @ $0.50)	−1.10
Water, boiler feed (1.1 M gal @ $0.40)	0.44
Supplies (20% of maintenance)	0.11
Analyses (20% of labor)	0.02
Insurance and taxes (2% of plant cost)	0.23
Depreciation (6-2/3% of plant cost)	0.76
Overhead (100% of labor)	0.10
Interest (8% of 1/2 plant cost)	0.45
Product loss (1% of production cost)	0.17
Total production cost	17.49

IV. Phosphoric acid section (162,360 mt P_2O_5/yr)	*Est. cost*
Plant cost—$12,615,000	*$/mt*
Sulfuric acid, 100% (2.85 mt @ $17.49)	49.85
Phos. rock, 33% P_2O_5 (3.38 mt @ $12.86)	43.47
Labor (0.26 man-hr @ $3.00)	0.78
Maintenance (5% of plant cost)	3.89
Electricity (330 kwh @ $0.01)	3.30
Water, cooling (5.5 M gal @ $0.02)	0.11
Supplies (20% of maintenance)	0.78
Analyses (20% of labor)	0.16
Insurance and taxes (2% of plant cost)	1.55
Depreciation (6-2/3% of plant cost)	5.18
Overhead (100% of labor)	0.78
Interest (8% of 1/2 plant cost)	3.11
Product loss (1% of production cost)	1.14
Total production cost (per mt of P_2O_5)	114.10
	$61.61/mt of 54% acid

V. Ammonium orthophosphate granulation section (312,180 mt/yr)	*Est. cost*
Plant cost—$4,145,000	*$/mt*
Ammonia (0.158 mt @ $49.61)	7.84
Phos. acid, 54% P_2O_5 (0.963 mt @ $61.61)	59.33
Labor (0.076 man-hr @ $3.00	0.23
Maintenance (5% of plant cost)	0.66
Electricity (20 kwh @ $0.01)	0.20
Water, dilution (0.072 M gal @ $0.10)	0.01
Fuel (3 gal @ $0.08)	0.24
Supplies (20% of maintenance)	0.13
Analyses (20% of labor)	0.05
Handling (4% of operating cost)	0.14
Insurance and taxes (2% of plant cost)	0.27
Depreciation (6-2/3% of plant cost)	0.89
Overhead (100% of labor)	0.23
Interest (8% of 1/2 plant cost)	0.53
Product loss (1% of production cost)	0.71
Total production cost	71.46

VI. Offsites for overall complex	*Est. cost*
Plant cost (25% of chem. plants)—$6,110,000	*$/mt*
Maintenance (5% of offsites cost)	0.98
Supplies (20% of maintenance)	0.20
Insurance and taxes (2% of offsites cost)	0.39
Depreciation (6-2/3% of offsites cost)	1.31
Interest (8% of 1/2 offsites cost)	0.78
Total operating cost	3.66
Cost of granular product	71.46
Total production cost less interest on working capital	75.12
Interest on working capital[a]	0.94
Total production cost including interest on working capital	76.06
Return on total investment[b] (10%)	12.12
Total (bulk product)	88.18
$/mt of plant nutrient[c]	135.66

[a]8% of half of working capital of $7,300,000.
[b]Includes fixed capital of $30,548,000 and working capital of $7,300,000.
[c]13% N and 52% P_2O_5 = 65% total plant food.

Table K. (K-3) Estimated Cost of Granular Ammonium Polyphosphate (15-60-0) Produced from Phosphorus and Ammonia Imported to Uruguay

Basis—150 mt/day ammonia and 492 mt/day P_2O_5 manufactured to produce 270,600 mt/yr of granular ammonium polyphosphate: 330 operating days/yr. Estimated plant cost—$12,793,000.

I. Ammonia port (49,500 mt/yr)	*Est. cost $/mt*
Facilities plant cost—$1,250,000	
Total production cost from Table J	49.61

II. Phosphorus port (70,900 mt/yr)	*Est. cost $/mt*
Facilities plant cost—$818,000	
Phosphorus (1.00 mt @ $289.07)	289.07
Ocean freight (1.00 mt @ $8.00)	8.00
Labor (4 men/yr @ $6,240)	0.35
Maintenance (5% of plant cost)	0.58
Electricity (1 kwh @ $0.01)	0.01
Fuel (2.625 gal @ $0.08)	0.21
Supplies (20% of maintenance)	0.12
Insurance and taxes (2% of plant cost)	0.23
Depreciation (6-2/3% of plant cost)	0.77
Overhead (100% of labor)	0.35
Interest (8% of 1/2 plant cost)	0.46
Product loss (1% of production cost)	3.03
Total production cost	303.18

III. Phosphoric acid (76% P_2O_5) section (213,632 mt/yr)[a]	*Est. cost $/mt*
Plant cost—$4,046,000[a]	
Phosphorus (0.332 mt @ $303.18)	100.66
Labor (0.15 man-hr @ $3.00)	0.45
Maintenance (5% of plant cost)	0.95
Electricity (36 kwh @ $0.01)	0.36
Water, cooling (13.4 M gal @ $0.02)	0.27
Water, filtered (0.07 M gal @ $0.10)	0.01
Sulfuric acid (6.35 lb @ $0.012)	0.08
Air (1.82 M cu ft @ $0.02)	0.04
Supplies (20% of maintenance)	0.19
Analyses (20% of labor)	0.09
Insurance and taxes (2% of plant cost)	0.38
Depreciation (6-2/3% of plant cost)	1.26
Overhead (100% of labor)	0.45
Interest (8% of 1/2 plant cost)	0.76
Product loss (1% of production cost)	1.07
Total production cost	107.02

IV. Ammonium polyphosphate granulation section (270,600 mt/yr)[b]	*Est. cost $/mt*
Plant cost—$4,120,000[b]	
Ammonia (0.182 mt @ $49.61)	9.03
Phos. acid, 76% P_2O_5 (0.79 mt @ $107.02)	84.55
Labor (0.18 man-hr @ $3.00)	0.54
Maintenance (5% of plant cost)	0.76
Electricity (50 kwh @ $0.01)	0.50
Water, cooling (1.46 M gal @ $0.02)	0.03
Supplies (20% of maintenance)	0.15
Analyses (20% of labor)	0.11
Handling (4% of operating cost)	0.19
Insurance and taxes (2% of plant cost)	0.30
Depreciation (6-2/3% of plant cost)	1.02
Overhead (100% of labor)	0.54
Interest (8% of 1/2 plant cost)	0.61
Product loss (1% of production cost)	0.99
Total production cost	99.32

V. Offsites for overall complex	*Est. cost $/mt*
Plant cost (25% of chem. plants)—$2,559,000	
Maintenance (5% of offsites cost)	0.47
Supplies (20% of maintenance)	0.09
Insurance and taxes (2% of offsites cost)	0.19
Depreciation (6-2/3% of offsites cost)	0.63
Interest (8% of 1/2 offsites cost)	0.38
Total operating cost	1.76
Cost of granular product	99.32
Total production cost less interest on working capital	101.08
Interest on working capital[c]	1.32
Total production cost including interest on working capital	102.40
Return on total investment[d] (10%)	8.03
Total (bulk product)	110.43
$/mt of plant nutrient[e]	147.24

[a]Total for two acid plants.
[b]Total for two granulation plants.
[c]8% of half of working capital of $8,923,000.
[d]Includes fixed capital of $12,793,000 and working capital of $8,923,000.
[e]15% N and 60% P_2O_5 = 75% total plant food.

Table L. (J-3A) Estimated Cost of Granular Ammonium Orthophosphate (13-52-0) Produced from Wet-Process Acid (54% P_2O_5) and Ammonia Imported to Uruguay

Basis—150 mt/day ammonia and 492 mt/day of P_2O_5 imported to produce 312,180 mt/yr of granular ammonium orthophosphate: 330 operating days/yr. Estimated plant cost—$8,151,000.

I. Ammonia port (49,500 mt/yr)	*Est. cost $/mt*
Facilities plant cost—$1,250,000	
Total production cost from Table J	49.61

II. Phosphoric acid (54% P_2O_5) port (300,667 mt/yr)	*Est. cost $/mt*
Facilities plant cost—$1,126,000	
Phos. acid, 54% P_2O_5 (1.00 mt @ $63.65)	63.65
Ocean freight (1.00 mt @ $8.00)	8.00
Labor (4 men/yr @ $6,240)	0.08
Maintenance (5% of plant cost)	0.19
Electricity (11 kwh @ $0.01)	0.11
Supplies (20% of maintenance)	0.04
Insurance and taxes (2% of plant cost)	0.08
Depreciation (6-2/3% of plant cost)	0.25
Overhead (100% of labor)	0.08
Interest (8% of 1/2 plant cost)	0.15
Product loss (1% of production cost)	0.73
Total production cost	73.36

III. Ammonium orthophosphate granulation section (312,180 mt/yr)	*Est. cost $/mt*
Plant cost—$4,145,000	
Ammonia (0.158 mt @ $49.61)	7.84
Phos. acid, 54% P_2O_5 (0.963 mt @ $73.36)	70.65
Labor (0.076 man-hr @ $3.00)	0.23
Maintenance (5% of plant cost)	0.66
Electricity (20 kwh @ $0.01)	0.20
Water, dilution (0.072 M gal @ $0.10)	0.01
Fuel (3 gal @ $0.08)	0.24
Supplies (20% of maintenance)	0.13
Analyses (20% of labor)	0.05
Handling (4% of operating cost)	0.14
Insurance and taxes (2% of plant cost)	0.27
Depreciation (6-2/3% of plant cost)	0.89
Overhead (100% of labor)	0.23
Interest (8% of 1/2 plant cost)	0.53
Product loss (1% of production cost)	0.83
Total production cost	82.90

IV. Offsites for overall complex	*Est. cost $/mt*
Plant cost (25% of chem. plants)—$1,630,000	
Maintenance (5% of offsites cost)	0.26
Supplies (20% of maintenance)	0.05
Insurance and taxes (2% of offsites cost)	0.10
Depreciation (6-2/3% of plant cost)	0.35
Interest (8% of 1/2 offsites cost)	0.21
Total operating cost	0.97
Cost of granular product	82.90
Total production cost less interest on working capital	83.87
Interest on working capital[a]	1.11
Total production cost including interest on working capital	84.98
Return on total investment[b] (10%)	5.39
Total (bulk product)	90.37
$/mt of plant nutrient[c]	139.03

[a]8% of half of working capital of $8,674,000.
[b]Includes fixed capital of $8,151,000 and working capital of $8,674,000.
[c]13% N and 52% P_2O_5 = 65% total plant food.

Table M. (M-3) Estimated Cost of Granular Triple Superphosphate (0-46-0) and Prilled Ammonium Nitrate (33.5-0-0) Produced from Phosphate Rock, Sulfur, and Ammonia Imported to Uruguay

Basis—150 mt/day ammonia imported and 492 mt/day of P_2O_5 manufactured to produce 469,260 mt/yr of blend. Estimated plant cost—$42,484,000.

I. Ammonia port	
(49,500 mt/yr)	*Est. cost*
Facilities plant cost—$1,250,000	*$/mt*
Total production cost from Table J	49.61

II. Nitric acid section	
(91,330 mt/yr)	*Est. cost*
Plant cost—$3,981,000	*$/mt*
Ammonia (0.292 mt @ $49.61)	14.49
Catalyst (0.137 mt @ $3.50)	0.48
Labor (0.17 man-hr @ $3.00)	0.51
Maintenance (5% of plant cost)	2.18
Electricity (7.3 kwh @ $0.01)	0.07
Water, cooling (53 M gal @ $0.02)	1.06
Water, boiler feed (0.408 M gal @ $0.40)	0.16
Steam, export (1.23 lb @ $0.50)	−0.62
Air (1.30 M cu ft @ $0.02)	0.03
Supplies (20% of maintenance)	0.44
Analyses (20% of labor)	0.10
Handling (4% of operating cost)	0.42
Insurance and taxes (2% of plant cost)	0.87
Depreciation (6-2/3% of plant cost)	2.91
Overhead (100% of labor)	0.51
Interest (8% of 1/2 plant cost)	1.74
Product loss (1% of production cost)	0.26
Total production cost	25.61

III. Ammonium nitrate prilling plant	
(116,000 mt/yr)	*Est. cost*
Plant cost—$5,269,000	*$/mt*
Nitric acid, 100% (0.765 mt @ $25.61)	19.59
Ammonia (0.208 mt @ $49.61)	10.32
Labor (0.14 man-hr @ $3.00)	0.42
Maintenance (5% of plant cost)	2.27
Electricity (29.7 kwh @ $0.01)	0.30
Water, cooling (3.438 M gal @ $0.02)	0.07
Steam (0.539 M lb @ $0.50)	0.27
Supplies (20% of maintenance)	0.45
Analyses (20% of labor)	0.08
Handling (4% of operating costs)	0.42
Insurance and taxes (2% of plant cost)	0.91
Depreciation (6-2/3% of plant cost)	3.03
Overhead (100% of labor)	0.42
Interest (8% of 1/2 plant cost)	1.82
Product loss (1% of production cost)	0.41
Total production cost	40.78

IV. Molten sulfur port	
(109,230 mt/yr)	*Est. cost*
Facilities plant cost—$1,175,000	*$/mt*
Molten sulfur (1.00 mt @ $35.00)	35.00
Ocean freight (1.00 mt @ $7.00)	7.00
Labor (4 men/yr at $6,240)	0.23
Maintenance (5% of plant cost)	0.54
Electricity (1 kwh @ $0.01)	0.01
Fuel (5.25 gal @ $0.08)	0.42
Insurance and taxes (2% of plant cost)	0.22
Depreciation (6-2/3% of plant cost)	0.72
Overhead (100% of labor)	0.23
Interest (8% of 1/2 plant cost)	0.43
Total production cost	44.80

V. Sulfuric acid section	
(324,000 mt/yr)	*Est. cost*
Plant cost—$4,140,000	*$/mt*
Sulfur (0.337 mt @ $44.80)	15.10
Labor (0.049 man-hr @ $3.00)	0.15
Maintenance (5% of plant cost)	0.64
Electricity (30 kwh @ $0.01)	0.30
Water, cooling (24 M gal @ $0.02)	0.48
Water, filtered (0.14 gal @ $0.10)	0.01
Steam, export (2.2 M lb @ $0.50)	−1.10
Water, boiler feed (1.1 M gal @ $0.40)	0.44
Supplies (20% of maintenance)	0.13
Analyses (20% of labor)	0.03
Insurance and taxes (2% of plant cost)	0.26
Depreciation (6-2/3% of plant cost)	0.85
Overhead (100% of labor)	0.15
Interest (8% of 1/2 plant cost)	0.51
Product loss (1% of production cost)	0.18
Total production cost	18.13

VI. Phosphoric acid section	
(113,520 mt P_2O_5/yr)	*Est. cost*
Plant cost—$10,146,000	*$/mt*
Sulfuric acid, 100% (2.85 mt @ $18.13)	51.67
Phos. rock, 33% P_2O_5 (3.38 mt @ $12.86)	43.47
Labor (0.37 man-hr @ $3.00)	1.11
Maintenance (5% of plant cost)	4.47
Electricity (330 kwh @ $0.01)	3.30
Water, cooling (5.5 M gal @ $0.02)	0.11
Supplies (20% of maintenance)	0.89
Analyses (20% of labor)	0.22
Insurance and taxes (2% of plant cost)	1.79
Depreciation (6-2/3% of plant cost)	5.96
Overhead (100% of labor)	1.11
Interest (8% of 1/2 plant cost)	3.58
Product loss (1% of production cost)	1.19
Total production cost/mt of P_2O_5	118.87
	$64.19/mt of 54% acid

Table M (continued)

VII. Triple superphosphate granulation section (353,100 mt/yr)[a] *Plant cost–$6,828,000*[a]	*Est. cost $/mt*
Phos. rock, 33% P_2O_5 (0.44 mt @ $12.98)	5.71
Phos. acid, 54% P_2O_5 (0.62 mt @ $64.19)	39.80
Labor (0.075 man-hr @ $3.00)	0.23
Maintenance (5% of plant cost)	0.97
Electricity (12 kwh @ $0.01)	0.12
Water, cooling (1.25 M gal @ $0.02)	0.03
Water, dilution (0.07 M gal @ $0.10)	0.01
Steam (0.1 M lb @ $0.50)	0.05
Fuel (3 gal @ $0.08)	0.24
Supplies (20% of maintenance)	0.19
Analyses (20% of labor)	0.05
Insurance and taxes (2% of plant cost)	0.39
Depreciation (6-2/3% of plant cost)	1.29
Overhead (100% of labor)	0.23
Interest (8% of 1/2 plant cost)	0.77
Product loss (1% of production cost)	0.51
Total production cost	50.59

VIII. Blending unit (469,260 mt/yr)[b] *Plant cost–$1,198,000*[b]	*Est. cost $/mt*
Ammonium nitrate, 33.5-0-0 (0.247 mt @ $40.78)	10.07
Triple superphosphate, 0-46-0 (0.753 mt @ $50.59)	38.09
Labor (0.16 man-hr @ $3.00)	0.48
Maintenance (5% of plant cost)	0.13
Electricity (2 kwh @ $0.01)	0.02
Supplies (20% of maintenance)	0.03
Analyses (20% of labor)	0.10
Insurance and taxes (2% of plant cost)	0.05
Depreciation (6-2/3% of plant cost)	0.17
Overhead (100% of labor)	0.48
Interest (8% of 1/2 plant cost)	0.10
Product loss (1% of production cost)	0.50
Total production cost	50.22

IX. Offsites for overall complex Plant cost (25% of chem. plants)–$8,497,000	*Est. cost $/mt*
Maintenance (5% of offsites cost)	0.95
Supplies (20% of maintenance)	0.19
Insurance and taxes (2% of offsites cost)	0.38
Depreciation (6-2/3% of offsites cost)	1.26
Interest (8% of 1/2 offsites cost)	0.76
Total operating cost	3.54
Cost of blend	50.22
Total production cost less interest on working capital	53.76
Interest on working capital[c]	0.65
Total production cost including interest on working capital	54.41
Return on total investment[d] (10%)	10.67
Total (bulk product)	65.08
$/mt of plant nutrient[e]	150.30

[a]Total for two granulation plants.
[b]Total for 14 separate blending units.
[c]8% of half of working capital of $7,577,000.
[d]Includes fixed capital of $42,484,000 and working capital of $7,577,000.
[e]8.7% N, 34.6% P_2O_5 = 43.3% of plant food.

Table N. (H-1A) Estimated Cost of Granular Urea-Ammonium Phosphate Produced from Phosphate Rock and Sulfur Imported to South Vietnam

Basis—400 mt/day ammonia plant and 219 mt/day P_2O_5 manufactured to produce 342,000 mt/yr of urea-ammonium phosphate: 330 operating days/yr. Estimated plant cost—$54,555,000.

I. Ammonia section (132,000 mt/yr)	*Est. cost*
Plant cost—$15,810,000	*$/mt*
Naphtha (0.88 mt @ $19.00)	16.72
Catalyst and chemicals	0.85
Labor (0.30 man-hr @ $3.00)	0.90
Maintenance (5% of plant cost)	5.99
Electricity (750 kwh @ $0.01)	7.50
Water, cooling (65 M gal @ $0.02)	1.30
Water, boiler feed (0.40 M gal @ $0.40)	0.16
Supplies (20% of maintenance)	1.20
Analyses (20% of labor)	0.18
Handling (4% of operating cost)	1.39
Insurance and taxes (2% of plant cost)	2.40
Depreciation (6-2/3% of plant cost)	7.99
Overhead (100% of labor)	0.90
Interest (8% of 1/2 plant cost)	4.79
Product loss (1% of production cost)	0.53
Total production cost	52.80

II. Urea solution section (193,000 mt/yr)	*Est. cost*
Plant cost—$9,856,000	*$/mt*
Ammonia (0.58 mt @ $52.80)	30.62
Carbon dioxide (0.785 mt @ no charge)	—
Labor (0.20 man-hr @ $3.00)	0.60
Maintenance (5% of plant cost)	2.55
Electricity (170 kwh @ $0.01)	1.70
Water, cooling (31.9 M gal @ $0.02)	0.64
Steam (4.29 M lb @ $0.50/M lb)	2.15
Supplies (20% of maintenance)	0.51
Analyses (2% of labor)	0.12
Insurance and taxes (2% of plant cost)	1.02
Depreciation (6-2/3% of plant cost)	3.41
Overhead (100% of labor)	0.60
Interest (8% of 1/2 plant cost)	2.04
Product loss (1% of production cost)	0.46
Total production cost	46.42

III. Molten sulfur port (69,300 mt/yr)	*Est. cost*
Facilities plant cost—$1,175,000	*$/mt*
Molten sulfur (1.00 mt @ $35.00)	35.00
Ocean freight (1.00 mt @ $12.00)	12.00
Labor (4 men/yr @ $6,240)	0.36
Maintenance (5% of plant cost)	0.85
Electricity (1 kwh @ $0.01)	0.01
Fuel (5.25 gal @ $0.08)	0.42
Insurance and taxes (2% of plant cost)	0.34
Depreciation (6-2/3% of plant cost)	1.13
Overhead (100% of labor)	0.36
Interest (8% of 1/2 plant cost)	0.68
Total production cost	51.15

IV. Sulfuric acid section (206,000 mt/yr)	*Est. cost*
Plant cost—$3,080,000	*$/mt*
Sulfur (0.337 mt @ $51.15)	17.24
Labor (0.077 man-hr at $3.00)	0.23
Maintenance (5% of plant cost)	0.75
Electricity (30 kwh @ $0.01)	0.30
Water, cooling (24 M gal @ $0.02)	0.48
Water, treated (0.14 M gal @ $0.10)	0.01
Steam, export (2.2 M lb @ $0.50/M lb)	−1.10
Water, boiler feed (1.1 M gal at $0.40)	0.44
Supplies (20% of maintenance)	0.15
Analyses (20% of labor)	0.05
Insurance and taxes (2% of plant cost)	0.30
Depreciation (6-2/3% of plant cost)	1.00
Overhead (100% of labor)	0.23
Interest (8% of 1/2 plant cost)	0.60
Product loss (1% of production cost)	0.21
Total production cost	20.89

V. Phosphoric acid section (72,270 mt/yr of P_2O_5)	*Est. cost*
Plant cost—$7,770,000	*$/mt*
Sulfuric acid, 100% (2.85 mt @ $20.89)	59.54
Phos. rock, 33% P_2O_5 (3.38 mt @ $21.00)	70.98
Labor (0.55 man-hr @ $3.00)	1.65
Maintenance (5% of plant cost)	5.38
Electricity (330 kwh @ $0.01)	3.30
Water, cooling (5.5 M gal @ $0.02)	0.11
Supplies (20% of maintenance)	1.08
Analyses (20% of labor)	0.33
Insurance and taxes (2% of plant cost)	2.15
Depreciation (6-2/3% of plant cost)	7.17
Overhead (100% of labor)	1.65
Interest (8% of 1/2 plant cost)	4.30
Product loss (1% of production cost)	1.59
Total production cost	159.23
	$85.98 mt of 54% acid

VI. Urea-ammonium phosphate granulation section (342,000 mt/yr)[a]	*Est. cost*
Plant cost—$5,953,000[a]	*$/mt*
Ammonia (0.066 mt @ $52.80)	3.48
Phos. acid, 54% P_2O_5 (0.391 mt @ $85.98)	33.62
Urea solution (0.566 mt @ $46.42)	26.27
Labor (0.14 man-hr @ $3.00)	0.42
Maintenance (5% of plant cost)	0.87
Electricity (20 kwh @ $0.01)	0.20
Supplies (20% of maintenance)	0.17
Analyses (20% of labor)	0.08
Handling (4% of operating cost)	0.18
Insurance and taxes (2% of plant cost)	0.35
Depreciation (6-2/3% of plant cost)	1.16
Overhead (100% of labor)	0.42
Interest (8% of 1/2 plant cost)	0.70
Product loss (1% of production cost)	0.69
Total production cost	68.61

Table N (continued)

VII. Offsites for overall complex	*Est. cost*
Plant cost (25% of chem. plants)–$10,911,000	*$/mt*
Maintenance (5% of offsites cost)	1.60
Supplies (20% of maintenance)	0.32
Insurance and taxes (2% of offsites cost)	0.64
Depreciation (6-2/3% of offsites cost)	2.13
Interest (8% of 1/2 offsites cost)	1.28
Total operating cost	5.97
Cost of granular product	68.61
Total production cost less interest on working capital	74.58
Interest on working capital[b]	0.86
Total production cost including interest on working capital	75.44
Return on total investment[c] (10%)	18.11
Total (bulk product)	93.55
$/mt of plant nutrient[d]	176.84

[a]Total for two granulation plants.
[b]8% of half of working capital of $7,365,000.
[c]Includes fixed capital of $54,555,000 and working capital of $7,365,000.
[d]31.7% N, 21.2% P_2O_5 = 52.9% of plant food.

Table O. (H-1B) Estimated Cost of Granular Urea-Ammonium Phosphate Produced from Phosphorus Imported to South Vietnam

Basis—400 mt/day ammonia plant and 219 mt/day of P_2O_5 imported to produce 342,000 mt/yr of granular urea-ammonium phosphate: 330 operating days/yr.
Estimated plant cost—$43,030,000

I. Ammonia section (132,000 mt/yr)	*Est. cost*
Plant cost—$15,810,000	*$/mt*
Total production cost from Table N	52.80

II. Urea solution section (193,000 mt/yr)	*Est. cost*
Plant cost—$9,856,000	*$/mt*
Total production cost from Table N	46.42

III. Phosphorus port (31,558 mt/yr P_4)	*Est. cost*
Facilities plant cost—$818,000	*$/mt*
Phosphorus (1.00 mt @ $289.07)	289.07
Ocean freight (1.00 mt @ $14.00)	14.00
Labor (4 men/yr @ $6,240)	0.79
Maintenance (5% of plant cost)	1.30
Electricity (1 kwh @ $0.01)	0.01
Fuel (2.625 gal @ $0.08)	0.21
Supplies (20% of maintenance)	0.26
Insurance and taxes (2% of plant cost)	0.52
Depreciation (6-2/3% of plant cost)	1.73
Overhead (100% of labor)	0.79
Interest (8% of 1/2 plant cost)	1.04
Product loss (1% of production cost)	3.13
Total production cost	312.85

IV. Phosphoric acid (76% P_2O_5) section (95,000 mt/yr)	*Est. cost*
Plant cost—$1,987,000	*$/mt*
Phosphorus (0.332 mt @ $312.85)	103.87
Labor (0.17 man-hr @ $3.00)	0.51
Maintenance (5% of plant cost)	1.05
Electricity (36 kwh @ $0.01)	0.36
Water, cooling (13.4 M gal @ $0.02)	0.27
Water, filtered (0.07 M gal @ $0.10)	0.01
Sulfuric acid (6.35 lb @ $0.012)	0.08
Air (1.82 M cu ft @ $0.02)	0.04
Supplies (20% of maintenance)	0.21
Analyses (20% of labor)	0.10
Insurance and taxes (2% of plant cost)	0.42
Depreciation (6-2/3% of plant cost)	1.39
Overhead (100% of labor)	0.51
Interest (8% of 1/2 plant cost)	0.84
Product loss (1% of production cost)	1.11
Total production cost	110.77

V. Urea-ammonium phosphate granulation section (342,000 mt/yr)[a]	*Est. cost*
Plant cost—$5,953,000[a]	*$/mt*
Ammonia (0.066 mt @ $52.80)	3.48
Phos. acid, 76% P_2O_5 (0.278 mt @ $110.77)	30.79
Urea solution, 46.6% N (0.566 mt @ $46.42)	26.27
Labor (0.14 man-hr @ $3.00)	0.42
Maintenance (5% of plant cost)	0.87
Electricity (20 kwh @ $0.01)	0.20
Supplies (20% of maintenance)	0.17
Analyses (20% of labor)	0.08
Handling (4% of operating cost)	0.18
Insurance and taxes (2% of plant cost)	0.35
Depreciation (6-2/3% of plant cost)	1.16
Overhead (100% of labor)	0.42
Interest (8% of 1/2 plant cost)	0.70
Product loss (1% of production cost)	0.66
Total production cost	65.75

VI. Offsites for overall complex	*Est. cost*
Plant cost (25% of chem. plants)—$8,606,000	*$/mt*
Maintenance (5% of offsites cost)	1.26
Supplies (20% of maintenance)	0.25
Insurance and taxes (2% of offsites cost)	0.50
Depreciation (6-2/3% of plant cost)	1.68
Interest (8% of 1/2 offsites cost)	1.01
Total operating cost	4.70
Cost of granular product	65.75
Total production cost less interest on working capital	70.45
Interest on working capital[b]	0.83
Total production cost including interest on working capital	71.28
Return on total investment[c] (10%)	14.66
Total (bulk product)	85.94
$/mt of plant nutrient[d]	162.46

[a]Total for two granulation plants
[b]8% of half of working capital of $7,109,000.
[c]Includes fixed capital of $43,029,000 and working capital of $7,109,000.
[d]31.7% N, 21.2% P_2O_5 = 52.9% plant food.

Table P. (H-1) Estimated Cost of Granular Urea-Ammonium Phosphate Produced from Wet-Process Phosphoric Acid (54% P_2O_5) Imported to South Vietnam

Basis—400 mt/day ammonia plant and 219 mt/day of P_2O_5 imported to produce 342,000 mt/yr of granular urea-ammonium phosphate: 330 operating days/yr.
Estimated plant cost—$40,931,000

I. Ammonia section (132,000 mt/yr)	*Est. cost $/mt*
Plant cost—$15,810,000	
Total production cost from Table N	52.80

II. Urea solution section (193,000 mt/yr)	*Est. cost $/mt*
Plant cost—$9,856,000	
Total production cost from Table N	46.42

III. Phosphoric acid port (134,000 mt/yr, 54% P_2O_5)	*Est. cost $/mt*
Facilities plant cost—$1,126,000	
Phos. acid, 54% P_2O_5 (1.00 mt @ $63.65)	63.65
Ocean freight (1.00 mt @ $14.00)	14.00
Labor (4 men/yr @ $6,240)	0.19
Maintenance (5% of plant cost)	0.42
Electricity (11 kwh @ $0.01)	0.11
Supplies (2% of maintenance)	0.08
Insurance and taxes (2% of plant cost)	0.17
Depreciation (6-2/3% of plant cost)	0.56
Overhead (100% of labor)	0.19
Interest (8% of 1/2 plant cost)	0.33
Product loss (1% of production cost)	0.81
Total production cost	80.51

IV. Urea-ammonium phosphate granulation section (342,000 mt/yr)[a]	*Est. cost $/mt*
Plant cost—$5,953,000[a]	
Ammonia (0.066 mt @ $52.80)	3.48
Phos. acid, 54% P_2O_5 (0.391 mt @ $80.51)	31.48
Urea solution (0.566 mt @ $46.42)	26.27
Labor (0.14 man-hr @ $3.00)	0.42
Maintenance (5% of plant cost)	0.87
Electricity (20 kwh @ $0.01)	0.20
Supplies (20% of maintenance)	0.17
Analyses (20% of labor)	0.08
Handling (4% of operating cost)	0.18
Insurance and taxes (2% of plant cost)	0.35
Depreciation (6-2/3% of plant cost)	1.16
Overhead (100% of labor)	0.42
Interest (8% of 1/2 plant cost)	0.70
Product loss (1% of production cost)	0.66
Total production cost	66.44

V. Offsites for overall complex	*Est. cost $/mt*
Plant cost (25% of chem. plants)—$8,186,000	
Maintenance (5% of offsites cost)	1.20
Supplies (20% of maintenance)	0.24
Insurance and taxes (2% of offsites cost)	0.48
Depreciation (6-2/3% of offsites cost)	1.60
Interest (8% of 1/2 offsites cost)	0.96
Total operating cost	4.48
Cost of granular product	66.44
Total production cost less interest on working capital	70.92
Interest on working capital[b]	0.85
Total production cost including interest on working capital	71.77
Return on total investment[c] (10%)	14.08
Total (bulk product)	85.85
$/mt of plant nutrient[d]	162.29

[a]Total for two granulation plants.
[b]8% of half of working capital of $7,228,000.
[c]Includes fixed capital of $40,931,000 and working capital of $7,228,000.
[d]31.7% N, 21.2% P_2O_5 = 52.9% plant food.

Table Q. (A-1) Estimated Cost of Blended Urea Prills (46-0-0) and Granular Diammonium Phosphate (18-46-0) Produced from Wet-Process Phosphoric Acid (54% P_2O_5) Imported to South Vietnam

Basis—400 mt/day ammonia plant and 219 mt/day P_2O_5 imported to produce 342,000 mt/yr of blends: 330 operating days/yr. Estimated plant cost—$39,475,000.

I. Ammonia section (132,000 mt/yr) Plant cost—$15,810,000	*Est. cost $/mt*
Total production cost from Table N	52.80

II. Urea prills section (172,000 mt/yr) Plant cost—$11,163,000	*Est. cost $/mt*
Ammonia (0.58 mt @ $52.80)	30.62
Carbon dioxide (0.785 mt @ no charge)	–
Labor (0.32 man-hr @ $3.00)	0.96
Maintenance (5% of plant cost)	3.25
Electricity (171 kwh @ $0.01)	1.71
Water, cooling (31.9 M gal @ $0.02)	0.64
Steam (4.29 lb @ $0.50)	2.15
Supplies (20% of maintenance)	0.65
Analyses (20% of labor)	0.19
Handling (4% of operating cost)	0.78
Insurance and taxes (2% of plant cost)	1.30
Depreciation (6-2/3% of plant cost)	4.33
Overhead (100% of labor)	0.96
Interest (8% of 1/2 plant cost)	2.60
Product loss (1% of production cost)	0.51
Total production cost	50.65

III. Phosphoric acid port (134,000 mt/yr, 54% P_2O_5) Facilities plant cost—$1,126,000	*Est. cost $/mt*
Total production cost from Table P	80.51

IV. Diammonium phosphate granulation section (157,000 mt/yr) Plant cost—$2,540,000	*Est. cost $/mt*
Ammonia (0.219 mt @ $52.80)	11.56
Phos. acid, 54% P_2O_5 (0.852 mt @ $80.51)	68.59
Labor (0.151 man-hr @ $3.00)	0.45
Maintenance (5% of plant cost)	0.81
Electricity (20 kwh @ $0.01)	0.20
Fuel (3 gal @ $0.08)	0.24
Water, treated (0.072 M gal @ $0.10)	0.01
Supplies (20% of maintenance)	0.16
Analyses (20% of labor)	0.09
Handling (4% of operating cost)	0.19
Insurance and taxes (2% of plant cost)	0.32
Depreciation (6-2/3% of plant cost)	1.08
Overhead (100% of labor)	0.45
Interest (8% of 1/2 plant cost)	0.65
Product loss (1% of production cost)	0.86
Total production cost	85.66

V. Blending unit (342,000 mt/yr)[a] Plant cost—$941,000[a]	*Est. cost $/mt*
Granular diammonium phosphate, 18-46-0 (0.459 mt @ $85.66)	39.32
Prilled urea, 46-0-0 (0.492 mt @ $50.65)	24.91
Filler (0.048 mt @ no charge)	–
Labor (0.17 man-hr @ $3.00)	0.51
Maintenance (5% of plant cost)	0.14
Electricity (2 kwh @ $0.01)	0.02
Supplies (20% of maintenance)	0.03
Analyses (20% of labor)	0.10
Handling (4% of operating cost)	0.07
Insurance and taxes (2% of plant cost)	0.06
Depreciation (6-2/3% of plant cost)	0.18
Overhead (100% of labor)	0.51
Interest (8% of 1/2 plant cost)	0.11
Product loss (1% of production cost)	0.67
Total production cost	66.63

VI. Offsites for overall complex Plant cost (25% of chem. plants)—$7,895,000	*Est. cost $/mt*
Maintenance (5% of offsites cost)	1.15
Supplies (20% of maintenance)	0.23
Insurance and taxes (2% of offsites cost)	0.46
Depreciation (6-2/3% of offsites cost)	1.54
Interest (8% of 1/2 offsites cost)	0.92
Total operating cost	4.30
Cost of blend	66.63
Total production cost less interest on working capital	70.93
Interest on working capital[b]	0.85
Total production cost including interest on working capital	71.78
Return on total investment[c] (10%)	13.66
Total (bulk product)	85.44
$/mt of plant nutrient[d]	161.51

[a]Total for eleven separate blending units.
[b]8% of half of working capital of $7,227,000.
[c]Includes fixed capital of $39,475,000 and working capital of $7,227,000.
[d]31.7% N, 21.2% P_2O_5 = 52.9% plant food.

Table R. (H-2A) Estimated Cost of Granular Urea-Ammonium Phosphate Produced from Phosphate Rock and Sulfur Imported to India

Basis—1,000 mt/day ammonia plant and 549 mt/day P_2O_5 manufactured to produce 856,000 mt/yr of urea-ammonium phosphate: 330 operating days/yr. Estimated plant cost—$105,235,000.

I. Ammonia section (330,000 mt/yr)	*Est. cost*
Plant cost—$27,110,000	*$/mt*
Naphtha (0.88 mt @ $19.00)	16.72
Catalyst and chemicals	0.85
Labor (0.16 man-hr @ $3.00)	0.48
Maintenance (5% of plant cost)	4.11
Electricity (50 kwh @ $0.01)	0.50
Water, cooling (77 M gal @ $0.02)	1.54
Water, boiler feed (0.53 M gal @ $0.40)	0.21
Supplies (20% of maintenance)	0.82
Analyses (20% of labor)	0.10
Handling (4% of operating cost)	0.78
Insurance and taxes (2% of plant cost)	1.64
Depreciation (6-2/3% of plant cost)	5.50
Overhead (100% of labor)	0.48
Interest (8% of 1/2 plant cost)	3.29
Product loss (1% of production cost)	0.37
Total production cost	37.39

II. Urea solution section (483,000 mt/yr)[a]	*Est. cost*
Plant cost—$21,870,000[a]	*$/mt*
Ammonia (0.58 mt @ $37.39)	21.69
Carbon dioxide (0.785 mt @ no charge)	–
Labor (0.16 man-hr @ $3.00)	0.48
Maintenance (5% of plant cost)	2.26
Electricity (170 kwh @ $0.01)	1.70
Water, cooling (31.9 M gal @ $0.02)	0.64
Steam (4.290 M lb @ $0.50)	2.15
Supplies (20% of maintenance)	0.45
Analyses (20% of labor)	0.10
Insurance and taxes (2% of plant cost)	0.90
Depreciation (6-2/3% of plant cost)	3.02
Overhead (100% of labor)	0.48
Interest (8% of 1/2 plant cost)	1.81
Product loss (1% of production cost)	0.36
Total production cost	36.04

III. Molten sulfur port (180,180 mt/yr)	*Est. cost*
Facilities plant cost—$1,175,000	*$/mt*
Molten sulfur (1.00 mt @ $35.00)	35.00
Ocean freight (1.00 mt @ $12.00)	12.00
Labor (4 men/yr @ $6,240)	0.14
Maintenance (5% of plant cost)	0.33
Electricity (1 kwh @ $0.01)	0.01
Fuel (5.25 gal @ $0.08)	0.42
Insurance and taxes (2% of plant cost)	0.13
Depreciation (6-2/3% of plant cost)	0.43
Overhead (100% of labor)	0.14
Interest (8% of 1/2 plant cost)	0.26
Total production cost	48.86

IV. Sulfuric acid section (534,600 mt/yr)	*Est. cost*
Plant cost—$5,740,000	*$/mt*
Sulfur (0.337 mt @ $48.86)	16.47
Labor (0.03 man-hr @ $3.00)	0.09
Maintenance (5% of plant cost)	0.54
Electricity (30 kwh @ $0.01)	0.30
Water, cooling (24 M gal @ $0.02)	0.48
Water, filtered (0.14 M gal @ $0.10)	0.01
Steam, export (2.2 M lb @ $0.50)	–1.10
Water, boiler feed (1.1 M gal @ $0.40)	0.44
Supplies (20% of maintenance)	0.11
Analyses (20% of labor)	0.02
Insurance and taxes (2% of plant cost)	0.21
Depreciation (6-2/3% of plant cost)	0.72
Overhead (100% of labor)	0.09
Interest (8% of 1/2 plant cost)	0.43
Product loss (1% of production cost)	0.19
Total production cost	19.00

V. Phosphoric acid section ($181,060$ mt/yr of P_2O_5)	*Est. cost*
Plant cost—$13,433,000	*$/mt*
Sulfuric acid, 100% (2.85 mt @ $19.00)	54.15
Phos. rock, 33% P_2O_5 (3.38 mt @ $21.00)	70.98
Labor (0.23 man-hr @ $3.00)	0.69
Maintenance (5% of plant cost)	3.70
Electricity (330 kwh @ $0.01)	3.30
Water, cooling (5.5 M gal @ $0.02)	0.11
Supplies (20% of maintenance)	0.74
Analyses (20% of labor)	0.14
Insurance and taxes (2% of plant cost)	1.48
Depreciation (6-2/3% of plant cost)	4.95
Overhead (100% of labor)	0.69
Interest (8% of 1/2 plant cost)	2.97
Product loss (1% of production cost)	1.45
Total production cost/mt of P_2O_5	145.35
	$78.49/mt of 54% acid

VI. Urea-ammonium phosphate granulation section (856,000 mt/yr)[b]	*Est. cost*
Plant cost—$14,860,000[b]	*$/mt*
Ammonia (0.066 mt @ $37.39)	2.47
Phos. acid 54% P_2O_5 (0.391 mt @ $78.49)	30.69
Urea solution (0.566 mt @ $36.04)	20.40
Labor (0.14 man-hr @ $3.00)	0.42
Maintenance (5% of plant cost)	0.87
Electricity (20 kwh @ $0.01)	0.20
Supplies (20% of maintenance)	0.17
Analyses (20% of labor)	0.08
Handling (4% of operating cost)	0.18
Insurance and taxes (2% of plant cost)	0.35
Depreciation (6-2/3% of plant cost)	1.16
Overhead (100% of labor)	0.42
Interest (8% of 1/2 plant cost)	0.69
Product loss (1% of production cost)	0.59
Total production cost	58.69

Table R (continued)

VII. Offsites for overall complex	*Est. cost*
Plant cost (25% of chem. plants)–$21,047,000	*$/mt*
Maintenance (5% of offsites cost)	1.23
Supplies (20% of maintenance)	0.25
Insurance and taxes (2% of offsites cost)	0.49
Depreciation (6-2/3% of offsites cost)	1.64
Interest (8% of 1/2 offsites cost)	0.98
Total operating cost	4.59
Cost of granular product	58.69
Total production cost less interest on working capital	63.28
Interest on working capital[c]	0.75
Total production cost including interest on working capital	64.03
Return on total investment[d] (10%)	14.16
Total (bulk product)	78.19
$/mt of plant nutrient[e]	147.81

[a]Total for two urea solution plants.
[b]Total for five granulation plants.
[c]8% of half of working capital of $15,987,000.
[d]Includes fixed capital of $105,235,000 and working capital of $15,987,000.
[e]31.7% N and 21.2% P_2O_5 = 52.9% plant food.

Table S. (H-2A-1) Estimated Cost of Granular Urea-Ammonium Phosphate Produced from Domestic Indian Phosphate Rock and Imported Sulfur

Basis—1,000 mt/day ammonia plant and 549 mt/day P_2O_5 manufactured to produce 856 000 mt/yr of urea-ammonium phosphate: 330 operating days/yr. Estimated plant cost—$105,235,000.

I. Ammonia section (330,000 mt/yr)	*Est. cost $/mt*
Plant cost—$27,110,000	
Total production cost from Table R	37.39

II. Urea solution section (483,000 mt/yr)[a]	*Est. cost $/mt*
Plant cost—$21,870,000[a]	
Total production cost from Table R	36.04

III. Molten sulfur port (180,180 mt/yr)	*Est. cost $/mt*
Facilities plant cost—$1,175,000	
Total production cost from Table R	48.86

IV. Sulfuric acid section (534,600 mt/yr)	*Est. cost $/mt*
Plant cost—$5,740,000	
Total production cost from Table R	19.00

V. Phosphoric acid section (181,060 mt/yr of P_2O_5)	*Est. cost $/mt*
Plant cost—$13,433,000	
Sulfuric acid, 100% (285 mt @ $19.00)	54.15
Phos. rock, 33% P_2O_5 (3.38 mt @ $10.00)	33.80
Labor (0.23 man-hr @ $3.00)	0.69
Maintenance (5% of plant cost)	3.70
Electricity (330 kwh @ $0.01)	3.30
Water, cooling (5.5 M gal @ $0.02)	0.11
Supplies (20% of maintenance)	0.74
Analyses (20% of labor)	0.14
Insurance and taxes (2% of plant cost)	1.48
Depreciation (6-2/3% of plant cost)	4.95
Overhead (100% of labor)	0.69
Interest (8% of 1/2 plant cost)	2.97
Product loss (1% of production cost)	1.08
Total production cost/mt of P_2O_5	107.80
	$58.21/mt of 54% acid

VI. Urea-ammonium phosphate granulation section (856,000 mt/yr)[b]	*Est. cost $/mt*
Plant cost—$14,860,000[b]	
Ammonia (0.066 mt @ $37.39)	2.47
Phos. acid, 54% P_2O_5 (0.391 mt @ $58.21)	22.76
Urea solution (0.566 mt @ $36.04)	20.40
Labor (0.14 man-hr @ $3.00)	0.42
Maintenance (5% of plant cost)	0.87
Electricity (20 kwh @ $0.01)	0.20
Supplies (20% of maintenance)	0.17
Analyses (20% of labor)	0.08
Handling (4% of operating cost)	0.18
Insurance and taxes (2% of plant cost)	0.35
Depreciation (6-2/3% of plant cost)	1.16
Overhead (100% of labor)	0.42
Interest (8% of 1/2 plant cost)	0.69
Product loss (1% of production cost)	0.51
Total production cost	50.68

VII. Offsites for overall complex	*Est. cost $/mt*
Plant cost (25% of chem. plants)—$21,047,000	
Maintenance (5% of offsites cost)	1.23
Supplies (20% of maintenance)	0.25
Insurance and taxes (2% of offsites cost)	0.49
Depreciation (6-2/3% of offsites cost)	1.64
Interest (8% of 1/2 offsites cost)	0.98
Total operating cost	4.59
Cost of granular product	50.68
Total production cost less interest on working capital	55.27
Interest on working capital[c]	0.64
Total production cost including interest on working capital	55.91
Return on total investment[d] (10%)	13.89
Total (bulk product)	69.80
$/mt of plant nutrient[e]	131.95

[a]Total for two urea solution plants.
[b]Total for five granulation plants.
[c]8% of half of working capital of $13,689,000.
[d]Includes fixed capital of $105,235,000 and working capital of $13,689,000.
[e]31.7% N and 21.2% P_2O_5 = 52.9% plant food.

Table T. (H-2B) Estimated Cost of Granular Urea-Ammonium Phosphate Produced from Phosphate Imported to India

Basis—1,000 mt/day ammonia plant and 549 mt/day of P_2O_5 imported to produce 856,000 mt/yr of urea-ammonium phosphate: 330 operating days/yr. Estimated plant cost—$86,066,000.

I. Ammonia section (330,000 mt/yr)	*Est. cost $/mt*
Plant cost—$27,110,000	
Total production cost from Table R	37.39

II. Urea solution section (483,000 mt/yr)[a]	*Est. cost $/mt*
Plant cost—$21,870,000[a]	
Total production cost from Table R	36.04

III. Phosphorus port (79,066 mt/yr)	*Est. cost $/mt*
Facilities plant cost—$820,000	
Phosphorus (1.00 mt @ $289.07)	289.07
Ocean freight (1.00 mt @ $14.00)	14.00
Labor (4 men/yr @ $6,240)	0.32
Maintenance (5% of plant cost)	0.52
Electricity (1 kwh @ $0.01)	0.01
Fuel (2.625 gal @ $0.08)	0.21
Supplies (20% of maintenance)	0.10
Insurance and taxes (2% of plant cost)	0.21
Depreciation (6-2/3% of plant cost)	0.69
Overhead (100% of labor)	0.32
Interest (8% of 1/2 plant cost)	0.41
Product loss (1% of production cost)	3.09
Total production cost	308.95

IV. Phosphoric acid (76% P_2O_5) section (238,236 mt/yr)[b]	*Est. cost $/mt*
Plant cost—$4,193,000[b]	
Phosphorus (0.332 mt @ $308.95)	102.57
Labor (0.13 man-hr @ $3.00)	0.39
Maintenance (5% of plant cost)	0.88
Electricity (36 kwh @ $0.01)	0.36
Water, cooling (13.4 M gal @ $0.02)	0.27
Water, filtered (0.07 M gal @ $0.10)	0.01
Sulfuric acid (6.35 lb @ $0.012)	0.08
Air (1.82 M cu ft @ $0.02)	0.04
Supplies (20% of maintenance)	0.18
Analyses (20% of labor)	0.08
Insurance and taxes (2% of plant cost)	0.35
Depreciation (6-2/3% of plant cost)	1.17
Overhead (100% of labor)	0.39
Interest (8% of 1/2 plant cost)	0.70
Product loss (1% of production cost)	1.09
Total production cost	108.56

V. Urea-ammonium phosphate granulation section (856,000 mt/yr)[c]	*Est. cost $/mt*
Plant cost—$14,860,000[c]	
Ammonia (0.066 mt @ $37.39)	2.47
Phos. acid, 76% P_2O_5 (0.278 mt @ $108.56)	30.18
Urea solution, 46.6% N (0.566 mt @ $36.04)	20.40
Labor (0.14 man-hr @ $3.00)	0.42
Maintenance (5% of plant cost)	0.87
Electricity (20 kwh @ $0.01)	0.20
Supplies (20% of maintenance)	0.17
Analyses (20% of labor)	0.08
Handling (4% of operating cost)	0.18
Insurance and taxes (2% of plant cost)	0.35
Depreciation (6-2/3% of plant cost)	1.16
Overhead (100% of labor)	0.42
Interest (8% of 1/2 plant cost)	0.69
Product loss (1% of production cost)	0.58
Total production cost	58.17

VI. Offsites for overall complex	*Est. cost $/mt*
Plant cost (25% of chem. plants)—$17,213,000	
Maintenance (5% of offsites cost)	1.01
Supplies (20% of maintenance)	0.20
Insurance and taxes (2% of offsites cost)	0.40
Depreciation (6-2/3% of offsites cost)	1.34
Interest (8% of 1/2 offsites cost)	0.80
Total operating cost	3.75
Cost of granular product	58.17
Total production cost less interest on working capital	61.92
Interest on working capital[d]	0.74
Total production cost including interest on working capital	62.66
Return on total investment[e] (10%)	11.92
Total (bulk product)	74.58
$/mt of plant nutrient[f]	140.98

[a]Total for two urea solution plants.
[b]Total for two acid plants using 11,000 lb P_4/hr, each.
[c]Total for five granulation plants.
[d]8% of half of working capital of $15,929,000.
[e]Includes fixed capital of $86,066,000 and working capital of $15,929,000.
[f]31.7% N, 21.2% P_2O_5 = 52.9% of plant food.

Table U. (H-2) Estimated Cost of Granular Urea-Ammonium Phosphate Produced from Wet-Process Phosphoric Acid (54% P_2O_5) Imported to India

Basis—1,000 mt/day ammonia plant and 549 mt/day of P_2O_5 imported to produce 856,000 mt/yr of urea-ammonium phosphate: 330 operating days/yr. Estimated plant cost—$81,208,000.

I. Ammonia section (330,000 mt/yr)	*Est. cost $/mt*
Plant cost—$27,110,000	
Total production cost from Table R	37.39

II. Urea solution section (483,000 mt/yr)[a]	*Est. cost $/mt*
Plant cost—$21,870,000[a]	
Total production cost from Table R	36.04

III. Phosphoric acid port (335,000 mt/yr, 54% P_2O_5)	*Est. cost $/mt*
Facilities plant cost—$1,126,000	
Phos. acid, 54% P_2O_5 (1.00 mt @ $63.65)	63.65
Ocean freight (1.00 mt @ $14.00)	14.00
Labor (4 men/yr @ $6,240)	0.07
Maintenance (5% of plant cost)	0.17
Electricity (11 kwh @ $0.01)	0.11
Supplies (20% of maintenance)	0.03
Insurance and taxes (2% of plant cost)	0.07
Depreciation (6-2/3% of plant cost)	0.22
Overhead (100% of labor)	0.07
Interest (8% of 1/2 plant cost)	0.13
Product loss (1% of production cost)	0.79
Total production cost	79.31

IV. Urea-ammonium phosphate granulation section (856,000 mt/yr)[b]	*Est. cost $/mt*
Plant cost—$14,860,000[b]	
Ammonia (0.066 mt @ $37.39)	2.47
Phos. acid, 54% P_2O_5 (0.391 mt @ $79.31)	31.01
Urea solution, 46.6% N (0.566 mt @ $36.04)	20.40
Labor (0.14 man-hr @ $3.00)	0.42
Maintenance (5% of plant cost)	0.87
Electricity (20 kwh @ $0.01)	0.20
Supplies (20% of maintenance)	0.17
Analyses (20% of labor)	0.08
Handling (4% of operating cost)	0.18
Insurance and taxes (2% of plant cost)	0.35
Depreciation (6-2/3% of plant cost)	1.16
Overhead (100% of labor)	0.42
Interest (8% of 1/2 plant cost)	0.69
Product loss (1% of production cost)	0.59
Total production cost	59.01

V. Offsites for overall complex	*Est. cost $/mt*
Plant cost (25% of chem. plants)—$16,242,000	
Maintenance (5% of offsites cost)	0.95
Supplies (20% of maintenance)	0.19
Insurance and taxes (2% of offsites cost)	0.38
Depreciation (6-2/3% of offsites cost)	1.27
Interest (8% of 1/2 offsites cost)	0.76
Total operating cost	3.55
Cost of granular product	59.01
Total production cost less interest on working capital	62.56
Interest on working capital[c]	0.76
Total production cost including interest on working capital	63.32
Return on total investment[d] (10%)	11.38
Total (bulk product)	74.70
$/mt of plant nutrient[e]	141.21

[a]Total for two urea solution plants.
[b]Total for five granulation plants.
[c]8% of half of working capital of $16,244,000.
[d]Includes fixed capital of $81,208,000 and working capital of $16,244,000.
[e]31.7% N, 21.2% P_2O_5 = 52.9% plant food.

Table V. (G-2B) Estimated Cost of Prilled Nitric Phosphate (28-14-0) Produced by the Sulfate Recycle Process from Phosphate Rock Imported to India

Basis—1,000 mt/day ammonia plant and 411.5 mt/day P_2O_5 imported to produce 969,960 mt/yr of nitric phosphate: 330 operating days/yr. Estimated plant cost—$89,696,000.

I. Ammonia section (330,000 mt/yr)	*Est. cost*
Plant cost—$27,110,000	*$/mt*
Total production cost from Table R	37.39

II. Nitric acid section (555,000 mt/yr)[a]	*Est. cost*
Plant cost—$13,000,000[a]	*$/mt*
Ammonia (0.292 mt @ $37.39)	10.92
Catalyst (0.137 mt @ $3.50)	0.48
Labor (0.0856 man-hr @ $3.00)	0.26
Maintenance (5% of plant cost)	1.17
Electricity (7.3 kwh @ $0.01)	0.07
Water, cooling (53 M gal @ $0.02)	1.06
Water, boiler feed (0.408 M gal @ $0.40)	0.16
Steam, export (1.23 M lb @ $0.50)	−0.62
Air (1.3 M cu ft @ $0.02)	0.03
Supplies (20% of maintenance)	0.23
Analyses (20% of labor)	0.05
Handling (4% of operating cost)	0.24
Insurance and taxes (2% of plant cost)	0.47
Depreciation (6-2/3% of plant cost)	1.56
Overhead (100% of labor)	0.26
Interest (8% of 1/2 plant cost)	0.94
Product loss (1% of production cost)	0.17
Total production cost	17.45

III. Nitric phosphate (28-14-0) prilling section (970,000 mt/yr)[b]	*Est. cost*
Plant cost—$31,647,000[b]	*$/mt*
Phos. rock, 33% P_2O_5 (0.445 mt @ $21.00)	9.34
Ammonia (0.200 mt @ $37.39)	7.48
Nitric acid, 100% (0.580 mt @ $17.45)	10.12
Gypsum, makeup (0.120 mt @ $8.40)	1.01
Carbon dioxide (0.196 mt @ no charge	—
Labor (0.217 man-hr @ $3.00	0.65
Maintenance (5% of plant cost)	1.63
Electricity (70 kwh @ $0.01)	0.70
Water, cooling (8 M gal @ $0.02)	0.16
Water, filtered (1 M gal @ $0.07)	0.07
Steam (2.40 M lb at $0.50)	1.20
Supplies (20% of maintenance)	0.33
Analyses (20% of labor)	
Handling (4% of operating cost)	0.40
Insurance and taxes (2% of plant cost)	0.65
Depreciation (6-2/3% of plant cost)	2.18
Overhead (100% of labor)	0.65
Interest (8% of 1/2 plant cost)	1.31
Product loss (1% of production cost)	0.38
Total production cost	38.39

IV. Offsites for overall complex	*Est. cost*
Plant cost (25% of chem. plants) $17,939,000	*$/mt*
Maintenance (5% of offsites cost)	0.92
Supplies (20% of maintenance)	0.18
Insurance and taxes (2% of offsites cost)	0.37
Depreciation (6-2/3% of offsites cost)	1.23
Interest (8% of 1/2 offsites cost)	0.74
Total operating cost	3.44
Cost of prilled product	38.39
Total production cost less interest on working capital	41.83
Interest on working capital[c]	0.48
Total production cost including interest on working capital	42.31
Return on total investment[d] (10%)	10.44
Total (bulk product)	52.75
$/mt of plant nutrient[e]	125.60

[a]Total for two nitric acid plants.
[b]Total for two prilling plants.
[c]8% of half of working capital of $11,599,000.
[d]Includes fixed capital of $89,696,000 and working capital of $11,599,000.
[e]28% N, 14% P_2O_5 = 42% plant food.

Table W. (G-2B-1) Estimated Cost of Prilled Nitric Phosphate (28-14-0) Produced by Sulfate Recycle Process from Domestic Indian Phosphate Rock

Basis—1,000 mt/day ammonia plant and 411.5 mt/day P_2O_5 to produce 970,000 mt/yr of nitric phosphate: 330 operating days/yr. Estimated plant cost—$89,696,000.

I. Ammonia section (330,000 mt/yr)	*Est. cost*
Plant cost—$27,110,000	*$/mt*
Total production cost from Table R	37.39

II. Nitric acid section (555,000 mt/yr)[a]	*Est. cost*
Plant cost—$13,000,000[a]	*$/mt*
Total production cost from Table V	17.45

III. Nitric phosphate (28-14-0) prilling section (970,000 mt/yr)[b]	*Est. cost*
Plant cost—$31,647,000[b]	*$/mt*
Phos. rock, 33% P_2O_5 (0.445 mt @ $10.00)	4.45
Ammonia (0.200 mt @ $37.39)	7.48
Nitric acid, 100% (0.580 mt @ $17.45)	10.12
Gypsum, makeup (0.120 mt @ $8.40)	1.01
Carbon dioxide (0.196 mt @ no charge)	–
Labor (0.217 man-hr @ $3.00)	0.65
Maintenance (5% of plant cost)	1.63
Electricity (70 kwh @ $0.01)	0.70
Water, cooling (8 M gal @ $0.02)	0.16
Water, filtered (1 M gal @ $0.07)	0.07
Steam (2.40 M lb @ $0.50/M lb)	1.20
Supplies (20% of maintenance)	0.33
Analyses (20% of labor)	0.13
Handling (4% of operating cost)	0.40
Insurance and taxes (2% of plant cost)	0.65
Depreciation (6-2/3% of plant cost)	2.18
Overhead (100% of labor)	0.65
Interest (8% of 1/2 plant cost)	1.31
Product loss (1% of production cost)	0.33
Total production cost	33.45

IV. Offsites for overall complex	*Est. cost*
Plant cost (25% of chem. plants)—$17,939,000	*$/mt*
Maintenance (5% of offsites cost)	0.92
Supplies (20% of maintenance)	0.18
Insurance and taxes (2% of offsites cost)	0.37
Depreciation (6-2/3% of offsites cost)	1.23
Interest (8% of 1/2 offsites cost)	0.74
Total operating cost	3.44
Cost of prilled product	33.45
Total production cost less interest on working capital	36.79
Interest on working capital[c]	0.41
Total production cost including interest on working capital	37.20
Return on total investment[d] (10%)	10.28
Total (bulk product)	47.48
$/mt of plant nutrient[e]	113.15

[a]Total for two nitric acid plants.
[b]Total for two prilling plants.
[c]8% of half of working capital of $9,967,000.
[d]Includes fixed capital of $89,696,000 and working capital of $9,967,000.
[e]28% N, 14% P_2O_5 = 42% plant food.

Table X. (G-2C) Estimated Cost of Prilled Nitric Phosphate (28-14-0) Produced by Odda Process from Ammonia and Phosphate Rock Imported to India

Basis—1,000 mt/day ammonia and 411.5 mt/day P_2O_5 imported to produce 969,960 mt/yr of nitric phosphate. Estimated plant cost—$59,669,000.

I. Ammonia port facilities (330,000 mt/yr)	*Est. cost*
Facilities plant cost—$3,088,000	*$/mt*
Imported ammonia (1.00 mt @ $40.00)	40.00
Labor (0.032 man-hr @ $3.00)	0.10
Maintenance (5% of plant cost)	0.47
Electricity (12.6 kwh @ $0.01)	0.13
Steam (0.265 M lb @ $0.50)	0.13
Supplies (20% of maintenance)	0.09
Insurance and taxes (2% of plant cost)	0.19
Depreciation (6-2/3% of plant cost)	0.62
Overhead (100% of labor)	0.10
Interest (8% of 1/2 plant cost)	0.37
Product loss (1/2% of operating cost)	0.01
Total production cost	42.21

II. Nitric acid section (555,491 mt/yr)[a]	*Est. cost*
Plant cost—$13,000,000[a]	*$/mt*
Ammonia (0.292 mt @ $42.21)	12.33
Catalyst (0.137 mt @ $3.50)	0.48
Labor (0.0856 man-hr @ $3.00)	0.26
Maintenance (5% of plant cost)	1.17
Electricity (7.3 kwh @ $0.01)	0.07
Water, cooling (53 M gal @ $0.02)	1.06
Water, boiler feed (0.408 M gal @ $0.40)	0.16
Steam, export (1.23 M lb @ $0.50)	−0.62
Air (1.30 M cu ft @ $0.02)	0.03
Supplies (20% of maintenance)	0.23
Analyses (20% of labor)	0.05
Handling (4% of operating cost)	0.24
Insurance and taxes (2% of plant cost)	0.47
Depreciation (6-2/3% of plant cost)	1.56
Overhead (100% of labor)	0.26
Interest (8% of 1/2 plant cost)	0.94
Product loss (1% of production cost)	0.19
Total production cost	18.88

III. Nitric phosphate prilling section (969,960 mt/yr)[b]	*Est. cost*
Plant cost—$31,647,000[b]	*$/mt*
Phos. rock, 33% P_2O_5 (0.445 mt @ $21.00)	9.34
Ammonia (0.200 mt @ $42.21)	8.44
Nitric acid, 100% (0.580 mt @ $18.88)	10.95
Labor (0.217 man-hr @ $3.00)	0.65
Maintenance (5% of plant cost)	1.63
Electricity (80 kwh @ $0.01)	0.80
Water, cooling (8 M gal @ $0.02)	0.16
Water, filtered (1 M gal @ $0.07)	0.07
Steam (1.60 M lb @ $0.50)	0.80
Supplies (20% of maintenance)	0.33
Analyses (20% of labor)	0.13
Handling (4% of operating cost)	0.39
Insurance and taxes (2% of plant cost)	0.65
Depreciation (6-2/3% of plant cost)	2.18
Overhead (100% of labor)	0.65
Interest (8% of 1/2 plant cost)	1.31
Product loss (1% of production cost)	0.39
Total production cost	38.87

IV. Offsites for overall complex	*Est. cost*
Plant cost (25% of chem. plants)—$11,934,000	*$/mt*
Maintenance (5% of offsites cost)	0.62
Supplies (20% of maintenance)	0.12
Insurance and taxes (2% of offsites cost)	0.25
Depreciation (6-2/3% of offsites cost)	0.82
Interest (8% of 1/2 offsites cost	0.49
Total operating cost	2.30
Cost of prilled product	38.87
Total production cost less interest on working capital	41.17
Interest on working capital[c]	0.50
Total production cost including interest on working capital	41.67
Return on total investment[d] (10%)	7.39
Total (bulk product)	49.06
$/mt of plant nutrient[e]	116.81

[a]Total for two nitric acid plants.
[b]Total for two prilling plants.
[c]8% of half of working capital of $12,050,000.
[d]Includes fixed capital of $59,669,000 and working capital of $12,050,000.
[e]28% N, 14% P_2O_5 = 42% plant food.

Table Y. (G-2C-1) Estimated Cost of Prilled Nitric Phosphate (28-14-0) Produced by Odda Process from Domestic Indian Phosphate Rock and Imported Ammonia

Basis—1,000 mt/day ammonia imported and 411.5 mt/day of P_2O_5 manufactured to produce 969,960 mt/yr of nitric phosphate. Estimated plant cost—$59,669,000.

I. Ammonia port facilities	
(330,000 mt/yr)	*Est. cost*
Facilities plant cost—$3,088,000	*$/mt*
Total production cost from Table X	42.21
II. Nitric acid section	
(555,491 mt/yr)[a]	*Est. cost*
Plant cost—$13,000,000[a]	*$/mt*
Total production cost from Table X	18.88
III. Nitric phosphate prilling	
section (969,960 mt/yr)[b]	*Est. cost*
Plant cost—$31,647,000[b]	*$/mt*
Phos. rock, 33% P_2O_5 (0.445 mt @ $10.00)	4.45
Ammonia (0.200 mt @ $42.21)	8.44
Nitric acid, 100% (0.580 mt @ $18.88)	10.95
Labor (0.217 man-hr @ $3.00)	0.65
Maintenance (5% of plant cost)	1.63
Electricity (80 kwh @ $0.01)	0.80
Water, cooling (8 M gal @ $0.02)	0.16
Water, filtered (1 M gal @ $0.07)	0.07
Steam (1.60 lb @ $0.50/M lb)	0.80
Supplies (20% of maintenance)	0.33
Analyses (20% of labor)	0.13
Handling (4% of operating cost)	0.39
Insurance and taxes (2% of plant cost)	0.65
Depreciation (6-2/3% of plant cost)	2.18
Overhead (100% of labor)	0.65
Interest (8% of 1/2 plant cost)	1.31
Product loss (1% of production cost)	0.34
Total production cost	33.93

IV. Offsites for overall complex	*Est. cost*
Plant cost (25% of chem. plants)—$11,934,000	*$/mt*
Maintenance (5% of offsites cost)	0.62
Supplies (20% of maintenance)	0.12
Insurance and taxes (2% of offsites cost)	0.25
Depreciation (6-2/3% of offsites cost)	0.82
Interest (8% of 1/2 offsites cost)	0.49
Total operating cost	2.30
Cost of prilled product	33.93
Total production cost less interest on working capital	36.23
Interest on working capital[c]	0.43
Total production cost including interest on working capital	36.66
Return on total investment[d] (10%)	7.23
Total (bulk product)	43.89
$/mt of plant nutrient[e]	104.50

[a]Total for two nitric acid plants.
[b]Total for two prilling plants.
[c]8% of half of working capital of $10,435,000.
[d]Includes fixed capital of $59,669,000 and working capital of $10,435,000.
[e]28% N, 14% P_2O_5 = 42% plant food.