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INVESTMENT AND PRODUCTION COST OF FERTILIZERS *

Background Paper

by

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This is a reprint of a paper prepared for the Fourth Session of the FAO Commission on Fertilizers which was held in Rome, 27 - 30 September 1977 - FERT/77/4.

INVESTMENT AND PRODUCTION COSTS FOR FERTILIZERS

This paper has been prepared as requested by the Commission at its Third Session. It indicates, for a range of operating conditions and locations, the effect of investment and production costs in new fertilizer plants on future prices of some nitrogenous and phosphatic fertilizers. The paper, prepared by Mr. William F. Sheldrick, Chief, Fertilizer Unit, World Bank, is based on a survey of investment estimates made for the appraisal of World Bank projects as well as on discussions with engineering contractors and reference to the work of other international agencies.

INVESTMENT AND PRODUCTION COSTS FOR FERTILIZERS

SUMMARY

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

In order to appreciate more fully the factors which influence fertilizer costs and to enable more realistic projections of future fertilizer prices, the costs of producing some nitrogenous and phosphate fertilizers have been calculated for a range of operating conditions and site locations. The results demonstrate the difficulties and dangers of projecting investment and production costs without specifically relating these to site conditions and other factors which influence costs.

For example, in the case of urea fertilizer which is produced using natural gas as a feedstock, investment related charges represent the major cost component. In many situations of high investment combined with low operating rates, the overall production cost is higher than less favourably placed locations regarding feedstock. It does not necessarily hold that the best location to produce nitrogenous fertilizers is where natural gas is cheapest. Sometimes, the reverse may be true.

Another issue which the calculations demonstrate is the disadvantage that a producer faces when commencing operations on a green field site in a developing country compared with a developed site. Investment costs can vary from \$150-\$300 million, which can increase the cost of urea by \$60 per ton or more, an increase which might be greater than the total cost of feedstock or fuel.

Taking into account the considered range of operating conditions, it appears that a plant contracted today to be on stream in the 1980's and operating with a 90 percent utilization would need an average urea ex-works price within the range of \$175-\$200 per ton (1977 dollars) in order to obtain an acceptable return on investment. The present f.o.b. price of urea is about \$125 per ton, so it is expected that urea prices will have to increase by the early eighties to justify new capacity which will be required to meet increasing demand.

The situation for phosphate fertilizers is similar although the cost of raw materials is much more important than investment costs compared with nitrogenous fertilizers. Phosphate fertilizers are therefore less sensitive to operating rate and to location. However, new plants will be built where materials are cheapest such as near or at a rock mine. Also, because the major developed phosphate deposits such as the USA and Morocco are already well established in the production of phosphate fertilizers, it seems likely that most new production will be in these and similarly placed sites. It is estimated therefore that the realization price to give an acceptable return on investment would be in the range of \$275-\$300 per ton P_2O_5 for phosphoric acid and about \$130-\$150 per ton of product for granular triple superphosphate. These projections are based on a rock transfer price of \$25 per ton and sulphur of \$65 per ton. The present day f.o.b. prices for phosphoric acid are \$200 per ton P_2O_5 and for triple superphosphate about \$100 per ton indicating, once again, that in real terms over the next few years, fertilizer prices have to rise to justify the cost of new production.

INTRODUCTION

Investment and production costs for fertilizers can vary widely depending on site location, cost of raw materials, financial charges on the project, etc., and it is extremely difficult to represent such data in a single generalized form. Also, many surveys on fertilizer costs fail to realize the extent to which the need for, and cost of infrastructure, can influence fertilizer costs. For example, the cost of expanding fertilizer production in a developed country may be little more than the battery limits cost of the plant itself, whereas in a developing country, the cost of infrastructure might be as much as, or more than the plant.

Another important factor influencing the capital and production costs of fertilizers is the size of operation. In most cases, production costs are reduced with increasing scale but it is important that this comparison must not be limited to the plant costs alone but must include total investment costs including infrastructure. Operating rate is another very important factor which must be taken into account in calculating operating costs. The fixed charges in many large fertilizer complexes are the most important single cost items, and increases in these because of low operating efficiencies can soon outweigh advantages in materials costs.

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

It is important therefore in presenting data on fertilizer costs that these different factors are accounted for in such a way that allowance can be made for changing conditions. The object of this short report has been to calculate both investment and operating costs for a range of fertilizer manufacturing conditions. Although the best data available on absolute costs has been used, a major emphasis has been placed on maintaining proper relative costs.

Cost data has been calculated for the principal nitrogen fertilizer, urea and also for one of the main phosphate intermediates and fertilizer (phosphoric acid and triple superphosphate). The main purpose of calculating these costs is to establish future likely selling prices for these materials from new plants now being contracted and from which production might be expected after about 1980. All the figures used in the calculations are on the basis of 1977 constant dollar values.

I. THE MANUFACTURE OF UREA

1. PLANT INVESTMENT AND OPERATING COSTS

1.1 General

Although most surveys on the cost of producing ammonia and urea normally compare different feedstocks and it is recognized that urea plants based on naphtha, heavy oil and coal are currently being evaluated and built, in general, and in particular for urea which is sold in the export market, natural gas appears to be the most attractive feedstock both from investment and operating costs, and is expected to remain so for some time.

As the main object of this exercise is to estimate the likely export price of fertilizers from new plants now being contracted, the calculations below are based on natural gas. Another important factor influencing the capital and production costs of urea is the size of operation. Although urea plants up to 2,000 tpd 1/ have been built as have 1,500 tpd

1/ Tons per day

ammonia plants, the most popular size at the present time is about 1,600-1,700 tpd urea and 900-1,000 tpd ammonia. At this size, there is now considerable technological experience and above this size, economies of scale at the present time seem to be limited.

In calculating production costs for urea, one of the main objectives has been to compare areas where there is cheap flared natural gas, usually in remote locations, with areas where gas is more highly priced but where other costs of manufacturing are low.

1.2 Basis for Cost Comparisons

Although fertilizer projects may often be based on similar production rates, there are usually significant differences in the investment costs depending on site locations, scope of project, etc. In order to try to categorize the projects into major headings, however, it is assumed that in general a project will come roughly into one of the following three areas:

A. A plant in a developed country such as the USA, Western Europe, Japan, etc. In these cases, most of the infrastructure will already exist, for example, there will be roads, a port, railroad, a social infrastructure that will provide people to build and work in the plant, schools, hospitals, etc.

B. A plant in a developing country such as India, Indonesia, Brazil, Pakistan, etc. In these cases, there will be some fertilizer and social infrastructure already existing which can usefully contribute towards the project but not as much as for Case A.

C. A plant in a remote location of a developing country such as certain Middle East or African countries. In this case, there would be no infrastructure of any sort available and all roads, ports, railways, civil works, amenities, etc., would have to be provided as part of the project cost.

1.3 Feedstock Cost

Present day gas prices vary widely from one location to another. In oil-rich areas of the developing world where associated gas is still being flared, the price of natural gas is basically the cost of collection and distribution which can be as low as $0.25 per M scft 1/ but will often be more. In most industrialized countries where gas is not so abundant, the current price varies between $0.80 and $3.0 per M scft.

In a fully integrated energy plant where gas is used to supply total energy such as electricity, steam, fuel as well as feedstock for the production of urea, analysis of plant performances of existing plants as well as theoretical considerations indicate that a reasonable average figure is about 35 M scft of gas per ton of urea produced. In defining the range of parameters for the costings, it is assumed that gas prices may increase up to $4.0 M scft over the next 10 years or alternatively other sources of feedstock and fuel for urea manufacture will reach equivalent levels.

1.4 Other Variable Costs

Analysis of several projects both in developed and developing countries show that the costs of variables other than feedstock and fuel do not vary signficantly from one site to another. Bag costs vary from about $8 to $12 per ton of product and catalysts and chemicals from about $1 to $2 per ton of product. Also, boiler and cooling water is normally less than $1 per ton. In the comparative costings, similar costs have been assumed for this item for all sites, although it is appreciated that these other variable costs may be two or three dollars cheaper in developed countries than developing countries. No special

1/ Thousand standard cubic feet

additional allowances has been made in any of these costings for electric power, as it has been assumed in all cases that power would be produced on the site from gas, and an appropriate allowance has been made in the investment costs for a 20 MW power station and also in the overall gas requirements.

1.5 Labour and Overheads

The cost of labour and overheads are also found to vary little from one site to another. To some extent, the cheap cost of local labour in developing countries is counteracted by greater numbers employed and sometimes by expensive expatriate labour. In some countries such as India, Pakistan, etc., where both skilled and unskilled labour is available, labour costs are likely to be cheaper, but in certain Middle East countries, where most labour is expatriate, costs may be higher. In any case, the differences are only likely to amount to a few dollars, so it has been assumed that labour and overheads would be the same in each case.

1.6 Capital Charges

Capital charges associated with ammonia/urea complexes assuming a reasonable return on investment usually amount to nearly 25 percent of the capital cost per annum. Depreciation is usually over 12 years. Often maintenance is assumed at about 3 percent of the plant investment but in this exercise, maintenance has been taken as 2 percent of the total plant investment cost per annum in view of the fact that the investment costs are large and contain several items only indirectly related to actual plant costs.

1.7 Operating Rates

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

2. INVESTMENT COSTS

2.1 Plant in Developed Country

In the USA, Western Europe and Japan, where fertilizer industries are well developed and large production sites already exist, some new fertilizer plants will be built on existing sites where many services such as transport, port facilities and amenities like housing, hospitals, etc., are also available. However, even for new sites, because of the existence of a well developed social and industrial infrastructure, offsite requirements are likely to be lower than for a developing country. Also, plants in developed countries can be erected more cheaply because freight of equipment is less, skilled labour is usually available and the climatic conditions and the availability of sweet water, etc., do not impose undue constraints on the design of plants. These factors have been taken into account in deriving the investment figures for a plant on a green field site in a developed country shown in Table 1. They are also based on discussions with producers of ammonia and urea in the USA and Western Europe and with engineering contractors.

2.2 Plant in Developing Country

The figures for investment costs in this particular case are based on a survey of investment estimates made for the appraisal of World Bank projects as well as on discussions with engineering contractors and reference to the work of other international agencies. It is assumed that there is some limited existing infrastructure and local facilities that can be used to assist the project, but the costs are essentially based on a green field site. It is also assumed that most of the market would be for local consumption but that part of the product is capable of being exported if required, through existing port facilities. All of the unskilled and part of the skilled labour can be provided from local resources. Typical countries which would fall into this category would be India, Indonesia, Pakistan, Brazil, etc.

2.3 Plant in Developing Country - Remote Location

It is assumed in this case that all infrastructure, both industrial and social, would have to be provided. In building up estimates for fertilizer plants in these locations, discussions have been held with both manufacturing and engineering companies who have made similar studies, and reference has also been made to a number of cost estimates prepared for the appraisal of World Bank projects in developing countries. Construction costs are usually very high because of the lack of local resources. Most workers are expatriates so that both temporary housing for construction staff and permanent housing for the operating staff must be provided. Port and railway facilities have often to be provided as have many other additional offsite facilities. In the Middle East, for example, fresh water is not available and this can necessitate more expensive air-cooled plant or desalination and other facilities. The product would be exported and would require special facilities for this.

2.4 Site Factor

One of the most difficult items to decide in estimating investment costs for fertilizer complexes in developing countries is the site factor. For developing countries generally, Tennessee Valley Authority (TVA) in their cost studies have taken a factor of 1.2' but for remote locations, most authorities feel that a higher figure should be taken. Recent publications on this subject 1/ 2/ recommend that a factor of about 1.3' should be taken, and this is also in line with World Bank analyses of investment costs for such plants. Allowing also for normal price and physical contingencies, a single factor has been assumed in each case to cover site and other factors as follows:

	Factor
Plant in Developed Country	1.10
Plant in Developing Country	1.25
Plant in Developing Country (Remote Location)	1.35

2.5 Barge-Mounted Ammonia/Urea Complexes

One possible method of reducing the large investment costs for fertilizer plants in certain remote locations is to use a 'barge-mounted' plant. This term is often used to cover several types of plants including platforms of various forms. The main procedure for such a plant is that it can be constructed on a floating base in the dockyard of a developed country and then towed to a remote location where it can be quickly commissioned. Sometimes, several barges may be needed to provide the range of chemical plants and services.

The main advantages claimed for these plants are that construction time can be reduced, effective quality control can be ensured, and the difficulties of employing large quantities of skilled workers in remote locations overcome. These plants would appear to be particularly applicable where soil conditions make it difficult to set up heavy equipment such as a urea complex on shore and where harbours and landing equipment are lacking and roads for transportation are incomplete. Many large and reputable contractors are now advertizing their ability to offer such facilities and although there is as yet little full scale experience, preliminary cost data have been included for comparative purposes.

1/ Hydrocarbon Processing - November 1976

2/ Chemical Age - February 28, 1975

Investment cost estimates for an ammonia/urea complex to produce 1,650 tpd based on natural gas in different locations are given in Table 1. In some cases, where it is felt that a specific location does not quite fit into one of the categories, capital costs may be assumed by interpolation. This could apply to plants in developing countries being erected on partially developed sites.

3. COMPARATIVE PRODUCTION COSTS

The production costs for urea are presented in Tables, 1, 2 and 3. In Table 3, the information is given in the form of a "cost envelope" to show the effect on production costs of factors such as gas price, investment cost and operating rate for a 1,650 tpd ammonia/urea complex. These costs contain depreciation but no interest charges.

Specific production costs are given for various sites in Table 4. In addition, this Table contains the ex-factory realization price per ton of urea necessary to achieve various returns on investment. Although gas prices are assumed which are believed to be most likely for the cases considered, adjustment in cost and realization price can be made easily as indicated in the tables.

4. DISCUSSION OF RESULTS

The results in Tables 3 and 4 demonstrate the importance of the three main variables, feedstock cost, investment cost and operating rate, on production and realization prices for urea. All factors are equally important, and the advantages of cheap natural gas currently available as flared gas in remote locations, can soon be outweighed by higher investment costs and lower operating rates.

The results show that the cost of producing urea and the realization prices go give reasonable returns on investment could vary considerably from site to site and even for each site itself depending on the parameters assumed.

In order to facilitate comparison of the data for various locations, a simple return on investment has been assumed. This has been based on the average realization price required over the project life although, in fact, prices will vary considerably during this period due to inflation and cyclical supply/demand imbalances. Although a return on investment (ROI) of 10 percent has been assumed for some calculations, this has been done mainly to establish the minimum realization price necessary to cover adequate servicing of capital, particularly at the beginning of the project life. A commercial company, however, would normally require at least 15 percent pre-tax return to provide adequate profit to justify the project. Exceptions to this case might occur in the energy-rich developing countries who have capital available and may be prepared to accept a lower ROI.

On the basis of a urea plant contracted today, assuming an operating rate of 90 percent, it is estimated that the average realization price for the various locations considered would have to fall within the range of US $175 to $200 per ton of urea in order to achieve a 15 percent return on investment. These prices are in constant 1977 dollars.

II. THE MANUFACTURE OF PHOSPHORIC ACID AND TRIPLE SUPERPHOSPHATE

1. PLANT INVESTMENT AND OPERATING COSTS

1.1 General

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

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

1.2 Basis for Cost Comparisons

Phosphoric acid and triple superphosphate are made in many places throughout the world, although in the last few years there has been a strong trend to manufacture phosphatic intermediates at or near the source of the phosphate rock mine. There are two main advantages in this; firstly, that signficant savings in freight can be derived from shipping a concentrate fertilizer intermediate or product rather than phosphate rock, and secondly, it allows the utilization of lower grade rocks. These rocks, which would have relatively low market value can be converted into high grade products at the mine site, in plants specially designed to deal with a single type of low grade feed. An analysis of new plants that have recently been built or are planned within the next five years, indicates that the majority of these plants will be at rock producing sites and that the average size of new plants is between 500 to 1,000 tpd P_2O_5.

In the cost basis therefore, it is assumed that the most likely place for a new phosphoric acid plant would be at a rock producing site and based on both economic and technical considerations, the size of the plant would be 1,000 tpd P_2O_5. One general exception to this situation would be at a site where rock is not produced but where by-product sulphuric acid is available cheaply from a smelting operation.

Three different scenarios have been considered:

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

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

C. Phosphate fertilizer plant in remote location of a developing country. The most likely case is a desert area where all transport facilities such as rail and ports (or jetty) would have to be provided. There would be no local labour to assist with construction and all amenities such as housing, etc., would have to be provided.

1.3 Feedstock Costs

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

1.4 Phosphate Rock

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

Although phosphate rock is generally sold according to its P_2O_5 content, the other factors mentioned above must also be taken into account in assessing overall rock costs. Generally, however, only the best quality high grade rocks are exported from the mine to produce phosphoric acid and it is becoming increasingly more common for low grade phosphates to be processed at their source. In these cases, a lower value is attributed to the rock, although normally due to the lower quality, additional investment costs are required.

1.5 Sulphur

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

In the costings, the current price of sulphur has been taken as $65 per ton. This would be a typical figure for landed sulphur in Europe or North Africa although prices may vary slightly elsewhere. The quantity of sulphuric acid required to acidulate phosphate rock varies according to rock composition and process efficiency. In the following costs, an overall efficiency for the sulphuric acid plant of 97 percent has been taken and for the phosphoric acid plant based on rock an efficiency of 95 percent has been assumed. Specific sulphuric acid consumption per ton of P_2O_5 may vary from about 2.40 per ton to 3.0 per ton depending on grade of rock. In this case, a 68/69 BPL rock is considered with a consumption of 2.9 tons of sulphuric acid per ton of P_2O_5.

1.6 Other Variable Costs

As for the case of nitrogenous fertilizers, other variable costs are not a major cost item and do not vary signficantly from one site to another, either as items or in aggregate, with the exception of gypsum disposal which is ferred to later.

Water, including process, boiler and cooling water, normally costs between $4 to $9 per ton P_2O_5.

About 300 Kwh 1/ of power is required per ton of P_2O_5 and at an assumed unit price of $0.03 per unit, the total cost of power is $9 per ton of P_2O_5.

1/ Kilowatt hours

Steam is generated in the sulphuric acid plant equivalent to about 1.1 ton of steam per ton sulphuric acid. This is sufficient for the concentration of phosphoric acid from 30 to 54 percent P_2O_5 which requires about 3 tons of steam per ton P_2O_5. For the sake of simplicity, no credit has been taken for the generation of electricity from this steam which is produced at 45 atmospheres. (As the steam is required at only 2 to 5 atmospheres, the high pressure steam can be reduced through a turbine generating electricity).

Gypsum Disposal - No extra costs have been taken into account to remove the by-product gypsum (5 tons $CaSO_4 2H_2O$ per ton of P_2O_5). It is assumed that the investment includes equipment (pipelines, etc.) for gypsum disposal. It should be appreciated, however, that the disposal of gypsum from phosphoric acid plants is becoming an increasing problem particularly in developed countries. In many cases today, permission to dump gypsum into estuaries cannot be obtained and gypsum disposal costs can run as high as $15 to $20 per ton of P_2O_5.

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

Labour and Overheads - The cost of labour and overheads for producing sulphuric and phosphoric acid should not vary greatly from site to site or even over a range of phosphoric acid plant capacity. To some extent, the cheap cost of local labour in developing countries is counteracted by greater numbers employed and sometimes by expensive expatriate labour. Generally, however, the cost in developing countries should be a little less than developed countries but not significantly so particularly as labour for phosphoric acid production is usually in the range of $5 to $10 per ton of P_2O_5.

In these costings, the cost per man has been assumed on average to be equivalent to $15,000 per year or about $8 per man hour as typical European/US figures. Overheads including administration, personnel services, etc., have been taken at 150 percent of labour cost. It is estimated that about 50 men, including supervision, would be required to operate a sulphuric and phosphoric acid plant producing 1,000 tpd P_2O_5.

1.7 Investment Related Costs

Depreciation has been assumed to be straight line over 12 years. An allowance has also been made for insurance. Maintenance is usually taken as 2 to 5 percent per annum of the investment per annum in costings of this type. In this specific case, maintenance has been assumed as 3 percent for the sulphuric acid plant, 6 percent for the phosphoric acid plant and 2 percent for the infrastructure and offsites. These assumptions take into account the difficulties of maintaining phosphoric acid plants due to high corrosion, etc.

1.8 Return on Investment

Realization prices have been calculated for a range of Return on Investments.

1.9 Investment Costs

Investment costs for phosphoric acid have been estimated on the same basis as for nitrogen fertilizer plants in developed and developing countries. Once again, cost estimates prepared for appraisals of several World Bank projects have been used as well as information received from industry and engineering companies. Investment costs for phosphoric acid are given in Table 5. In the case of triple superphosphate plants, it is assumed that a 50 tph 1/ granulation plant is erected on the same site as the phosphoric acid plant so that the investment costs for triple superphosphate are mainly the plant costs with some associated equipment plus storage.

1/ Ton per hour

1.10 Working Capital

In the case of phosphoric acid, the working capital has been calculated on the basis of 4 days rock stock, 40 days sulphur stock and phosphoric acid equivalent to 50 day's sales at cost. For triple superphosphate, working capital requirements have been taken as 4 days stock of rock, 10 days stock of phosphoric acid and 50 days sales of triple superphosphate at cost.

1.11 Operating Rate

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

2. COMPARATIVE PRODUCTION COSTS

The "cost envelope" for phosphoric acid is given in Tables 6 and 7. Generally, this information illustrates the effect of rock cost, operating rate and investment cost on phosphoric acid production costs, and also on realization prices that would be necessary to achieve a 10 percent return on investment. Cost data for phosphoric acid for various assumed locations are given in Tables 8 and 9. The cost data for triple superphosphate are given in Tables 10 and 11. In the calculations for triple superphosphate, it has been assumed that phosphoric acid would be transferred at the same site to a triple superphosphate plant and the transfer price is based on a 10 percent ROI from the phosphoric acid plant and a 90 percent operating rate. It has also been assumed in the calculations that rock would be $25 per ton and sulphur $65 per ton, as these are about the current average prices, but adjustments can easily be made to the production costs and realization prices for differing rock and sulphur prices as indicated.

3. DISCUSSION OF RESULTS

The cost of producing phosphoric acid and triple superphosphate varies significantly from site to site mainly because of the differing investment costs. However, raw material costs are a much more important component of the total costs for phosphate fertilizers than they are for nitrogen fertilizers. The calculations indicate that, assuming a 15 percent return on investment and a 90 percent operating rate, the realization price for phosphoric acid would have to be in the range of $275 to $380 per ton to justify plants being built in the different locations considered for a new plant now being contracted. As most of the future developments in phosphoric acid manufacture are likely to occur on developed sites of the main rock producers, realization prices are likely to be near the lower end of this range - say $275 to $300 per ton P_2O_5. Similarly, for bulk granular triple superphosphate, the range of prices calculated on the same basis is $130 to $165, with the most likely situation being about $130 to $150 per ton of product.

Table 1. Investment Cost Estimates for Ammonia/Urea Plants 1,650 tpd 1/ Based on Natural Gas

(million dolla.-s)

Item	Developed Country	Developing Country	Developing Country (Remote location)	Barge 2/ Mounted Plant
1. Land, Site Preparation and Civil Works, including Roads, Drains Workshops, Buildings etc	4	12	14	-
2. Machinery, Equipment and Spares	83	90	98	83
3. Freight and Insurance	3	12	20	11
4. Engineering Charges including Design, Erection, Licence Fees, etc.	30	40	50	59
5. Offsites and Other Expenses including Start-Up Fees, Housing Amenities, etc	16	30	55	9
6. Barges	-	-	-	53
7. Mooring Buoy	-	-	-	12
	136	184	237	227
Price, Physical and Site Contingency	14	46	83	23
Plant Investment	150	230	320	250
Working Capital	7	10	15	15
Total Investment	157	240	335	265

1/ Tons per day.

2/ Based only on preliminary investment cost estimates.

Table 2. Estimated Production Costs for Urea

(dollars per metric ton)

Basis : 1,650 tpd[1] bagged product
Capacity Utilization : 90 percent
Production : 330 days/year
544,500 tons urea/year

Site	Developed Site	Developing Site (some existing infrastructure)	Developing Site (remote Location)	Barge-Mounted Plant (Remote Location)
Plant Investment US$	US$150 million	US$230 million	US$320 million	US$250 million
Working Capital US$	US$ 7 million	US$ 10 million	US$ 15 million	US$ 15 million
Total Investment US$	US$157 million	US$240 million	US$335 million	US$265 million
Raw Materials	Gas at $2/M scft[2]	Gas at $0.6/M scft[2]	Gas at $0.3/M scft[2]	Gas at $0.3/M scft[2]
Natural Gas including Fuel and Gas for Steam and Power Generation	70.00	21.00	10.50	10.50
Other Variable Costs US$/ton	11.87	11.87	11.87	11.87
Fixed Costs US$/ton	45.96	62.82	80.69	67.04
Production Costs US$/ton	127.83	95.69	103.06	89.41
Profit (15% ROI[3]) US$/ton	48.06	73.50	102.54	81.09
Realization Price US$/ton (ex-factory)	175.89	169.19	205.63	170.50

Note: An increase in gas prices of US$ 0.1/M scft will increase the production cost and realization price of urea by US$3.5/ton of urea.

1/ Tons per day.
2/ Thousand standard cubic feet.
3/ Return on investment.

Table 3. Production Costs for Urea 1/
$/ton

Operating Rate (percent of design capacity)	Gas Price $/M scft 2/	Investment Cost ($ million) 100	200	300	400	500	600
100	0	43.74	62.72	81.70	100.67	119.65	138.63
	0.5	61.24	80.22	99.20	118.17	137.15	156.13
	1.0	78.74	97.72	116.70	135.67	154.65	173.63
	2.0	113.74	132.72	151.70	170.67	189.65	208.63
	4.0	183.74	202.72	220.76	240.67	259.65	278.63
90	0	47.28	68.37	89.46	110.54	131.63	152.72
	0.5	64.78	85.87	106.95	128.04	149.13	170.22
	1.0	82.28	103.37	124.46	145.54	166.63	187.72
	2.0	117.28	138.37	159.46	180.54	201.63	222.72
	4.0	187.28	208.37	229.46	250.54	271.63	292.72
80	0	51.71	75.43	99.15	122.88	146.60	170.32
	0.5	69.21	92.93	116.65	140.38	164.10	187.82
	1.0	86.71	110.43	134.15	157.88	181.60	205.32
	2.0	121.71	145.43	169.15	192.88	216.60	240.32
	4.0	191.71	215.43	239.15	262.88	286.60	310.32
70	0	57.40	84.51	111.62	138.74	165.85	192.96
	0.5	74.90	102.01	129.12	156.24	183.35	210.46
	1.0	92.40	119.51	146.62	173.74	200.85	227.96
	2.0	127.40	154.51	181.62	208.74	235.85	262.96
	4.0	197.40	224.51	251.62	278.74	305.85	332.96
60	0	64.99	96.62	128.25	159.88	191.51	223.14
	0.5	82.49	114.12	145.75	177.38	209.01	240.64
	1.0	99.99	131.16	163.25	194.88	226.51	258.14
	2.0	134.99	166.62	198.25	229.88	261.51	293.14
	4.0	204.99	236.62	268.25	299.88	331.51	363.14

1/ Contains depreciation but no charge for interest or return on investment.

2/ Thousand standard cubic feet

Table 4. **Realisation Prices versus Return on Investment for Urea**

	Developed Country					Developing Country South East Asia				
Gas Price	US$ 2.0/M scft 1/					US$ 0.60/M scft 1/				
Plant Investment	US$ 150 million					US$ 230 million				
Working Capital	US$ 7 million					US$ 10 million				
Total Investment	US$ 157 million					US$ 240 million				
Percent operating rate	100	90	80	70	60	100	90	80	70	60
Operating cost $/ton	123.23	127.83	133.57	140.96	150.80	89.41	95.69	103.55	113.65	127.11
Return on investment $/ton at:										
5 percent	14.42	16.02	18.02	20.60	24.03	22.05	24.50	27.56	31.50	36.75
10 "	28.84	32.04	36.04	41.20	48.06	44.10	49.00	55.12	63.00	73.50
15 "	43.26	48.06	54.06	61.80	72.09	66.15	73.50	82.68	94.50	110.25
20 "	57.68	64.08	72.08	82.40	96.12	88.20	98.00	110.24	126.20	147.00
25 "	72.10	80.10	90.10	103.00	120.15	110.25	122.50	137.80	157.50	183.75
Realisation price $/ton at various returns on investment at:										
5 percent	137.65	143.85	151.59	161.56	174.83	111.46	120.19	131.11	145.15	163.86
10 "	152.07	159.87	169.61	182.16	198.86	133.51	144.69	158.67	176.65	200.61
15 "	166.49	175.89	187.63	202.76	222.89	155.56	169.19	186.23	208.15	237.36
20 "	180.91	191.91	205.65	223.36	246.92	177.61	193.69	213.79	239.65	274.11
25 "	195.33	207.93	223.67	243.96	270.95	199.66	218.19	241.35	271.15	310.86
	Saudi Arabia Land Based Plant					Saudi Arabia Barge Mounted Plant				
Gas Price	US$ 0.30/M scft 1/					US$ 0.30/M scft 1/				
Plant Investment	US$ 320 million					US$ 250 million				
Working Capital	US$ 15 million					US$ 15 million				
Total Investment	US$ 335 million					US$ 265 million				
Percent operating rate	100	90	80	70	60	100	90	80	70	60
Operating cost $/ton	95.00	103.06	113.15	126.12	143.41	82.71	89.41	97.80	108.57	122.94
Return on investment $/ton at:										
5 percent	30.75	34.18	38.44	43.93	51.25	24.33	27.03	30.41	34.75	40.55
10 "	61.50	68.36	76.88	87.86	102.50	48.66	54.06	60.82	69.50	81.10
15 "	92.25	102.54	115.32	131.79	153.75	72.99	81.09	91.23	104.25	121.65
20 "	123.00	136.72	153.76	175.72	205.00	97.32	108.12	121.64	139.00	162.20
25 "	153.75	170.90	192.20	219.65	256.25	121.65	135.15	152.05	173.75	202.75
Realisation price $/ton at various returns on investment at:										
5 percent	125.75	137.24	151.59	170.05	194.66	107.04	116.44	128.21	143.32	163.49
10 "	156.50	171.42	190.03	213.98	245.91	131.37	143.47	158.62	178.07	204.04
15 "	187.25	205.60	228.47	257.91	297.16	155.70	170.50	189.03	212.32	244.59
20 "	218.00	239.78	266.91	301.84	348.41	180.03	197.53	219.44	247.57	285.14
25 "	248.75	273.96	305.35	345.77	399.66	204.36	224.56	249.85	282.32	325.69

Note: An increase in gas prices of US$ 0.10/M scft will increase the production cost and realisation price of urea by US$ 3.50/ton of urea.

1/ Thousand standard cubic feet.

Table 5 Investment Cost Estimates

Phosphoric Acid Complex to Produce 1000 tpd 1/ P_2O_5

US $ Million

Cost item	Expansion on Developed Site	New Site Developing Country Some Infrastructure	New Site Developing Country Remote Location No Infrastructure
1. Acquisition of Land, Site Preparation, Civil Works, Buildings and Stores	10	19	24
2. Machinery, Equipment and Spares	50	60	64
3. Freight and Insurance	2	4	6
4. Engineering Charges, including Design, Erection, License Fees, etc.	24	30	34
5. Offsites and other expenses including start-up fees. Housing amenities, etc.	6	11	26
6. Basic Cost Estimate	92	124	154
Price, Physical and Site Contingency	9	31	54
7. Plant Investment	101	155	208
8. Working Capital 2/	13	14	16
9. Total Investment	114	169	224

1/ Tons per day.

2/ Based on phosphate rock at $25 per ton and sulphur at $65 per ton.

Table 6

Phosphoric Acid

Production Costs (Per Ton P_2O_5) for Various Phosphate Rock and Investment Costs

Rock Price $/ton	Capital Cost $50 million				
	Percent Operating Rate				
	60	70	80	90	100
	Production Cost $/Ton				
15	173.80	167.37	162.54	158.76	155.78
25	207.32	200.89	196.04	192.28	189.30
35	240.84	234.41	229.56	225.80	222.82
45	274.36	267.93	263.08	259.32	256.34
55	307.88	301.45	296.60	292.84	289.86

Rock Price $/ton	Capital Cost $100 million				
	Percent Operating Rate				
	60	70	80	90	100
	Production Cost $/Ton				
15	209.40	197.88	189.12	182.50	177.14
25	242.92	231.40	222.74	216.02	210.66
35	276.44	264.92	256.26	249.54	244.18
45	309.96	298.44	289.78	283.06	277.70
55	343.48	331.96	323.30	316.58	311.22

Rock Price $/ton	Capital Cost $150 million				
	Percent Operating Rate				
	60	70	80	90	100
	Production Cost $/Ton				
15	245.01	228.40	215.95	206.12	198.50
25	278.53	261.92	249.47	239.74	232.02
35	312.05	295.44	282.99	273.26	265.54
45	345.57	328.96	316.51	306.78	299.06
55	379.09	362.48	350.03	340.29	332.58

Rock Price $/ton	Capital Cost $300 million				
	Percent Operating Rate				
	60	70	80	90	100
	Production Cost $/Ton				
15	351.83	319.97	296.03	277.44	262.60
25	385.35	353.49	329.55	310.96	296.12
35	418.87	387.01	363.07	344.48	329.64
45	452.39	420.53	396.59	378.00	363.16
55	485.91	454.05	430.11	411.52	396.68

Table 7

Phosphoric Acid

Realization Prices Per Ton P_2O_5 required to give 10 Percent Return on Investment

Rock Price US $/ton	Investment US$ million	Percent Operating Rate				
		60	70	80	90	100
15	300	511.3	456.7	415.6	373.7	358.3
	150	328.0	298.8	277.6	260.9	247.8
	100	265.7	246.2	231.4	220.0	210.9
	50	204.5	193.7	185.5	179.2	174.2
25	300	545.8	491.1	449.9	418.0	392.4
	150	356.5	333.0	311.7	295.0	281.8
	100	299.2	280.5	265.7	254.2	245.1
	50	239.0	228.0	219.4	213.4	208.3
35	300	580.2	525.3	484.1	452.1	426.4
	150	396.0	367.4	346.0	329.3	315.9
	100	334.6	314.8	299.9	288.3	279.1
	50	273.1	262.1	253.8	247.4	242.2
45	300	614.7	559.6	518.3	486.2	460.6
	150	430.4	401.7	380.1	363.4	350.0
	100	369.0	349.0	334.0	322.4	313.1
	50	307.7	296.5	288.1	288.5	276.3
55	300	649.1	593.9	552.5	520.3	494.6
	150	464.9	436.1	414.3	397.5	384.1
	100	403.5	383.4	368.3	356.6	347.2
	50	342.1	330.7	322.2	315.6	310.4

Sulphur price $65/ton
For each $1.00/ton increase in sulphur prices, realization prices increase by about $0.98/ton P_2O_5

Table 8. Estimated Production Cost for Phosphoric Acid

(US$/ton)

Basis: : 1,000 tpd[1] (100 percent P_2O_5)
Capacity Utilization : 90 percent
Production : 330 days/year
330,000 tons/year P_2O_5

Site	Developed Site	New Site – Developing Country (some existing infrastructure)	New Site – Developing Country (remote location)
Plant Investment US$ Working Capital US$ Total Investment US$	US$101 million US$ 13 million US$114 million	US$155 million US$ 14 million US$169 million	US$208 million US$ 16 million US$224 million
Raw Materials US$/ton			
Rock Phosphate (3.352 tons at $25/ton)	83.80	83.80	83.80
Sulphur (0.976 tons at $65/ton)	63.45	63.45	63.45
Other Variable Costs US$/ton	15.00	15.00	15.00
Fixed Costs US$/ton	53.90	79.89	105.05
Production Costs US$/ton	216.15	242.14	267.30
Profit (15 percent ROI[2])	57.57	85.32	113.13
Realization Price US$/ton	273.72	327.46	380.43

1/ Tons per day

2/ Return on investment

For each $1.00/ton increase in rock costs, production costs increase by $3.35/ton P_2O_5.

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

Table 9. **Realisation Prices versus Return on Investment for Phosphoric Acid US$/ton P_2O_5**

Rock $25/ton - Sulphur $65/ton

Site	Developed Site					New Site - Developing Country					New Site - Developing Country (remote location)				
Plant Investment	US$ 101 million					US$ 155 million					US$ 208 million				
Working Capital	US$ 13 million					US$ 14 million					US$ 16 million				
Total Investment	US$ 114 million					US$ 169 million					US$ 224 million				
Percent Operating Rate	100	90	80	70	60	100	90	80	70	60	100	90	80	70	60
Operating cost $/ton	211.08	216.15	223.29	232.01	243.63	234.15	242.14	252.12	264.96	282.08	256.80	267.30	280.44	297.32	319.83
Return on investment $/ton at: 5 percent	17.27	19.19	21.59	24.67	28.78	25.60	28.44	32.00	36.57	42.67	33.94	37.71	42.42	48.49	56.57
10 "	34.54	38.38	43.18	49.34	57.56	51.20	56.88	64.00	73.14	85.34	67.88	75.42	84.84	96.98	113.14
15 "	51.81	57.57	64.77	74.01	86.34	76.80	85.32	96.00	109.71	128.01	101.82	113.13	127.26	145.47	169.71
20 "	69.08	76.76	86.36	98.68	115.12	102.40	113.76	128.00	146.28	170.68	135.76	150.84	169.69	193.96	226.28
25 "	86.35	95.95	107.95	123.35	143.90	128.00	142.20	160.00	182.85	213.35	169.70	188.55	212.10	242.45	282.85
Realisation price $/ton at: 5 percent	228.35	235.34	244.88	256.68	272.41	259.75	270.58	284.12	301.53	324.75	290.74	305.01	322.86	345.81	376.40
10 "	245.62	254.53	266.47	281.35	301.19	285.35	299.02	316.12	338.10	367.42	324.68	342.72	365.28	394.30	432.97
15 "	262.89	273.72	288.06	306.02	329.97	310.95	327.46	348.12	374.67	410.09	358.62	380.43	407.07	442.79	489.54
20 "	280.16	292.91	309.65	330.69	358.75	336.55	355.90	380.12	411.24	452.76	392.56	418.14	450.12	491.28	546.11
25 "	297.43	312.10	331.24	355.36	387.53	362.15	384.34	412.12	447.81	495.43	426.50	455.85	492.54	539.77	602.68

For each $1.00/ton increase in rock cost realisation prices increase by about $3.35/ton P_2O_5.

For each $1.00/ton increase in sulphur prices realisation prices increase by about $0.98/ton P_2O_5.

Table 10

Estimated Production Cost for Granular Triple Superphosphate

(US $/ton)

Basis : 1,200 tpd[1] bulk product (46 percent P_2O_5)
Capacity Utilization: 90 percent
Production : 330 days/year
396,000 tons/year GTSP[2]

Site	Developed Site	Developing Site (Some Existing Infrastructure)	Developing Site (Remote Location)
Plant Investment US$	US$25 Million	US$29 Million	US$31 Million
Working Capital US$	US$8 Million	US$9 Million	US$11 Million
Total Investment US$	US$33 Million	US$38 Million	US$42 Million
Raw Materials US$/ton			
Phosphate Rock (0.44 tons at $25/ton	11.00	11.00	11.00
Phosphoric Acid - 0.34 tons [3]	86.54	101.66	116.52
Other Variable Costs US$/ton	2.95	2.95	2.95
Fixed Costs US$/ton	13.91	15.62	16.49
Production Cost US$/ton	114.40	131.23	146.96
Profit (15 percent ROI [4])	13.86	15.99	17.67
Realization Price US$/ton	128.26	147.22	164.63

1/ Tons per day
2/ Granular Triple Superphosphate
3/ Based on phosphate rock at $25/ton and sulphur at $65/ton
4/ Return on Investment

For each $1.00/ton increase in rock costs, production costs increase by $1.58/ton triple superphosphate
For each $1.00/ton increase in sulphur costs, production costs increase by $0.33/ton triple superphosphate

Table 11. Realisation Prices versus Return on Investment for Bulk Granular Triple Superphospate US$/Ton Product

Site	Developed Site					New Site - Developing Country					New Site - Developing Country (remote location)				
Plant Investment	US$ 25 million					US$ 29 million					US$ 31 million				
Working Capital	US$ 8 million					US$ 9 million					US$ 11 million				
Total Investment	US$ 33 million					US$ 38 million					US$ 42 million				
Percent operating rate	100	90	80	70	60	100	90	80	70	60	100	90	80	70	60
Operating cost $/ton 1/	113.01	114.40	116.14	118.38	121.36	129.67	131.23	133.18	135.70	139.04	145.31	146.96	149.02	151.57	155.20
Return on investment $/ton at: 5 percent	4.16	4.62	5.20	5.94	6.93	4.80	5.33	6.00	6.86	8.00	5.30	5.89	6.62	7.57	8.83
10 "	8.32	9.24	10.40	11.88	13.86	9.60	10.66	12.00	13.72	16.00	10.60	11.78	13.24	15.14	17.66
15 "	12.48	13.86	15.60	17.82	20.79	14.40	15.99	18.00	20.58	24.00	15.90	17.67	19.86	22.71	26.49
20 "	16.64	18.48	20.80	23.76	27.72	19.20	21.32	24.00	27.44	32.00	21.20	23.56	26.48	30.28	35.32
25 "	20.80	23.10	26.00	29.70	34.65	24.00	26.65	30.00	24.30	40.00	26.50	29.45	33.10	37.85	44.15
Realisation price $/ton at: 5 percent	117.17	119.02	121.34	124.32	128.29	134.47	136.56	139.18	142.56	147.04	150.61	152.85	155.64	159.24	164.03
10 "	121.33	123.64	126.54	130.26	135.22	139.27	141.89	145.18	149.42	155.04	155.91	158.74	162.26	166.81	172.86
15 "	125.49	128.26	131.74	136.20	142.15	144.07	147.22	151.18	156.28	163.04	161.21	164.63	168.88	174.38	181.69
20 "	129.65	132.88	136.94	142.14	149.08	148.87	152.55	157.18	163.14	171.04	166.51	170.52	175.50	181.95	190.52
25 "	133.81	137.50	142.14	148.00	156.01	153.67	157.88	163.18	170.00	179.04	171.81	176.41	182.12	189.52	199.35

1/ Based on a phosphoric acid transfer price from plant operating at 90 percent of design capacity with 10 percent ROI and rock at $25/ton and sulphur at $65/ton.

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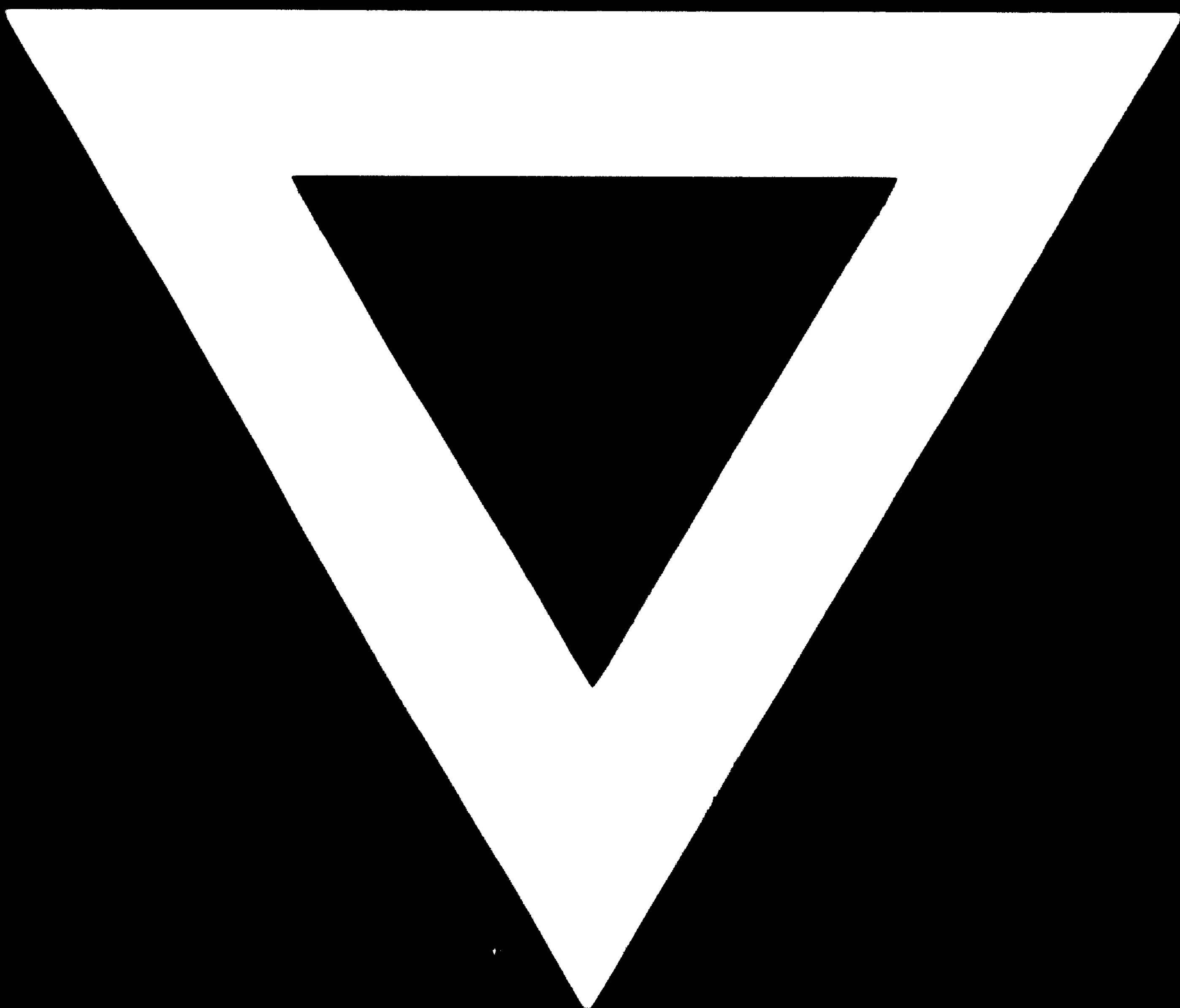

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