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9 ABSTRACT

Projected fertilizer demands to 1975 in Chile are estimated on the basis of climatic factors, soil considerations, land use, and present fertilizer consumption. Given the conclusion that production should exceed the Chilean market potential, the authors recommend the manufacture of ammonia and urea in small plants for domestic consumption, the wider adoption of DAP and potassium chloride as fertilizer materials, long-term fertilizer agreements with Peru, and the export of liquefied natural gas. These recommendations further necessitate the redesign of purchasing and processing systems to accommodate the cheapest forms of raw materials, development of sea-going transport, and the construction of quality fertilizer plants. The fertilizer situation in the Andean Common Market and Venezuela is also analyzed.

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Fertilizer Supply Study for CHILE

Prepared for
CORPORACION DE FOMENTO DE LA PRODUCCION (CORFO)
in cooperation with the
Agency for International Development

by

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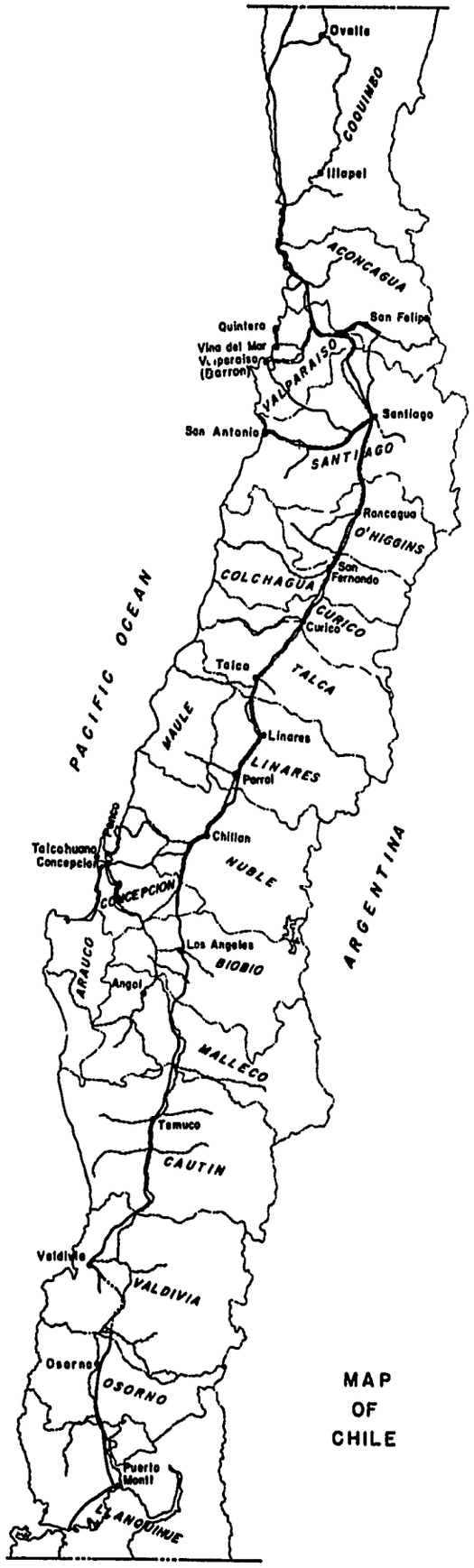
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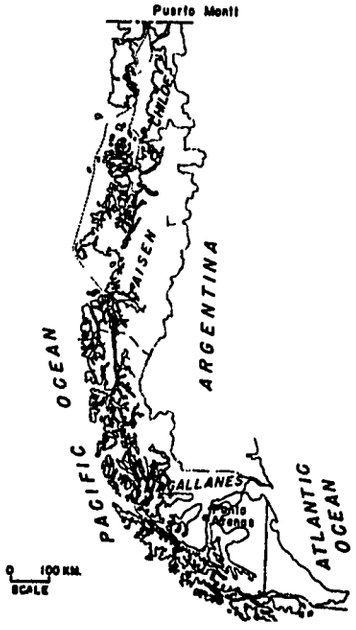
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competitive to imported urea at projected 1975 prices and foreign exchange costs would be much lower for internal production. Chile can import nitrogen as urea at a lower cost than it can produce nitrogen as either ammonium nitrate or ammonium sulfate from imported ammonia.

8. Chile can produce both ammonia and urea in plants sized to the estimated Andean market (about 150,000 tons/yr of N in 1975), at costs below importation costs, even at today's depressed fertilizer prices. However, if large ammonia and urea plants are sized to capture the Andean market, or to capture a portion of the world market, and then operated at rates substantially below full capacity, costs of production may significantly exceed costs of importation.

9. At present depressed world fertilizer prices, due to excess capacity for production, Chile can import phosphate fertilizers at costs lower than costs of manufacturing in Chile.

10. It is economically attractive for Chile to produce phosphate fertilizers when imported phosphates are valued at prices that closely approximate the total cost of production, which are likely in the world market by 1975. Total supply costs for Chilean production should be about the same as for importation, but foreign exchange costs would be much lower for internal production.

11. The most significant Chilean raw materials for fertilizer manufacture are low cost natural gas at Punta Arenas and waste SO_2 from stack gases at the El Teniente copper refinery at Caletones. The rock phosphate and sulfur in Chile are not economical to utilize in comparison with other sources.

12. The total systems costs for production of NSP in two plants located at Rancagua and Penco was about the same as for production of TSP at Rancagua. Production of either of these products at other locations resulted in higher total costs. Production cost was lower for NSP, but distribution cost was lower for TSP. Capital investment requirements were significantly lower for production of NSP than for production of TSP.

13. Based on using imported ammonia at cost of $44/ton c.i.f. Chilean ports, mixed fertilizer (18-46-0) can probably be imported at a lower cost than it can be produced. Rancagua was the Chilean plant location with the lowest systems cost for production of 18-46-0.

14. Products should be moved in bulk whenever possible to reduce transport and handling costs. Bulk movement of urea from Punta Arenas to ports serving the Central Valley should be considered. If a phosphate plant is located at Penco or San Antonio, bulk movement of phosphate products should be considered also.

15. Urea and TSP should not be bulk blended to produce mixed fertilizers because they react chemically. Therefore, production of some compound fertilizers in the existing Cia. Sud-Americana de Fosfatos (COSAF) granulation plant and/or in any new phosphate production facility should be considered.

16. Long-term trade agreements with Peru for barter of fertilizer materials could be very advantageous to both countries. For example, Chile might trade urea and/or ammonia to Peru for rock phosphate and potassium chloride from the Sechura desert. With such an agreement, Chile could carry bulk urea from Punta Arenas to northern Peru or to Ecuador–unloading at ports en route. On the return trip, bulk phosphate rock and/or potash salts could be unloaded at Chilean ports.

17. To take advantage of the long Chilean coastline, sea-going barges to carry bulk fertilizer materials should be considered in long-range planning for Chile's fertilizer systems. Barges of this type can move materials much more economically than trucks or trains. Also, they can service many shallow ports that conventional cargo ships cannot reach. Barges with bulk unloading equipment are in use. One barge in use on the West Coast of the United States transports both urea and ammonia.

As mentioned above, these same barges could be used to carry nitrogen fertilizers from Punta Arenas to ports in Peru and Ecuador–two Andean Common Market countries that should have demand for nitrogen fertilizers in excess of capacity in 1975. Rock phosphate and potash fertilizer from Peru could be returned to Chile on the backhaul. After unloading phosphate rock for a phosphate plant in Penco or San Antonio, bulk phosphate products could be loaded and carried to more southern ports as the round trip to Punta Arenas is completed. If such a barge transport system is developed, it might also be used to lower the cost of movement of Chilean nitrates and guano.

18. In construction of fertilizer plants, the building of a good quality plant by a proven and reputable contractor is the preferred practice. The additional capital investment required for a first-rate plant will usually be returned many times as increased operating time and efficiency. There is no substitute for good quality construction by a knowledgeable, reputable, and experienced firm. Proven processes usually are preferred over processes that have not been tried on a commercial scale.

ADDITIONAL COMMENTS

1. Doubling the 1969 nutrient consumption of Chile by 1975 will require a very effective and intensive market development program. In fact, developing this market will be more difficult than supplying the

SECTION I

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

THE SITUATION

1. Chile is faced with the problem of feeding a population which is growing at about the rate of 2.3%/year.

2. The total area of the country is about 76 million hectares (ha), but only about 1.6 million ha are suitable for cropping and 1.7 million ha are artificial prairies. Thus, there is a need to intensify use of the productive land.

3. The productive farm land is located in the central third of the country–in the Central Valley–between the Coastal Mountains and the Andes Mountains and parallel to the Pacific Ocean. It extends from about 200 kilometers (km) north of Santiago south to Puerto Montt–a band approximately 50 km by 1,200 km. More than 80% of fertilizer nutrients are used in the Central Valley.

4. A good highway (the Pan-American) and a good rail net run through the center of the Central Valley, and several ports are located on the Pacific coast parallel to the valley. Thus, transport conditions are good and internal distribution costs are a relatively low proportion of total cost of fertilizers to the farmer.

5. Irrigation is a critical factor in agriculture in the northern part of the Central Valley and northward. In the southern end of the Central Valley, rainfall is sufficient for a productive agriculture without extensive irrigation. The agriculture that has developed under irrigated conditions consists primarily of fruits, corn, rice, vegetables, sugarbeets, and dairying. South of the irrigated area the main crops are wheat, sugarbeets, and intensive pasture production for livestock and dairy products.

6. The A. T. Kearney & Company, Inc., which was contracted by the Banco del Estado de Chile to do a fertilizer marketing study in Chile, has projected that fertilizer nutrient consumption will double from 1969 to 1975, increasing from about 150,000 to 300,000 tons.

7. The TVA Team agrees that this quantity of fertilizer can be marketed if intensive programs of market development are carried out.

8. Based on the Kearney projection, about 40,000 tons of N, 107,000 tons of P_2O_5, and 38,000 tons of K_2O will be needed in Chile in 1975 in addition to the quantities that can be supplied from existing internal systems.

9. The supply from existing internal systems in 1975 is estimated as 48,000 tons of N and 10,000 tons of K_2O as Chilean nitrates; 50,000 tons of P_2O_5 as superphosphates; and 8,000 tons of P_2O_5 and 2,000 tons each of N and K_2O as guano blends.

THE FINDINGS

1. In addition to the Chilean market, there should be an additional market above existing production capacity for about 70,000 tons of N and 40,000 tons of P_2O_5 in the other Andean Common Market Countries (Bolivia, Colombia, Ecuador, and Peru) in 1975. If operation of small and relatively inefficient production facilities in Peru is discontinued, the nitrogen market there should be about an additional 40,000 tons of N.

2. Fertilizers for Chile should be obtained on the basis of the least cost per unit of plant nutrient including all costs of production, importation, transportation, storage, and handling. There is no apparent basis for paying a premium price for some types of fertilizers.

3. The need for sulfur has frequently been identified in isolated cases but response for a particular area or soil is not yet predictable. Research should be continued to better identify crop response to sulfur. The nutrient value of sulfur is a significant factor in choosing future fertilizer products and processes for Chile.

4. When two fertilizer materials are available at about the same cost per unit of primary and available nutrient, then the potential value of secondary and/or minor nutrients should be considered. For example, if triple superphosphate (TSP) and normal superphosphate (NSP) were available to the farmer at about the same cost per unit of P_2O_5, the NSP may be preferable for its sulfur content.

5. Practically all the potassium used in Chile has been supplied by Chilean nitrates and imported potassium sulfate. Since potassium chloride can be obtained at less than half the nutrient cost of potassium sulfate, its use should be expanded.

6. The lowest systems costs for importation of N and P materials is with a combination of urea, diammonium phosphate (DAP) (18-46-0), and TSP.

7. Chile can import ammonia at a lower price than it can manufacture ammonia in a plant sized for the Chilean market in 1975 (about 50,000 tons/yr of N). However, the ammonia produced in the 50,000 ton/yr plant can be converted to urea in Chile at a cost

fertilizer nutrients to satisfy it. Some suggestions for improving the effectiveness of fertilizers and for stimulating increased fertilizer use are:

a. Develop a stronger extension channel between research and farm production.
b. Use soil test values as the basis of fertilizer recommendations.
c. Support research work to correlate more accurately soil test values with agronomic response to lime, nitrogen, phosphate, potassium, and sulfur.
d. Keep other cultural practices–such as weed control, insect control, and irrigation–in harmony with higher rates of fertilizer use.
e. Maintain a continuous search for new plant varieties that respond to high levels of fertilizer use.
f. Study the long-term effects of lime in fertility programs on acid soils.
g. Provide an economic incentive for farmers to use more fertilizer by maintaining a ratio of product prices to fertilizer prices that makes its use profitable and by providing adequate credit at attractive terms for purchase of fertilizers.
h. Use the most economical procedures of bulk handling and bulk transport to hold down fertilizer costs.
i. "Seed" the market with imported fertilizers of the same type that will be produced in Chile before Chilean production plants come on stream.

2. It is economically attractive for Chile to produce both ammonia and urea in small plants sized for the Chilean market. Production costs in larger plants sized for the Chilean and Andean markets would be significantly lower than for plants sized for the Chilean market only. However, production costs in larger plants could significantly exceed costs in smaller plants if it is necessary to operate the large plants at substantially less than capacity. The building of plants before a market is developed is a high risk venture. It is suggested that the market be developed first–whether it be Chilean or Andean–and plant capacity designed to meet the market requirements, rather than attempting to capture or develop a market after a large plant is built. Advance planning and inter-country agreements with firm commitments should be reached before construction of plants sized for the Andean market and other export markets.

3. DAP and potassium chloride are two relatively economical fertilizer materials that are widely used in the world. However, due to some incidences of unfavorable results, their use in Chile is practically nil. The economics of use of these materials indicate that Chile should increase efforts to learn how to use them effectively.

4. The possible economic advantages of long-term fertilizer trade agreements with Peru are quite significant in planning the development of Chile's fertilizer industry. If trade agreements for Chile to send urea and/or ammonia and Chilean nitrates to Peru for phosphate rock and potassium chloride can be consummated, Chile would profit by:

a. Lower costs of production of ammonia and urea due to operation of larger, more economically sized units.
b. Lower transportation costs for fertilizers and raw materials by returning phosphate rock and potassium materials in the barges that carry nitrogen materials to Peru.
c. Much lower foreign exchange costs for Chilean fertilizer supply systems because Chilean raw materials and Chilean transportation systems would be fully utilized.

5. Unless otherwise indicated, the production costs and total systems costs calculated in this study for materials produced in Chile include a 10% return on capital investment. This is considered realistic for comparison of various systems costs with alternatives of Chilean production. However, in comparing total costs of systems involving Chilean production with importation systems costs, perhaps the Chilean production cost reflecting a 0% return on investment (R.O.I.) would be more realistic. (The production costs at 0% R.O.I. include interest and amortization costs.) Therefore, most of the tables comparing importation systems alternatives with production alternatives show systems costs with internal production at both 0% and 10% R.O.I.

6. The possibility of exporting liquefied natural gas (LNG) from Chile to other countries, such as the United States and Japan, should be thoroughly evaluated. Because of the deficit in some areas, long-term LNG prices are likely to increase.

7. If a decision is made to produce TSP for direct application in Chile, the continuous slurry process is recommended. This process gives a good quality, dense, spherical granular product, while avoiding a separate curing step. However, this granular TSP is not suitable for ammoniation and should not be bulk blended with urea.

Therefore, it is suggested that the run-of-pile TSP from the existing COSAF complex at Penco be used to produce mixed fertilizers This nongranular material could be ammoniated and granulated in the existing Penco granulation plant to give a granular mixed fertilizer suitable for bulk blending with urea and other materials. In addition to ammonia, urea, potassium chloride, and perhaps also ammonia-ammonium nitrate and/or urea solutions could be added in the granulation step at the COSAF plant to produce a variety of mixed fertilizers.

SECTION II

INTRODUCTION

This report on alternative systems for supplying Chile's fertilizer needs was prepared by a 4-man team from the National Fertilizer Development Center of the Tennessee Valley Authority (TVA). It was prepared for, and in cooperation with, the Corporacion de Fomento de la Produccion (CORFO), which reimbursed TVA for the expense of the study. The United States Agency for International Development (AID) Mission to Chile served as a liaison in the planning and execution of the study.

OBJECTIVES

At CORFO's request through USAID/Chile, TVA agreed to evaluate the technical and economic feasibility of various fertilizer supply systems for Chile and also to investigate the fertilizer situation in the other Andean Common Market countries and Venezuela. Specific objectives were:

1. To estimate 1975 fertilizer demand, including types and quantities of fertilizers required for each province.
2. To determine and compare costs of supplying the required fertilizers, including transport and handling, by various alternatives of importation and production, including both domestic and foreign currency costs.
3. To analyze briefly the fertilizer situation in the Andean Market and Venezuela, including fertilizer consumption, existing production facilities and raw materials, and projected fertilizer production capacity and demand.

BACKGROUND

In May 1968, AID/Chile arranged for a 2-man advance team from TVA to visit Chile to discuss a fertilizer study requested by CORFO. The team spent 2 weeks in Chile discussing the project, preparing an outline of work, and estimating the cost of the study. The report of the advance team, including the work outline, is in the appendix. The work outline was expanded later at CORFO's request to include an analysis of the fertilizer situation in the Andean Market and Venezuela, and the budget estimate was increased accordingly from $37,500 to $47,500.

In discussing the proposed study with CORFO the following assumptions were agreed upon to form the starting basis for the study:

1. TVA would review the fertilizer demand estimate of the A. T. Kearney & Company, Inc., which was contracted by Banco del Estado de Chile. If TVA was in general agreement with the Kearney estimate, then it would be used as the basis for the TVA study.
2. TVA also would utilize as much additional data from the Kearney study as possible, including port data, transportation, handling, and storage costs, etc.
3. TVA would be given the quantities and locations of use for sodium nitrate, potassium nitrate, and guano mined in Chile. Then TVA would compute systems costs for providing the additional fertilizer nutrients required.
4. TVA planning would utilize stack (waste) SO_2 from the El Teniente copper refinery at Caletones to produce any sulfuric acid needed for future fertilizer production.

The various alternative fertilizer supply systems costs computed by TVA should be considered only as order of magnitude costs. Small differences in costs of alternatives should not be considered as significant because of the many assumptions necessary in estimates of this type. On computing investment and operating costs, the TVA team utilized somewhat standardized assumptions that have been previously developed and used by TVA in other similar studies. Therefore, these assumptions are uniform and are considered to be sufficiently accurate and reliable for use in a study of this type.

The team visited different types of farms to get better acquainted with Chilean agriculture. This gave background for developing recommendations.

SECTION III

FACTORS RELATED TO FERTILIZER USE AND PROJECTED 1975 NUTRIENT DEMAND

The purpose of this section is to provide the setting for the study of fertilizer supply systems for Chile. Climatic factors, soil considerations, land use, and the fertilizer materials now being used were considered and the projected fertilizer use developed by Kearney was summarized.

CLIMATIC FACTORS

Briefly, the northern section of Chile is desert and subtropical, the central portion temperate, and the south rainy and cold.

Rainfall generally increases from north to south, with specific quantities at a given latitude determined by the height of terrain. The terrain may be described briefly in terms of mountain ranges and plains. There is a medium-high mountain range close to the sea and the high Andean mountain range on the east. The plains lie between the two mountain ranges; they range from intermediate height in the north to low in the south. This complex of topographic features results in greater amounts of rainfall along the coast than in the central plain and a still greater amount along the Andes (1).

The mean annual rainfall is shown in figure 1. Annual rainfall increases from only a fraction of a millimeter (mm) in Arica (at the northern extremity) to 117 mm in La Serena (one-third of the north-to-south distance) to over 2,500 mm at Valdivia (two-thirds of the N-S distance). Chile is also characterized by long dry periods during the summer when evapotranspiration is greater than precipitation. The occurrence of these dry periods, shown in figure 2, decreases in intensity to the south. In contrast to the dry periods, the May-August period (winter) is characterized by excessive rains.

Fluctuations in temperature are shown in figure 3. Generally, temperature conditions tend to be more uniform in the Central Valley, with extremes greater both to the north and to the south. The pattern of frost-free months is shown in figure 4.

In the Agricultural Development Program prepared by CORFO for 1961-1970, the country is divided into six zones primarily on the basis of rainfall and climate. These are:

Zone I. Tarapaca to Atacama: annual precipitation from 0 to 50 mm of rainfall.

Zone II. Coquimbo and Aconcagua: 50-300 mm. Arid temperate climate.

Zone III. Valparaiso to Talca: 300-1,000 mm in the Central Valley; 500-1,000 mm in the coastal region; and 400-2,000 mm in the Andean foothills. Semi-arid temperate climate.

Zone IV. Maule to Malleco: 1,000-1,500 mm in the Central Valley; 1,500-3,000 mm in the Andean foothills; and 1,000-3,000 mm in the coastal region. Temperate climate.

Zone V. Cautin to Chiloe: 1,200-1,400 mm on the coast; 1,500-2,500 mm in the Central Valley; and 2,500-4,000 mm in the Andean foothills. Humid temperate climate.

Zone VI. Aysen and Magallanes: 3,000-8,000 mm in the insular cordillera; 300-800 mm in Chilean Patagonia. Cold temperate climate.

The combination of climatic factors in Chile has made irrigation a critical factor in agriculture beginning in the Pica desert in the province of Tarapaca and extending through the Central Valley to include the province of Bio-Bio. Additionally, the need for irrigation extends through the province of Cautin. The agriculture that has developed under irrigated conditions consists primarily of fruits, vegetable crops, corn, rice, sugarbeets, and dairying. South of the irrigated area the main crops are wheat, sugarbeets, forest, and pasture with extensive livestock production.

A major crop is sugarbeets, which are grown under both irrigated and non-irrigated conditions.

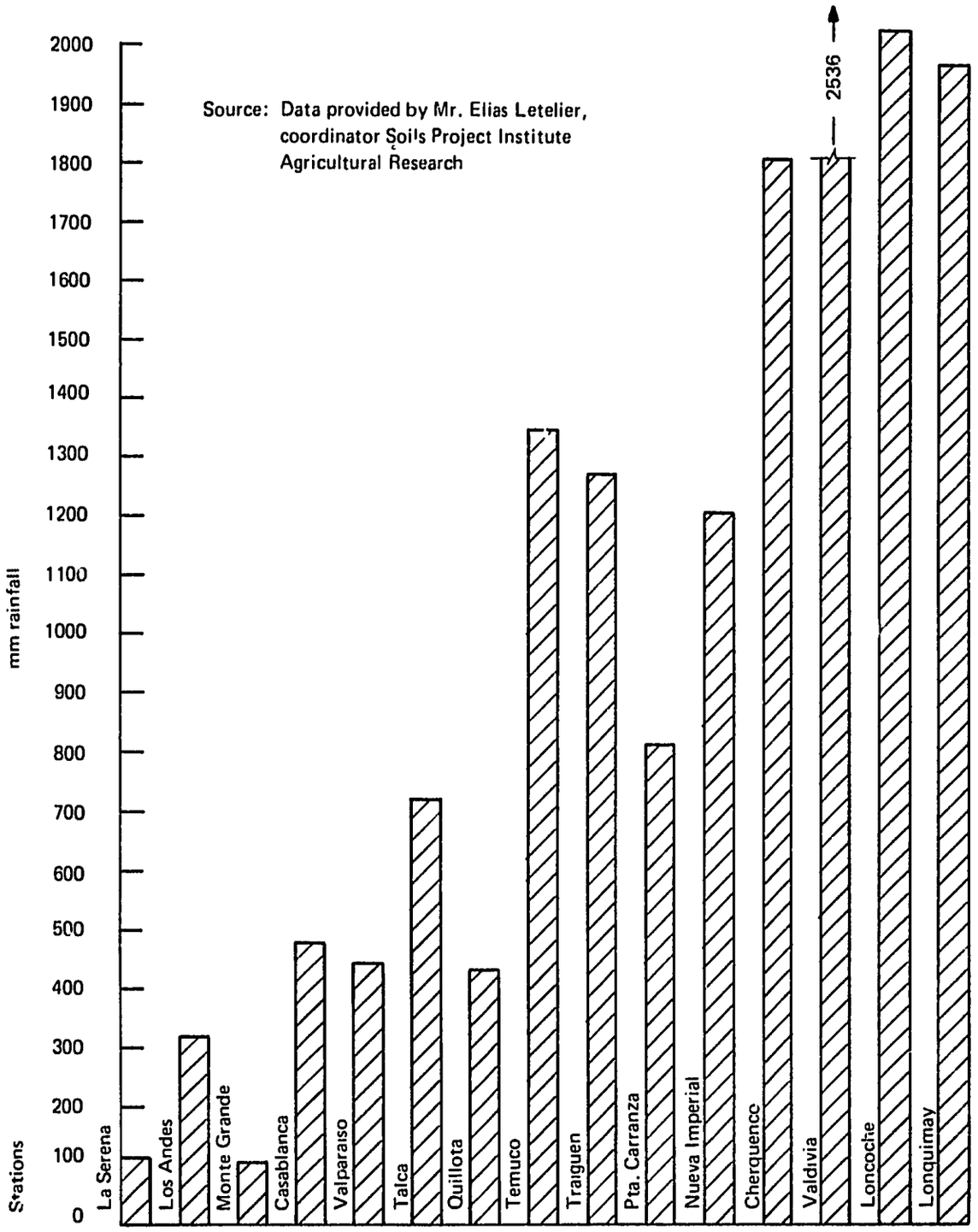
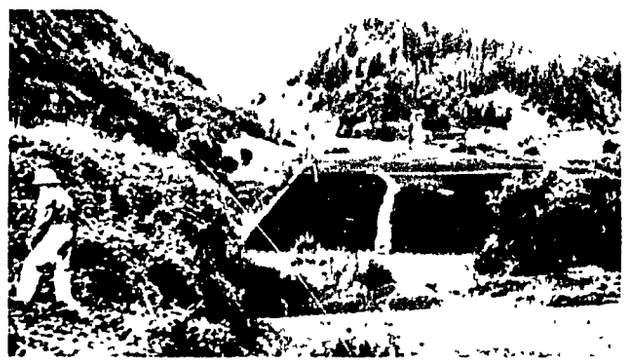


Figure 1. Mean Annual Rainfall at Selected Stations in Chile's Major Agricultural Region

Type of farming reflects topography, rainfall and other factors Modern farms are typical on the level region in the southern part of the Central Valley, while smaller farms are characteristic of other areas (below).



SOIL CONSIDERATIONS AND LAND USE

Soil Classification

The agricultural soils of Chile have been classified and mapped. Field data on profile descriptions and capacity of use are available from the Instituto de Recursos Naturales. Data on capacity of use of soils were published in 1968 as part of the plan for agricultural development 1965-1980. A summary of these data is presented in table 1. Descriptive data on chemical characteristics of soils are limited.

Fertilizer Response

Good agronomic data are available on the use of fertilizers in Chile. The Institute of Agricultural Research has experiment stations in Santiago, Chillan, and Temuco. The work of these stations is supplemented by seven substations located in the agricultural area from Vicuna to Osorno. Additionally, the sugarbeet institute (IANSA), the University of Chile, and the Catholic University do agronomic research.

Until 1969 soil laboratories for testing and making fertilizer recommendations were used very little. In 1969 the Institute of Agricultural Research supplemented its soil testing facilities at the La Platina Station at Santiago with a modern soil testing laboratory at Chillan with capacity for 10,000-20,000 samples/yr. Additional soil testing facilities are available at the United Nations Soils Department Project, the University of Chile, the Catholic University at Santiago, the University of Concepcion at Concepcion, and the Austral University at Valdivia. Pressures for increased use of fertilizers place an urgent need on the correlation of soil test values with agronomic responses to lime, nitrogen, phosphate, and potassium.

Letelier and Wright defined four distinct agricultural zones of the Central Valley in terms of fertilizer response to wheat (8). Selected response data from these are presented in table 2. Their work indicates that in general phosphorus and nitrogen are the major elements that need to be added to the soil for crop production. Calcium was found to be secondary with potassium giving less response than calcium.

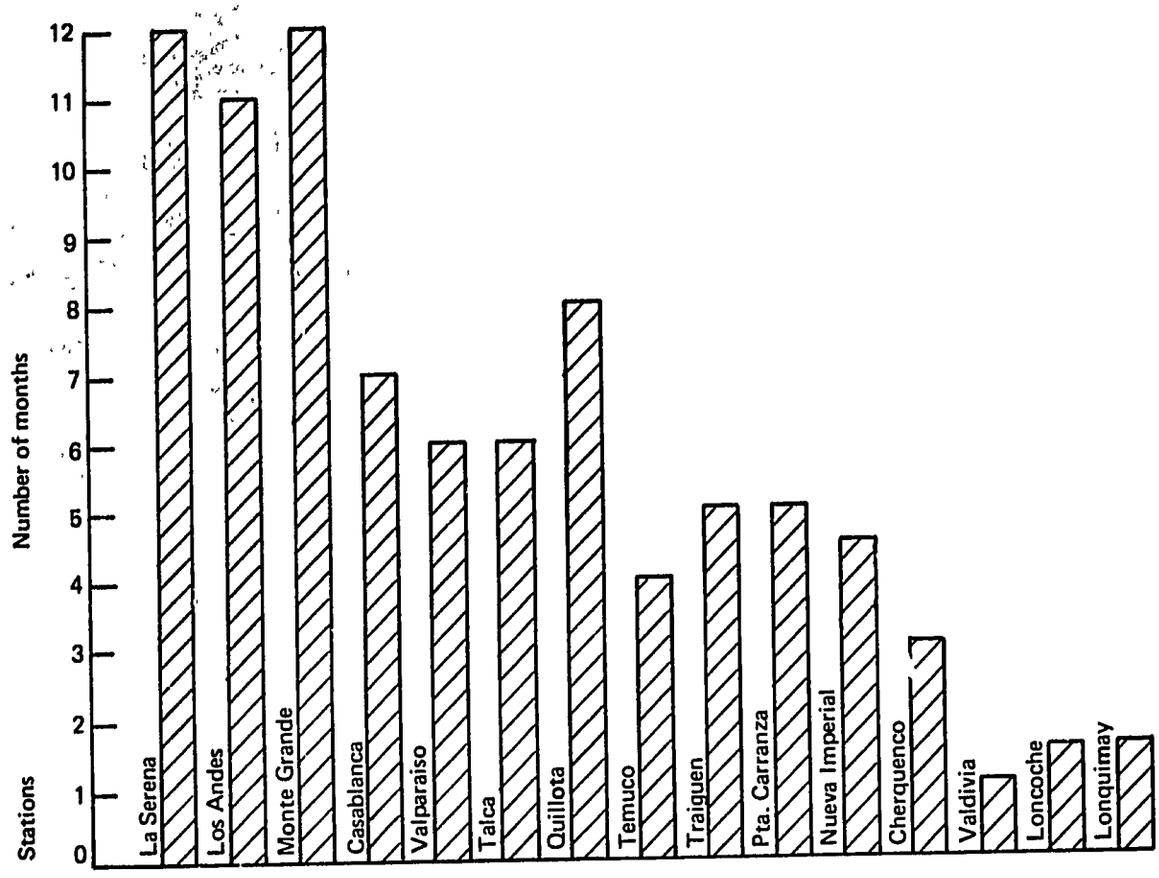


Figure 2. Number of Months in Which Evapotranspiration Exceeds Precipitation at Selected Stations in Chile's Major Agricultural Region

Briefly by zones they found that in:

Zone 1 (consisting of the provinces of Coquimbo, Aconcagua, Valparaiso, Santiago, O'Higgins, and Colchagua)–There are a few soil types "that do not conform to the regional pattern of a fertilizer response to nitrogen but to no other element."

Zone 2 (consisting of the provinces of Linares, Maule, Nuble, and Concepcion)–"In general, all soils show only a very slight response to potassium and lime, a slightly more marked response to phosphorus, and a good response to nitrogen."

Zone 3 (consisting of the provinces of Bio-Bio, Malleco, and Cautin)–"Slight responses to lime and potassium are more frequent and the response to added phosphorus in this zone becomes general and often is very marked." Phosphorus response in this area is correlated with soils derived from volcanic ash minerals. On the younger soils of volcanic origin crops, such as rape and sugarbeet cannot be grown at all without adding phosphorus. All crops and pasture show response to phosphate on these soils.

Zone 4 (consisting of the provinces of Osorno and Llanquihue)–"Both potassium and lime gave economic crop response on a number of soils, whereas nitrogenous fertilizers are much less effective, particularly if the soils have been under cultivation for some years. Almost all the soils in the zone gave a good response to added phosphorus and on some soils the response is outstanding."

Soil pH

From Santiago northward, soils are neutral or above on the pH scale. Going south from Santiago, the pH value begins to decrease, and soils are on the acid side of the scale in the more humid areas. Soils of pH 4.8-6.0 give very little response to lime. On soils of pH of less than 4.8, response has been obtained on sugarbeets but not on wheat. In pot

Table 1. Soil Classes in Chile

Class	Capability of Intensity of Use	Hectares	% of Land Surface
ARABLE			
I	Adequate soils for all crops of the zone without use limitations or risk of erosion. Permits intensive rotations and maximum use intensity. 1/1	90,834	0.12
II	Adequate soils for almost all crops of the zone with slight use limitations and slight risk of erosion. Permits intensive rotations but with some limitations. 2/3	711,533	0.94
III	Adequate soils for certain crops of the zone with moderate use limitations and moderate risk of erosion. Permits moderate rotations. 1/2	2,195,155	2.90
IV	Adequate soils for occasional crops with severe use limitations and severe risk of erosion. Permits only occasional crops. 1/5	2,270,850	3.0
	Total Arable	5,268,372	6.96
NONARABLE			
V	Adequate soils for special crops or permanent pastures, with very severe use limitations and limited to moderate risk of erosion.	2,270,850	3.0
VI	Soils not adequate for cropping without severe use limitations and severe risk of erosion. Only adequate for pastures and forest.	6,509,770	8.6
VII	Soils not adequate for cropping without very severe risk of erosion. Adequate for pastures and forest but with limitations.	12,338,285	16.3
VIII	Soils not adequate for use other than wild life.	49,277,445	65.1
	Total Nonarable	70,426,628	93.04
	Total Land Area	75,695,000	100.00

Source: Plan de Desarrollo Agropecuario 1965-1980. USO Potencial de Los Suelos de Chile Ministerio de Agricultura ODEPA, Santiago, Chile - 1968.

experiments in the greenhouse, rates of 12 tons/ha of finely ground $CaCO_3$ have been required to raise the pH from 5.8 to 6.7.

The need for phosphorus and potassium has been relatively low in the area north of Santiago, with the need for potassium somewhat lower than phosphorus. The need for both phosphorus and potassium increases to the south of Santiago, with the need for phosphorus increasing at a much faster rate.

The establishment of soil testing laboratories and the work that is under way to correlate yield response to soil-test values should provide a key factor in soil management and fertilizer use in the future.

Land Use

The total amount of land devoted to agriculture is projected in the Kearney report to remain unchanged

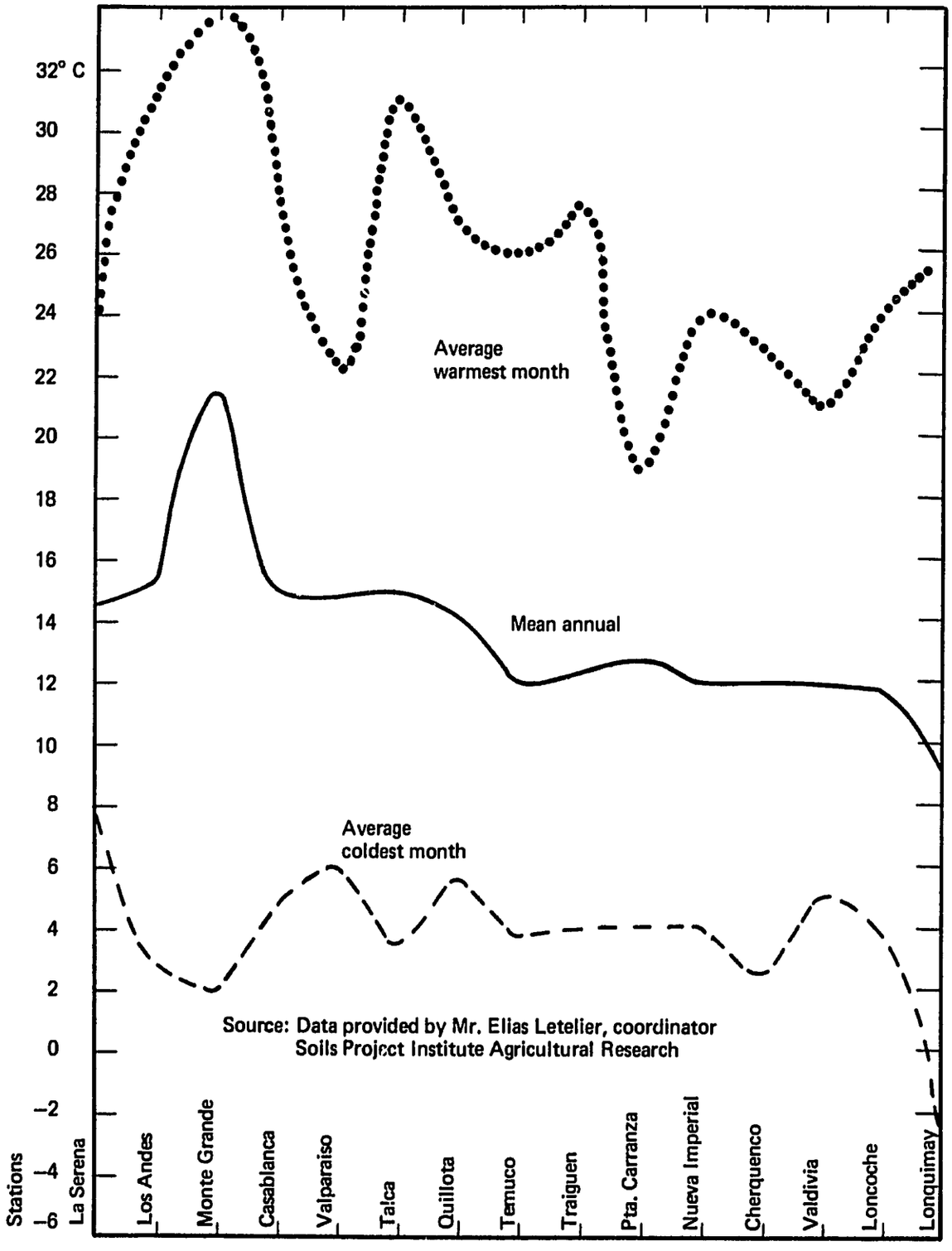
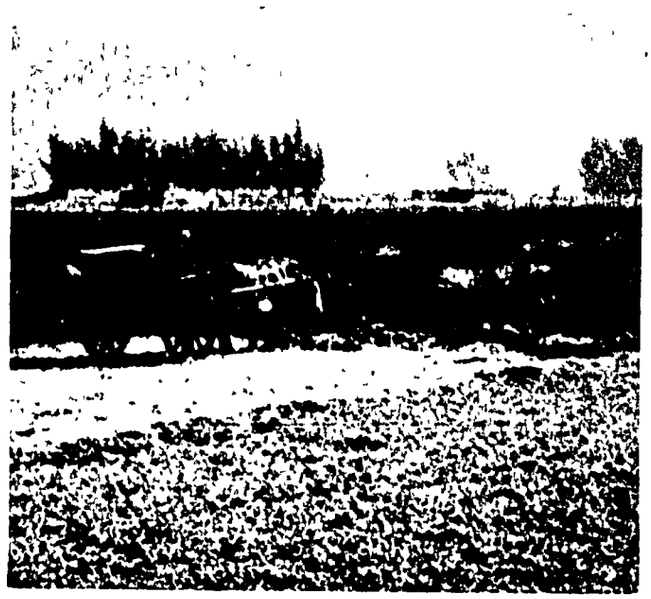


Figure 3. Temperature Values for Selected Stations in Chile's Major Agricultural Region



Hand harvesting and animal-drawn equipment are common in many areas.

through 1975. However, there is a trend toward more intensive use of land. From 1968 to 1975, land devoted to cultivated crops is projected to increase from 1,492,000 ha to 1,746,000 ha, a gain of 17%. During this same period, the area in artificial prairies is projected to increase from 1,114,000 ha to 2,174,000 ha, a 95% increase. These changes will reduce the natural prairies from 12,037,000 to 10,723,000 ha, or 11%.

The total land surface and distribution of Chile's agricultural land by major crops are shown in figure 5.

SUITABILITY OF NUTRIENT SOURCES

Nitrogen

Nitrogen has been used largely as sodium nitrate and potassium nitrate. Some urea has been used in recent years. Ammonium nitrate, ammonium sulfate, the ammonium phosphates, and other mixed fertilizers are also possible sources of nitrogen fertilizer. All of these materials are considered equally satisfactory sources of nitrogen with the following exceptions:

1. The ammonium form of nitrogen is preferred for rice grown under submersed conditions. These conditions increase the denitrification of nitrates; thus, the nitrate form of nitrogen should not be used for this crop. Even with the urea or ammonium form of nitrogen, flooding should immediately follow application of nitrogen to prevent oxidation of ammonium to nitrates.
2. Urea should not be applied as a surface application but should be incorporated into the soil. Losses of N as NH_3 have been observed on both acid and alkaline soils when urea is applied as surface applications.
3. Care should be taken in the continued application of high rates of sodium nitrate on soils under irrigation or areas of low rainfall. Salinity problems may develop under these conditions.

Benefits are sometimes claimed for such materials as calcium ammonium nitrate because it is not acid forming. The liming value of such a fertilizer is quite small in relation to cost. Usually it will be more economical to use an acid-forming nitrogen material and apply lime to correct the acidity.

Table 2. Response of Wheat to Main Fertilizers[a] in the Four Agricultural Regions: Average of 100 Field Trials 1954-56

	qq/ha[b]			
Zone	N	P	K	Ca
I	2.3	1.3	-0.7	–
II	5.5	3.5	0.4	2 0
III	3.3	6.4	1.2	1.6
IV	1.4	9.9	2.5	2.4

[a]Annual applications of fertilizers were approximately
Nitrogen 64 kg/ha N, as sodium nitrate
Phosphorus: 100 kg/ha P_2O_5, as fused phosphate "Melon"
Potassium 100 kg/ha K_2O, as sulfate of potash
Calcium, 900 kg/ha CaO, as calcium carbonate.
[b]1 q/ha = 89 lbs/acre approximately

Phosphate

Phosphate fertilizers have been used more widely than any other type of fertilizer in Chile. They appear to have

Production of livestock and dairy products is important, particularly in the southern part of the Central Valley where rainfall is plentiful.

been used at rates that were too high in relation to nitrogen and possibly potassium. Although the need for phosphate will continue to be high in relation to nitrogen and potassium, more attention needs to be given to establishing ratios of the three nutrients that will give the highest and most economical yield. Although several other phosphate materials have been available, most of this nutrient has been supplied as TSP. Some of the other phosphate carriers used–such as Bifos and Reno Blends–may have had agronomic advantages for special soil and crop conditions, but generally they have no overall advantage over TSP.

Other materials that are suitable should be considered on the basis of economics. These include NSP (0-20-0), DAP (18-46-0), and ammoniated superphosphates. If NSP can be supplied as cheaply per unit of P_2O_5 as TSP, its use would be recommended particularly in areas where sulfur response may be a possiblity. In areas where N-P grades are needed, DAP and ammoniated superphosphate would have the advantage of having both nutrients in the same material. However, these materials should not be placed too close to the seed [placement at planting should be 2 inches (in.) to the side and 2 in. below the seed]. Otherwise, seedling injury may occur during germination. This is particularly true on alkaline soils where ammonia may be released. Initial work with DAP in Chile showed some evidence of seedling damage to sugarbeets. However, with further research on placement and the release of ammonia, the problem should be overcome so that DAP can be used on sugarbeets in Chile. Perhaps using monoammonium phosphate (MAP) rather than DAP would reduce the possibility of seedling damage.

Fused magnesium phosphate has been given consideration also. Its phosphorus is citrate soluble but not water soluble. Its major use would be on full season crops–such as corn, grasses, and the legumes–in the more humid area of Chile. Generally, phosphates that have low water solubility decrease in effectiveness as particle size increases. They are not recommended for use on alkaline soils, as a starter fertilizer, or on vegetables and other crops that do not develop a massive root system.

Potassium

Potassium is the least used major plant nutrient. Even so, there are indications that too much potassium nitrate has been used in the northern part of Chile where soil supplies

of potassium generally are adequate. Most potassium has been supplied as potassium nitrate and guanos, although some potassium sulfate and potassium and magnesium sulfate mixtures have been used for several years.

Generally, the need for potassium is from Curico southward. In much of the northern part of this area the response to potassium has been slight. In the last 2 yrs responses to potassium on sugarbeets has been obtained in the Bio-Bio–Nuble areas. Observations of this nature and results of experimental work indicate that as cropping is intensified, the need for potassium will increase.

Potassium chloride has been used very little in Chile. It should be considered as a source of potassium, primarily on the basis of economics, as the need for potassium increases. If it is a significantly cheaper source of K_2O than potassium sulfate, there are only two objections concerning the use of potassium chloride. First, it should not be used on tobacco due to the bad effect on quality. Second, there have been problems with chlorine accumulations in the area around Santiago.

Secondary and Micronutrients

There are indications of localized micronutrient deficiencies in Chilean soils. Most of this has been through visual observations; research has not been extensive enough to predict areas of need. The need for sulfur has frequently been identified but response for a particular area or soil is not yet predictable. Some feel that the need for sulfur would probably rank next after N, P, and K. Careful attention should be given to NSP as an economical source of sulfur.

Lime

In Chile, lime has not been widely used as a fertilizer nutrient or as an amendment to regulate pH values. This has been true primarily because a large portion of the intensively cultivated soils have an adequate supply of Ca for plant growth and soil pH is inherently at or near the neutral value. Additionally, in the more humid areas where

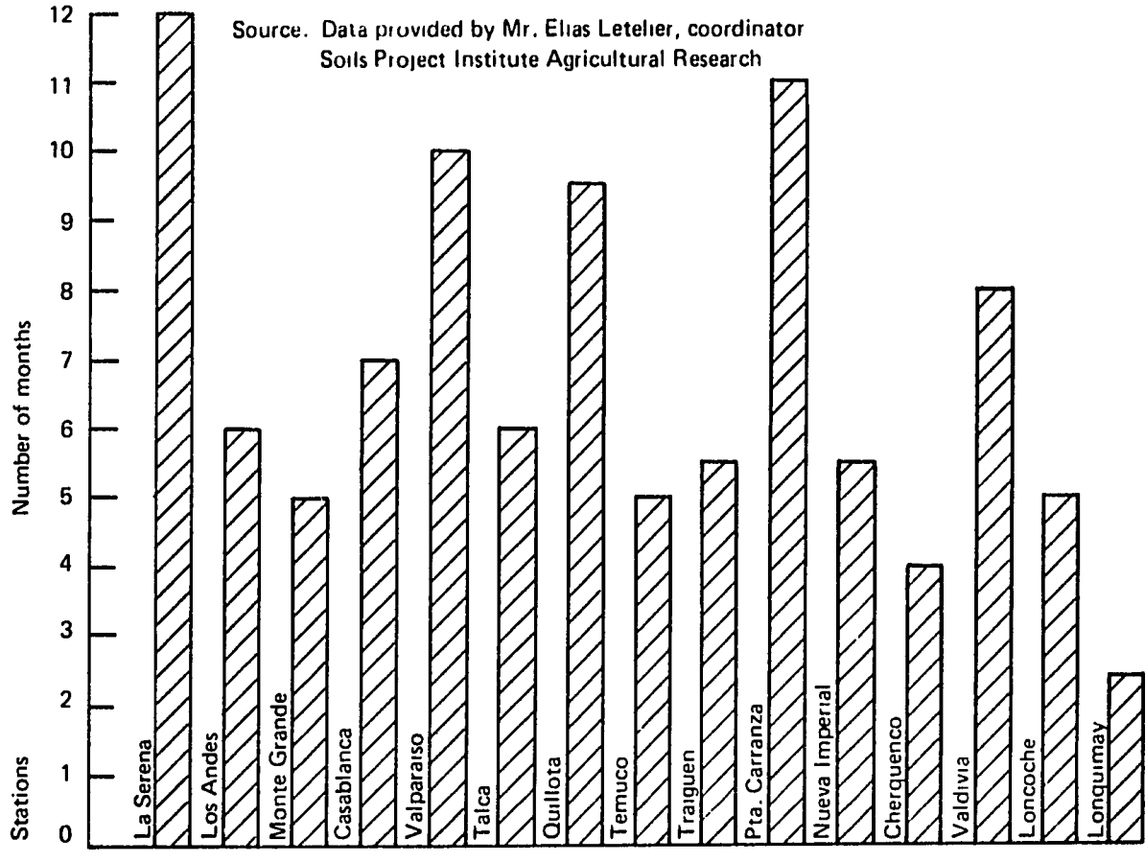


Figure 4. Number of Frost-Free Months at Selected Stations in Chile's Major Agricultural Region

At Puerto Montt, vegetables are shipped to and received from offshore islands by boat.

pH values are low, a large part of the soils are derived from volcanic ash. On these soils lime has not shown a response on crops such as wheat and the grasses used for artificial prairies the more extensive type agriculture. However, with the intensification of agriculture in the more humid regions lime will likely need to be given serious consideration in trying to obtain the greatest returns from fertilizer. The *long-term* effects of lime on the soil as a chemical system and the effect which it has on the response of other materials should be evaluated closely. Under soil conditions and farming systems where lime is needed, it usually gives a higher return per dollar invested than other fertilizer materials.

Mixed Fertilizer

Mixed fertilizers are used very little in Chilean agriculture. Two conditions will probably increase the need for their use. First, a more intensive agriculture will place greater emphasis on nitrogen and potassium use in conjunction with phosphate. This may create a situation where mixed fertilizer would be the most convenient and economical way to supply the fertilizer need. Second, when labor becomes more critical, particularly in the south, mixed fertilizer made by bulk blending and spreading services will likely become economic considerations. Bulk blends are particularly well suited to meeting soil fertility needs as indicated by soil tests. While the fertilizer industry is relatively young, thought should be given to selecting a minimum number of ratios of mixtures that will most adequately meet the soil fertility requirements of Chile.

General Observations

1. The number of grades of mixtures and the number of types of straight material should be kept to a minimum. With comparable particle size and solubility, one source of a nutrient is generally as good as any other and can be substituted as dictated by economic considerations; however, there will be isolated cases, as with the effect of chlorine in potassium chloride on tobacco, where a particular material should not be used.
2. All products should be bought on the basis of least cost per unit of plant nutrient.
3. Recently (1969), the Institute of Agricultural Research emphasized the need for soil testing services with the establishment of a soil testing laboratory at Chillan. Full support should be given to the use of soil testing as the basis for fertilizer use.
4. Each person (business or professional) who either recommends or provides fertilizer to farmers should be well grounded in the basics of soil-plant-fertilizer relationships.

5. To insure the maximum return from fertilizer, it should be considered as one of the inputs in a balanced and carefully planned farm management program. This idea should be a continuing part of all agricultural education and development.

6. Frequently, the Team heard reference to the "substitution" of one nutrient for another. This implies that a given quantity of one nutrient gives the same yield response as same quantity of another nutrient. If the practice of using only one nutrient is followed, in time the nutrients not added will be depleted from the soil. For example, if P is added without K for a number of years, there is likely to be a time when P will no longer give response without the addition of K. Thus, the practice of substitution is a short-run concept. Eventually, the nutrient in shortest supply will become limiting and will need to be included from both agronomic and economic points of view.

DISTRIBUTION OF NUTRIENT USE

The recent distribution of nutrient consumption is given by provinces in Exhibit 2-10 of the Kearney report (2). These data are condensed by four major regions of the country in table 3 From this one can see that more than 80% of Chile's fertilizer use is in the central and south central provinces. Three of these provinces, Cautin, Santiago, and Nuble consumed about one-third of the total.

Table 4 shows the relative use of the three major nutrients for 1967 Phosphates have had the largest use and accounted for 60% of the total. Nitrogen use was about one-half that of phosphate, and potassium showed limited use with only 10% of the total More nitrogen and less phosphate has been used in the central than in the south central region (regions identified in table 3). Generally, the use of nitrogen and potassium is concentrated in the central and northern areas and the use of phosphates is heavier in the south central and southern regions.

PROJECTED 1975 DEMAND

The discussion which follows is basically a summary of fertilizer projections made in the Kearney report.

Fertilizer has been recognized as an important production input by those who establish agricultural policy in Chile. Fertilizer cost in 1965 amounted to E° 71 million—13% of total agricultural inputs. By 1971 it is expected to account for E° 122 million (in Escudos of 1965)—15% of total agricultural inputs. Only animal feeds will exceed this production input in 1971.

In its Technological Study, the Kearney group concluded that fertilizer use in Chile is high in relation to other production inputs Farmers are aware of the need for fertilizer but do not understand why it is needed Generally, farmers are unaware of the difference in the function of nitrogen, phosphate, and potassium fertilizers Also, tillage practices, use of irrigation, quality seed, weed control, and other production practices are not in keeping with levels of fertilizer use. These observations are supported by comparing increased fertilizer with subsequent increases in agricultural production For example, fertilizer use in terms of nutrient units almost tripled in 11 yrs an average growth rate of 9 1%/yr. During the same time agricultural production grew at a rate of only 1.2%/yr.

These observations in no way lessen the importance of fertilizer as a production input To the contrary, increased fertilizer use will be essential to achieve the more intensive use of land which is projected for Chilean agriculture The significant point is that fertilizer is only one of many production items which must be used as a package Otherwise, fertilizer will not give its best response, or may even reduce yields. Thus, the projections which follow assume that Chilean agriculture will make more intensive use of land and that management assistance and education will receive as much or more emphasis than fertilizer All factors of production must add together to give an

Table 3. Relative Consumption of Plant Nutrients by Region (2).

	Percent of total country			Average yearly growth rate
	1963	1967	1968	1963-1968
Northern Provinces (Tarapaca - Coquimbo)	2	2	2	10 6%
Central Provinces (Aconcagua - Maule)	35	41	35	3.7
South-Central Provinces (Nuble - Valdivia)	44	43	46	5 0
Southern Provinces (Osorno - Magallanes)	19	14	16	0.6
Total	100	100	100	3.9%

Table 4. Relative Use of Fertilizer Nutrients and Materials—1967

	Nutrient	Materials
Nitrogen (N)	30%	54%
Phosphate (P_2O_5)	60	45
Potassium (K)	10	1
Total	100%	100%

Table 5. Recommended Rates of Plant Nutrient Use by Crop and Province[a]

Zone	Province	Wheat	Corn	Rice	Oats	Barley	Potatoes	Beans	Lentils	Sunflower	Rapeseed	Sugar-beets	Grapes	Vegetables	Artificial Pastures
							kg/ha								
I	Tarapaca	80-50-0	120-50-0				80-50-0								30-40-0
	Antofagasta	"	"												"
II	Atacama	80-50-0	120-50-0		60-50-0	60-50-0	80-50-0	0-40-0					80-50-0	50-50-0	30-40-0
	Coquimbo	"	"		"	"	"	"	40-40-0	40-30-0			"	"	"
III	Aconcagua	80-50-0	120-50-0	50-40-0	60-50-0	60-50-0	80-50-0	0-40-0	40-40-0	40-30-0			80-50-0	50-50-0	30-40-0
	Valparaiso	"	"	"	"	"	"	"	"	"			"	"	"
	Santiago	"	"	"	"	"	"	"	"	"			"	"	"
	O'Higgins	"	"	"	"	"	"	"	"	"			"	"	"
	Colchagua	"	"	"	"	"	"	"	"	"	0-0-0		"	"	"
IV	Curico	80-80-0	100-80-0	50-40-0	60-80-0	60-80-0	80-80-40	0-40-0	40-60-0	40-40-0		100-150-0	80-80-0	50-80-0	30-40-0
	Talca	"	"	"	"	"	"	"	"	"	0-0-0	"	"	"	"
	Linares	"	"	"	"	"	"	"	"	"	"	"	"	"	"
	Maule	"	"	"	"	"	"	"	"	"		"	"	"	"
V	Nuble	80-100-40	100-120-40	50-40-0	60-80-40	60-120-40	80-100-60	0-40-40	40-80-40	40-50-30	0-0-0	100-200-0	80-80-60	50-100-40	30-50-30
	Concepcion	"	"		"	"	"	"	"	"		"	"	"	"
	Arauco	"	"		"	"	"	"	"	"	"	"	"	"	"
	Bio-Bio	"	"		"	"	"	"	"	"	"	"		"	"
	Malleco	"	"		"	"	"	"	"	"	"	"	"	"	"
VI	Cautin	80-120-40	100-120-40		60-100-40	60-100-40	80-120-60	0-40-40	40-80-40		80-150-40	80-200-40		50-120-40	20-60-30
	Valdivia	"	"		"	"	"	"			"	"		"	"
VII	Osorno	80-150-50			60-100-40	60-100-40	60-150-80				80-150-40	50-250-80		50-120-40	20-60-30
	Llanquihue	"			"	"	"				"	"		"	"
	Chiloe				"	"	"					"			"
VIII	Aysen														20-60-30
	Magallanes														"

[a]At 90% of maximum crop yield, the levels shown are for general average conditions. Many soil conditions and farm practices may require either higher or lower amounts than indicated.
Source A. T. Kearney and Company, Inc.

High-quality, fresh fruits and vegetables are found in the traditional markets

economic return to the producer if fertilizer use is to increase as projected.

To establish a basis for making projections in the Kearney report, soil maps of Chile were studied in detail and soil-test and fertilizer-response data were evaluated. Confidence in the evaluation of such data was enhanced by conferences with research personnel and on-farm observations. Additionally, soil-test correlations developed in other countries and the data available in Chile were used to develop fertilizer recommendations by zones for each crop. The recommendations outlined in table 5 were developed to supply fertilizer sufficient to obtain response at the 90-92% level of maximum crop production. These recommended rates were then applied to the surfaces, as is outlined in figure 5, to make fertilizer projections for 1975.[1]

The relationships of projected tonnage to historical consumption are shown in figure 6 These projections indicate an increase in tonnage from 1969 to 1975 of 41,000 to 90,000 for nitrogen, 101,000 to 165,000 for phosphate, and 11,000 to 50,000 for potassium. Essentially, these projections indicate that fertilizer nutrient use should double by 1975 Indications are that use of phosphate will grow at a lesser rate than nitrogen but that potassium consumption should have the fastest growth rate of all. Several professional agriculturists in Chile who have reviewed these data think that the projections for potassium are too high The Kearney group indicated that the rapid rate of increase can be partially explained by the continuance of farmers in the northern province to use potassium where it is not recommended

The 1975 projected consumption of N, P_2O_5, and K_2O in Chile by province is presented in figure 7 The projected use portrayed by this chart closely parallels the historical patterns of use developed in Exhibit 2-10 of the Kearney report

The materials required to provide the 1975 projected consumption of N, P_2O_5, and K_2O are presented in figure 8 The materials that have normally been available in Chile were used to make these projections Although urea was projected to increase in importance and supply a large portion of the nitrogen, the nitrates were expected to supply the largest portion of the nitrogen requirements. TSP was expected to continue being the major phosphate material and phosphate nutrient supplier. DAP was not included because plans for its production in Chile were not definite at the time of the forecast. Potassium sulfate was projected to be the major form of potassium fertilizer.

[1] Although the TVA Team did not explore the crop production and fertilizer use data in the same detail as the Kearney group, it reviewed selected data, conducted interviews, and made field observations necessary to validate the assumptions and procedures for making projections.

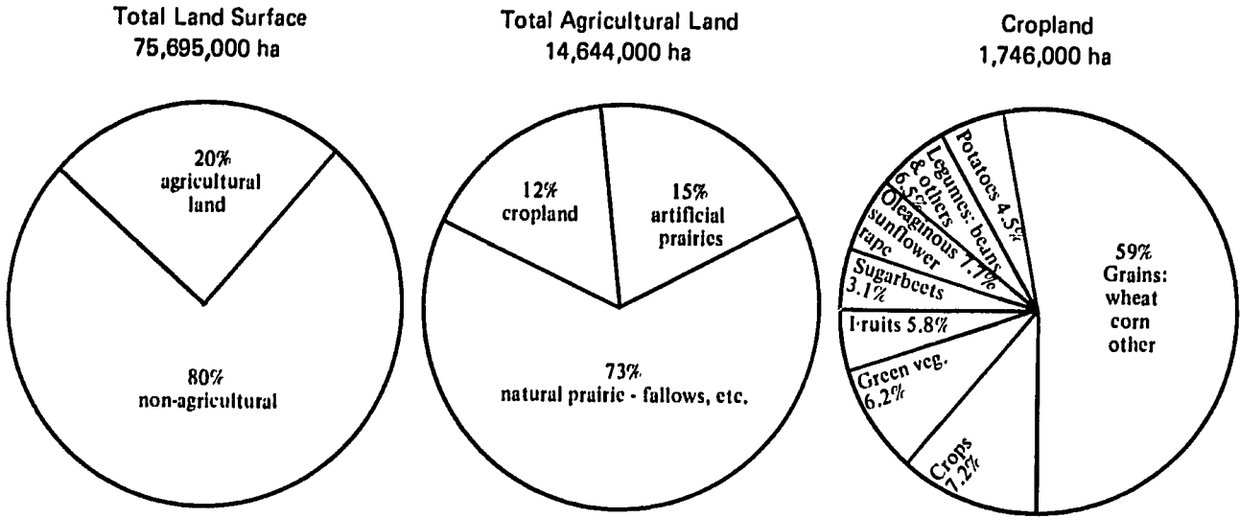


Figure 5. Total Land Surface and Distribution of Chile's Agricultural Land by Major Crop Uses (2) Projections for 1975

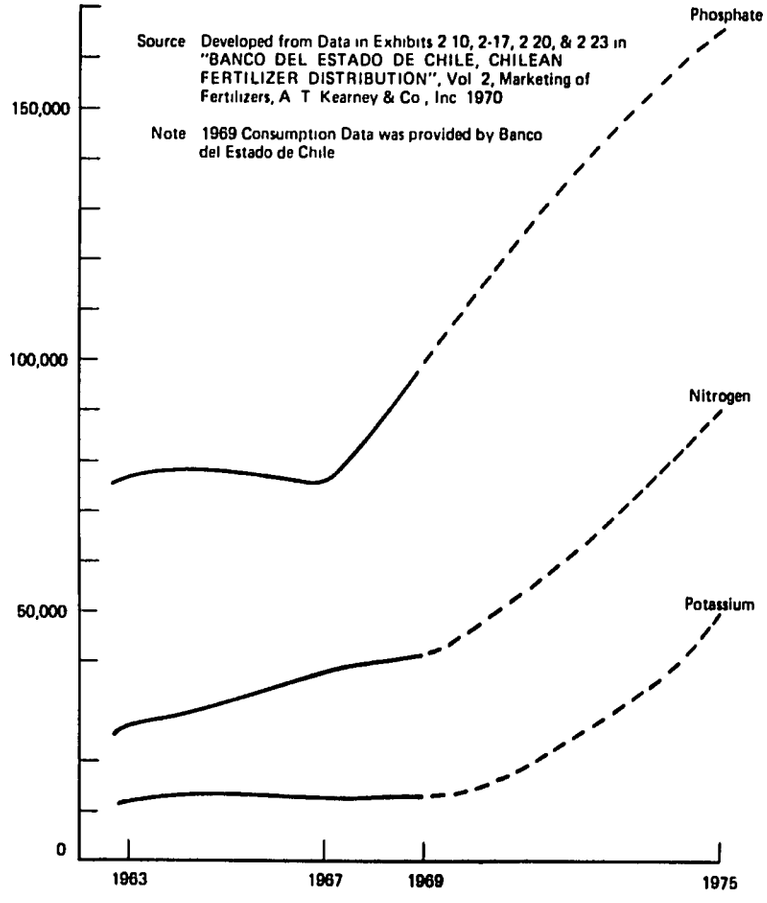


Figure 6. Historical and Projected Plant Nutrient Consumption

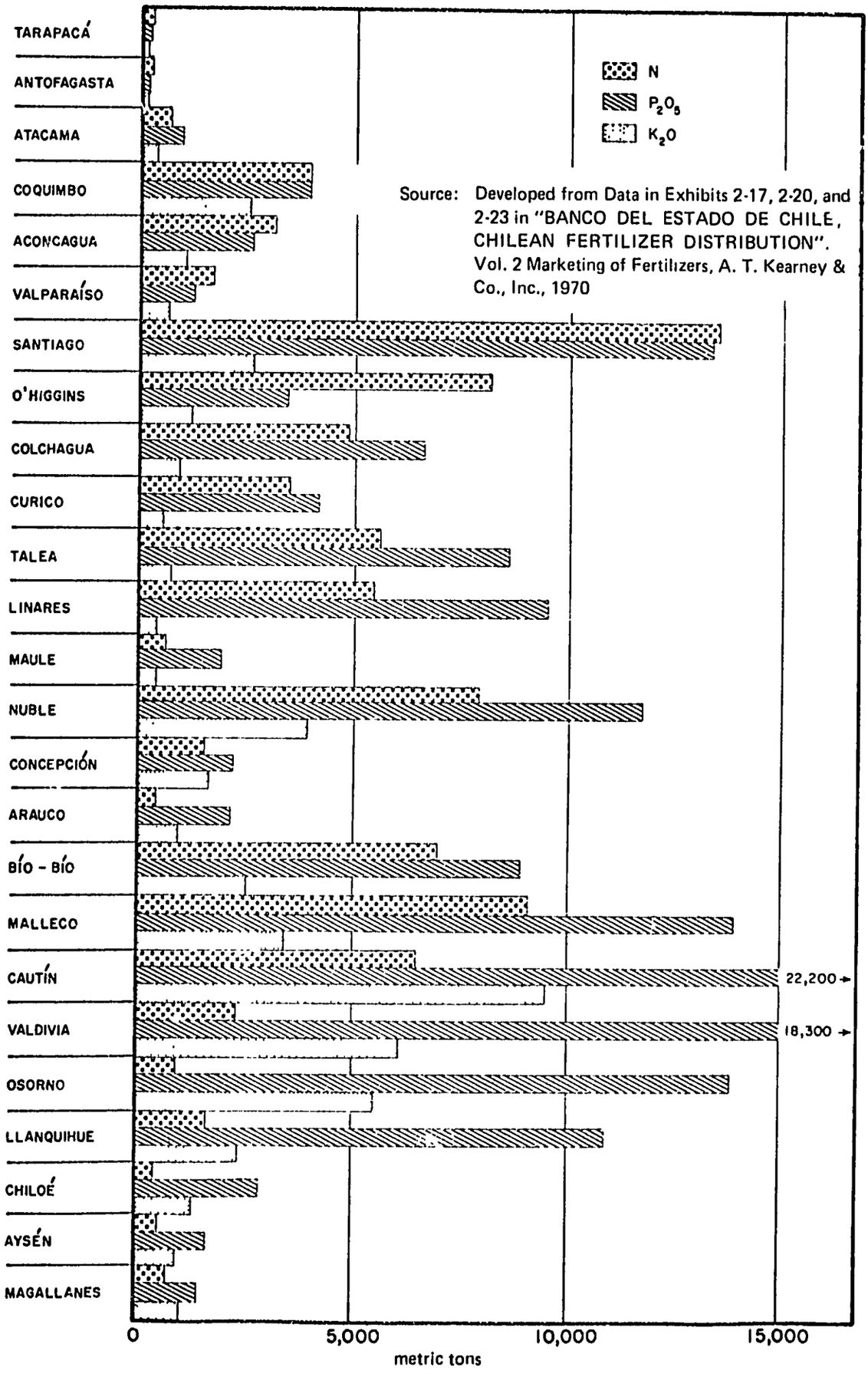


Figure 7. 1975 Projected Consumption of N, P_2O_5, and K_2O in Chile by Province

Source: Developed from Data in Exhibits 2-18, 2-21, and 2-24 in "BANCO DEL ESTADO DE CHILE, CHILEAN FERTILIZER DISTRIBUTION", Vol. 2 Marketing of Fertilizers, A. T. Kearney & Co., Inc.

	Materials
Nitrogen	1. Sodium Nitrate
	2. Potassium Nitrate
	3. (Guanos)
	4. Urea
	5. Others (20% N)
Phosphate	6. TSP
	7. Reno Blends
	3. Guano
	8. BIFOS Phosphate
	9. Other (20% P_2O_5)
Potash	2. (Potassium Nitrate)
	3. (Guanos)
	10. Potassium Sulfate
	11. K & Mg Sulfate

TARAPACA
1. —
2. (50)
3. (100)
4. 650
5. —
6. 100
7. —
8. —
9. —
10. —
11 —

ANTOFAGASTA	ATACAMA	COQUIMBO	ACONCAGUA
1. —	1 190	1. —	1. 650
2. (300)	2. (2,800)	2 (22,600)	2 (9,450)
3. (500)	3. (100)	3. (5,000)	3 (150)
4. 400	4 —	4 —	4. 3,500
5. —	5 —	5. —	5. 250
6. 200	6 1,700	6 4,700	6 4,800
7. —	7 150	7 1,000	7 500
8. —	8 100	8 600	8 300
9. —	9. 100	9 600	9 300
10. —	10 —	10 —	10 —
11. —	11 —	11 —	11 —

VALPARAISO	SANTIAGO	O'HIGGINS	COLCHAGUA
1 1,400	1 11,700	1 7,100	1 7,100
2 (5,200)	2 (24,750)	2 (11,950)	2 (8,100)
3 (1,600)	3 (1,900)	3 (450)	3 (200)
4 1,350	4 16,900	4 11,300	4 4,700
5. 150	5 1,100	5 700	5 400
6 1,650	6 22,800	6 6,400	6 12,550
7. 150	7 2,700	7 500	7 1,100
8 100	8 1,600	8 300	8 650
9 100	9 1,600	9 300	9 650
10 —	10 —	10	10 —
11 —	11 —	11	11 —

CURICO	TALCA	MAULE	LINARES
1 4,650	1 7,000	1 1,050	1 11,000
2 (3,500)	2 (5,850)	2 (2,800)	2 (2,450)
3 (2,600)	3 (1,500)	3 —	3 (1,500)
4 4,350	4 7,500	4 50	4 6,900
5 300	5 500	5 100	5 400
6. 6,850	6 15,700	6 3,900	6 17,900
7 600	7 1,500	7 50	7 1,350
8 350	8 900	8 —	8 800
9 350	9 900	9 —	9 800
10 —	10 —	10 —	10 —
11 —	11 —	11 —	11 —

NUBLE	CONCEPCION	ARAUCO	BIOBIO
1 12,900	1 1,000	1 700	1 35,100
2	2 —	2 —	2 —
3 (400)	3 (400)	3 (200)	3 (800)
4 12,600	4 2,950	4 250	4 2,800
5 600	5 100	5 50	5 550
6 22,900	6 4,400	6 4,050	6 17,250
7 1,500	7 100	7 300	7 950
8 900	8 100	8 150	8 600
9 900	9 100	9 150	9 600
10 5,500	10 2,300	10 1,300	10 3,600
11 3,600	11 1,400	11 900	11 2,300

MALLECO	CAUTIN	VALDIVIA	OSORNO
1 42,900	1 36,800	1 8,600	1 6,000
2 —	2 —	2 —	2 —
3 (1,100)	3 (1,200)	3 (1,400)	3 (1,100)
4 4,700	4 1,100	4 1,950	4 —
5. 700	5 550	5 200	5 50
6 26,900	6 43,000	6 33,350	6 25,900
7 1,800	7 2,950	7 3,300	7 2,250
8 1,100	8 1,800	8 2,000	8 1,350
9 1,100	9 1,800	9 2,000	9 1,350
10 4,900	10 13,900	10 8,900	10 8,000
11 3,200	11 9,400	11 5,800	11 5,300

LLANQUIHUE	CHILOE	AISEN	MAGALLANES
1 3,300	1. 860	1 —	1 —
2 —	2 —	2 —	2 —
3 (7,400)	3 (3,300)	3 (100)	3 —
4 2,600	4. 250	4 1,000	4 1,200
5 200	5.	5 —	5. 100
6. 17,500	6 3,700	6 3,400	6. 3,000
7 1,850	7. 400	7 —	7. —
8 1,100	8. 200	8. —	8. —
9 1,100	9 200	9. —	9. —
10 2,800	10. 1,700	10 1,300	10. 1,500
11 1,800	11. 1,200	11 900	11. 1,000

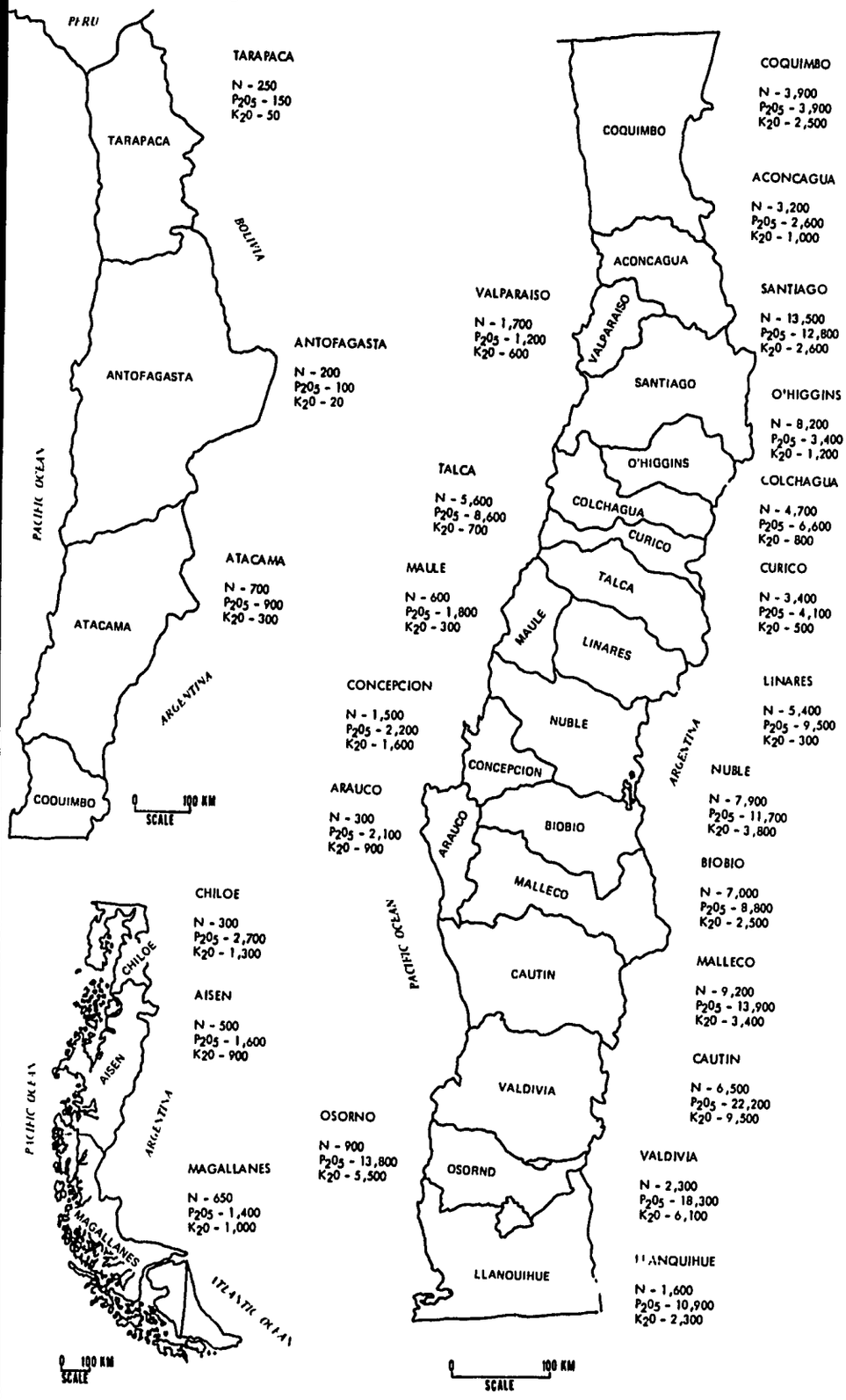


Figure 8. 1975 Projected Consumption of N, P_2O_5, and K_2O by Province (metric tons)

SECTION IV

EXISTING FERTILIZER RESOURCES: PRODUCTION FACILITIES, RAW MATERIALS, AND INTERMEDIATES

EXISTING PRODUCTION FACILITIES

Chile has facilities to produce 160,000 tons of N, 50,000 tons of P_2O_5, and 24,000 tons of K_2O as chemical fertilizer annually. All the N and K_2O capacity is as Chilean nitrates, and all the P_2O_5 is produced in a superphosphate plant located at Penco. Guano is estimated to supply about 2,000 tons/yr each of N and K_2O and 8,000 tons/yr of P_2O_5.

Chilean Nitrate Production

Practically all Chilean nitrate production is in three plants in Antofagasta province in the northern part of Chile by Sociedad Quimica y Minera S.A. (SQM). Total annual capacity by product is tabulated below:

Product	Tons
Sodium Nitrate, Grained	650,000
Sodium Nitrate, Crystalline	140,000
Potash Nitrate (15% N, 12% K_2O)	200,000

The maximum daily output by plant is given below.

Plant	Product	Tons
Pedro de Valdivia	Grained Sodium Nitrate	2,000
Maria Elena	Grained Potash Nitrate & Grained Sodium Nitrate	1,200
Victoria	Crystalline Sodium Nitrate	600

The ore containing 6-25% sodium nitrate, called "caliche", is mined in open-pit mines near the plants. The overburden, which may be 3-5 meters (m) thick, is drilled and blasted and then removed by mechanical drag lines. Then the caliche is removed in a similar way and dumped into rail trucks that convey it to the plants.

The Guggenheim process is utilized to extract the nitrates from the ore. The crushed caliche is leached with warm mother liquor and the leachate is then cooled so that the sodium nitrate crystallizes out.

To recover the potassium nitrate, the solid residue from the leaching operation is treated with water to dissolve both residual sodium nitrate and potassium nitrate together with sulfate, chloride, borate, and iodate salts. Imported potassium chloride is sometimes added to the solution to increase recovery of potassium nitrate. The dilute solution from the leaching operation is concentrated by solar evaporation in open-air ponds. As concentration proceeds, various salts crystallize out and are removed by suction dredges. When the solution in the ponds reaches the desired concentration, it is sent to crystallizers for cooling and removal of the potassium nitrate.

During the last 2 yrs labor problems have held output of nitrates down to about 600,000-650,000 tons/yr. About 250,000-300,000 tons/yr of nitrates are normally used in Chile, and the remainder is exported.

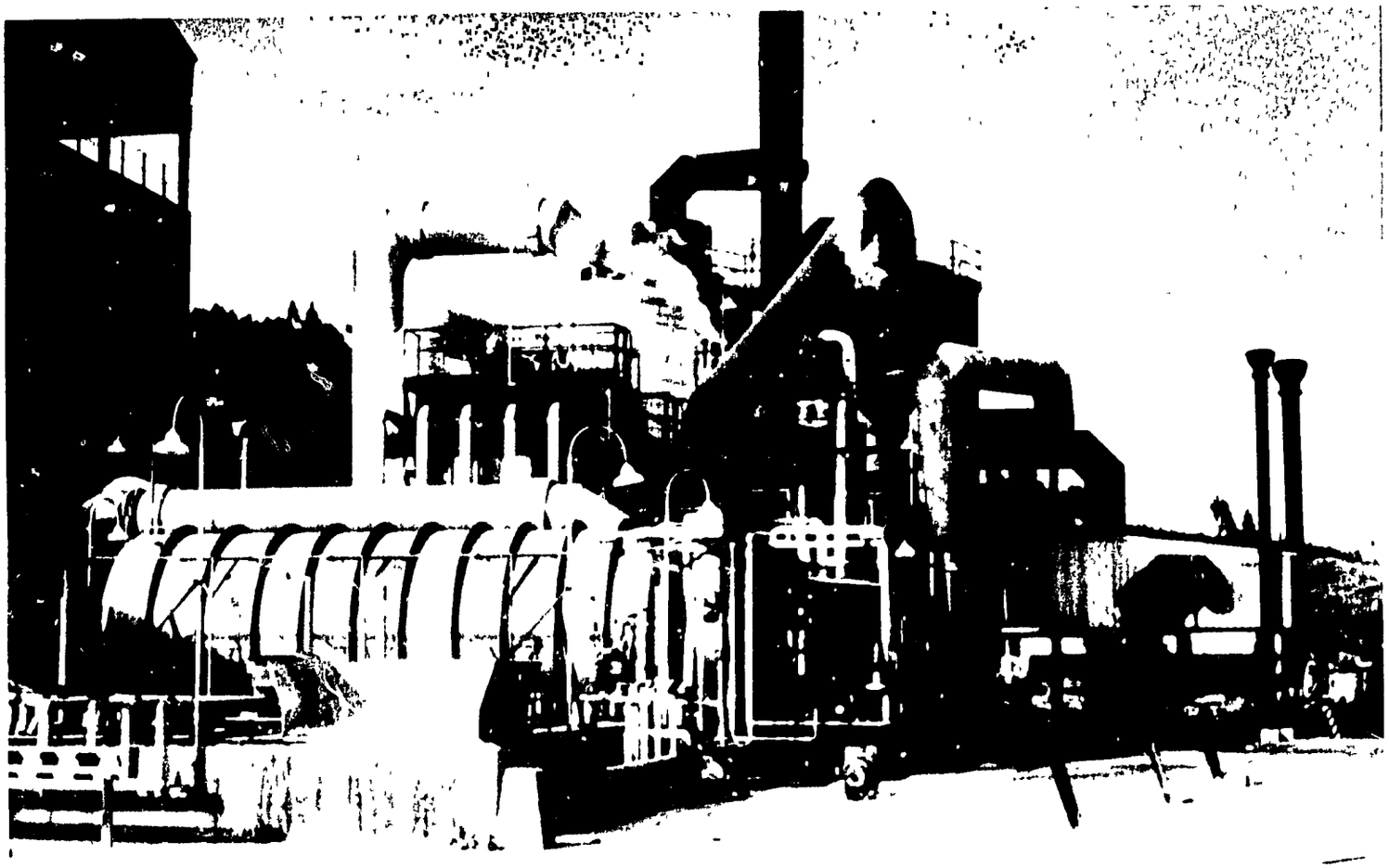
Phosphate Production

Phosphate fertilizers are produced in Chile at Penco by COSAF. Plant capacity is about 50,000 tons/yr of P_2O_5 as NSP (25% P_2O_5), TSP (46% P_2O_5), and enriched superphosphate (36% P_2O_5). The Penco production facilities were built in two parts The old plant began operation in about 1956, and the new plant in 1968

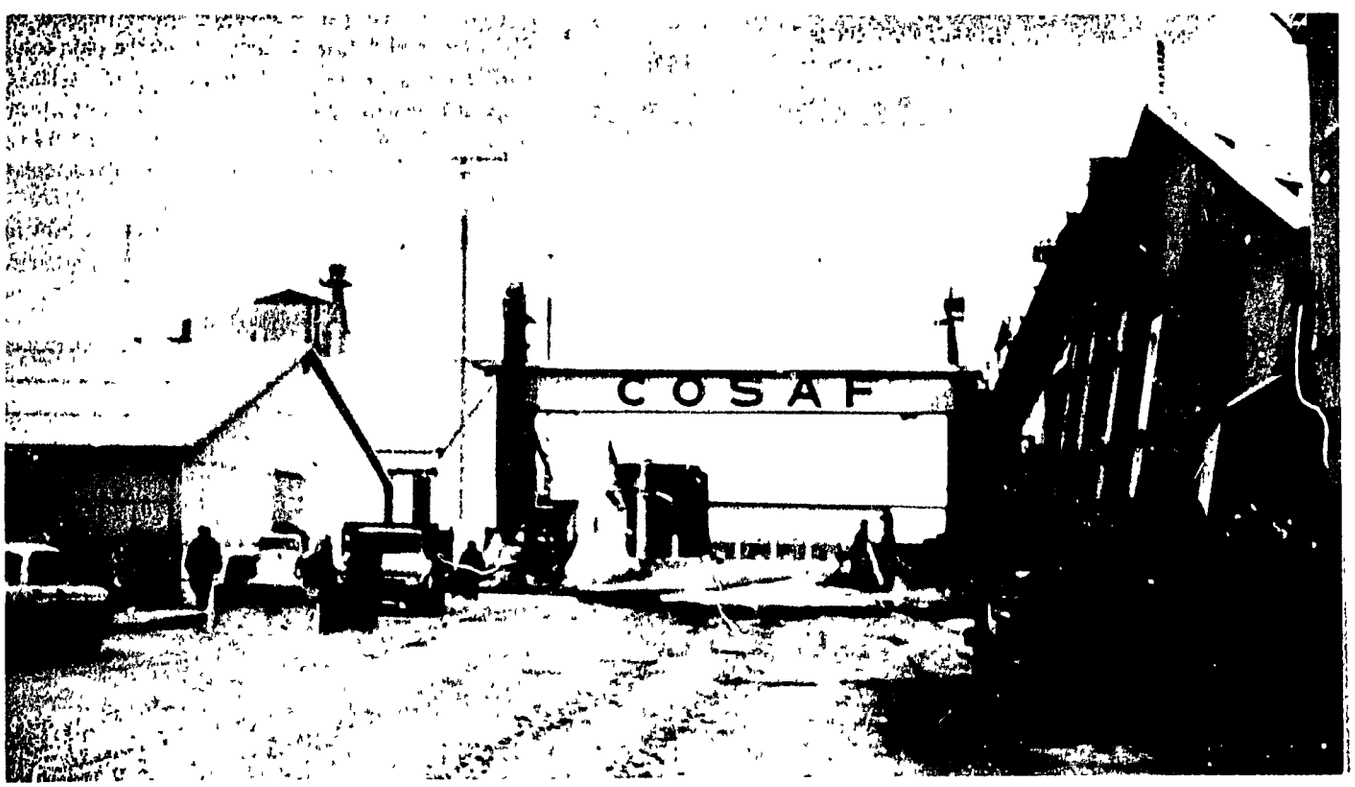
NSP is produced in the old plant by spraying sulfuric acid and water onto ground phosphate rock in a pan granulator The pan product is cured for about five days, reclaimed with a front-end loader and screened Crushed oversize and undersize are recycled Moroccan rock (38% P_2O_5) is used to produce a 25% P_2O_5 product The diameter of the pan granulator was estimated as about 12-14 feet (ft). Other components of the old plant include a 40 ton/day contact sulfuric acid plant, a 100 ton/day ring-roller mill for grinding rock, and a rotary blender with about a 1-2 ton capacity. The blender is utilized for mixing some TSP with rock phosphate before acidulation to produce a 36% P_2O_5 product.

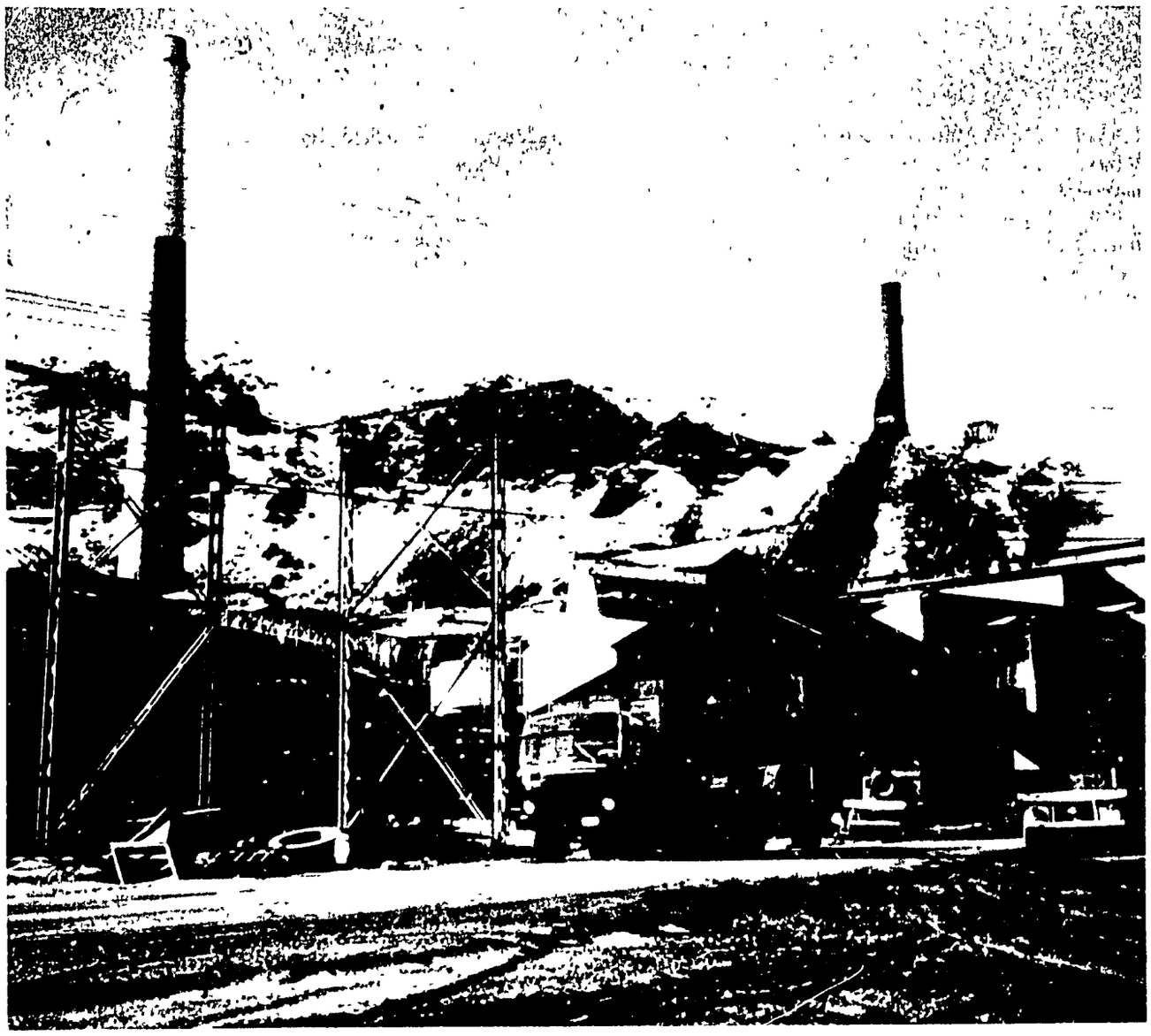
The new plant has a capacity of about 300 tons/day of either granular TSP or enriched superphosphate. Run-of-pile superphosphate is produced continuously in a cone mixer and Broadfield den. After curing, the superphosphate is granulated in a rotary drum granulator.

Sulfuric acid is produced in a 360 ton/day Monsanto contact unit. The sulfuric acid is utilized with ground Florida rock to produce wet-process phosphoric acid. The phosphoric acid unit is composed of a compartmented single tank reactor, an Eimco tilting pan filter, and Swenson evaporators. Steam from the sulfuric acid unit



COSAF produces phosphatic fertilizers at Penco.
Acid production facilities are shown above, and
the granulation facility and storage building below.





Waste sulfur dioxide from the El Teniente copper refinery at Caletones can be used to make sulfuric acid for use in fertilizer production
An expansion program at the refinery is nearing completion

is used in the phosphoric acid evaporators. Either imported elemental sulfur or sulfur produced in Chile is used for sulfuric acid feedstock.

The cured superphosphate is granulated in a Sackett rotary drum granulation unit. This unit includes an 8 ft x 16 ft granulator, a 10 ft x 50 ft dryer, a 10 ft x 50 ft cooler, screens, and oversize crusher, and a recycle return system.

The rock phosphate used in the new plant is ground in a ball mill with a 25 ton/hour (hr) capacity. Some finely ground rock phosphate (-325) mesh), with the trade name "Hyperphosphate," is also sold for direct application. Gafso rock is used for the Hyperphosphate.

All granular products from the Penco plant are packaged in 80-kilo jute bags with plastic liners. Hyperphosphate is packaged in paper bags.

Due to start-up problems with the new plant, output from COSAF's Penco plant has been less than rated capacity. In recent operation, production in the new plant was reported to be at 80% of capacity.

Production of Guano and Guano Blends

Guano is an organic fertilizer derived from the excrement of some types of sea birds. Two types of guano are harvested in Chile—red and white The white guano is freshly deposited material that contains about 14% N, 12-14% P_2O_5, and 2% K_2O. Red guano is material that was deposited many thousands of years ago and has undergone chemical changes. It contains about 0-3% N, 15-18% P_2O_5, and 0-2% K_2O.

Over 90% of current guano usage of about 18,000 tons/yr is red guano. Very little white guano is being harvested now because most of the birds have disappeared.

All red guano is marketed as a 5-20-6 grade mixed fertilizer, which is prepared by bulk blending the guano with necessary quantities of sodium nitrate, potassium nitrate, ammonium phosphate, TSP, potassium sulfate, and potassium chloride. Sales of the 5-20-6 total about 33,000 tons/yr. The blend is sold in 80-kilo jute bags with polyethylene liners.

All guano deposits are in the provinces of Tarapaca and Antofagasta. White guano is harvested by hand. Drag lines are used to harvest the red guano whenever possible, but in some inaccessible areas, it must also be removed manually. The guano and other feed materials are crushed and finely ground prior to blending The materials to be blended are pre-weighed and then blended batchwise in a rotary mixer of about 2-ton capacity. The blending plants are located at Iquique and Mejillones

Although guano is only harvested at a rate of 18,000 tons/yr, there is processing capacity for at least three times this rate Reportedly, the low processing rate was established to conserve reserves.

RAW MATERIALS

Chile has an abundance of natural gas, which is the most economical feedstock for production of nitrogen fertilizer. It has vast reserves of Chilean nitrates containing both N and K_2O. In addition to organic phosphate sources, such as guano, there are large phosphate deposits as low-grade apatite containing 12-30% P_2O_5. Extensive sulfur deposits are known, and an abundance of SO_2 and pyrites which could be used to make sulfuric acid.

Natural Gas

Exploitable reserves of natural gas in the province of Magallanes are estimated as about 120,000 million cubic meters (m^3). About 8 million m^3/day of natural gas containing 85-90% methane will be available at Cabo Negro, 30 km north of Punta Arenas, from liquefied petroleum gas (LPG) operation now under construction It is estimated that a natural gas flow of 13 million m^3 /day could be maintained for 25 yrs. Cost of this gas for ammonia production is estimated as $0.10-0.15/thousand cubic feet (ft^3).

Chilean Nitrates

Reserves of Chilean nitrate are not accurately known. They are estimated to be at least 100 million tons of nitrates in ore containing at least 6% $NaNO_3$ and an additional 100 million tons as lower grade ore. A typical analysis of the ore or "caliche" is tabulated below.

Component	Wt %
$NaNO_3$	6-10
NaCl	4.5-9.5
Na_2SO_4	10-30
Mg	0.2-1.3
K	0.5-1.6
$Na_2B_4O_7$	0.5-0.8
I_2	0.03-0.05
H_2O	1-2

Phosphate Apatite

Reserves of phosphate as inorganic apatite have been estimated at 3.8 million tons of material containing 12-30% P_2O_5 in a deposit north of Vallenar in Atacama province in northern Chile (5). The mineral is described as being mainly chloro-apatite. Analyses in weight (wt) % of two samples are given below:

Component	Sample 1	Sample 2
SiO_2	9.5	8.4
P_2O_5	28.0	24.7
CaO	37.2	36.0
Fe_2O_3	18.0	25.0
Al_2O_3	2.3	1.5
Cl	4.5	4.6
F	Trace	Trace
Mg	Trace	Trace

The mineral was mined from about 25 mines with shafts down to 100 m deep. A total of about 700,000 tons was removed from 1938 to 1965 and used to produce phosphate fertilizers by thermal processes. Mining operations were discontinued in 1965 because of high costs High costs were said to be due to the deep shafts, the hardness of the rock, the lack of mechanized equipment, and the lack of economical beneficiation processes

The apatite from the mining operations was used to produce phosphate fertilizers described as monocalcium phosphate and sold under the trade names "Fosfato Pelicano" and "Fosfato Melon." "Fosfato Melon" was produced by calcining a ground mixture of apatite, sodium sulfate, coal, and lime at 1,200° C. "Fosfato Pelicano" was produced in a similar manner, except that salitre was utilized instead of sodium sulfate. An analysis of the "Fosfato Pelicano" is given below.

Component	Wt %
P_2O_5	20-22
SiO_2	15
CaO	33
Fe_2O_3	9
Al_2O_3	2.5
Magnesia	3.5

Sulfur (3)

The sulfur deposits of Chile are among the largest known reserves of native sulfur ores in the world, with surveyed reserves of about 35-40 million tons of S in ores averaging about 50% S. (This sulfur ore or "volcanic sulfur" differs from elemental sulfur of the "Frasch" type in that it is combined with mineral impurities and must usually be refined before it can be used.) Situated on or near the volcanic peaks of the Chilean Andes, the deposits occur mostly at altitudes of 12,000-14,000 ft with some in the north as high as 20,000 ft. The principal layer of sulfur ore, or "caliche," consists of yellowish-white ore containing 45-75% sulfur, but rich pockets of almost pure sulfur (85-95% S) sometimes occur.

The principal known sulfur deposits are tabulated below:

	Number of sulfur deposits		Reserves	
Province	Surveyed	Not surveyed	Million tons[a]	Average % S
Tarapaca	10	31	12.6	52
Antofagasta	18	17	14.1	51
Atacama	11	3	13.4	50
Coquimbo	1	2	0.1	55
Santiago	–	1	–	–
Colchagua	1	–	0.5	50
Talca	–	1	–	–
Nuble	–	1	–	–
Bio-Bio	–	2	–	–
Cautin	–	2	–	–
Valdivia	–	3	–	–
	41	63	40.7	51

[a]Refers only to surveyed deposits.

Production capacity of individual mining and refining operations which have been active in the past 15 yrs, is about 120,000 tons. Sulfur refining is usually carried out in autoclaves.

Sulfur Dioxide in Metallurgical Gases

Potential for production of sulfuric acid from metallurgical gases is estimated as 4,000-4,500 tons/day of H_2SO_4. When the present expansion program at the El Teniente copper refinery at Caletones is completed, converted gases containing 5.5% SO_2 will be available in quantities sufficient to produce up to about 1,800 tons/day of sulfuric acid. Since this location is near the heavy fertilizer use area and since the waste SO_2 after the expansion will increase air pollution problems, CORFO requested that the TVA Team consider sulfuric acid production from this source.

INTERMEDIATE PRODUCTS

There are two intermediates available in Chile that can be used for fertilizer production. Sulfuric acid, which is an intermediate for production of either some phosphatic fertilizer or ammonium sulfate, is produced at a rate of about 1,700 tons/day in 23 plants. Most of this acid is consumed in metallurgical treatments. A listing of these sulfuric acid plants with their locations and capacities is given in table 6.

Red guano is used as an intermediate for blending with sodium nitrate, potassium nitrate, potassium chloride, potassium sulfate, TSP, and DAP to produce the 5-20-6 guano blend now marketed in Chile. Reserves of guano are estimated as 1,000,000 tons, and production rate is projected at about 18,000 tons/yr of 1.5-17-1 grade material.

Table 6. Sulfuric Acid Plants 1970

Plant	Geographical Location	Design	Process	Raw Material	Nominal Capacity mt/day
FASSA	Arica	Monsanto	Contact	Sulfur	15
Chuquicamata	Chuquicamata	Monsanto	Contact	Pyrites	67
Sudamericana de Explosivos	Calama	—	Contact	Sulfur ore	10
Mantos Blancos	Estacion Latorre	Lurgi	Contact	Sulfur	120
FASSA	Antofagasta	Lurgi	Contact	Sulfur	60
Chile Canadian	Paposo	Monsanto	Contact	Sulfur	40
ENAMI	El Salado	Petersen	Contact	Sulfur	20
Hoschild	Copiapo	Lurgi	Contact	Sulfur	30
FASSA	Vallenar	Monsanto	Contact	Sulfur	30
Brillador	La Serena	Chemiebau	Contact	Sulfur	10
Panuleillo	Ovelle	Petersen	Contact	Sulfur	15
ENAP	Concon	Chemiebau	Contact	Sulfur	15 (50% waste acid)
SAID	Quillota	Monsanto	Contact	Sulfur	15
Arteaga	Santiago	Mixo Packard	Lead Chamber	Sulfur	22
Rayonhil	Llolleo	Monsanto	Contact	Sulfur	45
Borlando	San Antonio	Own design	Contact	Sulfur	10
El Teniente	Caletones	Lurgi	Contact	SO_2 Gases	67
CAP	San Vicente	Monsanto	Contact	Sulfur	10
COSAF	Penco	Monsanto	Contact	Sulfur	40 + 360 (2 plants)
Chagres	Aconcagua	—	Contact	SO_2 Gases	100
Copper Co. of Chuquicamata	Chuquicamata	—	Contact	Sulfur ore	500
Paipote[a]	Copiapo	—	Contact	SO_2 Gases	120
				Total	1,721

[a]Under construction.

SECTION V

PRODUCTION ALTERNATIVES AND COSTS

To meet the expected annual demand for plant nutrients by 1975 (90,000 tons of nitrogen, 165,000 tons of P_2O_5, and 50,000 tons of K_2O), Chile must develop substantial additional sources of supply. In fact, the needed expansion in supply is much larger than current domestic production (table 7). Of the three major nutrients, nitrogen is the only one for which current production is equal to at least half of the projected 1975 need

POSSIBLE PRODUCTS

Feasible products for supplying Chile's nutrient needs are tabulated below.

K_2O		Nitrogen	
Material	Grade	Material	Grade
Potassium chloride	0-0-60	Ammonia	82-0-0
Potassium sulfate	0-0-52	Urea	45-0-0
		Ammonium nitrate	33.5-0-0
		Ammonium sulfate	21-0-0

P_2O_5		Mixed Fertilizer	
Material	Grade	Material	Grade
Triple Superphosphate	0-46-0	Compound Fertilizers	
Magnesium phosphate	0-20-0	Diammonium phosphate	18-46-0 (possibly also 11-55-0)
Ordinary superphosphate	0-20-0	Ammoniated superphosphates	
		Bulk Blends	

The additional potassium fertilizers are not available in Chile and must be imported. The N and P_2O_5 products were considered appropriate for possible manufacture in Chile Liquid fertilizers were not considered because the total fertilizer demand is not great enough to justify production of both liquid and solid fertilizers Also, liquid fertilizers require specialized storing and handling equipment and techniques not now available in Chile. Because byproduct sulfuric acid will be available, the wet process received primary consideration for production of phosphoric acid to produce ammonium phosphates and TSP. Nitric phosphates (products made by acidulation of phosphate rock with nitric acid) were not considered because they would result in production of much excess nitrogen fertilizer above Chile's needs and because very large plants are needed for economy [About 2 pounds (lbs) of N/lb of P_2O_5 are produced in commercial nitric phosphate processes.]

Table 7. Estimated Supply-Demand Relationship for Chile in 1975

	1,000 mt		
	N	P_2O_5	K_2O
Demand	90	165	50
Supply			
Chilean Nitrates	48	–	10
Guano	2	8	2
Penco Plant (COSAF)	–	50	–
Total	50	58	12
Additional Supply Requirement	40	107	38

CAPACITY AND LOCATION OF PLANTS

A tabulation showing several alternatives for location of plants and plant capacities is given in table 8. Punta Arenas was selected as the location for ammonia production because it is a source of natural gas which is the preferred and least-cost raw material for ammonia production For favorable economics, ammonia should be produced in large plants. Therefore plants were considered which would produce more than the nitrogen requirement of Chile in 1975 Consideration was given to operation of large plants at less than design capacity in case excess production could not be exported Also studies were made with an ammonia plant which would approximately supply the supplemental nitrogen needs of Chile in 1975

Punta Arenas was also selected as the site for urea plants which must be located adjacent to ammonia plants to utilize their ammonia and also their byproduct carbon dioxide which would otherwise be wasted As with ammonia plants, a range of sizes and operating levels were studied. One plant was sized only to supply Chile's additional nitrogen needs in 1975

Rancagua and Puerto Montt were considered as possible sites for production of ammonium nitrate because of the nearness of these cities to major fertilizer markets and sources of raw materials Penco and Puerto Montt are expected to be major ports for bulk handling fertilizer materials Penco is convenient for ocean shipping so plants which would have considerable excess capacity in 1975 were considered for this location in addition to considering plants sized for Chile's needs only. The excess production

Table 8. Plant Locations and Capacities

Material	Nitrogen Plants	Annual capacity 1,000 mt of nutrient
Ammonia	Punta Arenas	270
Ammonia	Punta Arenas	163
Ammonia	Punta Arenas	54
Urea	Punta Arenas	134
Urea	Punta Arenas	89
Urea	Punta Arenas	42
Ammonium Nitrate	Penco	70
Ammonium Nitrate	Penco	50
Ammonium Nitrate	Puerto Montt	50
Ammonium Nitrate	Rancagua	42
Ammonium Nitrate	Victoria	33
Ammonium Sulfate	Rancagua	42
	Phosphate Plants	
Triple Superphosphate	Rancagua, Penco, & San Antonio	120
Magnesium Phosphate	Valdivia	11
Ordinary Superphosphate	Rancagua, Penco, & San Antonio	120
	Mixed Fertilizer Plants	
Diammonium Phosphate	Rancagua, Penco, & San Antonio	N-47, P_2O_5-120

might be exported or some of it might be used for explosives or some other industrial use in Chile. Also, some nitrogen solutions made from ammonium nitrate, ammonia, and water might be utilized in the existing COSAF granulation plant at Penco

Ammonium nitrate reportedly can be produced from sodium nitrate, ammonia, and carbon dioxide by an ion exchange process; a co-product is sodium carbonate. Since SQM has an internal need for both of these materials, it is considering a plant to produce 33,000 mt/yr of nitrogen as ammonium nitrate at Victoria. A very preliminary study of this project was made because the process is in an early stage of development. A study was made also of a plant at Rancagua to produce Chile's needs for nitrogen in 1975 as ammonium sulfate since a source of the required sulfuric acid is located near there

The major raw materials needed for NSP or TSP production are sulfuric acid and phosphate rock. Since Rancagua is near a source of sulfuric acid and since San Antonio and Penco are ports for import of phosphate rock, these three cities were considered as sites for superphosphate production needed for Chile. These materials as well as ammonia are needed for mixed fertilizer (DAP) production which was considered for Rancagua, Penco, and San Antonio. The NSP and TSP, and the DAP plants, provide a slight margin above estimated phosphate requirements in 1975.

At CORFO's request, a fused magnesium phosphate plant to supply 11,000 mt/yr of P_2O_5 at Valdiva was studied.

MANUFACTURING PROCESSES

The following is a brief description of manufacturing processes which may be used to supply nitrogen and phosphate fertilizers in Chile When a choice of a process or process modification was available, the one considered most suitable for use in Chile was selected In some cases, where there was no clear-cut choice between processes or modifications, the processes are described in general terms to include more than one modification It should be emphasized that the choice of a process is often of secondary importance to the need for choosing a capable and experienced engineering and construction firm and providing this firm with sufficient capital to build a high-quality plant Although building a good quality plant requires additional capital investment, this investment will normally be returned many times as increased operating time and operating efficiency.

AMMONIA

The major steps involved in manufacture of anhydrous ammonia are: (a) gas preparation, (b) carbon monoxide conversion, (c) gas purification, and (d) ammonia synthesis. A flow diagram of a process which utilizes steam reforming of natural gas for hydrogen preparation is shown in figure 9. Although the natural gas at Punta Arenas reportedly contains no sulfur, a desulfurizer which uses zinc oxide is shown as a precautionary measure. The natural gas is

preheated, mixed with superheated steam, and passed through a nickel-base catalyst contained in tubes heated externally to about 900° C in a primary reformer. The effluent gas--consisting of H_2, CO, CO_2, excess steam, and unconverted hydrocarbons -passes through a secondary reformer containing the same type catalyst where the remaining unconverted hydrocarbons are reduced to about 0.3%. As the gas flows into the secondary reformer a controlled amount of preheated air is added to provide sufficient oxygen to reform the residual hydrocarbons and to supply the nitrogen needed to give a 3:1 ratio of H_2 to N_2 in the synthesis make-up gas.

Hot flue-gas from the primary reformer furnace is used to preheat the feed gases and generate high-pressure steam required for the reforming operation. The gas leaving the secondary reformer flows through a wasteheat boiler where more high pressure steam is produced for power recovery.

Carbon monoxide produced in the primary and secondary reformers is converted to hydrogen by reaction with steam in the presence of catalyst in the shift converter. This reaction is exothermic and no additional heat is required. The degree of CO conversion attained is a function of steam gas ratio, catalyst temperature, catalyst activity, and gas space velocity The reaction is carried out in a converter unit packed with multiple beds of catalyst. First, the steam-gas mixture flows through a bed of high temperature catalyst operated at about 370-450° C where CO is reduced to 3% or less. Then the gas is cooled and passed through a bed of low temperature catalyst operated at about 200° C. Here the CO is reduced to less than 0.5%. Zinc oxide is used to remove any hydrogen sulfide that might be present in the gas stream before it enters the low-temperature catalyst bed

Converted gas leaving the shift converter flows to the purification step where CO_2 is removed by countercurrent

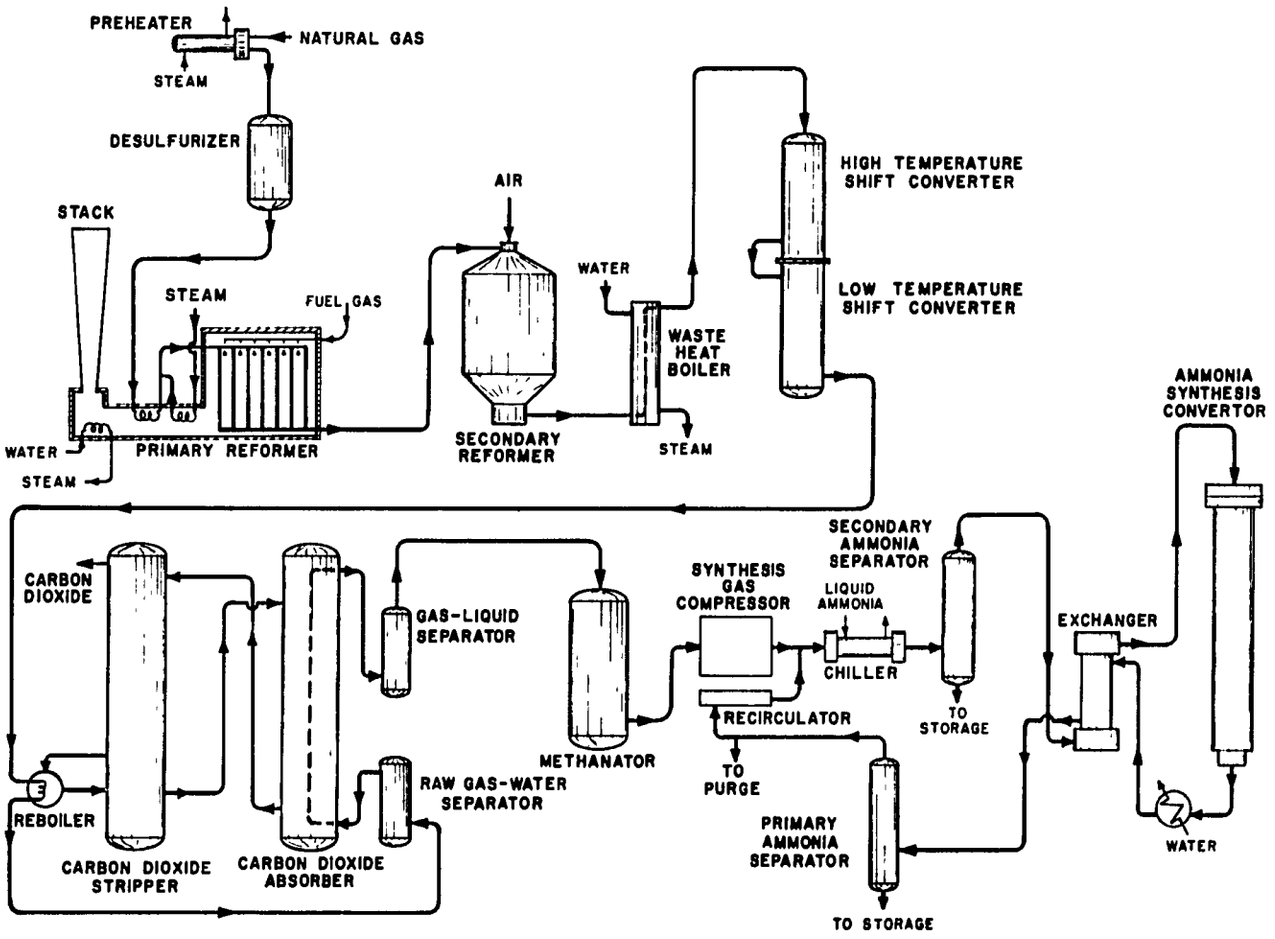


Figure 9. Flow Diagram of an Ammonia Plant

scrubbing. The CO_2-rich scrubber solution from the absorber is regenerated by stripping with steam (or hot gas) in a separate tower, and then recirculated. Usually either potassium carbonate or monoethanol amine (MEA) is used as the scrubbing medium.

Gas leaving the scrubber flows through the methanator unit operated at about 315° C where residual CO (about 0.4%) and CO_2 (less than 0.04%) are converted to methane by reaction with hydrogen. Methanation is the final purification step and reduces the total carbon oxide concentration in the ammonia synthesis make-up gas to less than 10 parts per million (ppm). These impurities must be kept as low as possible because CO will poison ammonia synthesis catalyst and CO_2 will react with ammonia in the synthesis recycle gas to form ammonium carbamate in pipelines and plant equipment.

The purified make-up gas consisting of hydrogen and nitrogen in the proper ratio, and small amounts of methane and argon, is compressed for ammonia synthesis. Centrifugal compression to about 175 kilograms per square centimenter (kg/cm^2) may be used for large plants while smaller plants use reciprocating compressors with possibly higher pressure.

The compressed make-up gas is combined with synthesis recycle gas, passed through an oil filter, and then through an ammonia-cooled condenser. From the ammonia cooled-condenser, the gas passes through an ammonia separator, a heat exchanger, and then into the ammonia synthesis converter The incoming gas is heated through exchange with outgoing gas and heat of reaction in the catalyst bed is sufficient to maintain catalyst temperature. A catalyst temperature of about 510° C allows a satisfactory reaction rate.

Gas leaving the converter is cooled and passed through a separator where ammonia is condensed and removed. Gas from the separator is compressed to restore the pressure lost by decrease in gas volume and then is combined with fresh make-up gas.

Methane and argon accumulate in the recycle gas and the concentration of these inert gases is controlled by maintaining a small, continuous purge.

Liquid ammonia flows from the two separators to a letdown tank where pressure is reduced to about 17 kg/cm^2 and most of the dissolved gases are removed. The liquid flows to storage from the letdown tank. Gases from the letdown tank and purge gas from the recycle loop flow to an absorption tower where the ammonia is dissolved in water and then converted to anhydrous ammonia by steam distillation in a stripping tower. The ammonia-free gas leaving the absorber is used as fuel in the primary reformer.

There is a significant economic advantage for use of centrifugal compressors in production of ammonia. Capital and operating costs are lower per ton of ammonia with centrifugal compression than with reciprocating compressors. However, plant capacity must be above about 400-500 tons/day before use of centrifugal compressors is feasible.

UREA

A typical urea plant takes ammonia and byproduct carbon dioxide from an ammonia plant and reacts it at elevated temperature (170-210° C) and pressure (170-400 kg/cm^2) to form urea (NH_2CONH_2). An intermediate product is ammonium carbamate (NH_4COONH_2). A typical flow diagram of urea production (total recycle) is shown in figure 10

Ammonia and carbon dioxide are fed into the reactor along with recycle ammonia and carbamate solution. About 60% of the carbon dioxide is converted to urea during passage through the reactor. Effluent containing urea, carbamate, and unreacted ammonia go to a high pressure decomposer and separator which returns some ammonia and carbon dioxide to the reactor Effluent containing urea and carbamate go on to the low pressure decomposer and separator where urea solution is separated from unreacted carbamate and then concentrated and prilled into finished product. Offgases from the concentrator are condensed (uncondensables are vented), and the condensate is fed back to the reactor after having absorbed carbamate from first the low pressure and then the high pressure separator. Excess ammonia not absorbed in the high pressure absorber is condensed and fed back to the reactor as anhydrous ammonia. In some cases, where low biuret content is desired, concentrated urea solution is crystallized and the crystals are melted and prilled into finished product

Recently, there have been some new processes introduced which use the feed ammonia or carbon dioxide to strip these gases from reactor effluent and re-introduce them to the reactor in gaseous form, thereby decreasing the amount of solution recycle. These processes are reportedly especially advantageous for large urea plants because of lower costs for recycle pumps and maintenance, but they have not as yet been proven over long periods of time.

The current tendency is to build large urea plants of the total recycle type. Single-train plants as large as 1,500 tons/day are now in operation. A plant of total recycle type is recommended for Chile, and it should be as large as market conditions permit to take advantage of economies of scale. Urea technology is changing rapidly, with improved processes announced every few months. If Chile decides to build a urea plant, Chilean engineers should be careful to keep abreast of and take advantage of latest technology at the time of construction.

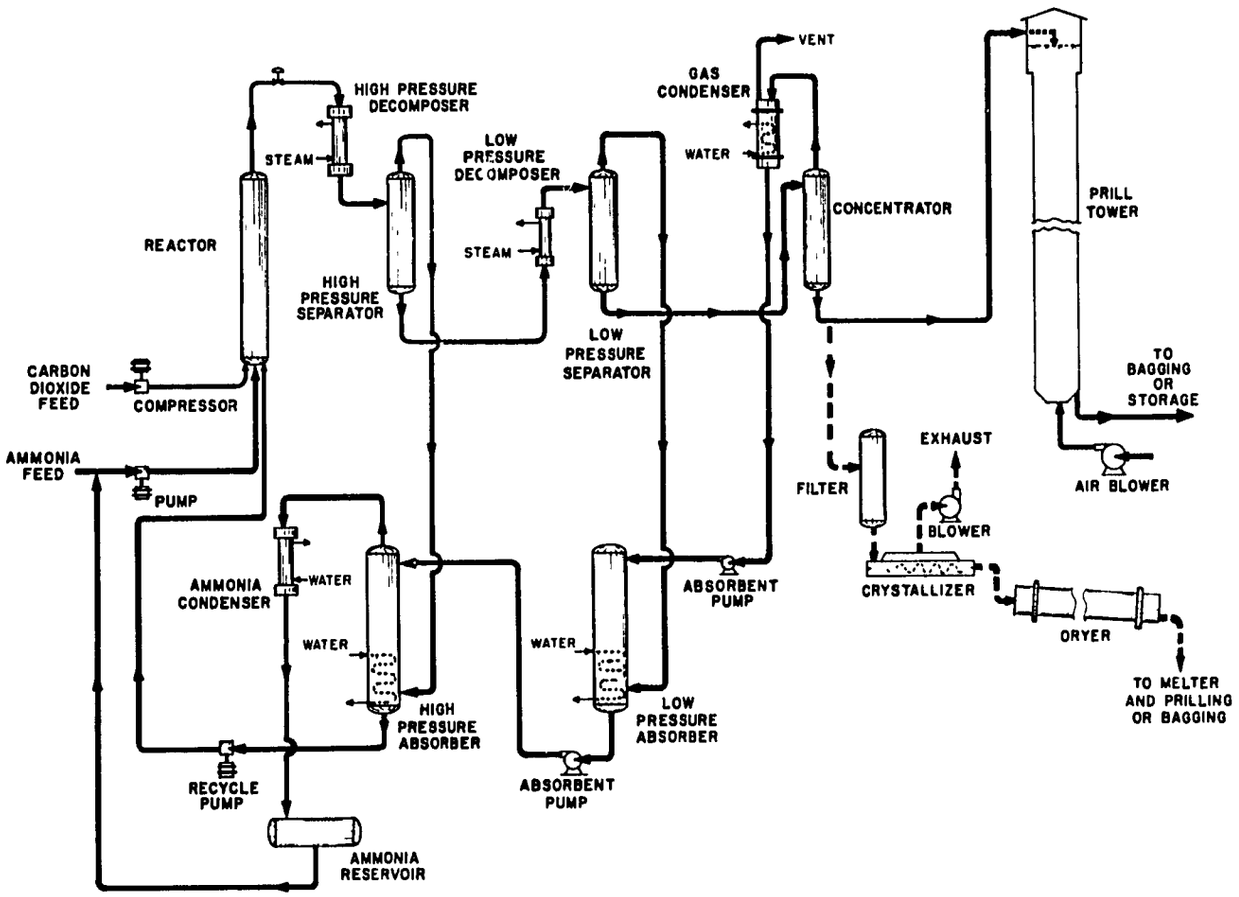


Figure 10. Total Recycle Urea Plant

Ammonium Nitrate

Ammonium nitrate for fertilizer use is normally produced by reacting ammonia with nitric acid. Production of nitric acid involves oxidation of ammonia and absorption of resulting nitrogen dioxide in water. Neutralization of the nitric acid with additional ammonia forms ammonium nitrate solution which is concentrated and prilled to form solid fertilizer

Nitric Acid- -The major steps in nitric acid manufacture include: (a) vaporization, superheating, and perhaps filtration of anhydrous ammonia for oil removal, (b) pre-heating, filtration, and compression of process air; (c) catalytic oxidation of ammonia; (d) cooling of combustion gases containing nitrogen oxides, (e) oxidation of nitric oxide to higher oxides; (f) absorption of nitrogen oxides in water to form nitric acid; (g) bleaching of acid by cooled air; (h) recovery of energy in tail gas; and (i) recovery of catalyst for resale. A flow diagram of a modern nitric acid plant is shown in figure 11.

Air is compressed to about 7 atmospheres pressure in a compressor driven by a power recovery turbine The air is filtered and preheated by heat exchange with combustion gases produced by oxidation of ammonia with the compressed air The heated air is mixed with superheated ammonia vapor which is oxidized catalytically by platinum (10% rhodium) gauze in the converter at about 900° C (Some unspecified catalysts are now on the market) The combustion gases are cooled as indicated previously by heat exchange with the incoming air and also by water to raise steam. The gases are then filtered to recover platinum dust and further cooled in condensers by external water sprays The gases and condensed weak acid then go to a reflux drum from whence they are fed, respectively, to the bottom and side of the absorber. Water fed at the top of the absorber and the weak nitric acid are enriched as they

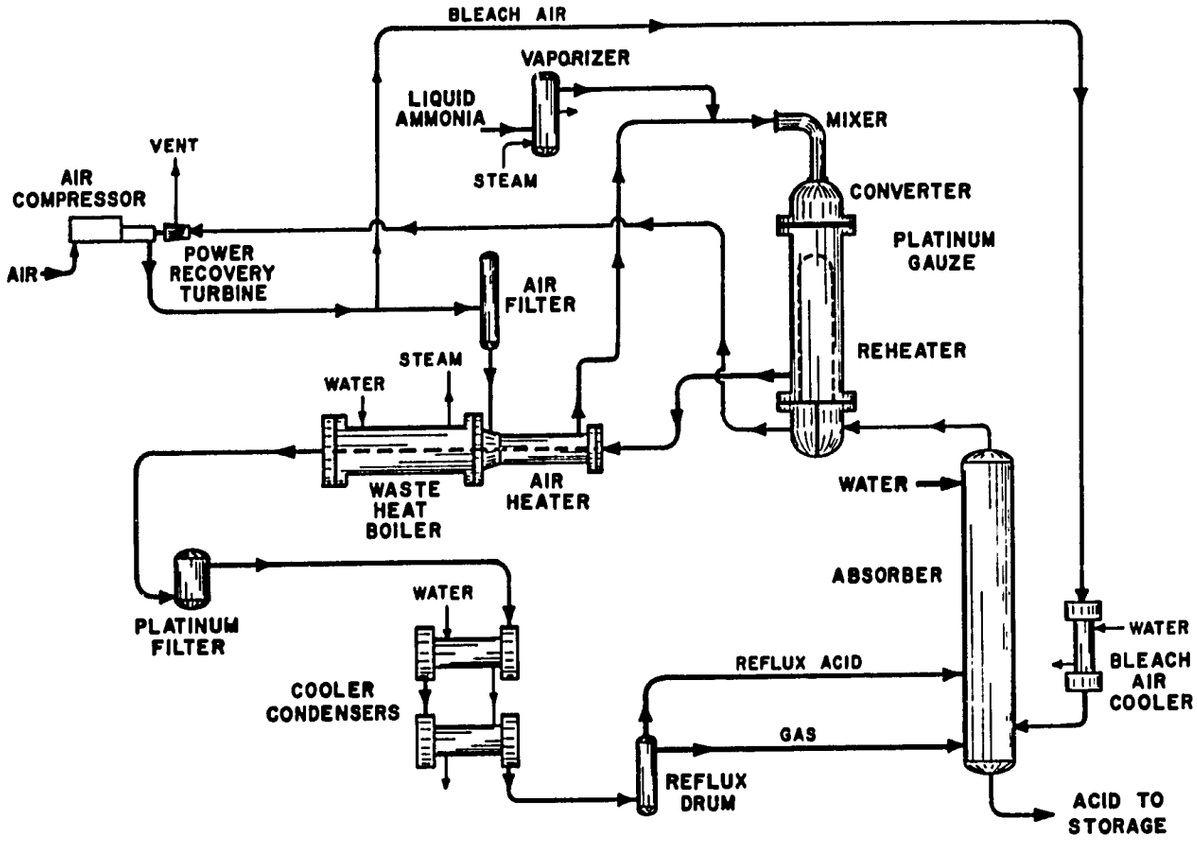


Figure 11. Flow Diagram of Nitric Acid Plant

feed countercurrent to the gases in the absorber. Cooled air is also fed at the bottom of the absorber to bleach nitrogen oxides from product nitric acid before it goes to storage. After absorption of the nitrogen oxides, the tail gases are reheated to drive the power recovery turbine and then vented to the atmosphere through a stack.

Conventional nitric acid processes that produce acid of concentration of 55-65% HNO_3 are satisfactory for ammonium nitrate production. There is no merit in building the more expensive plants that produce acid concentrations up to 70% HNO_3 because the heat of neutralization is in excess of that required for water removal.

Ammonium Nitrate Prilling Anhydrous ammonia is reacted with nitric acid, as shown in figure 12, and the resulting solution is concentrated by countercurrent contact with heated air in a falling-film evaporator. The concentrated solution is sprayed countercurrent to an upward stream of air in a prilling tower to allow droplets of ammonium nitrate to solidify into prills. The prills are cooled, sized, and conditioned before going to storage. Fines and oversize are dissolved in water and returned to the neutralizer.

The process for conversion of sodium nitrate to ammonium nitrate by ion-exchange resin which is being evaluated by SQM is not sufficiently developed to describe in detail. In general, it consists of using an ion-exchange resin to carry out the following double decomposition reaction:

$$2NaNO_3 + (NH_4)_2CO_3 = 2NH_4NO_3 + Na_2CO_3$$

A relatively weak solution of sodium nitrate would be fed to an ion-exchange column along with ammonia and the exhaust from diesel engines to supply carbon dioxide. Roughly, 10% solutions of ammonium nitrate and sodium carbonate would be withdrawn and concentrated to produce the solid materials.

Sulfuric Acid

Sulfuric acid is an important raw material for the manufacture of ammonium sulfate, which was considered as a nitrogen fertilizer, as well as for the manufacture of most phosphate fertilizers by acidulation of phosphate rock. As indicated previously, Chile has several possible sources of sulfur for manufacture of sulfuric acid; however, the most economic source was considered to be waste gas from a copper smelter at Caletones which borders the area of heaviest fertilizer use in Chile. The waste gas, containing 5-6% SO_2, should be usable in a contact sulfuric acid plant, a flow diagram of which is shown in figure 13.

Waste gas may contain dust or fume which would be detrimental to the operation of a sulfuric plant as well as to the product itself. Therefore, waste gas is usually subjected to cleaning by electrostatic precipitators and wet scrubbers. Cleaned gas containing sufficient oxygen as air to oxidize sulfur dioxide to sulfur trioxide is dried by contact with approximately 99% sulfuric acid which picks up the moisture in the gas and is diluted to about 93%. Mist is then removed from the gas and it is preheated to about 820° F before entering the catalytic converter which contains several stages packed with vanadium pentoxide catalyst. Conversion of sulfur dioxide to trioxide is exothermic and the gas is cooled between stages by heat exchange with the incoming gas. The gas containing sulfur trioxide is cooled with air and the sulfur trioxide is scrubbed from the gas by contact with the 93% sulfuric acid formed in drying the incoming gas. This scrubbing step forms 99% sulfuric acid product.

There are new sulfuric acid processes such as the double contact process which has two catalytic converters with sulfuric acid removal between converters The major purpose of these processes is to decrease air pollution by unconverted sulfur dioxide and this should not be of concern at Caletones since a much greater amount of sulfur dioxide will continue to be evolved from the smelter than will be evolved from a conventional contact acid plant.

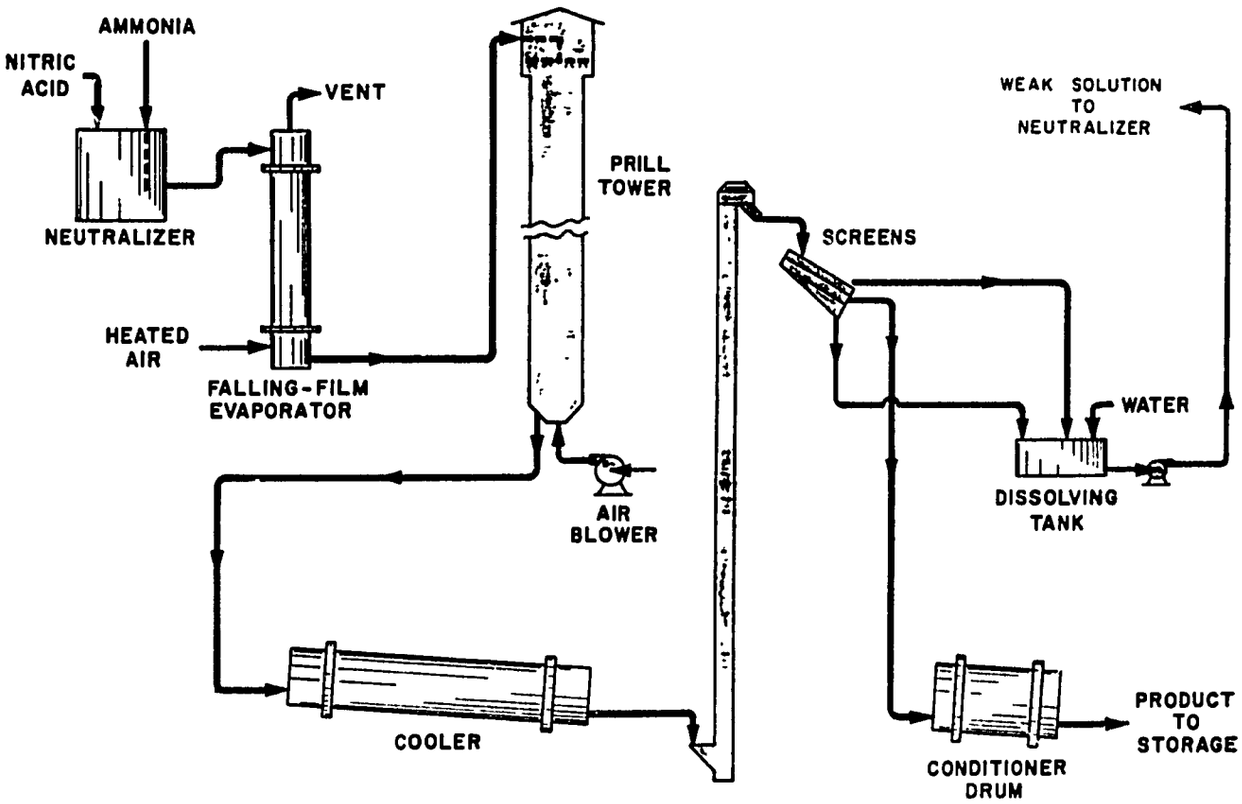


Figure 12. Simplified Flow Diagram for Producing High Density Ammonium Nitrate by Prilling

Ammonium Sulfate

Although such nitrogen fertilizers as urea, ammonium nitrate, and ammonium phosphate show much higher rates of growth, ammonium sulfate continues to be produced and used in very substantial quantities. There are several processes for manufacture of ammonium sulfate. Among them are vacuum crystallization processes, processes for recovery of byproduct ammonia from gases by scrubbing with sulfuric acid, processes for scrubbing waste gases containing sulfur oxides with ammonia solution, and organic chemical and steel production processes that result in production of byproduct ammonium sulfate. There is so much byproduct ammonium sulfate produced that in many locations it is not profitable to produce the material as the main product. Nevertheless, since small ammonium sulfate plants which serve a small area are sometimes economically attractive and since Chile's needs for nitrogen fertilizers are relatively small, a plant for producing ammonium sulfate from the marginal sulfuric acid production which may be available from an acid plant at Caletones was studied. (A large sulfuric acid plant may be built at Caletones to produce acid for production of phosphate fertilizer and industrial chemicals.) A flowsheet of the vacuum crystallization process for producing ammonium sulfate is shown as figure 14.

Vacuum is provided by a water-cooled condenser and steam ejector unit. Ammonia and sulfuric acid enter the vacuum crystallizer and the heat of reaction superheats the recirculating slurry which is flashed and cooled to some extent in the upper chamber of the crystallizer, usually under a vacuum of 55-58 cm of mercury. The consequent loss of water and cooling supersaturates the slurry, which descends to the lower chamber through an internal pipe and mixes with fine particles and fresh nuclei to produce large crystals.

Recirculation is induced either thermodynamically or by an external pump. The slurry is again brought into contact with additional ammonia and sulfuric acid, and the exothermic heat of reaction heats the slurry and causes dissolution of surplus fine particles and nuclei. Proper design of the lower vessel and the crystal removal device enables good size classification to be obtained prior to separation of crystals by centrifuging. The separated crystals are dried and sent to product storage.

Wet-Process Phosphoric Acid

Phosphoric acid is required for the manufacture of TSP, DAP, and other phosphate fertilizers. Most acid so used is manufactured by a conventional di-hydrate calcium sulfate formation (gypsum) process, a flow diagram of which is shown in figure 15. The process consists of: (1) reacting phosphate rock and sulfuric acid to form a slurry of weak phosphoric acid and gypsum, (2) filtering the gypsum from the phosphoric acid, and (3) concentrating the phosphoric acid. Sulfuric acid is fed to a mixing tank through which weak recycle acid from the filter is circulated. This mixture is fed to the reactor where it is reacted with phosphate rock. Indirect mixing of sulfuric acid and phosphate rock in this manner helps avoid coating of unreacted rock with gypsum and promotes growth of large, rapid-filtering gypsum crystals. The reaction is exothermic and cooling is provided to keep the slurry temperature in the range of about 75-80° C to insure that the calcium sulfate will be in gypsum form. Some of the fluorine in the phosphate rock is evolved from the reactor and the fumes from the reactor are scrubbed with water to avoid air pollution. Slurry from the reactor is filtered to provide about 30% P_2O_5 product acid which is concentrated to the desired level (a vacuum evaporator is shown as the means of concentration). The gypsum filter cake is washed countercurrently with water to provide the weak acid that is first mixed with the incoming sulfuric acid.

Triple Superphosphate

There are two general types of granular TSP processes–slurry and nonslurry. The nonslurry is a two-step process in which nongranular superphosphate (run-of-pile) is produced and cured for 3-4 weeks. Then the partially cured material is granulated with water and/or steam. The slurry process is a continuous or one-step process that gives a granular product directly. The product from the slurry process is harder, denser, and more spherical than the nonslurry product, and there is no time lag in production. Therefore, the slurry process is recommended for Chile. A flow diagram of the continuous slurry process is shown in figure 16.

Ground phosphate rock is mixed with dilute (38-40% P_2O_5) phosphoric acid in acidulation tanks. The resultant slurry is fed to a pugmill-type mixer where it is granulated with recycle fines. The material from the mixer is dried and screened. The product is conveyed to storage and the oversize material is crushed and recycled back to the mixer along with the undersize. Up to about 10 tons of material are recycled to the mixer for each ton of product produced, and the product is built up in very thin layers.

Magnesium Phosphate

There is some manufacture of fused magnesium phosphate in Japan and other areas, usually by electric-furnace smelting of phosphate rock and olivine or serpentine (magnesium silicates). Since a waterfront manufacturing site is available at Valdivia, an easily-worked deposit of serpentine is nearby, and the product is considered to be suitable for the local acid soils, CORFO

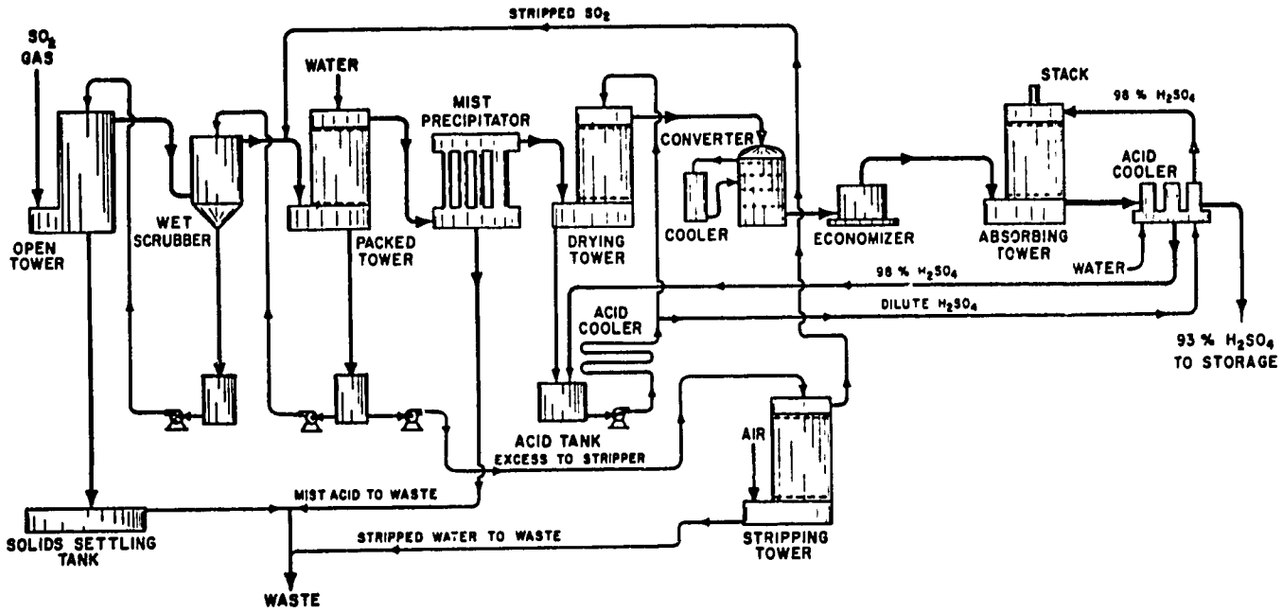


Figure 13. Production of Sulfuric Acid from Secondary SO_2 Sources (Smelter Gas, Pyrites, Pyrrhotines)

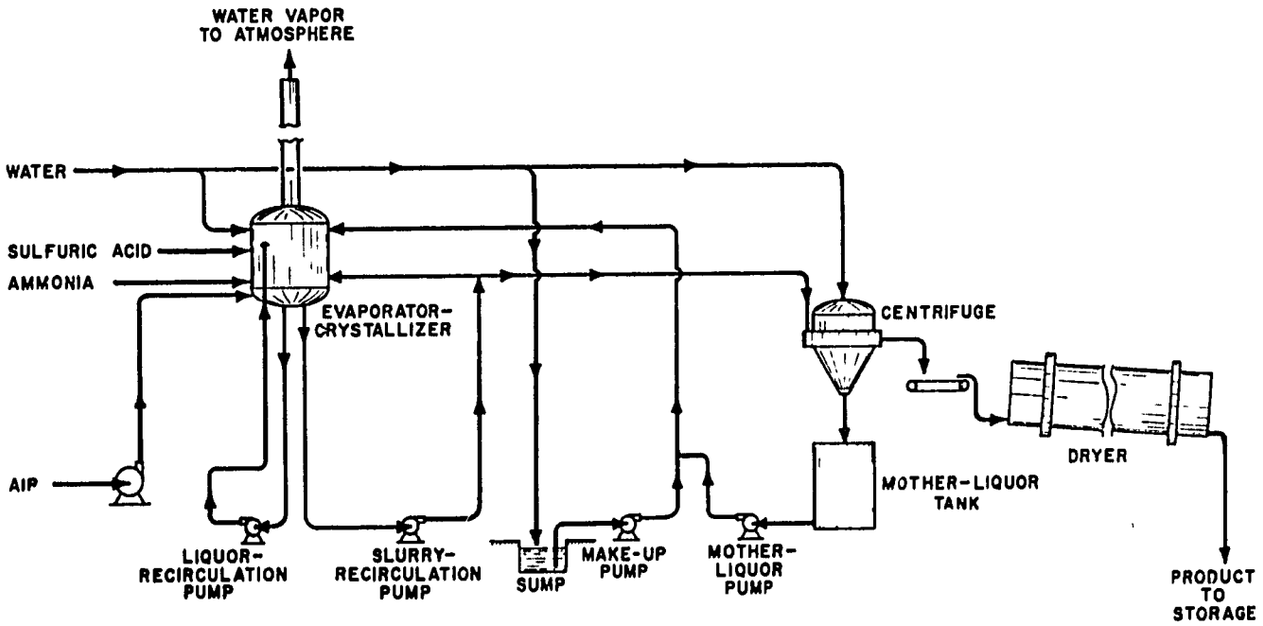


Figure 14. Flow Diagram of Ammonium Sulfate Process

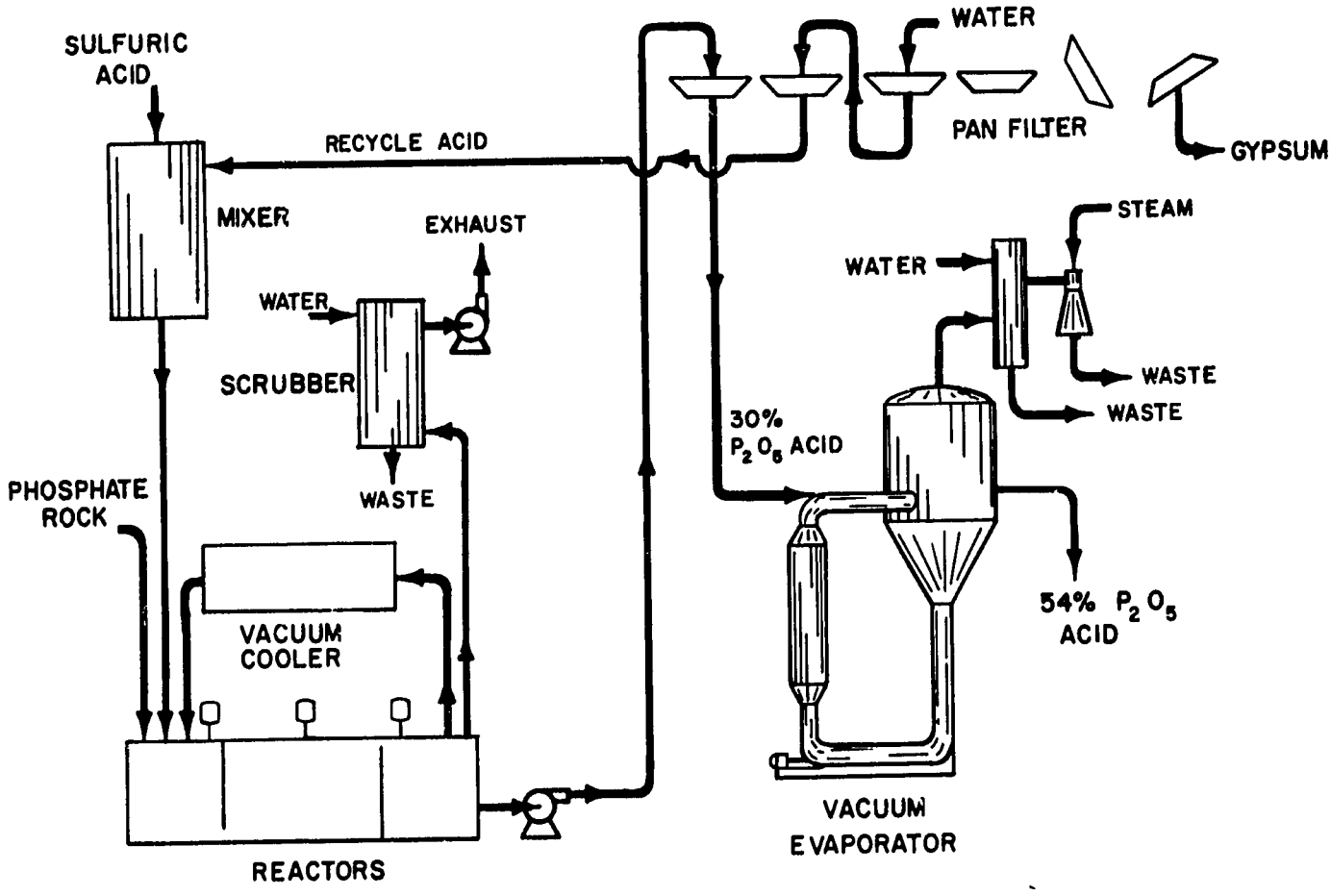


Figure 15. Flow Diagram of Wet-Process Phosphoric Acid Plant

requested that an electric fusion process be considered at this location. A flow diagram of the process is given in figure 17.

Phosphate rock will be imported and serpentine will be brought in by truck. The materials, sized to about 1 in. or smaller, will be mixed and charged to an electric furnace. The furnace serves to melt the materials and form the fused magnesium phosphate product. The fused product is quenched, dried, ground to approximately 100 mesh, and sent to storage.

Ordinary Superphosphate

NSP is produced by reacting sulfuric acid with finely ground phosphate rock. The product grade usually varies from about 17 to 21% available P_2O_5, depending primarily on the grade or purity of rock used. Chemically, NSP is similar to TSP, except that calcium sulfate is present as a diluent; both contain monocalcium phosphate as the primary active fertilizer ingredient. A flowsheet showing the steps for manufacture of granular NSP is shown in figures 18 and 19.

Phosphate rock is finely ground and reacted with sulfuric acid and water (equivalent to about 70% H_2SO_4) in a mixer. The fluid mass from the mixer is allowed to set up in a den and is disintegrated as it falls from the den. Alternately, the product may be granulated directly from the den with water and steam or it may be allowed to cure about a month and then be granulated. If direct granulation is employed, the rock may be overground and overacidulated somewhat to make up for the conversion of rock P_2O_5 that is lost by eliminating the curing step.

For Chile, direct granulation from the den in continuous flow is recommended. In any case, the product is dried to about 5% moisture content and sized before being sent to storage. Slow conversion of P_2O_5 to available form

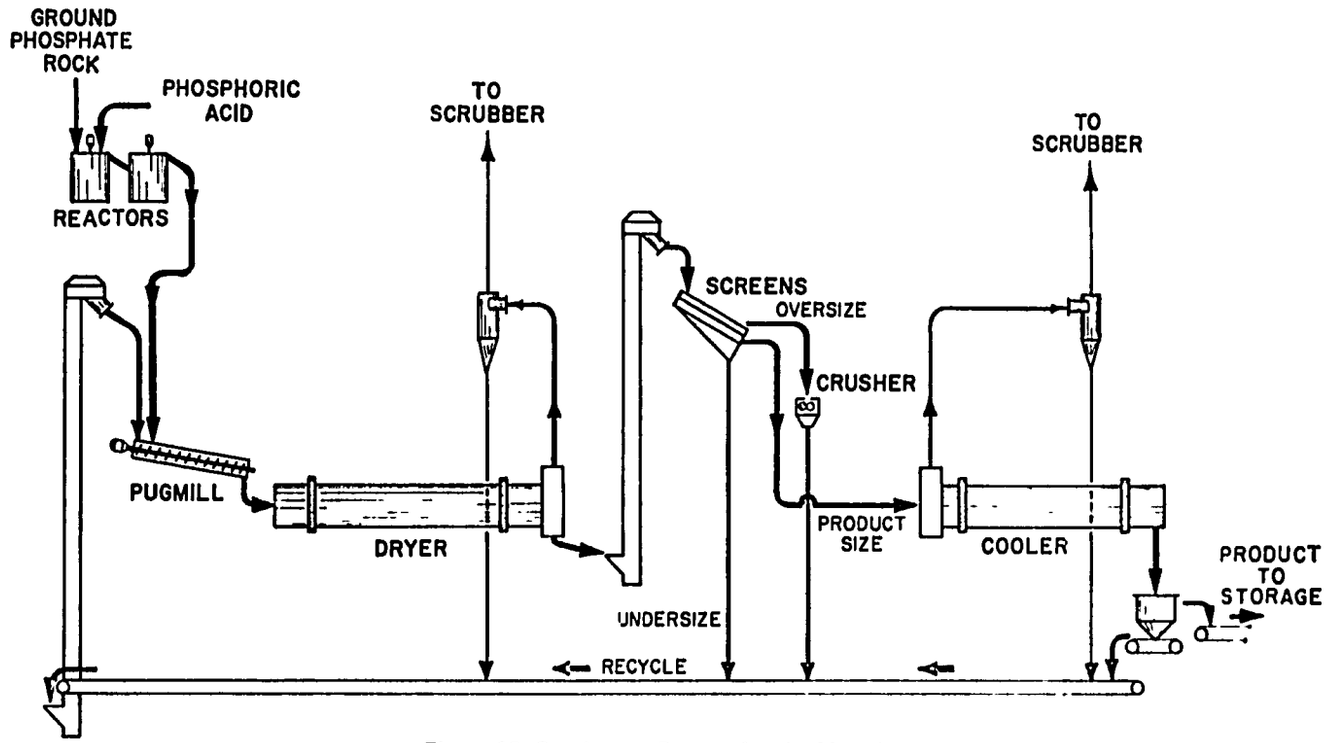


Figure 16. Continuous Process for the Manufacture of Granular Triple Superphosphate

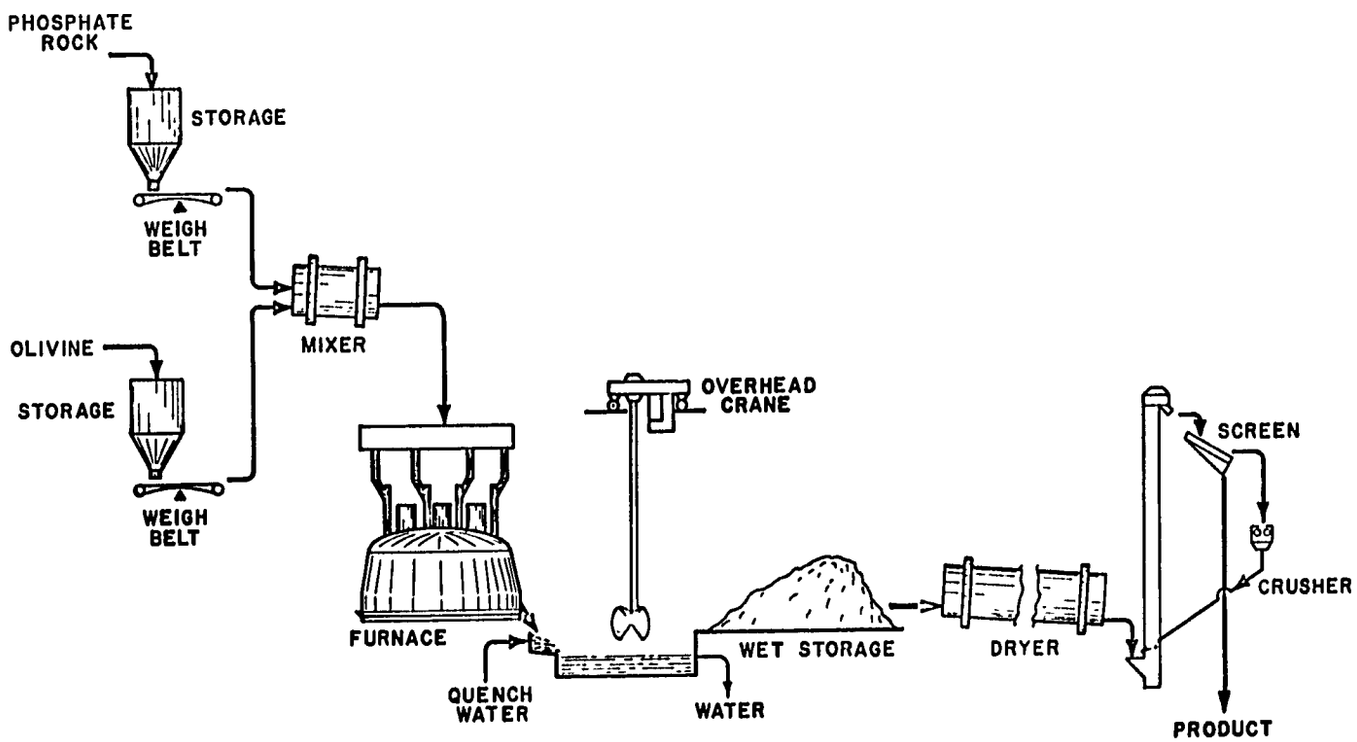


Figure 17. Flow Diagram of Magnesium Phosphate Fusion Process

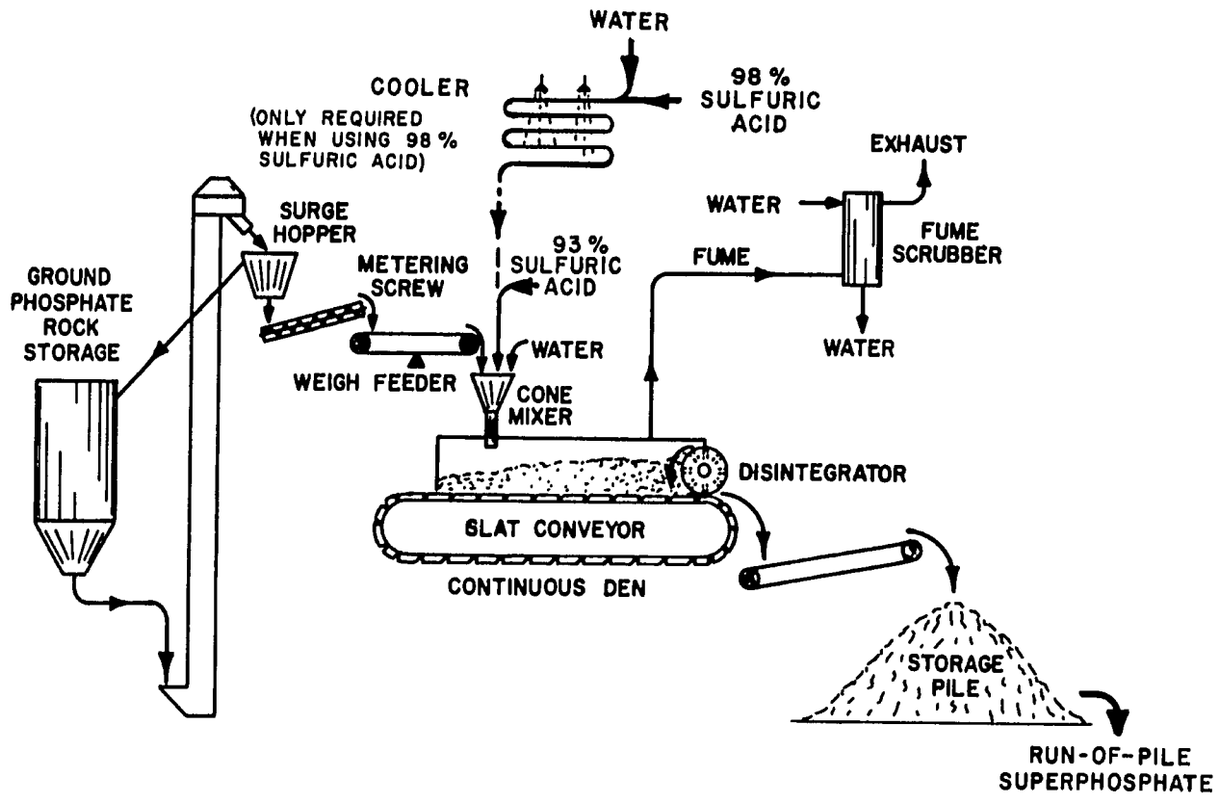


Figure 18. Mixing and Denning System for Ordinary Superphosphate Production

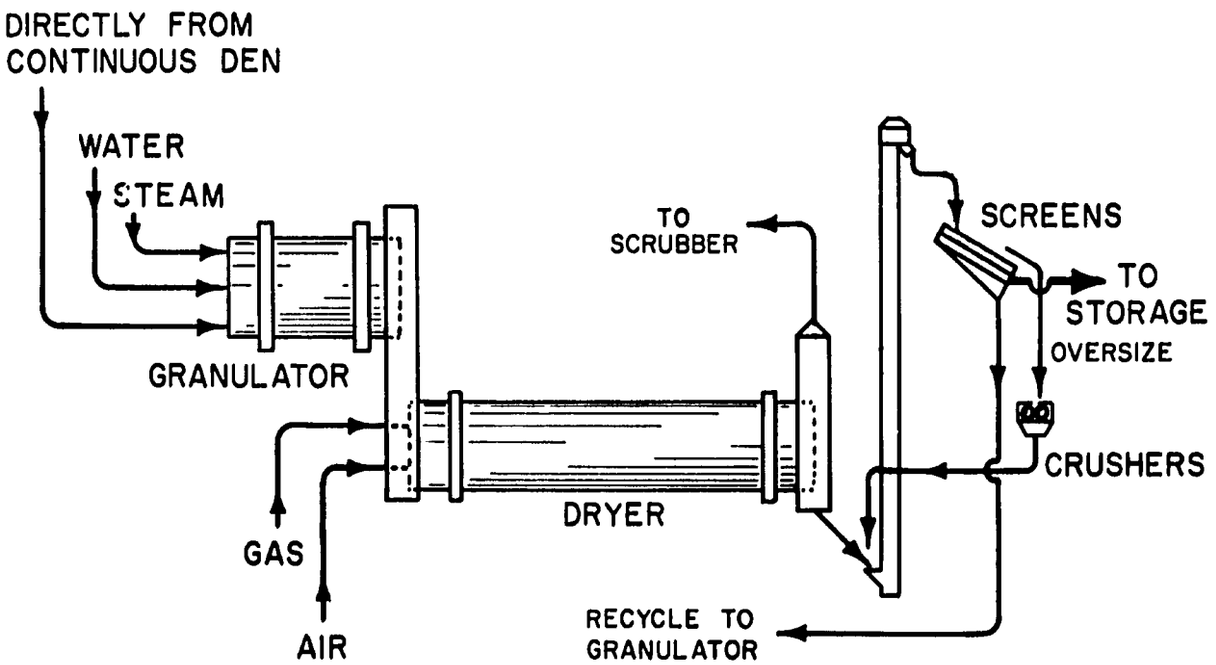


Figure 19. Granulation System for Ordinary Superphosphate

continues in storage if the product contains about 5% moisture.

Mixed Fertilizers

A mixed fertilizer is one containing at least two of the primary plant nutrients (N, P_2O_5, and K_2O) in definite, predetermined percentages. It may be produced either by dry mixing or by chemical processing; it may be solid or liquid, granular or nongranular.

Fertilizers considered for this study were DAP and ammoniated superphosphates. The world tendency is towards larger proportions of granular materials because they have generally better storage and handling properties than nongranular materials. A blended fertilizer or a bulk blend is a mixed fertilizer consisting of a mechanical mixture of granular fertilizer materials.

Diammonium Phosphates—DAP is produced by ammoniation of phosphoric acid. A flow diagram of a process which involves partial neutralization of phosphoric acid feed in a preneutralizer tank, followed by completion of the ammoniation to DAP in a rotary ammoniator-granulator (TVA process) is shown in figure 20. Excess ammonia, which must be fed to the ammoniator-granulator to produce DAP, is recovered by scrubbing the offgases with the acid to be used in the process. The granular product is dried and screened. The oversize is crushed and recycled back to the ammoniator-granulator along with the undersize. The product size material from the screens is cooled and conveyed to storage. The granule size is controlled primarily by varying the proportion of recycle.

The process utilizes the heat of reaction of ammonia and phosphoric acid to evaporate 80-90% of the water in the feed acid. In addition to scrubbing the offgases from the preneutralizer and ammoniator-granulator, most plants also scrub the offgases from the dryer and cooler with a portion of the acid feed. The gases are first passed through dry collectors, where the larger particles of dust are collected and recycled back to the ammoniator-granulator, and then gases are scrubbed with acid to remove any final traces of dust and ammonia before they are exhausted to the atmosphere. The usual practice is to feed concentrated phosphoric acid (54% P_2O_5) directly into the preneutralizer and to feed unconcentrated acid (30% P_2O_5) from the phosphoric acid filters into the scrubbers to

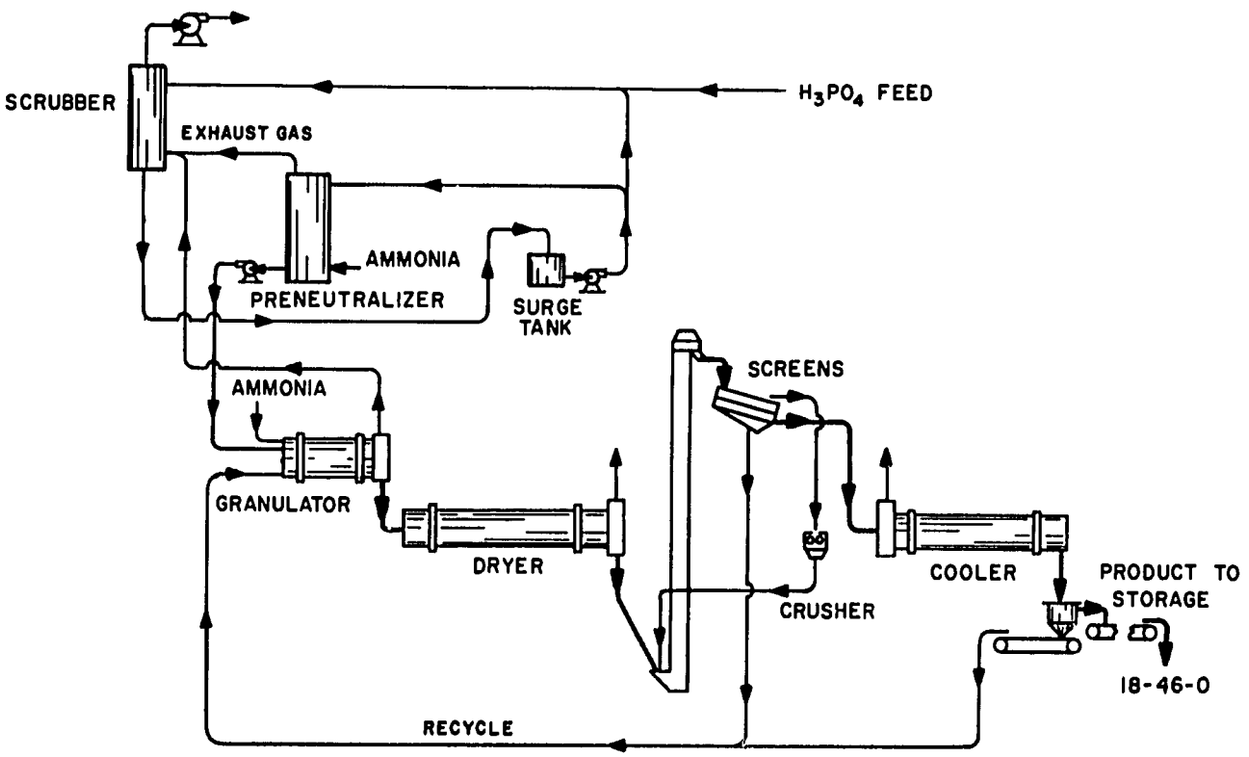


Figure 20. Flow Diagram of Diammonium Phosphate Plant

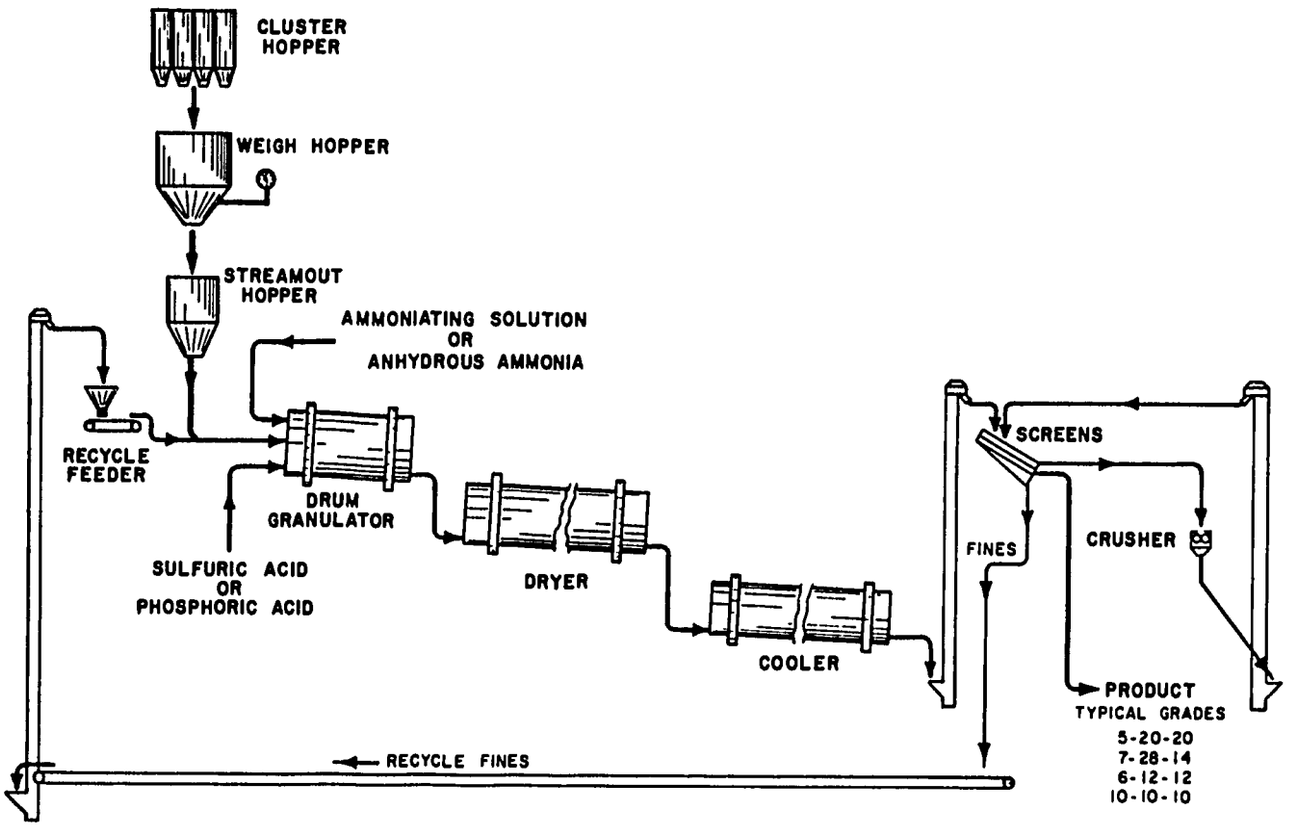


Figure 21. Flow Diagram of Typical Granulation Plant

minimize the amount of solids formation in the scrubbers. The draw-off from the scrubbers is fed into a surge tank, and then acid from the surge tank is fed into the preneutralizer and is also recycled back to the scrubbers. About half of the acid feed is 54% P_2O_5 concentration and the remainder is unconcentrated acid (30% P_2O_5). By scrubbing all of the effluent streams leaving the plant with the acid feed, a clean and efficient operation is maintained.

Up to about 40 tons/hr of product can be produced in a single train unit. By reducing the proportion of ammonia feeds, MAP (grade about 11-55-0) can be produced in the same equipment designed for DAP production.

Ammoniated Superphosphates—One of the most widely used procedures for production of mixed fertilizers is the simultaneous ammoniation and granulation of superphosphates. Nongranular (run-of-pile) TSP and/or NSP is ammoniated with either anhydrous ammonia or ammoniating solutions that also contain ammonium nitrate and water. This ammoniation is carried out continuously in a rotary drum, and the heat and liquid phase from the exothermic chemical reaction promote granule formation. The tumbling action of the rotary drum rounds and hardens granules that are formed. Normally, the product from the rotary ammoniator-granulator is dried, cooled, and screened. The oversize is crushed and recycled back to the ammoniator-granulator along with the undersize. Typical grades that can be produced from ammoniating solution, nongranular TSP, phosphoric acid, and potassium chloride are 15-15-15 and 20-20-0. A flow diagram of a conventional ammoniation-granulation plant is given as figure 21.

The new granulation unit of COSAF at Penco is typical of and practically identical to several plants in the United States that produce mixed fertilizers by ammoniation of superphosphates At the present time the Penco plant is used to granulate run-of-pile TSP and enriched superphosphate (36% P_2O_5). If an ammonium nitrate plant is constructed at Penco, it would be feasible to also utilize ammonia and or ammoniating solution from the ammonium nitrate plant to produce ammoniated mixed fertilizers in the COSAF plant. If an ammonia-urea complex is constructed at Punta Arenas, ammonia, urea, and/or ammonia-urea solutions could be provided to the COSAF unit for mixed fertilizer production. About the only additional equipment required by COSAF would be for

pumping, piping, metering, and distributing the ammoniating medium. (If grades containing potash were also desired, the COSAF would also need to install facilities for storing, feeding, and metering the potassium chloride.)

Bulk Blends---Bulk blending has grown rapidly in the U. S. because it has proved to be a convenient and economical way for supplying the farmer with the nutrients that he needs. The fertilizer materials to be blended are prepared in large, economical plants located near raw materials on economical transport routes. Then these materials are shipped in concentrated bulk form to the blending plant where they are mixed to suit the specific needs of each farmer–often as dictated by soil analysis. Usually the blend is carried to the field and applied in bulk form by the blender. Thus, the cost of bags and bagging are saved, and the farmer does not have to arrange for transporting and spreading his fertilizer. Also, during blending it is possible to also add some other inputs such as micronutrients and pesticides.

The potential for developing bulk blending plants is attractive in the southern area of the Central Valley where farms are relatively large and soil test programs have been initiated. Bulk handling and distribution of materials onto the large pastures, grain farms, and sugarbeet farms should be feasible. Bulk distribution on the smaller farms in the northern area of the Central Valley on vineyards, citrus, and vegetables is not as attractive, but there may be some merit in blending here to tailor the fertilizer to each farmer's needs, even if it is necessary to bag the blended product and spread it by hand.

There are a variety of designs for bulk blending plants that are satisfactorily utilized. Typically, a blending plant operation consists of the following sequence: (1) bulk raw materials are received and stored; (2) raw materials are recovered from storage and weighed or proportioned to give the desired mix, (3) raw materials are mixed or blended; (4) the blended product is discharged into distribution trucks; and (5) the product is carried to the field and applied, using the distribution equipment on the truck. A variety of mixer designs are utilized, with the rotary drum and ribbon mixer types probably the most common. Batch operation with 1-2 tons/batch blended is normal. A flow diagram of a typical blending plant is shown as figure 22.

Materials to be blended must be both physically and chemically compatible. If they are not compatible physically, they can become "unblended" or segregated during handling. If they are not chemically compatible, they may react to give a product with poor physical properties.

To assure physical compatibility, all materials should be granular or crystalline with as near the same particle size as is practical. Physical compatibility is not significantly affected by particle shape or density–only by size.

There are a few fertilizer materials that interact chemically and should not be blended. These are: urea and TSP, urea and NSP, urea and ammonium nitrate, and TSP and DAP.

Typical blend plants in the U. S. handle about 5,000-10,000 tons/yr of material, and cost about $50,000, not counting equipment for spreading product on farms

Blending plants usually service a fairly small area–perhaps within a radius of about 50 km. The cost of transport and spreading is usually around $3/ha for rates of about 700 lbs/ha.

INVESTMENT AND OPERATING COSTS

In some instances the manufacturing and investment cost estimates computed by the TVA Team differ slightly from values computed by Chilean engineers or from estimates supplied by outside engineering firms The estimates of the TVA Team may not be as reliable for some specific situations as more in-depth estimates by others However, the Team utilized somewhat standardized assumptions that were developed for estimates of this type and are believed to be reasonably accurate and reliable The uniformity of the standardized assumptions is needed to insure that the various alternative processes and supply systems are evaluated on the same basis.

The assumptions used for this estimate are listed below.

Investment Estimates

1. The battery limits investment cost of various plant units in Chile was assumed to be 1.3 times corresponding U. S. battery limits cost
2. The cost of auxiliary facilities for the complex (steam, power, water, supply, etc) was assumed to be 25% of the total battery limits cost of all the plant units included in the complex.
3. The cost of supporting facilities for the complex (roads, civil works, office and administrative buildings, etc) was assumed to be 25% of the total battery limits cost plus 25% of the auxiliary facilities cost.
4. The foreign exchange components of the investment costs were assumed to be as follows
   - 75% of battery limits cost of plant units
   - 25% of cost of storage facilities
   - 50% of auxiliaries
   - 35% of support facilities
5. Bulk storage capacity for solid fertilizers was assumed to be one-third of the annual production capacity
6. The cost of bulk storage buildings for solid fertilizer was assumed to be as follows:
   - Dehumidified storage -$16.50/mt of storage capacity (U. S. cost).
   - Atmospheric storage $11,00/mt of storage capacity (U. S. cost).

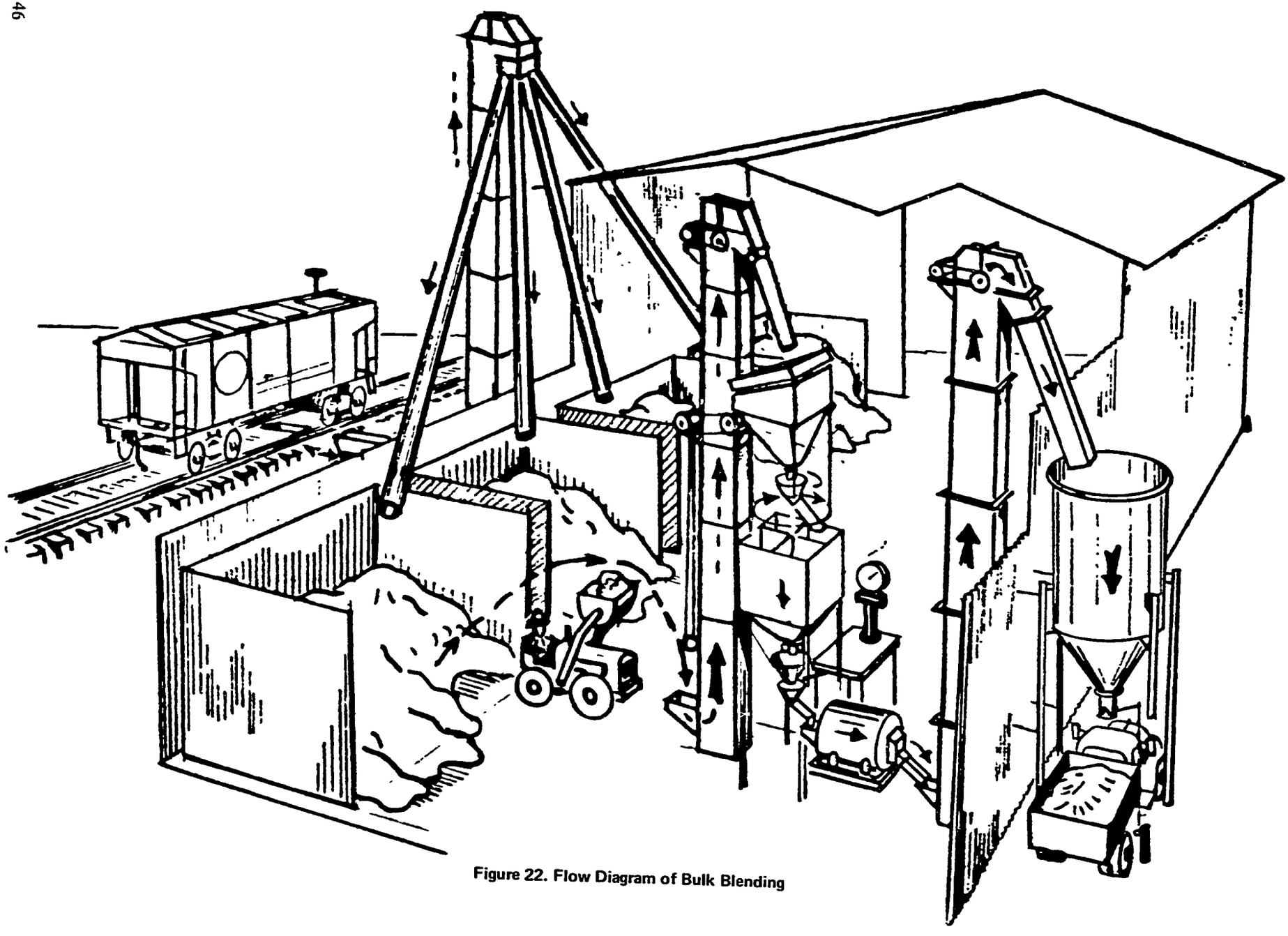


Figure 22. Flow Diagram of Bulk Blending

Production Cost Estimates

Depreciation - 15 yrs
Interest – 8% on one-half of plant investment
Taxes and insurance – 2% of plant investment
Operating labor $3/man-hr[2]
Maintenance - 5% of plant investment
Supplies – 20% of maintenance
Analyses – 20% of operating labor
Handling – 4% of operating cost (except in port storage facilities)
Overhead - 100% of operating labor
Utilities
- Electical power – $0.01 kilowatt hour (kwh)
- Cooling water – $0.02/1,000 gallons (M gal)
- Treated water – $0.10/M gal
- Boiler feed water - $0.40/M gal
- Fuel – $0.08/gal
- Steam - $0.50/M lb

Working capital – cost of 1 month's raw materials plus 3 month's in-plant value of products
Return on investment calculated at 0% and 10%; 10% value used in comparative evaluations emphasized in this report.

Table 9 shows estimates of production costs, total capital requirements, and the foreign exchange component of capital and production costs for some of the fertilizer plants studied. All production costs include either 0 or 10% R.O.I.; costs discussed in this section include 10% R.O.I.

The estimated production cost of ammonia at Punta Arenas varied from about $30 to $100/mt, depending on the cost assigned to natural gas, the operating level, and the size of the plant; the cost of urea varied similarly from about $46 to $85/ton. The total capital requirements for 1,000, 600, and 200 ton/day ammonia plants were about $32, $21, and $13 million, respectively, with about 60% required as foreign currency. Foreign currency required for production varied from $6 to $15/ton of ammonia.

Total capital requirement for urea production, not including the ammonia plants, decreased from $22 million to $12 million as the plant size was decreased from 900 to 280 tons/day, with a little over half being foreign currency. Foreign currency for production of urea was $7-15/ton, including the foreign currency component for production of ammonia in a 1,000 ton/day plant.

Estimated costs of producing ammonium nitrate from imported ammonia and nitric acid in 380-633 tons/day plants varied from $54 to $69/ton. Approximate data on conversion of sodium nitrate to ammonium nitrate and sodium carbonate by ion exchange in a 300 ton/day plant indicated a production cost of $113/ton of ammonium nitrate with no credit for byproduct sodium carbonate. If sodium carbonate byproduct was credited at either $27 or $60/ton, (estimated minimum and maximum values) the costs per ton of ammonium nitrate would be decreased to either $95 or $74. Capital requirements for the ammonium nitrate plants varied from $17 to $24 million, about half of which was foreign currency. Foreign currency for production was about $25/ton of ammonium nitrate.

The estimated production cost of sulfuric acid from smelter gas in a 915 ton/day plant costing $16 million was about $16/ton. (This acid plant was sized to provide about 150-200 tons/day of acid for industrial uses.) The foreign currency cost of the sulfuric acid ($2.97/ton) was included as a foreign component in the production cost of the materials it was used to produce, but the investment cost for sulfuric acid was not included in the investment cost for these plants. The production cost of ammonium sulfate in a 600 ton/day complex which cost $11 million (half foreign currency) was $40/ton, $16 of which was foreign currency.

TSP production cost an estimated $75/ton ($30 foreign currency) in 791 ton/day plants costing about $23 million, half of which was foreign currency. An electric furnace complex at Valdivia to produce 150 tons/day of fused magnesium phosphate was estimated to cost $3.45 million, about half of which would be foreign currency, and the fused product was estimated to cost $14/ton in foreign currency and $50 total. A large NSP complex at Rancagua (1,820 mt/day) probably would cost about $10 million (one-third foreign currency) and produce material for $25/ton, nearly half of which would be foreign expense. A DAP complex at the same location (791 mt/day) which would approximately produce Chile's needs for both nitrogen and P_2O_5 in 1975 was estimated to cost $12 million in foreign currency and $27 million in total currency. The production cost was estimated to be $45/ton in foreign currency or a total of $98/ton.

On a plant nutrient basis, the lowest estimated production cost of P_2O_5 was as NSP. Besides ammonia, the lowest estimated cost for production of nitrogen was as urea. However, overall economics takes into account delivery of fertilizer to the farm and most of the urea must be shipped a long distance from Punta Arenas. Also NSP is very low in analysis, (20% nutrient) and transport and handling costs are relatively expensive.

Curves showing the effect of raw material costs and other variables on the estimated cost of producing fertilizer materials are shown in figures 23-35. Figures 23 and 24 show the effect of operating level on the cost of producing ammonia and urea. In both cases, a small decrease in operating level from 100% of capacity has little effect on product cost. However, decreasing the operating level to about 40% of capacity, about doubles the production cost. Figure 25 shows the effect of natural gas cost on the cost of

[2] In developing countries lower rates likely would apply but larger numbers of personnel would be used. Experience indicates that total cost should be about the same.

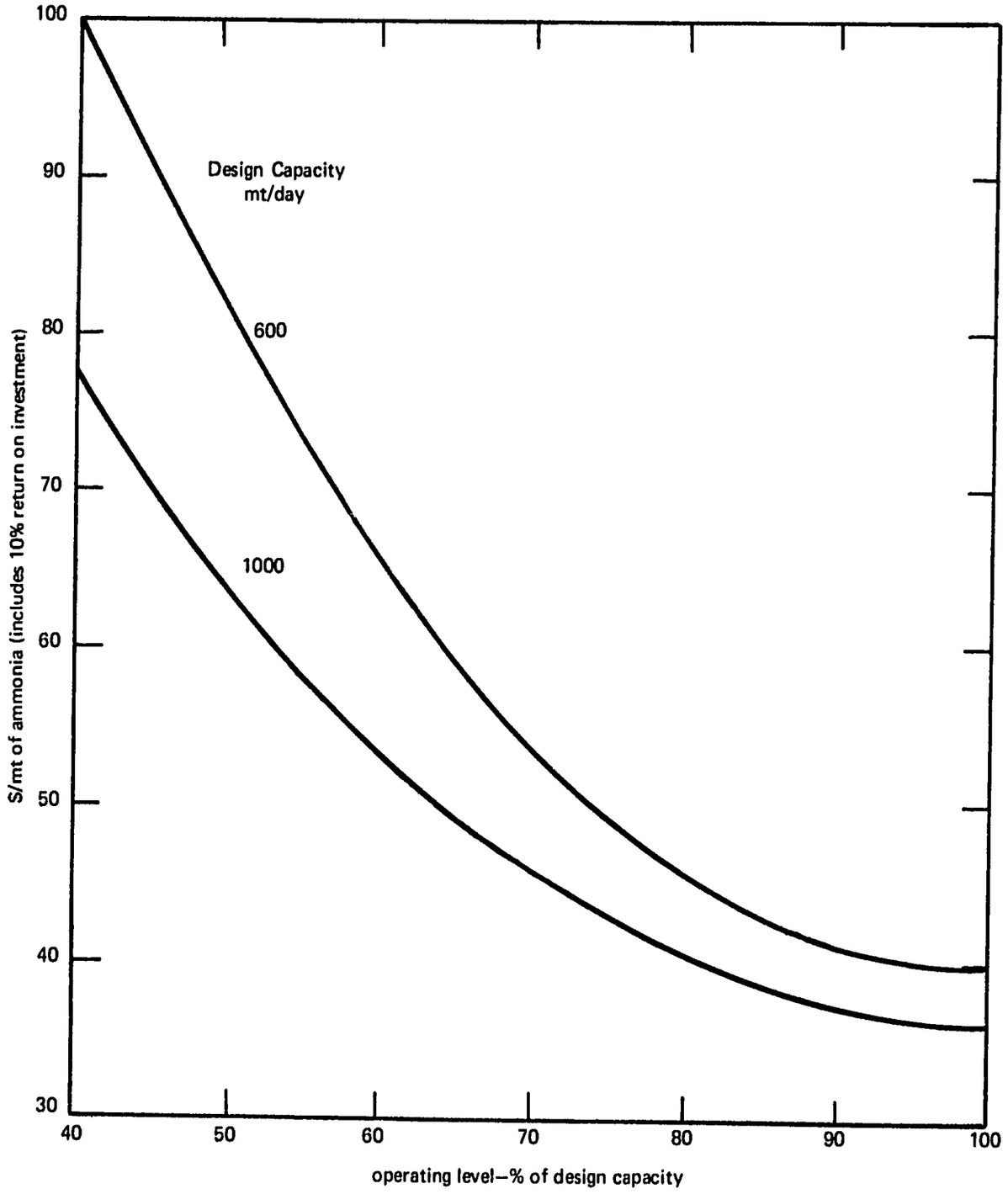


Figure 23. Effect of Operating Level on Cost of Producing Ammonia in Chile (Natural Gas @ $0.10/1000 ft^3)

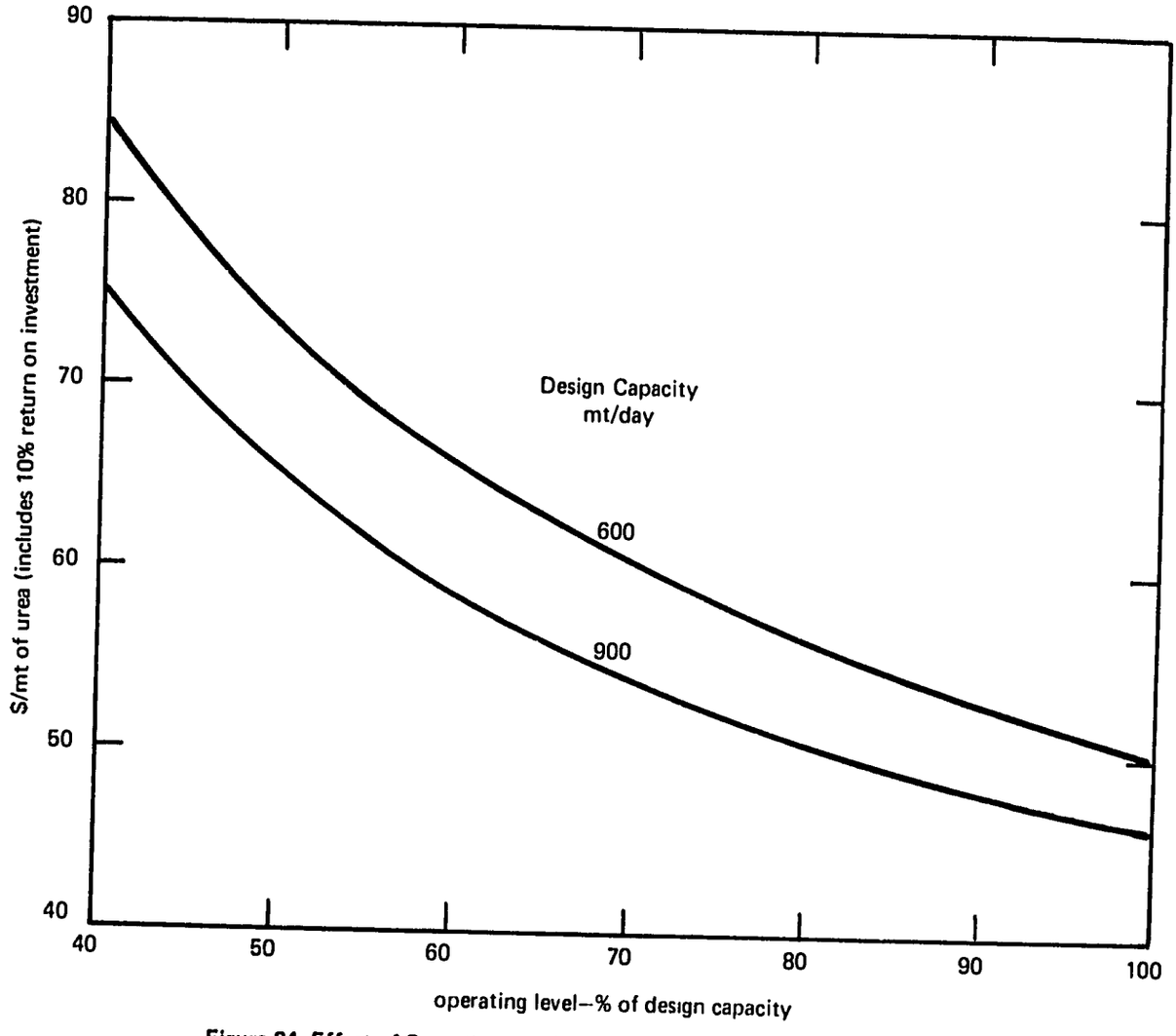


Figure 24. Effect of Operating Level on Cost of Producing Urea in Chile (Ammonia @ $32.54/mt)

producing ammonia in a 1,000 ton/day plant at various operating levels. When operating at full capacity, the cost of ammonia increases from about $31.50 to $43.50 as the cost of gas is increased from 0 to $0.30/1,000 ft^3 (Actual gas cost is expected to be $0.10-0.15/1,000 ft^3.) A similar effect is observed at lower operating levels except the cost of production is higher. For example, the cost of production at the 50% operating level with gas costing $0.10/1,000 ft^3 is about $63.50/ton of ammonia. Figure 26 shows similar data for a 600 ton/day ammonia plant.

Figures 27 and 28 show the effects of ammonia cost and operating level on production costs in 900 and 600 ton/day urea plants. The production cost of urea varied from less than $40 to more than $110/ton, the lower figure being for the larger plant operating at full capacity with ammonia costing $20/ton and the higher figure being for the smaller plant operating at 40% capacity with $80 ammonia. Figure 29 shows that urea production cost in a 280 ton/day plant operated at capacity increases from about $50 to $90/ton when ammonia cost is increased from $20 to $80/ton.

Figure 30 shows the effect of ammonia cost on cost of producing ammonium nitrate for two plant sizes. For a 633 ton/day plant, the production cost increases from about $46 to $61 as ammonia cost increases from $30 to $65/ton, the increase is from about $55 to $70 for a 380 ton/day plant. Figure 31 shows the effects of ammonia and sulfuric acid cost on the cost of producing ammonium sulfate in a 600 ton/day plant.

Table 9. Summary of Economic Evaluation (All production costs are for bulk products)

Fertilizer Material	Plant Location	Annual Production, 1,000 mt of Nutrient	Daily Production mt of Material	Cost, $/mt: Product, % Return on Investment 0	Product 10	Plant Nutrient 0	Plant Nutrient 10	Capital Requirement for Complex, $ Million[a]: Fixed Capital	Working Capital	Total	Foreign Currency for Fixed Capital $ Million	Production,[b] $/mt: Product	Plant Nutrient
Ammonia	Punta Arenas	270	1,000										
Natural gas, $0.00/1,000 ft				22.04	31.61	26.80	38.38	29.74	1.84	31.58	18.73	6.13	7.44
Natural gas, $0.10/1,000 ft				25.99	35.69	31.70	43.34	29.74	2.27	32.01	18.73	6.13	7.44
Operating level, 50%				44.47	63.65	54.20	77.29	29.74	1.90	31.64	18.73	10.22	12.41
Operating level, 40%				53.74	77.65	65.50	94.29	29.74	1.82	31.56	18.73	14.06	17.07
Natural gas, $0.20/1,000 ft				29.93	39.76	36.50	48.28	29.74	2.70	32.44	18.73	6.13	7.44
Ammonia	Punta Arenas	163	600										
Natural gas, $0.10/1,000 ft				28.57	39.33	34.80	47.75	19.81	1.49	21.30	12.49	6.72	8.16
Operating level, 70%				37.65	52.92	46.00	64.26	19.81	1.36	21.17	12.49	9.24	11.22
Operating level, 50%				60.27	81.56	73.50	99.04	19.81	1.27	21.08	12.49	12.60	15.30
Operating level, 40%				73.16	99.71	89.30	121.08	19.81	1.22	21.00	12.49	15.53	18.86
Ammonia	Punta Arenas	54	200										
Natural gas, $0.10/1,000 ft				47.42	66.66	57.70	80.95	11.89	0.81	12.70	7.49	11.41	13.86
Urea	Punta Arenas	134	900										
Ammonia, $32.54/mt				38.66	46.15	86.00	102.56	18.91	3.34	22.25	11.92	7.29	16.21
Operating level, 50%				51.33	65.51	114.00	145.58	18.91	2.14	21.05	11.92	11.01	24.48
Operating level, 40%				57.72	75.24	128.00	167.20	18.91	1.90	20.81	11.92	12.88	28.63
Urea	Punta Arenas	89	600										
Ammonia, $32.54/mt				41.32	50.15	92.00	111.44	15.13	2.36	17.49	9.53	8.03	17.96
Operating level, 70%				47.88	60.15	106.30	133.67	15.13	1.88	17.01	9.53	9.95	22.12
Operating level, 50%				56.51	73.36	125.70	163.02	15.13	1.55	16.68	9.53	12.51	27.81
Operating level, 40%				63.99	84.85	142.20	188.56	15.13	1.39	16.52	9.53	14.95	32.79
Ammonia, $60.00/mt				57.62	66.99	128.00	148.87	15.13	3.43	18.56	9.53	8.03	17.96
Urea	Punta Arenas	42	280										
Ammonia, $32.54/mt				47.69	59.81	106.00	132.91	10.66	1.34	12.00	6.73	9.87	21.94
Ammonia, $60.00/mt				64.00	76.66	142.00	170.36	10.66	1.87	12.53	6.73	9.89	21.94
Ammonium Nitrate	Penco	70	633	43.13	54.38	129.00	162.33	20.93	2.59	23.52	12.40	24.95	74.48
Ammonium Nitrate	Penco or Puerto Montt	50	450	49.14	61.64	147.00	184.00	16.60	2.06	18.66	9.90	26.60	76.50
Ammonium Nitrate	Rancagua	42	380	54.69	68.65	163.00	204.93	15.59	1.92	17.51	9.24	26.32	78.57
Ammonium Nitrate	Victoria[c]	33	300	92.10	113.30	275.00	328.00	18.38	2.65	21.03	12.06	24.30	72.50
Sulfuric Acid	Caletones		915	10.76	16.08	–	–	15.13	0.81	15.94	9.56	2.97	–
Ammonium Sulfate	Rancagua	42	600	34.52	39.94	163.00	188.40	8.67	2.07	10.74	4.90	15.93	75.16
Triple Superphosphate	Rancagua	120	791	66.25	75.15	144.00	163.00	17.81	5.38	23.19	10.85	30.33	66.15
Magnesium Phosphate	Valdivia	11	152	42.68	44.58	194.00	226.00	2.86	0.59	3.45	1.80	13.80	62.50
Ordinary Superphosphate	Rancagua	120	1,820	23.10	24.79	115.50	124.00	5.75	4.40	10.15	3.62	10.89	54.50
Diammonium Phosphate	Rancagua	N-47 P_2O_5-120	791	88.11	98.31	137.70	154.00	19.53	7.20	26.73	11.70	45.10	70.60

[a]Investment for ammonia plants not included in urea plants. Investment for sulfuric acid plant not included in ammonium sulfate and phosphate plants.

[b]Foreign currency for ammonia production in a 1,000 mt/day plant operated at full capacity included for urea plants. Foreign currency for imported ammonia at $44/mt included for other plants using ammonia. Foreign currency for sulfuric acid produced in 915 mt/day plant included for ammonium sulfate and phosphate plants. Foreign currency for phosphate rock at $15/mt included for phosphate plants.

[c]No credit for byproduct sodium carbonate.

Figure 32 shows the effects of phosphate rock and sulfuric acid costs on the cost of producing TSP in a 791 ton/day plant. With phosphate rock costing $20/ton, the cost of TSP increases from about $60 to $80/ton as the cost of acid is increased from $5 to $25/ton. Figure 33 shows that the cost of magnesium phosphate produced in a 152 ton/day plant increases from $41.50 to $49.50/ton as the cost of electric power is increased from 0.2 to 1¢/kwh. Figure 34 shows the effects of sulfuric acid and phosphate rock cost on the cost of producing NSP in a 1,820 ton/day plant. Figure 35 shows the effects of ammonia, phosphate rock, and sulfuric acid costs on the cost of producing DAP in a 791 ton/day plant.

COST OF RAW MATERIALS AND SERVICES

A tabulation of the annual requirement of major services and raw materials for the various production facilities is given in table 10. As shown, an ammonia plant to produce 270,000 mt/yr of nitrogen (1,000 mt/day of ammonia) would require annually 360 million m^3 of natural gas, 16.5 million kwh of electricity, 25.4 trillion gals/ton of cooling water, and 175 million gals of boiler feed water. As indicated previously several times this amount of natural gas is available at Punta Arenas where the plant would be located. The plant is self-supporting in steam. The requirements for smaller ammonia plants are almost directly proportional to their size.

A urea plant (900 mt/day) to produce 134,000 tons/yr of nitrogen requires 172,000 tons of ammonia, 51 million kwh of electricity, 9.5 trillion gals of cooling water, and 1.3 trillion lbs of steam. An ammonium nitrate plant to produce 70,000 mt of nitrogen requires 90,000 tons of ammonia, 8.6 million kwh of electricity, 9.2 trillion gals of cooling water, and 65 million gals of boiler feed water. Requirements for urea and ammonium nitrate plants also decrease in proportion to their size.

Twenty-one thousand tons of ammonia would be needed to produce 33,000 tons of nitrogen as ammonium nitrate from 105,000 tons of sodium nitrate. An ammonium sulfate plant to produce 42,000 tons/yr of nitrogen would require 51,000 tons of ammonia and 147,000 tons of sulfuric acid.

To produce 120,000 tons of P_2O_5 as TSP would require 250,000 tons of sulfuric acid, 410,000 tons of phosphate rock, 32 million kwh of electricity, 755 million gals of water, and 3 million lbs of steam. The major service required for a fused magnesium phosphate plant to produce 11,000 tons/yr of P_2O_5 would be 50 million kwh of electricity, 150 million gals of water, 35,000 tons of phosphate rock, and 13,000 tons of serpentine. NSP production equivalent to 120,000 tons of P_2O_5 would require 219,000 tons of sulfuric acid, 372,000 tons of phosphate rock, and 14.4 million kwh of electricity. DAP containing 47,000 tons of nitrogen and 120,000 tons of P_2O_5 would require 58,000 tons of ammonia, 343,000 tons of sulfuric acid, 406,000 tons of phosphate rock, 46 million kwh of electricity, 660 million gals of water, and 15 million lbs of steam.

Table 10. Annual Raw Materials and Utility Requirements

Fertilizer Material	Annual production 1,000 mt of nutrient	Natural gas, million m^3	Electricity, million kwh	Water: Cooling, trillion gal	Water: Boiler feed, million gal	Steam, trillion lbs	Ammonia 1,000 mt	Sodium nitrate, 1,000 mt	Sulfuric acid, 1,000 mt	Phosphate rock, 1,000 mt	Serpentine 1,000 mt
Ammonia	270	360	16.5	25.4	175	–	–	–	–	–	–
Ammonia	163	216	9.9	15.2	105	–	–	–	–	–	–
Ammonia	54	72	2.0	4.5	30	–	–	–	–	–	–
Urea	134	–	50.8	9.5	–	1.27	172	–	–	–	–
Urea	89	–	33.8	6.3	–	0.84	115	–	–	–	–
Urea	42	–	15.9	3.0	–	0.4	54	–	–	–	–
Ammonium Nitrate	70	–	8.6	9.2	65	–	90	–	–	–	–
Ammonium Nitrate	50	–	6.2	6.6	46	–	64	–	–	–	–
Ammonium Nitrate	42	–	5.2	5.5	39	–	54	–	–	–	–
Ammonium Nitrate	33	–	a	a	–	a	21	105	–	–	–
Ammonium Sulfate	42	–	a	a	–	a	51	–	147	–	–
Triple Superphosphate	120	–	31.8	0.755	–	0.003	–	–	250	410	–
Magnesium Phosphate	11	–	50	0.15	–	–	–	–	–	35	13.2
Ordinary Superphosphate	120	–	14.4	–	–	–	–	–	219	372	–
Diammonium Phosphate	N-47 P_2O_5-120	–	45.7	0.66	–	0.015	57.5	–	343	406	–

[a]Not available

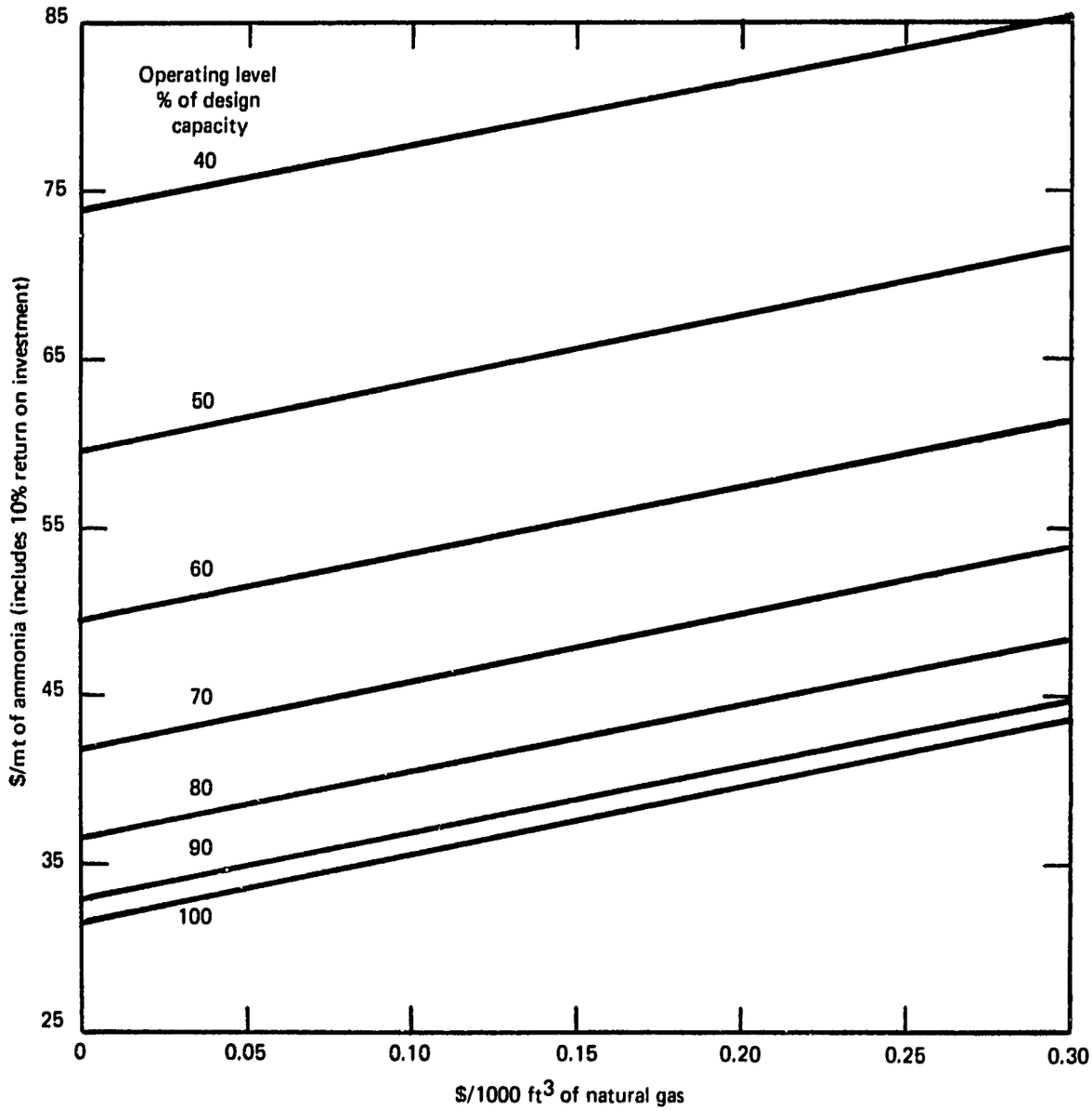


Figure 25. Effect of Changes in Cost of Natural Gas on Cost of Producing Ammonia in Chile at Various Operating Levels (1000 mt/day Design Capacity)

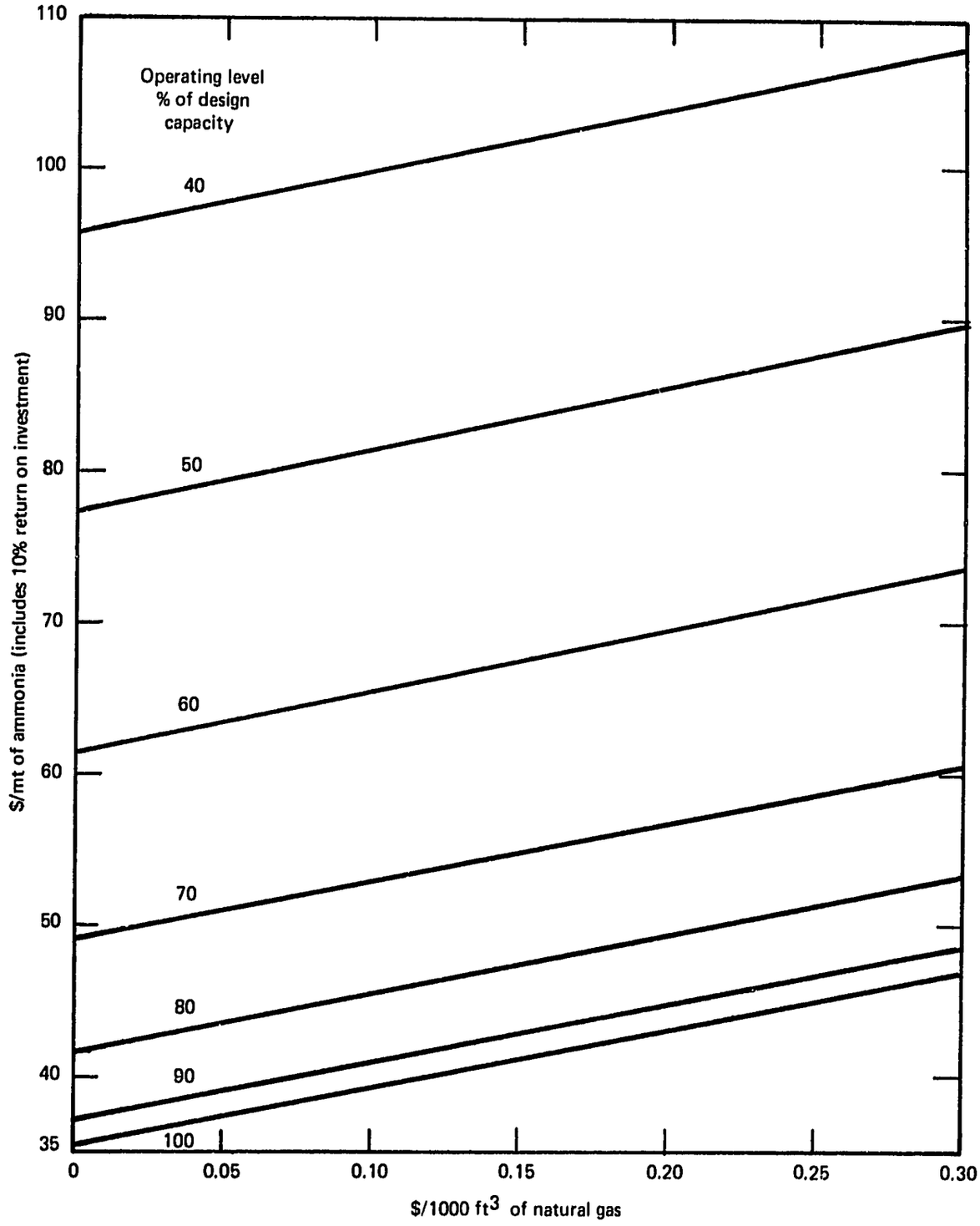


Figure 26. Effect of Changes in Cost of Natural Gas on Cost of Producing Ammonia in Chile at Various Operating Levels (600 mt/day Design Capacity)

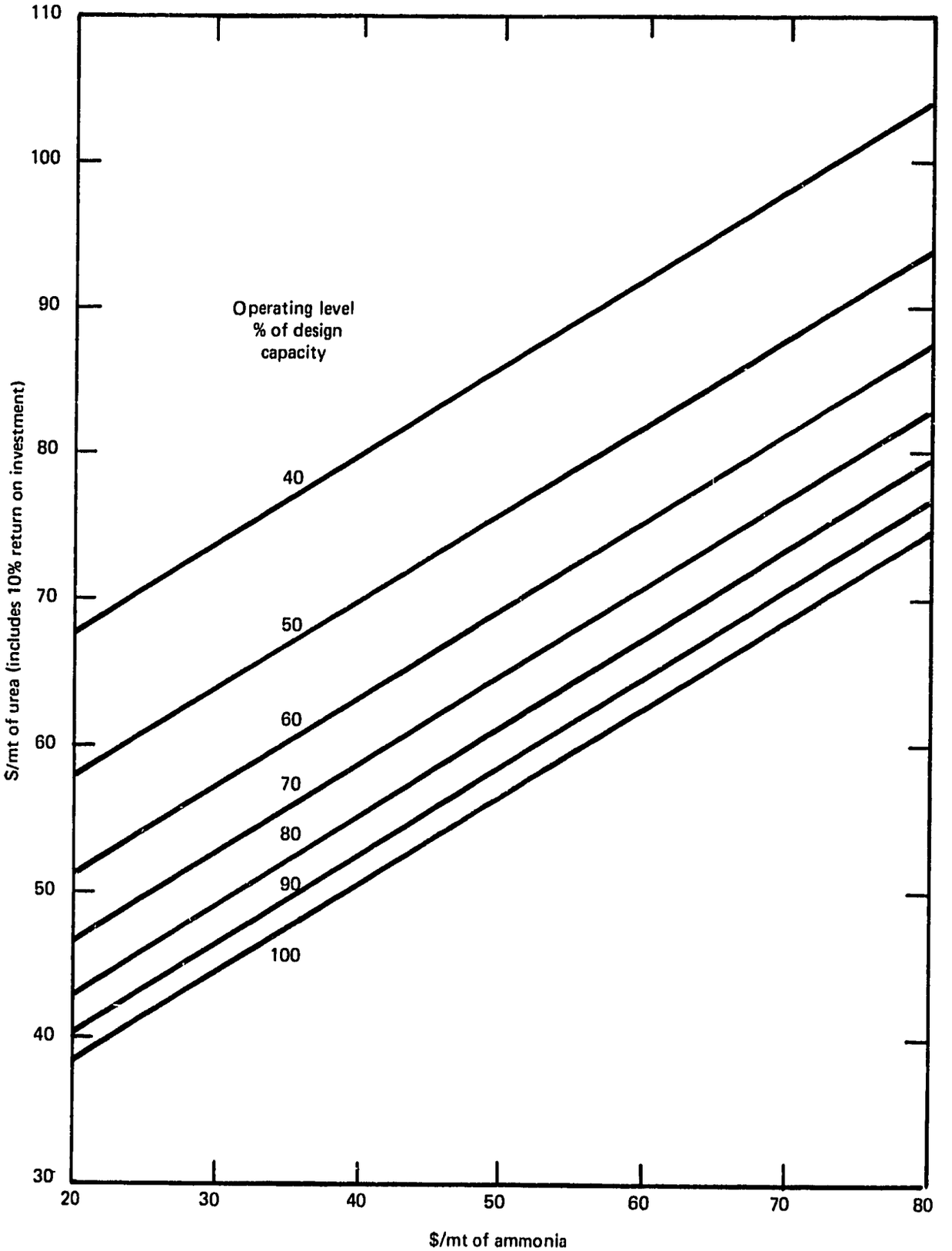


Figure 27. Effect of Changes in Cost of Ammonia on Cost of Producing Urea in Chile at Various Operating Levels (900 mt/day Design Capacity)

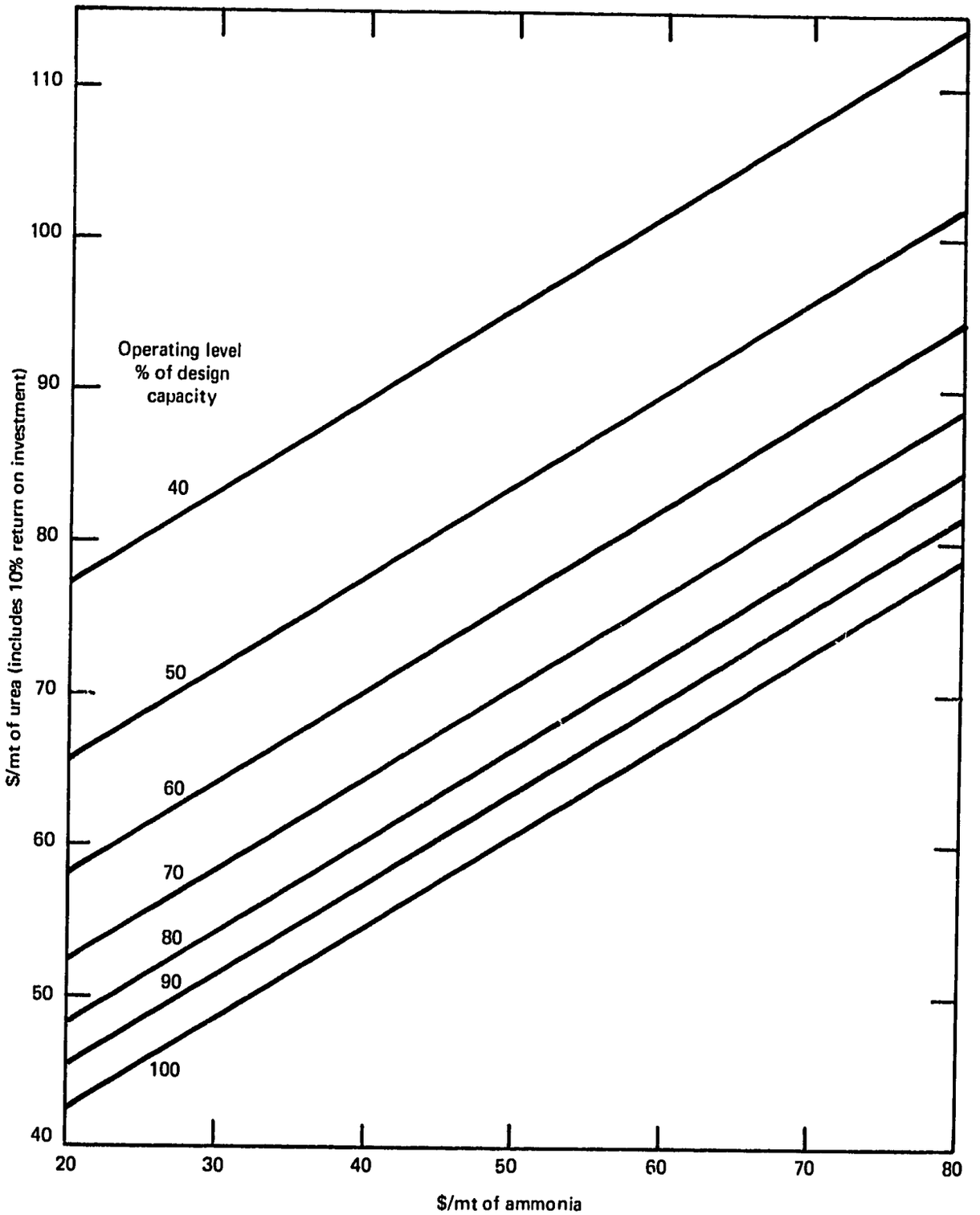


Figure 28. Effect of Changes in Cost of Ammonia on Cost of Producing Urea in Chile at Various Operating Levels (600 mt/day Design Capacity)

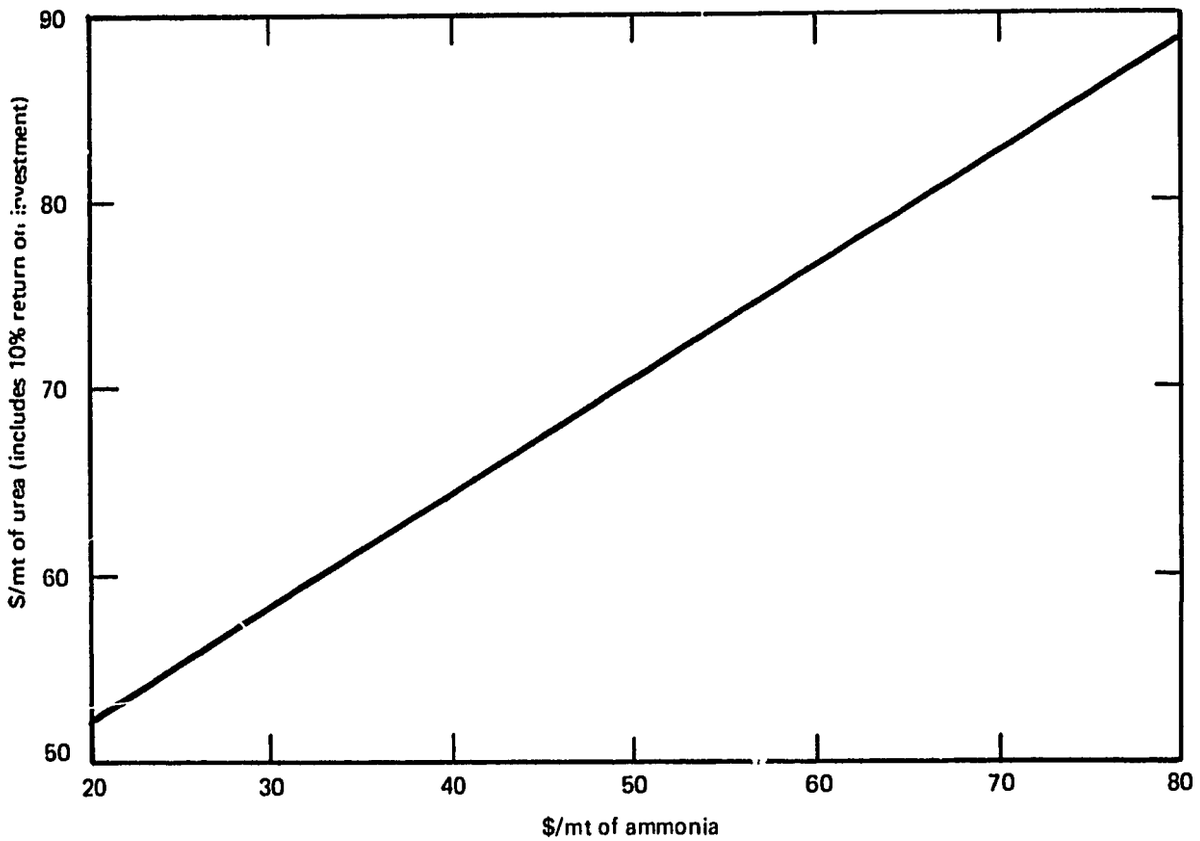


Figure 29. Effect of Cost of Ammonia on Cost of Urea in Chile (280 mt/day Design Capacity)

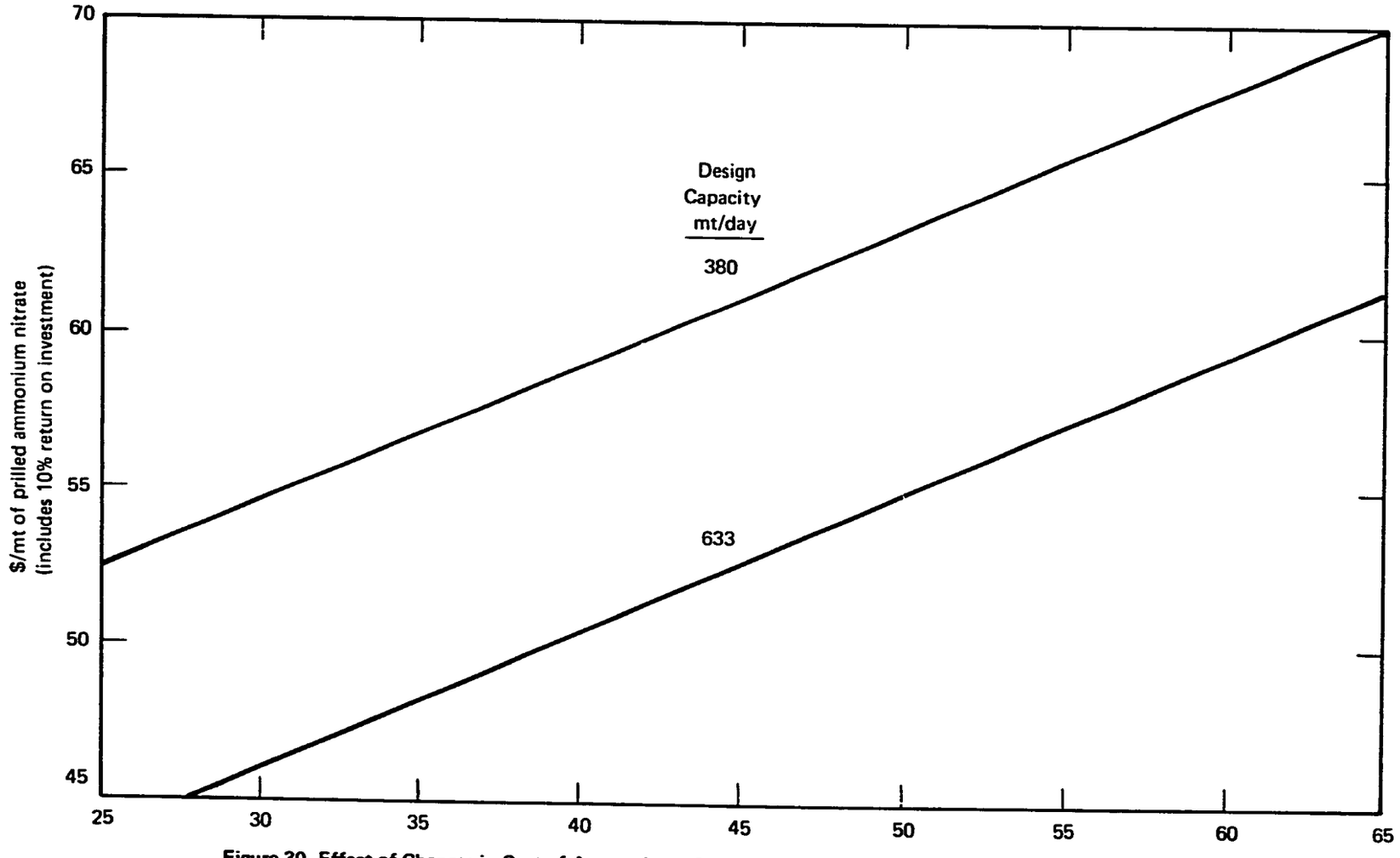


Figure 30. Effect of Changes in Cost of Ammonia on Cost of Producing Prilled Ammonium Nitrate in Chile

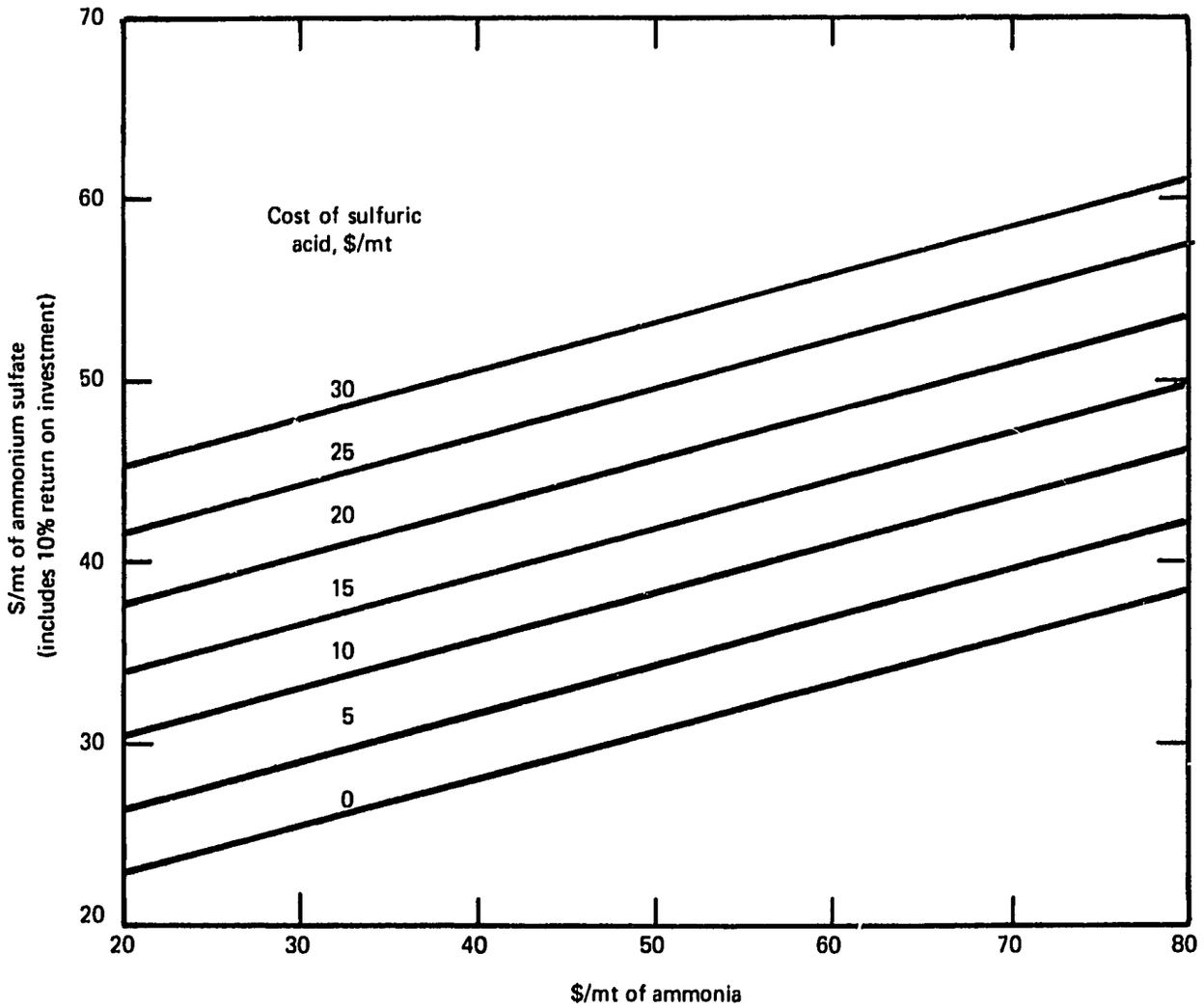


Figure 31. Effect of Changes in Cost of Ammonia and Sulfuric Acid on Cost of Producing Ammonium Sulfate in Chile (600 mt/day Design Capacity)

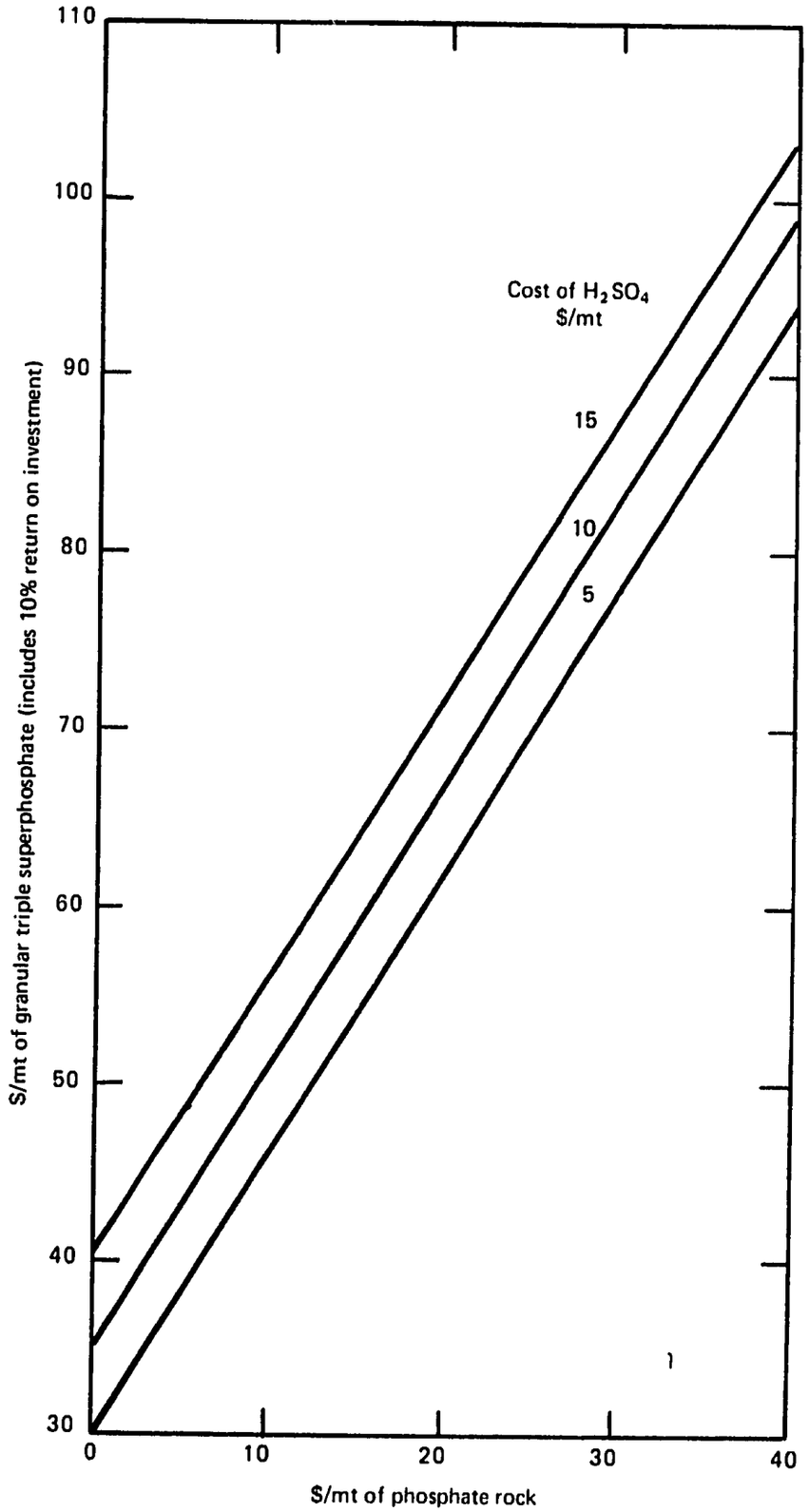


Figure 32. Effect of Changes in Cost of Phosphate Rock on Cost of Producing Granular Triple Superphosphate in Chile (Plant Capacity, 791 mt/day)

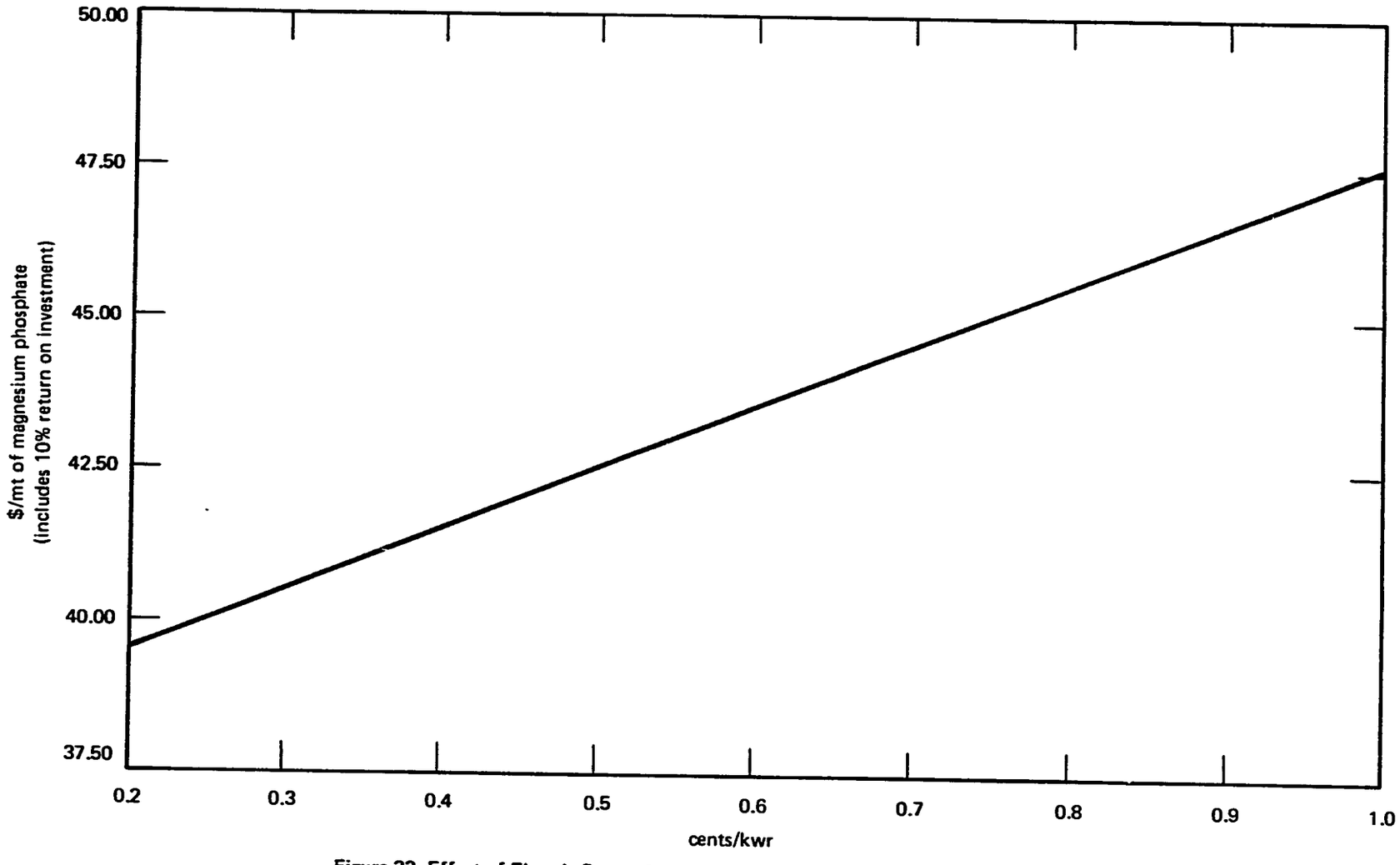


Figure 33. Effect of Electric Power Cost on Cost of Magnesium Phosphate at Valdivia, Chile (152 mt/day)

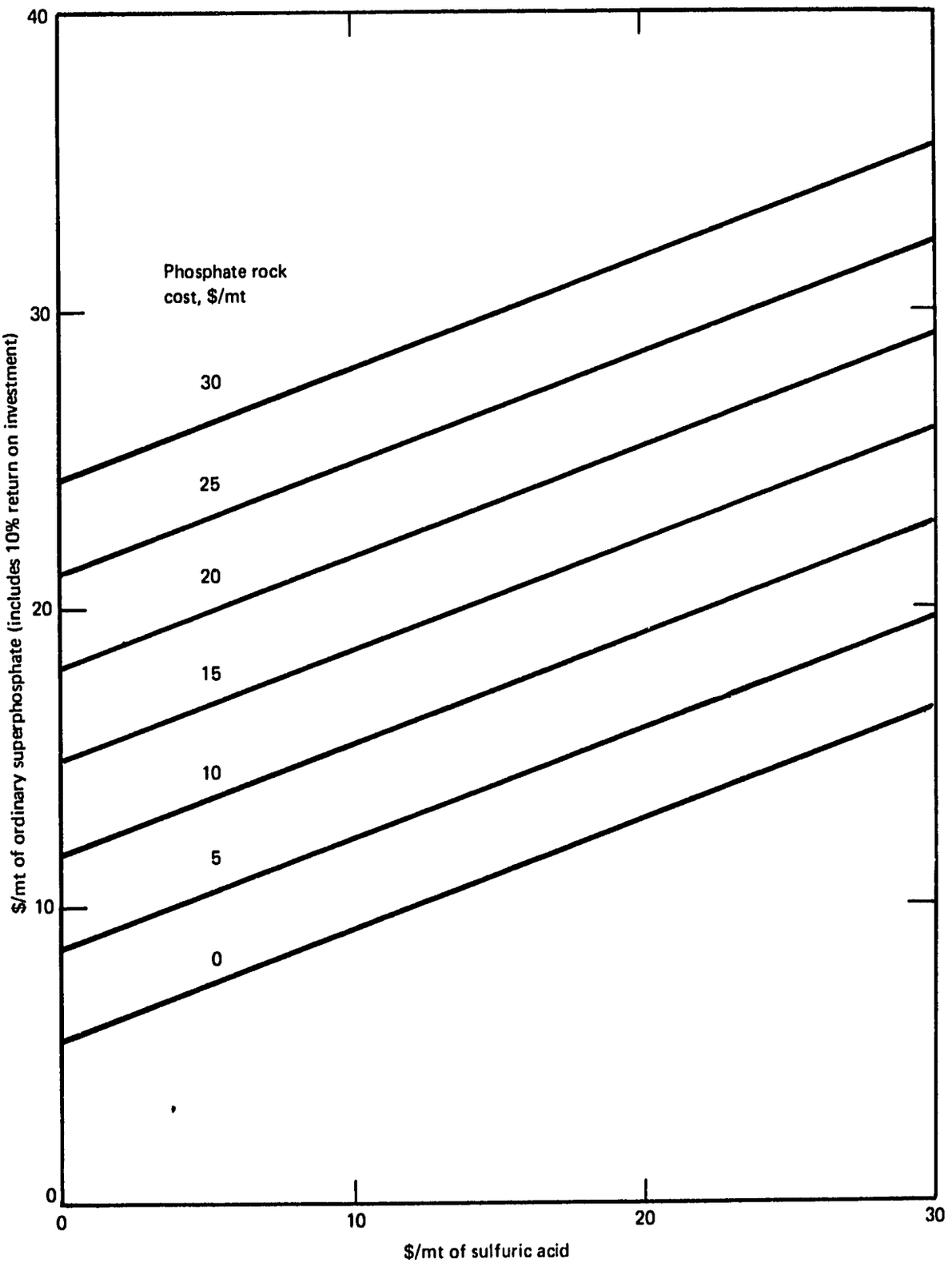


Figure 34. Effect of Cost of Sulfuric Acid and Phosphate Rock on Cost of Ordinary Superphosphate in Chile (1820 mt/day)

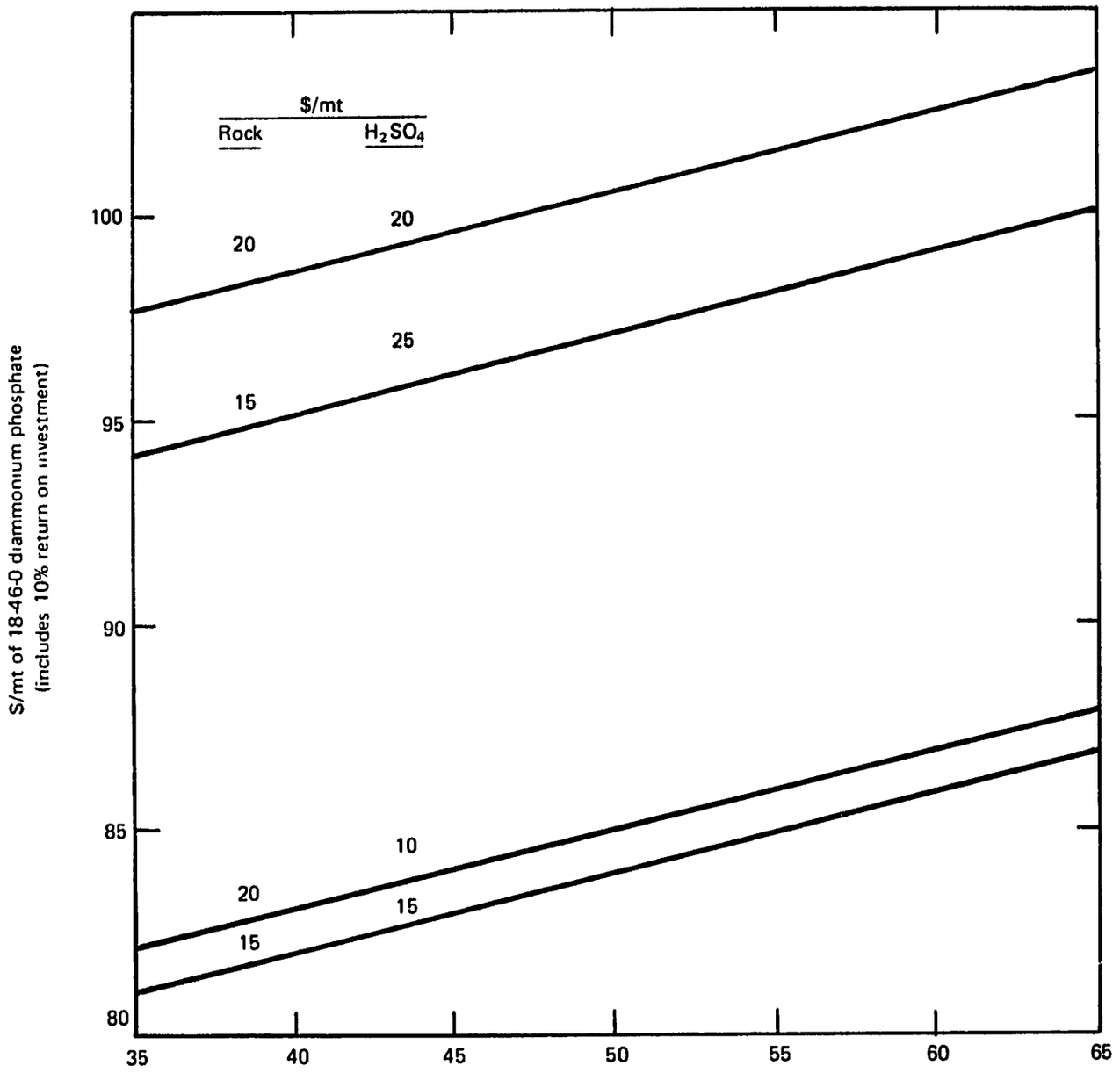


Figure 35. Effect of Changes in Cost of Ammonia on Cost of Producing Diammonium Phosphate in Chile (Plant Capacity, 791 mt/day)

SECTION VI

STUDY OF IMPORTATION

Based on estimated 1975 consumption, fertilizer production capacity available and under construction in 1969 can supply about 54% of the N requirements, 35% of the P_2O_5 requirements, and 24% of the K_2O requirements. The remainder of the plant nutrients could be supplied either by importing fertilizer materials or by constructing additional fertilizer plants. In order to evaluate the most desirable approach for supplying the additional nutrient requirements, the cost of supplying these nutrients should be considered for alternative fertilizer materials as well as under alternative price situations that may prevail in 1975. These various import possibilities can then be compared with production alternatives in order to decide if added capacity should be constructed in Chile and if so, at what locations.

The specific objectives of this section are to: (1) review the alternative fertilizer materials that may be imported into each province, (2) review ports through which fertilizer materials may be imported in the future, (3) review costs of importing and distributing fertilizer materials.

FERTILIZER MATERIALS AND QUANTITIES IMPORTED

Fertilizer materials imported were based upon the amount required to supply the nutrient requirements in each province above the quantity estimated to be supplied from existing Chilean production The nutrient requirements, those supplied from 1969 Chilean production capacity and those that will have to be supplied from other sources in 1975, are presented in table 11. The nutrients that will be supplied from nitrates, guano, and from the phosphate plant at Penco are not considered further in this section.[3] The total quantity of each material required in each province is presented in figure 8 Alternative fertilizer materials that may be imported to fulfill the nutrient requirements not supplied from present Chilean capacity are specified in this section. The substitutability of materials from an agronomic point of view were presented earlier.

The Kearney study suggested that fertilizers imported would include primarily urea and calcium ammonium nitrate (20% N) as sources of nitrogen; TSP and Bifos as sources of P_2O_5, and potassium sulfate, and potassium and magnesium sulfate as sources of K_2O. Estimates of the quantities of each material required in each province are presented in table 12

Alternative fertilizer materials that could be imported to supply the additional plant nutrient requirements in Chile are: (1) urea as the only source of N, (2) ammonium nitrate, the only source of N, (3) ammonium sulfate, the only source of N; (4) TSP, the only source of P_2O_5, (5) NSP, the only source of P_2O_5, (6) potassium sulfate, the only source of K_2O, (7) potassium chloride, the only source of K_2O; (8) DAP, the only source of P_2O_5 and supplemented with urea in provinces where N requirement exceeded the N supplied by DAP, and (9) DAP, the source of P_2O_5 and N in each province until the requirement of either nutrient is fulfilled and TSP or urea used to satisfy the remaining P_2O_5 or N requirement respectively. Requirements for each of these alternative fertilizer materials are shown by province in table 13

PORTS AND PORT COSTS

Chile has a long coast line and several ports that can handle bagged fertilizers

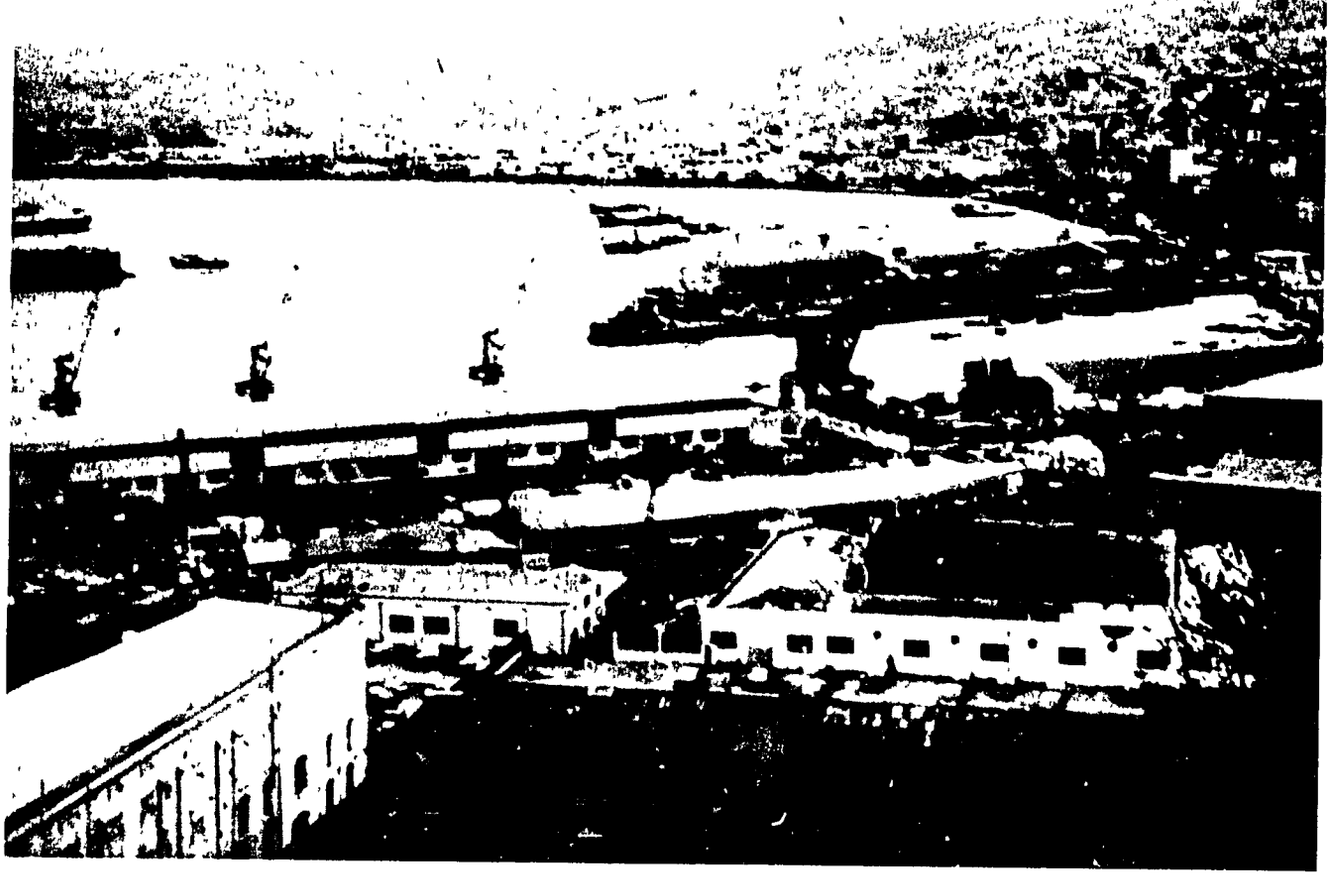
Since over 80% of the fertilizer nutrients are consumed in the Central Valley, the primary agricultural area, ports including and between Valparaiso and Puerto Montt handle most of the fertilizer imports (See table 14 for an estimate of fertilizers imported through each port in 1965 and 1967.) Ports located at Valparaiso (Baron) and Talcahuano (Lirquen) were the only ports that were equipped to handle bulk fertilizers in 1969

The Kearney study included a section on port facilities available for handling fertilizers both in bulk and in bags[4] The study also included a section on improvements planned at each port for handling fertilizers

The Kearney study suggests that all fertilizers should be imported in bulk and bagged at the port by 1975. This would include coastal movements of nitrates and guano as well as fertilizer materials, including urea, imported from other countries. Kearney shows four alternative import

[3] The movement of bulk nitrate materials through ports was estimated at 265,000 tons and bagged material at 35,000 tons/yr by SQM. Bulk coastal movements will play an important role in the utilizing of port facilities and bagging facilities at volumes sufficient to gain economies of size consistent with port and bagging cost estimates used in this study. For coastal movements of nitrates and guano by port of entry and province supplied from each port, see Banco del Estado de Chile, Port Analysis Supplement B. A. T. Kearney and Co., August 1969.

[4] For a detailed review of ports, facilities and planned improvements, see Banco del Estado de Chile, Port Analysis. *Chilean Fertilizer Distribution*, Supplement B. A. T. Kearney and Co.



The port at Valparaiso is one of two equipped to handle imported fertilizer in bulk.

patterns for bulk fertilizers. At the present time all fertilizer materials are handled in bulk at ports except for urea, guano, Thomas slag, and fused magnesium phosphate.

The import pattern considered for this study were similar to the Kearney study "Alternative IV" (the most economical alternative), where all fertilizers were imported in bulk through Baron, San Vicente, Penco, and Puerto Montt.

Baron at Valparaiso is equipped to receive fertilizers in bulk and bag it at the port and has a relatively low cost for handling and bagging fertilizers. The port at San Antonio is not equipped to handle bulk fertilizers and there are no plans to add facilities for handling bulk fertilizers. In the Talcahuano area, facilities for handling bulk materials are under construction at the San Vicente and Penco ports. Both should be operational before 1975. At Puerto Montt, channel improvement and port construction are under way and indications are that bulk fertilizers handling and bagging facilities should be operational before 1975. It was suggested in the Kearney study that each of these ports should be efficient and handling costs should approach the present cost at Baron. Therefore, handling and bagging costs were assumed to be the same at each port considered in this study.

Ocean freight was assumed to be that from U. S. Gulf Coast to Chilean ports at the tramp ship rate. Since Chile has a law, 12041, that requires half of the fertilizer imported to move in Chilean flag ships, half the ocean freight cost was assumed to be in Chilean currency, expressed in US$ equivalents, and half was assumed to require foreign exchange. Based upon differences in the cost of TSP f.o.b. Gulf Coast and c.i.f. Chilean ports in 1969, ocean freight costs were estimated at $9/mt.[5] Ocean freight costs, bulk unloading cost, handling cost, and bagging costs/mt are shown in table 15. These costs are partitioned into foreign exchange and Chilean currency, US$ equivalents. Fertilizers bagged in Chile are bagged in 80-kg jute bags with polyethylene liners The jute bags are imported and the polyethylene liners are produced in Chile.

It should be pointed out that all import tax, port tax, and bagging tax were omitted. These are costs subject to change, based on government policy. They must, of course, be added if actual total costs are to be estimated.

DISTRIBUTION FROM PORTS

Chile has a very good road and railroad system that extends the full length of the Central Valley and connects

[5] F.o.b. and c.i.f. costs of TSP imported in 1968-69 were provided by the Banco del Estado de Chile.

Table 11. Major Nutrient Requirements, Present Producing Capacity, and Quantities Required in Addition to Present Producing Capacity, 1975[a]

Province	Total Nutrient Requirement			Nutrients Supplied from Present Chile Production			Deficient Supply of Nutrient Requirements		
	N	P_2O_5	K_2O	N	P_2O_5[b]	K_2O	N	P_2O_5	K_2O
Tarapaca	300	150	50	8	104	50	292	46	
Antofagasta	200	100	20	20	8	20	180	92	
Atacama	700	900	300	700	79	300	–	821	
Coquimbo	3,900	3,900	2,500	3,900	1,504	2,500	–	2,396	
Aconcagua	3,200	2,600	1,000	1,575	275	1,000	1,625	2,325	
Valparaiso	1,700	1,200	600	1,062	402	600	638	798	
Santiago	13,500	12,800	2,600	5,675	1,688	2,600	7,825	11,112	
O'Higgins	8,200	3,400	1,200	2,975	339	1,200	5,225	3,061	
Colchagua	4,700	6,600	800	2,505	574	800	2,195	6,026	
Curico	3,400	4,100	500	1,382	3,113	500	2,018	987	
Talca	5,600	8,600	700	2,125	1,027	700	3,475	7,573	
Linares	5,400	9,500	300	2,215	4,220	300	3,185	5,280	
Maule	600	1,800	300	557	6	300	43	1,794	
Nuble	7,900	11,700	3,800	2,110	11,349	59	5,790	351	3,741
Concepcion	1,500	2,200	1,600	152	2,161	63	1,348	39	1,537
Arauco	300	2,100	900	178	179	3	122	1,921	897
Bio-Bio	7,000	8,800	2,500	5,630	8,566	66	1,370	234	2,434
Malleco	9,200	13,900	3,400	6,945	13,471	69	2,255	429	3,331
Cautin	6,500	22,200	9,500	5,895	1,718	0	605	20,482	9,500
Valdivia	2,300	18,300	6,100	1,382	2,179	53	918	16,121	6,047
Osorno	900	13,800	5,500	890	1,360	42	10	12,440	5,458
Llanquihue	1,600	10,900	2,300	390	2,421	404	1,210	8,479	1,896
Chiloe	300	2,700	1,300	188	920	121	112	1,780	1,179
Aysen	500	1,600	900	50	36	3	450	1,564	897
Magallanes	650	1,400	1,000	90	20	0	560	1,380	1,000
Total	90,050	165,250	49,670	48,599	57,719	11,753	41,451	107,531	37,917

[a]Source. Banco del Estado de Chile, *Marketing of Fertilizers*, Vol. 2, A. T Kearney and Co., Inc., 1969.
[b]It was assumed that TSP produced at Penco would be consumed in the Provinces of Concepcion, Bio-Bio, Nuble, Malleco, and Linares. These provinces represent the ones that minimize distribution cost from Penco

with each of the ports that will import bulk fertilizers All fertilizer was assumed to move from ports to provinces by rail since all shipments are from the port to a representative point in each province.[6]

Fertilizer moves at one rate regardless of volume and rates are, in general, a function of distance only. Rail rates for fertilizers are about 15% below the general cargo rate Savings might be realized by both the railroad and the fertilizer industry which could be passed to farmers as lower fertilizer prices if volume movements were based upon actual costs of the movement. U. S. rates have been reduced by 60% or more for volume movements and the rail companies are still realizing a profit from these hauls. This type analysis for the rail system is outside the scope of this study but should be considered in long-range planning.

The provinces serviced by each port location were based upon the least cost of shipping fertilizer materials from the port to the province It was assumed that fertilizer moving to the three northern provinces would be bagged at Valparaiso and for the two southern provinces would be bagged at Puerto Montt and moved by ocean-going ships to each of the respective provinces at the same rates as bagged nitrates.

Fertilizers imported into Valparaiso are assumed to move by rail to provinces between Coquimbo and Colchagua, imports into Talcahuano supply provinces from Curico to Cautin, and imports into Puerto Montt supply provinces from Valdivia south.

[6]Based on the Kearney study, Vol 3, Exhibit 3-8, rail appears less costly than truck for fertilizer movements for longer hauls The Kearney study further estimates the total cost of moving fertilizer to each warehouse location and savings if all warehouses were located on rail sidings. That amount of detail would be a duplication and is outside the scope of this study.

Table 12. Material Requirements by Province to Supply Major Plant Nutrient in Excess of the Chilean Production Capacity—The Kearney Estimate (2).

Province	N		P_2O_5		K_2O	
	Urea	Calcium Ammonium Nitrate[a]	TSP[b]	Bifos	Potassium Sulfate	K and Mg Sulfate
			mt			
Tarapaca	650	–	100	–	–	–
Antofagasta	400	–	200	–	–	–
Atacama	–	–	1,700	100	–	–
Coquimbo	–	–	4,700	600	–	–
Aconcagua	3,500	250	4,800	300	–	–
Valparaiso	1,350	150	1,650	100	–	–
Santiago	16,900	1,100	22,800	1,600	–	–
O'Higgins	11,300	700	6,400	300	–	–
Colchagua	4,700	400	12,550	650	–	–
Curico	4,350	300	1,850	350	–	–
Talca	7,500	500	15,700	900	–	–
Linares	6,900	400	10,800	800	–	–
Maule	50	100	3,900	–	–	–
Nuble	12,600	600	–	900	5,500	3,600
Concepcion	2,950	100	–	100	2,300	1,400
Arauco	250	50	4,050	150	1,300	900
Bio-Bio	2,800	550	–	600	3,600	2,300
Malleco	4,700	700	–	1,100	4,900	3,200
Cautin	1,100	550	43,000	1,800	13,900	9,400
Valdivia	1,950	200	33,350	2,000	8,900	5,800
Osorno	–	50	25,900	1,350	8,000	5,300
Llanquihue	2,600	200	17,500	1,100	2,800	1,800
Chiloe	250	–	3,700	200	1,700	1,200
Aysen	1,000	–	3,400	–	1,300	900
Magallanes	1,200	100	3,000	–	1,500	1,000
Total	89,000	7,000	221,050	15,000	55,700	36,800

[a]Other 20% N was assumed to be calcium ammonium nitrate.
[b]It was assumed that Penco would produce 50,000 units of P_2O_5, enough to supply all the Reno Blends, all the NSP and the TSP required in Nuble, Concepcion, Bio-Bio, Malleco, and part of the requirement in Linares, the closest Provinces in terms of distribution costs.

Rail cost for shipping fertilizers from each port to provinces are presented in table 16.

FERTILIZER PRICES

Three sets of prices are considered for the Kearney estimates of fertilizer material imports. The first two sets of prices are the weighted average f.o.b. prices paid by Chile in 1965 and 1969. The 1965 prices were selected because 1965 represents a recent period when world consumption or the effective world demand for fertilizers was more nearly equated with the world supply of fertilizer materials. The 1969 prices are the most recent prices available but represent a period of excess world fertilizer production capacity that has resulted in prices below total cost of production including capital cost. Many fertilizer producers were selling fertilizer at a price adequate to cover only the operating cost. Often part or all of the capital costs was not recovered in the selling price of fertilizers. This situation has allowed some developing countries to buy fertilizers at costs below the total manufacturing costs. even in large, efficient plants.

A recent study by TVA (11) indicates that world consumption of nitrogen and phosphate fertilizers should approach the world production capacity that now exists or is under construction by 1975. World capacity for potash fertilizers will exceed demand for many more years. However, limits recently placed on production by the Canadian government have contributed to a firming of potash prices.

Recent (1970) phosphate prices in the U. S. are somewhat higher. Some of the older, less efficient plants were closed and spring shipments were higher, resulting in

Table 13. Alternatives to the Kearney Estimates for Supplying Plant Nutrients in Excess of the Chilean Production Capacity[a]

Province	Nitrogen: Urea only source	Nitrogen: Ammonium Nitrate	Nitrogen: Ammonium Sulfate	P_2O_5: TSP only source	P_2O_5: Normal Superphosphate only source	K_2O: Potassium Sulfate only source	K_2O: Potassium Chloride only source	Source of N & P_2O_5: DAP only source of P_2O_5[b]: DAP	DAP only source of P_2O_5[b]: Urea	DAP limited by N or P_2O_5[c]: DAP	DAP limited by N or P_2O_5[c]: TSP	DAP limited by N or P_2O_5[c]: Urea
						mt						
Tarapaca	649	872	1,391	100	230	–	–	100	609	100	–	609
Antofagasta	400	537	857	200	460	–	–	200	320	200	–	320
Atacama	–	–	–	1,785	4,105	–	–	1,785	–	–	1,785	–
Coquimbo	–	–	–	5,209	11,980	–	–	5,209	–	–	5,209	–
Aconcagua	3,611	4,851	7,738	5,054	11,625	–	–	5,054	1,554	5,055	–	1,589
Valparaiso	1,418	1,905	3,038	1,735	3,990	–	–	1,735	725	1,735	–	725
Santiago	17,389	23,358	37,262	24,157	55,560	–	–	24,157	7,727	24,157	–	7,727
O'Higgins	11,612	15,597	24,881	6,654	15,305	–	–	6,654	8,949	6,655	–	8,950
Colchagua	4,878	6,552	10,452	13,100	30,130	–	–	12,195	–	12,195	906	–
Curico	4,485	6,024	9,610	2,146	4,935	–	–	2,146	3,627	2,146	–	3,627
Talca	7,722	10,373	16,548	16,463	37,865	–	–	16,465	1,138	16,463	–	1,138
Linares	7,078	9,507	15,167	11,478	26,400	–	–	18,678	–	11,478	–	2,487
Maule	96	128	205	3,900	8,970	–	–	239	–	239	3,661	–
Nuble	12,867	17,284	27,571	763	1,755	7,335	6,235	23,663	3,402	763	–	12,562
Concepcion	2,996	4,024	6,419	85	195	3,014	2,562	4,485	2,817	85	–	2,962
Arauco	271	364	581	4,176	9,605	1,759	1,495	678	–	678	3,498	–
Bio-Bio	3,045	4,090	6,524	509	1,170	4,773	4,057	8,116	–	509	–	2,841
Malleco	5,011	6,732	10,738	933	2,145	6,531	5,552	12,528	–	933	–	4,638
Cautin	1,344	1,806	2,881	44,526	102,410	18,692	15,888	3,361	–	3,362	41,165	–
Valdivia	2,040	2,740	4,372	35,046	80,605	11,857	10,078	30,675	–	5,100	29,946	–
Osorno	22	30	48	27,043	62,200	10,702	9,097	27,043	–	56	26,988	–
Llanquihue	2,689	3,612	5,762	18,433	42,395	3,718	3,160	18,433	–	6,723	11,710	–
Chiloe	249	334	533	3,870	8,900	2,312	1,965	3,870	–	623	3,247	–
Aysen	1,000	1,343	2,143	3,400	7,820	1,759	1,495	3,400	–	2,500	900	–
Magallanes	1,244	1,672	2,667	3,000	6,900	2,010	1,708	3,000	11	3,000	–	45
Total	92,116	123,735	197,388	233,765	537,655	74,462	63,292	233,869	30,879	104,755	129,015	50,220

[a]Each fertilizer material is the only source of that nutrient, for example, if TSP is the source of P_2O_5, then no other fertilizer material such as NSP is used as a source of P_2O_5.

[b]DAP is a 18-46-0 grade material and supplies both N and P_2O_5. Some provinces need additional N which is supplied by urea. Since all P_2O_5 was supplied by DAP in all provinces, there were 13,845 mt of N used in excess of the requirement. In order to make maximum use of N in DAP, Penco's production of TSP was assumed to be shipped to the following provinces: Colchagua, 907 mt; Maule, 3,661 mt; Arauco, 3,498 mt, Bio-Bio, 9,643 mt; Malleco, 15,305 mt; Cautin, 41,165; and Valdivia, 4,371 mt.

[c]P_2O_5 or N limits the use of DAP according to which requirement is satisfied first and TSP or urea used to supply the remaining requirement. TSP produced at Penco distributed same as designated in footnote (b).

Table 14. Tonnages of Fertilizer Materials Incoming by Port, 1965 and 1967[a]

(1,000 mt)

Port	Imports 1965	Imports 1967	Coastal Movement 1965	Coastal Movement 1967	Total 1965	Total 1967
Coquimbo	–	1.3	5.0	9.8	5.0	11.1
Valparaiso (Baron)	11.0	27.5	119.8	104.5	130.8	132.0
San Antonio	44.5	12.9	23.6	42.2	68.1	55.1
Talcahuano (Lirquen)	87.5[b]	79.6	64.8	82.3	152.3	161.9
Corral (Valdivia)	33.5	6.4	9.8	4.4	43.3	10.8
Puerto Montt	13.9	22.0	9.6	13.7	23.5	35.7
Subtotal	190.4	149.7	232.6	256.9	423.0	406.6
Ports North of Coquimbo	32.6	33.8	0.4	0.9	33.0	34.7
Ports South of Puerto Montt	–	–	5.0	5.8	5.0	5.8
Total	223.0	183.5	238.0	263.6	461.0	447.1

[a]Source: Banco del Estado de Chile, *Chilean Fertilizer Distribution*, "Physical Distribution of Fertilizers," Vol. 3, 1969, Exhibit 3-2a, A. T. Kearney and Co.
[b]Includes 14,700 tons of phosphate rock.

Table 15. Costs of Importing Bulk Fertilizers and Bagging at Ports per Metric Ton[a]

	Foreign Exchange	Chilean Currency	Total Cost
		US$	
Ocean Freight[b]	4.50	4.50	9.00
Unloading		1.00	1.00
Transfers at Ports[c]		1.80	1.80
Storage at Docks		0.50	0.50
Bagging Cost		1.58	1.58
Bags[d]:			
Jute	3.53		3.53
Polyethylene liners		0.59	0.59
Store			
Total	8.03	9.97	18.00

[a]Based on data supplied by Banco del Estado de Chile and from Banco del Estado de Chile, *Chilean Fertilizer Distribution*, A. T. Kearney and Co.
[b]Law 12041 requires that 50% of the fertilizer imported must move in Chilean flag ships
[c]Includes three transfers- from dock to storage, from storage to bagging facility, and from bagging facility to railcar or truck.
[d]Based on 80 kg bags

an improved supply-demand situation. Stocks of phosphate fertilizers in the U. S. are decreasing, and it is likely that export phosphate prices will tend to increase during the next few years. However, the excess TSP capacity in Mexico may contribute to continued depressed prices for that material. Recent urea prices in the U. S. are near the total cost of production. But as a result of excess urea capacity in Western Europe and parts of Asia, the current world market prices are below U. S. prices.

Chile should evaluate its fertilizer supply alternatives on the basis of fertilizer prices expected in 1975, when the market should be more stabilized. Recent fertilizer prices for materials of interest to Chile and projected 1975 prices are given in table 17. These prices were based on information from a recent TVA publication, *Technical and Economic Evaluation of Fertilizer Intermediates for Use in Developing Countries*.

F.o.b. and c.i.f. price estimates for 1965, 1969, and 1975 as used in this study are presented in table 18.

COSTS OF IMPORTING AND DISTRIBUTING FERTILIZERS IN CHILE, 1975

Total costs of importing and distributing alternative fertilizer materials and at alternative prices are presented in this section. The section will have four parts–nitrogen materials, phosphate materials, potassium materials, and mixtures. The alternatives considered in each part are as follows:

Supply System	
	Nitrogen Materials
IN-1	Kearney estimates of materials; 1975 prices.
IN-2	Same as IN-1 except 1969 prices were used.
IN-3	Same as IN-1 except 1965 prices were used.
IN-4	Urea is the only souces of N; 1975 prices.
	Phosphate Materials
IP-1	Kearney estimate of materials; 1975 prices.
IP-2	Same as IP-1 except 1969 prices were used.
IP-3	Same as IP-1 except 1965 prices were used.
IP-4	TSP is the only source of P_2O_5 ; 1975 prices.

Supply System	
	Potassium Materials
IK-1	Kearney estimate of materials; 1975 prices.
IK-2	Same as IK-1 except 1969 prices were used.
IK-3	Same as IK-1 except 1965 prices were used.
IK-4	Potassium sulfate is the only source of K_2O; 1975 prices.
IK-5	Potassium chloride is the only source of K_2O; 1975 prices.
	Mixed Fertilizers
IM-1	DAP is the only source of P_2O_5 and urea used where additional N is required; 1975 prices. (This alternative gives excess N in some provinces.)
IM-2	DAP use limited by P_2O_5 or N requirement whichever is satisfied first and TSP or urea used to supply the additional P_2O_5 or N requirement respectively; 1975 prices.

Part of the alternative presented in this section will be used in section VII to compare with alternative Chilean production estimates.

Nitrogen Materials

The total quantity of nitrogen supplied from each of the alternatives are identical at approximately 41,500 mt of actual N but either prices and/or types of material differ for each alternative.

Costs of importing ammonium nitrate (33.5% N) was not considered as an alternative import material because it has a higher price per unit of N than urea and since it is also considered to be explosive in nature and, therefore, hazardous by some shippers

Recent prices of ammonium sulfate have been very low. At these depressed price levels, it might be imported at costs competitive with or below urea on a cost per unit of N basis. However, ammonium sulfate prices vary widely and depend largely upon the supply available as a byproduct. Generally, the cost of a unit of N from imported ammonium sulfate is higher than urea under stable market conditions when transportation and distribution costs are included.

In alternatives IN-1, IN-2, and IN-3, urea prices were the only variables. If urea and calcium ammonium nitrate are the only sources of nitrogen imported in 1975, the total cost

Trucks and railroads are keys in the fertilizer distribution system in major farming areas.

Table 16. Costs per Metric Ton of Shipping Fertilizer Materials Other than Nitrates from Ports to Provinces[a]

	Port of Origin		
Province	Valparaiso US$	Talcahuano US$	Puerto Montt US$
Tarapaca[a]	10.75		
Antofagasta[b]	13.15		
Atacama[b]	11.28		
Coquimbo	9.82		
Aconcagua	3.17		
Valparaiso	.96		
Santiago			
O'Higgins	5.10	8.39	
Colchagua	5.88	7.60	
Curico	6.82	6.66	
Talca	7.77	5.73	
Linares	8.70	4.95	
Maule	10.54	5.10	
Nuble		3.39	
Concepcion		.80	
Arauco		5.10	
Bio-Bio		2.75	
Malleco		4.10	
Cautin		5.24	6.66
Valdivia			4.17
Osorno			2.60
Llanquihue			1.50
Chiloe			2.91
Aysen[b]			11.00
Magallanes[b]			9.30

[a]Rail rates were provided by Banco del Estado de Chile, Rail Tariffs, Empresa de F.F.S.C., Anexo Carta Comercial No 2266, Stgo. November 26, 1969. Rates were converted to US$ equivalents: E° 10.1 = $1, the exchange rate was based on the January 1970 exchange rate.

[b]It was assumed that bagged materials could be moved between ports at the same rate as bagged nitrated material plus handling and land shipment cost to move it to a central location in the province.

delivered to provinces will be $8.7 million or $210/mt of N assuming that prices increase as predicted by 1975. If prices remain near the 1969 level, total costs would be $6.1 million or $147/mt of N. If prices were to return to the 1965 level, total cost would be $8.5 million or $204/mt of N. Cost at 1965 prices are almost as high as at estimated 1975 prices. At 1975 prices (IN-1), almost 85% of the cost of nitrogen materials will require foreign exchange compared with 77% at 1969 prices, IN-2. That is, as the f.o.b. prices increase, a larger proportion of the total fertilizer cost will be foreign exchange. (See figure 36)

Cost of N/unit in calcium ammonium nitrate is expected to be higher than in urea when delivered to the provinces at 1975 prices. That is, the cost of N/mt in calcium ammonium nitrate is $216 compared to $210 in urea. At 1969 prices, the differential was much wider in favor of urea. This suggests that if all imported nitrogen requirements were in the form of urea, as in IN-4, costs could be reduced by about $230,000 at 1975 price levels. For additional detail about import costs of nitrogen materials, foreign exchange, and shipping cost, see table 19. import costs of nitrogen materials, foreign exchange, and shipping cost, see table 19.

Phosphate Materials

The same total quantity, 107,500 mt of P_2O_5 is supplied for each alternative considered. NSP was not considered as an alternative import material since its low concentration of P_2O_5 makes import cost over twice that of TSP. In alternatives IP-1, IP-2, and IP-3, the import materials were TSP and Bifos, as suggested in the Kearney report. Total costs for IP-1, the 1975 price alternative, was almost $19.1 million compared with $14.1 million in IP-2, 1969 prices. Costs of P_2O_5/mt in IP-1 was $177 and in IP-2, $131. In IP-3, the 1965 price situation costs were even higher than IP-1, $186/mt of P_2O_5.

For IP-1, the foreign exchange requirement was almost 82% of the cost of fertilizers delivered to warehouses in the provinces. In IP-2, the proportion was less, 76% because f.o.b. prices were lower and transfer and handling costs were the same for both alternatives (See figure 37.)

The cost of Bifos/mt of P_2O_5 delivered to provinces was $213 compared with $175 from TSP. Therefore, comparing IP-1 with IP-4, total cost of P_2O_5 could be reduced by $228,000 if the P_2O_5 requirements were supplied by importing only TSP. Foreign exchange requirements would also be reduced. Bifos is imported in bags and TSP is imported in bulk.

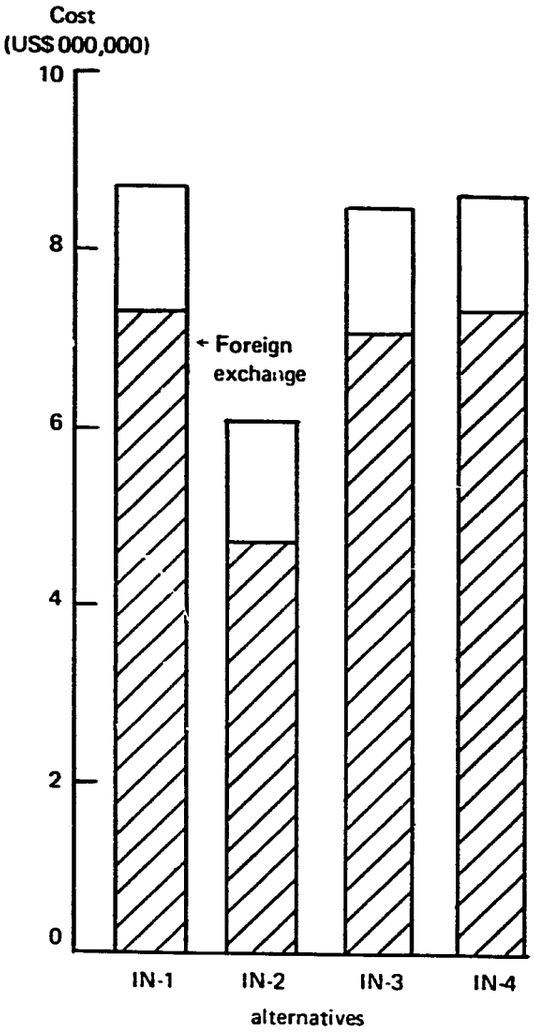
For more details about cost of importing, handling, and shipping phosphate fertilizer materials as well as foreign exchange requirements see table 20.

Potassium Materials

All potassium requirements in provinces north of Nuble are supplied from potassium nitrate and guano. Therefore, potassium materials except for Chilean coastal movements were imported through only two ports, Talcahuano and Puerto Montt.

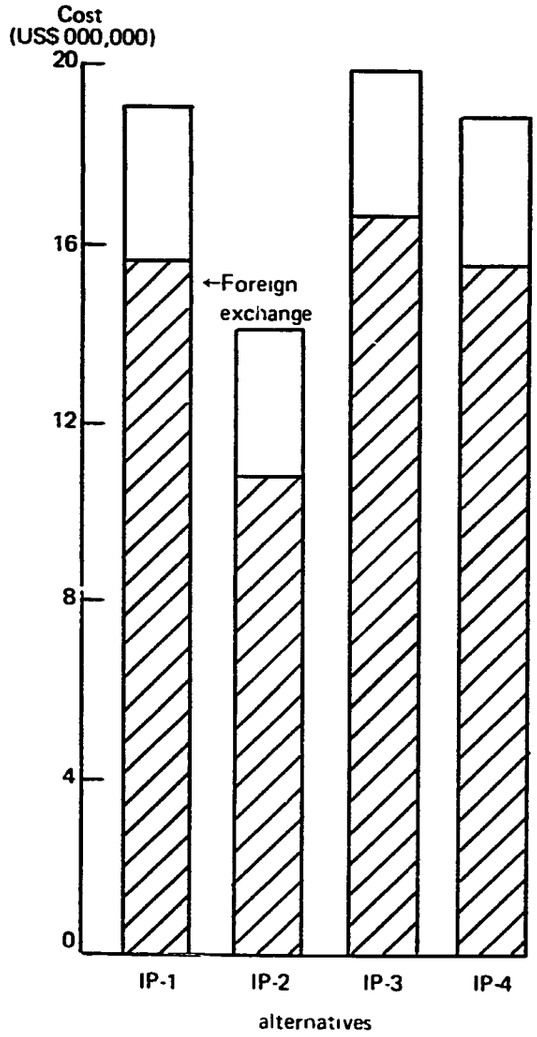
Under the assumption of IK-1, cost of importing potassium materials is almost $6.7 million or $175/mt of K_2O. That compares with a cost of $5.9 million or $156/ton of K_2O if 1969 prices prevail in 1975, IK-2. The prices in 1965 were even lower than in 1969. Therefore, if prices in 1975 were to return to the 1965 level and if potassium sulfate and potassium and magnesium sulfate

Figure 36. Estimated Total Costs and Foreign Exchange Requirements for Importing and Distributing 41,500 Tons/Year of N to Warehouses—1975[a]



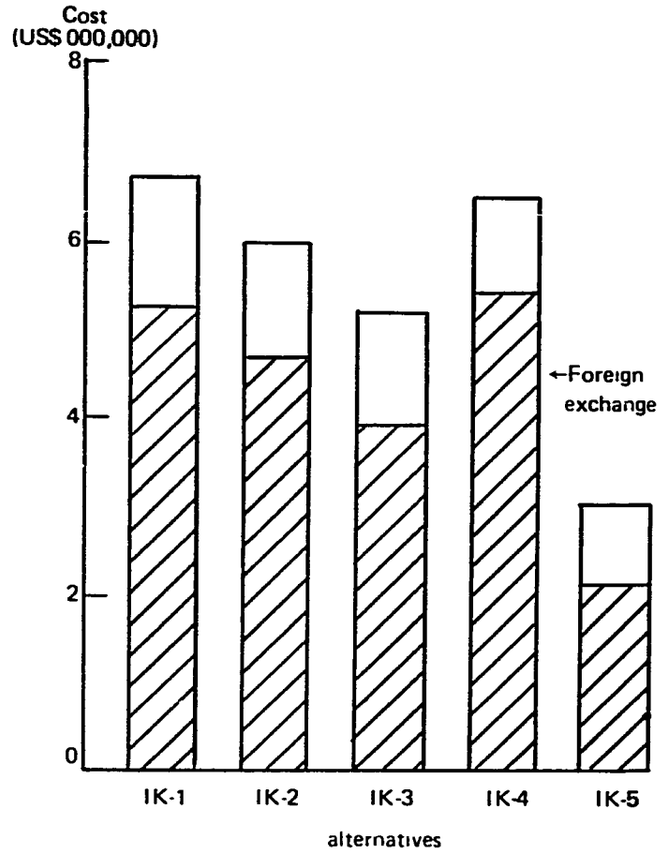
[a]IN-1 Kearney Estimates of Materials, 1975 prices.
IN-2 Kearney Estimates of Materials; 1969 prices.
IN-3 Kearney Estimates of Materials, 1965 prices.
IN-4 Urea is the only source of N, 1975 prices.

Figure 37. Estimated Total Costs and Foreign Exchange Requirements for Importing and Distributing 107,500 Tons /Year of P_2O_5 to Warehouses—1975[a]



[a]IP-1 Kearney Estimate of Materials, 1975 prices
IP-2 Kearney Estimate of Materials, 1969 prices.
IP-3 Kearney Estimate of Materials, 1965 prices.
IP-4 TSP is the only source of P_2O_5, 1975 prices.

Figure 38. Estimated Total Costs and Foreign Exchange Requirements for Importing and Distributing 41,500 Tons/Year of K_2O to Warehouses—1975[a]



[a]IK-1 Kearney Estimate of Materials, 1975 prices.
IK-2 Kearney Estimate of Materials, 1969 prices
IK-3 Kearney Estimate of Materials, 1965 prices
IK-4 Potassium sulfate is the only source of K_2O, 1975 prices.
IK-5 Potassium chloride is the only source of K_2O, 1975 prices.

Table 17. Recent and Projected Prices for Select Fertilizer Materials

Granular Fertilizer Material	Grade	Price $/mt of Material: Recent AID shipment	Currently quoted in U. S.	Projected 1975[a]
DAP, Bulk, f.o.b. Gulf Coast	18-46-0	55	68	76
TSP, Bulk, f.o.b. Gulf Coast	0-46-0	40	50	58
Potassium Sulfate, Bulk, f.o.b. Pacific Coast	0-0-52	65	65	65
Potassium Chloride, Bulk, f.o.b. Pacific Coast	0-0-60	26	32	25
Urea, Bagged in Jute and Polyethylene, f.o.b. Gulf Coast	45-0-0	82	81	72[b]
Anhydrous Ammonia, f.o.b. Gulf Coast in tankers	82-0-0	–	–	34

[a]Projected prices are not an extension of recent trends but reflect a supply and demand situation which would result in prices that approximate the total cost of production The world supply-demand situation in 1975 was based on recent TVA projections, published in. *Technical and Economic Evaluation of Fertilizer Intermediates for Use in Developing Countries*, TVA, 1970, page 14.
[b]Bulk prices

were the materials imported, IK-3, K_2O would cost $137/mt of K_2O. (See figure 38)

If all K_2O requirements were imported as potassium sulfate, IK-4, cost would be slightly less than in IK-1 where part of the requirement was assumed to be imported in the form of potassium and magnesium sulfate

The chloride form of K_2O cannot be used on all crops and on all soils However, for purposes of comparison, all imports were assumed to be in the form of potassium chloride, IK-5 If prices in 1975 are at the levels predicted by TVA, potassium chloride will provide a much cheaper source of K_2O. Total costs could be reduced by $3.5 million if potassium chloride were used instead of potassium sulfate, IK-5 compared with IK-4 Savings are even greater if potassium chloride is used to replace potassium and magnesium sulfate. Costs of K_2O/mt from potassium chloride is $78 48 versus $170.84 from potassium sulfate The foreign exchange requirement is also lower, $55 10/ton of K_2O in potassium chloride versus $143.33/ton of K_2O in potassium sulfate Thus, savings would be considerable to Chile if potassium chloride were imported to the maximum practical limit in lieu of other potassium materials. Costs of potassium chloride are lower for two reasons, (1) the f.o b. price/ton of nutrient is lower and (2) the concentration of K_2O is higher than in other materials. The latter results in lower shipping costs because fewer tons of materials are required to provide the same amount of K_2O.

For additional information about foreign exchange requirements and import and distribution cost of potassium materials, see table 21.

Mixed Fertilizers

Two systems of mixed fertilizer were considered for N-P combinations. DAP, an 18-46-0 grade, was the mixed fertilizer used in the analysis. In IM-1, DAP was assumed to be the only source of P_2O_5 and in many provinces provided an adequate or more than adequate quantity of nitrogen to supply the requirements. DAP supply was limited only by P_2O_5 requirement. However, in some provinces, particularly in the northern part of the Central Valley, additional nitrogen was required and was assumed to be supplied by imported urea. It should be pointed out that in total, nitrogen supplied in DAP was adequate to supply the entire Chilean need for nitrogen that must be imported. However, the N-P requirements by province were such that additional nitrogen must be supplied in some provinces to meet the demand while other provinces require less N than supplied in DAP if the P_2O_5 requirements were supplied from DAP.

In IM-2, the use of DAP was limited by either N or P_2O_5 requirements in each province depending upon which nutrient requirement was satisfied first TSP was used to supply the remaining P_2O_5 requirement in provinces where the N requirement determined the maximum level of DAP used. Urea was used as the source of N in provinces where the P_2O_5 requirement was supplied by DAP and additional N was required In this situation the N-P nutrients are supplied in each province according to the requirements; this differs from IM-1 in that no excess N is supplied in any of the provinces.

In IM-1, the total import cost of DAP was almost $23.0 million and urea an additional $2.9 million or the total cost

of supplying the N-P requirement from DAP and urea was $25.2 million. The cost per unit of N and P_2O_5 was $173.61/mt of nutrient. The foreign exchange requirement for importing DAP is $19.7 million and the additional urea required about $2.5 million for a total foreign exchange requirement of $22.1 million.

In IM-2, the total cost of DAP was $10.3 million, urea $4.7 million, and TSP $10.4 million. The total cost of supplying N and P_2O_5 under the assumptions of IM-2 was $25.4 million. The cost per unit of N and P_2O_5 was $170.75 or $2.86/ton of nutrient less than IM-1 The foreign exchange required was also less, $143.24/ton of nutrient as compared with $148.50 in IM-1.

Although TSP and urea are incompatible as blended mixtures, if they were used as straight materials to supply the requirement for N and P_2O_5, the total cost would be $27.5 million compared with a cost of $25.4 million in IM-2 (DAP, TSP, and urea are used). Foreign exchange requirements are also slightly less for IM-2, $21.3 million compared with $22.8 million using only TSP and urea

It is recognized that problems have been encountered in Chile with the use of DAP on some crops, particularly on sugarbeets. When DAP was first introduced in the United States, problems were also encountered there but were overcome with proper placement in relationship to the seed and plants Perhaps the problems with DAP in Chile can also be overcome through research

Import costs of supplying the N-P_2O_5 requirement can be reduced by using as much DAP as possible and providing additional N as urea and P_2O_5 as TSP as required to obtain the desired nutrient ratio.

For additional information about foreign exchange requirements and import and distribution costs for mixed fertilizers, see table 22

Table 18. Alternative Prices for Fertilizer Materials Imported into Chile[a]

Material	Prices paid by Chile[b]				World Prices	
	1965		1969		1975[c]	
	f.o.b.	c.i.f.[d]	f.o.b.	c.i.f.[d]	f.o.b.	c.i.f.[d]
			US$			
Nitrogen						
Urea	69.18	78.18	42.70	51.70	72.00	81.00
Calcium Ammonium Nitrate	21.00[e]	30.00	21.00	30.00	21.00	30.00
Phosphate						
TSP	62.50	71.50	35.75	44.75	58.00	67.00
Bifos (Bagged)	59.11	75.45	59.11	75.45	59.11	75.45
DAP	70.96	79.96	57.00	66.00	76.00	85.00
Potassium						
Potassium Sulfate	34.38[f]	43.38	47.55	56.55	65.00	74.00
K and Mg Sulfate	33.91[e]	42.91	33.91	42.91	27.00	36.00
Potassium Chloride	25.00[e]	34.00	25.00	34.00	25.00	34.00

[a]These prices represent alternative prices that Chile might expect to pay for fertilizers in 1975 if fertilizers are imported in bulk

[b]Prices provided by the Banco del Estado de Chile were for bagged fertilizers and were reduced by $10/ton, for an estimate of bulk prices f.o.b. Gulf Coast

[c]Based on world prices if supply and demand conditions equate near the total average cost of production

[d]Shipping costs were estimated at $9/mt from Gulf Coast to Chile ports, tramp steamer rates - based upon difference between f.o.b. Gulf Coast and c.i.f. Chile ports for bulk TSP, 1968-1969 Difference ranged from $7.99 to $10.09

[e]The 1969 price was used as an estimate of the 1965 price since Chile did not import any of the material in 1965

[f]1967 was the first purchase since 1965 and the 1967 price was used as an estimate of the 1965 price

Table 19. Cost of Importing and Distributing Nitrogen Fertilizers in Chile for Alternative Materials and Prices, 1975[a]

Ports	Metric Tons	Import, Handling & Bagging Cost at Port: f.o.b. Cost	Foreign Exchange[b]	Chilean Currency[c]	Total at Port[d]	Cost at warehouse in province: Shipping	Total
				US$			
IN-1				Urea			
Valparaiso	38,800	2,793,600	3,105,164	386,836	3,492,000	172,267	3,664,267
Talcahuano	43,200	3,110,400	3,457,296	430,704	3,888,000	185,016	4,073,016
Puerto Montt	7,000	504,000	560,210	69,790	630,000	34,919	664,919
Total	89,000	6,408,000	7,122,670	887,330	8,010,000	392,202	8,402,202
				Calcium Ammonium Nitrate			
Valparaiso	2,600	54,600	75,478	25,922	101,400	10,919	112,319
Talcahuano	3,850	80,850	111,766	38,384	150,150	16,924	167,074
Puerto Montt	550	11,550	15,966	5,484	21,450	2,194	23,644
Total	7,000	147,000	203,210	69,790	273,000	30,037	303,037
				Total (IN 1)			
Valparaiso	41,400	2,848,200	3,180,642	412,758	3,593,400	183,186	3,776,586
Talcahuano	47,050	3,191,250	3,569,062	469,088	4,038,150	201,940	4,240,090
Puerto Montt	7,550	515,550	576,176	75,274	651,450	37,113	688,563
Total	96,000	6,555,000	7,325,880	957,120	8,283,000	422,239	8,705,239
Per mt N	–	158 14	176.74	23 09	199 83	10.18	210.01
IN-2				Urea			
Valparaiso	38,800	1,656,760	1,968,324	386,836	2,355,160	172,267	2,527,427
Talcahuano	43,200	1,844,640	2,191,536	430,704	2,622,240	185,016	2,807,256
Puerto Montt	7,000	298,900	355,110	69,790	424,900	34,919	459,819
Total	89,000	3,800,300	4,514,970	887,330	5,402,300	392,202	5,794,502
				Calcium Ammonium Nitrate			
Valparaiso	2,600	54,600	75,478	25,922	101,400	10.919	112,319
Talcahuano	3,850	80,850	111,766	38,384	150,150	16,924	167,074
Puerto Montt	550	11,550	15,966	5,484	21,450	2,194	23,644
Total	7,000	147,000	203,210	69,790	273,000	30,037	303,037
				Total (IN 2)			
Valparaiso	41,400	1,711,360	2,043,802	412,758	2,456,560	183,186	2,639,746
Talcahuano	47,050	1,925,490	2,303,302	469,088	2,772,390	201,940	2,974,330
Puerto Montt	7,550	310,450	371,076	75,274	446,350	37,113	483,463
Total	96,000	3,947,300	4,718,180	957,120	5,675,300	422,239	6,097,539
Per mt N	–	95 23	113 83	23 09	136 92	10.18	147 10
IN-3				Urea			
Valparaiso	38,800	2,684,184	2,995,748	386,836	3,382,584	172,267	3,554,851
Talcahuano	43,200	2,988,576	3,335,472	430,704	3,766,176	185,016	3,951,192
Puerto Montt	7,000	484,260	540,470	69,790	610,260	34,919	645,179
Total	89,000	6,157,020	6,871,690	887,330	7,759,020	392,202	8,151,222
				Calcium Ammonium Nitrate			
Valparaiso	2,600	54,600	75,478	25,922	101,400	10,919	112,319
Talcahuano	3,850	80,850	111,766	38,384	150,150	16,924	167,074
Puerto Montt	550	11,550	15,966	5,484	21,450	2,194	23,644
Total	7,000	147,000	203,210	69,790	273,000	30,037	303,037
				Total (IN-3)			
Valparaiso	41,400	2,738,784	3,071,226	412,758	3,483,984	183,186	3,667,170
Talcahuano	47,050	3,069,426	3,447,238	469,088	3,916,326	201,940	4,118,266
Puerto Montt	7,550	495,810	556,436	75,274	631,710	37,113	668,823
Total	96,000	6,304,020	7,074,900	957,120	8,032,020	422,239	8,454,259
Per mt N	–	152.08	170.68	23 09	193 77	10.18	203.95
IN-4				Urea			
Valparaiso	39,957	2,876,904	3,197,759	398,371	3,596,130	177,114	3,773,244
Talcahuano	44,915	3,233,880	3,594,547	447,803	4,042,350	192,552	4,234,902
Puerto Montt	7,244	521,568	579,737	72,223	651,960	35,892	687,852
Total	92,116	6,632,352	7,372,043	918,397	8,290,440	405,558	8,695,998
Per mt N	–	160 01	177 85	22.16	200 01	9.79	209.79

[a]All costs are expressed in US$ equivalents. The quantities of materials and cost are for the amount of nitrogen that must be supplied from imports. Nitrogen supplied from nitrates and guano produced in Chile are omitted from this study.

[b]Includes f.o.b. cost of materials, 50% of the ocean freight, and cost of jute bags.

[c]Includes costs of unloading, transfers from dock to storage, to bagging facilities, to rail cars, polyethylene liners, storage at ports, and 50% of ocean freight cost.

[d]Includes all cost f.o.b. rail cars at ports.

Table 20. Cost of Importing and Distributing Phosphate Fertilizers in Chile for Alternative Materials and Prices, 1975[a]

Ports	Metric Tons	Import, Handling, & Bagging Cost at Port: F.o.b. Cost	Foreign Exchange[b]	Chilean Currency[c]	Total at Port[d]	Cost at warehouse in province: Shipping	Total
					US$		
IP-1				TSP			
Valparaiso	54,900	3,184,200	3,625,047	547,353	4,172,400	276,401	4,448,801
Talcahuano	79,300	4,599,400	5,236,179	790,621	6,026,800	421,607	6,448,407
Puerto Montt	86,850	5,037,300	5,734,706	865,894	6,600,600	308,726	6,909,326
Total	221,050	12,820,900	14,595,932	2,203,868	16,799,800	1,006,734	17,806,534
				BIFOS			
Valparaiso	3,650	215,751	245,572	42,778	288,350	19,323	307,673
Talcahuano	6,700	396,037	450,776	78,524	529,300	30,837	560,137
Puerto Montt	4,650	274,862	312,852	54,498	367,350	14,082	381,432
Total	15,000	886,650	1,009,200	175,800	1,185,000	64,242	1,249,242
				Total (IP 1)			
Valparaiso	58,550	3,399,951	3,870,619	590,131	4,460,750	295,724	4,756,474
Talcahuano	86,000	4,995,437	5,686,955	869,145	6,556,100	452,444	7,008,544
Puerto Montt	91,500	5,312,162	6,047,558	920,392	6,967,950	322,808	7,290,758
Total	236,050	13,707,550	15,605,132	2,379,668	17,984,800	1,070,976	19,055,776
Per mt P_2O_5	–	127.47	145 11	22 13	167 24	9 96	177 20
IP-2				TSP			
Valparaiso	54,900	1,962,675	2,403,522	547,353	2,950,875	276,401	3,227,276
Talcahuano	79,300	2,834,975	3,471,754	790,621	4,262,375	421,607	4,683,982
Puerto Montt	86,850	3,104,888	3,802,193	865,894	4,668,187	308,726	4,976,913
Total	221,050	7,902,538	9,677,569	2,203,868	11,881,437	1,006,734	12,888,171
				BIFOS[e]			
Valparaiso	3,650	215,751	245,572	42,778	288,350	19,323	307,673
Talcahuano	6,700	396,037	450,776	78,524	529,300	30,837	560,137
Puerto Montt	4,650	274,862	312,852	54,498	367,350	14,082	381,432
Total	15,000	886,650	1,009,200	175,800	1,185,000	64,242	1,249,242
				Total (IP 2)			
Valparaiso	58,550	2,178,426	2,649,094	590,131	3,239,225	295,724	3,534,949
Talcahuano	86,000	3,231,012	3,922,530	869,145	4,791,675	452,444	5,244,119
Puerto Montt	91,500	3,379,750	4,115,145	920,392	5,035,537	322,808	5,358,345
Total	236,050	8,789,188	10,686,769	2,379,668	13,066,437	1,070,976	14,137,413
Per mt P_2O_5	–	81 73	99.37	22 13	121 50	9 96	131 46
IP-3				TSP			
Valparaiso	54,900	3,431,250	3,872,097	547,353	4,419,450	276,401	4,695,851
Talcahuano	79,300	4,956,250	5,593,029	790,621	6,383,650	421,607	6,805,257
Puerto Montt	86,850	5,428,125	6,125,531	865,894	6,991,425	308,726	7,300,151
Total	221,050	13,815,625	15,590,657	2,203,868	17,794,525	1,006,734	18,801,259
				BIFOS[e]			
Valparaiso	3,650	215,751	245,572	42,778	288,350	19,323	307,673
Talcahuano	6,700	396,037	450,776	78,524	529,300	30,837	560,137
Puerto Montt	4,650	274,862	312,852	54,498	367,350	14,082	381,432
Total	15,000	886,650	1,009,200	175,800	1,185,000	64,242	1,249,242
				Total (IP 3)			
Valparaiso	58,550	3,647,001	4,117,669	590,131	4,707,800	295,724	5,003,524
Talcahuano	86,000	5,252,287	6,043,805	869,145	6,912,950	452,444	7,365,394
Puerto Montt	91,500	5,702,987	6,438,383	920,392	7,358,775	322,808	7,681,583
Total	236,050	14,602,275	16,599,857	2,379,668	18,979,525	1,070,976	20,050,501
Per mt P_2O_5	–	135.79	154.36	22 13	176.49	9 96	186.45
IP-4				TSP			
Valparaiso	57,994	3,363,652	3,829,344	578,200	4,407,544	292,781	4,700,325
Talcahuano	84,979	4,928,782	5,611,163	847,241	6,458,404	447,741	6,906,145
Puerto Montt	90,792	5,265,936	5,994,956	905,196	6,900,152	320,666	7,220,858
Total	233,765	13,558,370	15,435,463	2,330,637	17,766,100	1,061,188	18,827,328
Per mt P_2O_5	–	126 08	143 53	21 67	165 20	9 87	175.07

[a]All costs are expressed in US$ equivalents. The quantities of materials and import costs are for the quantity of P_2O_5 required in excess of the 50,000 units of P_2O_5 that may be supplied from the present facility at Penco and that supplied in guano.

[b]Includes f.o.b. cost of materials, 50% of the ocean freight, and cost of jute bags.

[c]Includes costs of unloading, transfers from dock to storage, to bagging facility, to rail cars, polyethylene liners, storage at port, and 50% of ocean freight cost.

[d]Includes all costs f.o.b. rail cars at ports.

[e]Bifos is imported from Germany in bags. Ocean freight cost was estimated at $16 34 from Germany to Chilean ports. It was assumed that 50% moved in Chilean flag ships. Costs of transferring Bifos from ship to rail car was estimated at $3.55.

Table 21. Cost of Importing and Distributing Potassium Fertilizers in Chile for Alternative Materials and Prices, 1975[a]

Ports	Metric tons	Import, Handling & Bagging Cost at Port: F.o.b. Cost	Foreign Exchange[b]	Chilean Currency[c]	Total at Port[d]	Cost at Warehouse in Province: Shipping	Total
				US$			
IK-1				Potassium Sulfate			
Talcahuano	31,500	2,047,500	2,300,445	314,055	2,614,500	129,500	2,744,000
Puerto Montt	24,200	1,573,000	1,767,326	241,274	2,008,600	95,310	2,103,910
Total	55,700	3,620,500	4,067,771	555,329	4,623,100	224,810	4,847,910
				K and Mg Sulfate			
Talcahuano	20,800	561,600	728,624	207,376	936,000	86,327	1,022,327
Puerto Montt	16,000	432,000	560,480	159,520	720,000	63,358	783,358
Total	36,800	993,600	1,289,104	366,896	1,656,000	149,685	1,805,685
				Total (IK-1)			
Talcahuano	52,300	2,609,100	3,029,069	521,431	3,550,500	215,827	3,766,327
Puerto Montt	40,200	2,005,000	2,327,806	400,794	2,728,600	158,668	2,887,268
Total	92,500	4,614,100	5,356,875	922,225	6,279,100	374,495	6,653,595
Per mt K_2O	–	121.62	141.20	24.31	165.51	9.87	175 38
IK-2				Potassium Sulfate			
Talcahuano	31,500	1,497,825	1,750,770	314,055	2,064,825	129,500	2,194,325
Puerto Montt	24,200	1,150,710	1,345,036	241,274	1,586,310	95,310	1,681,620
Total	55,700	2,648,535	3,095,806	555,329	3,651,135	224,810	3,875,945
				K and Mg Sulfate			
Talcahuano	20,800	705,328	872,352	207,376	1,079,728	86,327	1,166,055
Puerto Montt	16,000	542,560	671,040	159,520	830,560	63,358	893,918
Total	36,800	1,247,888	1,543,392	366,896	1,910,288	149,685	2,059,973
				Total (IK-2)			
Talcahuano	52,300	2,203,153	2,623,122	521,431	3,144,553	215,827	3,360,380
Puerto Montt	40,200	1,693,270	2,016,076	400,794	2,416,870	158,668	2,575,538
Total	92,500	3,896,423	4,639,198	922,225	5,561,423	374,495	5,935,918
Per mt K_2O	–	102 70	122 28	24.31	146 59	9 87	156.46
IK-3				Potassium Sulfate			
Talcahuano	31,500	1,082,970	1,335,915	314,055	1,649,970	129,500	1,779,470
Puerto Montt	24,200	831,996	1,026,322	241,274	1,267,596	95,310	1,362,906
Total	55,700	1,914,966	2,362,237	555,329	2,917,566	224,810	3,142,376
				K and Mg Sulfate			
Talcahuano	20,800	705,328	872,352	207,376	1,079,728	86,327	1,166,055
Puerto Montt	16,000	542,560	671,040	159,520	830,560	63,358	893,918
Total	36,800	1,247,888	1,543,392	366,896	1,910,288	149,685	2,059,973
				Total (IK-3)			
Talcahuano	52,300	1,788,298	2,208,267	521,431	2,729,698	215,827	2,945,525
Puerto Montt	40,200	1,374,556	1,697,362	400,794	2,097,856	158,668	2,256,824
Total	92,500	3,162,854	3,905,629	922,225	4,827,854	374,495	5,202,349
Per mt K_2O	–	83 37	102.94	24 31	127.25	9 87	137.12
IK-4				Potassium Sulfate			
Talcahuano	42,104	2,736,760	3,074,855	419,777	3,494,632	173,509	3,668,141
Puerto Montt	32,358	2,103,270	2,363,105	322,609	2,685,714	127,616	2,813,330
Total	74,462	4,840,030	5,437,960	742,386	6,180,346	301,125	6,481,471
Per mt K_2O	–	127 57	143.33	19.57	162.90	7.94	170 84
IK-5				Potassium Chloride			
Talcahuano	35,789	894,725	1,182,111	356,816	1,538,927	147,486	1,686,413
Puerto Montt	27,503	687,575	908,424	274,205	1,182,629	108,464	1,291,093
Total	63,292	1,582,300	2,090,535	631,021	2,721,556	255,950	2,977,506
Per mt K_2O	–	41.71	55 10	16.63	71.73	6.75	78.48

[a]All costs are expressed in US$ equivalents The quantities of materials and import costs are for the quantity of K_2O that must be imported in addition to the K_2O supplied in potassium nitrate and guano The K_2O requirements in all provinces north of Nuble are supplied from domestic production Thus all imports are received through the ports at Talcahuano and Puerto Montt

[b]Includes f o b cost of materials, 50% of the ocean freight and costs of jute bags

[c]Includes costs of unloading transfers from dock to storage, to bagging facility, to rail cars, polyethylene liners, storage at dock, and 50% of ocean freight costs.

[d]Includes all costs f o b rail cars at ports

Table 22. Cost of Importing and Distributing Mixed Fertilizers, Diammonium Phosphate, in Chile, 1975[a]

Ports	Metric tons	Import, Handling & Bagging Cost at Port: F.o.b.	Foreign Exchange[b]	Chilean Currency[c]	Total at Port[d]	Cost at Warehouse in Province: Shipping	Total
				US$			
IM-1				DAP			
Valparaiso	57,089	4,338,764	4,797,189	569,177	5,366,366	287,515	5,653,881
Talcahuano	90,359	6,867,284	7,592,867	900,879	8,493,746	378,458	8,872,204
Puerto Montt	86,421	6,567,996	7,261,95[illegible]	861,617	8,123,574	302,447	8,426,021
Total	233,869	17,774,044	19,652,013	2,331,673	21,983,686	968,420	22,952,106
				Urea[e]			
Valparaiso	19,884	1,431,648	1,591,317	198,243	1,789,560	90,530	1,880,090
Talcahuano	10,984	790,848	879,050	109,510	988,560	43,160	1,031,720
Puerto Montt	11	792	880	110	990	102	1,092
Total	30,879	2,223,288	2,471,247	307,863	2,779,110	133,792	2,912,902
				Total (IM-1)			
Valparaiso	76,973	5,770,412	6,388,506	767,420	7,155,926	378,045	7,533,971
Talcahuano	101,343	7,658,132	8,471,917	1,010,389	9,482,306	421,618	9,903,924
Puerto Montt	86,432	6,568,788	7,262,837	861,727	8,124,564	302,549	8,427,113
Total	264,748	19,997,322	22,123,260	2,639,536	24,762,796	1,102,212	25,865,008
Per mt N-P	–	134.24	148.50	17 72	166 21	7 40	173 61
IM-2				DAP			
Valparaiso	50,097	3,807,372	4,209,651	499,467	4,709,118	216,182	4,925,300
Talcahuano	36,656	2,785,856	3,080,204	365,460	3,445,664	195,531	3,641,195
Puerto Montt	18,002	1,368,152	1,512,708	179,480	1,692,188	88,710	1,780,898
Total	104,755	7,961,380	8,802,563	1,044,407	9,846,970	500,423	10,347,393
				TSP			
Valparaiso	7,900	458,200	521,637	78,763	600,400	76,614	677,014
Talcahuano	48,324	2,802,792	3,190,834	481,790	3,672,624	252,216	3,924,840
Puerto Montt	72,791	4,221,878	4,806,390	725,727	5,532,117	231,958	5,764,075
Total	129,015	7,482,870	8,518,861	1,286,280	9,805,141	560,788	10,365,929
				Urea			
Valparaiso	19,920	1,434,240	1,594,198	198,602	1,792,800	90,646	1,883,446
Talcahuano	30,255	2,178,360	2,421,308	301,642	2,722,950	114,355	2,837,305
Puerto Montt	45	3,240	3,601	449	4,050	419	4,469
Total	50,220	3,615,840	4,019,107	500,693	4,519,800	205,420	4,725,220
				Total (IM-2)			
Valparaiso	77,917	5,699,812	6,325,486	776,832	7,102,318	383,442	7,485,760
Talcahuano	115,235	7,767,008	8,692,346	1,148,893	9,841,238	562,102	10,403,340
Puerto Montt	90,838	5,593,270	6,322,699	905,655	7,228,355	321,087	7,549,442
Total	283,990	19,060,090	21,340,531	2,831,380	24,171,911	1,266,631	25,438,542
Per mt N-P	–	127.94	143.24	19 01	162.25	8.50	170 75

[a]All costs are expressed in US$ equivalents. In M-1 the quantities and costs of DAP are for the amount required to supply the P_2O_5 required in excess of the 50,000 units produced at Penco and that supplied from guano. Urea supplies the N requirement in each province not supplied from nitrates and guano produced in Chile or from DAP. DAP is assumed to be an 18-46-0 grade material. In M-2, the use of DAP is restricted to the amount that supplies the N or P_2O_5 requirement, whichever is supplied first. Urea and TSP is used to supply the remainder of the N or P_2O_5 respectively.

[b]Includes f.o.b. cost of materials, 50% of ocean freight, and cost of jute bags.

[c]Includes cost of unloading, transfers from dock to storage, to bagging facility, to rail cars, polyethylene liners, storage at dock, and 50% of ocean freight.

[d]Includes all costs f.o.b. rail cars.

[e]Urea is the amount required to satisfy the N requirement in each province that is not supplied by DAP.

SECTION VII

A COMPARISON OF THE COSTS OF VARIOUS ALTERNATIVES

On comparing the various alternative systems for supplying Chile's fertilizer needs, both total costs and foreign exchange costs should be evaluated. Capital investment costs, production costs, importation costs, and handling, bagging, and domestic transportation costs must all be considered in evaluations of the merits of the various alternative supply possibilities. For importation, the feasibility of bringing in either raw materials, intermediate products, or finished products should be studied.

NITROGEN SUPPLY

The various systems considered feasible for nitrogen supply were production of urea, ammonium nitrate, ammonium sulfate, and mixed fertilizers. To be economical, the urea must be produced in conjunction with ammonia production so that byproduct CO_2 from the ammonia plant can be utilized. Ammonium nitrate, ammonium sulfate, and mixed fertilizers can be produced from either imported ammonia or from ammonia produced in Chile. Either single nutrient fertilizers or mixed fertilizers can be imported. The most economical materials for importation are urea and DAP (18-46-0 grade). The most economical nitrogen material for importation was urea as shown in the previous section.

Nitrogen Fertilizer Market

The estimated nitrogen fertilizer market for Chile can be as small as the demands for Chile in excess of that which can be supplied by Chilean nitrates, it can be enlarged to include the Andean countries, or, it can be further enlarged to include a portion of the world market. It is impossible to estimate how much, if any, of the world market Chile might capture. Estimates of the potential market in Chile and in the other Andean countries in 1975 are given below.

	Tons/yr of Solid N Fertilizers in 1975
Chile	40,000
Peru	70,000
Ecuador	37,000
Total	147,000

The total market potential for N fertilizers is estimated as 40,000 tons/yr for Chile and about 150,000 tons/yr from the three Andean countries above what is expected to be supplied from existing sources (see next section). (Colombia and Bolivia are not expected to have any market for N fertilizers above what they plan to produce.) This assumes that the small and relatively uneconomical production facilities in Peru will not be operated. There is an additional industrial market in Chile for nitrogen that is estimated at about 16,000 tons/yr (8,000 as ammonia and 8,000 as ammonium nitrate explosives). Thus, Andean market might support as much as a 163,000 ton/yr nitrogen plant—of which 147,000 tons/yr would be as fertilizer. The possible market in Chile and Peru only is estimated as about 126,000 tons/yr of N with 110,000 as fertilizer.

Ammonia Supply

For this study, the following ammonia supply systems were considered: (1) importation, (2) production at 54,000 tons/yr of N (just to supply Chile's needs), (3) production at 163,000 tons/yr of N (to supply Chile's needs plus the Andean market), and (4) production of 270,000 tons/yr of N (the plant size Petroquimica has announced plans to build, primarily to sell nitrogen fertilizers into the world market). Costs for these four situations are tabulated below:

	Cost, $/mt NH_3	
Domestic Production of Ammonia	F.o.b. Plant at Punta Arenas	In Storage at Penco
54,000 tons/yr of N	66.66	76.66
163,000 tons/yr of N	39.33	49.33
270,000 tons/yr of N	35.69	45.69
Imported Ammonia[a]	–	49.55

[a]This is based on $34/ton cost for ammonia f.o.b. Trinidad.

The estimated costs of ammonia in storage at Penco are significantly lower (by about $27/ton) for imported ammonia than for domestic production at the 54,000 tons/yr rate. For the 163,000 tons/yr rate total costs are about the same for importation and domestic production. However, foreign exchange costs would be much lower (by about $38/ton) for domestic production. Production of ammonia in Chile at the world-market-oriented rate of 270,000 tons/yr of N would lower the ammonia cost by nearly $4/ton as compared with the 163,000 tons/yr rate. However, if the large plant were built and only operated at about the 163,000 tons/yr rate (about 60% of capacity), then the ammonia cost (f.o.b. plant) would increase to about $52, or $13/ton more than in the 163,000 tons/yr

plant. The 270,000 tons/yr plant would have to operate at about a 225,000 tons/yr (84% of capacity) to produce ammonia at the same cost as the 163,000 tons/yr plant operating at 100% capacity.

Looking only at ammonia production, it is economical for Chile to produce at about the rate that would supply the needs of Chile, Ecuador, and Peru in 1975 above existing sources Ammonia can be imported at lower cost than it can be produced at a rate for the Chilean market only. If a plant of 270,000 tons/yr capacity were built in Chile and its only market is the Andean market, or its equivalent, then ammonia costs will be much higher than for a smaller size plant designed to supply the Chilean and Andean market only.

Urea Supply

Three costs of production in three sizes of urea plants were considered. These sizes were 42,000 tons/yr of N (for the residual Chilean market in 1975), 89,000 tons/yr of N (for the residual Chilean market plus a portion of the Andean market), and 134,000 tons/yr of N (about the size of urea plant that Petroquimica has announced plans to build). Ammonia production prices appropriate for the three alternatives were utilized Resulting costs for urea production are tabulated below:

			Urea Cost, $/Ton Bulk		
				Landed at Penco	
Source of Urea	Urea production rate; 1,000 tons N/year	Ammonia cost $/ton	Total f.o.b. plant	Total	Foreign Exchange
Production at Punta Arenas	42	66.66	81.16	85.86	13.04
Production at Punta Arenas	89	39.33	54.72	59.42	8.53
Production at Punta Arenas	134	32.54	46.65	51.35	7.29
Importation (at estimated 1975 cost)	–	–	–	82	76

With production of urea in ammonia and urea plants sized to supply the marginal market for N fertilizer in 1975 (about 42,000 tons/yr), urea can be landed at Penco for about $85/ton, which is only slightly higher than the projected estimated 1975 import price for urea of $82/ton. However, foreign exchange costs are estimated at only about $13/ton for urea production in Chile as compared to $76/ton for importation -quite a significant difference.

For either of the two larger plants, total urea costs and foreign exchange costs are significantly lower for domestic production than for importation. However, if urea is produced in the largest plant, but operated below capacity, costs increase rapidly. For example, if urea were produced in a plant with 89,000 tons/yr capacity, operated at a 42,000 tons/yr rate, with ammonia at $39/ton, cost of urea production would increase to about $78/ton. If ammonia cost is increased to $50/ton, the f.o.b. cost of production of urea at the 42,000 tons/yr rate increases to $86/ton as shown below.

Cost of Ammonia, $/Ton	F.o b Plant Cost of Urea $/Ton in 89,000 tons/yr Plant Operated at	
	100% capacity	47% capacity (42,000 tons/yr)
39	55	78
50	62	86

Ammonium Nitrate and Ammonium Sulfate Supply

Other nitrogen fertilizers considered appropriate for Chilean agriculture are ammonium nitrate and ammonium sulfate. Production of these materials was based on imported ammonia at $34/ton, f o b Trinidad (about $50/ton in terminal storage at Chilean ports) As discussed above, this is also about the cost of producing ammonia in a 163,000 ton/yr plant (600 tons/day) at Punta Arenas and delivering the ammonia into terminal storage at Penco Two locations were considered to be appropriate for ammonium nitrate production Penco and Puerto Montt The only appropriate location for an ammonium sulfate plant was Rancagua (at the source of sulfuric acid) For comparison with costs of ammonium sulfate production, cost of producing ammonium nitrate at Rancagua was also calculated Since SQM is considering building a plant to produce ammonium nitrate from sodium nitrate at Victoria by an ion-exchange process, production costs for this plant were estimated.

Appropriate sizes for ammonium nitrate plants at Penco and Puerto Montt are about 50,000 tons/yr of N to supply Chile's fertilizer needs in 1975 and also to supply about 25,000 tons of ammonium nitrate for explosives. An ammonium nitrate plant of 42,000 tons of N/yr was estimated for Rancagua for comparison on the same production basis with ammonium sulfate. The plant capacity estimated for Victoria was 33,000 tons/yr of N–the size plant SQM is considering

Costs for production of bulk ammonium nitrate at either Penco or Puerto Montt are estimated to be about $62/ton of product or $147/ton of N. Increasing the sizes of the ammonium nitrate plant from 50,000 tons/yr of N to 70,000 tons/yr decreased production costs by about $7/ton of N. Ammonium sulfate production cost at Rancagua is about $40/ton of product or $163/ton of N. Ammonium

Adequate quantities of bagged fertilizer are generally available in major farming areas.

nitrate can be produced at Rancagua at about the same cost of N/unit as ammonium sulfate. Foreign exchange costs are about the same per ton of N for production of ammonium nitrate and ammonium sulfate.

Production costs for ammonium nitrate at Victoria by the ion-exchange process are impossible to estimate with any degree of accuracy because they depend on the values assigned to the feed sodium nitrate and the byproduct sodium carbonate. Also, the plant investment cost is uncertain at this stage. With sodium nitrate at $30/ton and no credit for byproduct sodium carbonate, production cost should be around $110/ton of ammonium nitrate. With sodium carbonate credited at about the estimated maximum possible value of $60/ton, cost of ammonium nitrate production decreases to about $75/ton. Actual production costs will likely be somewhere between $110 and $75/ton.

COMPARISON OF NITROGEN SUPPLY SYSTEMS

Total system costs—including costs of production or importation, bagging, handling, and transporting for some nitrogen fertilizers are given in table 23. All products were assumed to be bagged at either Chilean plants or ports, although in actual practice there may be some bulk handling within the country. It was assumed that urea would be transported in bulk from Punta Arenas and then bagged at the port of entry. Imported urea was assumed to be bagged at the port of entry. The ammonium nitrate and ammonium sulfate were assumed to be bagged at the production plant. Each system is based on supplying about 40,000 tons of N. The Kearney estimate of requirements by province was followed as closely as possible.

For N supply system N-1, which is production of ammonia and urea in a plant size to supply the Andean market, total cost is about $6.3 million, of which $1.2 million is foreign exchange. Total and foreign exchange costs of N/ton were $152 and $27.9, respectively. This assumes that plants operate at full capacity. If output drops below capacity, costs will increase rapidly.

The total cost for N supply system N-2 (ammonia and urea produced in plants sized to supply the Chilean market only) is $8.7 million, including $1.5 million in foreign exchange. Total cost of N/ton is $210, of which foreign exchange is $36.7 (with no R.O.I., total cost of N/ton is $183).

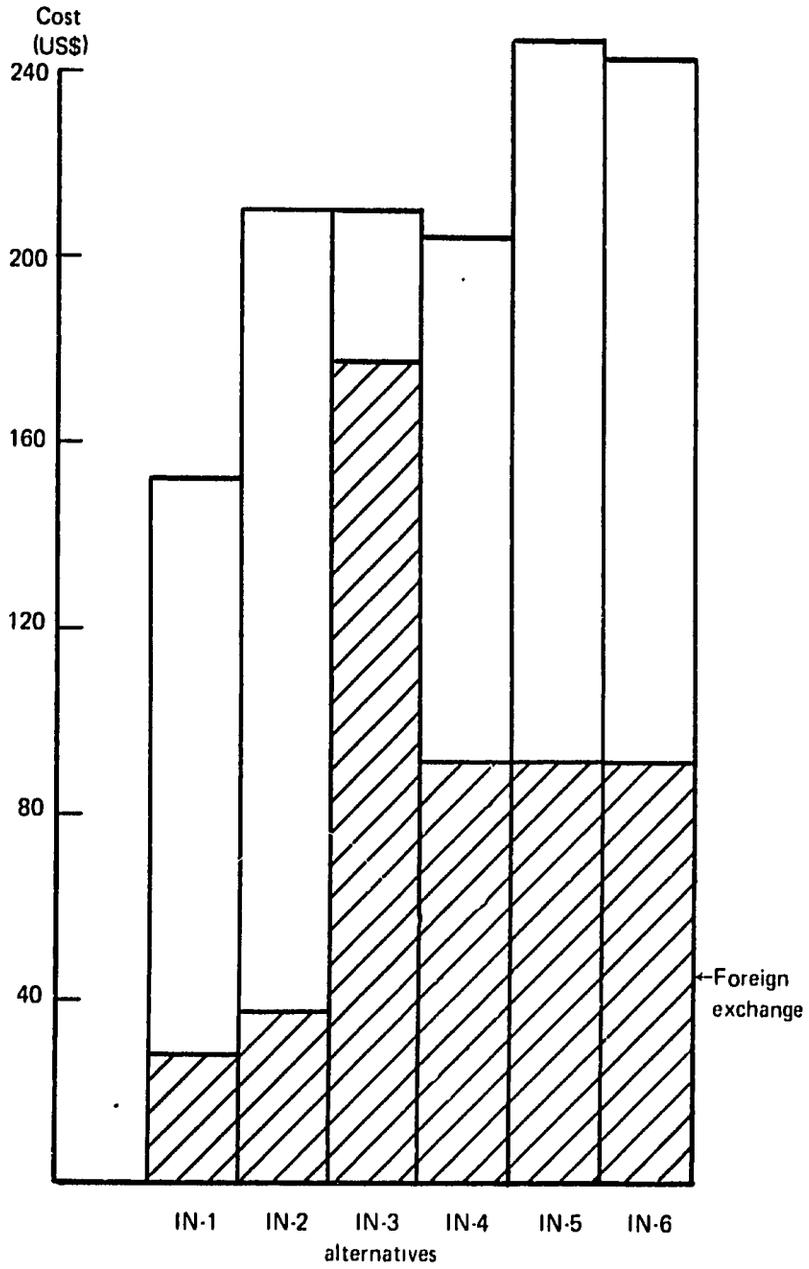
System N-3 is imported urea, which was summarized earlier. Total cost was $8.7 million—practically the same as for N-2—of which $7.4 million was foreign exchange. Total and foreign exchange costs of N/ton were $210 and $178, respectively.

Systems N-4 and N-5 were production of ammonium nitrate in plants of the same size at two port locations (Penco and Puerto Montt) with imported ammonia. Production costs were estimated to be about the same for either location. Due to higher costs of distribution, the total systems cost was $10.2 million for the plant located at Puerto Montt (system N-5) as compared with $9.4 million for the plant at Penco (system N-4). Total costs of N/ton were $228 for Penco and $245 for Puerto Montt.

System N-6 is for ammonium sulfate production at Rancagua. Total and foreign exchange costs were respectively $10.0 million and $3.8 million. Total systems cost of N/ton were $242. (See figure 39).

The lowest cost system is production of ammonia and urea in Chile in a plant size to supply the estimated Andean market. However, if production of ammonia and urea in these plants drops below about 50% of capacity, then supply costs will exceed costs for production of ammonia and urea in a smaller plant sized to supply the Chilean market only (system N-2).

Figure 39. Estimated Total Costs and Foreign Exchange Requirements Per Tons of N for Alternative Methods of Supplying 41,500 Tons/Year of N–1975[a]



[a]N-1 Urea produced at Punta Arenas in 98,000 mt of N per year plant.
N-2 Urea produced at Punta Arenas in 42,000 mt of N per year plant.
N-3 Imported urea.
N-4 Ammonium nitrate produced in 50,000 mt of N per year plant at Penco
N-5 Ammonium nitrate produced in 50,000 mt of N per year plant at Puerto Montt.
N-6 Ammonium sulfate produced in 42,000 mt of N per year plant at Rancagua.

Table 23. Cost of Supplying Nitrogen Fertilizers to Chile in 1975 by Alternative Systems

Nitrogen Supply System No.	Product	Source	Cost of Bulk[a] Material, $/Ton: Ton	Cost of Bulk[a] Material, $/Ton: Foreign Exchange	Material Quantity, Tons: Total	Material Quantity, Tons: Nitrogen	Cost of All Material[a] in Bulk, $ (1,000): Total	Cost of All Material[a] in Bulk, $ (1,000): Foreign Exchange	Cost of Bags, Bagging,[b] Handling & Transport, $: Per Ton: Total	Per Ton: F. E.	All Material (1,000): Total	All Material (1,000): F. E.	Supply System, $: Per Ton: Total	Per Ton: F. E.	All Material (1,000): Total	All Material (1,000): F. E.	Per Ton of N: Foreign Exchange	Per Ton of N: Total
N–1	Urea	Produced at Punta Arenas in 98,000 ton N/yr urea plant (NH cost = 39.33/ton	55	9	92,116	41,451	5,066	829	13.44	3.53	1,238	325	68.44	12.53	6,304	1,154	27.85	152.09
N–2	Urea	Produced at Punta Arenas in 42,000 ton N/yr urea plant (NH cost = 66.66/ton	81	13	92,116	41,451	7,461	1,198	13.44	3.53	1,238	325	94.44	16.53	8,699	1,523	36.73	209.87
N–3	Urea	Imported	72	72	92,116	41,451	6,632	6,632	22.28	8.03	2,052	740	94.28	80.03	8,684	7,372	177.85	209.79
N–4	Ammonium Nitrate	Produced at Penco in 50,000 ton N/yr plant	62	27	123,735	41,451	7,672	3,341	14.27	3.53	1,765	437	76.27	30.53	9,437	3,778	91.13	227.66
N–5	Ammonium Nitrate	Produced at Puerto Montt in 50,000 ton N/yr plant	62	27	123,735	41,451	7,672	3,341	20.09	3.53	2,486	437	82.09	30.53	10,157	3,778	91.13	245.04
N–6	Ammonium Sulfate	Produced at Rancagua in 42,000 ton N/yr plant	40	16	192,626	41,451	7,705	3,082	12.17	3.53	2,344	680	52.17	19.53	10,049	3,762	90.76	242.42

[a]For imported material this is cost f.o.b. vessel, for all others cost is in bulk storage at production plant.
[b]For imported material it is assumed that one-half of total will be shipped in Chilean ships.

Total systems cost for imported urea (N-3) (with urea at estimated 1975 costs) were estimated to be about the same as for Chilean production in the smaller plant (system N-2). However, foreign exchange costs were much lower for Chilean production. The costs for Chilean production include a 10% R.O.I. At 0% R.O.I., systems costs for N-2 would be about $27/ton of N lower than for system N-3 (importation).

For costs of production and distribution of ammonium nitrate at Penco (N-4) to be equal to costs of production and distribution of urea in the smaller plant (N-2), ammonia price for ammonium nitrate production would have to decrease to $24/ton c.i.f. Penco. To decrease costs of ammonia sulfate supply (system N-6) to equivalent of costs for urea supply (system N-2), a c.i.f. ammonia price of $4/ton would be required. Of course, neither of these ammonia prices is realistic.

PHOSPHATE SUPPLY

The supply systems that were considered to be feasible were Chilean production of TSP, NSP, and mixed fertilizer (DAP, 18-46-0 grade). At CORFO's request, production of fused magnesium phosphate (0-22-0 grade) was also considered. Importation of TSP and DAP were evaluated. (Importation of either elemental phosphorus or wet-process phosphoric acid as intermediates was considered. Estimates indicated that phosphoric acid can be produced by the wet process in Chile at about the same total cost as for production of phosphoric acid from imported phosphorus or for importation of wet-process acid Foreign exchange costs were significantly lower for domestic production. Because of the need to utilize the byproduct acid from the El Teniente copper refinery and the resultant lower foreign exchange requirements, importation of either phosphoric acid or elemental phosphorus was not attractive.)

Phosphate Fertilizer Market

The total market for P_2O_5 in Chile for 1975 was estimated as 165,000 tons. With about 8,000 tons of P_2O_5 from guano and up to 50,000 tons of P_2O_5 available from the Penco plant, the additional market is about 107,000 tons/yr of P_2O_5. This tonnage is adequate to support an economical size phosphate plant. There should be an additional market for about 40,000 tons of P_2O_5 in the other Andean countries. Chile has adequate sulfuric acid capacity at Rancagua to supply this market. However, there would not be as much economic incentive as in nitrogen production because the Chilean market in itself can support an efficient plant.

Possible Plant Locations

For production of phosphate fertilizers it was considered to be desirable and feasible to utilize byproduct sulfuric acid at Rancagua which can be produced from waste SO_2 in stack gases at the El Teniente copper refinery Three plant sites were considered to be feasible - Rancagua (near the copper refinery) and the two nearby port locations of Penco and San Antonio. Location at the ports would require transport of sulfuric acid, but would save the cost of rock transport. Port location for plants may also have some advantages for utilizing water transportation of products—particularly if any products are sold into the Andean or world markets (This is discussed in more detail at another location in this section)

Valdivia was considered as the location of the fused magnesium phosphate plant at CORFO's request. Valdivia is a port location where imported phosphate rock can be received and it is also near a serpentine (magnesium silicate) mine.

Supply of Triple Superphosphate

For production of TSP at Rancagua with phosphate at $20/ton, product cost is about $75/ton Whether or not it is more economical to produce TSP at San Antonio or Penco rather than Rancagua depends primarily on the relative cost of transport of the sulfuric acid and phosphate rock For TSP production, 1 52 tons of rock are required per ton of 93% sulfuric acid Rail transport cost of acid is estimated at $11.75/ton of 93% acid from Rancagua to Penco and transport and handling cost for rock at about $5/ton (The rock used at Rancagua would enter via San Antonio) Based on the higher acid transport cost, the production of TSP should be about $6 5/ton more at Penco, or about $81 5/ton of TSP. Production cost at San Antonio should be about the same as for Rancagua (In actual practice it is likely that freight costs for transporting rock from either Penco or San Antonio could be reduced significantly by hauling other commodities on the return trip. For example, product could be returned along the route from Rancagua to the port, or perhaps the cars hauling blister copper from Rancagua to San Antonio could be utilized to return rock This is discussed in more detail later. On the other hand, little if any use is seen for empty sulfuric acid cars returning from Penco or San Antonio.)

Supply of Normal Superphosphate

As in production of TSP, three locations were considered to be appropriate for NSP plants - Rancagua, San Antonio, and Penco. A detailed estimate indicated that the cost of production of NSP at Rancagua should be about $25/ton ($24.79). The variation in transport costs of

Table 24. Cost of Supplying Phosphate Fertilizers to Chile in 1975 by Alternative Systems

Phosphate Supply System Number	Product	Location of Production	Cost of Bulk[a] Material, $/Ton		Material Quantity, Tons		Cost of All Material in Bulk, $		Cost of Bags, Bagging, Handling and Transport[b], $				Cost of Supply System, $					
									Per Ton		All Material		Per Ton		All Material		Per Ton of P_2O_5	
			Total	Foreign Exchange	Total	P_2O_5	Total (1,000)	Foreign Exchange (1,000)	Total	Foreign Exchange	Total (1,000)	Foreign Exchange (1,000)	Total	F. E.	Total (1,000)	F. E. (1,000)	Total	F. E.
P-1	Triple Superphosphate	Rancagua	75	30	233,765	107,531	17,532	7,013	16.03	3.53	3,747	825	91.03	33.53	21,280	7,838	197.89	72.89
P-2	Triple Superphosphate	Penco	81.5	30	233,765	107,531	19,052	7,013	15.29	3.53	3,574	825	96.79	33.53	22,626	7,838	210.41	72.89
P-3	Triple Superphosphate	San Antonio	75	30	233,765	107,531	17,532	7,013	17.80	3.53	4,162	825	92.80	33.53	21,695	7,838	201.75	72.89
P-4	Triple Superphosphate	Imported	58	58	233,765	107,531	13,558	13,556	22.54	8.03	5,269	1,877	80.54	66.03	18,827	15,435	175.08	143.54
P-5	Normal Superphosphate	Rancagua	25	11	537,657	107,531	13,441	5,914	16.03	3.53	8,618	1,898	41.03	14.53	22,060	7,812	205.15	72.65
P-6	Normal Superphosphate	Penco	26.5	11	537,657	107,531	14,248	5,914	15.29	3.53	8,219	1,898	41.79	14.53	22,467	7,812	208.94	72.65
P-7	Normal Superphosphate	San Antonio	25	11	537,657	107,531	13,441	5,914	17.81	3.53	9,573	1,898	42.81	14.53	23,014	7,812	214.03	72.65
P-8	Normal ½	Rancagua	25	11	537,657	107,531	13,845	5,914	14.20	3.53	7,634	1,898	39.95	14.53	21,478	7,812	199.74	72.65
	Super ½	Penco	26.5	11														

[a]For imported material this is cost f.o.b. vessel; for all others cost is in bulk storage at production plant.
[b]For imported material it is assumed that one-half of total will be shipped in Chilean ships.

sulfuric acid and phosphate rock should increase product costs by about $1.50/ton at Penco. (The cost of production at San Antonio should be about the same as for Rancagua.) The possibility for backhauling other commodities including phosphate product in the rail cars would likely result in even more comparative economic advantage for production in the plant at Rancagua. (Since NSP production will require two production lines, the possibility of dual plant locations was also evaluated.)

Fused Magnesium Phosphate

The only location considered for production of this product was Valdivia - a port location near the serpentine mine. The plant size considered would produce 11,000 tons/yr the size that Carburo y Metalurgia S. A. tentatively plans to build. Production cost was estimated as $49.58/ton of product or $226/ton of nutrient.

COMPARISON OF PHOSPHATE SUPPLY SYSTEMS

Normal Superphosphate and Fused Magnesium Phosphate

The cost of supplying fused magnesium phosphate can be compared to the supply cost of NSP Both products have about the same nutrient content (about 20% P_2O_5) and both products have secondary and micronutrients that seem to be needed in some localities (Probably the most important additional nutrients these two fertilizers can supply are sulfur by NSP and magnesium by the fused magnesium phosphate) It is not practical to compare production costs for the two products at the same location and at identical production rates NSP should be produced near the sulfuric acid supply and fused magnesium phosphate should be produced near the source of serpentine Single furnaces for magnesium phosphate production cannot be built with product capacities as large as are possible and desirable for economical superphosphate production However, the cost comparison below indicates that NSP can be produced in Rancagua and shipped to Valdivia at about a 10% lower cost per nutrient unit ($2.27 vs $2.60) than for production of the magnesium phosphate in Valdivia.

Material	Cost, $/Ton Normal Superphosphate	Cost, $/Ton Magnesium Phosphate
Production cost, $/ton	24.79	49.58
Reclaiming from bulk storage	.60	.60
Bags and bagging	6.60	6.60
Loading bags on rail car	.60	.60
Shipment to Valdivia	12.75	–
Bagged product, f.o.b. rail car in Valdivia	45.34 (2.27/unit)	57.38 (2.60/unit)

TOTAL PHOSPHATE SUPPLY SYSTEMS COSTS

Total systems costs, including costs of production or importation, bagging, handling, and transportation for some phosphate fertilizers are given in table 24 All products were assumed to be bagged at plants or ports, although in actual practice there may be some bulk shipment and bulk handling within the country Each system is based on supply of 107,000 tons of P_2O_5 The pattern of nutrient requirement outlined in the Kearney proposal was followed closely

Systems P-1, P-2, and P-3 are for production of TSP at Rancagua, Penco, and San Antonio Foreign exchange costs are the same for all three systems System P-4 is for importation of TSP and is covered in more detail in section VI Cost results (top of p 87) show the lowest total cost by a small margin for importation, but foreign exchange costs are much higher Production at Rancagua gives the lowest systems cost of the three production plants (figure 40)

Systems P-5, P-6, P-7, and P-8 are for production of NSP at different locations Cost data summarized on p 86 show that the dual locations should be the best for NSP production, on the basis of lowest systems costs

Potassium Supply

Based on the Kearney projections there should be a market for 50,000 tons of K_2O in Chile in 1975, with 10,000 tons of K_2O to be derived from Chilean nitrates and 2,000 tons from guano Since there are no other K_2O sources in Chile, the additional market of 38,000 tons of K_2O must be supplied by importation Potassium chloride (60% K_2O) and potassium sulfate (52% K_2O) were considered feasible materials for importation Results from section VI (table 21) tabulated on p 87 show quite a significant economic advantage for potassium chloride

It may not be agronomically feasible to completely substitute KCl for K_2SO_4 However some substitution should be possible If only half of the K_2O as K_2SO_4 were replaced by KCl, then savings in total cost are estimated as about $1.75 million and foreign exchange savings as about $1.70 million in 1975.

Mixed Fertilizer Supply

There are several possibilities for supply of the additional nutrients needed in Chile in 1975 as mixed fertilizers Some of these possibilities are as follows: (1) production of DAP in Chile, (2) importation of DAP, (3)

Table 25. Cost of Supplying Mixed Fertilizer (18-46-0 Grade) to Chile in 1975 by Alternative Systems

Mixed Fert. Supply System No.	Product	Source	Cost of Bulk Material,[a] $/Ton Total	Cost of Bulk Material,[a] $/Ton Foreign Exchange	Material Quantity Tons Total	Material Quantity Tons N	Material Quantity Tons P_2O_5	Cost of All Material[a] in Bulk, $ Total	Cost of All Material[a] in Bulk, $ Foreign Exchange	Cost of Bags, Bagging Handling, and Transport[b], $ Per Ton Total	Per Ton Foreign Exchange	All Material Total	All Material Foreign Exchange	Cost of Supply System, $ Per Ton Total	Per Ton F.E.	All Material Total	All Material F.E.	Per Ton of Plant[d] Nutrients in 18-46-0 & TSP Total	Per Ton of Plant[d] Nutrients in 18-46-0 & TSP F.E.
M–1	18-46-0	Produced at[c] Rancagua	98	7171	233,869	42,000	107,531	22,919	16,605	15.33	3.53	3,586	826	113.33	74.53	26,505	17,430	196.21	129.03
M–2	18-46-0	Produced at[c] Penco	104	71	233,869	42,000	107,531	24,322	16,605	14.82	3.53	3,467	826	118.82	74.53	27,790	17,430	205.72	129.03
M–3	18-46-0	Produced at[c] San Antonio	98.5	71	233,869	42,000	107,531	23,036	16,605	17.18	3.53	4,018	826	115.68	74.53	27,054	17,430	200.27	129.03
M–4	18-46-0	Imported[c]	76	76	233,869	42,000	107,531	17,774	17,774	22.71	8.03	5,178	1,878	98.71	84.03	22,952	19,652	169.91	145.48
M–5	18-46-0	Rancagua	98	7171	104,755	18,860	48,187	10,626	7,438	12.25	3.53	1,284	370	110.25	74.53	11,550	7,807	172.26	116.45
	TSP	Rancagua	75	3030	129,015		59,346	9,676	3,870	19.10	3.53	2,464	455	94.10	33.53	12,140	4,326	204.56	72.89
	Total		85.31	48.37	233,770	18,860	107,531	19,942	11,308	16.03	3.53	3,748	825	101.34	51.90	23,690	12,133	187.43	96.00
M–6	18-46-0	Penco	104	71	104,755	18,860	48,187	10,895	7,438	15.32	3.53	1,605	370	119.32	74 53	12,499	7,807	186.43	116.45
	TSP	Penco	81.5	30	129,015		59,346	10,515	3,870	15.26	3.53	1,969	455	96.76	33.53	12,483	4,326	210.35	72.89
	Total		91.58	48.37	233,770	18,860	107,531	21,410	11,308	15.29	3.53	3,574	825	106.87	51.90	24,982	12,133	197.66	96.00
M–7	18-46-0	San Antonio	104	71	104,755	18,860	48,187	10,895	7,438	13.82	3.53	1,447	370	117.82	74.53	12,342	7,807	184.08	116.45
	TSP	San Antonio	75	30	129,015		59,346	9,676	3,870	21.04	3.53	2,715	455	96.04	33.53	12,391	4,326	208.79	72.89
	Total		88.0	48.35	233,770	18,860	107,531	20,571	11,308	17.80	3.53	4,162	825	105.80	51.90	24,733	12,133	195.69	96.00
M–8	18-46-0	Imported	76	76	104,755	18,860	48,187	7,961	7,961	22.78	8.03	2,386	841	98.78	84.03	10,347	8,803	154.33	131.29
	TSP		58	58	129,015		59,346	7,483	7,483	22.35	8.03	2,883	1,036	80.35	66.03	10,366	8,519	174,67	143.55
	Total		66.07	66.07	233,770	18,860	107,531	15,444	15,444	22.54	8.03	5,269	1,877	88.61	74.09	20,713	17,322	163.88	137.05

[a]For imported material this is cost f.o.b. vessel, for all others cost is in bulk storage at production plant.
[b]For imported material it is assumed that one-half of total will be shipped in Chilean ships
[c]Since requirements were larger than supplied by DAP in some areas, an additional 13,895 tons of N are needed to fulfill the total requirements in each province while approximately the same quantity was supplied over the requirement in other provinces.
[d]Where N was in excess of the requirement, the excess quantity was assigned a zero value

System	Option	Total Systems Costs, $/Ton P_2O_5 Total 0% R.O.I.	Total 10% R.O.I.	Foreign Exchange
P-1	Production at Rancagua	179	198	73
P-2	Production at Penco	191	210	73
P-3	Production at San Antonio	183	202	73
P-4	Importation (at estimated 1975 price)	175	–	143

System	Option	Total Systems Costs, $/Ton P_2O_5 Total 0% R.O.I.	Total 10% R.O.I.	Foreign Exchange
P-5	Production at Rancagua	196	205	73
P-6	Production at Penco	200	209	73
P-7	Production at San Antonio	205	214	73
P-8	Production of one half total at Rancagua and one half of total at Penco	191	200	73

System	Option	Systems Cost, $[a] Per Ton Material Total	Per Ton Material F.E.	Per Ton K_2O Total	Per Ton K_2O F.E.	All Material (1000) Total	All Material (1000) F.E.
K-1	Importation of KCl	47	33	78	55	2,980	2,100
K-2	Importation of K_2SO_4	89	74	171	143	6,481	5,510

[a]These costs are based on bulk importation with bagging at the Chilean port where the material was received. Prices are estimated 1975 prices.

production of ammoniated superphosphates in the COSAF plant at Penco, and (4) bulk blending single nutrient materials in smaller Chilean plants located near the market area. Total systems costs were estimated for importation of DAP and for production at Rancagua, Penco, and San Antonio.

Utilization of DAP to supply the additional 107,000 tons of P_2O_5 needed in 1975 will also provide 42,000 tons of N. This closely approximates the estimated 40,000 tons of additional N needed in 1975.[7]

A detailed estimate of the cost of production of DAP at Rancagua was prepared. Based on use of imported ammonia at a delivered cost to Rancagua of $62/ton ($34/ton f.o.b. Trinidad), cost of production of DAP was $98/ton, and foreign exchange was $71/ton. Production costs at Penco and San Antonio were estimated to be about $104 and $98.5/ton, respectively.

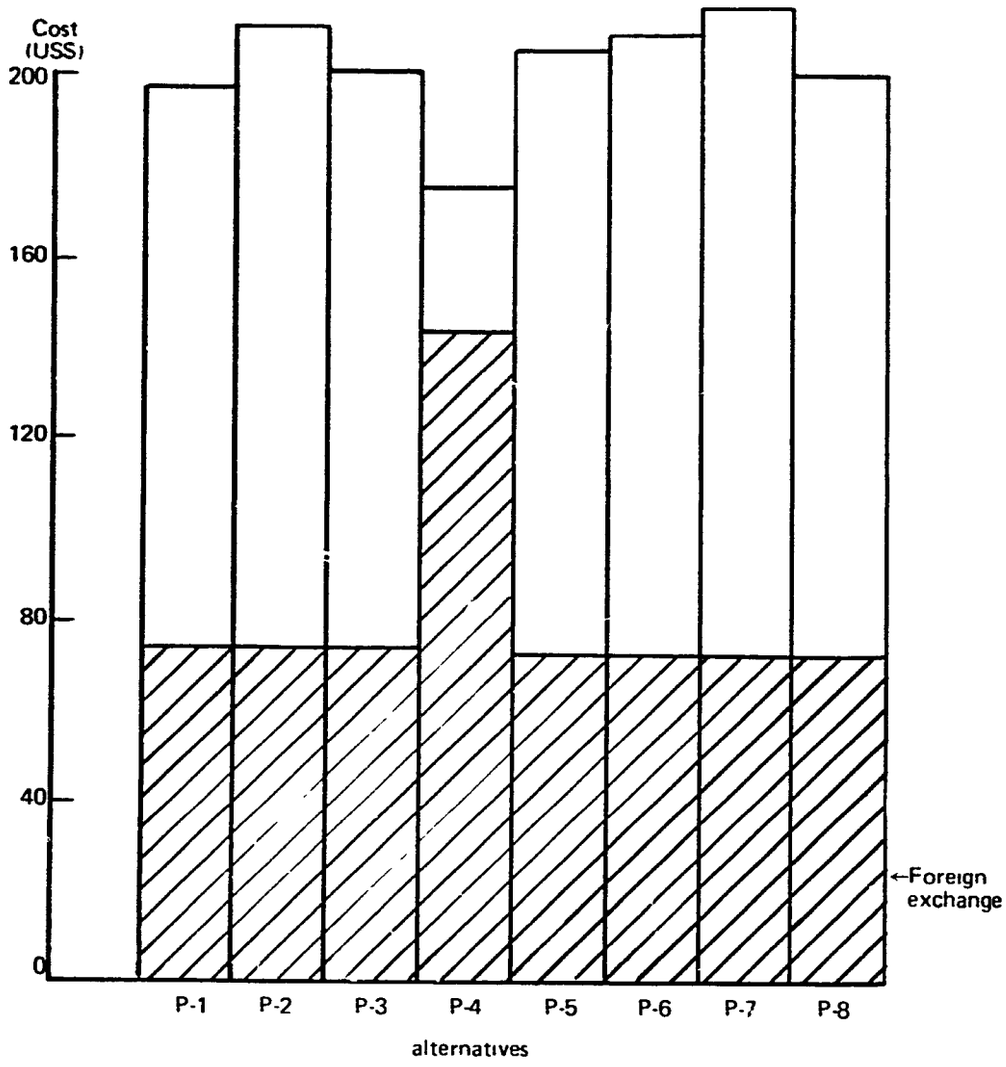
[7]Although the total supply is near the amount required, an additional 13,900 tons of N is required to supply requirements in provinces where the requirement is greater than N-P ratio of DAP when DAP supplies all the P_2O_5 requirement.

Comparison of Mixed Fertilizer Supply Systems. Total systems cost, including costs of production or importation, bagging, handling, and transportation for some alternative routes of supplying 18-46-0 grade are given in table 25. It was assumed that products produced in Chile would be bagged at the plant, and imports would be bagged at the receiving port. Each system is based on supply of 107,000 tons of P_2O_5 and will also supply 42,000 tons of N.

Systems M-1, M-2, and M-3 are production of DAP at Rancagua, Penco, and San Antonio. Foreign exchange costs are about the same for all three systems (figure 41). System M-4 is for importation of DAP and is covered in detail in section VI. Cost results from table 25, which are summarized on p. 89, show the lowest total systems cost for importation, but foreign exchange costs are somewhat higher with importation.

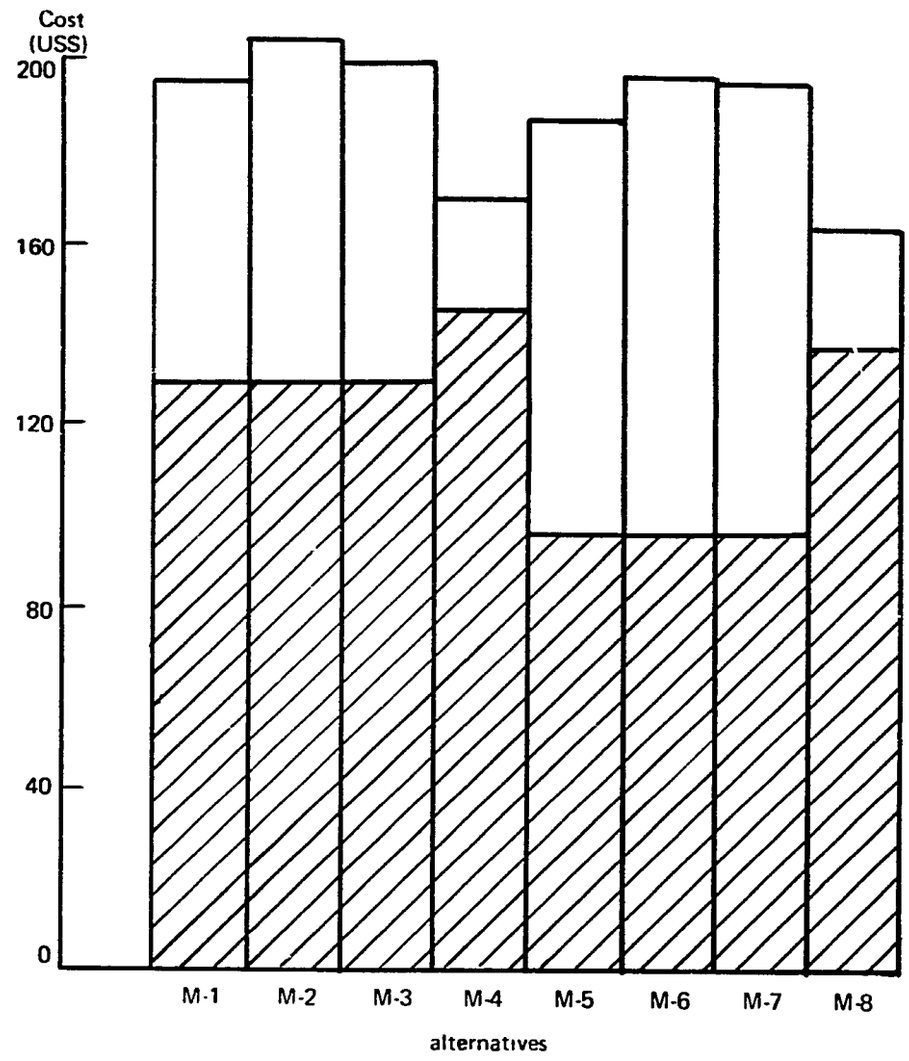
Comparison of Systems Costs with Combinations of Mixed Fertilizers and Straight Materials. In section VI, the lowest importation systems cost was for importation of a combination of urea, TSP, and DAP (system M-8). It is possible to produce both DAP and TSP in the same plant if

Figure 40. Estimated Total Costs and Foreign Exchange Requirements Per Ton of P_2O_5 for Alternative Methods of Supplying 107,500 Tons/Year of P_2O_5—1975[a]



[a]P-1 Triple superphosphate produced at Rancagua.
P-2 Triple superphosphate produced at Penco.
P-3 Triple superphosphate produced at San Antonio
P-4 Triple superphosphate imported
P-5 Normal superphosphate produced at Rancagua.
P-6 Normal superphosphate produced at Penco.
P-7 Normal superphosphate produced at San Antonio.
P-8 Normal superphosphate produced ½ at Penco, ½ at Rancagua.

Figure 41. Estimated Total Costs and Foreign Exchange Requirements Per Ton of Plant Nutrients in 18-46-0 and TSP—1975[a]



[a]M-1 18-46-0 produced at Rancagua
M-2 18-46-0 produced at Penco.
M-3 18-46-0 produced at San Antonio.
M-4 18-46-0 imported
M-5 18-46-0 and TSP produced at Rancagua
M-6 18-46-0 and TSP produced at Penco
M-7 18-46-0 and TSP produced at San Antonio.
M-8 18-46-0 and TSP imported

it is designed for this type operation. Therefore, systems costs with Chilean production of DAP and TSP not included on table 25 (m-5) are compared with the systems costs with all the material imported in table 25. Results are summarized at the bottom of this page For comparison, the systems with domestic production of urea (N-1 and N-2) and TSP (P-1) and the system with importation of urea (N-3) and TSP (N-4) are combined and also included.

With urea production in Chile at the rate for the residual Chilean market only + production of granular TSP, total systems costs are about the same as for production of the TSP-DAP combination. However, foreign exchange costs are much lower with urea production. Total costs for urea production in the smaller plant + TSP production are slightly higher than for importation, but again foreign exchange costs are much lower (by nearly $50/ton N + P_2O_5). With urea production in plants sized for Chile's market plus a portion of the Andean market, both total and foreign exchange costs are lower with Chilean production. Assuming Chile can get some portion of the Andean market, production of urea and TSP (or NSP) in Chile seems to be the most attractive alternative

Comparison of the Costs of Barge Shipment with Rail Shipment

A significant percentage of the cost of delivering fertilizers to the farmer is the cost of transport and handling. The marketing study by the A. T. Kearney Company, Inc. emphasized the economies possible in bulk handling of materials and recommended receiving all fertilizer material in bulk at ports. The Kearney study also relates that the Minister of Agriculture has established a policy stating that a plan of bulk distribution of fertilizers should be implemented in Chile in the near future However, emphasis is on internal bulk movement by rail, with some mention of bulk blending and bulk distribution onto farms. Another possibility for transport savings is internal bulk movement of materials by sea-going barges from a central location such as a production plant or bulk storage building where imported materials are received in large quantities to other Chilean ports

Materials normally can be moved for long distances by water at much lower cost than for rail or truck transport Typical costs for barge movement are in the range of $0.001-0.002/ton/km only 10-20% of Chile's rail freight rates The estimated costs for delivering phosphate products from either Rancagua by rail or San Antonio by barge are tabulated at the top of p 90 (Rancagua and San Antonio are alternative locations for phosphate production plants in Chile.)

A comparison of these costs, which also is summarized on p 90, indicates that by utilizing barge movement from San Antonio products can be delivered to Valdivia and Puerto Montt at about $11-12/ton lower cost than by rail from Rancagua The summary also indicates that cost savings per unit of plant nutrient should be 2-3 times higher for NSP than for TSP or DAP

The use of this type of barge transport would require specialized equipment at the receiving ports for unloading,

System	Option	Total Systems Costs, $ Tons N & P_2O_5 — Total 0% R.O.I.	Total 10% R.O.I.	Foreign Exchange
M-1	Production at Rancagua	180	196	129
M-2	Production at Penco	190	206	129
M-3	Production at San Antonio	184	200	129
M-4	Importation	171	–	145

Materials and Origin	Supply System No.	Systems Cost, $/Ton N & P_2O_5 — Total 0% R.O.I.	Total 10% R.O.I.	Foreign Exchange
Urea (I), DAP (P), TSP (P)[a]	None	176	191	108
Urea (I), DAP (I), TSP (I)	IM-2	171	–	143
Urea (P)[b], TSP (P)	N-2 + P-1	180	201	63
Urea (P)[c], TSP (P)	N-1 + P-1	141	160	55
Urea (I), TSP (I)	N-3 + P-4	183	–	153

[a]P - produced in Chile at Rancagua (least cost location), I importation.
[b]Urea production in 42,000 tons N/yr plant (Chile's N needs only).
[c]Urea produced in 89,000 tons N/yr plant (Chile's N needs and a portion of Andean market).

Shipment by Rail from Rancagua	To Valdivia	To Puerto Montt
Approx. distance, km.	770	1005
Cost, $/ton		
Reclaiming from bulk storage	.60	.60
Bags and bagging	6.60	6.60
Loading bags on rail car	.60	.60
Rail Freight	12.75	14.65
Unloading from rail car into storage	.60	.60
Total for bagged material in storage	21.15	23.05

Shipment by Barge from San Antonio	To Valdivia	To Puerto Montt
Approx. distance, km.	850	1200
Cost, $/ton		
Loading bulk material from storage onto barge	.60	.60
Barge Freight	1.70	2.40
Unloading barge to storage	1.00	1.00
Reclaiming from storage	.60	.60
Bags and bagging	6.60	6.60
Moving bags into storage	.60	.60
Total for bagged material in storage	11.10	11.80

Potential Savings with Barge Movement,	Destination	
$/Ton	Valdivia	Puerto Montt
Product	10.05	11.25
Unit Nutrient		
in NSP (0 20 0)	50.25	56.25
in TSP (0 46 0)	21.85	24.46
in DAP (18-46-0)	15.70	17.58

conveying, and storing bulk material. (The Kearney study recommended installation of equipment for unloading and storing bulk materials at Puerto Montt. Bulk unloading facilities are under construction at Penco and are already in use for handling nitrates at Baron and Talcahuano.) To minimize loading costs the production plants should also be located so that products can be moved from plant bulk storage, or from central bulk storage areas for imported materials, to barges by conveyor

The potential ammonia-urea plant site near Punta Arenas is at a port location where bulk loading of urea should be possible. If a phosphate production plant is located at San Antonio, it may be feasible to deliver bulk phosphate products southward by barge to ports from San Antonio to Punta Arenas and then deliver bulk urea from Punta Arenas northward on the return trip

If Chile should obtain agreements to supply nitrogen fertilizers to the Andean market countries of Peru and Ecuador, it may be possible to deliver urea by barge from Punta Arenas to various ports in Chile, Peru, and Ecuador and then return with rock phosphate from Peru's Sechura Desert to a phosphate plant at San Antonio. Then bulk phosphate products could be loaded and moved to ports south of San Antonio as the round-trip to Punta Arenas is completed. Potassium chloride and potassium sulfate will probably also be available as products from the Sechura Desert in Peru and are other possible products to backhaul to Chile.

A combination barge that hauls both urea and ammonia is now in use in the U. S., serving a route from Alaska to Washington state. A barge of this type might be used to supply both urea and ammonia to Peru and/or Ecuador, as well as points in Chile.

There are many different types of barges and port unloading facilities. For example, a barge may be self-propelled, or it may be towed, it may have gear for unloading cargo, or it may be dependent on shore gear. Recommending a specific system design for moving Chile's bulk fertilizer materials by water is outside the scope of this study. However, the possible economies with such a bulk system seem to warrant a detailed study of this aspect of Chile's future fertilizer supply systems.

Potential Savings in Phosphate Production Costs at Rancagua by Utilizing Backhaul in Phosphate Rock Rail Cars

Rancagua, which is adjacent to the potential location for a sulfuric acid plant and is also in the Central Valley

agriculture area, is a feasible location for a phosphate fertilizer plant. Rancagua is not a port location, and any phosphate rock used to produce fertilizers there would probably be imported through the port of San Antonio and hauled to the plant by rail. Rail freight costs are estimated as approximately $4/ton of rock.

There may be some possible savings in rock phosphate rail freight costs by utilizing the rock cars to carry other commodities on the return trip to San Antonio. Some possibilities are to haul phosphate products back to San Antonio or to haul blister copper to San Antonio. (Since rock phosphate is nonhygroscopic and insoluble in water, it can be hauled in practically any type of car. However, hopper-bottom bulk cars are preferred due to the relative ease and speed of unloading.)

The effects of savings in rock phosphate freight rates on costs of production of fertilizers are tabulated below for NSP and TSP and for DAP. Production costs were estimated for either complete elimination ($4/ton of rock) or 50% reduction ($2/ton of rock) of freight rates

The above tabulation indicates that a 50% reduction in rock freight rates from San Antonio to Rancagua should lower the production costs for NSP by about $1 2/ton and lower the costs for either DAP or TSP by about $3.2/ton

Production Cost at Three Rock Freight Rates and Two Rates of Return

	Full Freight ($4/ton)				50% Freight ($2/ton)				0% Freight Rate			
	$/Ton		$/Unit		$/Ton		$/Unit		$/Ton		$/Unit	
Product	0%	10%	0%	10%	0%	10%	0%	10%	0%	10%	0%	10%
NSP (0-20-0)	23.1	24.8	115	124	21 9	23 6	110	118	20 6	22 3	10 3	112
TSP (0-46-0)	66.2	75.2	144	163	63.0	72 0	137	157	59 9	68 9	130	150
DAP (18-46-0)	88.1	98.3	138	154	84 9	95.1	133	149	81 7	91 9	128	144

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SECTION VIII

ANALYSIS OF THE FERTILIZER SITUATION IN THE ANDEAN MARKET[8] AND VENEZUELA SUMMARY

An analysis of the fertilizer situation in the Andean Common Market countries, summarized in table 26, indicates that in 1975 fertilizer consumption will be aboout 340,000 tons each of N and P_2O_5, and about 180,000 tons of K_2O. This is almost double the actual nutrient consumption in these countries in 1968/69. Consumption in Venezuela is estimated at an additional 45,000 tons of N and 27,000 tons each of P_2O_5 and K_2O in 1975.

Existing production capacity plus that under construction in the Andean countries, given in table 26, can supply about 300,000 tons/yr of N, 130,000 tons/yr of P_2O_5, and 80,000 tons/yr of K_2O. Assuming that about 55,000 tons of N and 10,000 tons of K_2O of the Chilean nitrate production will be marketed in Chile and the other Andean countries, the residual market[9] for fertilizers in 1975 should be about 135,000 tons/yr of N, 200,000 tons/yr of P_2O_5, and 100,000 tons/yr of K_2O. If contracted fertilizer facilities with capacities totalling 24,000 tons/yr of N and 14,000 tons/yr of P_2O_5 are constructed in Bolivia, then the residual market will be reduced to about 110,000 tons/yr of N and 190,000 tons/yr of P_2O_5. Nitrogen production facilities in Peru are comparatively uneconomical and obsolete. If operation of these facilities is discontinued, the residual nitrogen market could be increased by about 40,000 tons/yr to about 150,000 tons/yr.

If contracted construction of facilities are completed, Bolivia will be self-sufficient in fertilizers in 1975. Even if these facilities are not constructed, the total market for fertilizers in Bolivia is small. Colombia will have excess production of nitrogen fertilizers. The major markets for nitrogen will probably be in Chile, Peru, and Ecuador. With the exception of Chile, phosphate markets will probably be small. Venezuela will have a surplus of nitrogen and phosphate fertilizers and will probably be competing for the residual markets in the Andean countries.

[8]The Andean Common Market countries are (1) Bolivia, (2) Chile, (3) Colombia, (4) Ecuador, and (5) Peru.

[9]Residual market refers to the amount of fertilizers that will be consumed in a country or a group of countries above the quantity that may be produced in that country(s) from existing production facilities including those under construction.

Table 26. Consumption, Production Capacity, and Residual Market for Chemical Fertilizers in Andean Common Market Countries

	Consumptions of Fertilizers[a] 1,000 mt of nutrients					
	Actual, 1968-69[b]			Projected 1975[c]		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Bolivia	2	1	1	8	7	4
Chile	34	99	10	90	165	50
Colombia	53	60	45	97	108	81
Ecuador	30	22	15	45	33	22
Peru	55	11	12	100	22	22
Totals	174	193	83	340	335	179

[a]Does not include organics

[b]Chile consumption from Kearney study, all others from *FAO Monthly Bulletin of Agricultural Economics and Statistics* 19 2 (February 1970)

[c]Chile projection from Kearney study, Bolivia projection from *A Fertilizer Program for Bolivia*, TVA, and all others by TVA Team.

Estimated Production Capacity for Solid Chemical Fertilizers, 1,000 ton/yr

	Existing or under construction			Contracted		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Bolivia	–	–	–	24	14	–
Chile	160[a]	50	27[a]	–	–	–
Colombia	104	66	50	–	–	–
Ecuador	8	10	4	–	–	–
Peru[c]	37	6	6	–	–	–
Totals	309 (149)[b]	132	8.7 (60)[b]	24	14	–

[a]All mined fertilizers (Chilean nitrates).

[b]Excluding Chilean nitrates

[c]Assumes that construction of planned nitrogen complex at Talara will continue to be postponed.

Residual Market for Fertilizers in 1975

	1,000 ton/yr[a]		
	N	P_2O_5	K_2O
Bolivia	(16)	(7)	–
Chile[a]	40	107	38
Colombia	(7)	42	31
Ecuador	37	23	18
Peru[b]	33	16	16
Totals	110[c]	188[c]	103[c]

[a]Assuming Chilean nitrates supply 48,000 N and 16,000 K_2O and guano supplies 2,000 N, 8,000 P_2O_5, and 2,000 K_2O.

[b]Assumes guano and Chilean nitrates supply 30,000 ton/yr of N.

[c]Assumes excess capacity in Bolivia and Colombia not marketed in other Andean countries

The most significant raw materials from the standpoint of fertilizer manufacture are listed below by country:

Bolivia natural gas and sulfur
Chile natural gas, sodium nitrate, potassium nitrate, and sulfur
Ecuador natural gas and sulfur
Peru natural gas, phosphate rock, and potash.
Venezuela natural gas and phosphate rock.

BOLIVIA

Consumption and Production Capacity

Fertilizer production capacity and consumption for Bolivia is given in table 27. Consumption in 1968/69 was only about 2,000 tons/yr of N and 1,000 tons/yr each of P_2O_5 and K_2O. Estimated consumption for 1975 is 8,000 tons of N and 7,000 tons of P_2O_5.

There are no fertilizer production facilities in Bolivia. Construction of a small nitrogen plant and a small phosphate plant is planned. The planned nitrogen plant location is the Santa Cruz area where natural gas is available as the feedstock. Nitrogen production of 24,000 tons/yr prilled ammonium nitrate is planned. Ammonia will be produced by reforming natural gas. Nitric acid will be produced as an intermediate and used in production of prilled ammonium nitrate. Some of this ammonium nitrate product will probably be utilized as an explosive in the mining industry.

The planned phosphate plant will produce NSP at Eucaliptus. Production capacity is estimated at 14,000 tons/yr of P_2O_5. Imported phosphate rock will be reacted with sulfuric acid produced from Bolivian sulfur. The sulfuric acid plant is in operation.

Raw Materials

Natural Gas Bolivia has adequate natural gas reserves in the vicinity of Santa Cruz to support an economical size nitrogen complex. Estimated recoverable reserves are 2,900 billion ft^3.

Phosphate Rock Some phosphate rock has been found in Bolivia, but known reserves are small and do not appear to have any economic significance. At a location near Aruro, remnants of dead animal bones are reported to have a composition of 12-15% P_2O_5. However, P_2O_5 reserves are estimated as only about 10,000 tons.

Sulfur Volcanic sulfur sources occur in a number of locations in the Andes along the border with Chile. The tabulation (3) below indicates that there are six sulfur deposits in Bolivia with total known reserves of about ½ million tons of ore. Production capacity is estimated as about 24,000 tons/yr of ore averaging about 50% S.

Deposit Location	Production Capacity	Reserves
Dept. Potosi, 6 km from Chilean border	10,000 tons/yr ore	¼ million tons of ore averaging 52.5% S
Dept. Potosi, 7 km from Chilean border	3,000 tons/yr	¼ million tons or ore containing 55% S
Napa in Dept. Potosi	2,000 tons/yr	unknown
Near Napa, Dept. Potosi	4,000 tons/yr	1.2 million tons of ore containing 65% S
Dept. Potosi	2,000 tons/yr	unknown
Near San Pedro de Atacoma	3,000 tons/yr	unknown

Potash— There are no known potassium deposits in Bolivia.

Table 27. Bolivia

Fertilizer Consumption[a] 1968/1969			Estimated Demand 1975[b]		
1,000 ton/yr					
N	P_2O_5	K_2O	N	P_2O_5	K_2O
2	1	1	8	7	4

Existing Production Capacity

None

Planned Production Capacity (Contracted)

Plant Ownership	Location	Capacity 1,000 ton/yr N	P_2O_5	K_2O
Yacimentos Petroliferos Fiscales Boliviano	Santa Cruz	24 (AN)	–	–
Bolivian Army Pension Fund	Eucaliptus	–	14 (NSP)	–

Sulfuric Acid Capacity

Company	Location	Production Capacity 1,000 ton/yr
Bolivian Army Pension Fund	Oruro	33

[a]*FAO Monthly Bulletin of Agricultural Economics and Statistics* 19:2 (February 1970).
[b]Tennessee Valley Authority. *A Fertilizer Program for Bolivia.*

CHILE

The quantities of fertilizer supplied and demanded in Chile are summarized in table 28. Consumption estimates are given in more detail in section III of this report. In 1975, consumption is estimated at 90,000 tons of N, 165,000 tons of P_2O_5, and 50,000 tons of K_2O. Production in 1975 is estimated at 160,000 tons/yr of N, 24,000 tons/yr of K_2O as Chilean nitrates, and 50,000 tons/yr of P_2O_5 as superphosphates. It is estimated that nitrates will supply 48,000 tons/yr of N for use in Chile and that the remainder will be exported. Guano will supply 8,000 tons/yr of P_2O_5, 2,000 tons of N, and 2,000 tons of K_2O. Therefore, the residual market in Chile should be about 40,000 tons of N, 107,000 tons of P_2O_5, and 38,000 tons of K_2O in 1975.

Raw materials for fertilizer manufacture include ore containing sodium and potassium nitrates, natural gas, and sulfur (both as volcanic sulfur and as byproduct sulfuric acid from copper refining operations). Known reserves of sodium nitrate are 100 million tons of sodium nitrate in ore containing 6% or more sodium nitrate plus additional 100 million tons of sodium nitrate in more dilute ore. Natural gas reserves are estimated to be over 80,000 million m^3 containing 85-90% methane. About 8.5 million m^3/day of methane are available as byproduct from LPG production at Cabo Negro. There is about 2,000 tons/day of existing sulfuric acid capacity in Chile primarily for metallurgical operations. Metallurgical gas is available for producing an additional 4,500 tons/day of sulfuric acid. Volcanic sulfur reserves are estimated at about 35-40 million tons of S in ore of at least 45% S. A more complete description of existing facilities and raw materials for fertilizer manufacture is given in section IV of this report.

COLOMBIA

Consumption and Existing Fertilizer Capacity

Table 29 summarizes the supply-demand relationship in Colombia. Consumption of fertilizer nutrients in 1968/69 was about 53,000 tons of N, 60,000 tons of P_2O_5, and 45,000 tons of K_2O. The consumption for 1975 is estimated at 97,000, 108,000, and 81,000 tons of N, P_2O_5, and K_2O, respectively. There is sufficient nitrogen capacity in operation to supply the quantity demanded through 1975. The residual market for P_2O_5 and K_2O should be about 40,000 and 30,000 tons respectively in 1975.

Present Fertilizer Industry

AMOCAR-ABOCOL Complex at Cartagena. This complex was originally built and wholly owned by Esso International, Inc. It is comprised of ammonia and nitric acid units which are located within the Esso refinery at Cartagena and urea and mixed fertilizer units which are located on adjacent property.

Recent changes in ownership have taken place. ABOCOL is now a separate corporation with Esso owning 50% of the stock. It purchases nitric acid and ammonia from ABOCOL (Esso) for production of urea and a variety of mixed fertilizers. The plant also imports phosphoric acid, phosphate rock, TSP, and potash (KCl and K_2SO_4). A brief description of each of the units follows.

AMOCAR

The ammonia unit is a typical C and I/Girdler reforming plant with a high-pressure synthesis loop [5,000 pounds per square inch gage (psig)]. It was originally designed to

Table 28. Chile

Consumption

Fertilizer Consumption[a] 1968/1969				Projected Demand 1975[a]		
			1,000 ton/yr			
N	P_2O_5	K_2O		N	P_2O_5	K_2O
34	99	10		90	165	50

Existing Production Capacity

Plant	Location	Capacity 1,000 ton/yr N	P_2O_5	K_2O
Sociedad Quimica y Minera (SOCHIM)	Maria Elena, Victoria and Pedro de Valdivia	160 (CN)	–	24 (CN)
Cia. Sud-Americana de Fosfatos (COSAF)	Penco	–	50 (NSP & TSP)	–

[a]From draft of Chilean Fertilizer Marketing Study by the A. T. Kearney & Company, Inc.

Table 29. Colombia

Fertilizer Consumption[a] 1968/1969				Projected Demand 1975[b]		
			1,000 ton/yr			
N	P_2O_5	K_2O		N	P_2O_5	K_2O
53	60	45		97	108	81

Existing Fertilizer Production Facilities
(In operation and under construction)

Plant	Location	Production capacity 1,000 ton/yr N	P_2O_5	K_2O
Amoniaco del Caribe		100 (AA), 8 NA)		
Abonos Colombianos S.A. (Abocol-Amocar complex)	Cartagena	37 (U) 17 (NPK)	17 (NPK)	17 (NPK)
Acerias Pas del Rio	Bogota	1 (ASB)		
Monomeros de Colombia Ltda.	Barranquilla	33 (NPK)	33 (NPK)	33 (NPK)
Fertilizantes Colombianos	Barrancabermeja	15 AA 8 (U), 8 (AN)		
Colminas	Turmeque		10 (NSP)	
Thomas slag from steel mills + small NSP plants	Various		6 (NSP)	
	Totals	115 (104 AS solids)	66 (All solids)	50 (All solids)

Sulfuric Acid Capacity

Company	Location	Production capacity 1,000 ton/yr
Fertilizantes Ecuatorianos (FERTISA)	Guayaquil	41

[a]*FAO Monthly Bulletin of Agricultural Economics and Statistics* 19:2.
[b]Projected by TVA Team.

produce 295 mt/day utilizing refinery offgas. Carbon dioxide removal is accomplished in a two-stage monoethanolamine system and CO conversion is carried out with two-stage, high-temperature shift conversion catalyst.

Rated capacity has been increased stepwise to 390 mt/day. Part of the increase was a result of changing from a feedstock of refinery gas to natural gas. Changes in heat exchange equipment account for the balance of the increase.

AMOCAR plans to continue to operate the plant as is with the exception of possibly installing a low-temperature shift conversion step. The rated capacity of the plant will be approximately 400 mt/day if this change is made.

The nitric acid unit was also C and I/Girdler designed and built and is a typical medium-pressure unit. The cooler condensers are cascade type. Design capacity is 150 mt/day, which is much more than the requirement of ABOCOL.

ABOCOL

The urea unit utilizes the Toyo Koatsu process and was built by C and I/Girdler. The unit was designed to produce 270 mt/day of prilled urea. The product is stored in combination burlap-polyethylene bags. The unit was constructed in 1962.

The mixed fertilizer unit utilizes a modified PEC process with 3 acidulation tanks, 12 neutralizers, and 1 mixing tank. It was also constructed by C and I/Girdler in 1962. There are 2 granulating lines each equipped with Spherodizers for granulation and drying, screens, and hammer mill crushers.

Solid raw materials are received at a nearby dock from ocean-going vessels. These materials are transported to the plant by a reversible belt conveyor.

Nitric acid and ammonia are received by pipeline from AMOCAR. A variety of grades is produced, including the following:

14-14-14	15-15-15
10-20-20	8-24-14
14-18-14-3Mg	12-24-12
14-14-14-2Mg	12-12-17-2Mg, B, Zn
10-20-10	12-6-22-2Mg, B, Zn

The rated capacity of the plant is 400 mt/day of the 1:1:1 ratio grades. Of course, the rate may be more or less than this, depending on the grade produced.

All products are conditioned with 2% by weight of kaolin-base clay. There are three bagging lines with a capacity of 30 mt/hr each. All the production is stored in polyethylene-lined burlap bags. Bagged storage capacity is 17,000 tons.

MONOMEROS Plant at Barranquilla

Construction of this plant has almost been completed. The process is a modified Dutch State Mines (DSM) ammonium sulfate precipitation process in which gypsum will be recovered for use in an adjacent cement manufacturing plant. The fertilizer plant will utilize byproduct ammonium sulfate from a caprolactam plant also under construction at the site.

Other raw materials include imported phosphate rock, phosphoric acid, potash (KCl), and ammonia. Nitric acid will be produced on site in a Stamicarbon unit.

MONOMEROS is jointly owned by the governments of Colombia and Venezuela. Caprolactam will be exchanged to Venezuela for ammonia. The design production tonnages for the fertilizer unit are as follows:

Grade	Mt/day
25-15-0	430
20-20-0	630
14-14-14	900

Fertilizantes Colombianos S. A. (FERTISA)

The basic plant essentially consists of a 65 ton/day Girdler-type Amopac ammonia unit, 135 ton/day nitric acid unit, and a 150 ton/day 26% ammonium nitrate unit. In addition, there is a 50 ton/day urea reactor and prilling tower. The ammonium nitrate is granulated in two pug mills. The urea plant is a partial recycle unit, with the offgases utilized in production of ammonium nitrate.

Normal Superphosphate Plants

Colombia has three or four very small NSP plants. These plants use small amounts of imported, or in some cases locally produced, phosphate rock in conjunction with spent sulfuric acid to produce a low-grade NSP. The quantities of spent sulfuric acid are very small; and therefore, the normal output of these plants combined amounts to less than 2,000 tons P_2O_5 equivalent/yr. For practical planning purposes, they can probably be discounted for the next 5-year fertilizer plan.

Colminas, a semiprivate rock mining venture, has contracted for construction of a NSP plant near Turmeque. This plant will have a capacity of 75,000 tons/yr of NSP. The plant will use locally produced phosphate rock and locally mined sulfur from volcanic sources. The phosphate rock mines are open and working; however, the sulfur mines are not yet operating.

Raw Materials

Phosphate Rock--Phosphate rock deposits have been found in two formations in Colombia-the La Luna formation and the Guadalupe formation. Rock samples have been analyzed from various areas in each deposit, but reliable data on extent of reserves and utility of the phosphate could not be found Some information on samples from specific localities is given below.

Area of Elias (Guadalupe formation)- --Phosphate was found in seams of less than ½ m thickness. Samples containing up to 32% P_2O_5 were analyzed

Area of Giradat-Ortega (Guadalupe formation)--samples were taken near Ortega that showed a P_2O_5 content of up to 17.5%. Southeast of Payonde samples from exposed slopes had P_2O_5 compositions of up to 28% P_2O_5. Thickness of phosphate seams was less than ½ m, but in areas the vertical depth of the phosphate deposit included four seams.

Area of Pondi-Cunday (Guadalupe formation)--Phosphate samples with a P_2O_5 content of up to about 28% P_2O_5 were analyzed. This is considered to be one of the deposits with the greatest potential for commercial exploitation.

Area of Sierra-Alto (La Luna formation)- --Phosphate was found in narrow seams with a P_2O_5 content of 11-15%.

Area of Turmeque (Guadalupe formation)--Phosphatic apatite occurs in seams 3-4 m thick. Samples analyzed had P_2O_5 contents as high as 22%.

North of Santander (La Luna formation)--This deposit is part of the formation that has given commercial deposits in Tachira state in Venezuela. Phosphorite occurs in long seams of about 1 m thickness. Samples of up to 32% P_2O_5 have been analyzed.

Sulfur

Sulfur ore has been found in several deposits in Central Colombia. The majority of these deposits are of small size near the craters of extinct volcanoes. Some deposits that may be of economic interest are listed below.

Caldas--This is a volcanic sulfur deposit with an unknown quantity of reserves.

Puroce--Three deposits are located in this area on the slope of a volcano. These are the only deposits now being economically exploited in Colombia. The operating company is Industria Puroce S. A. Ore containing 40-50% S is extracted by underground mining methods and refined in autoclaves located adjacent to the plant. Production rate for the last 5 years has been 20,000-30,000 tons/yr of refined sulfur.

Proven reserves in the Puroce area are about 6 million tons of ore.

Cundimaraca--Several sulfur ore deposits have been found in this area. Reserves are estimated as several million tons, but the sulfur content of the ore is low.

During the Second World War some of this sulfur was mined by open pit methods and refined in autoclaves. However, mining was later discontinued due to high costs.

Narino--Volcanic sulfur has been found in this area around the volcanoes Cumbal and Azufral. Estimated reserves in one area have been estimated as at least 300,000 tons of material containing 25% S.

Tolima--Twenty separate deposits of varying size have been reported in this area.

Potassium

There are no known potassium deposits of commercial value in Colombia.

ECUADOR

Consumption and Existing Fertilizer Capacity

The fertilizer market situation in Ecuador is given in table 30. Nutrient consumption in 1968/69 is estimated as about 30,000 tons of N, 22,000 tons of P_2O_5, and 15,000 tons of K_2O. Consumption in 1975 is projected at about 45,000 tons of N, 33,000 tons of P_2O_5, and 22,000 tons of K_2O. Existing fertilizer production capacity, a small mixed fertilizer plant, can produce 8,000 tons/yr of N, 10,000 of P_2O_5, and 4,000 of K_2O. No additional production capacity is planned. The residual market in 1975 should be about 37,000 tons of N, 23,000 of P_2O_5, and 18,000 of K_2O.

Table 30. Ecuador

Consumption

Fertilizer Consumption[a] 1968/1969			Projected Demand 1975[b]		
1,000 ton/yr					
N	P_2O_5	K_2O	N	P_2O_5	K_2O
30	22	15	45	33	22

Existing Fertilizer Production Capacity

Plant	Location	Capacity 1,000 ton/yr N	P_2O_5	K_2O
Fertilizantes	Guayaquil		9(WPA)	
Ecuatorianos, S.A.	Ecuador	8 (M)	10 (M)	4 (M)
Totals (Solids)		8	10	4

Sulfuric Acid Capacity

Company	Location	Capacity 1,000 ton/yr
Fertilizantes	Guayaquil	
Ecuatorianos, S.A.	Ecuador	41

[a]*FAO Monthly Bulletin of Agricultural Economics and Statistics*, 19:2 (February 1970).
[b]Projected by TVA Team.

Description of Production Facilities

FERTISA Complex--The FERTISA fertilizer complex at Guayaquil has a maximum capacity for production of about 10 tons/hr of either granular mixed fertilizers or granular ammonium sulfate. The complex consists of a sulfuric acid plant, a wet-process phosphoric acid plant, and a granulation plant.

Sulfuric acid is produced in a contact plant with a capacity of about 41,000 tons/yr. Feedstock for sulfuric acid production is Ecuadorian volcanic sulfur from Tixan in the province of Chimborazo.

Sulfuric acid is used to produce phosphoric acid by the conventional dihydrate wet process. Plant capacity is 20 tons/day of P_2O_5 as 30% P_2O_5 acid The phosphate rock (32-33% P_2O_5) is imported from Florida. The reactor is mild steel with a brick lining. It is divided into four compartments. The reactor product is filtered on a 60-ft Eimco tilting pan filter. The filter grade acid (30% P_2O_5) is used in the granulation plant without any additional concentration by evaporation.

The granulation plant essentially consists of a 7- x 14-ft TVA-type rotary ammoniator granulator, dryer, cooler, screens, and crushing equipment. Anhydrous ammonia used in the granulator unit is imported by W. R. Grace and stored in a 12,000 ton atmospheric storage terminal. In addition to production of granular ammonium sulfate, some grades produced are 10-30-10, 6-24-24, 12-24-12, and 13-13-20. Imported potash and some imported TSP are used in production of the mixed fertilizers.

Raw Materials

Natural Gas--Probably the most significant raw material available in Ecuador is natural gas. A very large gas field in the bay near Guayaquil was recently discovered. Exact reserves are not yet known, but are believed to be extensive. A gas flow rate of 10 million ft^3/day was measured through a 3/8 in. opening during early testing. The possibility of production of LNG for sale to markets in the United States and Japan is under consideration.

Phosphate Rock--There are no known reserves of phosphate rock in Ecuador.

Sulfur--There are several locations of volcanic sulfur in Bolivia. At the present time, a deposit at Tixan in the province of Chimborazo is being mined at a rate of about 300 tons/day. A portion of this material is used in the FERTISA production complex at Guayaquil. Reserves are estimated as about 1 million tons of S.

There is also some mining of volcanic sulfur in the province of Carchi in Northern Ecuador.

Potassium--No economical deposits of potassium have been located in Ecuador.

PERU

Consumption and Existing Fertilizer Capacity

The fertilizer supply-demand situation in Peru is summarized in table 31. Fertilizer consumption was about 55,000 tons of N, 11,000 of P_2O_5, and 12,000 of K_2O in 1968/69. Estimated consumption in 1975 is about 100,000 tons of N and about 22,000 tons each of P_2O_5 and K_2O.

Table 31. Peru

Consumption

Fertilizer Consumption[a] 1968/1969			Estimated Demand 1975[b]		
N	P_2O_5	K_2O	N	P_2O_5	K_2O
55	11	12	110	22	22

Existing Fertilizer Production Capacity

Plant	Location	Capacity 1,000 ton/yr N	P_2O_5	K_2O
Fabrica de Fertilizantes del Cuzco (Cachimayo)	Cuzco	13 (AA) 13 (AN)	–	–
Fertilizantes Sintecos S.A. (Fertisa)	Lima	20 (AA) 20 (AN + AS)	–	–
Industrias Quimicas S.A. (Indus)	Lima	4 (M)	6 (M)	6 (M)
Totals (Solids)		37	6	6

Sulfuric Acid Capacity

Company	Location	Production capacity 1,000 ton/yr
Compania Industria del Centro S.A.	La Oroya	66

[a]*FAO Monthly Bulletin of Agricultural Economics and Statistics*, 19:2 (February 1970).
[b]Projections by TVA Team.

There are three small fertilizer plants in Peru, with a total capacity of about 37,000 tons/yr of nitrogen and 6,000 tons/yr each of P_2O_5 and K_2O. These plants are relatively small and uneconomical. It is possible that operation may be discontinued before 1975. Guano supplies are variable, depending on the bird population, and can range from about 10,000-30,000 tons of N/yr. (At the present time, the supply of birds is decreasing and N supply from guano should be low.)

If existing plants are shut down by 1975, the residual market should be about 70,000 tons/yr of N and about 20,000 tons/yr each of P_2O_5 and K_2O. Peru has periodically announced an intent to build a large ammonia-urea fertilizer complex at Talara, but detailed plans and timing have not been worked out.

Present Fertilizer Industry

Fabrica de Fertilizantes del Cuzco (CACHIMAYO) This state-owned fertilizer plant, which is located near Cuzco, was built for the Development and Reconstruccion Corporacion of the Department of Cuzco in 1965 and it has a capacity of 13,000 tons of N/yr Due to sales and distribution problems and electric power failures, output has been only a fraction of capacity The plant can produce prilled ammonium nitrate (33.5% N) or ammonium nitrate–limestone (26% N) Ammonia is produced from electrolytic hydrogen Nitric acid is derived from the pressure oxidation of ammonia Limestone used in the 26-0-0 grade product is mined locally

The electrolytic ammonia process was chosen to use the output of a new hydro-electric plant on the Urubamba River near Machu Picchu It is expected that the reliability of the power supply to the plant will be improved as additional planned generating units are added

Fertilizantes Sinteticos S A. (FERTISA) FERTISA operates a nitrogen plant at Callao Total output is about 18,000 tons/yr of N. The fertilizer products are about 45,000 tons/yr of pan-granulated ammonium nitrate (33.5-0-0) and about 15,000 tons/yr of crystalline ammonium sulfate (21-0-0). Ammonia is produced by partial oxidation of Bunker C oil, and nitric acid by the pressure oxidation of ammonia. Oil is purchased from Empresa Petrolera Fiscal Refineria La Pampilla. Sulfuric acid is obtained from Industrias Quimicas S. A. (INDUS), an adjacent plant, which purchases it from Cerreo de Pasco

Solid products are bagged in 70-kg jute bags. FERTISA sells about 5,000-6,000 tons/yr of N to the adjacent INDUS granulation plant as ammonia and ammonia-ammonium nitrate-water solutions.

Industrias Quimicas S. A. (INDUS)—INDUS operates NSP and mixed fertilizer ammoniation-granulation plant at Callao, adjacent to the FERTISA plant. Capacity of the plant is about 100 tons/day of nongranular NSP (20% P_2O_5) and about 200 tons/day of granular mixed fertilizers. A portion of the superphosphate is used in the granulation plant. Plant products are bagged in 70-kg jute bags. Grades produced are tabulated below:

	Grades
0-20-0	12-12-6
10-10-10	12-12-17
12-12-12	16-16-0
10-20-0	10-8-18 + 2MgO

Phosphate rock, potassium chloride, and a small quantity of 18-46-0, are imported from the United States. Sulfuric acid comes from Cerreo de Pasco. INDUS can purchase the acid from Cerreo de Pasco at a cost lower than its production cost, and the sulfuric acid plant is not operated.

Plans for Future Plant Construction

For several years Peru has been considering building an ammonia-urea fertilizer complex in the vicinity of Talara which would utilize the natural gas in that area as the feedstock to the ammonia plant. Initially, a 600 ton/day ammonia plant and a 650 ton/day urea plant were contemplated as a part of the "Quinor Plan." More recently, a special committee of the fertilizer industry in Peru has recommended construction of a smaller nitrogen complex with a capacity for production of 300 tons/day of ammonia and 350 tons/day of urea. Although a final decision as to plant capacity has not yet been reached, it seems likely that a nitrogen complex will be built in Peru during the next 5 years.

Raw Materials

Natural Gas—Natural gas reserves in the region of Talara in Northern Peru are of sufficient quantity and quality to support a large ammonia plant. Several feasibility studies have indicated that ammonia production from this gas is technically feasible, but lack of markets and other problems have resulted in postponement of construction.

Phosphate Rock—Probably the known phosphate deposit of greatest potential economic significance in South America is in the Sechura Desert in Northen Peru. Significantly, the deposit is located in the western part of the desert and very near to the Pacific coast. The area is connected to Piura on the Pan-American highway and by an asphalt road to the village of Sechura. Construction of a pier at Bayovar Bay, near the rock deposit, has been initiated.

Total proven reserves are 560 million tons of material on the basis of a 31% P_2O_5 content, with additional indicated reserves of about 860 million tons (31% P_2O_5 basis). The P_2O_5 content of the drill cores has ranged from 1% to about 24%. Overburden, which is the form of loose sand, ranges from 0 to a maximum of about 40 ft of thickness. The overburden to product ratio is never greater than 1:1 and is normally less than 1:5.

Large-scale pilot beneficiation tests have shown that the phosphate can be upgraded economically by flotation. Processing tests have indicated that the rock is suitable for use in production of phosphoric acid, superphosphates, and other mixed fertilizers. Plans for marketing two grades of rock were formulated. One grade would be produced from beneficiated but uncalcined rock and would contain 29% P_2O_5. The other grade would be 31% P_2O_5 produced by calcining the beneficiated product. The uncalcined material would probably be preferred for direct application, and the calcined material, for further chemical processing.

Initial plans were to produce 800,000 tons/yr of phosphate rock. A later revised plan now being studied calls for ultimate production (after 7 years of operation) of about 1.4 million tons of 31% P_2O_5 material (calcined) and about 0.5 million tons of 20% P_2O_5 (uncalcined) material.

Sulfur (Volcanic)—Sulfur ore deposits have been found in several areas of Peru. These deposits occur largely in volcanoes similar to those in Northern Chile. The sulfur ore (Caliche) generally contains 40-50% S. There has been no recorded sulfur production from native ore for a long time. Some areas where sulfur deposits have been found are listed below.

Area	Reserves
Yu Came (Cano region)	3 million tons of ore
Tutupaca Volcano (moqnega region)	11.5 million tons of ore averaging 50% S
Caparaja Volcano	5.5 million tons of ore containing 40-90% S
Caropuna Volcano (north of Chuquibamba)	Unknown
Ubinas Volcano (Chimbote region)	Unknown
Sechura (40 km inland from Bayovar)	Unknown

Sulfur (Industrial Gases)—There are three operating plant units that are producing waste gases that might be suitable for manufacture of sulfuric acid. Total output is equivalent to about 60,000 tons/yr. Two of these units are operated by Cerreo de Pasco Corporation at Oroyo. A lead

refining plant has 12,000 tons/yr of S in offgases and a copper refining plant has 10,000 tons/yr of S in waste gases. Also, Southern Peru Copper Company at Ilo generates about 35,000 tons/yr of S in offgases from copper refining.

Potassium—In a depression area in the Sechura Desert, beneath the area containing phosphate deposits, potassium chloride and magnesium chloride are contained in brines. Six areas were explored and evaluated. Total proven reserves are 18,000,000 tons of potassium chloride as 1% potassium chloride solution and 30,000,000 tons as 0.57% solution.

Pilot-scale tests have indicated that production of potassium chloride by utilizing solar evaporation is feasible. Plans for production of 200,000 tons/yr of potassium chloride have been formulated. No target date for initiating production has yet been set.

VENEZUELA

Table 32 gives a summary of the fertilizer supply-demand relationship in Venezuela. Consumption in 1968/69 was about 25,000 tons of N and 15,000 tons each of K_2O and P_2O_5. Consumption of fertilizer in 1975 is expected to increase to about 47,000 tons/yr of N and 27,000 tons/yr each of P_2O_5 and K_2O. Existing fertilizer production facilities plus those under construction will supply about 200,000 tons of N and 140,000 tons of P_2O_5. Therefore, Venezuela has nitrogen and P_2O_5 capacity to produce supplies far in excess of estimated consumption of N for 1975. Also construction of additional capacity as a large ammonia-urea complex has been announced.

Existing Fertilizer Industry

Present Moron Plant—The existing facilities at the Moron fertilizer complex produce ammonium nitrate, TSP, and ammoniated mixed fertilizers. Ammonia is produced from natural gas and used in production of nitric acid, ammonium nitrate, and mixed fertilizers. Sulfuric acid is produced in a sulfur-burning contact plant from imported sulfur. The sulfuric acid is used to produce crystalline ammonium sulfate, wet-process phosphoric acid, and NSP. The phosphoric acid is used in production of TSP. About half of the TSP is granulated and sold as a single nutrient product, and about half is used along with the NSP in production of mixed fertilizers. Imported Florida phosphate rock together with some rock phosphate from Riecito are utilized in production of the wet-process phosphoric acid and the superphosphates The granular mixed fertilizers and the TSP are granulated in a 6- x 8-ft TVA-type rotary ammoniator-granulator. Capacities of the various units are listed below.

Type of plant	Production capacity, tons/day
Ammonia	100
Sulfuric acid	200
Phosphoric acid	50
Ammonium sulfate	150
Normal superphosphate	120
Triple superphosphate	120
Mixed fertilizers	

Table 32. Venezuela

Fertilizer Consumption[a] 1968/69				Projected Demand 1975[b]		
			1,000 ton/yr			
N	P_2O_5	K_2O		N	P_2O_5	K_2O
26	15	15		47	27	27
Existing Production Facilities						
Plant	Location		N	P_2O_5	K_2O	
Instituto Venezolano de Petroquimica	Moron		27 (AA) 8 (U), 17 (AS) 10 (ANL), 19 (M)	19 (M), 18 (NSP), 18 (TSP), 18 (WPA)	19 (M)	
(Under construction)						
Instituto Venezolano de Petroquimica	Moron		164 (AA) 111 (U), 26 (M)	90 (WPA) 84 (M)	17 (M)	
Total in operation and under construction			191 (AA), 119 (U), 17 (AS), 10 (ANL), 62 (M), 191 total solid	103 (M), 18 (NSP) 18 (TSP), 18 (WPA) 139 total solid	36 (M) 36 total solid	

[a]*FAO Monthly Bulletin of Agricultural Economics and Statistics* 19:2.
[b]Projected by TVA Team.

Moron Expansion—The Moron fertilizer complex is being expanded by construction of economically-sized units for production of ammonia, urea, sulfuric acid, wet-process phosphoric acid, and ammoniated mixed fertilizers based on granulation of ammonium phosphates with either potassium chloride or potassium sulfate. It is planned to utilize some byproduct sulfur from petroleum refining as feedstock in the sulfuric acid plant and to expand the output of the Riecito phosphate mine to supply rock phosphate for the complex. Capacities for the new units are listed below.

Type of plant	Production capacity tons/day
Ammonia	600
Urea	350
Sulfuric acid	1,300
Wet-process acid (as P_2O_5)	600
Granular mixed fertilizers	400

Raw Materials

The geology of Venezuela is relatively well known as compared with other Latin American countries. Potential raw materials for fertilizer manufacture include two minable phosphate deposits, natural gas, byproduct sulfur from petroleum refining, and volcanic sulfur.

Phosphate Rock–Moron Deposit—A phosphate deposit located in Falcon state and known as the Riecito Mine is reported to have about 13.9 million mt of minable ore with an average grade of 26.6% P_2O_5, 23.2% SiO_2, and 3.6% iron and aluminum oxides. The estimated recoverable tonnage of product is about 9.3 million mt with an average grade of 31.8% P_2O_5.

The phosphate deposit covers an area of an approximate length of 1,350 m and an average width of 400 m. Some material is now being mined and beneficiated by crushing and screening. The beneficiated product is utilized in the existing plant facilities at Moron.

A plan for mining up to 750,000 tons/yr of matrix to yield about 500,000 tons/yr of phosphate products is being evaluated. Open-pit mining utilizing portable drills, blasting, and mechanical shovels is planned. The mine product will be beneficiated by flotation and utilized in the expansion of the Moron production facilities.

Phosphate Rock–Labatera Deposit (Tachira State)—Several relatively small deposits have been identified in Tachira state. Probably the most significant of these deposits is located near La Molina where proven phosphate reserves are reported as 250,000 tons of ore of an average P_2O_5 content of about 21%. An average analysis of 10 core samples from this deposit was as follows:

Total P_2O_5 –	20.6%
CaO –	46.6%

An open-pit mine has been opened in the La Molina deposit, revealing a uniform phosphate seam with a 2-m depth. Some material is being extracted from the mine by hand methods and utilized locally. Data on rate and quantity of removal are not available.

Sulfur–Volcanic—Two volcanic sulfur deposits have been identified–near El Pilar in the state of Sucre and at Frais Matias near Puerto Piritu. The El Pilar deposit is probably the best known and most significant. No detailed survey of reserves exists, but estimates of reserves vary from ½ to 1 million tons of sulfur in ore containing 25-70% S with an average S content of about 50%. There was some exploitation of this deposit from 1884 to 1896 by a German company which selectively mined and shipped out high grade ore. No mining is being done at the present time.

Not much is known about the Frais Matias deposit. It was discovered in 1953 and reserves have been estimated as 1 million tons of ore containing 25% S.

Sulfur–Petroleum Products—Crude oils in the western part of Venezuela have a high sulfur content (2.2-2.8% S). The Creole refinery at Amuay is installing desulfurization equipment that should allow production of at least 300 tons/day of elemental sulfur (based on a 1.0% S content in fuel products). Shell is reported to be installing sulfur removal equipment at the Cordon refinery that will produce 100 tons/day of S.

Sulfur–Gypsum—Gypsum deposits on the peninsula of Paria are reported to have reserves of about 65,000,000 mt. This gypsum is presently being mined and utilized by the cement factory of Puerto la Cruz.

Potassium—There are no known deposits of potassium minerals of commercial value. There may be some potential for potash recovery from brines from the sea of Aroya in the state of Sucre. These brines are reported to contain 1.29% K.

APPENDIX

REPORT OF ADVANCE TVA TEAM TO CHILE

May 17 to 31, 1969

In July 1968 TVA was contacted by the Corporacion de Fomento (CORFO) requesting that TVA furnish technical help to CORFO in analyzing the fertilizer situation in Chile. CORFO recognized that fertilizers were one of the most important inputs in the development of Chilean agriculture and that expansion in their use as well as improvement in quality would be necessary. In light of this it was CORFO's concern to undertake a program that would, wherever possible and practical, encourage Chilean fertilizer manufacture to replace, in a large measure, the necessity for the import of large and continuing amounts of fertilizers.

General points to be covered would include:

1. Present and future production
2. Types of fertilizer adapted to the soils
3. New materials
4. Marketing and international competition
5. Future projections

Further exchange of correspondence led to the transmittal (Mario Sarquis, CORFO, to Donald McCune, TVA, Feburary 5, 1968) of a more detailed outline of proposed work for TVA's consideration and response.

At about this time TVA learned of another study that was being sponsored by the Banco del Estado as part of an AID loan. This study was understood to be covering certain aspects of the proposal by CORFO to TVA. At this time, TVA asked assurance that these two studies were neither in conflict nor a duplication of efforts. AID/Chile informed TVA that the two studies would be complementary and advised that an advance team come to Chile at AID expense to work out the scope of work, coordinate these efforts with the Banco del Estado study, determine the personnel that would be required, and to agree with CORFO on the timing of the study, the method of financing, and the type of report to be produced.

On May 18, 1969, Donald L. McCune, Agronomist and Director of the International Fertilizer Development Staff, TVA, and Charles H. Davis, Chemical Engineer, also of the International Fertilizer Development Staff, TVA, arrived in Chile as this advance team. This report spells out the scope of work, the timing, the method of financing, and as far as possible, the personnel requirements, and the cost to CORFO.

Upon arrival in Chile, and after conversations with various organizations including AID, CORFO, Banco del Estado, IANSA, the Kearney team (contractors for the Banco del Estado study), COSAF, IIAP, ODEPA, and others, it was obvious that the first part of the study—that was spelled out in the February 5, 1969, letter from CORFO to TVA—was, for the most part, being included in the study for the Banco del Estado. Assuming that the fertilizer consumption projections, the fertilizer retail information, the transport system, and the port information are adequately covered, TVA proposes to concentrate its efforts on the problems of supplying Chile's fertilizer needs to the point of the wholesale distributor.

TVA proposes to take the fertilizer demand figures of "The Study of Chile Fertilizer System" by Banco del Estado and work out alternative plans for supplying these fertilizers to determine the most economic system. The demand figures of Banco del Estado will be broken down into tons/year of N and P_2O_5 needed in each province or similar geographical subdivision for each year of the projection.

The Banco del Estado should suggest which fertilizer should be used, but TVA should have option to choose the most appropriate of the acceptable fertilizers TVA will utilize information from the Banco del Estado study as much as possible to minimize duplication of efforts.

Using the demand of the Banco del Estado study, TVA will investigate alternative plans for supplying the fertilizers to the dealers with suggestions as to which plans are preferable.

The study will compare the economics and technical feasibility of the various supply possibilities, such as importations of finished fertilizers, intermediates or local manufacture, carrying the fertilizer material to the wholesale outlets. The TVA study will include various feasible alternatives for supplying the fertilizers, showing probable capital investment costs, raw materials costs, production costs, and transportation and distribution costs. These costs will be broken down, whenever possible, into estimates giving the local currency and foreign exchange proportions.

Various plant processes and locations will be suggested. The Penco plant and any other available manufacturing facilities will be included. Chilean raw materials will be fully considered.

Once the economic and technical feasibility of the various alternatives have been evaluated it will then become the responsibility of CORFO or others to determine which alternatives are best for Chile. This study in no way attempts to evaluate the social and/or political impacts.

TVA suggests that Banco del Estado transmit the draft of "The Study of the Chilean Fertilizer System" to the TVA National Fertilizer Development Center as soon as it is available. (According to the Banco del Estado work plan, this draft is to be completed by the end of September 1969.) TVA will study the report draft, gather all necessary information and return to Chile to complete the study of the Chilean fertilizer supply system.

It is estimated that the TVA Team will remain in Chile for about 6 to 8 weeks. Before the TVA Team leaves Chile, a finished draft of their report will be submitted to CORFO for study and discussion The TVA Team will return to the United States to edit the draft and publish the report. This will require about an additional six weeks. The TVA Team will probably be made up of three persons, two chemical engineers and an agronomist-economist. The size of the TVA Team, and their length of stay in Chile will be somewhat dependent on the completeness of the Banco del Estado study. Based on a three-man TVA Team, spending 7 to 8 weeks in Chile and up to 4 weeks in the United States, the total maximum TVA cost is estimated at $34,000, including travel to and from Chile and per diem in Chile at U S Government standard levels. In addition, the equivalent of $2,500 in Escudos will be made available to the team leader to hire bilingual secretarial help and for interpreter and translator fees.

For support in doing their study, the TVA Team will require from CORFO office space and equipment, including a typewriter and desk top calculator, and transportation in Chile, including lodging on trips away from Santiago It is also desirable that CORFO make available a bilingual counterpart member of the team, preferably a chemical engineer The use of a counterpart team member should give CORFO a better understanding of the team's methodology and recommendations Also, the counterpart member would be very useful to the team in their gathering of data

The general outline of the fertilizer supply study TVA proposes is listed below It includes the principal points of the proposed second phase (Fertilizer Supply Study) listed in the letter from Mario Sarquis of CORFO to Donald L. McCune of TVA, dated February 5, 1969. As Mr. Sarquis suggested, the study will be done in the depth appropriate to a preliminary study and will not include descriptions, flow sheets, production rates, raw materials requirements, cost information, etc.

OUTLINE

I. Statement of Demand, Giving Types and Quantities of Fertilizers Required in Each Province
   This will be largely a restatement of data from the Banco del Estado study, but it may be necessary to project demand figures more than five years.
II. Study of Raw Materials and/or Intermediates, Availability and Costs
   A. Nitrogen
   B. Phosphorus
   C. Sulfur
   D. Potassium
III. Study of Production
   A. Possible products
   B. Plant location and capacities
   C. Discussion of processes
   D. Raw materials and utilities requirements
   E. Costs (foreign and domestic)
      1. Investment
      2. Production
IV. Study of Importation
   A. Materials and quantities
   B. Ports of entry
   C. Costs
   D. Discussion of probable trends in world market fertilizer prices
V. Comparison of Costs to Wholesale Outlets Including Transport and Handling by Various Alternatives of Importation and Production, Including Both Domestic and Foreign Costs
VI. Conclusions and Recommendations
   Listing the most feasible alternatives from an economic and technical standpoint, taking into account probable effects of new developments in fertilizer technology and probable future trends in products, processes, and costs. Social and/or political aspects of the various alternatives will not be considered in this study.

The advance TVA Team has studied the outlines of the Banco del Estado "Study of Distribution of Fertilizers in Chile" and is of the opinion that it covers practically all the topics of interest on the demand and marketing side. However, the TVA Team suggests that information regarding the taxes and duties on the importation and sale of various fertilizers and also information about the physical facilities and costs for sulfuric acid transport be added to the Banco-sponsored study. TVA also requests that the drafts of the various sections of the Banco-sponsored study be transmitted in English to them as they are completed.

Method of Payment

TVA will be reimbursed for actual salaries and benefits and expenses incurred in this study plus a 25% overhead charge[10]—up to an agreed upon amount of dollars. Since TVA's charter required that work be done through other agencies it is recommended that the agreed upon amount of money be made available to AID/Chile who will, through a normal Participating Agency Service Agreement, arrange for TVA's participation and will reimburse TVA as the work is completed.

[10]Overhead will not be applicable to the cost of the international airline tickets.

BUDGET BREAKDOWN ($)

Team Leader	3 months	8,285[a]
Chemical Engineer	3 months	7,043
Chemical Engineer	3 months	7,043
Per diem (at approved U. S. Government rates) including taxi fares while in travel status and while in Chile		2,000
Supplies and materials (including up to 50 copies of final report)		1,229
Subtotal		25,600
Overhead at 25%		6,400
Subtotal		32,000
International airfares		2,000
Total	Total	34,000

ESCUDOS EQUIVALENTS

Bilingual secretarial help	1 250
Translator and interpreter help	1 250
Estimated Social Security and taxes 40%	1,000
Total	3,500

[a]Salaries and benefits are only estimates pending salary adjustments due July 1, 1969