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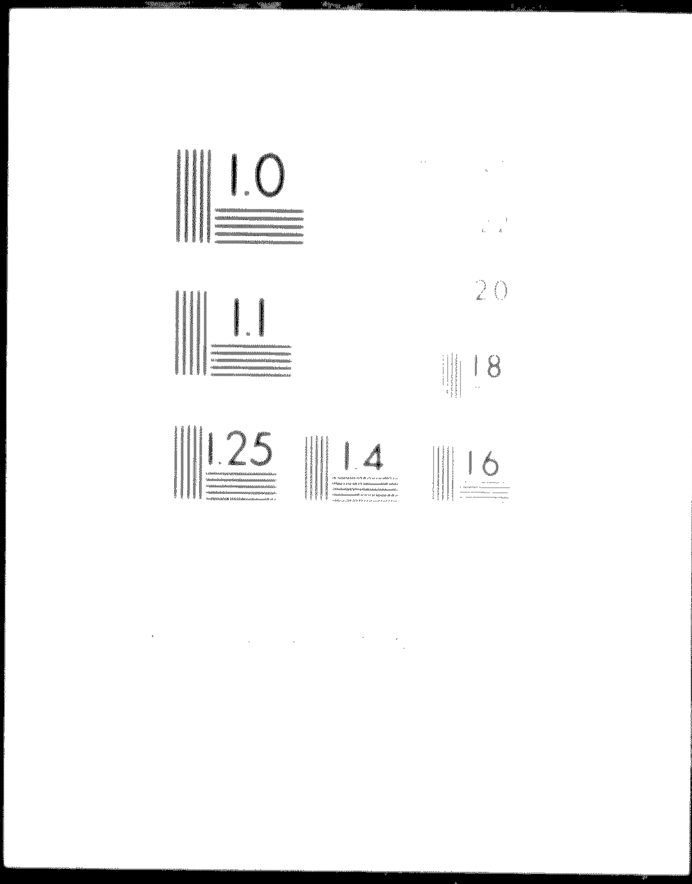

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FEASIBILITY STUDY

FOR

PHOSPHATE-BASED FERTILIZER PRODUCTION

IN CYPRUS

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Foreword

A feasibility study for the production of fertilizers, especially phosphatic fertilizers in Cyprus, is contained in this report.

Cyprus presently imports nitrogenous and phosphatic fertilizers mostly in the form of ammonium sulphate and normal superphosphate involving a foreign exchange expenditure of about US$4,000,000.00 per year. Fertilizer is vital to the economy of the country since agricultural products account for 40 percent of its exports. To increase agricultural productivity, fertilizer is the most important input.

This study shows that saving of about US$2,500,000.00 can be effected if Cyprus puts up its own facilities for the manufacture of single superphosphate using indigenous pyrites for sulphuric acid production and using imported phosphate rock. Production of synthetic ammonia is not recommended at this stage but could be taken up later. At this stage ammonium sulphate and ammoniated superphosphate could also be made using imported ammonia.

As the first step, it is recommended that action be taken immediately to put up facilities to produce 15,000 metric tons of P_2O_5 annually in the form of normal superphosphate analyzing

18-20 percent P_2O_5. The quantity per year will be 75,000 tonnes or 250 tonnes per day of superphosphate containing 20 percent P_2O_5. This will require a sulphuric acid plant of 120 tonnes per day capacity or an annual capacity of 36,000 tonnes. The total capital cost will be US$2.2 million and a working capital of $570,000. It has been calculated that superphosphate can be produced (bagged) at $25.6 per tonne compared to an imported price of $30 per tonne or more.

The Cyprus Government should make a decision soon on this project and the United Nations Industrial Development Organization can assist in preparing tender documents, analyses of tenders and assist in placing orders for plant and equipment if the government so desires.

The best location for the plant seems to be Larnaca, with Limassol as second choice.

1. Introduction and Scope of Study

Following the letter of April 4th, 1966 from the Cyprus Government Planning Commission to Dr. E. C. Hald, UNDP Resident Representative in Cyprus, and the visit of Mr. K. P. R. Menon of OSFO (outlined in his memo of 15th April 1966) it was decided by the CID and other United Nations agencies to study the Cyprus Government's suggestions for UN assistance in industrial development, using CID staff members and experts as well as outside experts according to need.

Accordingly, the following visits to Cyprus were made:

1. Pulp and Paper	:	Mr. Sahlberg, June 1966
2. Fertilizers	:	Eng. M. C. Verghese, August 1966
3. Saw Mill and Industrial Estate	:	Messrs. B. Coggan and S. Najundan, October 1966

The CID suggested to the Cyprus Government through the Resident Representative, Dr. Hald, and they agreed that UN make a feasibility study for production of fertilizers in Cyprus, especially phosphatic fertilizers.

This study accordingly was commissioned by CID under the SIS Programme.

2. Summary and Recommendations

2.1 Summary

The agricultural pattern and level in Cyprus, now totally dependent on imported fertilizers, is sufficient to support an economically feasible domestic fertilizer project based on the production of 75,000 tons annually of single superphosphate using sulphuric acid made from local pyrites and phosphate rock imported from North Africa and possibly Florida.

In addition, the domestic production of ammonium sulphate based on local pyrites and imported ammonia, to manufacture simultaneously a range of granulated N-P-O (or N-P-K fertilizers using imported potash) is economically feasible.

This study substantially confirms an earlier UN report regarding the feasibility of producing single superphosphate in Cyprus by taking advantage of locally available pyrites. Hence, it was thought advisable to pursue the feasibility of making ammonium sulfate as well and this has also been found to be justified. The combined projects would yield savings in foreign exchange amounting to about $2,500,000 annually at current price levels and would employ some 85-100 people, with an annual local payroll of about $1,000,000.

The present foreign exchange expenditure for importing fertilizers is around US$4,000,000.00 per year.

The profitability of the project should be adequate enough to interest private investors, if desired. To enable alternative methods of financing and operation to be explored, detailed cost calculation patterns have been developed and are included in the study.

Possibilities exist for the development of a limited fertilizer export trade and also other local industries based on reasonably-priced sulfuric acid made from local pyrites, but these considerations are outside from the scope of this study.

The total fixed capital required is of the order of $[illegible].4 million for the outlined projects and the working capital is $1.3 million. No ammonia plant is included as refrigerated ammonia is already available from Trinidad and will also be exported from Algiers, Greece, the Persian Gulf and elsewhere within the next year or two.

[illegible] <u>Recommendations</u>

1. Immediately investigate the current and short-range ([illegible] year) future sulfuric acid needs of Cyprus.

2. Develop and implement a project with the following capacities:

   a. 30[illegible] tons/day 1[illegible] per cent sulfuric acid plus the daily needs established by [illegible].1 above, based on local pyrites.

   b. 175 tons/day run-of-pile single superphosphate.

   c. 175 tons/day ammonium sulfate via ammoniation in a granulation unit to produce [illegible] to 450 tons/day of granulated N-P-0 and N-P-K fertilizers.

3. Develop the transportation and use of bulk fertilizer and also re-use of bags (if not already established, to yield a savings of the order of $3[illegible],000 annually).

4. Determine the most desirable mixed fertilizers to be produced for use in Cyprus and develop a corresponding farmer education program.

3. Cyprus: Its Economy and Agriculture

3.1 General

Cyprus is the third largest island in the Mediterranean and has an area of 3,572 square miles. It lies 44 miles south of Turkey, 530 miles east of Greece, 60 miles west of Syria and 240 miles north of the United Arab Republic. The landscape is dominated by the Troodos Mountains in the southwest and the Kyrenia range along the northern coast, with the central plain of Mesaoria lying between these ranges. The climate is beneficial; summers are hot and dry, and winters are mild. Average annual temperature is 6[illegible]°F., and average annual rainfall is 19.8 inches, although periodic droughts occur.

The present population is about 600,000 and the annual growth rate is approximately 1.7 percent.

3.2 The Economy

Cyprus is predominantly an agricultural nation with about half of the labor force occupied in farming. Available arable land is some 2,036 square miles, representing 2.2 acres per capita. Copper concentrates, copper and iron pyrites are the principal mineral products and these account for a significant percentage of total exports. Other exports include potatoes, citrus fruits, raisins and carobs.

Following independence, Cyprus remained in the Sterling Bloc and joined the Commonwealth. It became a member of the United Nations in 1960 and is also a member of the International Monetary Fund and the International Bank for Reconstruction and Development. The Cyprus pound is stable, even though imports have been more than twice as much as exports in recent years. (A sound domestic manufacturing fertilizer program will be of great help in reducing imports of fertilizer and food, increasing food exports, and in minimizing this imbalance.) In 1964, the average per-capita income was about C£ 212 ([illegible]) annually (1 Cyprus pound = 1,000 mills = $.S. $2.80).

The year 1965 was one of considerable economic progress. Gross national product increased by about 20 percent over 1964 and gross domestic product rose to C£ 130 million ($ 364 million) of which agriculture, forestry and fishing contributed 29 percent. Imports accounted for C£ 44 million ($ 123 million) and exports contributed only C£ 24 million ($67 million) to give a trade gap of C£ 20 million ($6? million). However, this was more than offset by net invisible earnings of C£ 23 million (66. million) due to [redacted] military expenditures and a net inflow of miscellaneous capital of C£ 8 million (22.4 million). This resulted in a favorable balance of payments of about C£ 9 million and Cyprus foreign exchange reserves attained the level of C£ 46.8 million ($131 million).

Wheat and barley production nearly doubled between 1964 and 1965, while exports of citrus fruits, potatoes, carrots, grapes and olives increased substantially.

Mining production of asbestos, chrome, cement copper, cuprous concentrates, copper and iron pyrites increased by 50 to 100 percent in some cases. Mineral export earnings in 1965 amounted to C£ 9.2 million ($26 million) compared to C£ 7.1 million ($20 million) in 1964; this increase was due to increased tonnages, as well as higher sales prices. Mining and minerals beneficiation are the most important industrial operations and are currently undertaken by three companies, which mine and concentrate copper and iron pyrites for export. These are, the Cyprus Mining Corporation which has 60 percent of the business, the Hellenic Company and the Limni Company which have 25 percent and 15 percent respectively of the total mineral export trade.

Other industries include fruit canning, beer making and fruit juice production. Two thermal power stations are in operation; one near Larnaca of 70 MW capacity and another 90 MW plant near Limassol. A projected oil refinery of 5,000 barrels per day near Larnaca is under consideration by the Shell and Mobil oil companies.

3.3 Agriculture

3.3.1 The Soil

All Cyprus soils are deficient in Nitrogen and Phosphorus; hence, regular applications of fertilizers containing these elements are essential for satisfactory crop production.

At present, adequate amounts of Potassium occur in many areas, except in hilly or mountain regions. In time, Potassium and secondary or micronutrients will have to be added to other soils, to replace those elements removed by regular cropping.

3.3.2 Crops

The 1965 crop pattern for Cyprus is shown on the following Table (Table 3.3.2.1)

TABLE 3.3.2.1

1965 CROP PATTERN FOR CYPRUS

CROP TYPE	AREA (DONUMS)	PRODUCTION (METRIC TONS)	C £ VALUE AT PRODUCERS PRICES
Vegetables	129,585	256,070	6,470,656
Citrus Fruits	-	-	3,013,500
Deciduous Fruits	590,000	6,920	662,720
Other Fruits	625,995	3,450	225,784
Almonds	195,000	3,230	335,920
Other Nuts	105,420	335	46,870
Cereals	1,076,200	226,950	7,107,592
Legumes & Fodder	56,100	7,400	276,880
Industrial	49,970	2,930	835,696
Aromatics	240	37	8,431
Carobs & Olives	4,760,000	65,300	3,510,600
Grapes	-	125,000	2,290,000
TOTAL	7,588,510	697,622	24,784,649

Detailed figures for 1965 are given in Appendix 1. Crop areas for the years 1960 to 1965 are shown in Appendix 2.

3.3.3 Agricultural and Food Balance

Nearly half of Cyprus is arable and under permanent cultivation. In 1964, agricultural exports amounted to approximately C£8.6 million ($24 million) representing 48 percent of total exports. These exports consisted of oranges and potatoes (approximately C£2.13 million ($5.9 million) each; plus barley, lemons, grapefruit, grapes, almonds, carrots, carobs and others.

However, food imports in 1964 amounted to C£7.5 million ($21 million) equivalent to 20 percent of the total. Vegetable oils from various European countries, maize from Roumania, U.S.A. and Lebanon, and soybean meal from Israel and Belgium were typical examples. Hence, there are opportunities for foreign-exchange savings to be made by increased agricultural production with the help of additional fertilizer applications.

4. FERTILIZER USE AND NEEDS

4.1 Consumption

At present, all fertilizer materials are imported, and recent consumption figures are given below:

TABLE 4.1.1

RECENT FERTILIZER CONSUMPTION IN CYPRUS (MT OF MATERIAL)

Type of Fertilizer	1962	1963	1964	1965
Ammonium Sulfate	22,158	25,736	15,335	20,024
Calcium Ammonium Nitrate	9,447	17,745	11,260	12,147
Single Superphosphate	34,140 (Single and Triple combined)	37,083	29,560	28,589
Triple Superphosphate		3,455	2,221	4,543
Potash	475	356	386	205
[illegible]-11-0	15,954 ([illegible]-11-0 and 6-8-[illegible] combined)	11,371	13,655	12,696
6-8-[illegible]		12,229	7,573	2,440
TOTAL	82,174	107,975	79,990	80,653

In terms of primary nutrients, the 1962 to 1965 usage was as follows:

TABLE 4.1.2

CYPRUS APPROXIMATE PRIMARY NUTRIENT CONSUMPTION FOR 1962 to 1965

	1962	1963	1964	1965
N	7,600	10,500	6,000	7,700
P_2O_5	9,100	11,300	9,100	9,400
K_2O	890	1,000	600	200
TOTAL	17,590	22,800	15,700	17,300

4.2 Projected Needs

According to the Food and Agricultural Organization of the United Nations, the utilization of fertilizers per hectare of arable land under permanent crops is comparable to that in U.S.A., (about 40 kilograms of $N + P_2O_5 + K_2O$ per hectare) with the exception of potash. However, this compares unfavorably with the usages of some other small countries and islands. FAO figures for 1956 to 1958, in terms of Kg of primary nutrients per hectare are: Taiwan 160; United Kingdom 140; Japan 260 and Netherlands 440.

Ideal rates of fertilizer application are much greater than actual usage, not only in Cyprus, but in many parts of the world, based on agronomic considerations. Recommended application rates for Cyprus are given in Appendix 3, which are 2 to 3 times actual consumption in some instances. During the past few years, fertilizer usage has not grown significantly, as seen in Table 4.1.2. But, taking into account several recent factors such as the expansion of newly irrigated land and an anticipated reduction of nitrogen fertilizer prices (especially urea) it is believed that annual growth-rates for nitrogen and phosphorus primary nutrients will be at least 5 percent and 4 percent respectively during the next few years. A probable reduction in potash prices should also induce additional use and a growth rate for K_2O of 5 percent annually will be assumed. On these bases, the projected needs will be:

TABLE 4.2.1

PROJECTED PRIMARY NUTRIENT NEEDS FOR CYPRUS

Metric Tons

YEAR	N	P_2O_5	K_2O
1965	7,700	9,400	200
1966	8,100	9,800	210
1967	8,500	10,200	220
1968	9,000	10,600	230
1969	9,400	11,000	240
1970	9,900	11,400	250
1971	10,400	11,900	260

5. Domestic Fertilizer Production Considerations

5.1 General

It is evident from Tables 4.1.1, 4.1.2 and 4.2.1 that current and future fertilizer needs in Cyprus are relatively small. All requirements are presently imported and the possibility of domestic production must be carefully weighed in terms of feasibility and effects on the economy of the country. Major considerations are reviewed below.

5.2 Nitrogen Fertilizers

Virtually all nitrogen fertilizers in the world are now made from ammonia, with the exception of small tonnages of Chilean sodium nitrate. A minimum practical size of ammonia plant is considered to be about 60 tons per day of ammonia (NH_3) or 50 tons per day of N, equivalent to 17,500 tons of N annually on a 350 day-per-year basis. This capacity is still greatly in excess of Cyprus needs, yet corresponding manufacturing costs would be uneconomic by present standards as present-day plants are mostly in the 1,000 ton per day category. (Feedstock for ammonia production is preferably natural gas, followed by petroleum refinery gas and/or naphtha). So far, no commercial quantities of natural gas in Cyprus are known, and although some petroleum refinery gas and liquid feedstocks might eventually become available from the envisaged refinery near Larnaca, it is doubtful if ammonia produced from these sources or from imported naphtha could ever compete with ammonia soon to be available from large plants in North Africa, based on low-cost natural gas.

Hence, proximity to large sources of reasonably-priced ammonia and derivatives such as urea and ammonium nitrate should be more advantageous than small-scale domestic production from higher-cost feedstock, especially under anticipated conditions of plentiful supplies and reduced prices. For these reasons domestic production of ammonia, ammonium nitrate and urea does not appear to be justified at the present time, and the continued importation of such products is recommended. It should be added that capital outlays for nitrogen fertilizer plants, even of modest size, are in the 15 to 20 million dollar category, and domestic requirements do not justify expenditures of this magnitude. A possible exception is the production of ammonium sulfate made from imported ammonia and locally-made sulfuric acid, which will be reviewed in a later section.

5.3 Phosphate Fertilizers

5.3.1 General

With the exception of special products such as bone meal, virtually all phosphate fertilizers are derived from phosphate rock. No commercial sources of phosphate rock on Cyprus are known, but proximity to large deposits in Morocco, Algeria, Tunis, Egypt and Israel enable rock imports to be obtained at competitive prices. Phosphate rock is also available from Florida, U.S.A.

In several of these countries, manufacture of phosphate fertilizers is also undertaken for both domestic and export purposes. This raises the question whether--like nitrogen materials--phosphate fertilizers should also be imported in preference to domestic manufacture? However, to produce phosphate fertilizers from phosphate rock, the latter must be solubilized and the usual agent is sulfuric acid. The availability of ample supplies of pyrites in Cyprus, therefore, emphasizes the possibilities of domestic phosphate production provided the scale of operations and economics justify a commercial operation.

5.3.2. Scale of Operations

The domestic P_2O_5 demand is relatively small by modern standards and ranges from about 10,000 to 12,000 metric tons between 1966 to 1971; i.e., 33 to 40 tons per day ultimately, on a 300 day-per-year basis. This is equivalent to 200 tons per day of superphosphate containing 20 percent P_2O_5 or 250 tons of super containing 16 percent P_2O_5. (In U.S.A. and other countries, many plants are ten to twenty times this size in terms of P_2O_5 output). As a result, manufacturing costs can be expected to be correspondingly higher than for fertilizers made in large, modern installations. One way of offsetting this disadvantage to some degree might be to make fertilizer materials for export, in addition to domestic needs, if advantageous price-levels could be attained and suitable markets found and this possibility will be examined in a subsequent section.

5.3.3 Possible Alternate Types of Phosphate Fertilizer

The following types of phosphate fertilizer are in commercial use ranging from the oldest and simplest to the most modern and complex:

No.	Type	N%		Typical Analysis P_2O_5%		K_2O%	
1	Ground Phosphate Rock	0	-	30 to 37	-	0	
2	Single Superphosphate	0	-	16 to 20	-	0	
3	Ammoniated Superphosphate	4	-	18	-	0	
4	Triple Superphosphate (TSP)	0	-	46 to 49	-	0	
5	Ammoniated TSP	6	-	45	-	0	
6	Ammonium Phosphate	11 to 18	-	46 to 48	-	0	
7	Nitrophosphates	20	-	20	-	0	
8	Calcium Metaphosphates	0	-	64	-	0	
9	Potassium Metaphosphates	0	-	56	-	31	
10	Ammonium Polyphosphates	10	-	34	-	0	(Liquid)

The most popular types throughout the world are single superphosphate, triple superphosphate, diammonium phosphate (18-46-0) and various nitrophosphates. Where ammonia is available, ammoniated superphosphates are often produced, and potash is frequently added to make wide ranges of low, or medium-analysis mixed and granulated fertilizers. Ground rock is used on an appreciable scale in localities where soils are sufficiently acidic to solubilize the phosphate (e.g., North-Central U.S.A., Malaysia).

The metaphosphates, although attractive as regards their nutrient contents, are produced only in a few special cases because of technical and cost considerations. The ammonium polyphosphates are relatively new materials and are mostly produced in liquid form to supplement existing markets in countries having established distribution networks and equipment for liquid fertilizers.

[illegible] <u>Selection of Proposed Products and Processes</u>

In selecting the most suitable alternate products and processes for further study and ultimate recommendation, several factors must be considered. These include:

- Agronomic suitability and present usage pattern
- Raw material availability and costs
- Scale of operations
- Economic plant-size and capital costs
- Flexibility of product range and capacity
- Complexity
- Manufacturing costs
- Obsolescence

For domestic production and use in Cyprus, careful consideration of the above items indicates the best choice of fertilizers to be (1) the superphosphates and (2) granulated mixtures based on superphosphates made with the aid of imported ammonia and/or nitrogen salts plus imported potash according to need.

Another important factor is acceptability. Most farmers throughout the world are reluctant to use unfamiliar fertilizers and since superphosphates are well-established in Cyprus, no market resistance should arise. From Table 4.1.1 it will be seen that both single and triple superphosphates are used, which has raised the possibility of producing high-analysis triple superphosphate (0-48-0) instead of the lower-analysis single superphosphate. Accordingly, both types of product will be compared, to establish the preferred route.

6. PRINCIPAL PROCESS AND PLANT DETAILS

6.1 Single Superphosphate - Process Calculations

6.1.1 General

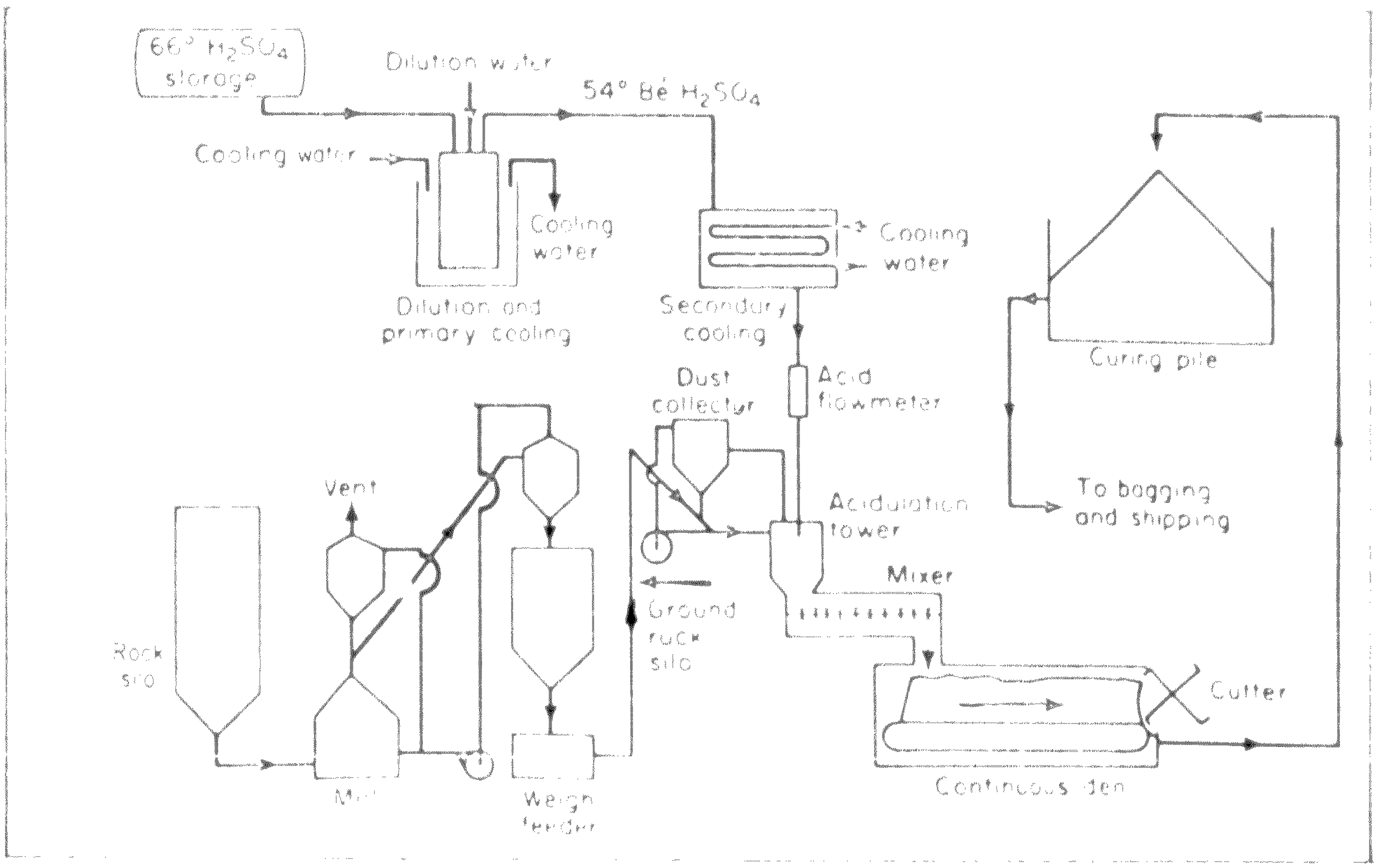
Single or normal superphosphate is made by reacting ground phosphate rock with strong sulfuric acid. Part of the calcium in the rock is transformed into monocalcium phosphate and the remainder forms gypsum. Calcium fluoride in the rock also reacts with the sulfuric acid to form hydrogen fluoride, some of which reacts with the silica and water present to yield hydrofluosilicia acid and hydrated silica. The remainder escapes as a gaseous mixtures of HF and SiF_4 which is usually scrubbed with water before being released to the atmosphere. The empirical reactions are:

$$3\left[Ca_3(PO_4)_2\right]CaF_2 + 7H_2SO_4 \rightarrow 3Ca(H_2PO_4)_2 + 7CaSO_4 + 2HF \qquad (1)$$

$$4HF + SiO_2 \rightarrow SiF_4 + 2H_2O \qquad (2)$$

$$3SiF_4 + 4H_2O \rightarrow SiO_2.2H_2O + 2H_2SiF_6 \qquad (3)$$

When suitable markets exist, the hydrofluosilicic acid can be concentrated to a 16 percent solution by recycling the scrubber water and used to make detergents, insecticides and ceramic materials.



Continuous process for the manufacture of normal superphosphate (Van Wazer, *Phosphorus and Its Compounds, Vol. II Interscience*)

Fig. 1

(Equipment also suitable for triple superphosphate if phosphoric acid is used instead of sulfuric acid).

[illegible].1. Size of Plant

From Table 4.[illegible].1, it will be seen that the annual P_2O_5 domestic requirement ranges from a current need of about 1[illegible],[illegible] metric tons to approximately 12,000 tons in 1[illegible]1. These are relatively small demands and the additional capital cost needed to provide spare capacity for a probable post-1[illegible]1 increase will be modest. Accordingly, a design capacity of 15,000 metric tons of P_2O_5 annually will be used as a basis.

Single superphosphate plants can be started and shut down without difficulty and in many cases, are not operated during the slackest months. Accordingly, a 300-day operating year will be assumed which corresponds to a maximum net production capacity

$$\frac{15,000}{300} \quad \text{or} \quad 50 \text{ tons } P_2O_5 \text{ per day}$$

On the basis of [illegible] percent total P_2O_5 in the product plus 10 percent allowance for losses and contingencies, the daily output rating will therefore be:

$$\frac{50 \times 1.1}{[illegible]} = [illegible] \text{ metric tons maximum capacity per 24-hour day}$$

If lower grade phosphate rock is more economic to procure than higher grade phosphate rock, this will result in the production of superphosphate containing 16 percent P_2O_5 and the capacity will be

$$\frac{50 \times 1.1}{0.16} = 345 \text{ metric tons of superphosphate}$$

Time must be allowed for cleaning and repairs, and a 16-hour operating day is often adopted. On this basis, the hourly production rate of the envisaged plant at design capacity would be:

$\frac{275}{16}$ or 17.3 metric tons per hour

6.1.3 Raw Material Requirements

Phosphate Rock

The amount of phosphate rock required per ton of single superphosphate depends on the grade or rock used. For example, if it were desired to make a product containing 20 percent total P_2O_5, this would be equivalent to (2204 X 0.2) or 441 lbs. P_2O_5 per metric ton of single super. If the phosphate rock of high-grade were used, say 74 BPL (Bone Phosphate of Lime) containing about 34 percent P_2O_5, the amount of rock needed per ton of product would be:

$\frac{441}{0.34}$ or 1,350 lbs., say, allowing for a light loss in grinding and processing. Proportionately greater amounts of lower-grade rocks would be required.

Sulfuric Acid

Sulfuric acid requirements vary somewhat, according to the type and source of rock used, and usually range between 60 to 65 lbs. of 100 percent H_2SO_4 per 100 lbs. of rock. On the latter basis, the acid requirements for a 74 BPL rock would theorectically be:

$\frac{1350 \times 65}{100}$ or 880 lbs. 100% H_2SO_4

Water

The sulfuric acid is diluted to about 70 percent concentration (approximately 55°Bé) before use. 380 lbs. or [illegible] imperial gallons are theoretically required for this purpose per ton of product. The acid is diluted before being added to the rock and much heat is evolved in this operation, which is removed by cooling with water in a special type of heat exchanger. The amount of cooling water needed depends on the design of the exchanger and the inlet water temperature, but can range between 1,000 and 2,000 gallons per ton of product. Water used for dilution purposes needs to be relatively pure and low in chlorides. River water is suitable for cooling and even sea water can be employed, provided suitable materials of construction have been used in fabricating the cooler.

Thus, typical raw material requirements per metric ton of single superphosphate can be expressed approximately as:

	Quantity	Ton per Ton
Phosphate Rock (say 74% BPL)	1,350 lbs.	.61
Sulfuric Acid (100% H_2SO_4)	880 lbs.	0.40
Process Water (for dilution and reaction)	380 lbs.	0.17
		1.1[illegible]

Annual Needs

To produce an annual quantity of (15,000) or 75,000 tons of single superphosphate, the yearly rock needs would therefore be approximately:

75,000 x 0.61 or 46,000 metric tons

The yearly 100 percent sulfuric acid needs would be:

75,000 x 0.40 or 30,000 metric tons

On the basis of 300 operating days, the theoretical minimum design rating of the sulfuric acid plant would therefore be:

$\frac{30,000}{300}$ or 100 metric tons per 24 hours

It is highly probable that other uses for sulfuric acid exist in Cyprus, as it is commonly regarded as the backbone of most industrial and commercial operations. In many countries, the total usage is about twice the amount used to make fertilizers. Even in Cyprus, the possibility of making ammonium sulfate fertilizer from imported ammonia exists and perhaps alum for water-treatment purposes as well as other chemicals. Sulfur dioxide for fumigants and battery acids are other typical examples.

Therefore, it is recommended that the size of the proposed sulfuric acid plant be finally chosen after other potential needs in Cyprus have been examined. A larger production volume should result in lower acid costs with benefits to all. In the meantime, calculations will be based on a daily capacity of 110 metric tons to allow for small losses and contingencies.

7. PRINCIPAL DESIGN DETAILS

7.1 General

A complete fertilizer plant based on single superphosphate usually contains the following sections:

Section Number	Description
100	Phosphate Rock Handling, Storage and Grinding
200	Superphosphate Manufacture
300	Granulating and/or Bagging and Shipping
400	Sulfuric Acid Manufacture
500	Offsites, Ancillary Services and Buildings

Basic design features of the various sections in the envisaged plant will be on the following lines. It will be assumed at this stage, that the plant will be built adjacent to deep water, to minimize transportation costs for phosphate rock and ammonia, as well as any exports that might later be developed. A further study will be necessary, however, to determine the optimum location.

7.2 Section 100: Phosphate Rock Handling, Storage and Grinding

Phosphate Rock Handling and Storage

Ground phosphate rock is received via coastal steamers or ocean-going vessels in the 2,000 to 10,000 ton category and unloaded by grabs to a conveyor-elevator system which transfers the material to a steel-framed, asbestos covered storage building.

Since annual maximum P_2O_5 needs at design capacity are 15,000 tons, corresponding to about 50,000 tons of rock per year, a practical delivery schedule would be of the order of ten, 5,000-ton cargoes each year. Therefore, a storage building having a capacity of about 8,000 tons is required.

Phosphate rock is retrieved from the storage pile by a mobile, front-end bucket loader and dumped into the boot of an elevator which feeds the hopper of the rock-grinding mill.

Phosphate Rock Grinding

The rock is ground to a suitable fineness (about 70% through a 100-mesh Tyler screen) in a ring-roller mill fitted with an air classifying system. Since the single superphosphate production rate at design capacity is 17.3 metric tons per hour, this corresponds to (17.3 X 0.59) or 10.2 metric tons of rock per hour, for a 16-hour operating day. After grinding, the rock is conveyed from the product cyclone to a ground rock storage bin, ready for use in the superphosphate unit. A closed air-system and bag filter ensures virtually dustless operation to prevent pollution of the surrounding air.

7. Section 200: Single Superphosphate Production

Concentrated sulfuric acid is diluted with water in a cooler made of graphite or other suitable material and stored in a small holding-tank. The quantity of concentrated acid needed per hour is (17.3 X 0.4 or 7 metric tons, say per 16-hour operating day. Phosphate rock is conveyed from the feed hopper via a continuous feeding-weighing mechanism and combined with the correct amount of diluted acid in a continuous mixer and the resulting slurry is slowly conveyed through a tunnel or "den" by means of a slotted belt.

While in the den, the slurry hardens and after emerging is disintegrated by rotating cutter blades. The powdered material is conveyed to a storage building and is allowed to cool and cure for several weeks, during which time some free-moisture is given off and the reaction proceeds to near-completion. On the basis of a 6-day operating week and a daily output of 275 metric tons, a 6-week curing and storage capacity would be equivalent to (275 X 6 X 6) or nearly 10,000 tons. [illegible]

Fume Abatement and Fluorine Recovery

Vapors from the mixer and den are conveyed by a plastic duct and fan system to a scrubbing tower, and washed with water before being released to atmosphere, in order to prevent pollution of the surrounding countryside by toxic fluorine compounds. Should the plant be located on tidal water, the liquid effluent can most probably be discharged directly to the sea or river. If the plant were to be located inland, the scrubber effluent may have to be treated with lime before being sent to the sewer or a local stream.

By recycling the scrubber water, it is usually possible to build up the concentration of hydrofluosilicic acid to at least 15%.

The hydrated silica present can be separated by clarification and the liquor used to produce sodium or potassium fluosilicate, if such products can find local markets for pesticide, ceramic or detergent manufacture.

Section 300: Granulating and/or Bagging and Shipping

Bagging and Shipping Only

After curing, the single superphosphate is recovered from the storage pile by a front-end loader and delivered to the hopper of an elevator which conveys the material to a vibrating screen. Oversize is crushed in a small disintegrator and returned to the feed hopper. Undersized superphosphate falls into the feed hopper of a bagging machine. Assuming 80-lb. paper or plastic bags will be used, the maximum bagging rate will be:

$$\frac{275 \text{ tons}}{16 \text{ hours}} \times \frac{2204}{80} \quad \text{or 475 bags per hour}$$

i.e., 8 bags per minute of screened, run-of-pile product

Although one machine of appropriate design is fully capable of this output, to avoid delays due to occasional breakdown and to provide flexibility regarding working hours, smaller bag sizes and the possibility of producing more than one product, two bagging machines of eight, 80-lb bags per minute are recommended. Preference is for valve-type plastic bags which require no sewing and are dustless and rot-proof.

If sewn paper bags were to be used, then two suitable closing machines would also be required.

A small storage space for new bags and a storage building or annex for about 3 day's bagged production, i.e., large enough to hold about 900 tons of bagged material, plus a truck-loading conveyor and platform will complete the section.

Granulated, Mixed Fertilizer Production

Modern fertilizer preference is for granulated mixtures which are formulated to suit specific soils and crops, according to recommendations by qualified agronomists and the experience of skilled farmers. Granulated material is easier to store, ship and apply; losses due to dusting and windage are lower than for powdered fertilizer, and better agronomic control can be achieved. For these reasons, the production and use of carefully formulated, granular N-P and N-P-K fertilizers in Cyprus is recommended as a superior alternative to 0-P-0 screened, run-of-pile single superphosphate applied alone, or in conjunction with separate nitrogen (and sometimes potassium) materials.

To make granulated fertilizer, solid ammonium sulfate is ground to about 30 mesh (Tyler) and mixed with the appropriate weight of single superphosphate (and potash, if required). Smaller plants use batch weighing and mixing; in larger ones, these operations are often continuous. The mixture is conveyed to a rotary drum and mixed with a little water, plus recycled fine material. Under the proper operating conditions the damp mass will be transformed into granules, which are dried and screened. Undersized, fine material is recycled to the granulator; oversized particles are crushed and recycled. Granules within the required size-range are conveyed to storage, for ultimate bagging and sale.

Ammonium Sulfate Production in Situ

At this time, it is not possible to predict the various grades of fertilizer that will be needed - this is the prerogative of the Cyprus agronomists and farmers. However, as a general guide, the 1965 average product analysis and product ratios, according to Tables 4.1.1 and 4.1.2 were:

$$N = \frac{7,700}{80,653} \quad \text{or} \quad 9.55\%$$

$$P_2O_5 = \frac{9,400}{80,653} \quad \text{or} \quad 11.65\%$$

$$K_2O = \frac{200}{80,653} \quad \text{or} \quad 0.25\%$$

This corresponds to a typical average product grade of 10-12-0.3. The corresponding Nutrient Ratio = 1:1.22:0.03.

One or two mixed fertilizers in current use include:

7-11-0
6-8-8

One practical way of making largely water-soluble, low-analysis grades of this type is to make ammonium sulfate "in situ" by ammoniating sulfuric acid in the rotary granulator. In this method, sulfuric acid and anhydrous ammonia are introduced via separate distributor pipes mounted below the surface of the moving material in the drum. Water is added to assist granulation and to provide evaporative cooling. (In some cases, part of the ammoniation and cooling by dilution can be undertaken in a pre-neutralizing vessel prior to addition of this solution to the granulator, according to preference and plant design.)

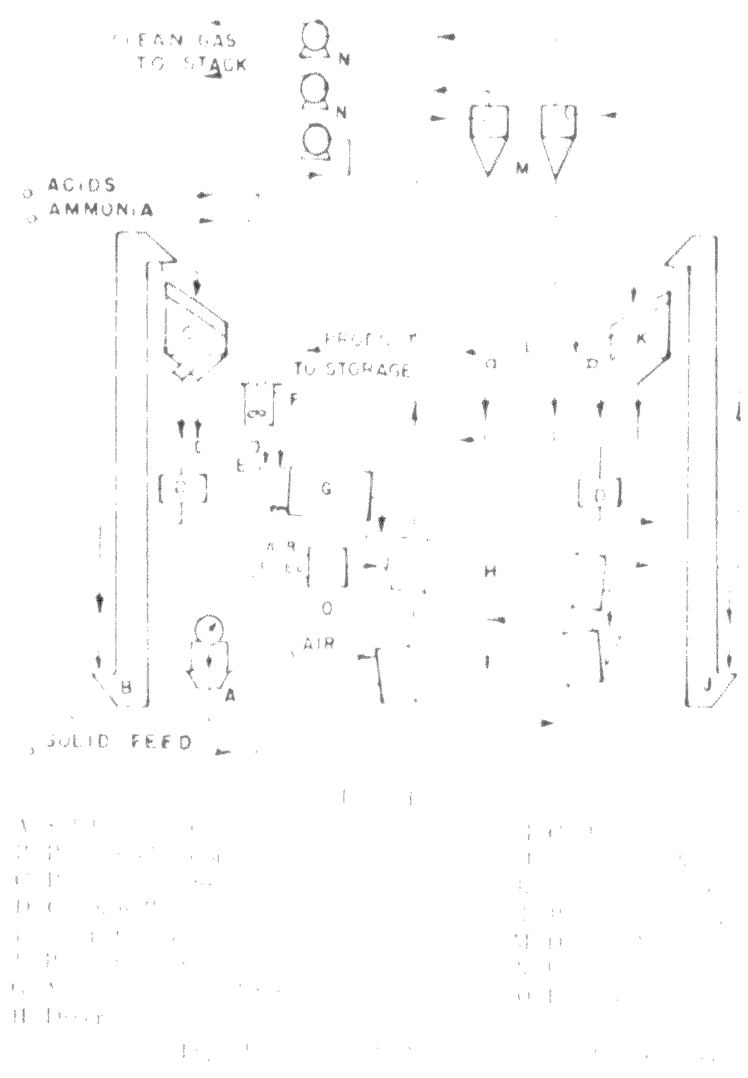


Fig 2

Should some solid ammonium sulfate be required for direct application or for export, this can be made in a separate unit, as described in Section of this report.

Raw Material Requirements

If all the nitrogen needs were to be furnished in the form of in-situ ammonium sulfate, corresponding raw material requirements can be approximately calculated as follows:

Assume average grade to be 10-12-1 during the next few years. The maximum P_2O_5 capacity has previously been established as 15,000 tons per year. Hence, the corresponding maximum nitrogen need will be 15,000 X 10/12 or 12,500 tons.

This is equivalent to:

$$\frac{12{,}500}{0.21} \text{ or } 60{,}000 \text{ tons per year of ammonium sulfate}$$

In turn, this would require:

60,000 X 34/132 or 15,500 tons of ammonia

and 60,000 X 98/132 or 44,700 tons of 100% sulfuric acid

On a 300 day per operating year basis, this is equivalent to 51 tons of anhydrous ammonia per day and 149 tons of 100% sulfuric acid per day at maximum plant output.

This extra sulfuric acid requirement would increase maximum total needs to:

	Metric Tons Per Day
For Single Superphosphate Production	110 tons
For Ammonium Sulfate Production	149 tons
	259 tons

On the assumption that a growing local demand already exists for sulfuric acid in Cyprus, a 300 ton per day unit will be used for cost calculation purposes.

Ammoniated Superphosphate Manufacture

Subject to agronomic suitability, it is possible to add nitrogen to a superphosphate-type fertilizer by the direct absorption of ammonia. In this way, less sulfuric acid is needed, although it must be mentioned that the water-solubility of the product is reduced, as dicalcium phosphate is formed as a result of ammoniation.

In practice, gaseous, anhydrous ammonia is mixed with cured single superphosphate in the rotary drum-granulator. The gas enters via sparger pipes located well below the surface of the rolling solids and quickly reacts with the superphosphate. It is customary to ammoniate to the extent of about 4 lbs. of ammonia per 22 lbs. of P_2O_5. Thus, one metric ton of single superphosphate containing some 440 lbs. P_2O_5 would need 80 lbs. of NH_3 for ammoniation. On an annual basis, 75,000 tons of single superphosphate would thus take up $\left(\frac{75,000 \times 80}{2200}\right)$ or 2,730 tons of anhydrous ammonia. In turn, this corresponds to

$2730 \times \frac{44,700}{15,500}$ or 7,900 tons of 100% H_2SO_4

or, about 2,600 tons of sulfur

or, approximately 6,500 tons of pyrites containing 40 percent sulfur

If ammoniation of single superphosphate on the above lines is acceptable to Cyprus agronomists and farmers, it is recommended that this method be used, together with the simultaneous production of ammoniation "in situ", as product costs will be correspondingly reduced. However, it is not recommended that the proposed size of the sulfuric acid plant be reduced accordingly. The incremental capital cost saving would be small, and countries contemplating further industrial development such as Cyprus must have ample sulfuric acid capacity to meet their growing needs.

7.5 Section 400: Sulfuric Acid Manufacture from Pyrites

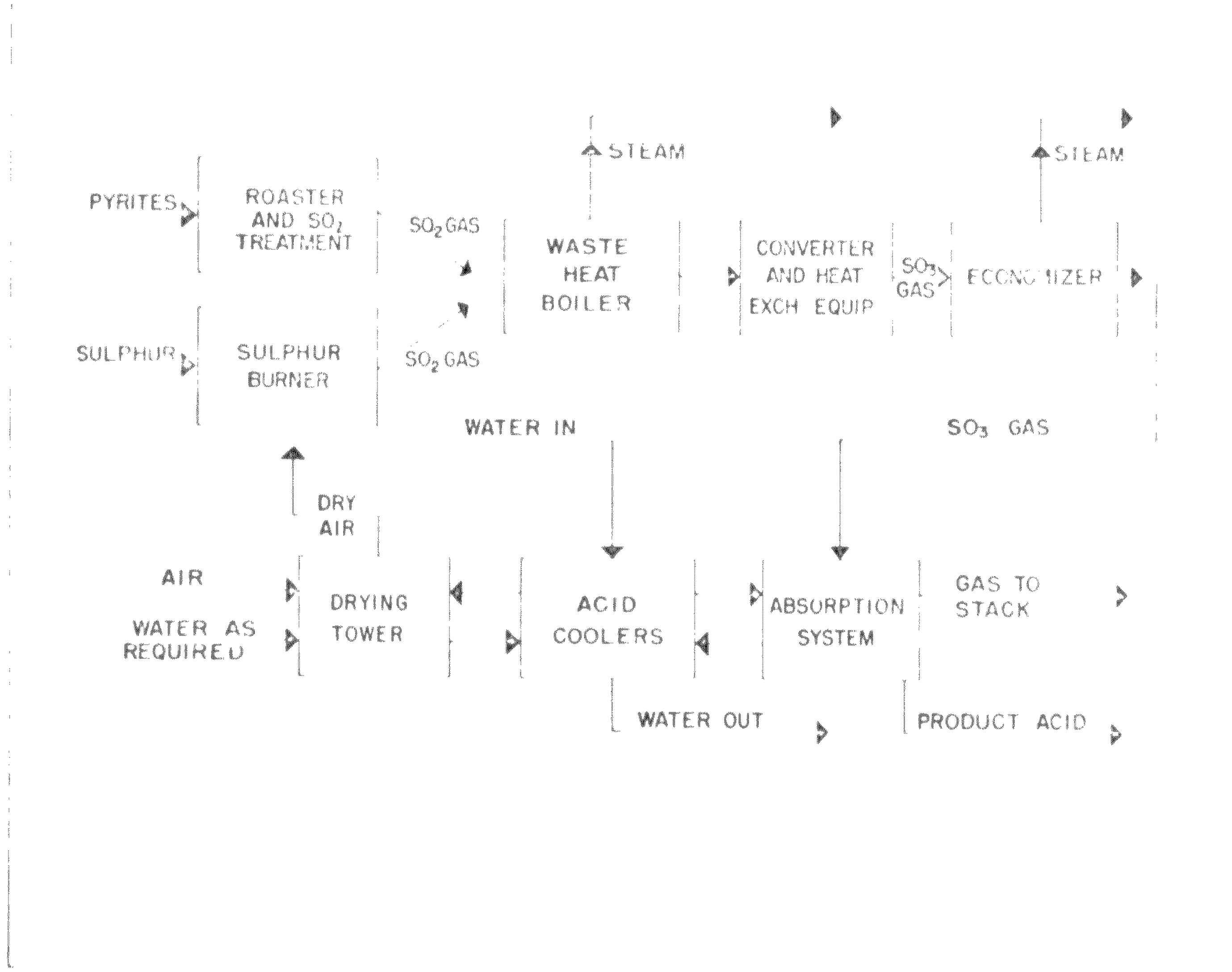
General

In this process, iron pyrites, FeS, is roasted with air to produce sulfur dioxide and iron oxide. The SO_2 is oxidized to SO_3 and absorbed in water to form sulfuric acid. The Fe_2O_3 or "pyrites cinder" is either sold for iron and steel manufacture, or stockpiled for future use or discarded, according to circumstances. For the envisaged Cyprus project it is proposed to stockpile the cinder for future purposes, at a site adjacent to the fertilizer plant.

It will be assumed that a suitable feed of pyrites will be constantly available from local mines. Modern pyrites roasters and associated sulfuric acid plants are flexible as regards the gradeof raw material used and can usually operate with SO_2 concentrations as low as 3 to 4 percent. Hence, low-grade ores can be used when locally obtainable, leaving the higher-grade material for export. Of course, arsenic and other impurities which act as catalyst poisons should be as low as possible. Normally, mill "concentrates" do not need to be ground, but run-of-mine material usually needs screening and crushing to below 6 mm (3 mesh, Tyler).

Minimum Reserves of Pyrites Required

For single superphosphate manufacture only, annual sulfuric acid requirements are 30,000 metric tons, corresponding to about 10,000 tons of sulfur or 25,000 tons of pyrites concentrates on a 40 percent S basis. If the original ore were to contain about 18 percent S, the annual need would be nearly 60,000 tons. Since a



Flow diagram of the contact sulphuric acid process. Either elemental sulphur or pyrites may be used as the raw material to produce sulphur dioxide. (*Adapted from Duecker and West, The Manufacture of Sulphuric Acid, Reinhold.*)

Fig. 3

15 year life would normally be required, this would correspond to a minimum reserve of about 1 million metric tons.

To produce sufficient sulfuric acid for the ammonium sulfate required as well, (assuming all the nitrogen requirements were produced in this form) the calculations for Section 300 show that the additional acid needed is in the ratio of 149:110 or 1.35. Hence, an additional minimum reserve of 1.35 million tons of pyrites would be required, to make a total of about 2[illegible] million tons of recoverable 16 to 18 percent [illegible], [illegible] equivalent.

Sulfuric Acid Production

Pyrites Roasting

Two principal types of equipment are used to roast pyrites (and other sulfur-containing ores). These are; the multiple-hearth furnace and the fluidized-bed or "turbulent-layer" furnace. The former consists of several circular hearths mounted vertically above each other and provided with rotating arms or rabbles. Ore is fed to the top hearth and gradually descends to successively lower beds; the sulfur is burnt to SO_2 and iron-oxide cinder is discharged from the lowest hearth, before being quenched and stockpiled. The sulfur-containing gases pass to a waste-heat boiler and scrubbing system prior to oxidation, to remove dust and harmful impurities. The oxidation reaction is exothermic and supplies sufficient heat for roasting; in fact, some furnaces include coils for cooling and steam-raising purposes.

The fluidized-bed furnace in its simplest form is a large cylindrical chamber divided into upper and lower compartments by a perforated plate through which air is blown to fluidize the charge and oxidize the sulfur present. Fresh pyrites is continually added to the roasting material above the perforated plate, which is often fitted with water coils for temperature-regulation and steam-raising purposes. The hot, sulfur-containing gases pass via a waste-heat boiler to a cyclone to remove fine cinder, which is discharged together with overflow material from the fluidized bed.

Proposed Installation

Roasting

For the envisaged installation in Cyprus, it is proposed that a Fluidized-Bed type of roaster be used, because of more favorable capital and operating cost considerations. The "battery-limits" unit will include an open-air storage pile area large enough to accommodate a 60 day requirement of pyrites concentrates, i.e.,

[illegible] / 10 or about [illegible],000 tons, say.

The pyrites will be picked up by a front-end loader and dumped in the hopper of an elevator which transfers the material to a hopper mounted above a screw feeder, which conveys a controlled quantity of concentrate into the roasting chamber. The hot-sulfur-containing gas passes to a waste-heat boiler, as previously mentioned, and a cyclone unit for separation of fines, before entering the scrubbing system. The hot calcine is quenched with cold water in a large tank and later conveyed to a nearby cinder stockpile.

Scrubbing (typical)

The sulfur-containing gas leaving the roaster cyclone enters a multi-stage electrostatic dust precipitator and then passes through a humidifying tower and a packed cooling tower; both irrigated with weak sulfuric acid. The partially-cleaned gas then passes to a series of wet electrostatic precipitators to remove acid mist, before entering a drying tower fed with [illegible] to 99% sulfuric acid, to prevent subsequen[illegible] corrosion.

SO_2 Conversion and Hydration

The dry SO_2 gas is drawn through the preceding scrubbing units by a large blower, which sends it under positive pressure to a converter-heat exchanger system. Converters are towers containing several beds of vanadium pentoxide catalyst interposed with heat-exchangers. Incoming gas is first brought to the required temperature in one exchanger by means of hot, partially converted gas, since the oxidation of SO_2 to SO_3 is strongly exothermic, and then passed through a similar series of catalyst beds and exchangers. Additional oxidation air is drawn through a drying tower fed with concentrated sulfuric acid and added to the vapor system as required. The simplified reaction can be empirically expressed as:

$$2SO_2 + O_2 \longrightarrow$$

After leaving the last converter/heat exchanger section, the SO_3-containing gas is cooled and absorbed in recycled concentrated sulfuric acid circulating in a packed tower, to give a concentration of about 98.5 percent H_2SO_4. As additional acid is produced, it is adjusted to the desired concentration by the addition of weaker acid or water and pumped to mild-steel storage tanks. Gases leaving the hydrator-absorber should be virtually free from SO_2, SO_3 and H_2SO_4 mist, in a well-designed and operated plant.

Section 500: Offsites, Ancillary Services and Buildings

Major offsites and services that will be needed include:

- Maintenance Shop,
- Laboratory,
- Change House,
- Cafeteria,
- First Aid Room,
- Fire Protection,
- Office,
- Gatehouse and Security
- Fencing,
- Substation,
- Water Supply and Treatment
- Weighbridge,
- Factory Roads (and Railroad.)

Depending on the eventual location, a dock and/or approach roads (and possibly a railroad from the pyrites sources) may also have to be constructed, but these will not be included in the project capital-cost calculations. The layout of these offsites will largely be determined by the local conditions of the plant site, with particular emphasis on minimum material-handling costs.

Preferred buildings for fertilizer plants are steel-framed structures protected by acid-resistant paint and covered with corrugated asbestos sheeting. Occasionally, reinforced concrete is used, according to local conditions and costs. Modern fertilizer factories are mostly built on standard chemical and industrial plant principles and can be landscaped to harmonize with the surrounding area, thus bearing little resemblance to the traditionally dirty installations of former years.

8. TRIPLE SUPERPHOSPHATE MANUFACTURE

8.1 General

Appreciable quantities of triple superphosphate are presently imported by Cyprus, because the higher P_2O_5 content (approximately 4[illegible] percent) offers freight advantages compared to imported single superphosphate which has only about 20 percent P_2O_5. As a result, a review of triple superphosphate manufacture and economics has been requested for comparative purposes.

8.2 The Process

To make triple superphosphate, phosphoric acid is first produced by reacting ground phosphate rock with a mixture of sulfuric acid and phosphoric acid, followed by separating by filtration the gypsum produced, and concentrating the phosphoric acid solution from about 30 percent to 54 percent P_2O_5. The concentrated acid is then reacted with more phosphate rock in a mixer and den similar to the units used for single superphosphate manufacture, and conveyed to a curing and storage pile.

Phosphoric Acid Production

Phosphate rock containing 70 to 76 BPL (32 to 35 percent P_2O_5) is ground to about 70 percent through 200 mesh (Tyler) in a system similar to that described under Section 100 for single superphosphate manufacture and delivered by air-conveyor or other means to a feed hopper. A closely-controlled amount of ground rock is continuously fed to a multi-compartmented tank in which a hot slurry of sulfuric acid, phosphoric acid, rock and gypsum is circulated. The rock reacts with the acids to form gypsum and phosphoric acid in the following empirical manner:

$$Ca_{10}(PO_4)_6F_2 + 10\,H_2SO_4 + 20\,H_2O \longrightarrow 6H_3PO_4 + 10CaSO_4.2H_2O + 2HF$$

The slurry overflowing the reaction vessel is filtered on a multi-stage, continous vacuum machine of the tilting pan or moving-belt type and washed with hot water by counter-current displacement. The first filtrate is product-acid containing 30 to 32 percent P_2O_5; the second filtrate is recycled to the reaction vessel and helps to dissolve fresh rock; the third filtrate is used to wash the gypsum filter cake in the second stage. After thorough washing, the gypsum is dumped from the filter and usually slurried and sent to a waste pond. The product phosphoric acid is subsequently concentrated in a vacuum evaporator to about 54 percent P_2O_5 and stored in rubber-lined, steel tanks.

Triple Superphosphate Production

To make triple superphosphate, additional phosphate rock of 74 to 76 BPL (34 to 35 percent P_2O_5) is ground to a fineness of about 80 percent through 200 mesh (Tyler) and reacted with concentrated phosphoric acid in a mixer and den similar to that described in Section 200 for single superphosphate manufacture. The product is disintegrated and stored in a curing pile for several weeks, after which it is retrieved, pulverized, bagged and shipped. Alternatively, it can be used to make mixed fertilizers, in conjunction with other materials, as is done with single superphosphate. However, the greater P_2O_5 content of triple enables correspondingly higher-analysis products to be made. The empirical reaction for triple superphosphate manufacture is:

$$Ca_3(PO_4)_2 + 4H_3PO_4 + H_2O \longrightarrow 3CaH_4(PO_4)_2 \cdot 2H_2O$$

(Some fluorine-containing gases are also evolved.)

Material Requirements

Wet-Process Phosphoric Acid

If it were required to produce the planned Cyprus P_2O_5 needs (15,000 tons annual plant capacity soon after 1971) in the form of 48 percent P_2O_5 triple superphosphate, this would correspond to:

$$\frac{15,000}{0.48} \text{ or } 31,500 \text{ tons of product}$$

15,000 tons of P_2O_5 corresponds to:

$$\frac{15,000}{0.34} \text{ or } 44,000 \text{ tons of } 34\% \ P_2O_5 \ (74 \text{ BPL}) \text{ rock}$$

On the assumption of a typical weight ratio of 1 ton triple equals approximately:

40% by weight of secondary rock

60% by weight of 54% P_2O_5 acid

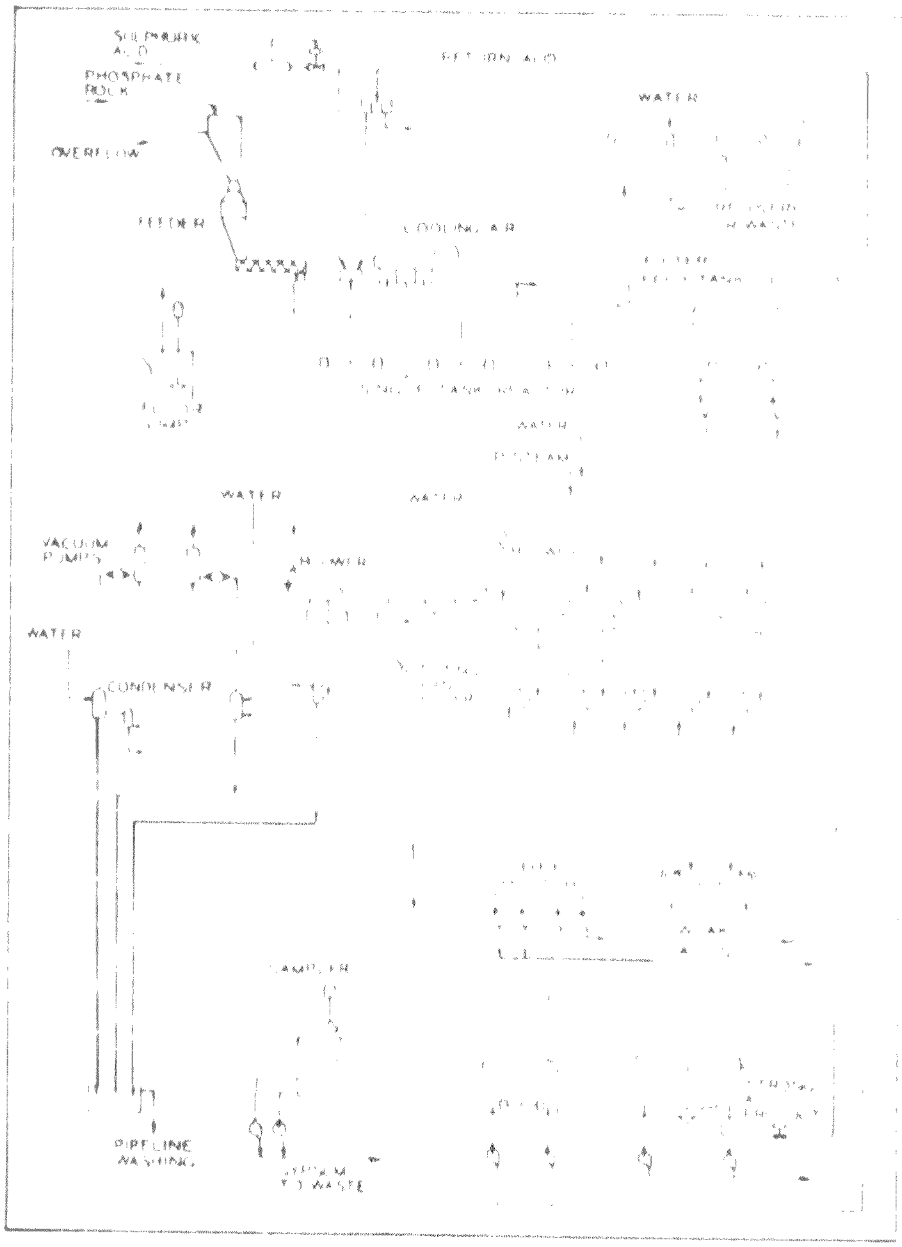


Fig 4

Single reaction tank system for the manufacture of wet process phosphoric acid making use of a tilting pan filter. (*Weber and Edwards, Developments in Phosphoric Acid Manufacture, The Fertiliser Society Proc.*)

Then 31,500 tons of triple corresponds to:

(31,500 X 0.6) or 19,000 tons of 54% acid

or 10,400 tons P_2O_5 in the form of

54% P_2O_5 acid

This would require a wet-process phosphoric acid plant having a capacity of:

$\frac{10,400}{330}$ or <u>31.5 tons P_2O_5 on a 330 operating day-per-year basis</u>

(This is a very small plant by today's standards and in most cases would be considered to be below the economic size-limit.)

Sulfuric Acid and Sulfur or Pyrites Requirements

The annual sulfuric acid requirements (at 15,000 tons per year P_2O_5 capacity as triple superphosphate) corresponding to a need of 10,400 tons of P_2O_5 in the form of 54% P_2O_5 wet-process acid can be found by assuming a typical H_2SO_4 (100%) requirement of 2.75 tons per ton of P_2O_5.

Hence, the annual H_2SO_4 need would be:

(10,400 X 2.75) or 28,500 tons, which on a 330 operating-day basis is: $\frac{28,500}{330}$ or 87 tons per day

This corresponds to:

1) Sulfur 100%

28,000 X 0.33 or 9,500 tons of S per year

or 28.6 tons of S per operating day

or

2) Pyrites, 40% S

$\frac{9,500}{0,4}$ = 24,000 tons per year

or

73 tons per day

(Actual quantities would be slightly higher because of process losses and conversion factors below unity)

Secondary Phosphate Rock Needs

Since the design capacity of the triple superphosphate plant would be 31,500 tons per year, 40% by weight would be secondary rock, or (31,500 X 0.4) = 13,000 tons, approx.

Total Phosphate Rock Needs (34% P_2O_5 or 74 BPL basis)

The total phosphate rock needs (before allowing for process losses) would therefore be approximately:

	Metric Tons	
	P_2O_5	Rock
For Phosphoric Acid Production	10,500	31,000
As Secondary Rock	4,500	13,000
	15,000	44,000

9. SOLID AMMONIUM SULFATE MANUFACTURE

9.1 General

Previous calculations have indicated that a maximum need of 12,500 tons of Nitrogen will be required in the early, post-1971 years, which corresponds to some 60,000 tons of ammonium sulfate. In Section 7.4 of this Report, it was suggested that this quantity could be made in situ, during granulation, at minimum capital and operating cost, provided no solid ammonium sulfate were needed for separate application purposes.

Should it be desired to produce all the ammonium sulfate in solid form, 60,000 tons annual production would require 15,500 tons of anhydrous ammonia and 44,700 tons of 100 percent sulfuric acid, which on a 330 day-per-year basis (compared to an assumed 300 for the single superphosphate unit) amounts to:

182 metric tons per day of ammonium sulfate,
requiring approximately,
47 metric tons per day of anhydrous ammonia,
135 metric tons per day of 100% sulfuric acid

Since process units of this type are normally built in sizes of 50- and 100-ton multiples, a 200 metric ton per day ammonium sulfate installation would be specified.

9.2 The Process

Anhydrous ammonia and concentrated sulfuric acid are reacted in a vacuum (or atmospheric) crystallization vessel according to the reaction:

$$2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$$

Most modern units are based on a continuous vacuum evaporator/crystallizer specially designed to give close control over supersaturation and hence, achieve good crystal formation. The heat of reaction is controlled by addition of water to the system. Crystals of the desired size are continuously withdrawn from the evaporator/crystallizer and conveyed to a centrifuge for washing and dewatering. Final drying is undertaken in a rotary-shell drier, prior to storage, bagging and shipping. The required vacuum is induced by steam jets, operated by surplus steam produced in the adjoining sulfuric acid unit.

Recommended storage capacity for bulk and bagged material would total about 3 weeks production, or 4,000 tons, say.

A - "Krystal" Type Vacuum Evaporator-Crystallizer
B - Forced-Circulation Pump
C - Slurry Recirculation Pump
D - Mother-Liquor Recycle Pump
E - Mother-Liquor Tank
F - Continuous or Batch Centrifune
G - Slurry Concentrator
H - Drier Conveyor
I - Rotary Drier
J - Dried-Product Conveyor
K - Vacuum Condenser-Ejector Unit

Fig. 5 Direct [illegible]
[illegible]

10. COST CALCULATIONS AND COMPARISONS

10.1 Bases and Assumptions

General

Costs are in U.S. dollars.

Tonnages are in Metric Tons.

Gallons are in Imperial Gallons

Costs are for plants, erected, ready-to-run, in Cyprus.

Allowances for typical process conversion efficiencies and losses are shown, where significant.

Economic and Financial

Capital costs and operating requirements are based on composite figures furnished by experienced major contractors in U.S.A. and Europe. For comparative purposes, the following indirect cost ratios are used throughout:

Supervision and factory overhead -	100% of direct labor
Maintenance -	5% of plant cost
Depreciation -	10% of plant cost
	5% of offsites cost
Interest -	6% of 50% of fixed capital
	6% of 100% of working capital -where applicable
Taxes (except income tax), insurances, contingencies -	3% of fixed capital

10.2 Single Superphosphate Manufacture Only

10.2.1 Fixed Capital Costs

10.2.1.1 Sulfuric Acid Unit

Maximum Need

110 tons of 100% H_2SO_4 per 24-hour day, equivalent to 33,000 tons per year of 300 operating days (for superphosphate only).

Allow 5% for production losses and contingencies, to give an approximate Design Capacity of 120 metric tons per day.

Capital Cost

	U.S. $
Pyrites Roasting Unit	420,000
Contact Acid Unit	870,000
	1,290,000
Pyrites - Storage, Handling	
at $5 per ton of storage	
6,000 X $5	30,000
Sulfuric Acid Storage	
1,000 tons at $20	20,000
Sub Total	1,[illegible],000

Sub Total (carried forward)	1,340,000
Land, Site Preparation and Contingencies - say 10% of Sub Total	134,000
Total Fixed Capital Cost	$1,474,000

10.2.1.2 Single Superphosphate Unit

Maximum Feed

250 tons of single superphosphate per 16-hour operating day, or 15.6 tons per hour totalling 75,000 tons per year of 300 operating days.

Allow 10% for production losses and contingencies, to give an approximate Design Capacity of 17.0 tons per hour.

Capital Cost

Single Superphosphate Unit plus Offsites for entire factory

	U.S. $
Unground Rock Storage and Handling (8,000 tons storage capacity)	139,000
Rock Grinding (10 tons/hour)	105,000
Single Superphosphate Unit (17 tons/hour)	85,000
Curing & Run-of-Pile Storage (10,000 tons capacity)	128,000
Bagging and Shipping (475 80-lb. bags/hour)	64,000
Offsites (for entire factory)	130,000
Land (5 acres at $4,000/acre, say)	20,000
	671,000
Contingencies 10%	67,000
	738,000

Stack-gas scrubbing is included, but not fluorine-salt recovery.

Total Fixed Capital Cost

Sulfuric Acid Unit	$1,474,000
Single Superphosphate Unit and Offsites	738,000
	$2,212,000
	(₵ 0.79 million)

10.2.2 Working Capital

10.2.2.1 Sulfuric Acid Manufacture $

Raw Material

6,000 tons of stockpiled pyrites, equivalent to 1 month's needs. Assume 30-days credit given (at least). Then, working capital and corresponding interest should be zero.

0

Work-in-Progress and Finished Product

10 day's production of H_2SO_4 or 1,000 tons at $17 per ton, say, plus miscellaneous supplies 20,000

$20,000

10.2.2.2 Single Superphosphate Manufacture

	$
Raw Material	
Sulfuric Acid	0
Phosphate Rock (say 5,000 tons average at $15 per ton)	75,000[1)]
Work-in-Progress	
Run-of-Pile Super (say 5,000 tons yearly average at $20/ton)	100,000
Finished Goods	
60 days equivalent production, sold and awaiting payment on 60-day terms at $25/ton cost, say	375,000
	$550,000
	(₱ 1.97 million)

1) Note: If about ten, 5,000-ton monthly shipments of rock were purchased annually and 30-day credit given, the corresponding working capital need and interest should be zero

10.2.3 Manufacturing Cost - [illegible]

10.2.3.1 Sulfuric Acid (110 tons per day)

	$ per ton of 100% H_2SO_4
Raw Materials	
Pyrites	
In absence of a firm quoted price, a value of £3 or $8.4 per ton will be used for an assumed 48% S material. (It would be expected that lower grades could be bought at a discounted, pro-rata sulfur content owing to their reduced export appeal). Assume a 90% conversion.	6.40
Utilities	
Water at 85°F. (Imperial Gallons)	
for pyrite and calcine slurry, 900	
gas purification, 3,000	
acid cooling, 8,000	
process needs 25	
11,925	
at $0.05 per 1,000 gallons, say	0.60
Power	
85 kwh./ton at $0.007/unit	0.59
Labor	
Assume direct labor rates to be 50% above current per-capita average of about 250, i.e. $1,050 p.a. 4 shifts of 5 men each	0.57

Supervision and Factory Overhead	
@ 100% of direct labor, say	0.57
Maintenance	
@ 5% of plant cost	1.82
Depreciation	
@ 10% of plant cost	3.64
Interest	
On 50% of fixed capital at 6%, say 1.2	
On 100% of working capital at 6%,	
say 0.03	1.23
Taxes, Insurances, Contingencies	
@ 3% of fixed capital, say	1.20
Total Cost/Ton	$16.62

NOTE: No credits allowed for possible sales of pyrites cinder and by-product steam

10.2.3.2 Single Superphosphate Manufacture
(250 tons per day or 75,000 tons per year)

Raw Materials	$ per ton of Product
Phosphate Rock	
ex Casablanca, say, delivered	
Cyprus @ $16.15/ton 74 BPL	
0.61 X $16.5	10.10

Sulfuric Acid	$ per ton of Product
ex captive unit at cost	
0.40 X $16.62	6.65
Utilities	
Water	
Process 40 gallons	
Cooling, Scrubbing 2,000 gallons	
2,040 gallons	
@ $0.05/1,000 say	0.10
Power	
21 kwh. per ton @ $0.007	0.15
Labor (direct)	
2 shifts of 4 men - process	0.11
= 8 X $1050 / 75,000	
2 shifts of 6 men - bagging and shipping	0.17
Supervision and Overhead	
(100% of direct labor)	0.28
Maintenance	
@ 5% of ~~plant cost~~ Fixed Capital	
$738,000 X 5 / 100 X 75,000	0.49

Depreciation

@ 10% of plant cost	0.77
@ 5% of offsites	0.11

Interest

On 50% of fixed capital @ 6%

$$\frac{\$738{,}000}{2} \times \frac{6}{100} \times \frac{1}{75{,}000} \qquad 0.29$$

On 100% of working capital @ 6%

$$\frac{\$550{,}000}{75{,}000} \times \frac{6}{100} \qquad 0.44$$

Taxes, Insurances, Contingencies

@ 3% of fixed capital cost

$$\frac{\$738{,}000 \times 3}{75{,}000 \times 100} \qquad 0.30$$

Sub Total	19.96

Bags

28, 80-lb. bags per ton @ $0.20 ea.	5.60
Total Cost per ton, bagged	$25.56

10.3 Granulated, Mixed Fertilizer Production

10.3.1 General

As indicated in Section 7.4, it is considered that a fertilizer plant for Cyprus should not be restricted to powdered, screened, run-of-pile single superphosphate. The availability of local pyrites and rising costs of sulfur throughout the world, plus the current market for ammonium sulfate in Cyprus strongly favors the manufacture of ammonium sulfate as well (not only for domestic consumption but, later, for exports too). This production can be economically undertaken in a granulation unit, whereby granular, smooth-flowing fertilizers containing appropriate percentages of nitrogen and phosphate are made from run-of-pile single superphosphate, sulfuric acid, and ammonia. Potash can also be incorporated in the granules, according to need, when desired.

The simultaneous production of ammonium sulfate during granulation leads to considerable savings, as little additional equipment is needed. Furthermore, no separate transportation and application of nitrogen fertilizer and phosphate fertilizer has subsequently to be undertaken, which benefits the farmer. Another major advantage is that the installation of a larger-sized sulfuric acid plant appreciably reduces the cost of production, which, in turn, reduces the manufacturing cost of single superphosphate and ammonium sulfate. In addition, the availability of attractively-priced sulfuric acid in Cyprus would undoubtedly promote its use outside the fertilizer industry.

Hence, a survey of other sulfuric acid needs in Cyprus is recommended before the final plant size is selected. In the meantime, cost calculations will be on the basis of a 300 ton-per-day unit operating at 260 tons-per-day capacity for 330 days per year. Although the phosphate fertilizer unit calculations have been made on the basis of 300 operating days, because of likely reasonable demands it is customary to operate sulfuric acid plants for at least 330 days per year. The extra production should find a ready sale as acid or as ammonium sulfate in the export market.

10.3.2 Sulfuric Acid Manufacture (2)

Basis: 300 tons per day unit operating at a rate of 260 tons/day of 100% H_2SO_4 for 330 days/year (86,000 tons/year).

Operating data and costs as for the 110 tpd. installation outlined in Section 10.2.1.1, pro-rated accordingly.

Fixed Capital Cost	$3,000,000	
Working Capital	$ 55,000	

Manufacturing Cost	$ per ton 100% H_2SO_4
Raw Materials	
Pyrites as for 110 tpd. unit	6.40
Utilities	
@ 0.9 of 110 tpd. unit	1.07
Labor (direct)	
Personnel as for 110 tpd. unit	0.19
Supervision and Factory Overhead	
Personnel as for 110 tpd. unit	0.19
Maintenance	
5% of plant cost	1.74
Depreciation	
10% of plant cost	3.48
Interest	
50% of fixed capital @ 6%	1.05
100% of working capital @ 6%	0.04
Taxes, Insurances, Contingencies	
@ 3% of fixed capital	1.05
Total cost per ton 100% H_2SO_4	$15.21

10.3.3 Sulfuric Acid Manufacture (3)

Since it is believed that a domestic market for sulfuric acid already exists, or can be created (as well as an export market, since transportation facilities are now available) it is of interest to calculate the manufacturing cost when a 300 tpd. capacity plant is operated at full capacity for 350 days a year, as is customary, i.e., at an annual output of 105,000 tons.

Manufacturing Cost	\$ per ton 100% H_2SO_4
Raw Materials	6.40
Utilities	1.07
Labor (direct)	0.19
Supervision and Overhead	0.19
Maintenance	1.43
Depreciation	2.86
Interest	0.89
Taxes, Insurances, Contingencies	0.86
Total Cost per ton 100% H_2SO_4	\$13.89

The advantages of increased production levels are thus appreciable, as summarized below.

Case	Operation	Cost per Metric Ton of 100% H_2SO_4
1	120 tpd. unit operating at 110 tpd. for 330 days	$16.62
2	300 tpd. unit operating at 260 tpd. for 330 days	$15.21 (a reduction of $1.41/ton over 1)
3	300 tpd. unit operating at 300 tpd. for 350 days	$13.89 (a reduction of $2.73/ton over 1)

For the following cost calculation purposes, a sulfuric acid cost of $15.21 will be used, as the extent of local and export acid markets are not known at this stage.

10.3.4 Granulations-Ammoniation Mixed Fertilizer Manufacture

For cost and savings calculation purposes, a production level of 10,000 tons per annum of nitrogen will be used, equivalent to $\frac{10,000}{0.21}$ or 48,000 tons approximately of ammonium sulfate.

To allow for future expansion, however, the design output of the plant will be based on 12,500 tons of N, or 60,000 tons of ammonium sulfate.

Based on the various materials imported in recent years, an equivalent mixed fertilizer has been shown in Section 7.4 to be 10-12-0.3. Hence, the design capacity for an ammoniation-granulation unit for 12,500 tons of N annually would be $\frac{12,500}{0.1}$ or 125,000 tons per year.

On a 300 day per year basis, this is equivalent to $\frac{125,000}{300}$ or 417 tons per day, i.e., 17.4 tons per hour on a 24-hour basis. To allow for changeovers, stoppages and cleaning, a 20 ton-per-hour unit will be used for calculation purposes.

Manufacturing Cost

Basis: 125,000 tons per year of granulated 10-12-1 and similar mixtures equivalent to 48,000 tons/year of ammonium sulfate.

Fixed Capital Cost

Ammoniation-Granulation Unit

Design basis - 20 metric tons per hour of granulated 10-12-0 (or 10-12-1)

Raw Material Storage and Handling	$
Single Superphosphate - nil	0
Sulfuric Acid:	
8 days supply at 150 tons/day max.	
= 2,000 tons @ $20 per ton stored	40,000
Ammonia:	

12,500 tons of N per year or 15,000 tons of anhydrous ammonia, i.e., 1,500 tons per month. This would require a bulk, refrigerated storage tank of about 2,500

Ammonia: cont'd.

tons capacity, based on monthly deliveries from Algiers, Trinidad or elsewhere

2,500 tons @ $125 per ton capacity	313,000

Ammoniation-Granulation Unit 20 tph.

Including pre-neutralizer, granulator, drier, screens, mill, conveyors, elevators, erected	200,000
Building	
100 feet X 60 feet @ $8 per square foot	48,000
Bagging and Shipping	
As for the single-superphosphate unit, but operating on 3 shifts included in the single-superphosphate unit calculations	0
Total additional capital cost needed to produce all the required N, in the form of in-situ ammonium sulfate (not including the larger sulfuric acid unit)	601,000

Working Capital

Raw Materials

Ammonia
Assume average inventory of 2,000 tons, half of which is on 30-day credit. Assume delivered price is $50/ton - then working capital is 1,000 X 50 or $50,000 — 50,000

Sulfuric Acid
8 day's production needs @ $17/ton, 150 tons/day 8 X 150 X 17 — 20,000

Ammonium Sulfate
In process and storage (as a component of mixed fertilizer) 14 day's production @ $25/ton 100 X 14 X 50 — 112,000

Ammonium Sulfate
(As a component of mixed fertilizer)
Sold on 60-day credit, equal to 60 day's production — 480,000

662,000

Manufacturing Cost	$ per ton of dry product
(1) Calculated in terms of Ammonium Sulfate Production Only.	
Raw Materials	
Anhydrous Ammonia @ $50/ton delivered	
34/132 X 1.02 X $50	13.20
Sulfuric Acid from Captive Unit	
98/132 X 1.01 X $15.21	11.40
Utilities	
Water	
Process and Miscellaneous	
1,000 gallons @ $0.05	0.05

Power	
25 kwh./ton @ \$0.007	0.18
Fuel	
5 gallons Bunker C/ton @ \$0.1	0.50
Labor (direct)	
4 shifts of 3 men	
$\frac{12 \times \$1050}{48,000}$	0.26
Supervision and Factory Overhead	
100% of direct labor	0.2[illegible]
Maintenance	
2[illegible] of ammonia storage	
$\frac{313,000 \times [illegible].5}{100 \times 48,000}$	0.1[illegible]
5% of remainder	
$\frac{[illegible],000 \times 5}{100 \times 48,000}$	0.29
Depreciation	
10% of fixed capital	
$\frac{601 \times 10}{100 \times 48,000}$	1.25
Interest	
50% of fixed capital [illegible]	
$\frac{601,000 \times 6}{2 \times 100 \times 48,000}$	0.38
100% of working capital [illegible]	
$\frac{660,000 \times 6}{100 \times 48,000}$	0.83

<u>Taxes, Insurances, Contingencies</u>

@ 3% of fixed capital

$\frac{601,000 \times 3}{100 \times 48,000}$	0.38
Total manufacturing cost/ton bulk	$29.14

<u>Bagging Costs</u> (and Shipping)

<u>Equipment</u>

Same equipment will be used as for bagging single superphosphate, operated 24 tons/day and at a higher rate	0

<u>Labor</u>

2 additional shifts of 6 men	
$\frac{12 \times 1,050}{48,000}$	0.26

<u>Bags</u>

28, 80-lb. bags/ton @ $0.20 each	5.60
	5.86

Total Equivalent Cost of Bagged Ammonium Sulfate, made in-situ as granulated mixed fertilizer	35.00

Manufacturing Cost of Granulated Mixed Fertilizer

By adding the separate manufacturing costs of single superphosphate and ammonium sulfate made in-situ, the manufacturing cost of an equivalent, granulated, bagged 10-12-0 can be found.

However, the cost reduction made possible by a large sulfuric acid plant must be taken into consideration. Thus, by making sulfuric acid as under Case 2, for a cost of $15.21 instead of $1[illegible].[illegible]2, as under Case 1, the cost per ton of single super becomes approximately $25.00 per ton, representing a saving of $0.5[illegible] per ton.

The cost per ton of the 10-12-0 can be calculated as follows:

[illegible]5,000 tons single super @ $25.00/ton	=	$1,870,000
4[illegible],000 tons ammonium sulfate @ $35/ton	=	$1,[illegible]80,000
		$3,550,000

Cost/ton $\frac{3,550,000}{123,000}$

or $28.9

10.4 Triple Superphosphate Manufacture As An Alternative to Single Superphosphate

10.4.1 General

The manufacturing cost of triple superphosphate made in Cyprus has been requested, to compare with the cost of single superphosphate. To produce triple, phosphoric acid must first be made, and its cost must be found before the cost of the corresponding triple superphosphate can be calculated.

The corresponding 74 BPL phosphate rock needs have been shown to be:

	Metric Tons	
	P_2O_5	Rock
For Phosphoric Acid Production	10,500	31,000
As Secondary Rock	4,500	13,000
	15,000	44,000

The corresponding triple superphosphate, 48% P_2O_5 will be:

$$\frac{15,000}{0.48} = 31,300 \text{ tons annually}$$

i.e., 105 tons per day, 300 day/year basis, or 13.2 tons/hour, 8 hours per day.

10.4.2 Phosphoric Acid-Manufacturing Cost

Capacity = 10,500 tons P_2O_5 per year or 35 tons/day per year of 300 operating days.

Capital Cost of Entire Unit

Fixed Capital	U.S. $
Underground Rock Storage, Handling, Grinding - as for single superphosphate under 10.2.1.2	
Storage	139,000
Grinding	105,000
Wet-Process Phosphoric Acid Unit 35 tons P_2O_5/day including evaporator, acid storage and gypsum disposal	1,000,000
Triple Superphosphate Unit 6.6 tons/hour, 16 hours/day capacity as for single-super unit	85,000
Curing and Run-of-Pile Storage 5,000 tons capacity	70,000
Bagging and Shipping 125 - 80 lb. bags per hour	30,000
Offsites (for entire factory)	130,000
Land 6 acres @ $4,000/acre, say	24,000
Sub Total	1,583,000
Contingencies 10%	158,000
Total Fixed Capital Cost	$1,741,000

Capital Cost Allocated to Phosphoric Acid Production

Approximate annual rock requirements:

Primary rock for acid	= 31,000 tons	or 0.7
Secondary rock for acidulation	= 13,000 tons	or 0.3
Total	44,000 tons	or 1.0

Hence, fixed capital allocation for phosphoric acid plant will be taken as:

	$
Unground Rock Storage, Handling, Grinding	
0.7 X $244,000 or	170,000
Wet-Process Acid Unit 100% or	1,000,000
Offsites 0.7 X $130,000 or	91,000
Land 0.7 X $24,000 or	17,000
	1,278,000
Contingencies 10%	128,000
Total Fixed Cost, P_2O_5 Plant	$1,406,000

Working Capital

Raw Material

0.7 X $75,000	53,000

Work in Progress

5 days production, approx.	
@ $126 per ton P_2O_5 31.5 X 5 X $126	22,000
	75,000

Manufacturing Cost, 54% P_2O_5 Phosphoric Acid

35 tons P_2O_5 per day

Raw Materials	$ ton P_2O_5
Phosphate Rock 74 BPL @ $16.15	
Allowing for 92% conversion	
$\frac{\$16.15}{0.34 \times 0.92}$	51.5
Sulfuric Acid - 100%	
Assume 2.6 tons per ton P_2O_5	
$\frac{2.6 \times \$16.62}{0.9}$	48.0
Utilities	
Water - for process and steam	
1,000 gals./ton @ $0.20	0.2
- for cooling and scrubbing	
15,000 gals./ton @ $0.05	0.75
Power 230 kw./ton @ $0.007	1.60
Labor	
Rock Handling, Grinding	
70% of 3 man, 2 shifts @ $1,050/year	
$\frac{1050 \times 6}{10,500 \text{ tons}}$	0.60
Acid plant and concentration	
$\frac{3 \text{ men, } 4 \text{ shifts @ } \$1,050}{10,500 \text{ tons}}$	1.20

<u>Supervision and Overhead</u>	
100% of direct labor	1.80
<u>Maintenance</u>	
5% of plant cost	
$\frac{\$1,406,000}{10,500} \times \frac{5}{100}$	6.70
<u>Depreciation</u>	
10% of plant cost	
$\frac{\$1,300,000 \times 10}{10,500 \times 100}$	12.40
5% of remainder	
$\frac{106,000 \times 5}{10,500 \times 100}$	0.51
<u>Interest</u>	
On 50% of fixed capital @ 6%	
$\frac{703,000 \times 6}{10,500 \times 100}$	4.00
On 100% of working capital @ 6%	
$\frac{75,000 \times 6}{10,500 \times 100}$	0.43
<u>Taxes, Insurances, Contingencies</u>	
@ 3% of capital cost	
$\frac{\$1,460,000 \times 3}{10,500 \times 100}$	4.17
Total Cost 54% P_2O_5 acid per ton P_2O_5	$133.86

i.e., $133.86 X 0.54 or $72 per ton of H_3PO_4 containing 54% P_2O_5.

10.4.3 **Triple Superphosphate Manufacturing Cost** (Screened Run-of-Pile)

Equivalent to 15,000 tons/year of P_2O_5,

equivalent to 31,500 tons of 48% TSP per year,

or 105 tons/day, i.e., 13.2 tons/hour on an

8-hour day basis.

Fixed Capital Cost	
\$(1,741,000 - 1,406,000)	335,000
Working Capital	
As for single superphosphate 75,000 plus	
10% for extra value of the TSP	
550,000 X 1.10 or say	600,000

Manufacturing Cost	**\$/ton TSP**
Raw Materials	
0.6 tons 54% P_2O_5 acid	
0.6 X \$72	43.20
0.4 tons rock @ \$16.15/ton	6.45
Utilities	
Water	
Scrubbing - 2,000 gal. @ \$0.05/1,000	0.10
Power	
10 kwh. @ \$0.007	0.07
Labor	
1 shift of 4 men - process	0.13

Labor (cont'd.)	
1 shift of 6 men, bagging and shipping	0.14
Supervision and Overhead	
100% of direct labor	0.19
Maintenance	
5% of capital cost	0.53
$\frac{335,000 \times 5}{31,500 \times 100}$	
Depreciation	
10% of plant cost	
$\frac{335,000 \times 10}{31,500 \times 100}$	1.06
Interest	
On 50% of fixed capital @ 6%	
$\frac{335,000 \times 6}{2 \times 31,500 \times 100}$	0.33
On 100% of working capital @ 6%	
$\frac{600,000 \times 6}{31,500 \times 100}$	1.15
Taxes, Insurances, Contingencies	
3% of fixed capital	
$\frac{3335,000 \times 3}{31,500 \times 100}$	0.32
Total cost/ton TSP, bulk	$53.67
Bags	
28, 80-lb. bags/ton @ $0.20 each	5.60
Total cost/ton TSP, bagged	$59.27

10.5 <u>Crystalline Ammonium Sulfate Manufacture</u>

<u>Production Requirements</u>: 48,000 tons/year of ammonium sulfate per 330 days, or 145 tons per day.

<u>Plant Capacity</u>

60,000 tons/year or 182 tons per day

	$
<u>Fixed Capital Cost</u>	
Atmospheric saturator/crystallizer, centrifuge, drier and ancillary equipment, plus building	720,000
<u>Sulfuric Acid Storage</u>	
As for 10.3.4	40,000
<u>Ammonia Storage</u>	
As for 10.3.4	313,000
<u>Product Storage</u>	
5,000 tons @ 2 sq.ft./ton @ $8.0	80,000
<u>Bagging and Shipping</u>	
As for 10.3.4	64,000
<u>Offsites</u>	
All allocated to the single superphosphate unit	0
	1,217 ,000

	$
<u>Working Capital</u>	
As for 10.3.4	
Ammonia	50,000
Sulfuric Acid	20,000
Inventory - about 1 month's production, plus 2 month's production sold on 60-day credit terms	592,000
	662,000

Manufacturing Cost	$ per ton Ammonium Sulfate
Raw Materials	
Ammonia @ $50 per ton	13.20
Sulfuric Acid @ $15.21/ton	11.40
Utilities	
Water	
Process 1,300 gallons @ $0.20	0.26
Cooling 4,000 gallons @ $0.05	0.20
Power	
70 kwh./ton @ $0.007	0.49
Steam	
20 lbs./hr.	0.01
Fuel	
3 gallons Bunker C fuel @ $0.10	0.30
Labor (direct)	
4 shifts of 2 men - process	
$\frac{8 \times \$1,050}{48,000}$	0.18
Supervision and Factory Overhead	
100% of direct labor	0.29
Maintenance	
2% of ammonia storage	0.16
5% of remainder	
$\frac{904,000 \times 5}{48,000 \times 100}$	0.94

<u>Depreciation</u>	
10% of fixed capital	2.53
$\frac{1,217,000 \times 6}{48,000 \times 100}$	
<u>Interest</u>	
50% of fixed capital @ 6%	
$\frac{1,217,000 \times 6}{48,000 \times 2 \times 100}$	0.76
100% of working capital @ 6%	
$\frac{662,000 \times 6}{48,000 \times 100}$	0.83
<u>Taxes, Insurances, Contingencies</u>	
3% of fixed capital	
$\frac{1,217,000 \times 3}{48,000 \times 100}$	0.76
Total Manufacturing Cost/ton, bulk	$32.31
<u>Bagging and Shipping</u>	
<u>Labor</u>	
1 shift of 6 men	0.13
<u>Bags</u>	
28, 80-lb. bags/ton @ $0.20 each	5.60
	5.73
Total Cost of Bagged Crystalline Ammonium Sulfate	$38.04

10.6 Effects of Smaller Plant Capacities and Lower Outputs on Costs

For comparative purposes, approximate capital and manufacturing costs corresponding to 10,000 tons of P_2O_5 annually (instead of 15,000 tons used in the previous calculations) have been requested. It is stressed that 10,000 tons of P_2O_5 correspond to current needs only and are inadequate to meet expanding requirements - in fact, by the time the plant was built, it would be too small. Moreover, manufacturing costs would be increased and most of the potential savings would be lost.

At lower plant capacities and outputs, raw material costs remain the same (or increase slightly because of reduced plant efficiencies). Utility costs normally increase. Labor costs in most cases rise in proportion to the reduction in capacity over a wide range, as minimum numbers of men are normally used and team sizes do not increase in proportion to capacity. Working capital costs per ton may remain the same, or increase because of the fixed size of unit shipments, e.g., rock and ammonia. Fixed capital costs per ton and other corresponding charges also increase, because plant costs are not in direct proportion to capacity. For a reduction from 15,000 to 10,000 tons in annual capacity, i.e., to 0.67 of the former, capital costs can be expected to be reduced to about 0.8 of the larger size and cost calculations will be made on this basis, e.g.

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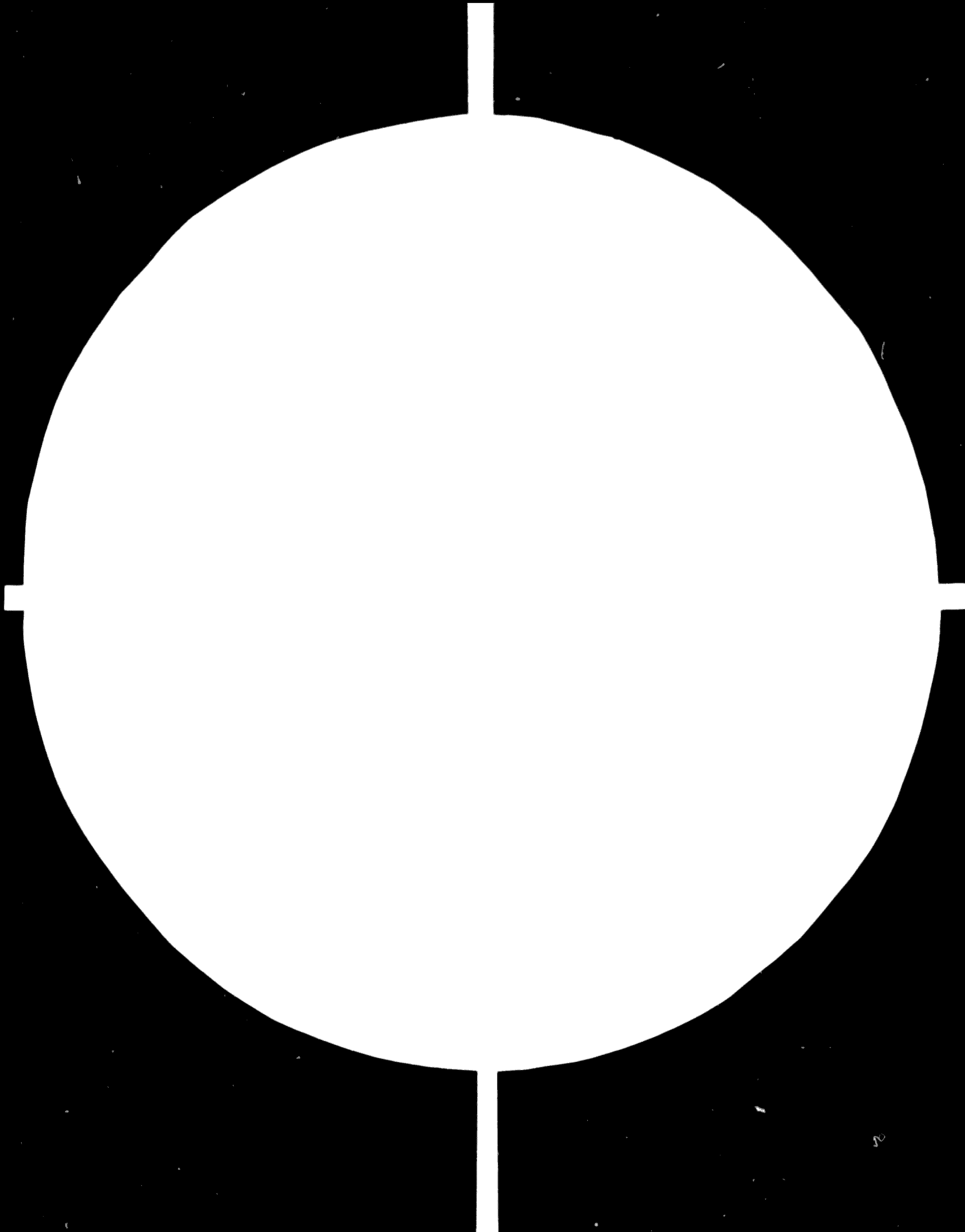

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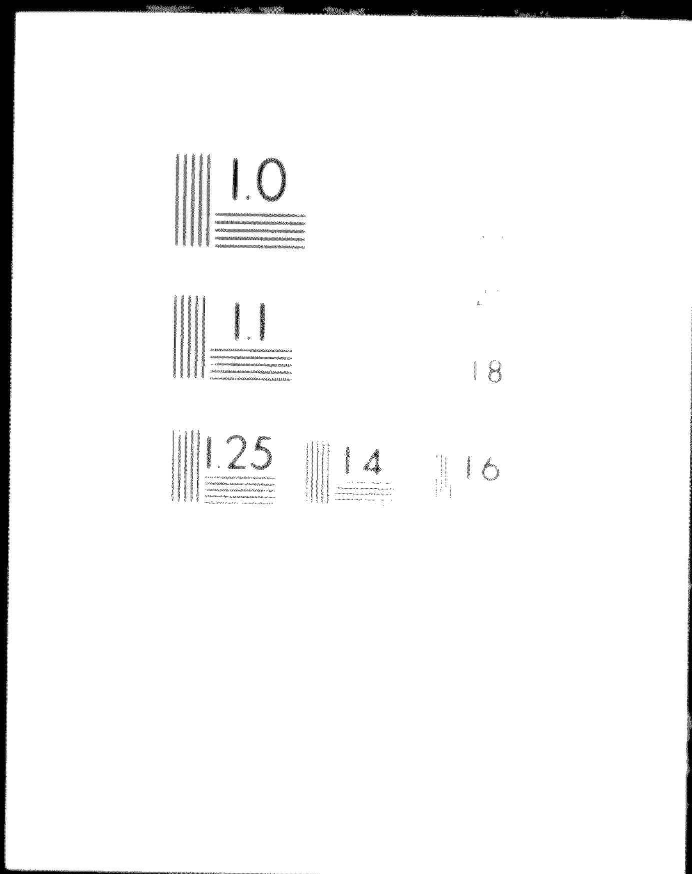

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10.6.1 Sulfuric Acid Manufacture

110 X 0.67 or 75 tpd. capacity	\$ per ton 100% H_2SO_4
Raw Materials	
Pyrites	6.40
Utilities	
1.19 X 1.1	1.32
Labor	
0.57 X 1.5	0.85
Supervision	
100% of direct labor	0.85
Maintenance	
$1.82 \times \frac{0.80}{0.67}$	2.17
Depreciation	
$3.64 \times \frac{0.80}{0.67}$	4.35
Interest	
$1.23 \times \frac{0.80}{0.67}$	1.47
Taxes, Insurances, Contingencies	
$1.20 \times \frac{0.80}{0.67}$	1.43
Total Cost/Ton	\$18.85

Increase in cost = 18.85 - 16.62

= 2.23 or 13.4%

10.6.2 Single Superphosphate Manufacture

75,000 X 0.67 or 50,000 tons per year		$ per ton Single Superphosphate
Raw Materials		
Phosphate Rock		10.10
Sulfuric Acid	0.40 X $18.85	7.55
Utilities		
0.25 X 1.1		0.27
Labor		
$0.28 \times \frac{0.80}{0.67}$		0.38
Supervision and Overhead		
100% of direct labor		0.38
Maintenance		
$0.49 \times \frac{0.80}{0.67}$	(Plant)	0.92
0.11 X 1.0	(Offsites)	0.11
Interest		
Fixed capital	$0.29 \times \frac{0.80}{0.67}$	0.35
Working capital	0.44 X 1.0	0.44
Taxes, Insurances, Contingencies		
$0.30 \times \frac{0.80}{0.67}$		0.36
	Total cost/ton, bulk	21.45

21.45 - 19.96

Increase in cost = $1.49/ton

= 7.5%

10.5.3 Ammonium Sulfate Manufacture

(In situ as granulated mixed fertilizer

48,000 X 0.67 or 32,000 tons/year)

		$per ton equivalent, solid ammonium sulfate
Raw Materials		
Ammonia		13.20
Sulfuric Acid	0.75 X $18.85	14.20
Utilities		
0.73 X 1.1		0.80
Labor		
$0.26 \times \frac{0.80}{0.67}$		0.31
Supervision and Overhead		
100% of direct labor		0.31
Maintenance		
$0.45 \times \frac{0.80}{0.67}$		0.54
Depreciation		
$1.25 \times \frac{0.80}{0.67}$		1.48
Interest		
Fixed capital	$0.38 \times \frac{0.80}{0.67}$	0.45
Working capital		0.83
Taxes, Insurances, Contingencies		
$0.38 \times \frac{0.80}{0.67}$		0.46
	Total Cost/ton, bulk	$31.75

Cost increase = $31.75 - 29.14

= $2.61 per ton or 9%

10.6.3 Phosphoric Acid Manufacture

10,500 tons/year P_2O_5 X 0.67 =

7,000 tons or 23.4 tons P_2O_5 per day

		$ per ton P_2O_5
Raw Materials		
Phosphate Rock		51.50
Sulfuric Acid	$\frac{2.6 \times \$18.85}{0.9}$	54.50
Utilities		
2.55 X 1.1		2.81
Labor		
1.8 X $\frac{0.80}{0.67}$		0.27
Maintenance		
6.7 X $\frac{0.80}{0.67}$		8.00
Depreciation		
12.91 X $\frac{0.80}{0.67}$		15.50
Interest		
4.43 X $\frac{0.80}{0.67}$		5.30
Taxes, Insurances, Contingencies		
4.17 X $\frac{0.80}{0.67}$		5.00
	Total Cost/ton P_2O_5	$142.88

Cost increase = $142.88 - 133.86

= $9.02

= 6.7%

Cost per ton 54% P_2O_5 acid = $142.88 X 0.54

10.6.4 Triple Superphosphate Manufacture

31,500 tons/year X 0.67 =

21,200 tons/year

		$ per ton TSP
Raw Materials		
Phosphate Rock	0.4 tons @ $16.15	6.45
Phosphoric Acid	0.6 tons acid @ $77	46.20
Utilities		
$0.17 X 1.1		0.19
Labor		
$0.27 \times \frac{0.80}{0.67}$		0.32
Supervision and Overhead		
100% of direct labor		0.32
Maintenance		
$0.53 \times \frac{0.80}{0.67}$		0.63
Depreciation		
$1.06 \times \frac{0.80}{0.67}$		1.27
Interest		
$1.48 \times \frac{0.80}{0.67}$		1.77
Taxes, Insurances, Contingencies		
$0.32 \times \frac{0.80}{0.67}$		0.38
	Total Cost/ton TSP bulk	57.53

Cost increase = 57.53 - 53.67

= $3.86 per ton or 7.2%

11. COMPARISONS OF CAPITAL AND OPERATING COSTS

11.1 Sulfuric Acid

Case 1

120 tpd. unit operating at 110 tpd. for 330 days/year

Fixed Cost	$1,474,000
Working Capital	$ 20,000
Total Capital, 100% Equity	$1,494,000

Manufacturing Cost, per ton 100% H_2SO_4 $16.62

Case 2

300 tpd. unit operating at 260 tpd. for 330 days/year

Fixed Cost	$3,000,000
Working Capital	$ 55,000
Total Capital, 100% Equity	$3,055,000

Manufacturing Cost, per ton 100% H_2SO_4 $15.21

Case 3

300 tpd. unit operating at 300 tpd. for 350 days/year

Fixed Cost	$3,000,000
Working Capital	$ 55,000
Total Capital, 100% Equity	$3,055,000

Manufacturing Cost, per ton 100% H_2SO_4 $13.89

11.2 Single Superphosphate

250 tpd. for 300 operating days/year, 16 hrs./day

Fixed Cost	$738,000
Working Capital	$550,000
Total Capital Cost, 100% Equity	$1,288,000

Manufacturing Cost per ton of Single Superphosphate

	Bulk	Bagged
For Case 1, H_2SO_4	19.96	25.56
For Case 2, H_2SO_4	19.40	25.00
For Case 3, H_2SO_4	18.86	24.46

11.3 Ammonium Sulfate (48,000 tons/year)

(1) Made "in situ" as a granulated, mixed fertilizer with Case 2 acid

Fixed Cost	$601,000
Working Capital	$662,000
Total Capital Cost	$1.263,000

Equivalent Manufacturing Cost per ton Ammonium Sulfate

Bulk	Bagged
29.14	35.00

(2) Made as dry, crystalline ammonium sulfate 21% N

Fixed Cost	$1,217,000
Working Capital	$ 662,000
Total Capital Cost, 100% Equity	$1,879,000

Equivalent Manufacturing Cost per ton Ammonium Sulfate

Bulk	Bagged
32.31	38.04

11.4 **Triple Superphosphate**

31,500 tons/year product containing 48% P_2O_5

(same P_2O_5 equivalent as the single superphosphate in 11.2)

Phosphoric Acid and TSP Units:

Fixed Cost		$1,741,000
Working Capital		$ 600,000
Total Capital Cost, 100% Equity		$2,341,000

Manufacturing Costs

1 ton P_2O_5 as 54% P_2O_5 acid			$133.86
1 ton TSP	Bulk	Bagged	
	53.[illegible]7	59.27	

11.5 **Ammoniated Superphosphate**

By "fixing" some of the ammonia with superphosphate, in place of sulfuric acid, some savings can be made, at the expense of a reduced P_2O_5 water solubility. At an output of 15,000 tons P_2O_5 per year, this has been shown to be equivalent to 7,900 tons/year of H_2SO_4, which at $15.21/ton is $120,000 per annum. Hence, the savings/ton of single super would be $\frac{120,000}{75,000}$ or $1.60 per ton.

11.6 **Manufacturing Costs at a Lower Output Corresponding to 10,000 Tons P_2O_5/Year**

	$ per ton
Sulfuric Acid 100% H_2SO_4	1[illegible].85
Single Superphosphate, bulk	21.45
Ammonium Sulfate, "in situ"	31.75
Phosphoric Acid, 54% P_2O_5 per ton 100% P_2O_5	142.38
Triple Superphosphate 48% P_2O_5	57.53

* Providing agronomic efficiency is not impaired.

12. PRODUCT SELECTION AND PROJECT FEASIBILITY

12.1 Product Selection - General

Competitive Materials and Prices

To measure the economic feasibility of the project, the estimated manufacturing costs must be compared with import prices for corresponding materials. Of course, savings in foreign exchange and other considerations may also be decisive factors in assessing the worth of the project.

12.2 Single Superphosphate

An earlier U.N. study based on a visit to Cyprus in mid-1966 indicated a landed price of about $32 per ton at that time, presumably for bagged, powdered material.

For comparative purposes, the following European prices at that time were listed:

					$/ton
Granulated	18%	P_2O_5	super,	bagged, ex works, Greece	33.2
Powdered,	18%	"	"	, bulk, Med. Port, France	24.8
Powdered,	18%	"	"	, bulk, ex works, Holland	30.3
Powdered,	18%	"	"	, bulk, ex works, Germany 7/'66	35.4
Powdered,	18%	"	"	, bulk, ex works, Germany 12/'66	37.6
Granulated,	18%	"	"	, bagged, ex works, Grmny, 7/'66	40.00
Granulated,	18%	"	"	, bagged, ex works, Grmny, 12/'66	42.40

As can be seen, prices can vary appreciably according to time of year, source, whether powdered or granular, and whether in bulk or in bags. World demand and supply balances, as well as sulfur and rock prices also affect superphosphate prices, making it difficult to select a true mean figure. Hence, a landed price of $32 per ton for powdered, bagged, 18% water soluble; 20% total P_2O_5 material will be used for comparative cost-study purposes, even though this may well be conservative, especially for future material. A corresponding sales price for domestically-produced material will be used.

Profitability

1. 75,000 tons bagged single super only/year, without simultaneous ammonium sulfate manufacture.

	$/ton
Manufacturing Cost =	25.56
Sales and Administration	1.00 say
	26.56

Total Revenue: 75,000 X $32 = $2,400,000

Total Costs: 75,000 X $26.5=$1,990,000

Pre-tax Profit = $ 410,000

Total Fixed Capital

Sulfuric Acid	\$1,474,000
Single Super Unit plus Offsites	738,000
	\$2,212,000

Profitability (Pre-tax)

(1) On Sales = $\frac{410,000}{2,400,000}$ = 17.1%

(2) On Equity (50% of Fixed Capital) =

$\frac{410,000}{2,212,000 \times 0.5}$ = 37%

12.3 75,000 tons bagged single super/year in conjunction with ammonium sulfate manufacture.

	\$/ton
Manufacturing Cost	25.00
Sales and Administration	1.00 say
	26.00

Total Revenue:	75,000 X \$32.0	\$2,400,000
Total Costs:	75,000 X \$26.10	\$1,950,000
Pre-tax Profit		\$ 450,000

Total Fixed Capital \$2,212,000

Profitability (Pre-tax)

(1) On Sales = $\frac{450,000}{2,400,000}$ = 18.8%

(2) On Equity (50% of Fixed Capital) =

$\frac{450,000}{2,212,000 \times 0.5}$ = 40.7%

12.4 <u>48,000 tons equivalent, bagged ammonium sulfate produced "in situ" with granulated single superphosphate</u>.

<u>Competitive Sales Prices</u>

Ammonium sulfate prices are traditionally subject to variation, because of fluctuating world consumption and supply patterns. For example, typical European prices in September, 1966 were quoted in the journal NITROGEN as:

	$ ton	
	Bulk	Bagged
21% N, delivered farm, U.K.	-	55.8
21% N, ex works, West Germany	53.0	-
21% N, delivered farm, Holland	42.8	-
20/21% N, delivered farm, Italy	-	54.4
20.5% N, delivered farm, Belgium	42.4	-

Other prices included:

		Bulk	Bagged
July, 1966	Bid to East Pakistan, f.o.b. European port	-	47.46
July, 1966	Bid to East Pakistan, f.o.b. European port	38.37	-
July, 1966	Accepted bid to Egypt, C and F, 235,000 tons	38.50	
Aug., 1966	Accepted bid by Turkey from Italy and Nitrex 200,000 tons @ $46.30, bagged p/e lined jutes.		46.30

The bulk bids to Pakistan and Egypt were considered by the trade to be due to an exceptionally large availability plus a temporary price weakness, and not representative of general price levels. As another guide, in 1964, some 15,[illegible]5 tons of ammonium sulfate were imported into Cyprus, with a value of $650,000. This is equivalent to $40.6 per ton. Because of rising world sulfur costs, sulfuric acid prices have since risen about 10% in many areas. Accordingly, a conservative increase of 5% on the 1964 ammonium sulfate price of $40.6/ton will be made, to give a price of $43.0 for bagged, competitive imports.

Taking $42.5 as a selling price, profits and profitability can be calculated:

	$ per ton
Manufacturing Cost, bagged	35.0
Sales and Administration	1.0
	36.0

Total Sales Revenue	48,000 X $43.0 =	2,060,000
Total Manufacturing Cost	48,000 X $36.0 =	1,730,000
Pre-tax Profit		330,000

Total Fixed Capital:

Sulfuric Acid Expansion	$1,526,000
Ammoniation/Granulation Unit	601,000
	$2,127,000

Profitability (Pre-tax)

(1) On Sales = $\frac{330,000}{2,060,000}$ = 16.4%

(2) On Equity (50% of Capital Cost) =

$\frac{330,000}{2,127,000 \times 0.5}$ = 31.0%

12.5 Granulated, Mixed Fertilizers

It should be borne in mind that the granulated mixed fertilizer produced by producing ammonium sulfate "in situ" with granulated superphosphate is worth appreciably more than the price of run-of-pile single superphosphate and ammonium sulfate bought separately. This extra value could be at least $5 per ton, and is not included in the preceding profit and profitability calculations. Perhaps these benefits could be passed on, without extra charge, to the farmers in Cyprus, in the form of better fertilisers having lower handling costs and other advantages.

12.6 Triple Superphosphate

The higher P_2O_5 content of triple superphosphate (46 to 48%) offers transportation savings over single superphosphate (16-20%) per unit of P_2O_5, but only when the distance is appreciable. This is because the cost of a unit of P_2O_5 in triple costs more than a unit of P_2O_5 in single superphosphate. In the preceding calculations, a ton of bulk triple costs $53.67 or $1.12 per unit, while a ton of bulk single-super costs $19.96 or $1.0 per ton of P_2O_5. Fixed capital costs were about $1,000,000 higher for triple manufacture owing to the cost of the phosphoric acid unit needed.

In other parts of the world, the potential transportation advantages of triple are not realized unless distances of several hundred miles are involved. Hence, importing triple into Cyprus, as is now done, is likely to give a lower delivered cost per ton of P_2O_5, but trucking a few miles from a plant in Cyprus to outlying farms is not likely to justify using triple. It should be added that no agronomic advantages of triple superphosphate over single-super are known - in fact single superphosphate is often superior, as the calcium sulfate it contains helps to prevent deficiencies of calcium and sulfur arising in the soil. Therefore, the manufacture of single superphosphate, and not triple superphosphate, is recommended.

12. Crystalline Ammonium Sulfate

Indicated manufacturing costs for bulk ammonium sulfate produced in conjunction with granulated single-super, and as a separate crystalline product are $29.14 and $32.31 respectively. Corresponding capital costs are $[illegible]01,000 and $1,21[illegible],000. Moreover, the "in situ" method produces a range of granulated, mixed N-P-O or N-P-K fertilizers as well. Therefore, the manufacture of ammonium sulfate by the in-situ granulation method is recommended for Cyprus needs. (The production of the crystalline or a granulated product for export purposes may be a future possibility.)

12.[illegible] Reduced Scale of Manufacture

The scaling-down of production facilities and outputs from a basis of 15,000 tons/year of P_2O_5 to 10,000 tons would give, in general, a capital cost reduction of about 20%, but would increase manufacturing costs to levels which would scarcely justify domestic production. Furthermore, these outputs would not meet future needs. Therefore, a minimum [illegible] level of 15,000 tons of P_2O_5 per annum is recommended [illegible]

13. FINANCIAL CONSIDERATIONS

13.1 Total Capital Cost

Based on the recommended processes and products indicated in Section 12, the total capital cost would be:

Total Fixed Capital - including offsites

300 tpd. Sulfuric Acid Unit	$3,000,000
250 tpd. Single Super Unit (plus offsites)	738,000
(160 tpd. "In situ" Ammonium Sulfate) ( ) (480 tpd. Granulated Mixed Fertilizer Unit)	601,000
Equivalent to 10-12-0	
	$4,339,000

13.2 Total Working Capital

Pyrites on 30 to 60 day credit		0
Phosphate Rock		75,000
Sulfuric Acid	35,000 + 20,000	55,000
Ammonia		50,000
Work-in-Progress and Customer Credits:		
as Single Superphosphate		475,000
as Ammonium Sulfate		592,000
Bags (1 month's supply average)		60,000
		1,307,000

13.3 Financing

Cost calculations have been made on the basis of 50% equity financing of the capital cost, i.e., $\frac{4,339,000}{2}$ or $2.2 million approximately and borrowing the remainder at 6%. These arrangements are usually flexible and different equity ratios might be preferred, according to eventual circumstances. The basic cost data developed in this Study will enable recalculations to be made easily, for different conditions.

13.4 Foreign Exchange Savings

Importation of 75,000 tons of single superphosphate and 48,000 tons of ammonium sulfate at current price levels would cost approximately $2,400,000 plus $2,060,000 or $4,460,000 annually. (Importation of equivalent, granulated mixed fertilizers would cost considerably more.) Annual purchases of phosphate rock, ammonia and bags at current price levels would amount to:

Phosphate Rock	75,000 tons X $10.7	$758,000
Ammonia	48,000 tons X $13.2	633,000
Bags	123,000 X $5	615,000
		$2,006,000

Hence, foreign exchange savings would be at least:

($4,460,000 - 2,006,000) or $2,454,000 annually

13.5 Possible Savings on Bag Costs

Based on an assumed cost of $0.20 per bag, (which may be higher than a price which can be eventually obtained) the annual bag costs are appreciable and amount to $615,000. Since Cyprus is a small island, it should be possible to introduce (1) direct bulk delivery of fertilizers to many points of use and (2) return and re-use the bags.

In this way, it should be possible to save about 50% of the annual bag costs, amounting to $2.5 per ton of fertilizer or a total of $300,000 savings in foreign exchange annually. These savings would also increase profitability to a considerable degree.

13.0 Employment of Local Labor

The approximate number of employees, including shift operators, indirect workers and supervision, would amount to:

Sulfuric Acid Unit	30 men
Single Superphosphate Unit	25 men
Ammoniation-Granulation Unit	15 men
Administration and Sales	15 men and women
	85 people

This annual payroll represents about $1 million dollars in the form of extra jobs and wages for people in Cyprus, with a resultant benefit to the economy and an upgrading of local skills.

14. Optimum Plant Location

There are certain overall considerations which influence the location of a fertilizer project:

1. Nearness to consuming areas
2. Availability of electric power, water & fuel
3. Port facilities
4. Proximity to indigenous raw materials
5. Facility to import raw materials and machinery
6. Proximity to towns for housing personnel
7. Transport facilities

The possible locations which could be considered are:

1. Limassol
2. Larnaca
3. Famagusta
4. Xeros

Of the above locations, the first three are on the southern coast of the island and Xeros is on the northern coast.

Nearness to consuming areas will not be a serious consideration in Cyprus since it is a small island and all the above locations are connected by good roads and internal transport by trucks is a good possibility.

Availability of electric power, water and fuel is important and as far as power and fuel are concerned, a south coast location is better. There is a 90 mega watt power station near Limassol and a 70 mega watt power station near Larnaca. As regards fuel, since the refinery is coming near Larnaca, this will be a better location. The availability of water in all the above locations have to be carefully studied.

Harbour facilities seem to be better on the south coast. For the production of 15,000 tons P_2O_5 per year as single superphosphate 50,000 tons per year of rock phosphate has to be imported. Hence, any location selected should have facilities for docking of ships whereby the rock can be unloaded direct to the wharf. Further, if in the future ammonia is to be imported for ammonium sulphate manufacture or for ammoniation, a south coast location is better.

The most important indigenous raw material is pyrites and for a project to produce 15,000 tons of P_2O_5 as single superphosphate 24,000 tons of pyrites per year will be needed. The Xeros location is best from the nearness to pyrites mines as well as the main processing plant for pyrites is also located there. If a southern coast location is selected, pyrites will have to be transported by trucks from the mines or the processing plants.

The facility to import raw materials and machinery is better at the south coast location since phosphate rock has to come from Jordan, U.A.R. or North Africa.

As regards housing of personnel, it is assumed any of the locations will be suitable.

Transport facilities to existing consuming centres for fertilizer may not be a problem from any of the suggested sites.

The most critical consideration for the final selection of location should be the facilities for import of phosphate rock. Further, if ammonia production is contemplated in the future, the raw material has to come from the refinery. Therefore, the most suitable location seems to be Larnaca with Limassol as the second choice.

ANNEX 1

[illegible]

Basic Economic Data

	1961	1962	1963	1964
Gross national product (1962 prices)				
Total ($ million)	[illegible]	[illegible]	364	[illegible]
Per capita GNP (dollars)	[illegible]	[illegible]	[illegible]	[illegible]
Agricultural production index (1952-54=100)	[illegible]	[illegible]	125	120
Per capita index	[illegible]	[illegible]	[illegible]	102
Wheat (1,000 MT)	49	[illegible]	[illegible]	68
Electric power output (Mil. KWH)	[illegible]	277	300	317
Foreign trade ($ million)				
Total exports (f.o.b.)	50	58	61	[illegible]
Minerals	[illegible]	[illegible]	(21)	(20)
Total imports (c.i.f.)	113	129	135	109
Trade balance	-63	-71	-74	-53
Gold and foreign exchange (end of year - $ million)	59	60	95	104
Cost of living index (1958=100)	102	102	104	104

Ref. U.S. Dept of State

Annex 2

C O P Y

Preliminary Forecast of Fertilizer consumption
in terms of plant nutrients
(Metric Tons)

Year	N	P_2O_5
1965	7730	8350
1966	8117	8684
1967	8523	9031
1968	8950	9392
1969	9397	9768
1970	9867	10159
1971	10360	10565

The above projections take into account both the expansion of newly irrigated land and the growing importance of urea owing to the reduction in its price. As it will be seen phosphorous consumption will increase by 4% per year, a higher rate than the one experienced in the past. Nitrogen will grow at a faster rate than phosphorous as in the past and record a 5 % growth on the 1965 level.

Our real requirements are much greater, and taking the present cropping system into consideration over 10,000N and 10,000 P_2O_5 is currently needed.

Annex 3

IMPORT OF FERTILIZERS INTO CYPRUS (in metric tons)

Year	Super-phosphate	Triple Super-phosphate	[illegible]-11-[illegible]	[illegible]-[illegible]-[illegible]	Ammonium Sulphate	Calcium Ammonium Nitrate	Potash	Total
1[illegible] (x)	33,14[illegible]		15,[illegible]54		[illegible],15[illegible]	[illegible],447	475	31,174
1[illegible]3 (xx)	3[illegible],[illegible]3	3,453	11,371	12,22[illegible]	[illegible]5,[illegible]30	17,745	356	107,973
1[illegible]4 (xx)	[illegible],5[illegible]	2,221	13,[illegible]55	[illegible],573	1[illegible],335	11,26[illegible]	386	79,990
1[illegible] (xx)	[illegible],[illegible]	4,543	12,[illegible]	[illegible],44[illegible]	20,[illegible]24	12,147	203	80,651

Source:

(x) Imports and Exports Statistics

(xx) Monthly Report of the Department of Commerce and Industry.

F. Faster
c/o UNDP, [illegible]
P. O. Box 1[illegible]5
Nicosia, Cyprus

<u>Annex 4</u>

7 October 1966

Mr. [illegible] Verm[illegible]
Inter[illegible] Adviser
Centre for Industrial Development
United Nations

<u>New York</u>

Dear Mr. Verm[illegible],

At [illegible] please find the analysis of the various types of pyrites exported from Cyprus at the moment. All three are flotation [illegible] extremely fine. Usually left in the [illegible] for a considerable [illegible] so the moisture content is extremely low.

	I	II	III
Copper	.[illegible]7%	.10-.15%	.[illegible]5%
Sulphur	4[illegible].95%	47 - 48%	[illegible].6[illegible]
Zinc	.19%	na	.15%
Iron	[illegible]	41 - [illegible]	na
Silica	[illegible].54%	na	na
Lime	.09	na	na
Magnesia	nil	na	na
Alumina	1.46%	na	na
Arsenic	.017%	na	na
Lead	.006%	na	na
Selenium	.045%	na	na
Molybdenum	nil	na	na
Cobalt	.050%	na	na
Silver	.1[illegible]9 oz/L.ton		
Gold	.0[illegible]4 "		

The data I are from the Cyprus Mines Corporation, II from the Hellenic Mining Co. Ltd (Kokkinopezoula) and III from the Cyprus Sulphur and Copper Co, Ltd.,

As to the reserve on which the expectations for the future are based, there is a reserve conservatively estimated to be [illegible] 8 million tons which contain about .8% sulphur in the region of Mavrovouni ([illegible]), which is considered to be uneconomic for export. It was not possible to get other data except the statement that it was not expected that the mining could cause extraordinary difficulties.

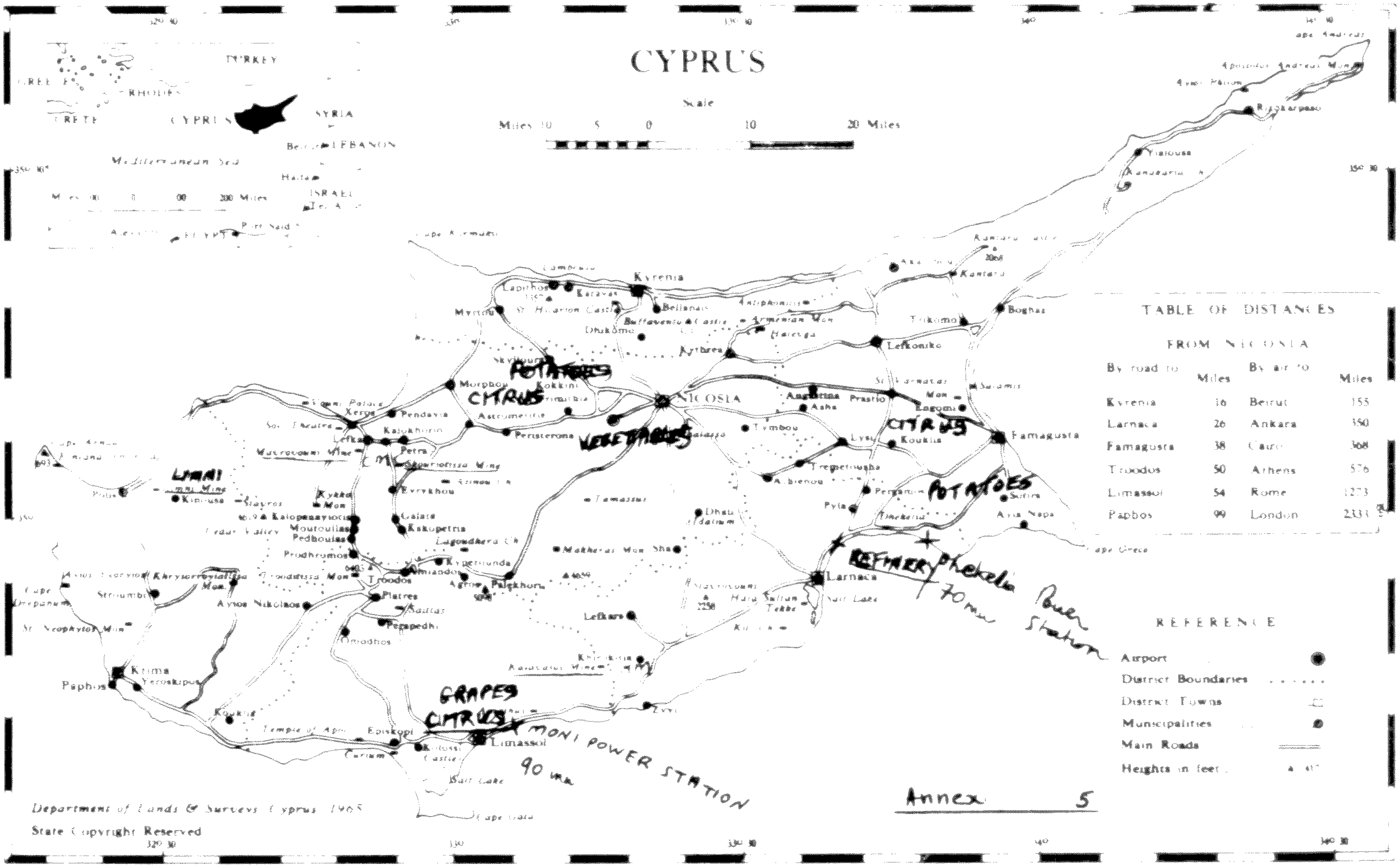
Yours sincerely,

copies sent to:

Mr. A. van der Heide, chief
Section for Europe and the Middle East
Bureau of Tech. Ass. Operations

New York

Mr. Carl G. Hald


CYPRUS
Scale
Miles 10 5 0 10 20 Miles
TURKEY
RHODES
CRETE
CYPRUS
SYRIA
LEBANON
Mediterranean Sea
ISRAEL
EGYPT
Port Said
TABLE OF DISTANCES
FROM NICOSIA
By road to Miles / By air to Miles
Kyrenia 16 / Beirut 155
Larnaca 26 / Ankara 350
Famagusta 38 / Cairo 368
Troodos 50 / Athens 576
Limassol 54 / Rome 1273
Paphos 99 / London 2331
REFERENCE
Airport
District Boundaries
District Towns
Municipalities
Main Roads
Heights in feet
Kyrenia
Nicosia
Famagusta
Larnaca
Limassol
Paphos
Ktima
Troodos
Platres
Morphou
Lefka
Xeros
Lefkoniko
Trikomo
Boghaz
Rizokarpaso
Yialousa
Episkopi
Lefkara
Pyla
Salamis
POTATOES
CITRUS
VEGETABLES
GRAPES
CITRUS
POTATOES
LIMNI
REFINERY
Phekelia Power Station 70 mw
MONI POWER STATION 90 mw
Annex 5
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ILL 5.5+10