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RECOMMENDATIONS FOR MANUFACTURE - DISTRIBUTION OF AGRICULTURAL MINERALS IN BRAZIL

AGRI RESEARCH, INC.
Manhattan, Kansas

and

LITWIN ENGINEERING COMPANY, INC.
Wichita, Kansas

1964

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MANHATTAN, KANSAS

agri RESEARCH, INC. P.O. BOX 727, MANHATTAN, KANSAS 66503

RECOMMENDATIONS FOR THE MANUFACTURE AND DISTRIBUTION OF FERTILIZERS, AGRICULTURAL LIMESTONE AND LIVESTOCK MINERALS IN BRAZIL

Agri Research, Inc.
Manhattan, Kansas

and

Litwin Engineering Company, Inc.
Wichita, Kansas

Subsidiary of Dunlap and Associates, Inc., Darien, Connecticut

RECOMMENDATIONS FOR THE MANUFACTURE AND DISTRIBUTION OF FERTILIZERS, AGRICULTURAL LIMESTONE AND LIVESTOCK MINERALS IN BRAZIL

A Report to

The Ministry of Agriculture
Government of Brazil

and

Office of Agriculture and Rural Development
USAID/Brazil

Contract la-152
1964

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PREFACE

This report supplements the report "Economic and Technical Feasibility of Increased Manufacture and Use of Fertilizers, Agricultural Limestone and Livestock Minerals in Brazil" published by Agri Research, Inc. under AID contract la-152, 1964. This report emphasizes fertilizer raw materials, product distribution and particularly the processing plant facilities necessary to manufacture required fertilizers, agricultural limestone and livestock minerals.

Since the original report provides considerable background information on the fertilizer, agricultural limestone and livestock mineral situation in Brazil, the efforts in this report are aimed at specific recommendations. For a more complete understanding of the agricultural minerals situation in Brazil, the original report should be consulted.

The objectives of this report are as follows:

1. To recommend possible means and facilities for supplying present and estimated future demands for fertilizers, limestone and livestock minerals.
2. To recommend locations for required facilities and types of plants.
3. Provide preliminary engineering drawings, and estimated investment and operating costs for various types of fertilizer plants.

SUMMARY

In order for Brazil to maintain or increase present domestic consumption and exports of agricultural products, food and fiber production must be increased. Improvement in quality of Brazilian diets is needed, and increased exports are necessary to finance economic development of the country. These goals all require increases in agricultural production. Although Brazil has vast areas of virgin land, soils in such areas are generally unproductive and require fertilizer and lime for profitable production.

Demand Requirements for Fertilizers

Fertilizer demand requirements for Brazil were estimated for the period 1965-1980 for three geo-economic regions -- North-Northeast, Central and South. The projections for each region were based primarily on a continuation of historical trends. However, in some cases the projections were modified to account for factors which would tend to restrict or accelerate fertilizer consumption.

Table 1 shows estimates of fertilizer consumption by five-year intervals from 1965 to 1980. Nitrogen consumption in Brazil is expected to increase from 96,000 tons in 1965 to over 600,000 tons by 1980. Consumption of P_2O_5 is expected to increase from 196,000 tons to over 600,000 tons during the same period. Demand for K_2O is

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Table 1. Estimated consumption of fertilizer by region of Brazil, 1965 to 1980
(Metric tons)

	Nitrogen (N)			
Year	North[1/]	Central[2/]	South[3/]	Brazil
1965	5,600	78,000	12,500	96,100
1970	7,500	157,000	24,900	189,400
1975	12,000	289,200	47,900	349,100
1980	24,100	509,800	88,300	622,200

	Phosphate (P_2O_5)			
Year	North	Central	South	Brazil
1965	16,800	128,000	51,900	196,700
1970	25,600	183,800	76,200	285,600
1975	38,900	263,900	112,000	414,900
1980	59,300	378,800	164,600	602,700

	Potash (K_2O)			
Year	North	Central	South	Brazil
1965	9,100	97,600	20,000	126,700
1970	13,400	173,000	36,900	223,300
1975	21,600	291,600	65,000	378,200
1980	38,100	469,600	109,500	617,200

1/ The North includes the states of Bahia, Sergipe, Alagoas, Pernambuco, Paraiba, Rio Grande do Norte, Cera, Maranhao, Northern Para and the northern two-thirds of Goias.

2/ The Central includes the states of Minas Gerias, Espirito Santo, Rio de Janeiro, Parana, Sao Paulo and southern Goias.

3/ The South includes the states of Rio Grande do Sul and Santa Catarina.

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estimated to increase from 126,000 tons to about 617,000 tons.

Recommended Fertilizer Facilities

North-Northeast

The following fertilizer plants, to be located in Recife, are recommended to supply fertilizer for the North-Northeast.

2,000 lb. tons	Estimated Investment
One, anhydrous ammonia storage vessel (12,000 tons)	$1,200,000
One, nitric acid plant (150 T/D)	1,500,000
One, ammonium nitrate prilling and solutions plant (150 T/D)	1,200,000
One, sulfuric acid plant (200 T/D)	900,000
One, normal superphosphate plant (400 T/D)	1,400,000
One, granulation plant (200 T/D)	800,000
Total	U.S.$7,000,000

Total investment for this combined fertilizer facility is estimated to be U.S.$7 million, of which an estimated U.S.$2 million will require foreign exchange.

The recommended plants and storage should be located as near as possible to the present port facilities in Recife, or at a port site developed specifically for this complex. These plants would operate on imported anhydrous ammonia, sulfur and potassium chloride and

on phosphate rock from Fosforita Olinda.

The plants specified, together with existing fertilizer plants would provide an annual production of 30,000 tons of P_2O_5, 26,000 tons of nitrogen and 25,000 tons of K_2O for use in the North-Northeast. These quantities of N, P_2O_5 and K_2O, based on consumption estimates, are sufficient to supply this area through 1970.

It is estimated that the recommended facility could provide foreign exchange savings of over U.S.$8,000,000 annually.

Central

Sao Paulo, Brazil's most highly industrialized city and centrally located with respect to its major agricultural area, is ideally situated for a major fertilizer complex. The following fertilizer plants are recommended to be located at a port site as near to Sao Paulo as possible.

2,000 lb. tons	Estimated Investment
Two, 12,000 ton atmospheric anhydrous ammonia storage vessels	$2,200,000
Unloading and storage facilities for phosphate rock, sulfur and potash	1,000,000
One, 300 ton per day nitric acid and ammonium nitrate plant	4,200,000
One, 300 ton per day phosphoric acid plant	2,700,000
One, 200 ton per day normal superphosphate plant	800,000

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2,000 lb. tons	Estimated Investment
One, 500 ton per day sulfuric acid plant	$1,800,000
One, 300 ton per day triple superphosphate plant	2,000,000
One, 25 ton per hour high-analysis granulation plant equipped with pre-neutralization for manufacture of diammonium phosphate	1,400,000
Total	U.S.$16,000,000

Total estimated investment for this fertilizer complex is U.S. $16,000,000 not including dock facilities, of which an estimated U.S. $4,500,000 will be required in foreign exchange.

The recommended plants will operate on imported anhydrous ammonia, phosphate rock, sulfur and potassium chloride. These plants, together with existing and planned fertilizer plants in the Central region, will provide sufficient N, P_2O_5, and K_2O to meet annual demand estimates through 1970.

It is estimated that this fertilizer complex could permit foreign exchange savings of as much as U.S.$19 million annually compared to importing an equivalent amount of manufactured fertilizers.

South

The largest irrigated rice producing area in Brazil is located in this region. Because of the desirability of using an ammonical form of nitrogen on irrigated rice, we recommend that a 100-125 ton per

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day anhydrous ammonia plant and a 150 ton per day urea plant be erected near the Ipiranga refinery at Rio Grande. These plants will provide sufficient nitrogen, based on estimated future consumption, to meet demands for nitrogen (24,900 tons) in Rio Grande do Sul and Santa Catarina through 1970.

Also recommended for the Southern region is a 400 ton per day normal superphosphate plant and a 350 ton per day triple superphosphate plant to operate on imported phosphate rock. These plants will provide approximately 72,200 metric tons of P_2O_5.

The recommended plants and estimated investments are as follows:

2,000 lb. tons	Estimated Investment
One, anhydrous ammonia plant (125 T/D)	$ 4,200,000
One, urea plant (150 T/D)	2,500,000
One, sulfuric acid plant (300 T/D)	1,200,000
One, phosphoric acid plant (150 T/D)	1,500,000
One, normal superphosphate plant (400 T/D)	1,400,000
One, triple superphosphate plant (350 T/D)	2,300,000
Total	U.S.$13,100,000

It is estimated that the recommended plants could provide potential foreign exchange savings of U.S.$8,700,000 compared to the cost of importing an equivalent amount of manufactured fertilizers.

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A summary of estimated total investment and potential foreign exchange savings for each region is shown in Table 2.

Table 2. Total estimated investment required for the recommended fertilizer plants and estimated resulting foreign exchange savings for Brazil.

	Estimated Investment			Estimated Annual Foreign Exchange Savings[1]
	Local Currency	Foreign Exchange	Total	
	(U.S.$)	(U.S.$)	(U.S.$)	(U.S.$)
North-Northeast	$ 5,000,000	$ 2,000,000	$ 7,000,000	$ 8,000,000
Central	11,500,000	4,500,000	16,000,000	19,000,000
South	9,100,000	4,000,000	13,100,000	8,700,000
Brazil	$25,600,000	$10,500,000	$36,100,000	$35,700,000

[1] The estimates of foreign exchange savings represent the difference between costs of manufacturing fertilizers in Brazil with the recommended plants as compared to the cost of importing manufactured fertilizers.

Assuming estimated fertilizer requirements and sufficient investment capital, the recommended plants should be on stream by 1970 for Brazil to minimize foreign exchange expenditures. The plants recommended for the Central region should receive first priority and be erected as soon as possible. The Central region has a history of relatively high fertilizer consumption so the presence of abundant, relatively inexpensive fertilizer could act as a stimulus to increased use. Initially, excess production could be shipped to the Southern region.

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The plants recommended for the South should also be constructed as soon as possible, particularly the ammonia and urea plants. The phosphate fertilizer plants could be postponed until 1969 or 1970 if the plants in the Central region are on stream in the near future.

Although the Northeast needs more and less-expensive fertilizer, the facilities for the Central and South should receive first priority, particularly if funds are limited. The low level of demand in the Northeast dictates the construction of plants of a minimum economic capacity. This makes the plants recommended for the Northeast relatively less attractive from the view point of private investment. However, if consumption estimates are realized, the recommended plants could operate at or near capacity by 1970.

No attempt has been made to recommend fertilizer plants for construction beyond 1970 even though fertilizer demand estimates were made through 1980. The plants that have been recommended can be expanded or duplicated if necessary. However, with the potential sources of phosphate and raw materials for the manufacture of nitrogen in Brazil, it would be to Brazil's advantage if these sources could be utilized. The speed at which these potential sources are developed and the cost of the raw materials will determine if and when they can be used. The potential sources of fertilizer raw materials should be evaluated continuously to determine the economics of their use relative to imported raw materials.

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Agricultural Limestone Requirements

Many of the agricultural soils in Brazil are acid. In order to increase crop yields and to permit the maximum response from the application of fertilizers agricultural limestone is required. Although very little agricultural limestone has been produced or used in the past, (an estimated 250,000 tons in 1963), more farmers are beginning to recognize its value.

It is estimated that at least 10 million hectares of cropland in 1963 were so acid as to need limestone. To raise the pH by 1.0, for example from 4.5 to 5.5, on the acid soils of Brazil, would require approximately three tons of limestone per hectare. On ten million hectares, 30 million tons would be required. If this amount was applied every eight years, 3,700,000 tons of limestone would be required per year. This is 15 times the current production of agricultural limestone in Brazil.

In view of the importance attached to the correction of acid soils in Brazil, the production of at least 3,700,000 tons of agricultural limestone per year should be adopted as a goal to be reached through a 25 percent increase per year over a 12 year period.

Future investment in and expansion of the agricultural limestone industry should be done, insofar as possible, with portable plants. The initial investment and operating costs for a portable plant are less

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than for a stationary plant of equal capacity. Besides producing a less expensive product, portable plants permit reduced transportation costs.

In order to reach 3,700,000 tons of agricultural limestone production by 1976, a total of 42 plants with daily capacities of 550 metric tons each will be required. Based on the type of stripping operations undertaken, total investment would be approximately U.S.$16 million. Plants of the size recommended would permit, again depending on the type of stripping operation, production costs ranging from U.S.$1.18 to $1.75 per ton.

Livestock Mineral Requirements

Very little is known in Brazil about the specific needs for livestock minerals. However, from the information that is available, it appears that there is a general need for phosphorous, calcium and salt and, in specific areas, a need for trace minerals such as zinc, iron, copper, iodine and cobalt.

Feeding experiments that have been conducted by U.S. and Brazilian nutritional advisors show excellent results from the feeding of phosphorous and calcium.

It is estimated that one million tons of calcium and 764,000 tons of phosphorous will be required for livestock and poultry production in 1970. On the basis of the general evidence available, it is

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recommended that enough calcium and phosphorous be produced in Brazil by 1970 to meet at least five percent of the annual requirements for these two minerals for cattle, sheep and goats. It is assumed that very little calcium or phosphorous will be fed to horses. With most of the bones available for processing into animal feed presently being incorporated into tankage, swine and poultry in some areas of Brazil are probably receiving reasonably adequate supplies of calcium and phosphorous at the present time. Based on these assumptions, approximately 23,900 tons of calcium and 20,100 tons of phosphorous will be required by 1970 to supply five percent of the cattle and sheep requirements. Both of these minerals can be supplied in supplemental form from either steamed bonemeal or defluorinated tricalcium phosphate.

The manufacture and use of defluorinated tricalcium phosphate appears to be the most feasible means for supplying feed phosphate and calcium in Brazil at the present time. This material can be produced from normal superphosphate by a simple calcination step. The process is easily operated, the product has been proven to be an excellent source of phosphorous and calcium for animals and the equipment can be manufactured in Brazil.

To meet the suggested 1970 production goal of 23,900 tons of calcium and 20,100 tons of phosphorous, eight plants producing 18,000 tons of defluorinated superphosphate per year will be required. These

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plants will require a total estimated investment of U.S. $4.3 million. Plants of the size recommended would permit production costs of U.S. $64.45 per ton of material, not including profit.

There does not appear to be any serious shortage of salt in Brazil. If salt production continues to increase at the same annual rate as it has in the past, sufficient salt will be available to meet the effective demand for both livestock and the human population.

No attempt has been made in this study to analyze the need for or to make recommendations for trace minerals. Information on the problem of trace mineral deficiencies is not sufficient to make reasonable recommendations for specific problem areas. Research should be intensified, particularly in areas of the country where trace mineral deficiencies are suspected. Until more information is available, farm supply firms located in suspected deficient areas should be encouraged to import trace minerals for mixing with other livestock and poultry feeds.

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INTRODUCTION

Historically, agricultural crop production in Brazil has been increased mainly by expanding the cultivated acreage. Cultivated area in Brazil increased from 19 million hectares in 1950 to about 30 million hectares in 1963. It is estimated that the cultivated area will increase to approximately 48 million hectares by 1980.

Fertilizer consumption in Brazil has been limited, particularly before 1950. Although the total volume of fertilizer used is still quite small compared to the cultivated area, the use of fertilizers has increased rapidly since 1950. This increase in fertilizer consumption, however, has been confined almost entirely to the South and Central regions of the country. The volume of fertilizer used in the Northern two-thirds of the country is small. Consumption of fertilizers in Brazil by region for the period 1953-1963 is shown in Table 3.

The population of Brazil is expected to increase from 71 million people in 1960 to about 128 million people by 1980. In order to meet the food requirements for this rapidly increasing population and to maintain or increase the production of export products such as coffee, cocoa and sugar, agricultural production must increase substantially.

Excluding importation, there are two possible means of obtaining the additional production -- (1) by increasing the area of cultivated cropland and/or (2) increasing agricultural productivity using

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Table 3. Apparent consumption of fertilizer in Brazil by region, 1953-1963
(Tons of element)

	Nitrogen (N)				Phosphate (P_2O_5)				Potash (K_2O)			
Year	North[1/]	Central[2/]	South[3/]	Total	North	Central	South	Total	North	Central	South	Total
1953	3,449	15,366	1,766	20,581	5,402	35,273	18,542	59,217	4,789	23,770	2,667	31,226
1954	2,329	13,004	2,432	17,765	5,670	40,311	24,242	70,223	2,773	22,329	3,247	28,349
1955	3,642	16,808	2,500	22,950	7,666	55,594	17,710	80,970	4,683	38,864	5,976	49,523
1956	2,631	22,212	5,398	30,241	6,824	53,099	25,381	85,304	4,461	30,757	6,414	41,632
1957	5,064	18,955	4,537	28,556	9,495	72,413	36,784	118,692	5,521	44,722	9,947	60,190
1958	4,624	28,739	8,036	41,399	11,468	87,453	44,427	143,348	5,282	45,134	14,606	65,022
1959	3,392	35,020	6,371	44,783	13,640	70,703	39,661	124,004	4,634	43,918	8,874	57,426
1960	4,943	55,333	6,483	66,759	13,159	77,644	40,789	131,592	5,725	87,315	13,056	106,096
1961	3,008	45,768	6,287	55,063	10,689	85,510	22,568	118,767	5,471	55,716	9,539	70,726
1962	5,208	40,775	6,912	52,895	12,098	88,119	21,992	122,209	7,130	54,352	8,846	70,328
1963	5,629	52,942	7,514	66,085	11,091	98,355	28,793	138,239	10,625	77,045	13,512	101,182

1/ The North includes the states of Bahia, Sergipe, Alagoas, Pernambuco, Paraiba, Rio Grande do Norte, Ceara, Maranhao, northern Para and the northern two-thirds of Goias.

2/ The Central includes the states of Minas Gerias, Espirito Santo, Rio de Janeiro, Parana, Sao Paulo and southern Goias.

3/ The South includes the state of Rio Grande do Sul and Santa Catarina.

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fertilizers and other modern farming practices.

Although Brazil has large areas of land that could be brought into agricultural production at a cost and over time, there are problems associated with this approach that make rapid expansion of agricultural land in the short-run unlikely.

1. Land available for new agricultural development is available only in locations quite removed from present agricultural development and population centers. In the South and South-Central regions there is limited undeveloped fertile land remaining that is suited for mechanized agriculture.
2. Although the soils in the various regions vary, the general low level of fertility and relatively high acidity of the undeveloped areas will require the immediate use of fertilizers and limestone.
3. The increased distance of new areas from present population centers, coupled with a lack of transportation facilities, will increase the costs of bringing land into production, raise the cost of production requisites and increase costs of marketing agricultural products.

The second alternative, increased productivity on existing land, involves the upgrading of all farming techniques, with increased

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fertilization being the most important. Usually, increased fertilization is the most efficient means to increased production, particularly if existing levels of fertilization are low and if the newly developed areas need to be fertilized initially in order to obtain a reasonable level of production.

Although the increased use of fertilizers will give the most rapid and efficient increase in food and fiber production in Brazil, there are a number of economic, social and institutional factors that, unless corrected, will continue to restrict the use of fertilizers.

The major factors include:

1. A generally unfavorable relationship between the price of fertilizers and the price of agricultural products.
2. A general lack of readily available credit for agricultural production.
3. The small farm size and relatively low level of farm mechanization. High levels of fertilization do not fit well with the man-powered agriculture existing in many areas of Brazil.
4. The lack of efficient transportation systems and facilities.
5. The lack of facilities for the marketing and processing of agricultural products.

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6. The shortage of foreign exchange available for the importation of fertilizers.
7. The general lack of fertilizer sales services, both educational and physical.
8. The general lack of good fertilizer experimental work and production functions to help determine how much fertilizer to use in given situations and when to apply it.

Undoubtedly, future increases in agricultural production will be obtained by a combination of increased fertilization and expansion of cultivated land. Which of the two methods will contribute the most to production will depend largely on how fast the restrictions to fertilizer use are modified or eliminated.

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NITROGEN

The apparent consumption of nitrogen fertilizers in Brazil increased from 20,581 tons in 1953 to over 66,000 tons in 1963. The average annual rate of increase during this period was 14.45 percent.[1/] Although projecting total Brazilian fertilizer consumption is helpful in industry planning, projecting consumption by geo-economic regions is more useful, particularly since there are wide variations in the level of agricultural technology within Brazil.

Since fertilizer sales data are not generally available by state, fertilizer consumption was projected for three broad regions, North-Northeast, Central and South.[2/] The apparent fertilizer consumption for each region was derived by adding domestic production and imports for each region.

Because of the transportation patterns and various other characteristics of each of the regions, inter-regional shipments of fertilizers will not materially affect the consumption estimates for the individual regions. An exception is rock phosphate shipped from Recife in the

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1/ The rate of increase used for projection purposes in the original report was 12.5 percent. That rate was calculated by using the two end point values only. The 14.45 percent rate of increase was derived by using all the data between 1953 and 1963.

2/ Op. cit. Table 3, p. 15.

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Northeast to the Central and Southern regions. In developing consumption data, shipments of phosphate from the Northeast to the other two regions were taken into consideration.

Figure 1 shows the historical and projected trends in consumption of nitrogen fertilizer for each region. Table 4 shows the projected volumes of nitrogen consumption for five-year intervals from 1965 to 1980. Table 5 shows the rates of increase used to obtain the consumption estimates for each region.

As can be observed, the rate of growth in nitrogen consumption for the North-Northeast was increased from 1970 to 1980 compared to previous years because of the present relatively low level of use. However, the rate of growth will probably not increase appreciably until nitrogen fertilizer becomes more readily available and less expensive at the farm. It was assumed that a nitrogen fertilizer facility will have been constructed in the Northeast by 1970 so that fertilizer can be made more readily available and at a lower price.

It is believed that nitrogen consumption in the Central and South will continue to increase but at a slower rate than in the past. This will be due to the restraints to fertilizer use mentioned earlier in this report. However, even at the slower rates of increase shown in Table 3, the ratio of N to P and K will exceed a 1:1:1 relationship by 1980.

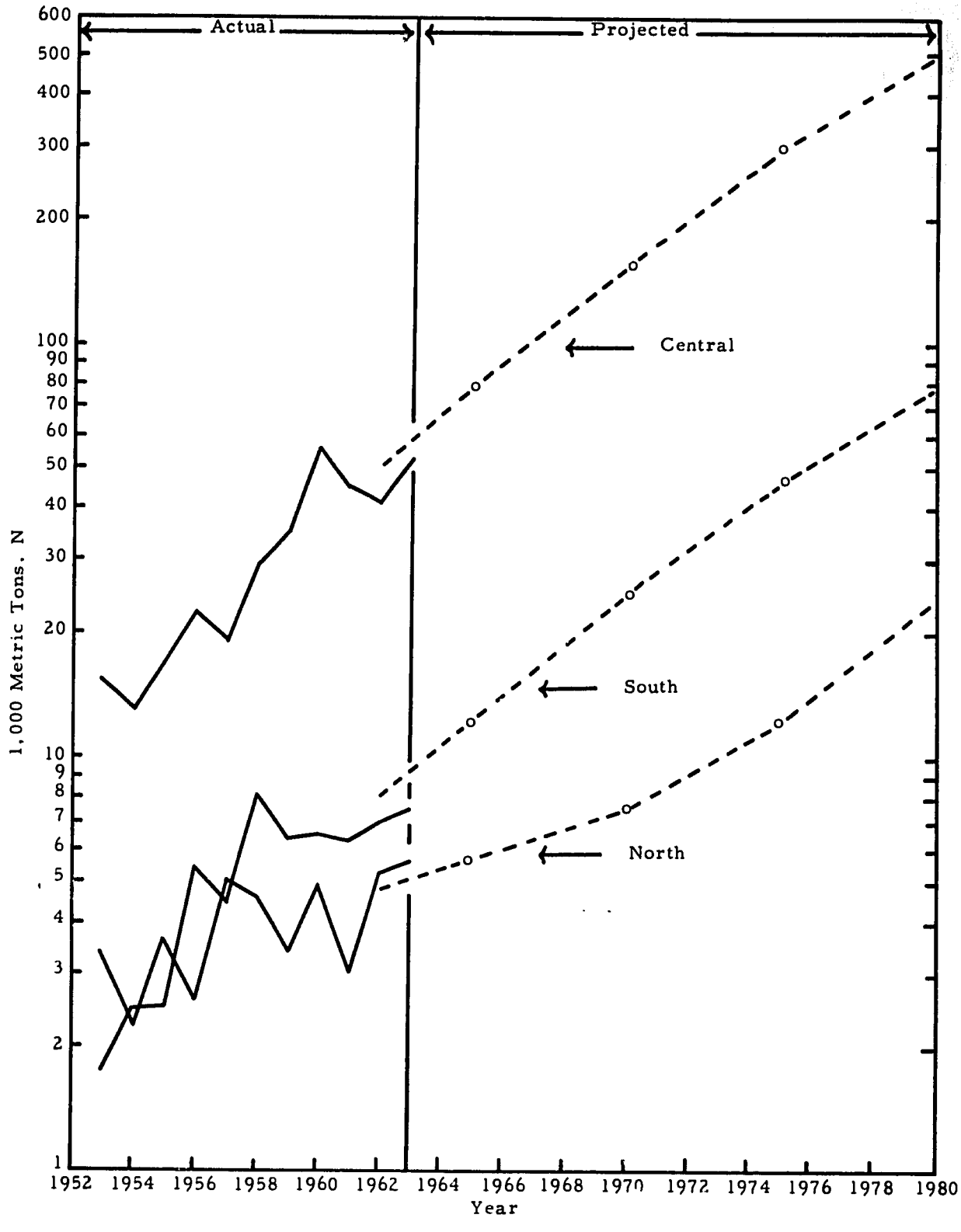

Figure 1. Apparent consumption of nitrogen fertilizers by region of Brazil, 1953-1963, with projections to 1980

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Table 4. Estimated consumption of nitrogen fertilizer for Brazil by region, 1965-1980
(Metric tons)

Year	Region			
	North-Northeast	Central	South	Brazil
1965	5,600	78,000	12,500	96,100
1970	7,500	157,000	24,900	189,400
1975	12,000	289,200	47,900	349,100
1980	24,100	509,800	88,300	622,200

Table 5. Historical and estimated rates of increase in nitrogen consumption for Brazil by region, 1953-1980

Year	Region		
	North-Northeast (percent)	Central (percent)	South (percent)
1953-63	5.0	15.8	14.8
1964-70	5.0	15.0	15.0
1971-75	10.0	13.0	14.0
1976-80	15.0	12.0	13.0

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The estimated cultivated area in Brazil, as previously noted, is expected to increase from 30 million hectares in 1963 to about 48 million hectares in 1980. Should Brazil reach both the cropped land area and the level of nitrogen fertilizer consumption projected for 1980, the average application rate would be 13.0 kilograms of N per hectare of cultivated land. This compares to an average application rate in 1963 of only 2.0 kilograms per hectare. By 1980, the application rate per hectare should be 22.0 kilograms in the Central region, 14.0 kilograms in the South and 1.5 kilograms in the North-Northeast.

Present Nitrogen Production Facilities

The nitrogen fertilizer production industry in Brazil is presently quite small, consisting of only three firms. Two of these firms are steel companies, Cia, Siderurgica National (CSN) and Usiminas, both of which produce small quantities of ammonium sulfate from coke oven gases. The other company is Petrobras which produces anhydrous ammonia and ammonium nitrate limestone from refinery off-gases at Cubatao. The CSN plant is located at Volta Redonda and the Usiminas plant is located at Belo Horizonte.

Table 6 shows Brazilian nitrogen production in 1963. The 13,448 tons of nitrogen fertilizer produced represented only 20.5 percent of the total consumption of nitrogen fertilizer in that year.

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Table 6. Brazilian nitrogen fertilizer production, 1963

Company	Tons product	Tons N
Petrobras - Cubatao	56,000 ANL[1]	11,480[3]
CSN - Volta Redonda	7,200 AS[2]	1,476
Usiminas - Belo Horizonte	2,400 AS	492
	65,600	13,448

1/ Ammonium nitrate limestone.
2/ Ammonium sulfate.
3/ Total N production for Petrobras was 14,950 tons with 3,470 tons going for non-fertilizer uses.

With the present production capacity, and an estimated demand by 1970 for 189,400 tons of nitrogen, Brazil will need to import 175,950 tons of nitrogen for fertilizer. The North-Northeast and South will need to import their entire requirements since all of the present production facilities are located in the Central region. By 1970, if the entire nitrogen deficit were to be imported, the cost in foreign exchange would be about U.S. $57.2 million.[1/]

There are several methods whereby Brazil could reduce the foreign exchange cost and at the same time become self-sufficient in nitrogen production. The possible means to self-sufficiency in nitrogen fertilizer production are presented in the recommendations section of this report.

1/ Based on the average CIF price of U.S. $43.00 for ammonium sulfate in 1963.

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PHOSPHATE

The estimated consumption of phosphate fertilizers in Brazil increased from 59,217 tons of P_2O_5 in 1953 to 138,239 tons of P_2O_5 in 1963. The average annual rate of growth in use of phosphate during this period was 8.0 percent. As in the case of nitrogen, phosphate consumption in Brazil was analyzed by three broad regions, North-Northeast, Central and South.[1/] The consumption in each region was derived by adding together domestic production of P_2O_5 and imports for each region. In the case of domestic production, the volume of P_2O_5 shipped from Fosforita Olinda in the Northeast to the other two regions was considered in deriving consumption for each region. Aside from the shipments from Fosforita Olinda to the other regions, inter-regional shipments of phosphate are not sufficient to affect the consumption estimates for the individual regions.

Figure 2 shows the historical and projected trends in consumption of phosphate fertilizer for each region. Table 7 shows the projected volumes by five-year intervals from 1965 to 1980.

1/ Op. cit. Table 3, p. 15.

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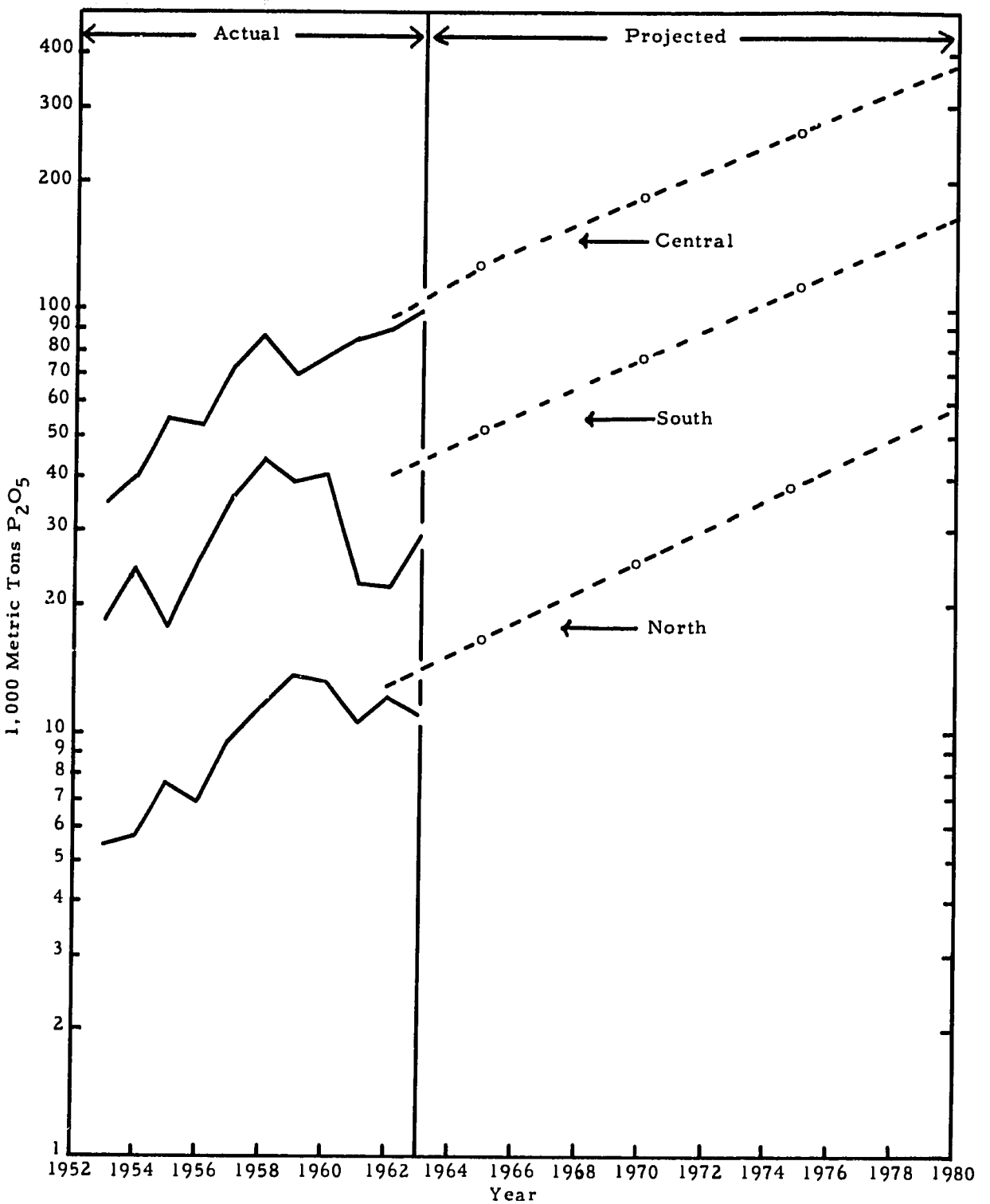

Figure 2. Apparent consumption of phosphate fertilizers by region of Brazil, 1953-1963, with projections to 1980

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Table 7. Estimated consumption of phosphate fertilizer for Brazil by region, 1965-1980, (Metric tons)

	Region			
Year	North-Northeast	Central	South	Brazil
1965	16,800	128,000	51,900	196,700
1970	25,600	183,800	76,200	285,600
1975	38,900	263,900	112,000	414,900
1980	59,300	378,800	164,600	602,700

Table 8 shows the rates of increase used to obtain the consumption estimates for each region. It is expected that phosphate consumption in the North-Northeast will continue to increase at about the same rate as has been experienced in the past. Although the present level of P_2O_5 consumption is low, it is about three times as great as the consumption of N and K_2O. As the level of fertilization increases, a larger percentage of fertilizer expenditures will be spent on nitrogen.

Consumption of phosphate fertilizer in the South is expected to increase at the 1953-1963 historical rate until 1980.

In the Central region the consumption of phosphate fertilizer is expected to increase at a slower rate than in the past. This will be due partly to the restraints to fertilizer use mentioned earlier in this report and partly to a shift in total fertilizer expenditures to nitrogen to bring nitrogen and phosphate consumption into a more practical balance.

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Table 8. Historical and estimated rates of increase in phosphate consumption for Brazil by region, 1953-1980

Year	Region		
	North-Northeast	Central	South
	(Percent)	(Percent)	(Percent)
1953-63	8.7	9.8	7.8
1964-70	8.7	7.5	8.0
1971-75	8.7	7.5	8.0
1976-80	8.7	7.5	8.0

Should Brazil reach both the cropped land area and the level of phosphate fertilizer consumption projected for 1980, the average application will be 12.5 kilograms of P_2O_5 per hectare of cultivated land. This compares with an average application rate in 1963 of 4.2 kilograms per hectare. By 1980, the application rate per hectare should be 16.0 kilograms in the Central region, 26.0 kilograms in the South and 3.0 kilograms in the North-Northeast.

Present Phosphate Production Facilities

The phosphate fertilizer industry in Brazil is presently the largest and has the greatest potential of the three major fertilizer materials. There are four companies producing phosphate rock in Brazil. These companies are Fosforita Olinda, Companhia Agricola de Minas Gerais S/A,

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(CAMIG), Quimbrasil and Serrote.

Table 9 shows the phosphate rock production of these companies in 1963. The 42,650 tons of P_2O_5 produced was about 30 percent of the total P_2O_5 consumed in Brazil in 1963.

Table 9. Phosphate rock production in Brazil, 1963

Company	Location	Tons rock	Tons P_2O_5
Fosforita Olinda	Recife	60,000	17,100
CAMIG	Araxa	30,000	8,700
Quimbrasil	Jacupiranga	38,000	13,600
Serrote	Juquia	11,500	3,250
Total		139,500	42,650

The rock phosphate plant capacity is greater than actual output figures would indicate. The designed capacity of the Fosforita Olinda is 240,000 to 250,000 tons of rock phosphate per year. However, due to transportation and marketing problems, the plant has never operated anywhere near capacity.

The Quimbrasil plant has a capacity of over 100,000 tons of rock phosphate per year. The major problem at this location in recent years has been the depletion of reserves.

The CAMIG plant has an annual capacity of 60,000 tons of phosphate rock. The market for Araxa rock, however, is limited due to

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the high iron content which makes it unsuited for acidulation. The present production is applied directly on the soil as rock phosphate.

It is estimated that the Serrote facilities could provide as much as 70,000 tons of phosphate rock per year.

At the present time, the only soluble P_2O_5 produced in Brazil is normal superphosphate. The estimated production of normal superphosphate in 1964 was as follows:

Table 10. Estimated production of normal superphosphate in Brazil, 1964

Company	Location	Tons NSP	Tons P_2O_5
Quimbrasil	Sao Paulo	220,000	45,000
Superfosfatos	Sao Paulo	80,000	16,400
Elekeiroz	Sao Paulo	45,000	9,200
Ferticap[1/]	Sao Paulo	15,000	3,000
CRA	Porto Alegre	20,000	4,100
ICISA	Rio Grande	18,000	3,600
Profertil	Recife	12,100	2,400
Total		410,100	83,700

[1/] New plant started in July, 1964.

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Assuming a total demand for P_2O_5 of 210,000 tons by 1970, and present rock phosphate production levels, Brazil will need to import 167,350 tons of P_2O_5 for fertilizer. However, with recent developments at Quimbrasil and the unused capacity at Fosforita, plus other potential phosphate deposits, Brazil could be almost self-sufficient in phosphate rock suitable for acidulation by 1970.

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POTASH

There is no production of potash in Brazil and the country is dependent upon imports for all potash fertilizer requirements. Potash fertilizer imports in 1963 amounted to 101,180 metric tons of K_2O compared to 31,226 metric tons in 1953. The average annual rate of increase in use of K_2O during this period was 12.0 percent.

Since there is no production of potash fertilizers in Brazil, imports into each of the regions were considered to be equal to consumption.

Figure 3 shows the historical and projected trends in potash fertilizer consumption for each region. Table 11 shows the projected volumes for five-year intervals from 1965 to 1980.

Table 11. Estimated consumption of potash fertilizer for Brazil by region, 1965-1980, (Metric tons)

	Region			
Year	North-Northeast	Central	South	Brazil
1965	9,100	97,600	20,000	126,700
1970	13,400	173,000	36,900	223,300
1975	21,600	291,600	65,000	375,200
1980	38,100	469,600	109,500	617,200

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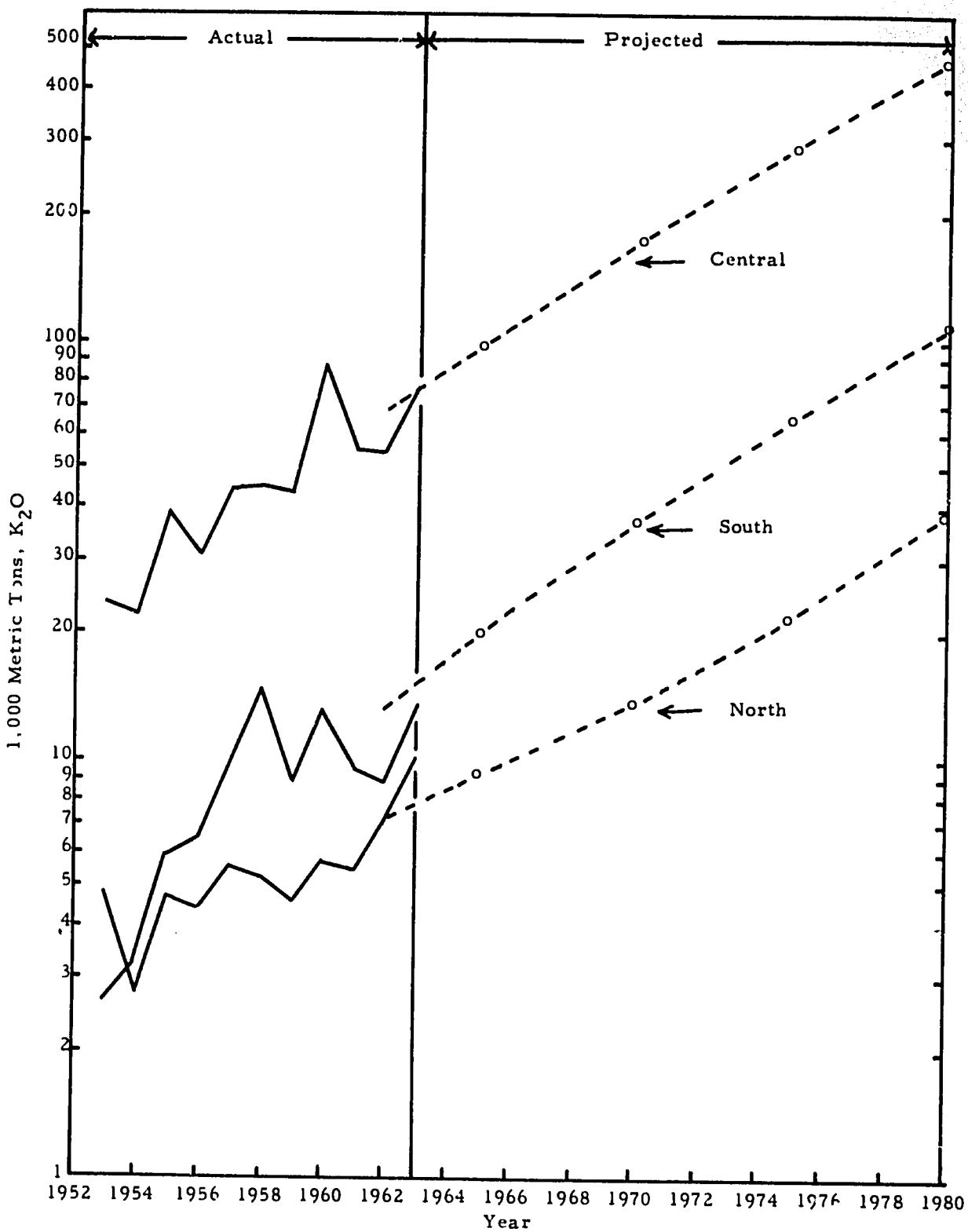

Figure 3. Apparent consumption of potash fertilizers by region of Brazil, 1953-1963, with projections to 1980

Table 12 shows the rates of growth used to obtain the K_2O consumption estimates for each region.

Table 12. Historical and estimated rates of increase in potash consumption for Brazil by region, 1953-1980

Year	Region		
	North-Northeast	Central	South
	(Percent)	(Percent)	(Percent)
1953-63	8.0	12.0	14.0
1964-70	8.0	12.0	13.0
1971-75	10.0	11.0	12.0
1976-80	12.0	10.0	11.0

The rate of growth in the use of potash fertilizers in the North-Northeast is expected to increase at least to 1980. This estimate is predicated on the fact that potash consumption in the North-Northeast in the past has been low relative to the rest of Brazilian agriculture, and to consumption of P_2O_5 in the North-Northeast. Because of the generally low level of prosperity of agriculture in the region, the poor availability and the relatively high price of fertilizer, the rate of growth in fertilizer consumption already experienced in other areas of Brazil will not be reached in the North-Northeast before 1980.

The rate of growth in fertilizer consumption in the Central and

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South, which has been quite high in the past, is expected to decrease as consumption reaches relatively higher levels. The size of farms and the low level of mechanization will begin to be more restrictive as the volume of fertilizer used becomes larger. High fertilizer application rates are not complementary to low levels of mechanization. Other factors such as transportation and the price of fertilizer relative to agricultural product prices will also become more restrictive unless corrected.

Assuming that the cropland area in Brazil will be about 48 million hectares by 1980 and that consumption of potash fertilizers will be approximately 617,000 metric tons, the average application rate will be 13.0 kilograms per hectare of cropland. This compares to an average application rate of 3.0 kilograms per hectare in 1963. The estimated average application rate by 1980 for each region is expected to be 2.0 kilograms in the North-Northeast, 20.0 kilograms in the Central region and 13.0 kilograms in the South.

Potash Production

Under present circumstances in Brazil, virtually nothing can be done in terms of potash processing to improve the potash fertilizer supply. Should the potash deposit recently discovered by Petrobras in Sergipe prove to be economically feasible to develop and process, the potash outlook in Brazil could change considerably.

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At the time this report was written very little information about the deposit in Sergipe was available. One informant with a knowledge of the area stated that the deposit consisted of carnallite and was located 400 - 800 meters below the surface of the ground. He also said that the above information was based on the analysis of a limited number of core drillings so the exact extent of the deposit is still undetermined.

Another source of information indicated that the deposit was located 400 - 800 meters below the surface and consisted of sylvinite.

If preliminary "rumors" regarding this deposit are reasonably accurate as to the depth and type of material, it could be on considerable value to the Brazilian economy assuming that it is large enough to be economically developed.

Further exploratory work should be undertaken immediately and preliminary engineering studies should be started to determine the feasibility of developing this deposit.

The cost in foreign exchange of importing the total estimated consumption of potash fertilizers will be U.S. $18.2 and U.S. $49.3 million annually by 1970 and 1980 respectively.[1/]

1/ Based on the average CIF price of U.S. $49.00 per ton of potassium chloride in 1963.

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FERTILIZER INDUSTRY RECOMMENDATIONS

While Brazil constitutes the major land mass in South America, it is primarily a coastal-populated country. Any practical plans for fertilizer facilities must be predicated on this population distribution and on agricultural and transportation developments.

North-Northeast Brazil

North-Northeast Brazil contains approximately 20,000,000 people whose main source of livelihood is agriculture. It constitutes one of the poorer economically developed areas in Brazil and is receiving substantial attention for agricultural and industrial development. This points to a growing need for fertilizers and to the necessity of expanding manufacturing facilities as agricultural integration in terms of roads, markets, farm machinery and financing improves.

Recife

The present major factor in fertilizer production in the Northeast is Fosforita Olinda in Recife. This company processes phosphate ore to a high concentration of P_2O_5 by water separation and grinding to produce a good quality ground phosphate rock. Current production is sold as ground rock for direct application to the soil, and approximately 30,000 tons were sent by coastal shipping to Sao Paulo and ports south in 1963 for acidulation to normal superphosphate and for

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direct application.

A small quantity of Fosforita ground phosphate rock is acidulated with sulfuric acid by Profertil. Profertil, also located in Recife, now has a 20 ton per day sulfuric acid plant and contemplates building another. Except for the small quantities of ground phosphate rock used and sold by Profertil and Fosforita Olinda, all other fertilizers consumed in the Northeast are imported through the port of Recife.

In view of the inadequacy of roads, farm machinery, available credit and present low consumption of fertilizers, it is recommended that only fertilizer plants of minimum economic capacity be considered for this area. These facilities must also be chosen on the basis of stepwise integration starting with the most profitable processing and integrating into more elaborate plants. In view of the absence of natural gas and the inherent economics of small anhydrous ammonia plants, we recommend an atmospheric storage vessel of 12,000 short tons capacity for the importation of anhydrous ammonia. This will permit the importation of ammonia from a 9,000 ton ocean freighter. Production costs for ammonia at Recife, based on imported oil or naphtha, would be a minimum of U.S.$55 to U.S.$60 per metric ton. Importation contracts probably can be achieved for less than this amount. The present cost estimate for imported NH_3 at Recife is

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U.S. $44-49 per metric ton.[1/] Therefore, the production of ammonia at Recife cannot be recommended at the present time.

Importation of anhydrous ammonia by this method will permit marketing anhydrous ammonia for direct application during heavy fertilizer seasons. This, however, requires distribution equipment, which in the beginning may not be available.

Along with importation facilities, we recommend the installation of a 150 ton per day nitric acid plant operating off imported ammonia; and a 150 ton per day ammonium nitrate plant utilizing this nitric acid making both 83 percent ammonium nitrate solutions and prilled ammonium nitrate. The solutions will be a source of nitrogen to granulation plants and the prill can be used for direct application. While urea is a desirable fertilizer material for sugar cane, it can be manufactured only when carbon dioxide is available from an ammonia plant at zero cost. Also, granulation techniques are more developed for the use of ammonium nitrate than for urea. Both are equally suitable and competitive sources of nitrogen, therefore, we recommend nitric acid rather than urea.

1/ This is an estimate only since a quote to someone only generally interested in the cost of anhydrous ammonia importation may be quite different than for someone actually interested in buying and importing anhydrous ammonia.

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The estimated investment costs for the nitrogen facilities follow:

2,000 lb. tons	Estimated Investment
12,000 tons atmospheric NH_3 storage	$1,200,000
Nitric acid plant (150 T/D)	1,500,000
Prilled ammonium nitrate (150 T/D) and solutions	1,200,000
Total	U.S.$3,900,000

A nitrogen facility in Recife will allow considerable savings in foreign exchange and supply fertilizer to farmers at much lower prices than at present. Assuming that total use of anhydrous ammonia will be 90 metric tons per day, annual ammonia consumption in the Northeast will be 31,500 tons. At a cost of U.S.$44.00 per ton, total annual expenditure for anhydrous ammonia will be about U.S.$1,500,000. An equivalent volume of N imported as urea would cost U.S.$5,100,000 or U.S.$6,000,000 if imported as ammonium sulfate.1/

Allowing a 20 percent return on the fixed investment for profit and income taxes, the estimated wholesale price of ammonium nitrate would be U.S.$56 per metric ton. Assuming transportation to the farm of 150 kilometers and 15 percent of the wholesale price for retail margin, the retail price of ammonium nitrate delivered to the farm

1/ Based on the 1963 CIF imported price for bagged urea of U.S.$87 per ton and for bagged ammonium sulfate of U.S.$46 per ton.

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should be about U.S.$70.00 per ton. This is equivalent to U.S.$212 per ton of nitrogen, about U.S.$20 less per ton of nitrogen than the CIF price of imported ammonium sulfate in 1963.

Table A-1 in the appendix shows the estimated cost of producing nitric acid for a typical plant. Appendix Figure A-7 shows the effect of the cost of anhydrous ammonia and plant size on the cost of producing nitric acid. Appendix Figure A-6 is a process flow sheet for a nitric acid plant.

In conjunction with the nitrogen facility, we recommend the erection of a 200 ton per day sulfuric acid plant primarily for the acidulation of the upgraded phosphate rock from Fosforita Olinda. This will permit the manufacture of normal superphosphate at the rate of about 400 tons per day for use as a source of P_2O_5 in a granulation facility, and for direct application. The estimated investment cost for the acid and superphosphate plant is:

2,000 lb. tons	Estimated Investment
Sulfuric acid plant (200 T/D)	$ 900,000
Normal superphosphate (400 T/D)	1,400,000
Total	U.S.$2,300,000

The estimated annual savings in foreign exchange from manufacturing normal superphosphate with this plant from local phosphate

rock rather than importing an equivalent amount of normal superphosphate is estimated to be about U.S.$5,000,000.

Table A-4 in the Appendix shows the estimated cost of production for a typical sulfuric acid plant and Appendix Table A-5 shows the estimated cost of production for a typical normal superphosphate plant. Appendix Figure A-13 is a process flow sheet for sulfuric acid and Appendix Figure A-15 is a process flow sheet for normal superphosphate.

At present, potash will need to be imported. Unloading and bulk handling facilities will be required for both potash and brimstone. No estimate can be made for these facilities without an on-site engineering survey.

With ammonium nitrate, normal superphosphate and potash available, we recommend a conventional high analysis granulation plant with a capacity of 200 short tons per day of product. A plant of this nature will require an estimated investment of about U.S.$800,000.

A second phase may consist of a large anhydrous ammonia facility manufacturing ammonia from imported naphtha or crude oil and a phosphoric acid plant which will permit the manufacture of triple superphosphate and diammonium phosphate. However, at the rate of increase projected for nitrogen fertilizer consumption for the Northeast, the ammonia plant will probably not be practical before 1980.

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Although these facilities (even the first phase of these facilities) will make the Northeast region sufficient in fertilizers through 1970, initially they represent an over-capacity in terms of the present market. This fact may deter investment based solely on the profit motive. Some special tax or financing considerations may be necessary until markets develop to sustain capacity operation of the proposed facilities.

Total estimated investments for all the facilities recommended in the Northeast for the first phase follow:

2,000 lb. tons	Estimated Investment
Anhydrous ammonia storage (12,000 tons)	$1,200,000
Nitric acid plant (150 T/D)	1,500,000
Ammonium nitrate prilling (150 T/D)	1,200,000
Sulfuric acid plant (200 T/D)	900,000
Normal superphosphate (400 T/D)	1,400,000
Granulation (200 T/D)	800,000
Total	U.S.$7,000,000

This integrated facility would make available the following volumes of N, P and K:

	Metric tons
N (assuming 90 T/D total NH_3 use)	26,000 tons
P_2O_5 (as normal superphosphate)	24,500 tons
K_2O (imported as Kcl)	25,000 tons

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Total N, P and K that would be available from the new facilities, plus presently existing facilities, would be N, 26,000 tons; P_2O_5, 30,000 tons and K_2O, 25,000 tons.

It is estimated that total annual savings in foreign exchange realized from this fertilizer complex could be as much as U.S. $8,800,000.

Fosforita Olinda

The major well-known phosphate reserve in the Northeast is the one controlled by Fosforita Olinda near Recife. The latest information indicates a reserve of 30 to 50 million tons, probably nearer to 30 million. Of this only 3 or 4 million tons can be mined by present open pit methods, with existing equipment, due to high overburden.

While a well-designed and maintained processing plant with a capacity of at least 200,000 tons per year of product is in operation, high freight costs and market limitations have caused the plant output to drop from a high of 165,000 tons in 1959 to a low of 50,000 tons in 1963, resulting in financial problems for the owners. In the past, high freight costs have been due more to port costs and the mandatory use of Brazilian ships than to any technical or equipment limitations. Added to this was the fact that foreign rock was protected by a low official exchange rate, whereas Olinda rock had tc move and sell at the free rate. This latter situation has now been eliminated.

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Another problem is that plant production is about equally split between two grades of material. The high-grade material is 33-34 percent P_2O_5, a reasonably good acidulation material, sold dry, unground for the manufacture of normal superphosphate. The other material is a fine fraction, 50 percent of the concentrator output, 24-25 percent P_2O_5, high in silica, 22-23 percent, and quite high in iron and aluminum, about 5.0 percent. This latter material is not suitable for acidulation to normal superphosphate (NSP) and would be relatively expensive and difficult for the manufacture of phosphoric acid. Current practice is to blend the low and high-grade materials and sell a product of 28-30 percent P_2O_5, ground and bagged for direct application to the soil.

Although the recommended normal superphosphate plant will require about 72,000 tons of the high grade product, the problem of the low grade product remains. We suggest that a process economic study be conducted with the low grade material to determine if the silica and iron content can be reduced and the resulting product used to manufacture phosphoric acid. If this can be accomplished, the Northeast will be well supplied with soluble P_2O_5 for quite a number of years and Fosforita Olinda would be put on a stronger financial basis.

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Salvador (Bahia)

The primary impetus to a fertilizer activity in Salvador is established by the presence of the Petrobras refinery. Petrobras is planning to begin construction of anhydrous ammonia and urea facilities in the near future and plans to be on stream by late 1967. Current plans call for a 200 ton per day anhydrous ammonia plant to operate off of natural gas and a 250 ton per day urea plant. This leaves uncommitted about 50 tons per day of anhydrous ammonia. Petrobras plans to ship the urea by truck to major markets south. The road between Salvador and Recife is impassable at certain times of the year. If the condition of this road is improved, the economics of shipping anhydrous ammonia by tank car or truck to the proposed facility at Recife should be examined. Another major restriction on the transportation of ammonia anywhere in Brazil is the lack of high pressure tank cars.

The most economical method of utilizing this excess ammonia would be converting it to urea by establishing a larger urea plant. As an alternative, brimstone could be imported at Salvador and sulfuric acid manufactured to make ammonium sulfate. Normally this is not an economical product and it is an expensive means of converting the excess anhydrous ammonia to a solid form which can be more easily stored and shipped. However, since many of the soils in

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Brazil require sulfur for good yields, ammonium sulfate may be the cheapest and easiest means of applying sulfur. An alternative to this approach would be to manufacture nitric acid and ammonium nitrate prills. However, insufficient ammonia is available for economic production of nitric acid.

Markets in and about Salvador presently do not warrant importing of raw materials for manufacturing high analysis grade fertilizers. The volume of granulated fertilizers that will be demanded in the area can be more economically imported from the proposed facility at Recife.

Sergipe

Early in 1965 a potash discovery in Sergipe near Aracaju was announced. At the writing of this report very little factual information was available regarding this new deposit. Preliminary indications are that the deposit consists of sodium chloride and sylvinite. The development of this deposit could mean savings in foreign exchange of U.S. $18.2 million annually by 1970 and as much as U.S. $49.3 million annually by 1980.[1/] Considering the potential savings that are possible, further exploratory studies should be conducted as soon as possible.

1/ Based on the average CIF import price of U.S. $49 per ton of potassium chloride in 1963.

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Trauira Island

Before leaving Northern Brazil, Trauira Island, near Candido Mendes, which contains an estimated 11-15 million tons of phosphate ore should be mentioned. Unquestionably at some time this ore will be mined and utilized. However, the remote location of this island, the high aluminum and iron content of the ore (see Table 13) and the small size of the deposit will all deter its economical exploitation.

In the United States a phosphate mining operation is considered uneconomical unless 30 million tons of ore can be mined.

Table 13. Chemical analysis of Trauira Island phosphate ore

Mineral	Analysis [1] 1	Analysis [2] 2
	(Percent)	(Percent)
H_2O	11-17	17-18
SiO_2	1-2	7
Al_2O_3	10-30	31
Fe_2O_3	20-50	5-7
TiO_2	1	1
P_2O_5	10-25	28-30
CaO	1-3	3-6

1 Aluminum phosphate and ferruginous mineral ores.

2 Aluminum phosphate and non-ferruginous mineral ores.

Note: Some parts of the Island have a P_2O_5 analysis as high as 36 percent.

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Central Brazil

Central Brazil has the potential of being self-sufficient in phosphates and may at some future date become competitive in the manufacture of nitrogen. Aside from the possibility of developing the recently discovered potash deposits in Sergipe, Brazil is dependent upon importation for its potash supplies. For some time to come it is probable that major requirements of raw materials for fertilizer manufacture in Central Brazil, including some ammonia, phosphate rock, potash and sulfur, will have to be imported. Freight and material handling constitute a substantial portion of the cost of fertilizer manufacture and distribution. Because of these considerations, it becomes economically imperative for the present that major manufacturing facilities be located adjacent to seaports.

Sao Paulo

Sao Paulo, being Brazil's most highly industrialized city and centrally located with respect to its most highly productive agricultural area, is ideally situated for a major fertilizer complex. The congestion and overcrowding of the port of Santos, however, poses a severe handicap to this location. The possibility of an adjacent suitable shore line for a dock facility, together with approximately 1,000 acres of level land, should be investigated. We suggest considering Sao

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Sebastiao. We recommend the following plant facilities for an integraded fertilizer complex to be located on dock facilities near Sao Paulo.

2,000 lb. tons	Estimated Investment
Two, 12,000 ton atmospheric storage anhydrous ammonia vessels	$ 2,200,000
Phosphate rock, potash and sulfur unloading and storage facilities	1,000,000
One, 300-ton per day nitric acid, ammonium nitrate plant, including prilling	4,200,000
One, 300-ton per day phosphoric acid plant	2,700,000
One, 200-ton per day normal superphosphate plant	800,000
One, 500-ton per day sulfuric acid plant	1,800,000
One, 300-ton per day triple superphosphate plant	2,000,000
One, 25-ton per hour high analysis granulation plant equipped with pre-neutralization for the manufacture of diammonium phosphate	1,400,000
Total	U.S.$16,000,000

The total investment for these facilities, including storage and warehousing, excluding dock facilities, is estimated at approximately U.S.$16,000,000. The total capacity of these facilities, depending upon the analysis and balance of products made, would be approximately 800 to 1,000 tons per day. This would represent approximately 300,000 tons of NPK fertilizers and other fertilizers per year. These

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facilities together with existing fertilizer plants and plants now under construction would be adequate to supply the estimated requirements through 1970 for the Central region. These recommended facilities are of competitive and economical capacities and can be expanded or duplicated as markets increase.

The supply of basic fertilizers by 1970 for the Central region might be as follows:

Source	Product (Metric tons)		
	Nitrogen	P_2O_5	K_2O
Imported			173,000
Quimbrasil (own rock)		108,000	
Present NSP facilities (imported rock)		30,000	
Petrobras (Bahia)	57,400		
Petrobras (Cubatao)	12,000		
CSN and USIMINAS	3,000		
Recommended new facility	82,000	65,000	
Total	154,400	193,000	173,000

These figures indicate that nitrogen production will almost equal 1970 consumption estimates (Table 4), and that there will be an excess of P_2O_5 of about 10,000 metric tons over 1970 consumption estimates (Table 7).

A port-oriented facility such as we have recommended, located as near as possible to Sao Paulo has a number of short and long-term advantages.

1. Products produced and ammonia imported by this facility could be retailed directly to farmers and/or

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sold wholesale to mixers and other fertilizer firms in Sao Paulo, Minas Gerais and Rio de Janeiro. The manufacturers of normal superphosphate in the Central region could probably use this facility rather than Santos to import phosphate rock if they choose.

2. If and when the potash deposit in Sergipe is developed, the proposed facility could be used to import potash from Sergipe.

3. This facility with its integrated processing plants would help minimize the transportation problems and costs. Initially, investment in anhydrous ammonia tank cars could be held to a minimum.

4. At such time as the demand for nitrogen fertilizer warrants, a large anhydrous ammonia plant could be constructed at Bahia to operate on natural gas. The ammonia produced could be shipped to the proposed Sao Paulo facility by coastal shipping or by tank car.

Estimated Production Costs and Foreign Exchange Savings

We estimate that anhydrous ammonia could be imported from Trinidad, in large vessels on a contract basis for U.S.$44-49 per metric ton unloaded. The cost in foreign exchange, by 1970, assuming

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100,000 metric tons of anhydrous ammonia through-put, would be approximately U.S. $4.4 million annually. The cost of an equivalent volume of nitrogen imported as ammonium sulfate or urea would be U.S. $17.6 million and U.S. $17 million respectively.[1/]

In order to estimate the wholesale price for the imported anhydrous ammonia, an amount equivalent to 20 percent of the fixed capital investment for profit and income taxes for the storage facilities was added to the estimated import price. This is equal to about U.S. $4.00 per ton for 100,000 tons and brings the estimated wholesale price of ammonia to U.S. $48 to $53 per metric ton.

The cost of producing nitric acid, with the size plant that has been recommended, and costing in ammonia at U.S. $48 per ton, is estimated at U.S. $22.60 per ton. Costing in ammonia at U.S. $48 per ton and nitric acid at U.S. $22.60 per ton, the cost of producing ammonium nitrate is estimated to be about U.S. $39 per ton bagged. Allowing a profit of 20 percent on fixed investment in the nitric acid and ammonium nitrate plants brings the estimated wholesale price of ammonium nitrate to U.S. $47.85 per ton. This is equivalent to about U.S. $145 per metric ton of nitrogen.

1/ Based on the 1963 CIF import price at Santos for urea and ammonium sulfate of U.S. $94 and U.S. $43 per ton respectively.

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In order to estimate the retail price of ammonium nitrate delivered to the farm, the following assumptions were used:

1. Truck transportation in bags from Sao Paulo to Presidente Prudente.
2. Retail margin, 15 percent of wholesale cost at Sao Paulo.
3. Delivery to a farm 10 kilometers from Presidente Prudente.

Under these assumptions, the estimated cost of ammonium nitrate to the farmer would be U.S. $67 per ton, or about U.S. $202 per ton of nitrogen. This is considerably less than the U.S. $300 or more per ton of nitrogen paid by Brazilian farmers in March of 1963.

Table A-1 in the Appendix shows the estimated production costs for a typical nitric acid plant. Appendix Figure 7 shows the effect of plant size and cost of anhydrous ammonia on the cost of producing nitric acid. Appendix Figure 6 is a process flow sheet for nitric acid.

The cost of importing rock phosphate to the recommended facility is estimated at U.S. $17.91 per metric ton.[1/] Assuming the importation by 1970 of 65,000 tons of P_2O_5 as 34 percent rock phosphate, the total cost in foreign exchange by 1970 would be approximately U.S. $3.5 million annually. The cost of imported sulfur needed for producing

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[1/] Based on the 1963 CIF price, at Santos, for rock phosphate of U.S. $17.91 per ton.

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normal super and triple superphosphate is estimated at U.S.$30 per ton delivered to the sulfuric acid plant. The total cost for sulfur by 1970 would be U.S.$1,650,000 annually. The total cost of imported sulfur and rock phosphate would be about U.S.$4,200,000.

The cost of importing the equivalent amount of P_2O_5 as normal superphosphate or triple superphosphate would be U.S.$11.2 million and U.S.$9.7 million respectively.[1/] The annual savings in foreign exchange by importing rock phosphate and sulfur and manufacturing normal or triple superphosphate would be approximately U.S.$5.5 to 7.0 million.

The estimated cost of producing sulfuric acid, with the size plant that has been recommended and costing in sulfur at U.S.$30 per metric ton, is estimated at U.S.$13.20 per metric ton. The estimated cost of producing normal superphosphate costing in rock phosphate at U.S.$20.41 per ton[2/] and sulfuric acid at U.S.$13.20 per ton would be approximately U.S.$22.00 per ton. The estimated cost of producing triple superphosphate would be U.S.$45 per ton.

1/ Based on the 1963 CIF price, at Santos, of U.S.$35 per ton for normal superphosphate and U.S.$67.40 per ton for triple superphosphate.

2/ Estimated CIF price of $17.91 plus $2.50 per ton for unloading expenses.

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The estimated wholesale price of normal super and triple superphosphate, allowing a 20 percent return on fixed investment for profit and income taxes, would be approximately U.S. $28.00 per ton and U.S. $55.00 per ton respectively.

Using the same assumptions as indicated in estimating the retail price of ammonium nitrate, the estimated cost delivered to the farm would be U.S. $45.00 per ton for normal superphosphate and U.S. $76.00 per ton for triple superphosphate. At these prices the cost per ton of P_2O_5 as normal superphosphate would be U.S. $225 per ton and the cost per ton of P_2O_5 as triple superphosphate would be about U.S. $186 per ton. Because of the assumptions used in estimating investment costs, the actual cost of nitrogen and phosphate delivered to the farmer would probably be slightly higher than the estimates provided in this report.

Table A-6 in the Appendix shows the estimated production costs for a typical phosphoric acid plant. Appendix Figure A-16 is a phosphoric acid process flow sheet. Appendix Figure A-17 shows capital investment for phosphoric acid while Appendix Figures A-18 to A-20 show the cost of producing phosphoric acid as related to the cost of raw materials.

Tables A-7 and A-8 in the Appendix show the estimated cost of producing triple superphosphate. Appendix Figure A-21 is a process

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flow sheet for triple superphosphate.

The estimated investment costs for the various plants that are recommended in this report are based on costs in the United States. The cost estimates do not include transportation to Brazil. No attempt was made to estimate investment costs based on equipment manufactured in Brazil. The reason for this is that very little of the equipment needed in the manufacture of fertilizers is now made in Brazil, although much of it can be. It is impossible to get reliable estimates without spending considerable time and money to provide equipment specifications. It is reported by persons in the fertilizer industry in Brazil that the cost of equipment manufactured in Brazil will probably run considerably higher, for some equipment as much as two times as high and delivery times are longer. Obviously, if this is in fact the case, the cost of manufacturing fertilizers in Brazil will be higher than the estimates provided in this report if Brazilian-made equipment is used.

Whether the equipment should be imported from the United States or Europe or manufactured in Brazil will have to be determined when bids for the design and construction of specific plants are requested.

Direct Application Nitrogen

It is estimated that at present Brazil uses about 40 percent of its nitrogen for direct application, all as solid materials, mainly as

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ammonium sulfate. The cheaper liquid forms, such as anhydrous ammonia and aqua ammonia, are not used because they are not available and because there is a widespread misconception that the technology is too advanced for present Brazilian agricultural conditions.

Brazil should start now to promote the use of direct application ammonia or aqua ammonia. These materials have been proven, in other countries, to be the most economical source of nitrogen applied in the ground as well as being equal to any other source of nitrogen in agronomic quality where the soil is suitable.

The anhydrous ammonia import facility that has been recommended for the Central region could easily supply sufficient ammonia for direct application as well as the other nitrogen plants recommended. However, Brazil should not delay getting started with direct application liquid nitrogen until a plentiful supply of ammonia is available. It should prepare for that day now, on a small scale, by using either local ammonia from the Petrobras Cubatao plant or, if it cannot be made available, from imported ammonia. In small 500-ton lots, ammonia could be unloaded in Santos by utilizing available facilities and trucks which belong to Ultragaz.

We recommended that five stations for direct application of liquid nitrogen, either as anhydrous or aqua ammonia, be installed in the State of Sao Paulo. The choice between anhydrous and aqua

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ammonia is a matter of local preference. Anhydrous ammonia must be converted into aqua at the distribution station. Aqua is generally easier to apply than anhydrous. The final cost of N in the ground is about the same for aqua and anhydrous. The cost of these five stations would be about $275,000, including all the necessary applicators and nurse tanks.

A comparison of the cost of nitrogen to the farmer as ammonium sulfate and as liquid ammonia is shown on Table 14. It shows that in Brazil, even with high-priced imported ammonia, nitrogen can reach the farmer cheaper as ammonia than as ammonium sulfate.

We suggest the following locations in Sao Paulo as possible sites for an anhydrous ammonia station, (1) Campinas, (2) Piracicaba, (3) Presidente Prudente, (4) Ribeirao Preto, (5) Sao Jose de Rio Preto and (6) Itapetininga.

The specifications and estimated cost of an anhydrous ammonia station located in the state of Sao Paulo are shown in Table 15. Estimated anhydrous ammonia station operating costs are shown in Table 16.

The anhydrous ammonia station investment is estimated at U.S. $52,400. If custom application is to be made available to customers then several tractors would also be needed. This would mean additional investment of U.S. $10,000 - 12,000.

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Table 14. Estimated cost of nitrogen to the farmer in Sao Paulo - comparison between direct application anhydrous ammonia and ammonium sulfate, U.S. dollars

	Ammonium sulfate	3,000 TPY anhydrous ammonia imported in 500 ton ship lots		30,000 TPY anhydrous ammonia imported in 5,000 ton ship lots	
Applied as	Am. sulfate 20.5% N	Anhydrous 82.2% N	Aqua 20% N	Anhydrous 82.2% N	Aqua 20% N
	$/ton	$/ton	$/ton	$/ton	$/ton
Cost CIF Santos	$ 41.00	$100.00	$100.00	$ 85.00	$ 85.00
Unloading	1.30	0.17	0.17	0.17	0.17
Port storage-2 shipments at $2/ton x month	-	8.00	8.00	8.00	8.00
Rail transportation to Sao Paulo	1.00	-	-	-	-
Store-bag-load-administration-profit	8.70	-	-	-	-
Truck transportation to farm-400 km at $0.0167/ton x km	6.70	-	-	-	-
Truck transportation to anhydrous or aqua station 500 km at $0.042/ton x km	-	21.00	21.00	21.00	21.00
Anhydrous or aqua station costs and profit	-	24.15	26.00	24.15	26.00
Administration at 7% sales	-	11.54	11.54	9.65	9.65
Cost to farmer (not including his labor)	$ 58.70	$164.86	$166.71	$147.97	$149.82
Cost to farmer per ton of N	$286.34	$200.56	$202.81	$180.01	$182.26
Cost to farmer cents per pound N	$ 0.13	$ .091	$ .092	$ .082	$ .083

Table 15. Specifications and estimated costs of an anhydrous ammonia station, Brazil

Storage Capacity	30,000 Gallons
Tank dimensions:	
Inside diameter of tank	108 inches
Over-all length of tank	64 feet 6 inches
Weight - pounds	80,000
Cost	U.S. Dollars
Tank	$ 9,700
Delivery	800
Site preparation	200
Foundation	600
Compressor	1,800
Valves & piping	1,200
Installation	800
Electrical	300
Contingency	500
Battery limits total	$15,900
5-ton shipping scale	1,500
Office, furnished & equipped 400 Ft^2 at $20/$Ft^2$	8,000
10 applicators at $800	8,000
15 nurse tanks on trailer at $800	12,000
2 pick-up trucks at $3,500	7,000
TOTAL	$52,400

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Table 16. Estimated anhydrous ammonia station operating costs
Basis: 600 TPY NH_3 - 60 operating days - Brazil,
U.S. dollars

	No.	Rate $/working day	$ Total/ day	$ Total/ 60 days
Labor:				
Station manager	1	$10.00	$10.00	$ 600
Station clerk	1	5.00	5.00	300
Station attendant	2	2.50	5.00	300
Total			$20.00	$ 1,200
Fringe benefits at 60 percent of labor costs				720
Total labor & supervision				$ 1,920
Maintenance 6 percent x $52,400 investment				3,140
Depreciation 7 percent x $52,400 investment				3,670
Taxes and insurance 1 percent x $52,400 investment				520
Supplies - utilities				100
Total operating costs				$ 9,250
Profit 10 percent x $52,400 investment				5,240
Total				$14,490
Per ton NH_3				$24.15

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Potential Domentic Sources of Phosphate

Jacupiranga

The principal deposit of phosphate in Sao Paulo and the Central region has been that of Serrana at Jacupiranga. The overlying, weathered apatite has nearly been exhausted so that production has fallen from a peak of 70,000 tons per year in 1961 to about 35,000 tons in 1964.

About three years ago intensive studies were started on methods of beneficiation for the large underlying deposit of low-grade carbonatite-apatite with the help of Quimbrazil, the principal manufacturer of normal superphosphate in Brazil. The project has been successfully developed through the full-size float cell stage.

The deposit has been thoroughly prospected, above ground level, and reserves appear to be at least 150 million tons of ore at 6.5 percent P_2O_5. Present plans call for construction of a plant to produce 150,000 tons of phosphate rock concentrate per year to be on stream by late 1967. A second 150,000 ton per year plant is expected to be on stream by late 1970 or early 1971. The product, if all goes as planned, will be one of the finest acidulation grade phosphate rocks in the world.

If the plans move ahead as scheduled, this deposit will supply Brazil with 54,000 tons of P_2O_5 by 1967 and 108,000 tons of P_2O_5 by

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1971. This is equivalent to about 60 percent of the 1970 projected consumption of P_2O_5 for the Central region.

Araxa

The phosphate deposits at Araxa are estimated at 90,000,000 tons of ore. These deposits are some of the largest in Brazil and every effort should be made for their development. There are, however, serious processing problems which must be resolved before they can be utilized. They contain a high content of non-magnetic iron. In an effort to utilize these deposits CAMIG, together with the help of Japanese consultants, prepared a process economic study for the manufacture of a product called "thermophos". This consists of fusing the phosphate ore with serpentine ore to produce a fused magnesium phosphate in an electric furnace. The resulting product is in the form of a coarse dust which is only citrate soluble. It is unknown whether or not this material can be acidulated with sulfuric acid to produce a water soluble phosphate product.

It is also unknown whether or not the material coming from the furnace or as further processed with sulfuric acid is suitable for granulation. The electric furnace product, being insoluble, probably has little advantage over the application of finely ground phosphate rock. The cost of producing this non-water soluble P_2O_5 product is non-competitive to even electric furnace acid. Nowhere in the world

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is electric furnace acid used in fertilizer manufacture except in the United States. Even here its use is limited and subject to overload quantities only. The probability of future electric furnace plants being built in the United States or anywhere is remote. We accordingly do not recommend proceeding with the CAMIG fused magnesium phosphate proposal.

Funds should be made available to conduct a thorough process economic study on the Araxa deposits to determine (1) can the iron be removed? (2) how much sulfuric acid is required for acidulation and what is the condition of the product? (3) can phosphoric acid be made directly from the ore by use of an electric furnace? If this is possible, the phosphoric acid could be used for food and medical uses, but would be uneconomical for fertilizers, (4) can the rock be acidulated with hydrochloric acid? (5) are there other processing techniques such as a combination of acidulation and ion exchange or solvent extraction in which the ore can be processed economically?

Assuming that an economic processing technique would result from this study, these deposits then could be utilized for supplying P_2O_5 to the fertilizer complex at Sao Paulo.

Appendix Figure A-22 shows the cost of manufacturing P_2O_5 as electric furnace acid as related to cost of power and raw materials. Table A-9 shows estimated investment for an electric furnace phos-

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phoric acid plant while Table A-10 shows the estimated cost of producing electric furnace phosphoric acid.

Goias

It appears, from the limited information available, that there may be a deposit of apatite near Catalao, Goias that may be of commercial interest for phosphate production. The size of the deposit is unknown and we know of no estimates regarding the volume of ore reserves. A sample of ore, collected by Sylvio Frois Abreu, Brazilian National Institute of Technology, in April, 1961, was analyzed by the Divisao de Quimica Inorganica Industrial. The results of the analysis follow:

Umidade	3.7%
Loss	4.9
SiO_2	25.5
Fe_2O_3	16.0
P_2O_5	13.0
Al_2O_3	11.0
TiO	U.A.
MnO_2	Traces
CaO	18.4
MgO	5.4

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Na_2O	0.2
K_2O	1.8

This deposit, because of its location relative to future expansion of agriculture as well as present agricultural areas could be of major importance to the fertilizer industry in Brazil. We recommend that further study of the deposit be conducted as soon as possible to determine the size of the deposit and its overall quality in order to evaluate its potential as a source of phosphate for fertilizer production.

Potential Domestic Sources of Raw Materials for Nitrogen Production

Capuava

It is reported that refinery gases and naptha are available at the Uniao refinery at Capuava in sufficient quantities to manufacture 300 tons of anhydrous ammonia per day. Depending on the cost of these raw materials, ammonia may be produced in this quantity for about U.S. $40 per ton for an investment of approximately U.S. $5.3 million. At such time as ammonia can be produced at this location cheaper than it can be imported, this source of raw material supply should be considered. It may be close enough to the recommended facilities for pipeline delivery.

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Volta Redonda

It is reported that coke oven gases are available at the Compania Siderurigica National (CSN) steel mill at Volta Redonda for production of anhydrous ammonia. However, reports on the quantity of gas vary from enough to produce 200 tons per day of anhydrous ammonia to 400 tons per day. We recommend that CSN be contacted to determine how much coke oven gas would be available and at what price. Investment and production costs for production of ammonia are usually higher using coke oven gases than for natural gas or light naptha. However, a large anhydrous ammonia plant operated off of cheap coke oven gases may be competitive.

A plant at this location could provide ammonia to the facilities proviously recommended and to Araxa when and if phosphate fertilizers are produced there.

Besides the Uniao refinery and the CSN steel mill there is very little in terms of potential domestic raw materials for the production of anhydrous ammonia on an economical scale. The only other possible source might be the Presidente Bernardes refinery in Cubatao. Outside of these three sources, the only other possibility is importing naptha. However, at present world prices for naptha it would appear that the cost of producing anhydrous ammonia from imported naptha would be relatively expensive. Should it become possible to import

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naptha at a price which would make possible economical production of anhydrous ammonia, then an ammonia plant should be included with the facilities that have been recommended for the Sao Paulo area.

Another idea that has been discussed, for supplying nitrogen fertilizers for Brazilian agriculture, involves shipping anhydrous ammonia from Santa Cruz, Bolivia. An ammonia plant would be constructed at Santa Cruz to operate off the natural gas reserves in that area. Anhydrous ammonia would be transported by rail from Santa Cruz to Sao Paulo. We recommend that this plan be explored in more detail to determine its economic and physical feasibility. However, from limited knowledge of the rail and highway systems between Santa Cruz and Sao Paulo it appears that it will be some time before such a plan would be feasible.

An alternative that should also be studied is the possibility of laying a pipeline from Santa Cruz to Sao Paulo to transport natural gas. Natural gas could then be made available for other industries as well as for fertilizers.

Appendix Figure A-1 is a process flow sheet for anhydrous ammonia based on natural gas feed. Appendix Figure A-2 is a process flow sheet for anhydrous ammonia based on oil and naptha feed materials. Appendix Figures A-3 through A-5 show estimated costs

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of producing anhydrous ammonia as related to plant size, type and cost of raw materials and process used.

South Brazil

Southern Brazil as defined in this study encompases the states of Rio Grande do Sul and Santa Catarina. This region is similar to the Central region in that it has a relatively high degree of agricultural development. It differs from the Central region in climate and in terms of the major commodities produced. The South produces the largest volume of wheat and irrigated rice in Brazil and also produces large quantities of corn.

Because of the large acreages of irrigated rice and the desirability of using an ammonical form of nitrogen on irrigated rice, we recommend a 100-125 ton per day anhydrous ammonia plant and a 150 ton per day urea plant to be located near the Ipiranga refinery at Rio Grande. A 125 ton per day ammonia plant will supply sufficient nitrogen, based on estimated future consumption, through 1971-72 and initially will represent an over supply (see Table 4). The estimated investment required for these two plants is as follows:

2,000 lb. tons	Estimated Investment	
One, 125 ton per day anhydrous ammonia plant	U.S.	$ 4,200,000
One, 150 ton per day urea plant		2,500,000
Total	U.S.	$ 6,700,000

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Anhydrous ammonia could be used directly on irrigated rice by injecting it into the irrigation water. However, with the lack of transport and application facilities suitable for ammonia, and due to the lack of experience on the part of the farmers in the area in handling anhydrous ammonia we recommend that the ammonia be converted to urea.

A facility of the nature recommended, because of its relatively low capacity, will not permit the production of ammonia or urea at as low a price as would be desirable but it will probably be cheaper than urea imports. The cost of refinery off gases or naptha will be the major factor in the cost of producing anhydrous ammonia. Dependent on the cost of raw materials, the cost of producing ammonia with a 125 ton per day plant will be about U.S. $49 per metric ton. The cost of producing urea with a 150 ton per day plant costing in ammonia at U.S. $49 per ton would be about U.S. $48 per metric ton of urea. This is considerably less than the C.I.F. imported price in 1963 of U.S. $94 per ton of urea for imports at Rio Grande. This represents potential foreign exchange savings of over U.S. $4 million annually.

If the Ipiranga refinery cannot provide sufficient off gases or naptha for 100-125 tons of ammonia per day at a cost such that ammonia can be produced for U.S. $49-55 per metric ton, then

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importation of urea will probably be the most efficient means of obtaining nitrogen. Urea may be shipped in from the Central region at such time as ammonia and urea are manufactured at one of the potential locations in the Sao Paulo area.

We also recommend for the Southern region a 400 ton per day normal superphosphate plant and a 350 ton per day triple superphosphate plant to operate on imported phosphate rock. Estimated investments for the necessary facilities are as follows:

2,000 lb. Tons	Estimated Investment
One, 150 T/D. phosphoric acid plant	U.S. $1,500,000
One, 300 T/D. sulfuric acid plant	1,200,000
One, 400 T/D. normal superphosphate plant	1,400,000
One, 350 T/D. triple superphosphate plant	2,300,000
Total	U.S. $6,400,000

These plants will provide approximately 72,200 metric tons of P_2O_5. An equivalent amount of P_2O_5 imported as normal superphosphate would require about U.S. $9,000,000 in foreign exchange. Imported as triple superphosphate would also require about U.S. $9,000,000 in foreign exchange.1/ The savings in foreign exchange

1/ Based on the 1963 CIF import price at Rio Grande of U.S. $66 per ton for triple superphosphate and U.S. $29 per ton for normal superphosphate.

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from importing phosphate rock and sulfur to manufacture normal and triple superphosphate is estimated to be U.S. $4,700,000 annually.

The recommended new phosphate fertilizer plants, plus the presently existing normal superphosphate plants of ICISA and Cia Riograndense Adubos will provide 80,000 metric tons of P_2O_5 per year. This is about 4,000 tons of P_2O_5 more than projected consumption in 1970 (see Table 7).

The retail price of normal superphosphate and triple superphosphate manufacture with the recommended plants and delivered to the farmer is estimated to be about the same as in the Central region; U.S. $45 per metric ton for normal superphosphate and U.S. $75-80 per ton for triple superphosphate.

The phosphate plants could be located at either Porto Alegre or Rio Grande. If they were located in Rio Grande the products manufactured could be used in a granulation plant with urea or ammonia to produce complex fertilizers. However, with Rio Grande located in the lower end of the region, distribution costs would be higher. If the plants were to be located in Porto Alegre, phosphate would have to be hauled to Rio Grande. Since much of the urea produced will be need to be transported north and west from Rio Grande, the same trucks or rail cars could be used to haul the needed volume of phosphate back to Rio Grande from Port Alegre.

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Appendix Figure A-2 is a process flow sheet for producing anhydrous ammonia from naptha and Figure A-12 is a process flow sheet for urea. The estimated production cost for anhydrous ammonia as related to plant capacity, type of raw materials and process is shown in Appendix Figure A-3.

The estimated cost of producing prilled urea and urea solutions is shown in Appendix Tables A-2 and A-3 respectively.

Summary - Locations of Recommended Fertilizer Plants

Figure 4 shows the location of all the additional nitrogen fertilizer plants that have been recommended. This figure also shows the location of existing nitrogen plants and the location of the three main potential sources of raw materials for nitrogen production.

Figure 5 shows the location for all the additional phosphate fertilizer plants that have been recommended for Brazil. The figure also shows the locations of existing normal superphosphate plants.

Figure 6 shows the location of presently mined phosphate deposits and the location of potential phosphate and potash deposits.

Fertilizer Production After 1970

No attempt has been made to recommend specific fertilizer plants beyond 1970, even though demand estimates were made through 1980. The plants that have been recommended can be expanded or duplicated as required. However, with the potential sources of phosphate, potash and raw materials for the manufacture of nitrogen in Brazil it would be to Brazil's advantage if these sources could be utilized. The speed at which the potential sources are developed and the cost of the raw materials will determine if and when they can be used. The potential sources of fertilizer raw materials should be evaluated continuously to determine their use relative to imported raw materials.

The creation of institutional and legal barriers that will restrict the importation of fertilizer raw materials in order to promote or force the use of local raw materials should not be considered unless absolutely necessary. Although such a policy would be of some benefit to companies or individuals who are producing fertilizers from local raw materials, it would defeat the broader long range goals of increasing the supply of relatively inexpensive food and fiber for domestic consumption and exportation.

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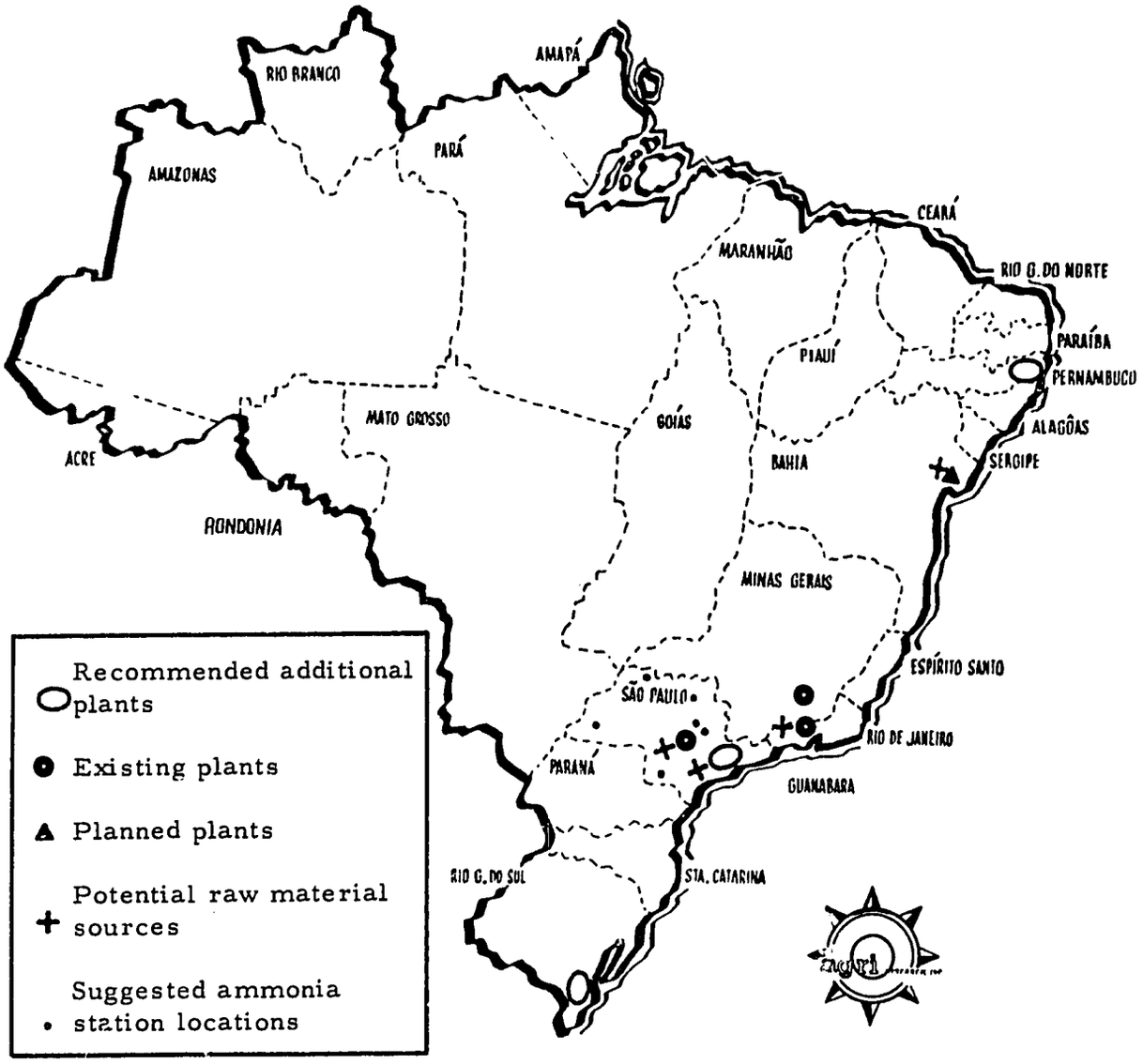

Figure 4. Location of recommended nitrogen fertilizer plants, existing nitrogen plants, planned nitrogen plants and potential sources of raw materials for nitrogen fertilizer production in Brazil

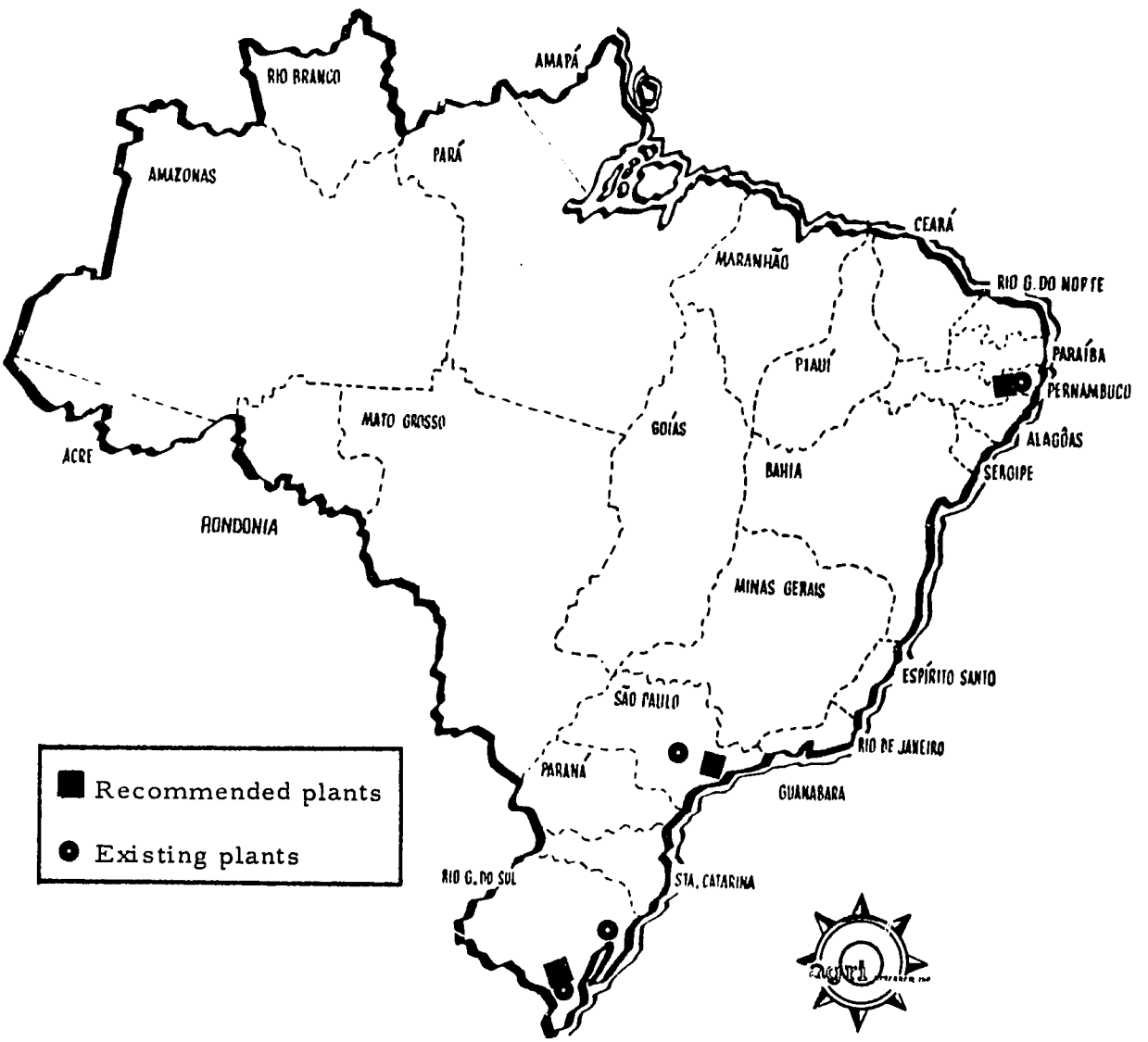

Figure 5. Location of recommended phosphate fertilizer plants and existing phosphate fertilizer plants in Brazil.

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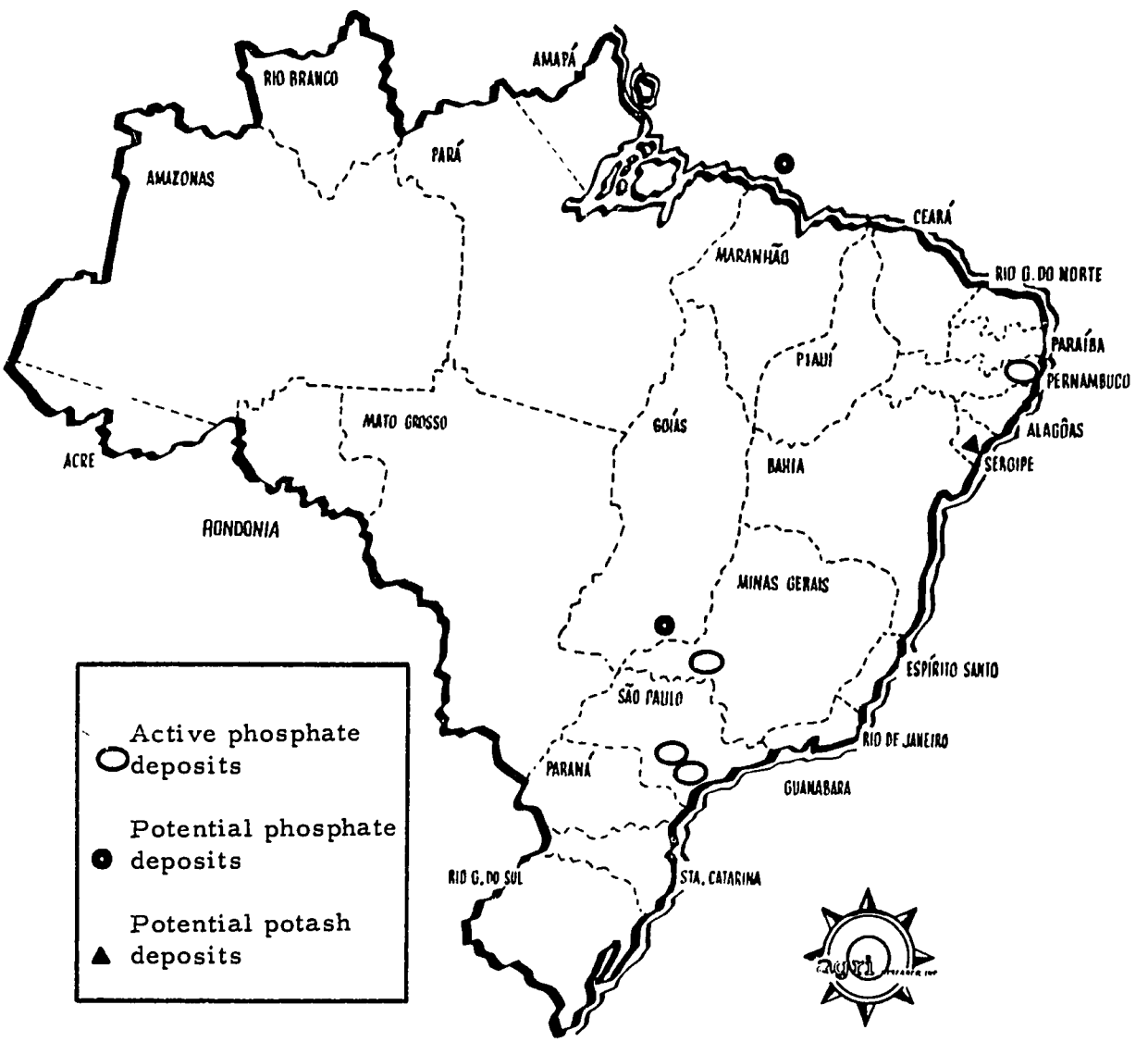

Figure 6. Location of active phosphate deposits and potential phosphate and potash deposits in Brazil

LIMESTONE

In the past, very limited amounts of agricultural limestone have been used in Brazil despite the fact that soils are generally acid in character. It is estimated that at least 10 million hectares of cropland in 1963 were so acid as to need limestone and the area of acid soils may be as much as 20 million hectares.

Soil surveys in Sao Paulo, for example, indicate that more than 90 percent of the soils are highly acid with pH of 4.5 to 5.9. In fact, one-third of the soils in the state have a pH of 5.1 or less.

In Rio Grande do Sul, an analysis of about 100 samples of soils indicated that 78 percent of the soils were acid with a pH value of less than 5.5 and of these 35 percent are extremely acid with a pH value of less than 5.0.

Of all the soil ameliorants, ground limestone is the cheapest per ton in most parts of Brazil. Not only is it the least costly per ton byt also on most acid soils, where it is readily accessible, it is likely to produce the largest monetary profit per unit of cost. Furthermore, limestone use is essential on acid soils in conjunction with the application of the more costly fertilizer elements. Correction of soil acidity provides conditions which permit maximum yield response from the application of fertilizers.

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Limestone, in addition to reducing soil acidity, provides a plant food, calcium, that is available in insufficient quantities in some of Brazil's agricultural soils. Dolomitic limestone contains the carbonates of both calcium and magnesium, both equally effective in reducing acidity, but the latter supplies another plant food, magnesium, frequently in deficient supply.

Production of agricultural limestone in Brazil is far short of the amount required. It is estimated that 250,000 tons of agricultural limestone were produced in 1963.

To raise the pH by 1.0, for example from 4.5 to 5.5, on the acid soils of Brazil, would require approximately three tons of limestone per hectare. On ten million hectares 30 million tons would be required. If this amount was applied every 8 years, 3,700,000 tons of limestone would be required per year. This amount is 15 times the current production of agricultural limestone in Brazil.

In view of the importance attached to the correction of acid soils in Brazil, the production of at least 3,700,000 tons of agricultural limestone per year should be adopted as a goal to be reached through a 25 percent increase per year over a 12 year period. Brazilian farmers, particularly in the south, already exhibit a greater recognition of the need for limestone than they do for fertilizers. High costs appear to be the chief barrier to increased use at present.

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High transportation costs make fixed plant locations uneconomical except to serve small market areas. The use of portable crushing plants, however, would permit greatly reduced costs.

Recommendations

Future investment in and expansion of the agricultural limestone industry should be done, insofar as possible, with portable plants. The initial investment and the operating costs for a portable plant are less than for a stationary plant of equal capacity. Besides producing a less expensive product, portable plants permit reduced transportation costs. Due to the large number of limestone deposits in Brazil and the ease with which portable units can be moved, production can be localized, thereby holding truck or rail movement of the final product to a minimum.

Table 17 shows the investment cost for a portable plant under four different stripping situations. Based on 150 days of operation per year and 550 tons per day of production, 82,500 tons per year, investment cost per ton of annual production would be:

	Investment per ton annual production
Situation A (very light stripping - portable)	$4.11
Situation B (moderate stripping - portable)	4.54
Situation C (heavy stripping - portable)	5.86
Situation D (heavy stripping - fixed location, portable)	6.27

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Table 17. Equipment cost analysis under four stripping situations, cost in U.S. dollars, f.o.b. factory in the United States

Situation "A"	
1. Very Light Stripping	
2. Portable Operation	
Dozer	$ 35,000.00
Crushing & Hauling Equipment	304,270.00
	$339,270.00
Situation "B"	
1. Moderate Stripping (but is full time job)	
2. Portable Operation	
Dozer for stripping	$ 35,000.00
Dozer for around plant	35,000.00
Crushing & Hauling Equipment	304,270.00
	$374,270.00
Situation "C"	
1. Heavy Stripping	
2. Portable Operation	
Push Tractor & Scrapers	$144,000.00
Dozer around plant	35,000.00
Crushing & Hauling Equipment	304,270.00
	$483,270.00
Situation "D"	
1. Heavy Stripping	
2. Stationary Operation (portable plant)	
Push Tractor & Scrapers	$144,000.00
Dozer around plant	35,000.00
Crushing & Hauling units	304,270.00
Two Heavy Duty Quarry Trucks	34,000.00
	$517,270.00

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These investment rates compare to an estimated investment per ton of annual capacity of $7.86 for a stationary plant.

Table 18 shows an estimate of operating costs for a portable limestone crushing plant under the four different stripping operations outlines above. Operating costs vary from $1.185 with very light stripping to $1.758 for heavy stripping and a thin limestone ledge. The operating costs of a portable plant under all four operating situations are less than the estimated cost of $1.90 for a stationary plant.

One the basis of 82,500 tons of production per year valued at 3,000 cruzeiros per ton converted at CR $1,400 = U.S. $1.00, the value of total production would be U.S. $176,550. Net returns on investment under the four stripping situations are shown below:

Situation	Net Return U.S. dollars	Return on investment (Percent)	Return plus interest on investment (Percent)
A - light stripping portable operation	$78,952	23	30
B - moderate stripping portable operation	68,723	18	25
C - heavy stripping portable operation	43,313	9	16
D - heavy stripping fixed location	31,515	6	13

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Table 18. Estimated operating cost, portable limestone crushing operation, four different stripping situations, Brazil, 1964

Cost item	A. Light Stripping		B. Moderate Stripping		C. Heavy Stripping portable		D. Heavy Stripping stationary	
	Cost per year (150 days)	Cost per ton of limestone crushed[1]	Cost per year (150 days)	Cost per ton of limestone crushed[1]	Cost per year (150 days)	Cost per ton of limestone crushed[1]	Cost per year (150 days)	Cost per ton of limestone crushed[1]
	(U. S. Dollars)							
Labor[2]	$ 7,000	$ .095	$ 8,500	$ .103	$ 9,300	$ .113	$ 10,900	$ .133
Operating cost, all equipment[3]	43,200	.524	48,000	.582	57,600	.698	63,600	.771
Depreciation[4]	22,700	.275	25,300	.307	32,300	.392	34,500	.418
Interest on investment[5]	24,000	.291	26,000	.315	34,000	.412	36,000	.436
Total operating cost	$97,800	$1.185	$107,800	$1.307	$133,200	$1.615	$145,000	$1.758

1 Based on annual output of 82,500 tons agricultural limestone.

2 Includes: foreman, bookkeeper, quarry labor, crusher labor, and equipment operators, total 11 to 16 men, working 150 days per year.

3 Includes fuel, repairs, parts and other supplies.

4 Based on 10-year life, adjusted for 150 days use per year.

5 At 7 percent annual interest.

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The above returns are substantially higher compared to a total return on invested capital for a stationary plant of approximately 10 percent.

These costs of producing agricultural limestone are based on an assumed production period of 150 days at 550 metric tons per day. This corresponds more or less to the time that would be available for the application of limestone. Under these conditions agricultural limestone would not be stockpiled to any extent. However, if crushing operations were extended to 300 days per year and the ground limestone stockpiled, fixed costs per ton would be reduced by 50 percent. This represents potential reductions of $0.30 - $0.40 per ton.

In the United States agricultural limestone is stockpiled in the open. Under these conditions losses are nominal so the savings incurred from operating 300 days, more than offset any losses. In Brazil, however, many areas have considerably more rainfall than the United States and it is not known with exactness what effect the additional moisture would have on losses. However, from information available it can be concluded that it is probably not economical to construct cover for stockpiling limestone.

Another means of reducing the cost of production of limestone in Brazil is to produce crushed road rock and agricultural limestone in

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the same operation. The type of plant described in this report has a daily capacity of 500 metric tons of crushed road rock plus 320 M. T. of agricultural limestone. This production combination is more efficient, assuming there is a market for both products, than producing only agricultural limestone. In Brazil, both products should be produced wherever circumstances will permit it on a profitable basis.

We recommend that agricultural limestone production be increased to at least 3, 700, 000 metric tons annually. This can be accomplished in 12 years by increasing production by 25 percent annually. Table 19 shows the additional production and investment needed for each year from 1965 to 1976 to achieve the recommended yearly production of 3. 7 million tons of agricultural limestone.

Since portable limestone plants are not presently manufactured in Brazil it will be necessary, at least initially, to import most of the equipment. It is not unreasonable to expect that equipment of this nature could be manufactured in Brazil by 1970. This means that a total of seven to nine plants will need to be imported at a total cost of 2. 6 - 3. 4 million U. S. dollars in foreign exchange, not including freight from the U. S. to Brazil. Equipment manufacturers in Brazil should be encouraged to manufacture portable limestone crushers either by licensing the right to do so from existing equip-

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Table 19. Additional production, number of plants and investment needed in Brazil, by year from 1965 to 1976, to reach an annual production of 3.7 million tons of agricultural limestons.

Year	Additional volume needed 1/ (M. T.)	Total volume produced (M. T.)	Additional plants needed 2/	Total installed plants	Additional investment needed 3/ (100 U.S. dollars)	Total accum. investment (100 U.S. dollars)
1965	62,500	312,500	1	1	374.3	374.3
1966	78,100	390,600	1	2	374.3	748.6
1967	97,700	488,300	1	3	374.3	1,122.9
1968	122,000	610,300	2	5	748.6	1,871.5
1969	152,600	762,900	2	7	748.6	2,620.1
1970	190,700	953,600	2	9	748.6	3,368.7
1971	238,400	1,192,000	3	12	1,122.9	4,491.6
1972	298,000	1,490,000	4	16	1,497.2	5,988.8
1973	372,500	1,862,500	4	20	1,497.2	7,486.0
1974	465,600	2,328,100	6	26	2,245.8	9,731.8
1975	582,100	2,910,200	7	33	2,620.1	12,351.9
1976	727,600	3,637,800	9	42	3,368.7	15,720.6

1/ Assuming production in 1964 of 250,000 tons.

2/ Plants producing only agricultural limestone at an annual rate of 82,500 tons.

3/ Investment cost is based on the amount of equipment for a moderate stripping operation.

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ment firms or by developing their own equipment.

We recommend that any program to promote expanding production of agricultural limestone in Brazil be initially concentrated in the four southern states. The bulk of the agricultural production is located in the states of Sao Paulo, Parana, Santa Catarina and Rio Grande do Sul, and it is generally known that a large proportion of the soils are quite acid. Also, farmers in this four-state area use more limestone than in other areas and have a greater appreciation for its value in increasing productivity.

Initially, we also recommend that one or two portable limestone crushing plants be imported as soon as possible and located in the Piracicaba, Sao Paulo area. These plants should be placed under competent management and be used to demonstrate the potential of portable limestone crushing plants. We feel that because of the agriculture in the general area and the existence of a large number of limestone crushing units, that the area near Piracicaba has the greatest potential for creating interest in increased production of agricultural limestone.

In order to recommend reasonably specific locations for all of the recommended plants, the following factors would have to be considered.

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1. The pH level of soils adjacent to a specific potential location.

2. The acreage of cropland in the area adjacent to the proposed location by kind of crops grown.

3. The availability, location and nature of limestone deposits in the area.

To obtain this type of information would necessitate a major study with location of agricultural limestone plants specifically in mind. In many areas considerable soil analysis would have to be undertaken. However, Figure 7 gives an indication, based on cropland acreage, location of acid soils and estimated number of limestone deposits, of the number of plants that we feel should be located in each state.

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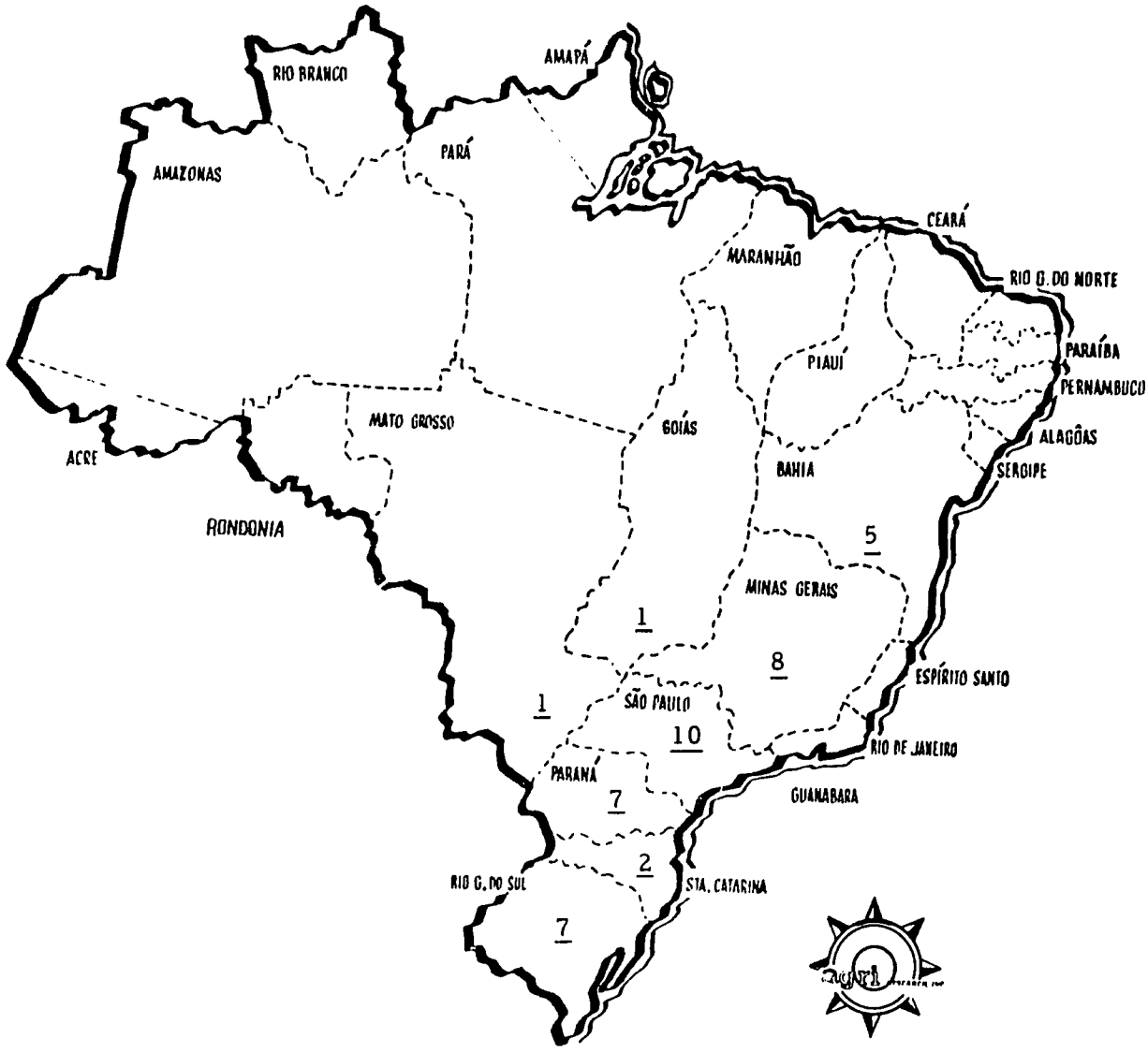

Figure 7. Suggested locations, by states, for the 42 portable limestone plants recommended for Brazil.

LIVESTOCK MINERALS

Very little is known in Brazil about the specific needs for livestock minerals. However, from the information that is available it appears that there is a general need for phosphorus, calcium and salt and, in specific areas, a need for trace minerals such as zinc, iron, copper, iodine and cobalt.

Feeding experiments conducted by Dr. Joseph Conrad and Dr. Marcelo Mendes 1/ in Minas Gerais and Mato Grosso tend to substantiate the need for phosphorus and calcium. In Mato Grosso, 400 head of beef cows on the Donald Strang Entre Rios Fazenda were started on an experiment in August, 1963. The experiment was designed to study the effect of urea-molasses, disodium phosphate and bonemeal on reproduction in beef cattle in the Pantanal area. The results of a preliminary evaluation made in June, 1964, are shown in Table 20. Feeding of phosphorus supplements appears to have increased the fertility index from 54 percent to 74 or 77 percent

Dr. Conrad, based on work in Minas Gerais, feels that, "basically two nutrients -- phosphorus and protein -- are severely limiting cattle production in the state of Minas Gerais and Central Brazil". The phosphorus situation can only be solved by the installa-

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1/ Dr. Marcelo Mendes, ETA, Rio, Technical Advisor and Dr. Joseph Conrad, Purdue-Brazil project and ETA project 55, Nutritional Advisor.

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Table 20. Preliminary results of the effect of minerals on reproduction in beef cattle, Mato Grosso, Brazil, 1964

Treatment	Lot 1 Control	Lot 2 90% molasses 10% urea	Lot 3 Disodium phosphate	Lot 4 Bonemeal
No. cows	100	100	100	100
No. calves weaned 1/	100	100	100	100
Cows in gestation				
Definitely	28	36	54	63
Doubtful	53	41	41	29
Negative	19	22	5	8
Fertility index 2/	54%	56%	74%	77%
Experimental feed consumed per cow	0	401 kg.	1.1 kg.	9 kg.
Cost of experimental feed per cow (cruzieros)	0	8,850	1,765	400

1/ The number of calves weaned from the above cows in the laction period prior to the beginning of the experiment. The purpose of selecting cows with calves at side was to insure selecting cows capable of conception.

2/ Calculated on the basis that 50 percent of the doubtfuls are with calf.

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tion of a plant or plants to produce either defluorinated phosphate or dicalcium phosphate, separately or in conjunction with a fertilizer plant.

Requirements for Livestock Minerals

Estimated Brazilian national requirements for calcium and phosphorus for livestock and poultry production in 1962 and 1970 are shown in Table 21. Total requirements in 1962 are estimated to have been 875,000 tons of calcium and 640,990 tons of phosphorus. By 1970, it is estimated that 1.0 million tons of calcium and 764,000 tons of phosphorus will be required. Under normal conditions, these requirements would be met from feeds and forages consumed. However, because soils in Brazil are generally deficient in calcium and phosphorus, these two minerals are also generally deficient in animal diets composed only of feeds and forages. With present research information, however, it is not possible to estimate the magnitude of the deficiency of calcium and phosphorus.

Recommendations

On the bases of the general evidence available, we recommend that enough calcium and phosphorus be produced in Brazil by 1970 to meet at least 5 percent of the annual requirements for these two minerals for cattle, sheep and goats. We feel that very little, if any,

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Table 21. Estimated mineral requirements of Brazilian livestock and poultry, national total, 1962 and 1970

Species of livestock	Annual mineral requirements -tons			
	Calcium		Phosphorus	
	1962	1970	1962	1970
Cattle	384, 345	433, 620	320, 580	361, 680
Hogs	212, 660	280, 600	154, 470	203, 820
Horses	73, 620	87, 870	84, 940	101, 380
Sheep and Goats	38, 520	43, 320	35, 310	39, 710
Poultry	166, 660	210, 960	45, 690	58, 010
TOTAL	875, 305	1, 056, 370	640, 990	764, 600

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calcium or phosphorus will be fed to horses for some time in the future. With most of the bones available for processing into animal feed presently being incorporated into tankage, swine and poultry in some areas of Brazil are probably receiving reasonably adequate supplies of calcium and phosphorus at the present time. Based on these assumptions, approximately 23,900 tons of calcium and 20,100 tons of phosphorus will be required by 1970 to supply 5 percent of the cattle and sheep requirements. Both of these minerals can be supplied in supplemental form from either steamed bonemeal or defluorinated tricalcium phosphate.

Steamed bonemeal is a by-product of the meat packing industry and based on 1962 slaughter data for Brazil, sufficient quantities of bonemeal could have been produced in 1962 to supply 25 percent of the calcium and phosphorus requirements for livestock and poultry. However, most of the bones presently available are being processed in tankage or other feed supplements fed primarily to poultry and swine. About 20 percent of the bones are used for fertilizer. As long as there is sufficient demand for tankage it is unlikely that much bonemeal will be processed since the monetary return from using the bone in tankage is greater than if used for steamed bonemeal.

The manufacture and use of defluorinated tricalcium phosphate appears to be the most feasible means for supplying feed phosphate

and calcium in Brazil at the present time. This material can be produced from normal superphosphate by a simple calcination step. The process is easily operated, the product has been proven to be an excellent source of phosphorus and calcium for animals and the equipment can be manufactured in Brazil.

In manufacturing feed phosphate from normal superphosphate care should be taken to insure that the fluorine content in the feed product is not greater than 1 part F to 100 parts of P. Also the fluorine and sulfur off gases should be thoroughly scrubbed and neutralized with limestone before they are disposed of in order to prevent air and water pollution.

A typical cost estimate for a plant designed for 18,000 tons per year of 14 percent P product is as follows:

	Cost - U.S. $
Bucket elevator 40' - 40TPH	$ 10,000
Weight hopper, 2 tons, auto batch	2,000
Belt conveyor 150' - 40 TPH	25,000
Feed bin, 32 tons, with feeder	8,000
7' x 90' kiln, fire box, feed, pipe scrubber and stack	200,000
Quench and conveyor to storage 150' - 5 TPH	15,000
Payloader	15,000
Shipping mill	70,000
Structures	40,000
Electrical 240 HP	36,000
	$411,000
Engineering and contingencies at 30 percent	124,000
TOTAL	$535,000

The above estimate is based on the assumption that the feed phosphate plant is made a part of an existing superphosphate plant and that sufficient land, utilities, tracts, etc. are available.

An operating cost estimate for Brazil in the state of Sao Paulo, for a 18,000 TPY plant as of March, 1964 follows:

NSP at 20%, 1.74 T at 26.67/ton	$835,304
Fuel, 8M^2 BTU/ton (53 gpt) at $0.072/gal.	68,688
Power, 100 KWH/ton at $0.007/KWH	12,600
Depreciation, $535,000 at 10 years	53,500
Maintenance at 7%	37,450
Insurance and taxes at 2%	10,700
Operating labor, 2 men/shift, 4 shifts plus 5 men/shift - 13 men at $1,000/year	13,000
Fringe and social benefits at 100% operating labor	13,000
Plant overhead at 100% of labor & finge benefits	26,000
Supplies, $1 per ton	18,000
Bags, $4 per ton	72,000
YEARLY TOTAL	U.S. $1,160,242
Cost per ton	$64.45

At the rate of exchange of 1400 cruzeiros per U.S. dollar, this is CR $90,230 per ton.

We were unable to uncover any meaningful experimental feeding data in Brazil that showed how calcium and/or phosphorus affected the rate of growth of cattle so the profitability of feeding these minerals could be determined. However, in order to obtain a general idea of the profitability of feeding calcium and phosphorus, an analysis was made of the preliminary results obtained in the study of the

effect of minerals on reproduction mentioned earlier.

In this study the control herd had a fertility index of 54 percent while the herd fed disodium phosphate had a fertility index of 74 percent. This means that for every 100 cows receiving disodium phosphate 20 more calves could be expected, compared to the same number of cows receiving no calcium or phosphorus. Assuming that all the extra calves reach market weight, the extra income generated would be 1.8 million cruzeiros 1/. The cost of feeding defluorinated superphosphate to 100 cows for 12 months would be 17,100 cruzeiros. Although these figures are based on preliminary results, it is clearly demonstrated that supplemental feeding of calcium and phosphorus to cow herds is profitable even if the final evaluation of the experiment shows only half the improvement in conception as was indicated in the preliminary evaluation.

In order to provide the 23,900 tons of calcium and 20,100 tons of phosphorus supplement recommended for 1970, eight plants producing 18,000 tons of defluorinated superphosphate per year will be required. These plants will require a total estimated investment of U.S. $4.3 million.

1/ Based on a market weight of 460 kilograms and a price of CR $90,000 per head (reported to be the price in Sao Paulo in April 1964).

Figure 8 shows the recommended locations for these plants. These locations were selected on the basis of (1) cattle, sheep and goat population, (2) location of superphosphate plants, and (3) transportation systems and facilities available. Although the plants in Sao Paulo and Recife must supply large distribution areas, transporting feed phosphate to distribution centers is more economical than building feed phosphate plants throughout the country and shipping superphosphate to them. If, due to the development of the fertilizer industry, superphosphate facilities are established in other areas of the country, then consideration should be given to the possibility of a feed phosphate plant with those facilities.

Feed grade dicalcium phosphate is also an excellent source of phosphorus and in the United States it is preferred over defluorinated superphosphate. However, the manufacture of dicalcium phosphate is a more complicated process and requires phosphoric acid which is not presently manufactured in Brazil. As the fertilizer industry in Brazil develops, phosphoric acid will undoubtedly be produced. At such time as it is, consideration should be given to the manufacture of feed grade dicalcium phosphate.

The recommended priorities for investment and location of feed phosphate plants are shown in Table 22. By 1970, more information should be available concerning the need for calcium and phosphorus

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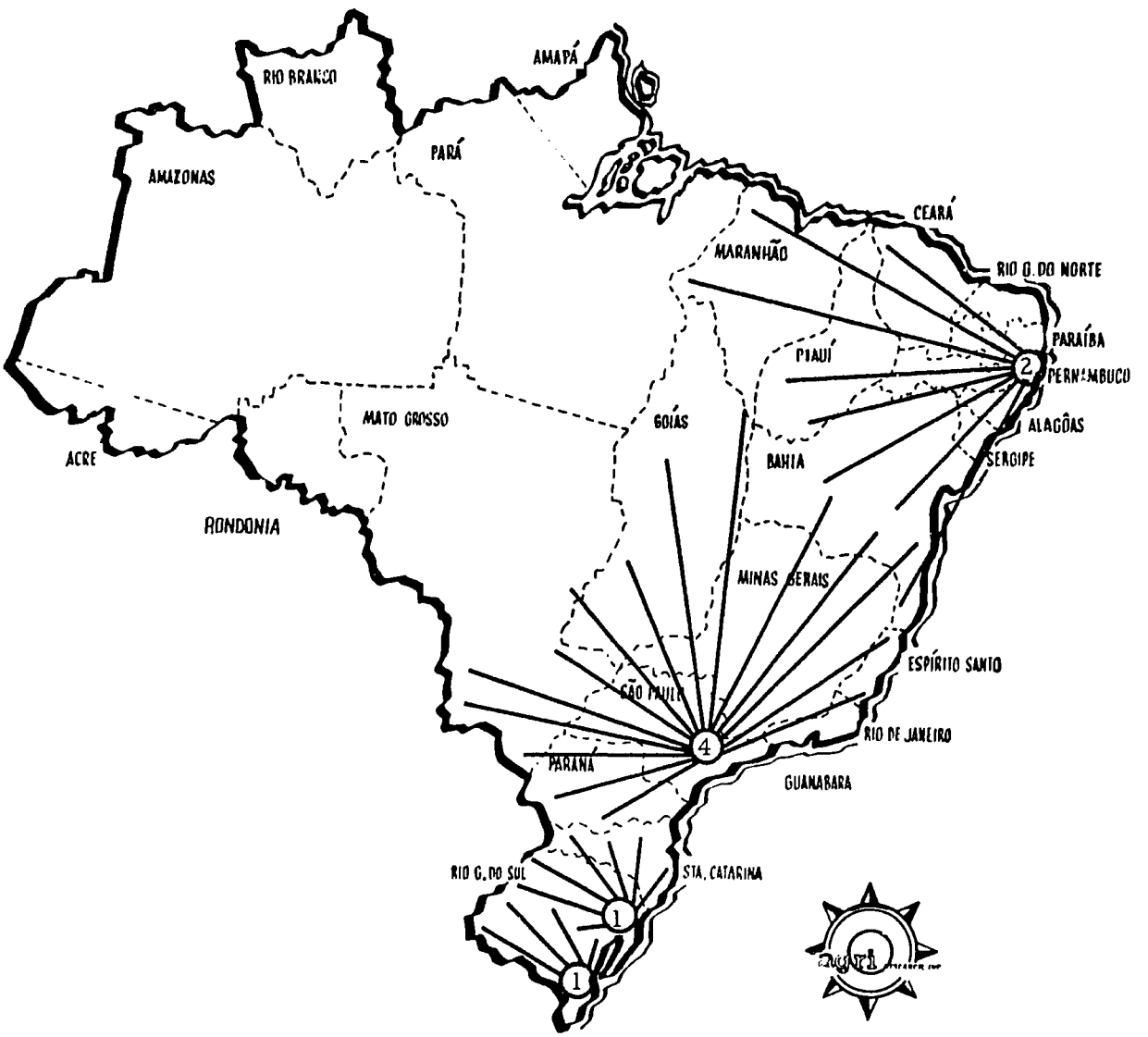

Figure 8. Recommended locations for feed phosphate plants, Brazil, 1970.

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Table 22. Additional production, number and location of plants, and investment needed, in Brazil from 1965-1970, to reach an annual production of 144,000 tons of feed phosphate

	Year					
	1965	1966	1967	1968	1969	1970
Additional volume needed (tons P)	2,500	2,500	2,500	2,500	5,000	5,000
Total volume produced (tons P)	2,500	5,000	7,500	10,000	15,000	20,000
Additional plants needed 1/	1	1	1	1	2	2
Location of additional plants	Sao Paulo	Sao Paulo	Porto Alegre	Recife	Sao Paulo & Rio Grande	Sao Paulo & Recife
Total installed plants	1	2	3	4	6	8
Additional investment needed (100 US$) 2/	540.0	540.0	540.0	540.0	1,080.0	1,080.0
Total accumulative investment (100 US$)	540.0	1,080.0	1,620.0	2,160.0	3,240.0	4,320.0

1/ Based on a plant producing 18,000 tons per year of 14 percent defluorinated superphosphate.
2/ Investment cost is based on the assumption that the plants will be located adjacent to a normal superphosphate plant.

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for livestock production. Production of these two minerals after 1970 should be based on the new information at hand.

We have not attempted, in this study, to analyze the need for or to make recommendations for trace minerals for livestock. Information on the problem of trace minerals deficiencies in Brazilian livestock production is not sufficient to make reasonable recommendations for specific problem areas. Research work should be intensified, particularly in areas of the country where trace mineral deficiencies are suspected. Until more information is available, farm supply firms located in suspected deficient areas should be encouraged to import trace minerals for mixing with other livestock and poultry feeds or import mineralized salt.

There does not appear to be any serious shortage of salt supplies in Brazil. During the period from 1953 to 1962 the average annual rate of increase in salt production was 7.5 percent. Assuming a continuation in salt production of 7.5 percent per year, total production by 1970, will be 2.3 million tons. If all of the major species of livestock and the human population in Brazil in 1970 were to receive the amount of salt required for good health and growth, it is estimated that 2.6 million tons of salt will be needed. However, even if production were to equal the optimum requirement, there would be substantial numbers of livestock and some humans who, for one

reason or another, would not receive the required amounts. Thus, 2.3 million tons will adequately supply the effective demand for salt in 1970.

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APPENDIX A

INFORMATION RELATING TO THE COST OF PRODUCTION, INVESTMENT AND PROCESSES FOR VARIOUS TYPES OF FERTILIZER PLANTS

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APPENDIX A

Information Relating To The Cost Of Production, Investment And Processes For Various Types Of Fertilizer Plants

The information on investment and production costs given in this Appendix is based on a United States - Florida location. Thus, the cost figures presented cannot be used directly as being entirely representative of the situation in Brazil. However, the same relationships between various processes and plant capacities should hold for Brazil.

Plant capacities and production costs are based on short tons (2,000 pounds). In order to roughly calculate capacities in terms of Metric tons (2,240 pounds) the short ton capacities or tonages should be multiplied by .90. The approximate production cost per metric ton can be obtained by multiplying the short ton production cost by 1.10.

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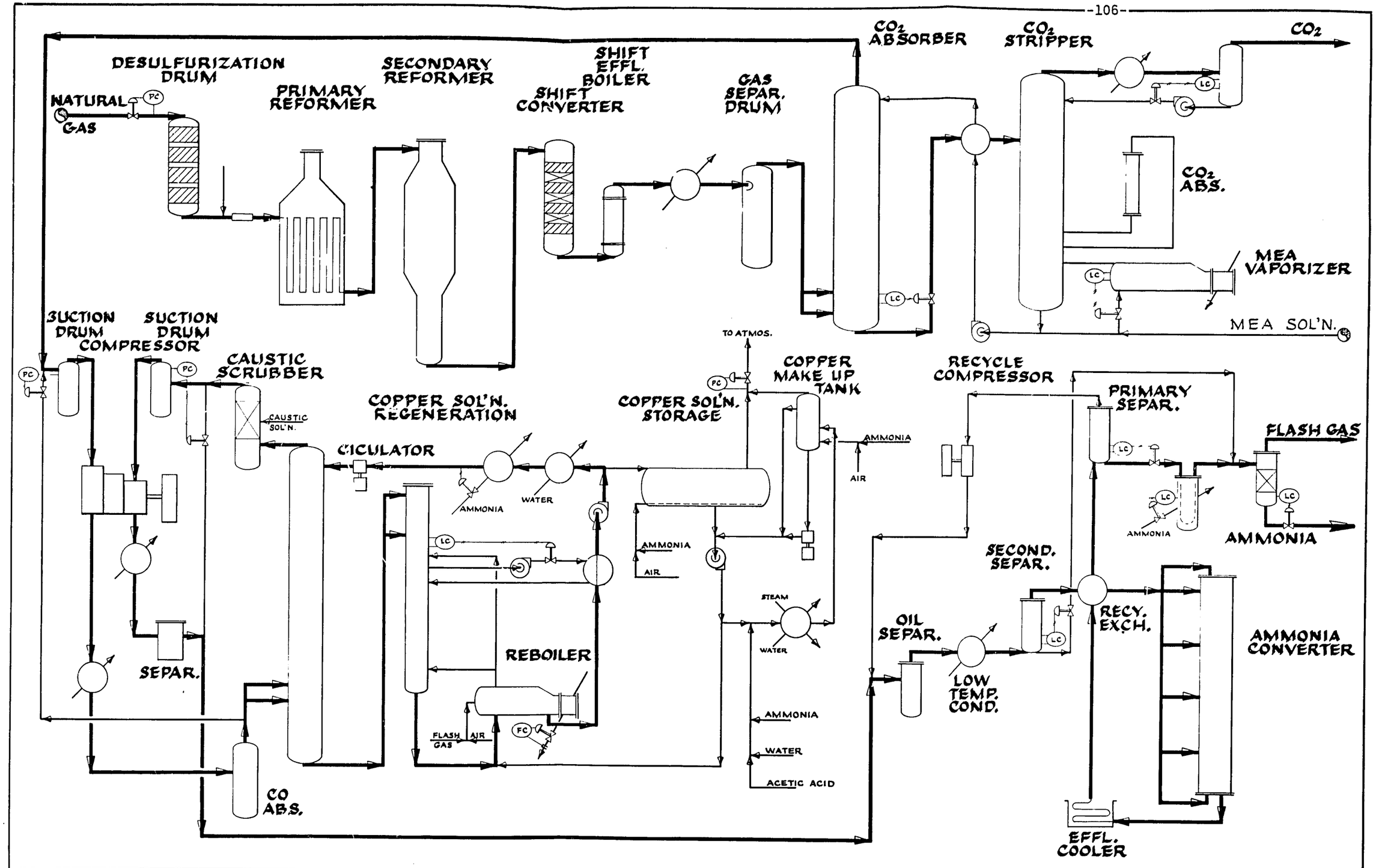

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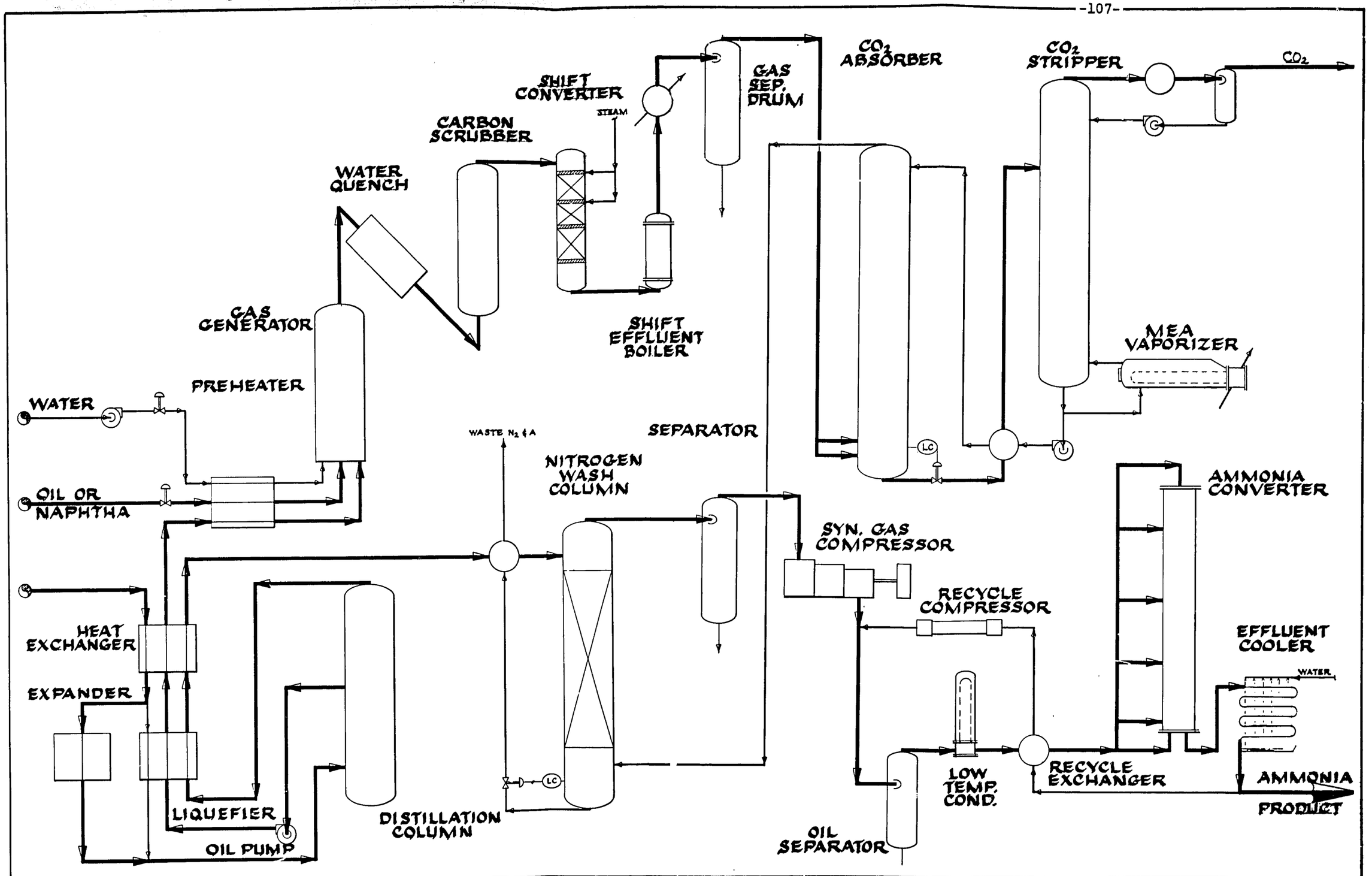
AMMONIA

FIGURE A-1



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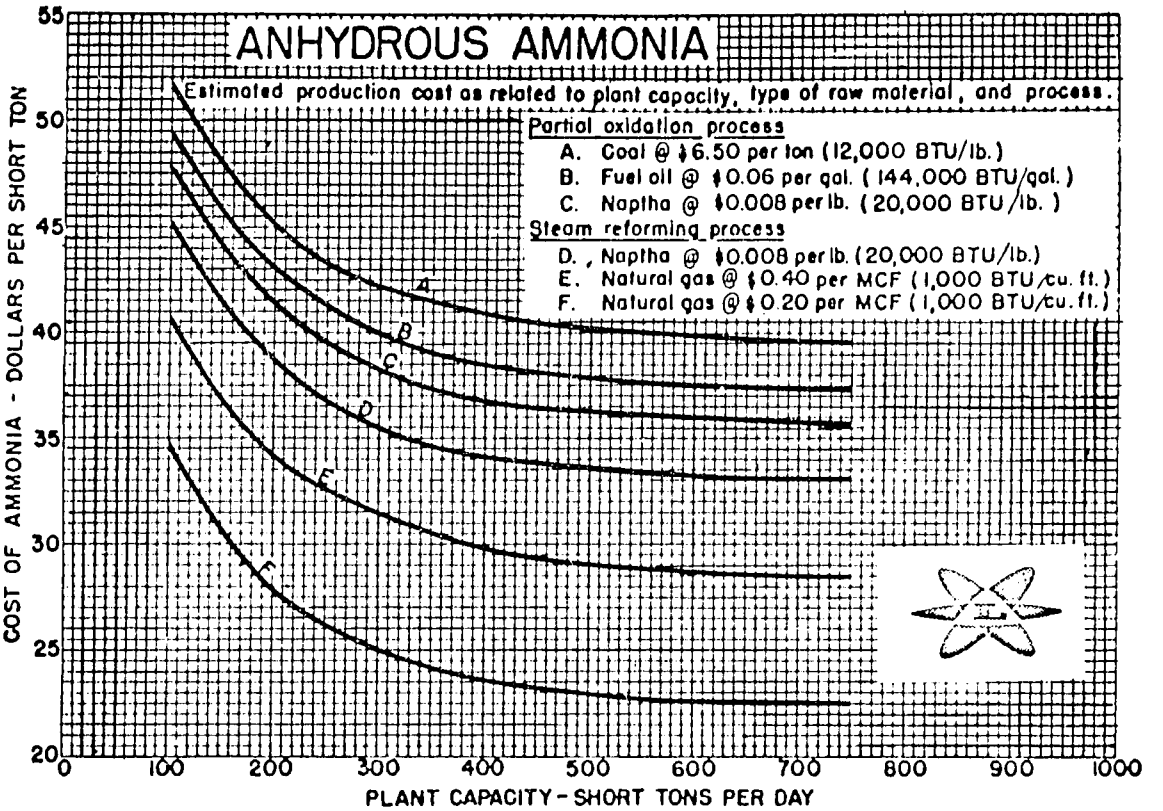
AMMONIA
OIL & NAPHTHA FEED

FIGURE A-2



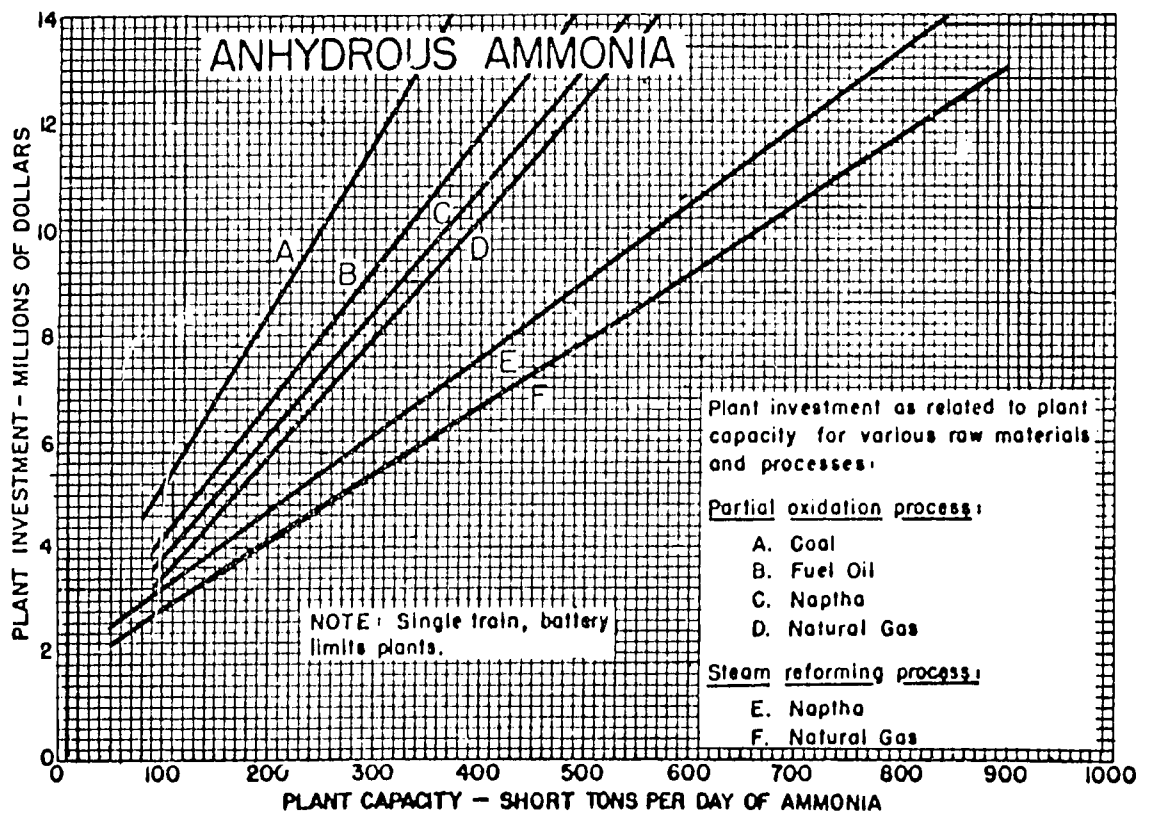


Figure A-3.

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Relative Costs of Producing Anhydrous Ammonia

Raw Material	Cost	Energy Content (BTU's)	Quantity Per Ton of NH_3	Production Cost Ratio
Steam Reforming Process:				
Natural gas	$ 0.20 per MCF	1,000 per cu. ft.	28,400 cu. ft.	1.00
Natural gas	$ 0.40 per MCF	1,000 per cu. ft.	28,400 cu. ft.	1.25
Naptha	$16.00 per ton	20,000 per lb.	0.8 tons	1.46
Partial Oxidation:				
Naptha	$16.00 per ton	20,000 per lb.	0.8 tons	1.55
Fuel oil	$ 0.06 per gal.	18,500 per lb.	0.85 tons	1.62
Coal	$ 6.50 per ton	12,000 per lb.	1.7 tons	1.72

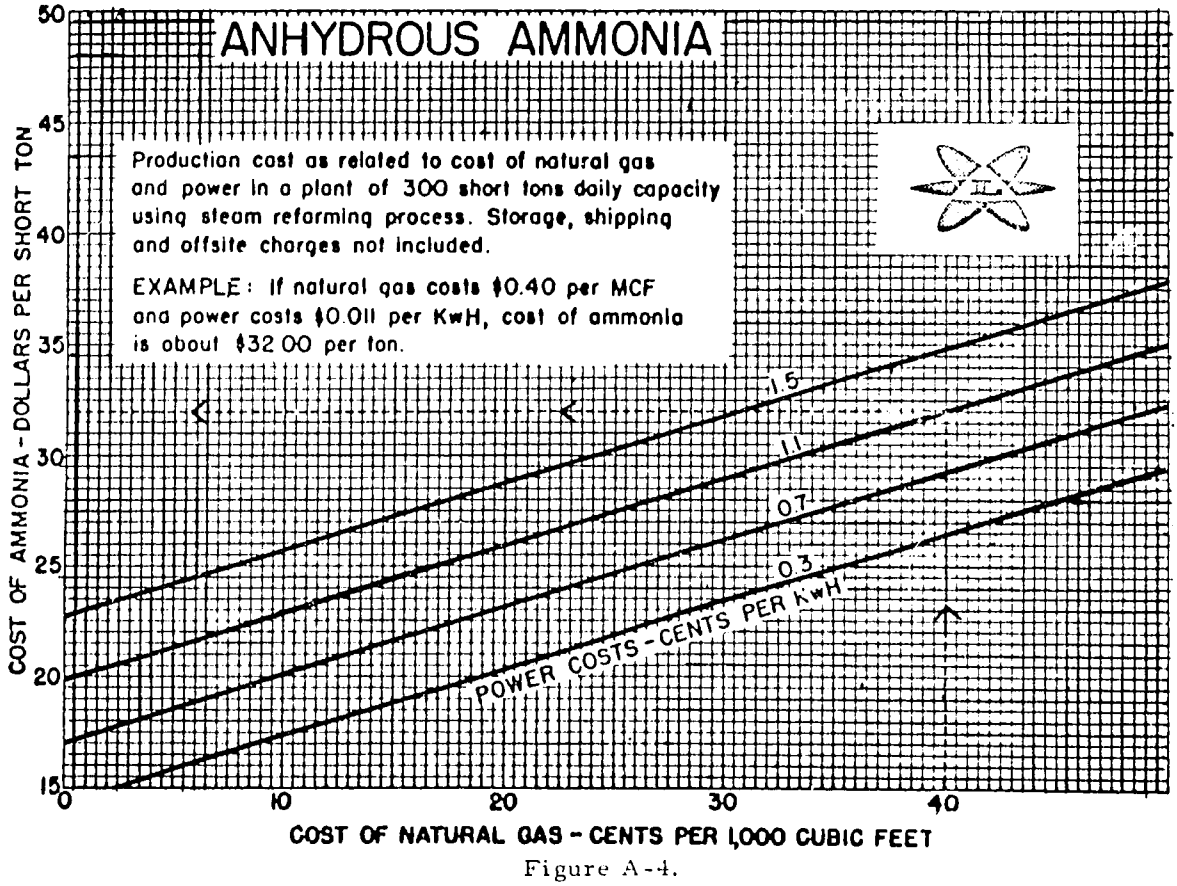

Figure A-4.

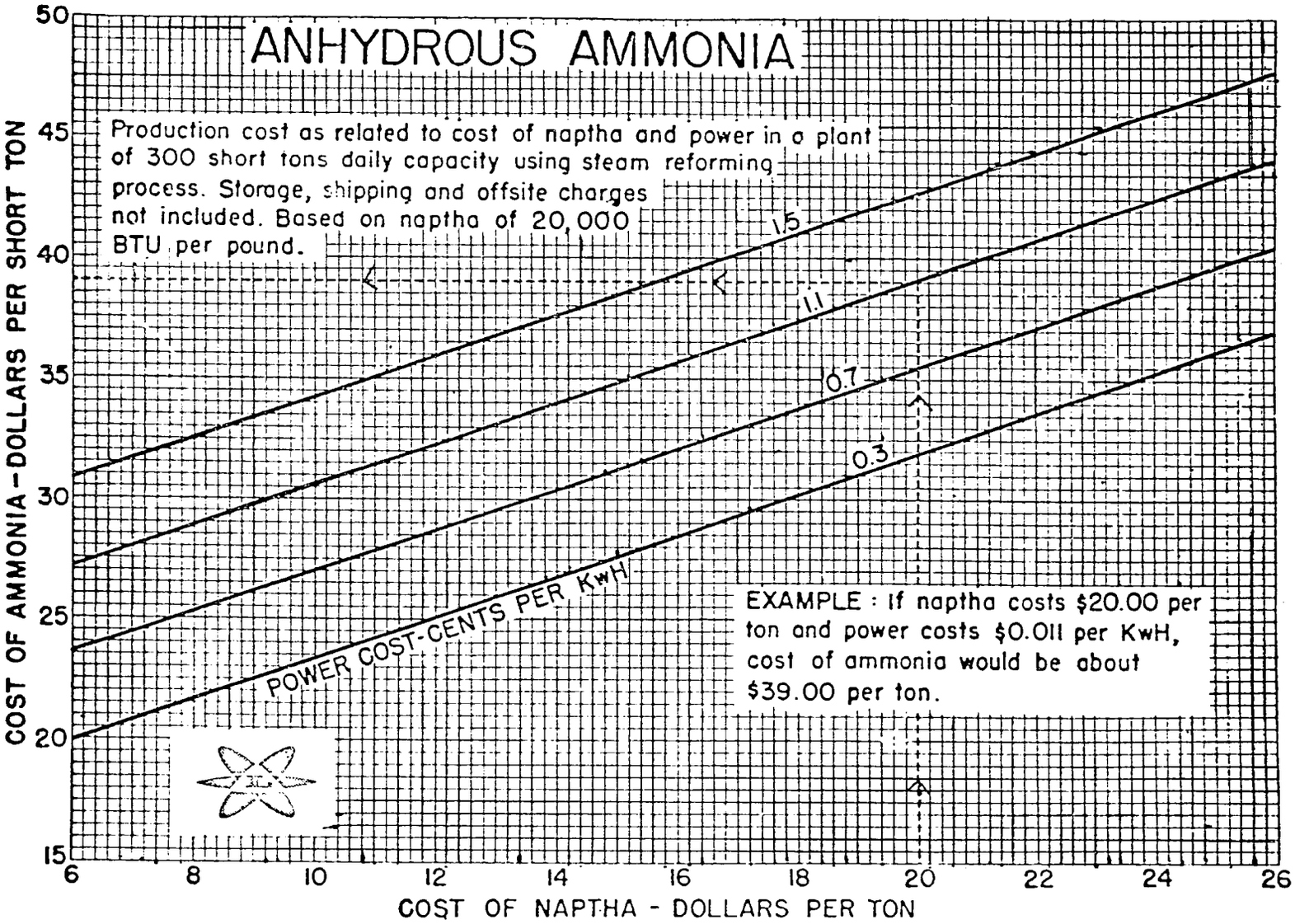
ANHYDROUS AMMONIA
Production cost as related to cost of naptha and power in a plant of 300 short tons daily capacity using steam reforming process. Storage, shipping and offsite charges not included. Based on naptha of 20,000 BTU per pound.
1.5
1.1
0.7
0.3
POWER COST-CENTS PER KwH
EXAMPLE : If naptha costs $20.00 per ton and power costs $0.011 per KwH, cost of ammonia would be about $39.00 per ton.
COST OF AMMONIA-DOLLARS PER SHORT TON
50
45
40
35
30
25
20
15
6
8
10
12
14
16
18
20
22
24
26
COST OF NAPTHA - DOLLARS PER TON

Figure A-5.

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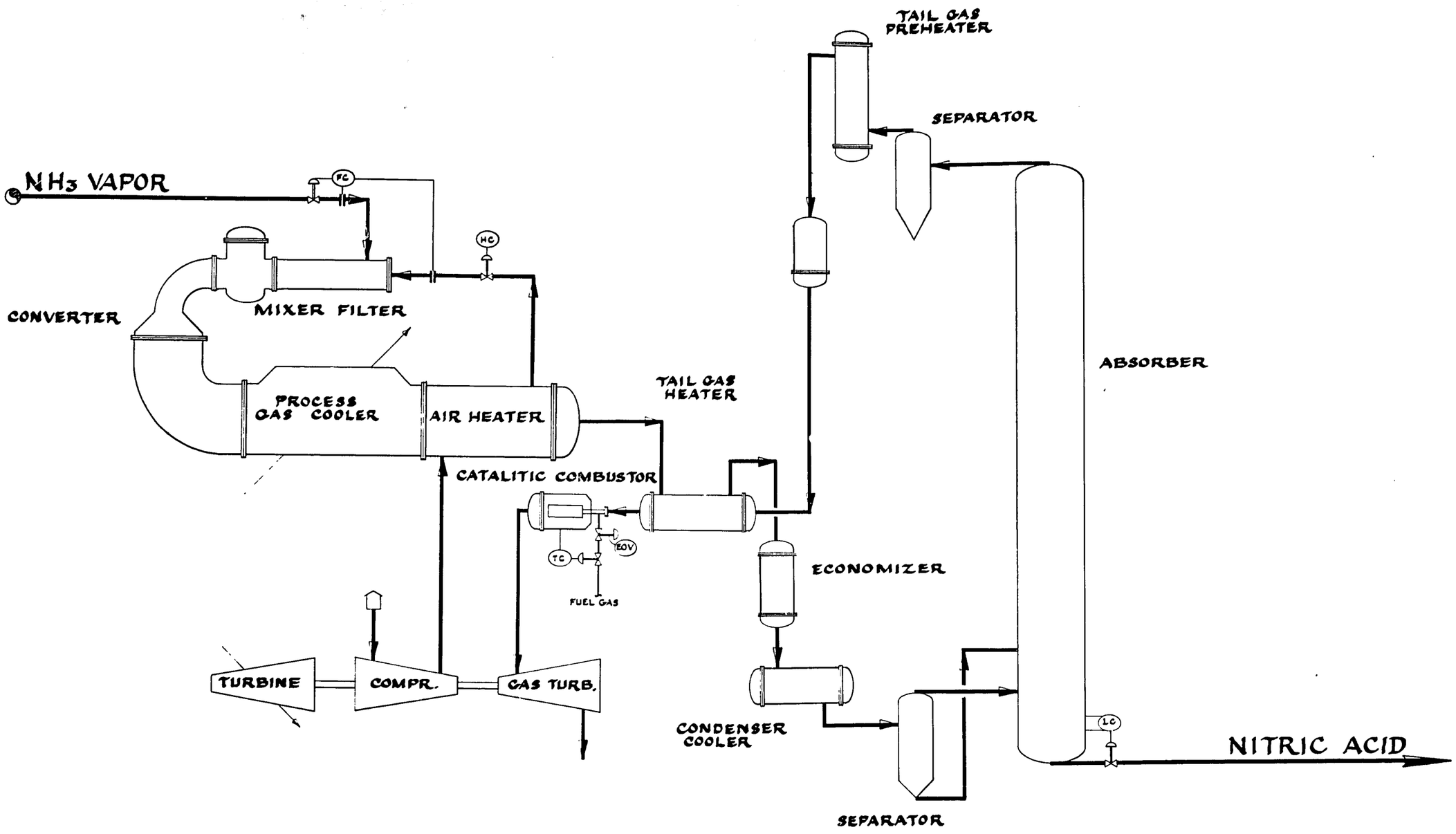

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NITRIC ACID

FIGURE A-6

Table A-1. Estimated production cost of nitric acid

Assumptions:

Plant capacity - 100 tons of 100% nitric acid per day (as 60% HNO_3).
Plant location - Florida, U.S.A.
Plant cost - $1,100,000
Process - Uhde-type high pressure, 95% conversion.

Direct Costs:

Raw Materials	Units	Units Per Ton	Units Per Year	U.S. Dollars Per Unit	U.S. Dollars Per Year	U.S. Dollars Per Ton
Ammonia 2/	Short tons	0.292	10,230	$92.00	$1,115,000	$31.90
Power	KwH	9.0	315,000	0.007	2,205	.06
Catalyst	Grams	0.182	6,380	2.61	16,600	.48
Cooling water	M gallons	36.0	1,260,000	0.05	63,000	1.80
Extra steam	M pounds	0.26	9,100	0.50	4,550	.13
Total Raw Materials					$1,201,355	$34.37
Operating Labor 3/						2.00
Maintenance and supplies						1.00
Total Direct Costs						$37.37

Indirect Costs:

Depreciation (at 10%)	3.14
Insurance and taxes (at 3%)	1.00
Interest on investment and working capital (at 4%)	1.45
All other 4/	1.50
Total Indirect Costs	$ 7.09
Total Gross Manufacturing Cost	$44.46
Less steam credit (at $1.15 per ton) 5/	-1.15
Total Net Manufacturing Cost	$43.31
Manufacturing Cost Less Cost of Ammonia 6/	$11.41

1/ Dollars per ton of 100% HNO_3.
2/ Based on purchased ammonia at currently quoted price.
3/ Two men per shift at $2.30 per hour, multiplied by a factor of 1.8 to allow for fringe benefits.
4/ Overhead, etc., assumed to be 50 percent of operating and maintenance labor.
5/ Assumes steam produced at the rate of 2,300 pounds per ton of HNO_3.
6/ Ammonia cost varies independently of other costs.

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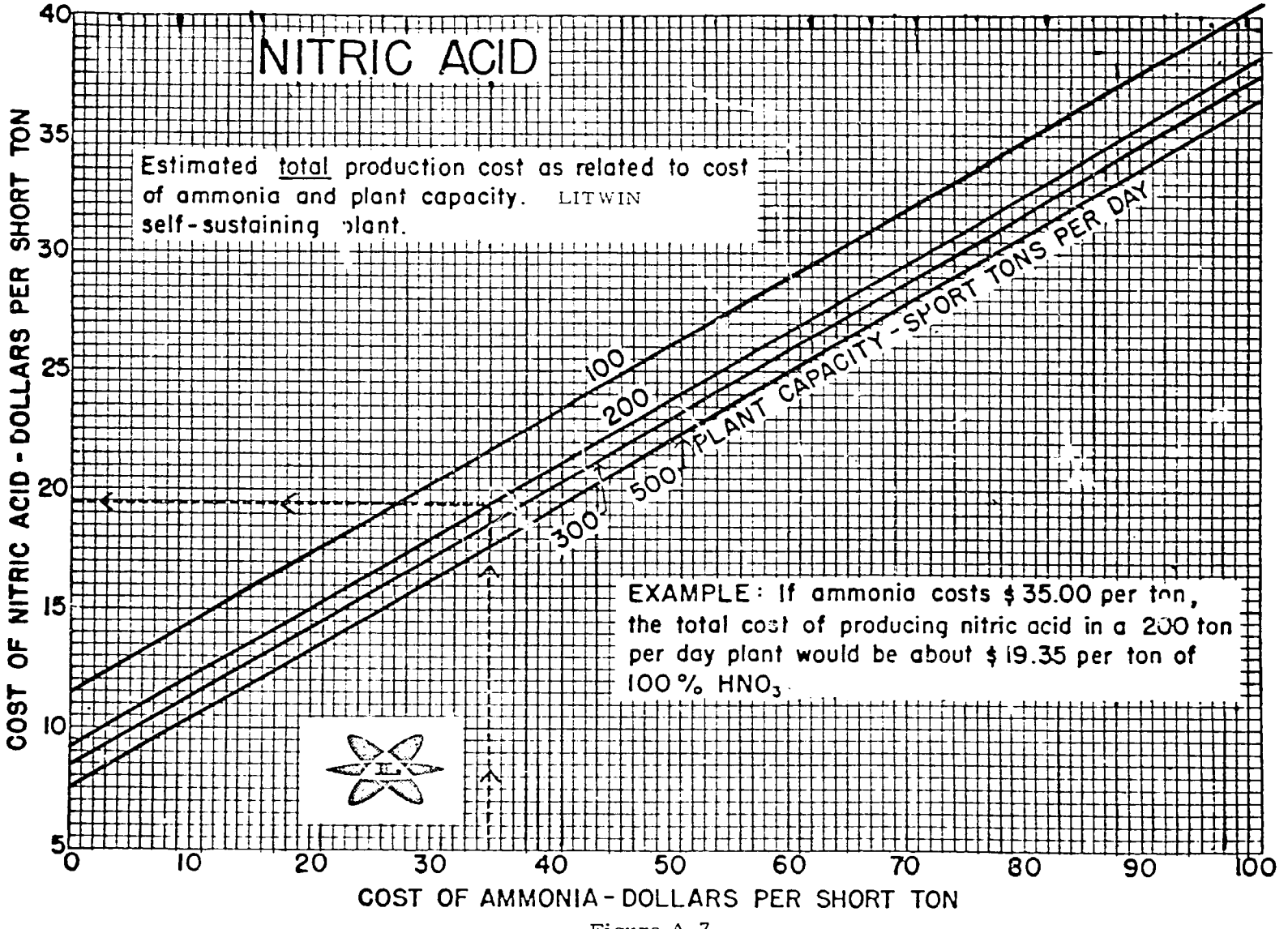
NITRIC ACID
Estimated total production cost as related to cost of ammonia and plant capacity. LITWIN
self-sustaining plant.
PLANT CAPACITY - SHORT TONS PER DAY
100
200
300
500
EXAMPLE: If ammonia costs $ 35.00 per ton, the total cost of producing nitric acid in a 200 ton per day plant would be about $ 19.35 per ton of 100 % HNO_3.
COST OF NITRIC ACID - DOLLARS PER SHORT TON
COST OF AMMONIA - DOLLARS PER SHORT TON
40
35
30
25
20
15
10
5
0
10
20
30
40
50
60
70
80
90
100

Figure A-7.

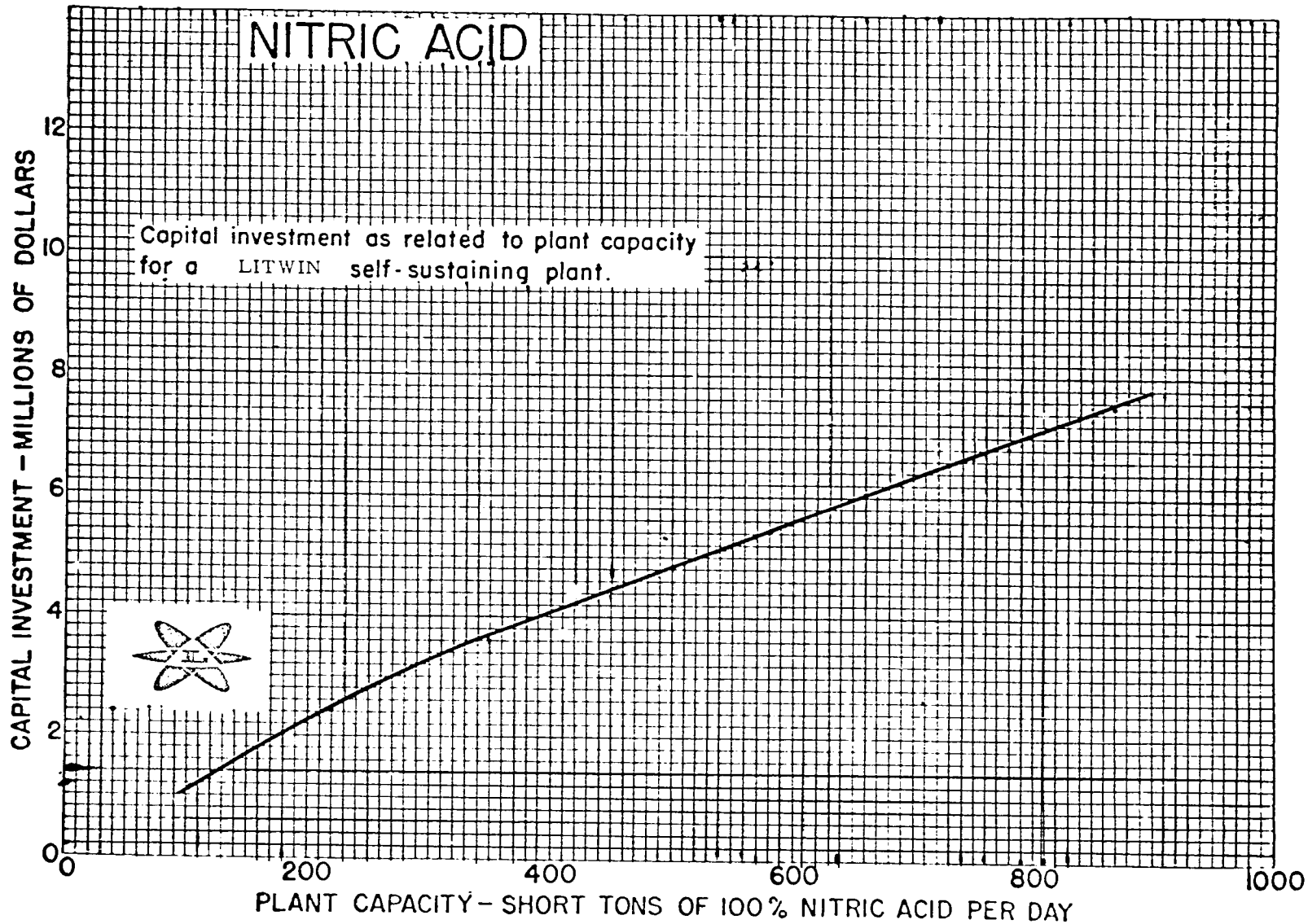
NITRIC ACID
Capital investment as related to plant capacity for a LITWIN self-sustaining plant.
CAPITAL INVESTMENT – MILLIONS OF DOLLARS
0
2
4
6
8
10
12
0
200
400
600
800
1000
PLANT CAPACITY – SHORT TONS OF 100% NITRIC ACID PER DAY

Figure A-8.

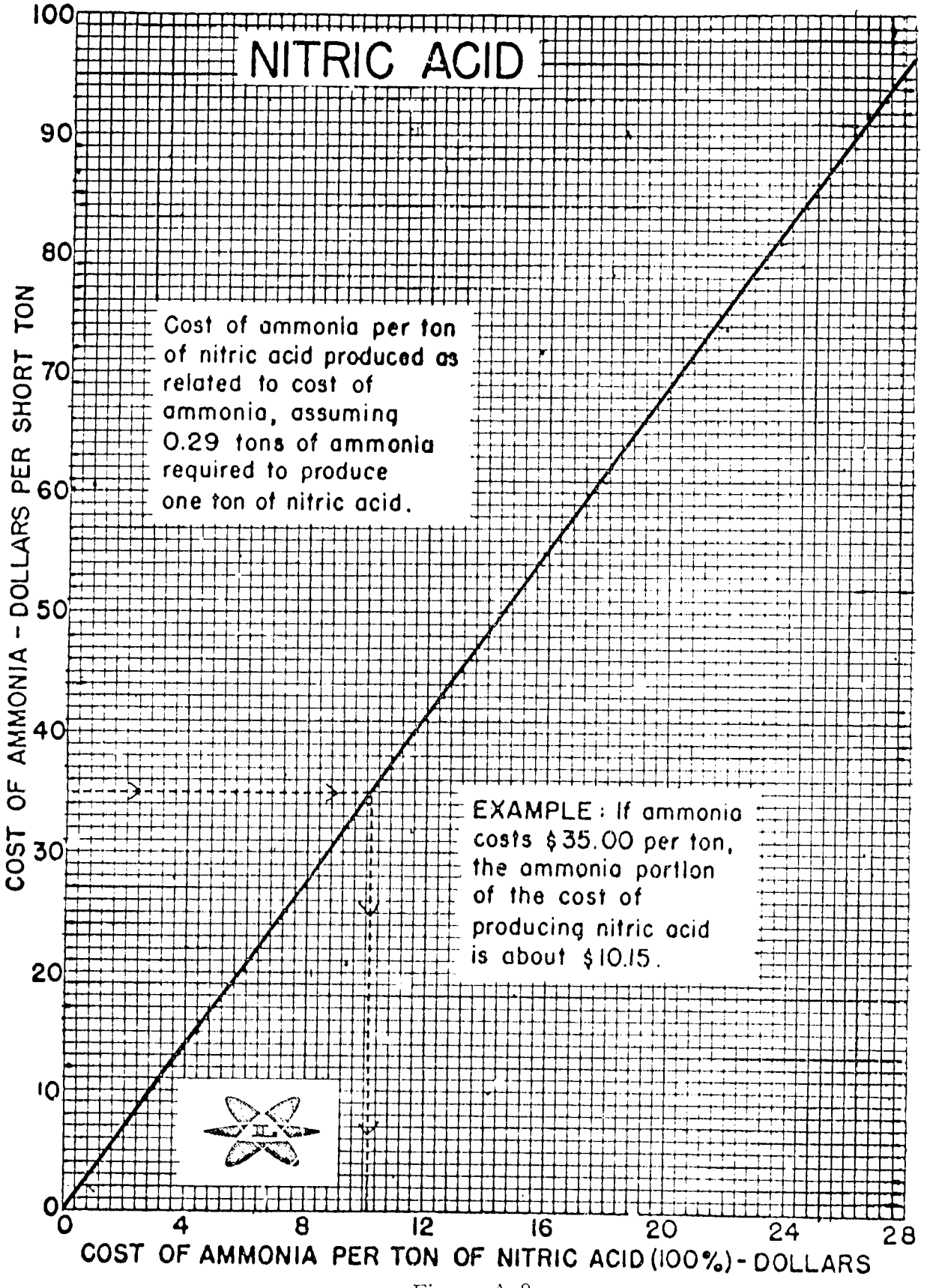
NITRIC ACID
Cost of ammonia per ton of nitric acid produced as related to cost of ammonia, assuming 0.29 tons of ammonia required to produce one ton of nitric acid.
EXAMPLE: If ammonia costs $35.00 per ton, the ammonia portion of the cost of producing nitric acid is about $10.15.
COST OF AMMONIA - DOLLARS PER SHORT TON
COST OF AMMONIA PER TON OF NITRIC ACID (100%) - DOLLARS
0
10
20
30
40
50
60
70
80
90
100
0
4
8
12
16
20
24
28

Figure A-9.

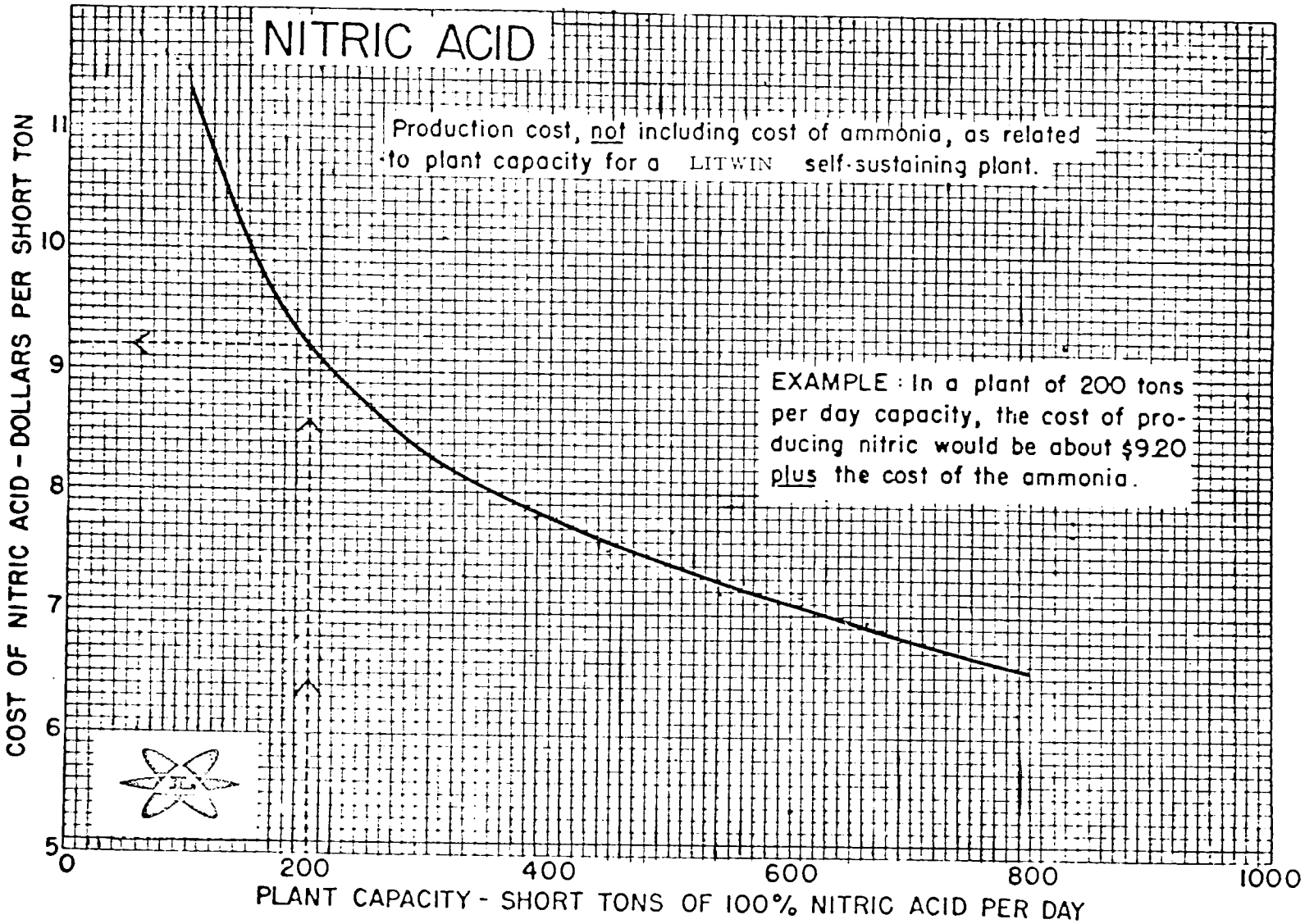

Figure A-10.

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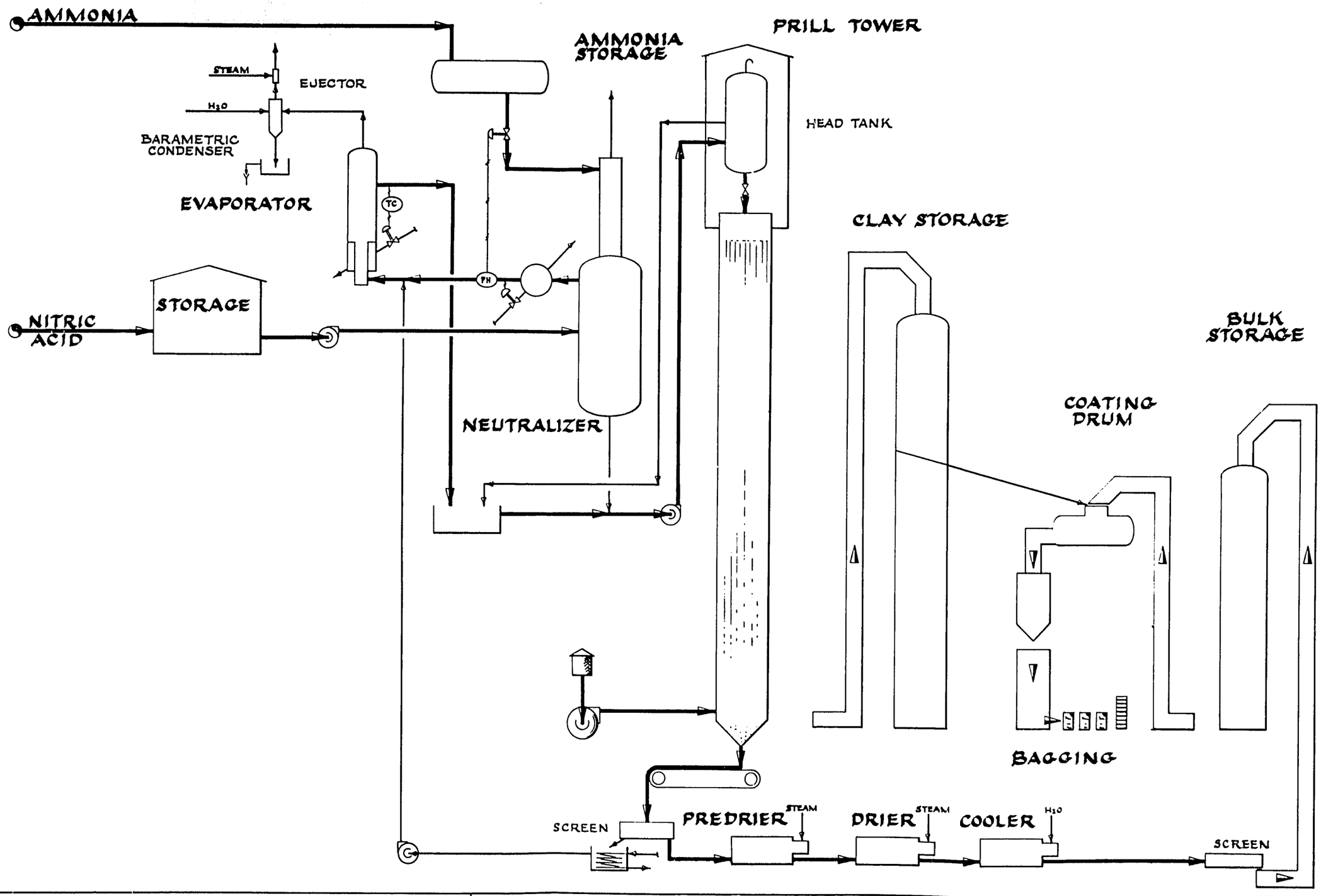

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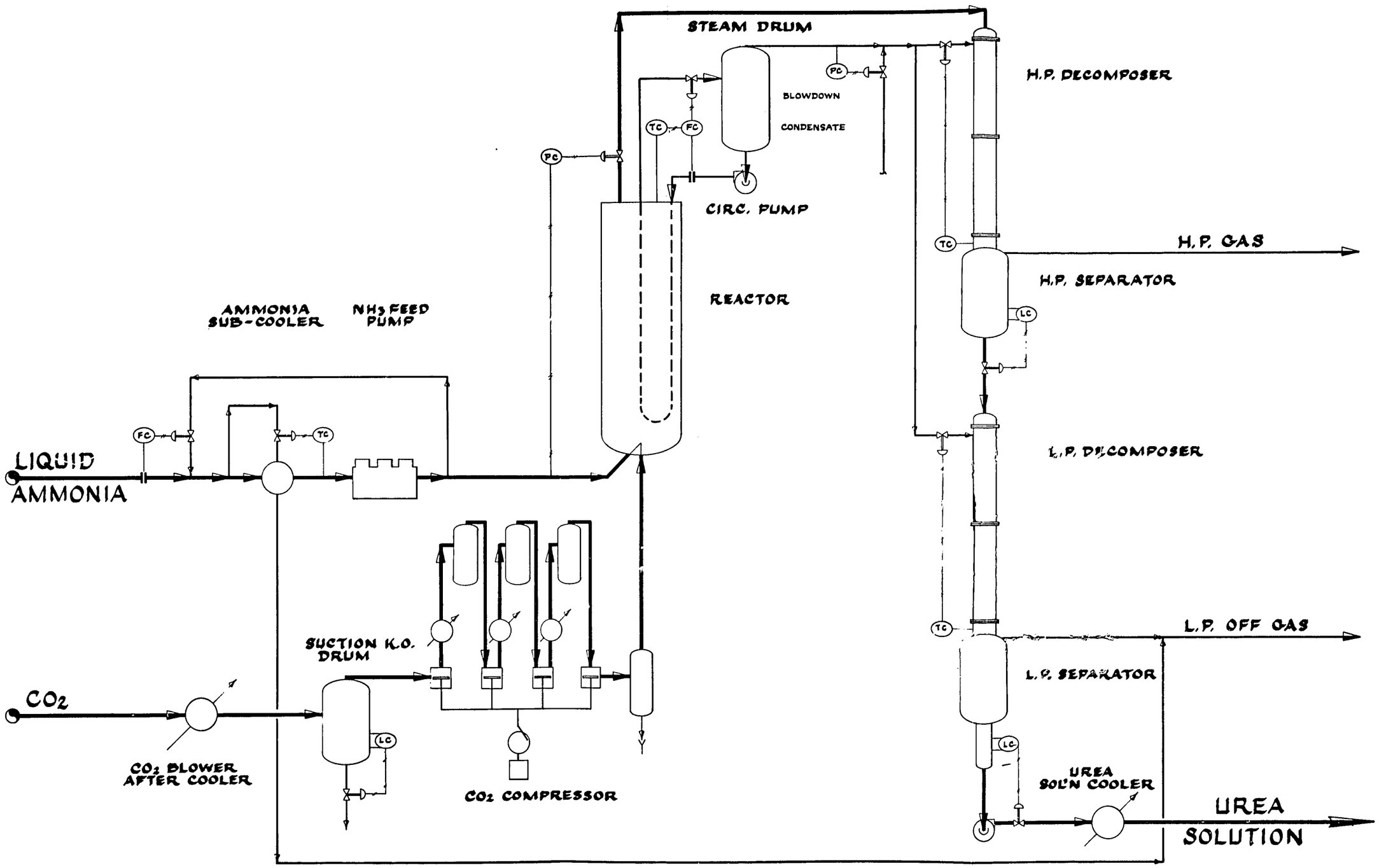
AMMONIUM NITRATE PRILLING

FIGURE A-11



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UREA

FIGURE A-12

Table A-2. Estimated production cost for prilled urea

Assumptions:

100 T/D Prilled Urea Plant
350 Stream D/Yr. = 35,000 T/Yr.

Direct Materials	Units	Unit Cost	Totals
NH_3 (Anhydrous)	0.567	$35.00	$19.86
CO_2	1.468	-	-
Bage	25	$ 0.25 ea.	6.25
Other Direct Costs			
Variable Costs			
Operating labor - hrs.	0.335	$ 2.00/hr.	$ 0.67
Repair labor - hrs.	0.084	1.95/hr.	0.16
Payroll taxes, ins. & retirement			0.06
Repair materials and supplies			0.30
Operating supplies			0.07
Miscellaneous			0.02
Sub Total			$ 1.28
Utilities			
Steam @ 40 & 150 psig	1320 #/T	$ 0.45/M#	$ 0.60
Electrical power	185 KwH/T	0.01/KwH	1.85
Cooling water	5810 Gal./T	0.03/M Gal.	0.17
Sub Total			$ 2.62
Total Variable Costs			$ 3.90
Fixed Costs			
Supervision and clerical			$ 0.30
Gen. taxes and insurance @ o.75% investment			0.39
Depreciation ($1,830,000 - 15 yrs. straight line basis)			3.50
Total Fixed Costs			$ 4.19
Total Other Direct Costs			$ 8.09
Factory Overhead @ 50% T. Labor			$ 0.42
Total Production Costs			$34.62

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Table A-3. Estimated production cost for urea solutions

Assumptions:

100 T/D Urea Solutions Plant
350 Stream D/Yr. = 35,000 T/Yr.

Direct Materials	Units	Unit Cost	Totals
NH_3 (Anhydrous)	0.567	$35.00	$19.86
CO_2 (from Amine Unit)	1.468	No charge	-
Other Direct Costs			
Variable Costs			
Operating labor - hrs.	0.272	$ 2.00/hr.	$ 0.55
Repair labor - hrs.	0.045	1.95/hr.	0.19
Payroll taxes, ins. and retirement			0.05
Repair materials and supplies			0.16
Operating supplies			0.04
Miscellaneous			0.01
Sub Total			$ 1.00
Utilities			
Steam @ 40 psig	330#/T	$ 0.40/M#	$ 0.132
Electrical power	152 KwH/T	0.01 KwH	1.520
Cooling water	3980 Gal./T	0.03/M Gal.	0.119
Sub Total			$ 1.771
Total Variable Costs			$ 2.77
Fixed Costs			
Supervision and clerical			$ 0.17
Gen. taxes and insurance @ 0.75% investment			0.21
Depreciation ($995,000 - 15 yrs. straight line basis)			1.89
Total Fixed Costs			$ 2.27
Total Other Direct Costs			$ 5.04
Factory Overhead @ 50% T. Labor			0.37
Total Production Costs			$25.27

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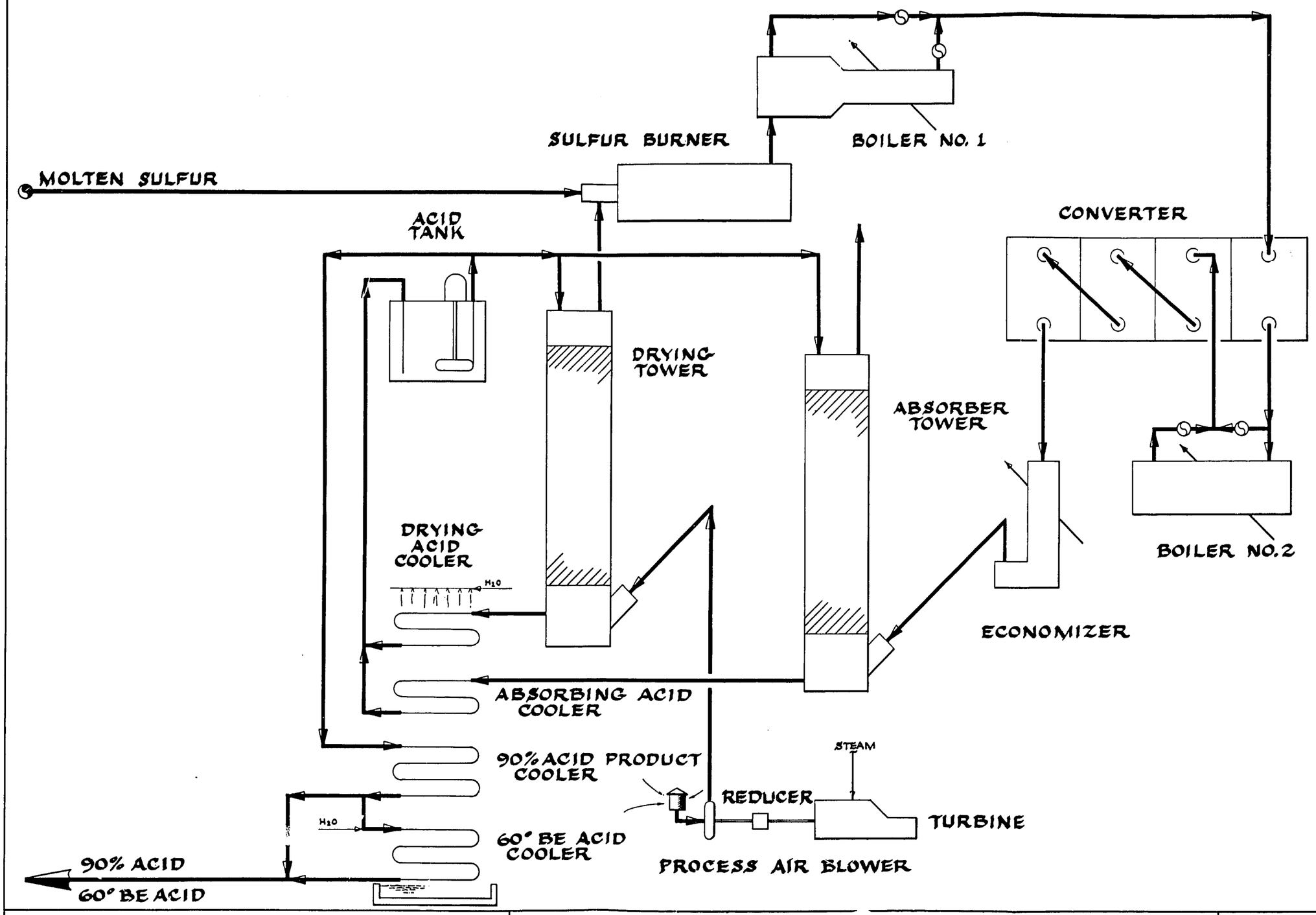

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SULFURIC ACID

FIGURE A-13

Table A-4. Estimated production cost for sulphuric acid

Assumptions:

100 T/D Sulphuric Acid Plant
330 Stream D/Yr. = 33,000 T/Yr.
Plant Investment - $500,000

Direct Materials	Units	Unit Cost	Totals
Sulphur	.333T/T	$24.50/T	$ 8.16
Other Direct Costs			
Variable Costs			
Operating labor - hrs.		$ 2.00/hr.	$ 0.65
Repair labor - hrs.		1.95/hr.	0.20
Payroll taxes, ins. and retirement			0.15
Operating supplies			0.05
Miscellaneous			0.02
Sub Total			$ 1.07
Utilities			
Cooling water	7,775 Gal/T.	0.03/M Gal.	$ 0.23
Electric power	5 KwH/T	0.01	0.43
Plant exports steam	-	-	-
Sub Total			$ 0.66
Total Variable Costs			$ 1.73
Fixed Costs			
Supervision and clerical			$ 0.12
General taxes and insurance			0.20
Depreciation ($500,000 - 15 yrs. straight line basis)			1.00
Total Fixed Costs			$ 1.32
Total Other Direct Costs			$ 3.05
Factory Overhead @ 50% Labor			$ 0.43
Total Production Costs			$11.64

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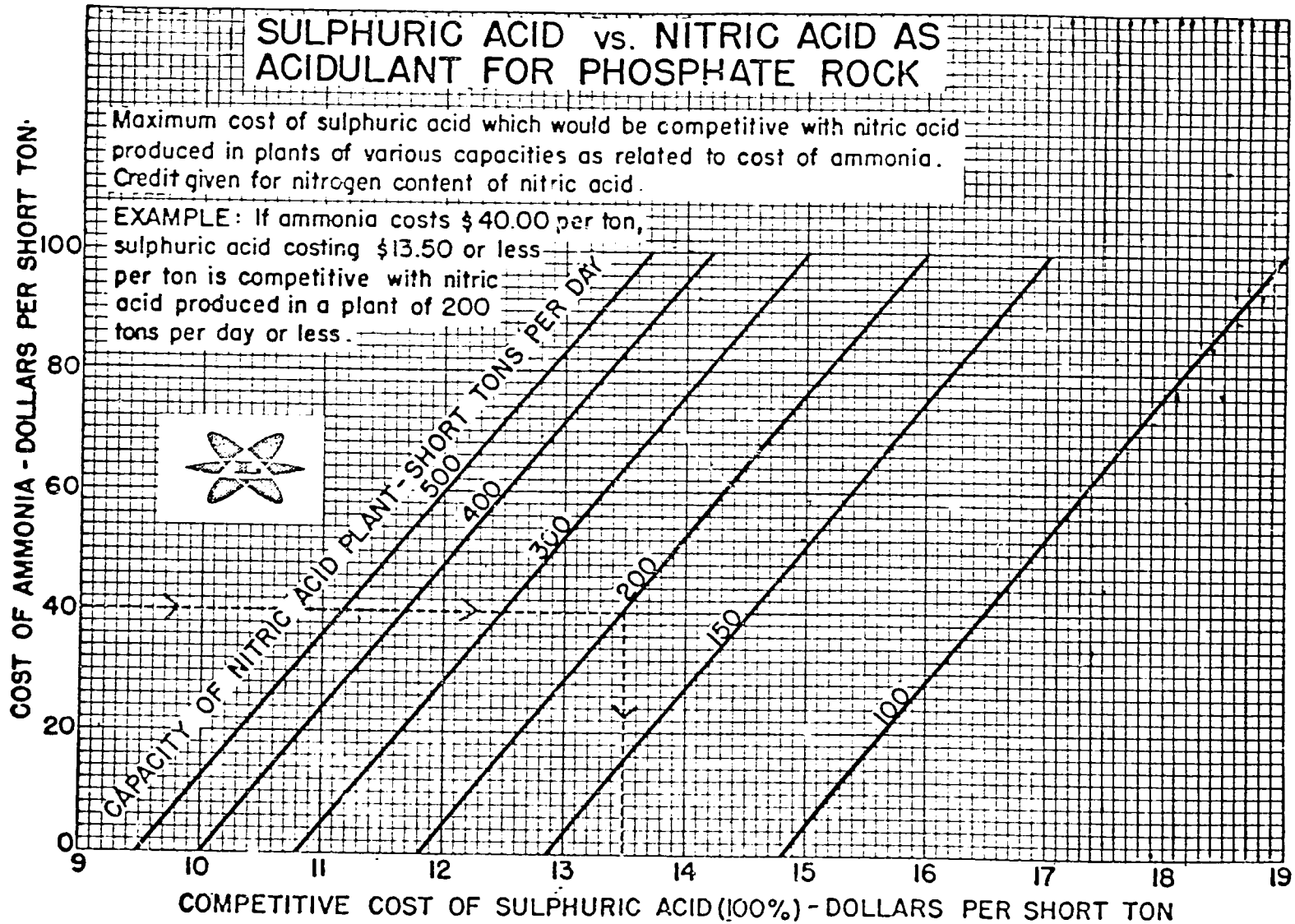
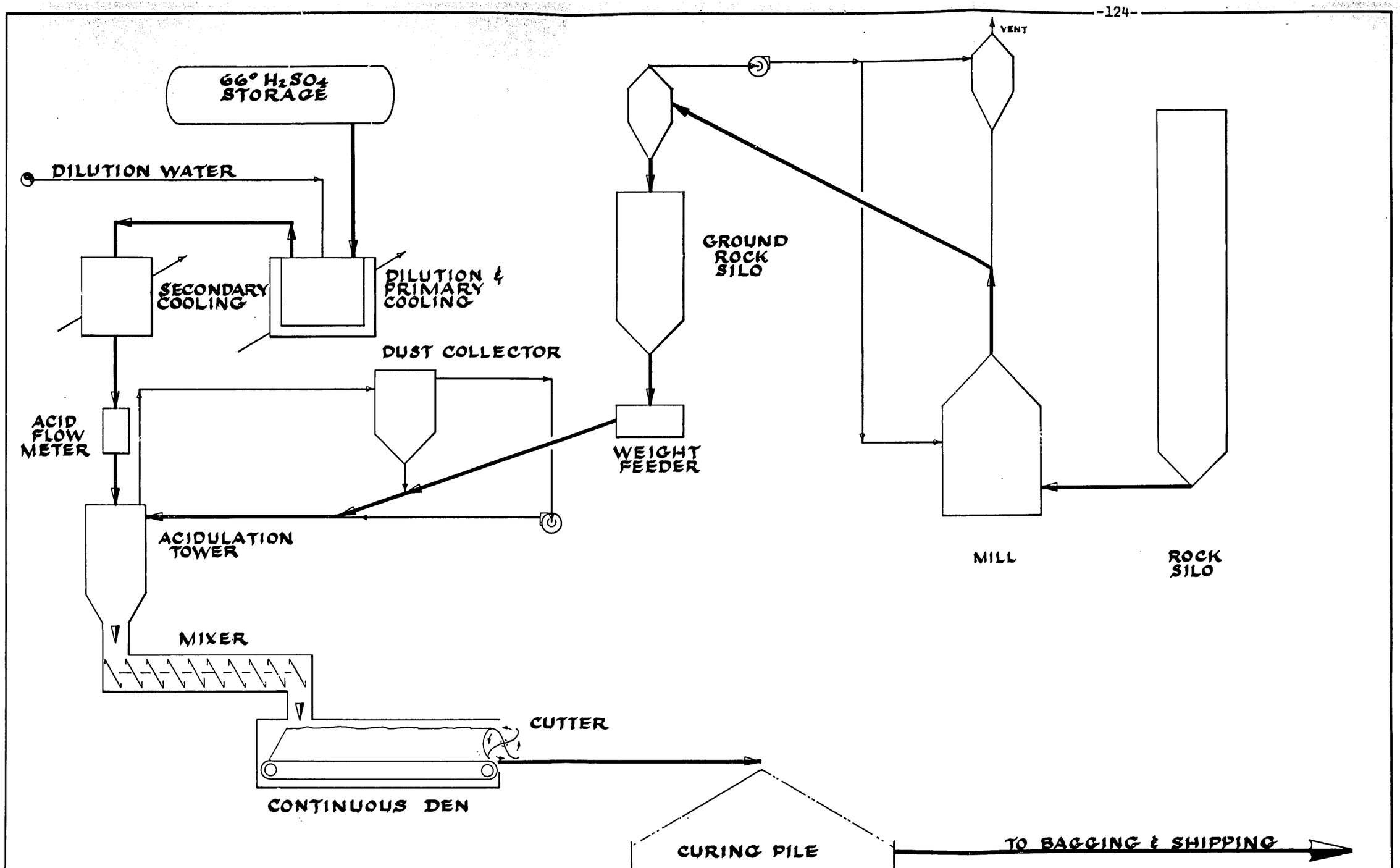

SULPHURIC ACID vs. NITRIC ACID AS ACIDULANT FOR PHOSPHATE ROCK
Maximum cost of sulphuric acid which would be competitive with nitric acid produced in plants of various capacities as related to cost of ammonia. Credit given for nitrogen content of nitric acid.
EXAMPLE: If ammonia costs $40.00 per ton, sulphuric acid costing $13.50 or less per ton is competitive with nitric acid produced in a plant of 200 tons per day or less.
CAPACITY OF NITRIC ACID PLANT-SHORT TONS PER DAY
500
400
300
200
150
100
COST OF AMMONIA - DOLLARS PER SHORT TON
0
20
40
60
80
100
9
10
11
12
13
14
15
16
17
18
19
COMPETITIVE COST OF SULPHURIC ACID (100%) - DOLLARS PER SHORT TON

Figure A-14.



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NORMAL SUPERPHOSPHATE

FIGURE A-15

Table A-5. Estimated production cost of normal superphosphate 1/

Assumptions:

Plant capacity - 120,000 short tons per year.
Production rate - 20 tons per hours, 250 days per year.
Plant location - Florida, U.S.A.
Plant cost (estimated) - $ 800,000 2/
Raw materials - sulphuric acid, phosphate rock and power to be purchased.
Shrinkage allowance - 15 percent.

Direct Costs: Raw Materials	Units	Units Per Ton	Units Per Year	U.S. Dollars Per Unit	U.S. Dollars Per Year	U.S. Dollars Per Ton of Product
Phosphate rock (32% P_2O_5)	Short tons	0.636	76,500	$ 6.60	$ 505,000	$ 4.20
Sulphuric acid (100%)	Short tons	0.470	56,400	24.00	1,350,000	11.30
Electric Power	Kwtt	20.8	2,500,000	.007	17,500	0.15
Total Raw Materials Cost						$15.65
Operating Labor and Supervision 3						1.02
Maintenance and Supplies						0.34
Total Direct Costs						$17.01
Indirect Costs:						
Depreciation (at 10 percent)					80,000	0.67
Taxes and insurance (at 3 percent)					24,000	0.20
All other indirect costs						0.80
Total Indirect Costs						$ 1.67
Total Manufacturing Cost						$18.66
Processing Share of Manufacturing Cost (bulk)						$ 3.01

1/ 20 percent P_2O_5 equivalent.
2/ Made up of: Rock grinding, $55,000; acid dilution, $30,000; dens, $20,000; acidulation, $20,000; and storage, $400,000; grinding and bagging product, $50,000; process building, $145,000; contingencies, $80,000.
3/ Includes two skilled and six unskilled laborers and one supervisor.

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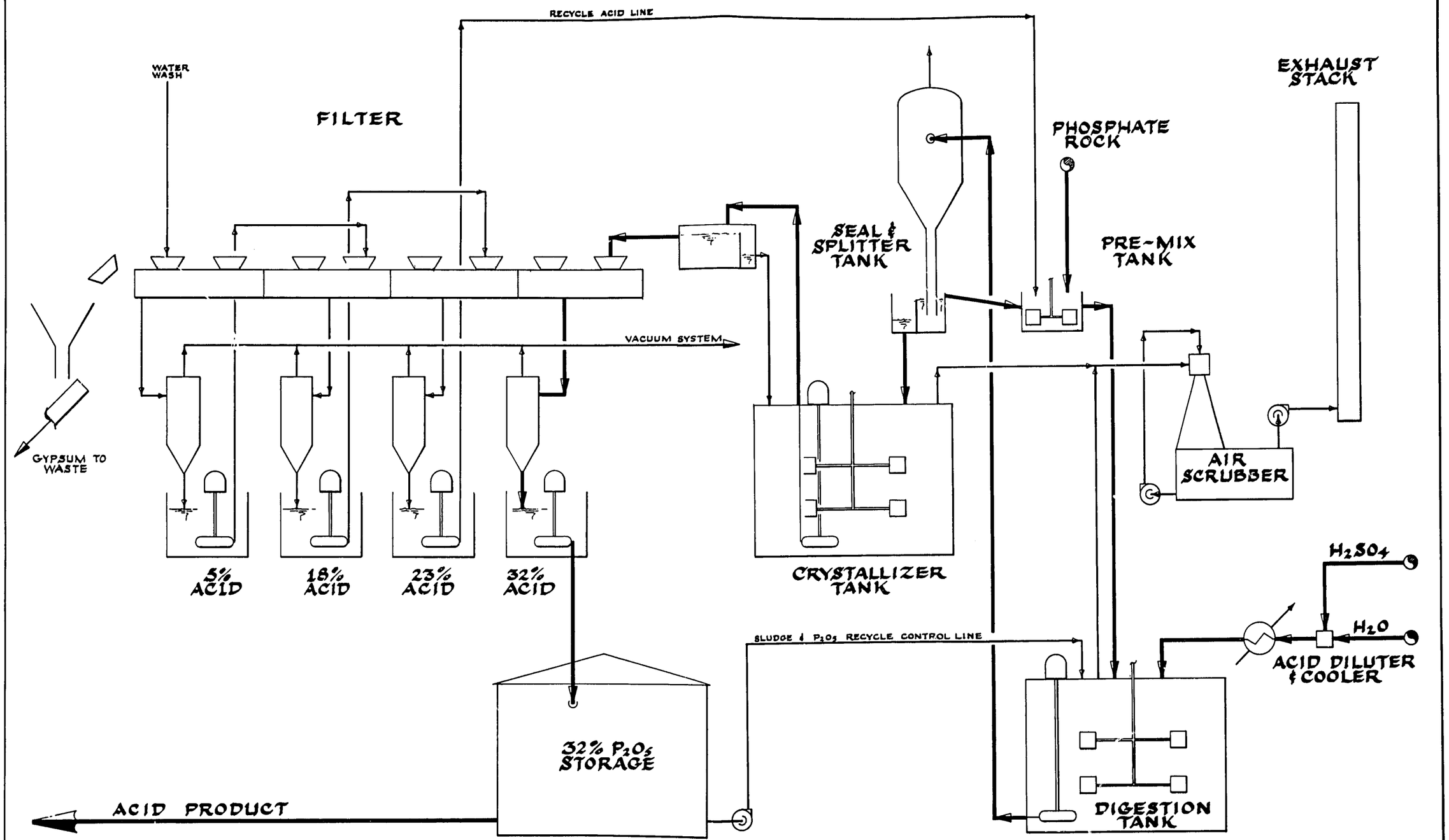

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PHOSPHORIC ACID

FIGURE A-16

Table A-6. Estimated investment for a wet process phosphoric acid plant

Assumption :

Plant capacity - 37,500 short tons P_2O_5 equivalent as 75% H_3PO_4 (54% P_2O_5)
Plant location - Florida, U.S.A.
Raw materials - to be purchased.

Plant investment:

Unloading and conveying	$ 275,000
Crushing and grinding	130,000
Sulphuric acid plant (300 short tons per day 100% H_2SO_4)	1,300,000
Phosphoric acid production (as 32% P_2O_5 equivalent acid)	1,460,000
Phosphoric acid concentration (to 54% P_2O_5 equivalent acid)	435,000
Phosphoric acid storage (two weeks production)	210,000
Utilities, offsite and miscellaneous (buildings, shops, grading, sewers, etc.)	150,000
Total Plant and Equipment	$3,960,000
Working Capital (at 15%)	594,000
Total Plant Investment	$4,554,000

Table A-6. Estimated production cost of wet process phosphoric acid

Assumptions:

Plant capacity - 37,500 short tons P_2O_5 equivalent as 75% H_3PO_4 (54% P_2O_5).
Plant location - Florida, U.S.A.
Plant investment - $4,554,000 including working capital (See Table 5).
Raw materials - sulphur, phosphate rock and power to be purchased.

Direct Costs:

Raw Materials	Units	Units Per Ton	Units Per Year	U.S. Dollars Per Unit	U.S. Dollars Per Year	U.S. Dollars Per Ton P_2O_5
Phosphate rock 1/	Short ton	3.06	115,700	$ 7.725	$ 895,000	$23.60
Sulphur 2/	Short ton	0.84	31,500	21.90	690,000	18.40
Water (for steam)	M gallons	0.91	34,100	0.07	2,390	0.06
Water (for cooling)	M gallons	14.00	525,000	0.005	2,620	0.07
Electric power 3/	KwH	225.00	8,400,000	0.007	58,800	1.57
Total Raw Materials					$1,648,810	$43.70
Labor 4/						
Operating and supervisory					$ 218,000	$ 5.82
Maintenance					97,500	2.60
Non-operating					50,500	1.35
Total Labor					$ 366,000	$ 9.77
Supplies						
Operating (at 10% of operating labor cost)					$ 21,800	$ 0.58
Maintenance (at 100% of maintenance labor cost)					97,500	2.60
Total Supplies					$ 119,300	$ 3.18
Total Direct Costs					$2,134,110	$56.65

Indirect Costs:

Depreciation (at 10% average)	$ 396,000	$10.58
Taxes and insurance (at 3%)	118,800	3.16
Overhead (at 50% of operating and maintenance labor)q	157,750	4.20
Interest (at 4% of total plant investment)	182,000	4.85
Total Indirect Costs	$ 854,550	$22.79
Total Manufacturing Cost 5/	$2,988,660	$79.44

1/ Assumed to be 74.75% b.p.l., or 33.9-34.4% P_2O_5 equivalent, purchased at the quoted price of $7.725 per short ton, f.o.b., washed, dried unground.

2/ Purchased as molten sulphur, off-color, at quoted price of $24.50 per long ton, f.o.b.

3/ Approximately 20% of electric power is used for rock grinding, which amounts to about $0.75 per short ton. Actual power cost, with associated equipment, may be as much as $0.003 per KwH above base rate.

4/ Based on number of men required per 24 hours, as follows: Operating and supervisory, 26; maintenance, 12; and non-operating, 6. Operating and supervisory breaks down as follows: Supervisory, 3; sulphuric acid, 6; phosphoric acid, 9; unloading, 2; grinding, 3; storage and miscellaneous, 3; calculated on the basis of average hourly wage of $2.30 multiplied by a factor of 1.8 to allow for overtime, fringe benefits and other factors.

5/ Does not allow for selling expenses, profit margin or gypsum disposal facilities. Gypsum disposal is estimated to cost about $0.50 per ton of gypsum.

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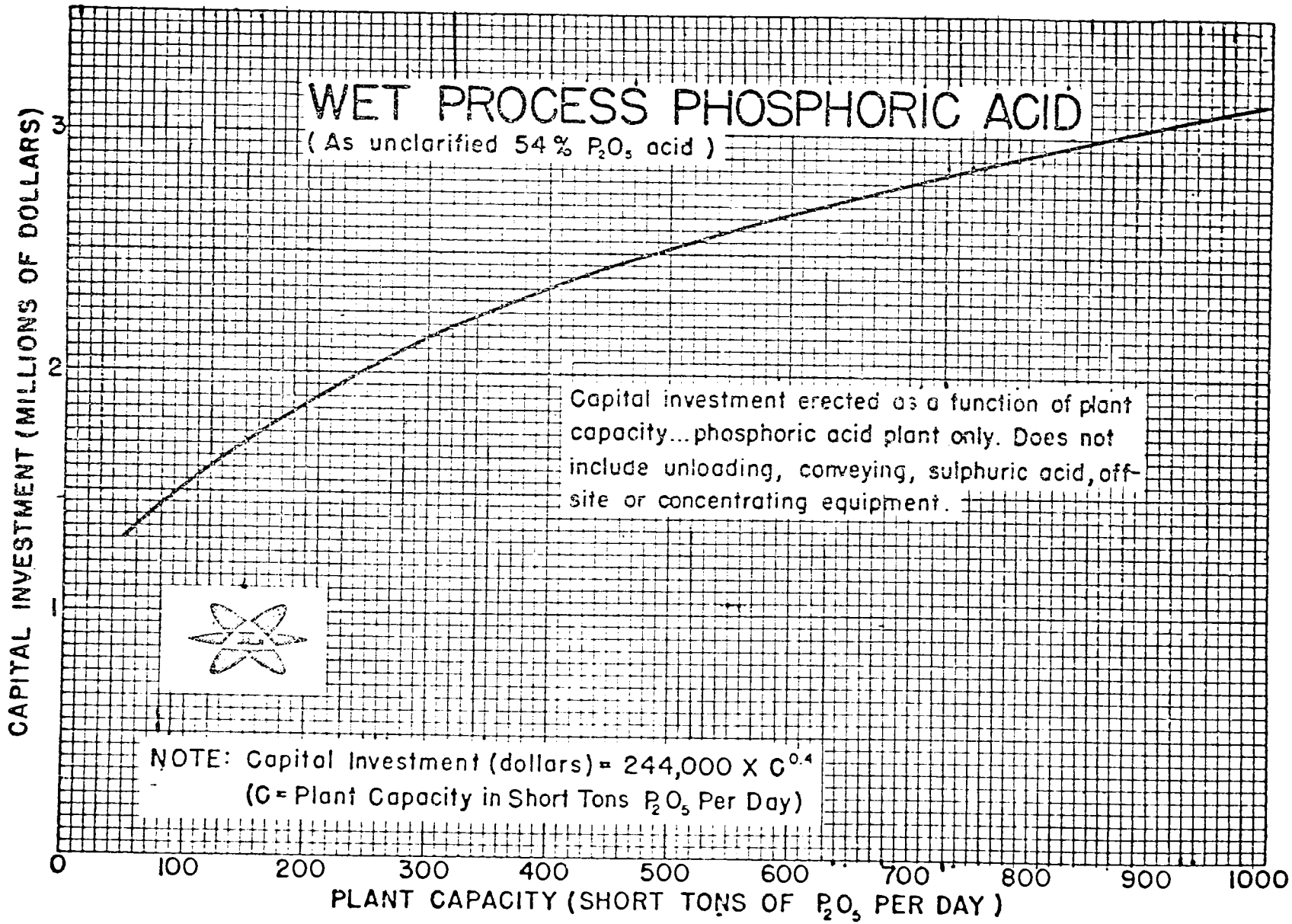

Figure A-17.

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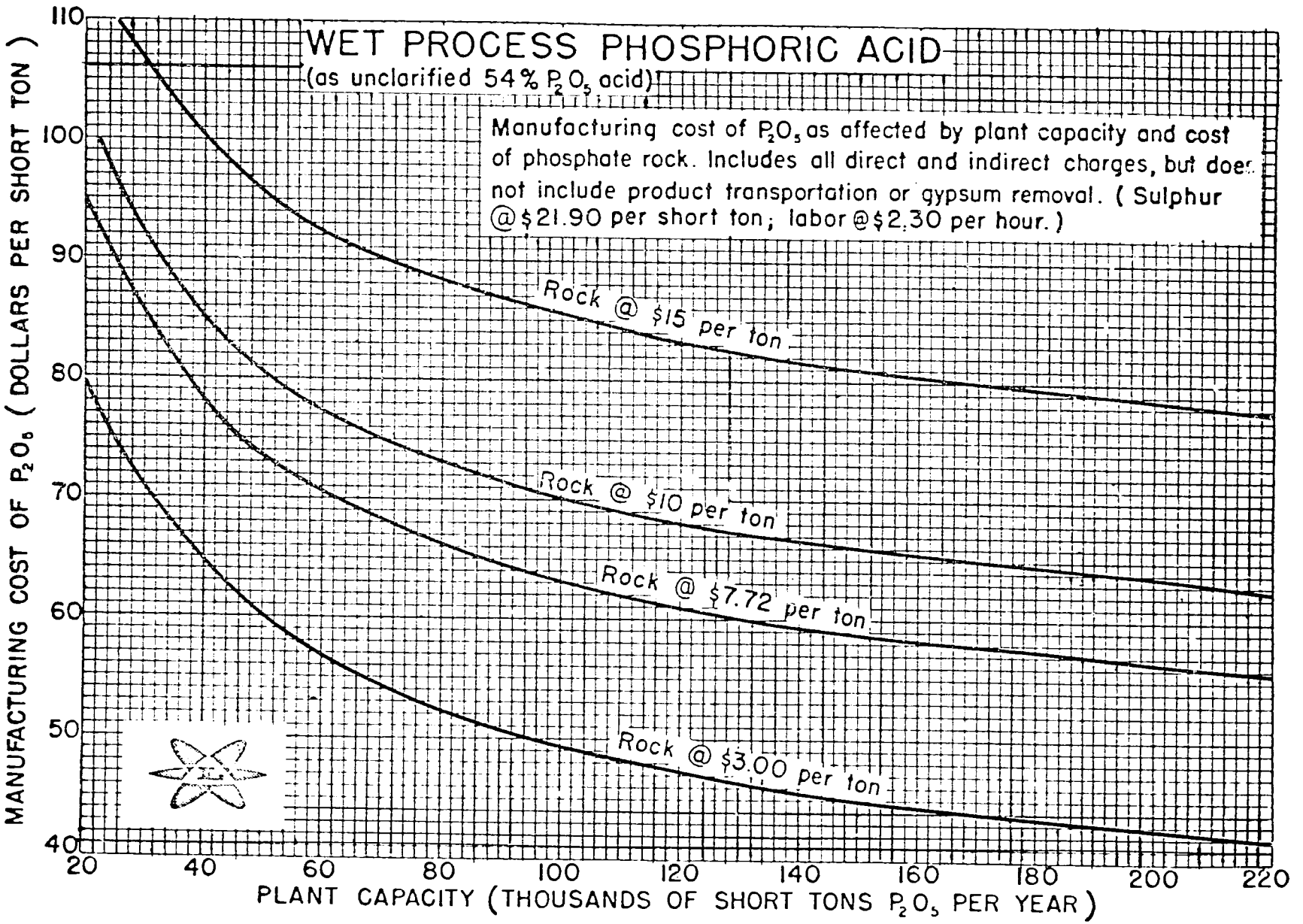
WET PROCESS PHOSPHORIC ACID
(as unclarified 54% P_2O_5 acid)
Manufacturing cost of P_2O_5 as affected by plant capacity and cost of phosphate rock. Includes all direct and indirect charges, but does not include product transportation or gypsum removal. (Sulphur @ $21.90 per short ton; labor @ $2.30 per hour.)
Rock @ $15 per ton
Rock @ $10 per ton
Rock @ $7.72 per ton
Rock @ $3.00 per ton
MANUFACTURING COST OF P_2O_5 (DOLLARS PER SHORT TON)
110
100
90
80
70
60
50
40
20
40
60
80
100
120
140
160
180
200
220
PLANT CAPACITY (THOUSANDS OF SHORT TONS P_2O_5 PER YEAR)

Figure A-18.

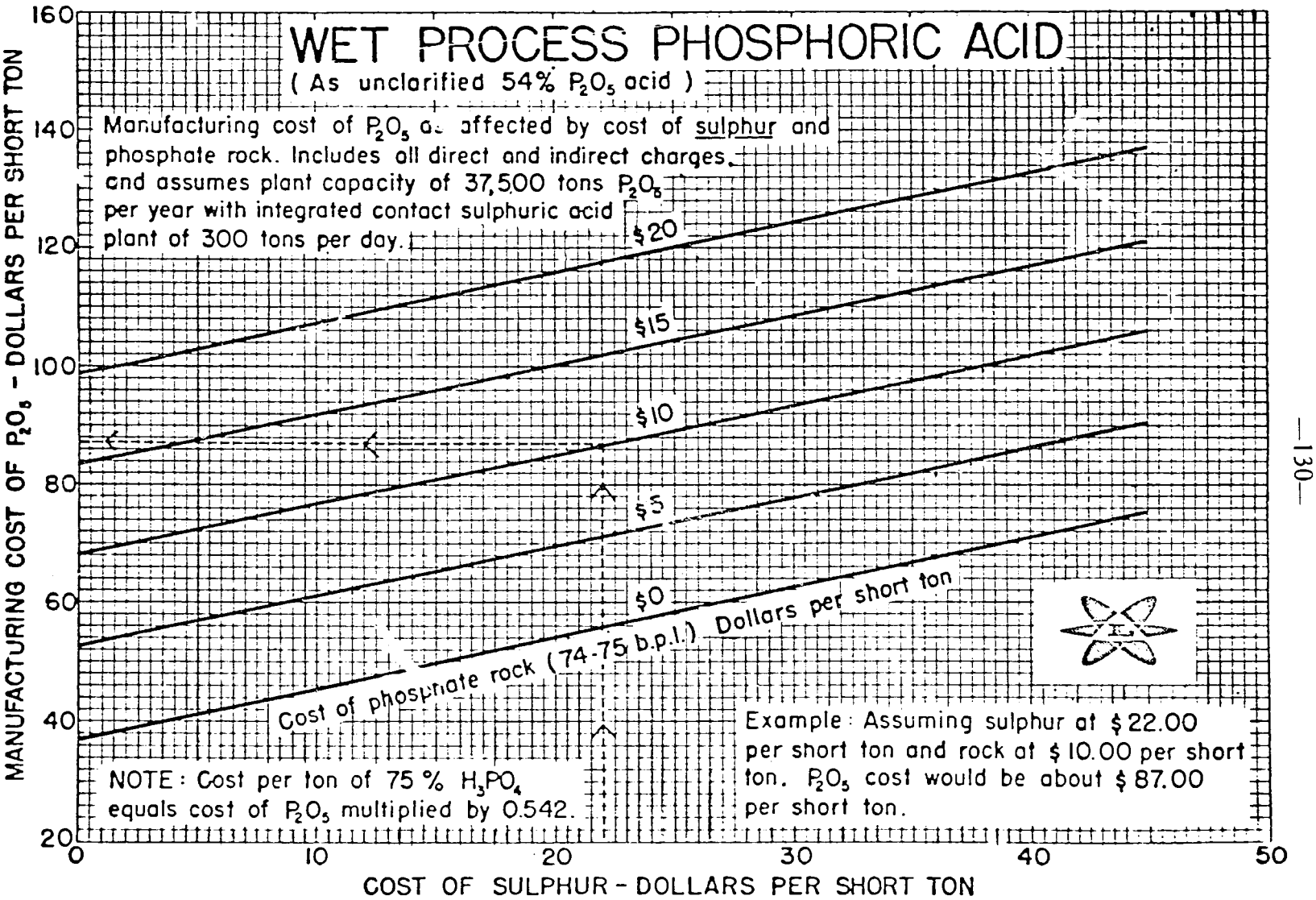
WET PROCESS PHOSPHORIC ACID
(As unclarified 54% P_2O_5 acid)
Manufacturing cost of P_2O_5 as affected by cost of sulphur and phosphate rock. Includes all direct and indirect charges, and assumes plant capacity of 37,500 tons P_2O_5 per year with integrated contact sulphuric acid plant of 300 tons per day.
$20
$15
$10
$5
$0
Cost of phosphate rock (74-75 b.p.l.) Dollars per short ton
NOTE: Cost per ton of 75 % H_3PO_4 equals cost of P_2O_5 multiplied by 0.542.
Example: Assuming sulphur at $22.00 per short ton and rock at $10.00 per short ton. P_2O_5 cost would be about $87.00 per short ton.
MANUFACTURING COST OF P_2O_5 - DOLLARS PER SHORT TON
160
140
120
100
80
60
40
20
0
10
20
30
40
50
COST OF SULPHUR - DOLLARS PER SHORT TON

Figure A-19.

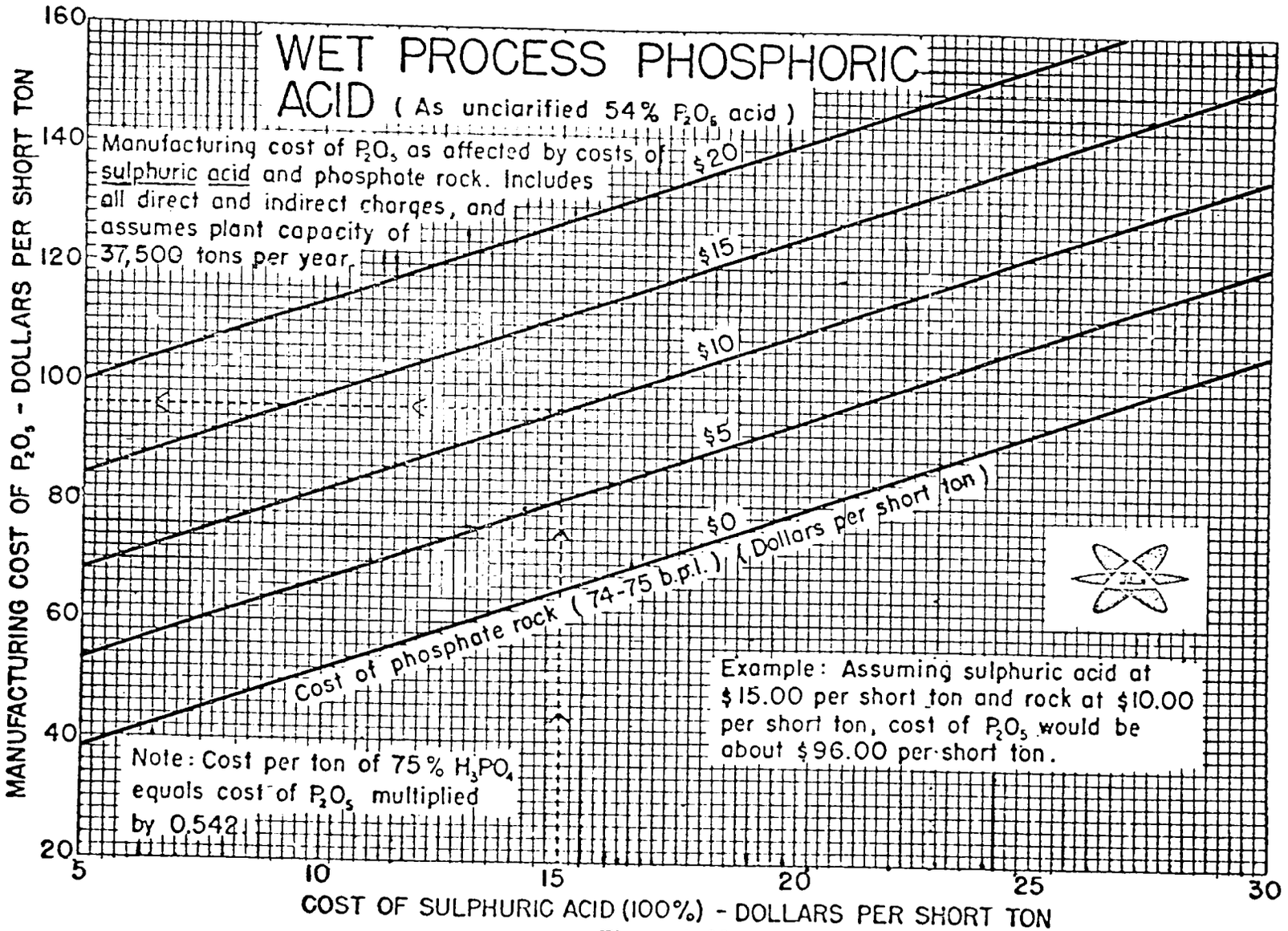
WET PROCESS PHOSPHORIC ACID (As unclarified 54% P_2O_5 acid)
Manufacturing cost of P_2O_5 as affected by costs of sulphuric acid and phosphate rock. Includes all direct and indirect charges, and assumes plant capacity of 37,500 tons per year.
$20
$15
$10
$5
$0
Cost of phosphate rock (74-75 b.p.l.) (Dollars per short ton)
Example: Assuming sulphuric acid at $15.00 per short ton and rock at $10.00 per short ton, cost of P_2O_5 would be about $96.00 per short ton.
Note: Cost per ton of 75% H_3PO_4 equals cost of P_2O_5 multiplied by 0.542
MANUFACTURING COST OF P_2O_5 - DOLLARS PER SHORT TON
160
140
120
100
80
60
40
20
5
10
15
20
25
30
COST OF SULPHURIC ACID (100%) - DOLLARS PER SHORT TON

Figure A-20.

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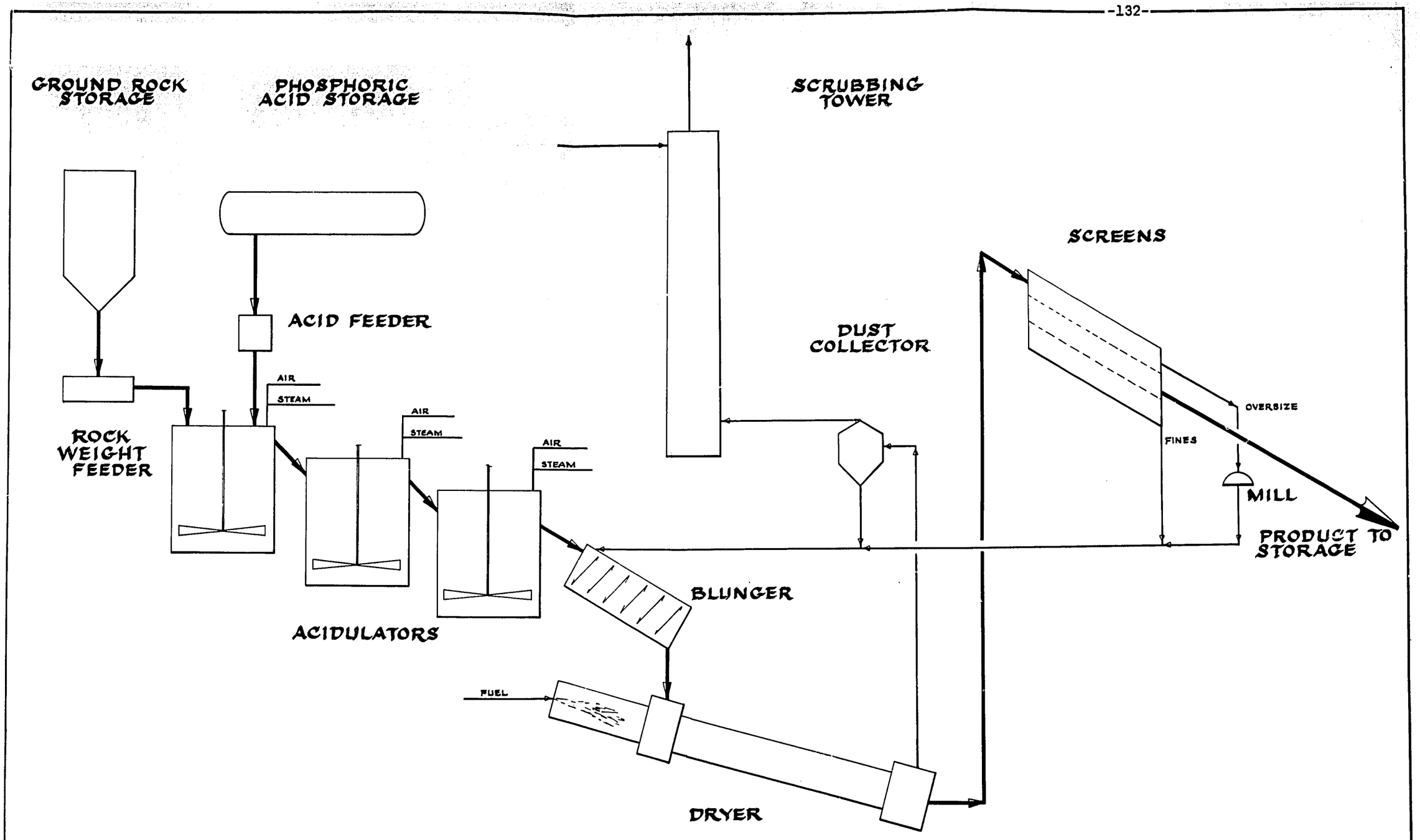

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GRANDULAR TRIPLE SUPERPHOSPHATE

FIGURE A-21

Table A-7. Estimated production cost of granular triple superphosphate

Assmuptions:

Plant capacity - 115,000 short tons per year, 46 percent P_2O_5 equivalent.
Plant location - Florida, U.S.A., associated with a wet process phosphoric acid facility.
Plant cost - $2,000,000 1/
Process - Continuous slurry.

Direct Costs: Raw Materials	Units	Units Per Ton	Units Per Year	U.S. Dollars Per Unit	U.S. Dollars Per Year	U.S. Dollars Per Ton Of Product 2/
Phosphoric acid (100%)	Short tons	0.45	51,800	$57.40	$2,980,000	$25.90
Phosphate rock (34% P_2O_5) 3/	Short tons	0.42	48,000	7.73	371,000	3.22
Power 4/	KwH	8.00	920,000	0.007	6,900	0.06
Fuel oil	Gallons	3.00	345,000	0.06	20,700	0.18
Total Raw Materials					$3,378,600	$29.36
Operating and supervisory labor					74,000	0.64
Maintenance and supplies					92,200	0.80
Total Direct Costs					$3,544,800	$30.80
Indirect Costs:						
Depreciation (at 10% per year of investment)					200,000	1.74
Taxes and insurance (at 3% per year of investment)					60,000	0.52
Interest on investment and working capital (at 4%)					92,000	0.80
All other (overhead, administration, etc.)					74,600	0.65
Total Indirect Costs					$ 426,600	$ 3.71
Total Manufacturing Cost					$3,970,000	$34.51

1/ Assumes storage for 50,000 short tons at a cost of $700,000.
2/ Stated in terms of dollars per ton of product (46 percent P_2O_5 equivalent). To convert to cost per ton of P_2O_5 equivalent, divide by 0.46.
3/ Assumes that rock will be purchased unground.
4/ Rock grinding requires about seven KwH per ton.

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Table A-8. Estimated production cost of pulverized triple superphosphate

Assumptions:

Plant capacity - 115,000 short tons per year, 46 percent P_2O_5 equivalent.
Plant location - Florida, U.S.A., associated with wet process phosphoric acid facility.
Plant cost - $1,000,000.
Process - T.V.A. cone mixer.

Direct Costs: Raw Materials	Units	Units Per Ton	Units Per Year	U.S. Dollars Per Unit	U.S. Dollars Per Year	U.S. Dollars Per Ton Of Product 2/
Phosphoric acid (100%)	Short ton	0.45	51,800	$57.40	$2,980,000	$25.90
Phosphate rock (34% P_2O_5) 3/	Short ton	0.42	48,000	7.73	371,000	3.22
Power 4/	KwH	7.00	820,000	0.007	5,750	0.05
Total Raw Materials					$3,356,750	$29.17
Operating and supervisory labor					18,400	0.16
Maintenance and supplies					11,500	0.10
Total Direct Costs					$3,386,650	$29.43
Indirect Costs:						
Depreciation (at 10% per year of investment)					100,000	0.87
Taxes and insurance (at 3% per year of investment)					30,000	0.26
Interest on investment and working capital (at 4%)					46,000	0.40
All other (overhead, administration, etc.)					15,000	0.13
Total Indirect Costs					$ 191,000	$ 1.66
Total Manufacturing Cost					$3,577,650	$31.09

1/ Assumes storage for 50,000 short tons at a cost of $700,000.
2/ Stated in terms of dollars per ton of product (46 percent P_2O_5 equivalent). To convert to cost per ton of P_2O_5 equivalent, divide by 0.46.
3/ Assumes that rock will be purchased unground.
4/ Rock grinding requires about seven KwH per ton.

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Table A-9. Estimated investment for an electric furnace phosphoric acid plant

Assumptions:

Plant capacity - 37,000 short tons P_2O_5 per year as 75% H_3PO_4 (54% P_2O_5 equivalent).
Plant location - Florida, U.S.A.
Furnace requirements - One 25,000 Kw unit.

Electric Furnace:		
Preparation 1/		
Unloading and conveying	$ 275,000	
Nodulizing and sintering	725,000	
Coke preparation (drying, etc.)	175,000	
Silica preparation	120,000	
Burden preparation (proportioning)	250,000	
Total Preparation	$1,545,000	
Furnace Construction		
Furnace and condenser 2/	1,280,000	
Gas scrubber 3/	120,000	
Total Furnace Construction	$1,400,000	
Total Furnace and Preparation		$2,945,000
Utilities, Offsite and Miscellaneous (including acid unit)		
Steam, air, water	200,000	
Electrical (at $20.00 per KvA, including substation)	500,000	
Miscellaneous sewers, change and maintenance building, site preparation, shope and laboratory equipment, etc.	150,000	
Total Utilities, Offsite, Miscellaneous	$ 850,000	
Total Electric Furnace		$3,795,000
Phosphoric Acid Plant		
Plant	$ 360,000	
Storage (two weeks production)	210,000	
Total Acid Plant	$ 570,000	
Total Plant Investment (furnace and acid plant)		$4,365,000

1/ It is assumed that phosphate rock mining and washing facilities exist, but that preparation is needed to produce a suitable burden.
2/ Does not include electrostatic precipitators.
3/ To clean up evolved carbon monoxide for use as fuel.

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Table A-10. Estimated production cost of electric furnace phosphoric acid 1/

Assumptions:

Plant capacity - 37,500 short tons P_2O_5 equivalent per year as furnace grade phosphoric acid.
Plant location - Florida, U.S.A., integrated with electric furnace phosphorus unit.

Direct Costs:						
Raw Materials 5/	Units	Units Per Ton	Units Per Year	U.S. Dollars Per Unit	U.S. Dollars Per Year	U.S. Dollars Per Ton P_2O_5
Cooling and hydrating water	M gallons	20.00	750,000	$ 0.05	$ 37,500	$ 1.00
Lime 2/	Short tons	0.0133	500	16.00	8,000	0.22
Power	KwH	500.00	18,800,000	0.007	131,000	3.50
Steam	100 pounds	2.75	104,000	0.65	67,500	1.80
Total Raw Materials					$ 244,000	$ 6.52
Labor 3/						
Operating and supervisory					38,500	1.03
Maintenance					18,500	0.49
Non-operating					8,400	0.30
Total Labor					$ 81,100	$ 2.24
Supplies						
Operating					3,850	0.10
Maintenance					18,500	0.49
Total Supplies					$ 22,350	$ 0.59
Total Direct Costs (acid plant only)					$ 347,000	$ 9.35
Indirect Costs:						
Depreciation (at 7.5% per year of investment)					42,700	1.14
Insurance and taxes (at 3% per year of investment)					17,100	0.46
All other (overhead, administration, etc.)					45,000	1.20
Total Indirect Costs (acid plant only)					$ 104,800	$ 2.80
Total conversion cost (acid plant)					$ 452,250	$ 12.15
Cost of Phosphorus (from Table 7)					$4,535,400	$120.89
Total Cost of Phosphoric Acid (furnace and conversion)					$4,987,650	$133.04 4/

1/ Costs of converting electric furnace phosphorus to 75 percent H_3PO_4 (54 percent P_2O_5 equivalent)
2/ Includes neutralizing lime for both furnace and conversion plants.
3/ Assumes four men for operating and supervisory; two men for maintenance, and one non-operating employee. Average hourly wage of $2.30 was assumed and multiplied by a factor to allow for fringe benefits, overtime, etc.
4/ It is estimated that two furnaces (total capacity 75,000 tons per year P_2O_5 equivalent per year) and a correspondingly larger acid conversion plant could produce 75 percent H_3PO_4 at a cost of $104.00 per short ton of P_2O_5 equivalent. The estimated combined capital investment would be $7,300,000.
5/ Other than phosphorus.

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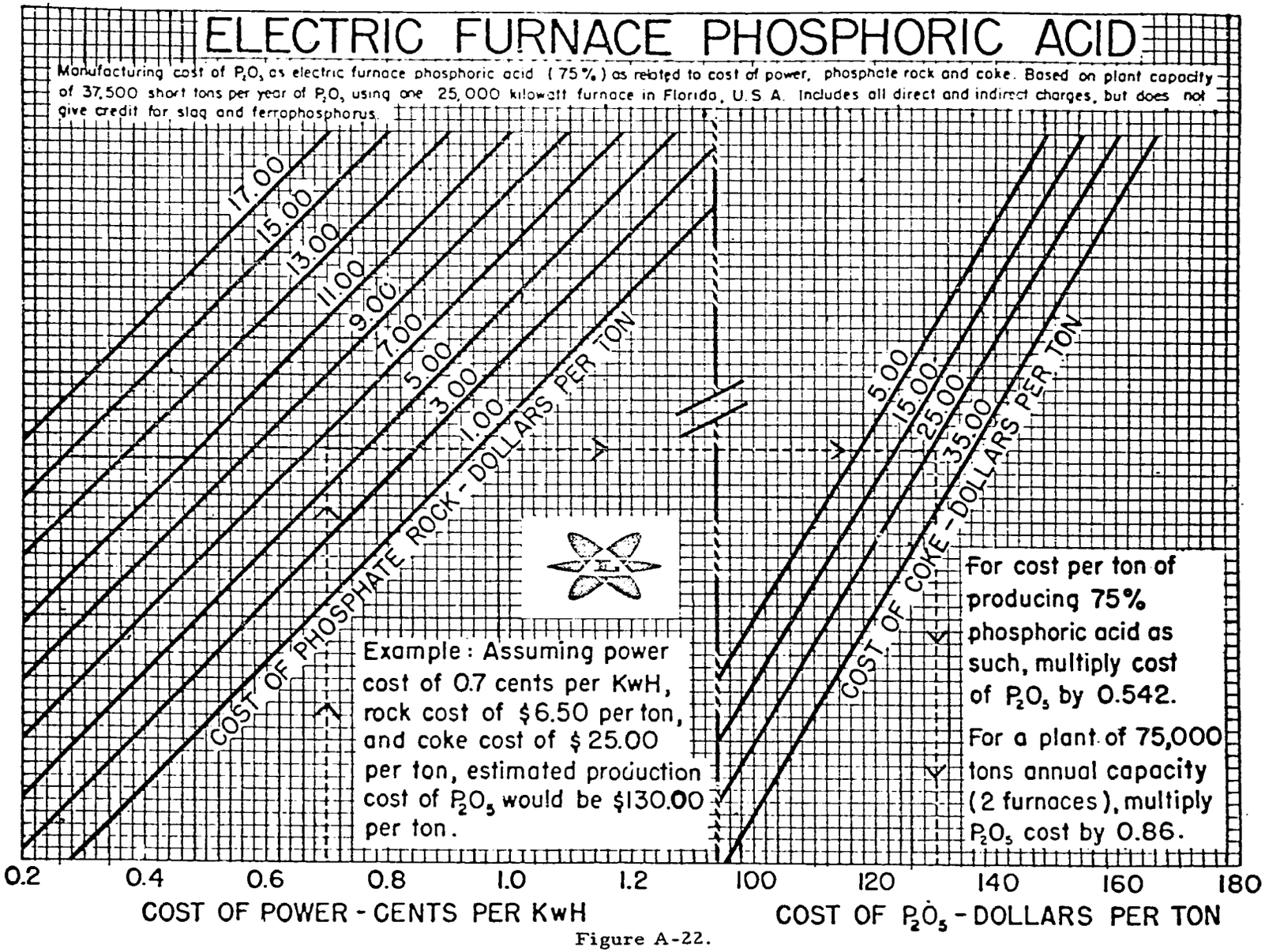
ELECTRIC FURNACE PHOSPHORIC ACID
Manufacturing cost of P_2O_5 as electric furnace phosphoric acid (75%) as related to cost of power, phosphate rock and coke. Based on plant capacity of 37,500 short tons per year of P_2O_5 using one 25,000 kilowatt furnace in Florida, U.S.A. Includes all direct and indirect charges, but does not give credit for slag and ferrophosphorus.
17.00
15.00
13.00
11.00
9.00
7.00
5.00
3.00
1.00
COST OF PHOSPHATE ROCK - DOLLARS PER TON
5.00
15.00
25.00
35.00
COST OF COKE - DOLLARS PER TON
Example: Assuming power cost of 0.7 cents per KwH, rock cost of $6.50 per ton, and coke cost of $25.00 per ton, estimated production cost of P_2O_5 would be $130.00 per ton.
For cost per ton of producing 75% phosphoric acid as such, multiply cost of P_2O_5 by 0.542.
For a plant of 75,000 tons annual capacity (2 furnaces), multiply P_2O_5 cost by 0.86.
0.2
0.4
0.6
0.8
1.0
1.2
COST OF POWER - CENTS PER KwH
100
120
140
160
180
COST OF P_2O_5 - DOLLARS PER TON

Figure A-22.

Table A-11. Estimated production cost of electric furnace phosphorus 1/

Assumptions:

Plant capacity - 37,000 short tons P_2O_5 equivalent per year as elemental phosphorus.
Plant location - Florida, U.S.A.
Furnace requirement - One 25,000 Kw unit.

Direct Costs:

Raw Materials	Units	Units Per Ton	Units Per Year	U.S. Dollars Per Unit	U.S. Dollars Per Year	U.S. Dollars Per Ton P_2O_5
Phosphate rock 2/	Short tons	3.46	130,000	$ 6.245 3/	$ 812,000	$ 21.60
Silica	Short tons	1.27	47,500	3.00	142,500	3.80
Coke 4/	Short tons	0.60	22,500	25.00	563,000	15.00
Cooling water	M gallons	11.00	412,000	0.05	20,600	0.55
Power	KwH	5,820	218 x 10	0.007	1,526,000	40.70
Electrodes	Pound	13.00	490,000	0.25	122,500	3.26
Fuel oil 5/	Gallon	50.00	1,880,000	0.06	112,500	3.00
Total Raw Materials					$3,299,000	$ 87.91
Labor 6/						
Operating and supervisory					275,000	7.34
Maintenance					91,600	2.45
Non-operating					34,600	0.92
Total Labor					$ 401,200	$ 10.71
Supplies						
Operating (at 10% of operating labor)					27,500	0.73
Maintenance (at 100% of maintenance labor)					91,600	2.45
Annual repairs					17,000	0.45
Total Supplies					$ 136,100	$ 3.63
Total Direct Costs (furnace only)					$3,836,400	$102.25

Indirect Costs:

Depreciation (at 7.5% per year of investment)					285,000	7.60
Insurance and taxes (at 3% per year of investment)					114,000	3.04
All other (overhead, administration, etc.)					300,000	8.00
Total Indirect Costs (furnace only)					$ 699,000	$ 18.64
Total Manufacturing Cost (furnace only) 7/					$4,535,400	$120.89

1/ Per ton of recovered P_2O_5 as elemental phosphorus, assuming 90% overall recovery.
2/ Assuming 70 bpl rock, approximately 32% P_2O_5 equivalent.
3/ Quoted purchase price f.o.b. mine. Rock cost for this grade might be as low as $1.50 per ton or as high as $7 - $15 per ton if this grade were purchased, shipped long distance, difficult to mine, or required agglomeration.
4/ Assumed to be 86% F.C., at $15.00 per ton f.o.b., plus $10.00 per ton freight.
5/ Used for coke drying at four gallons per ton of coke; for steam at nine gallons per 1,000 pounds, and for rock drying at four gallons per ton of rock.
6/ Assume 33 men for operating and supervisory. 10 men for maintenance, and six non-operating employees. Average hourly wage was assumed at $2.30 multiplied by a factor to allow for fringe benefits, overtime, etc.
7/ Could be reduced by about $9.09 per ton if slag and ferrophosphorus is sold (slag at $2.00 per ton; ferrophosphorus at $50.00 per ton).

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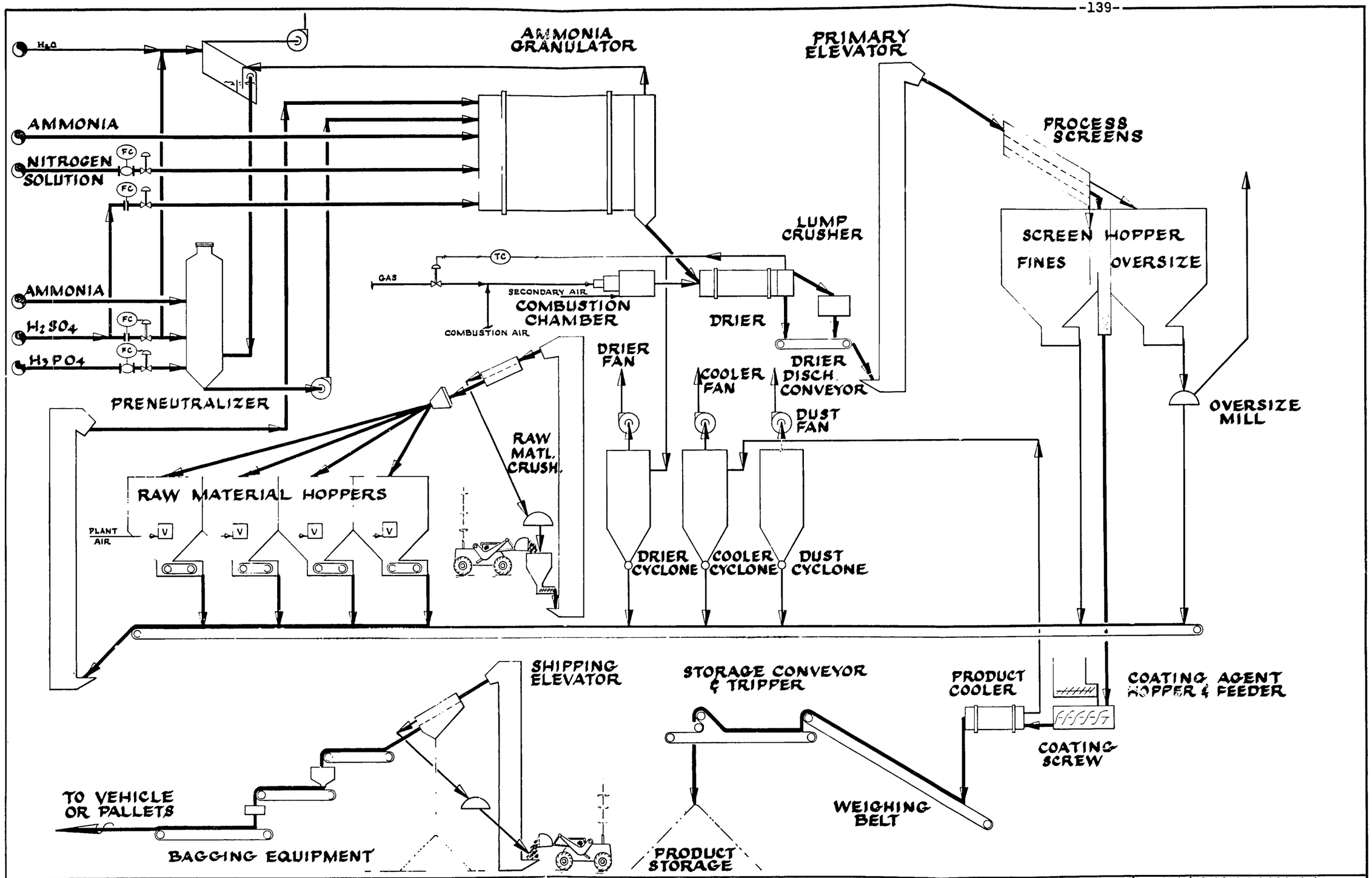

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DIAMMONIUM PHOSPHATE & GRANULATION

FIGURE A-23

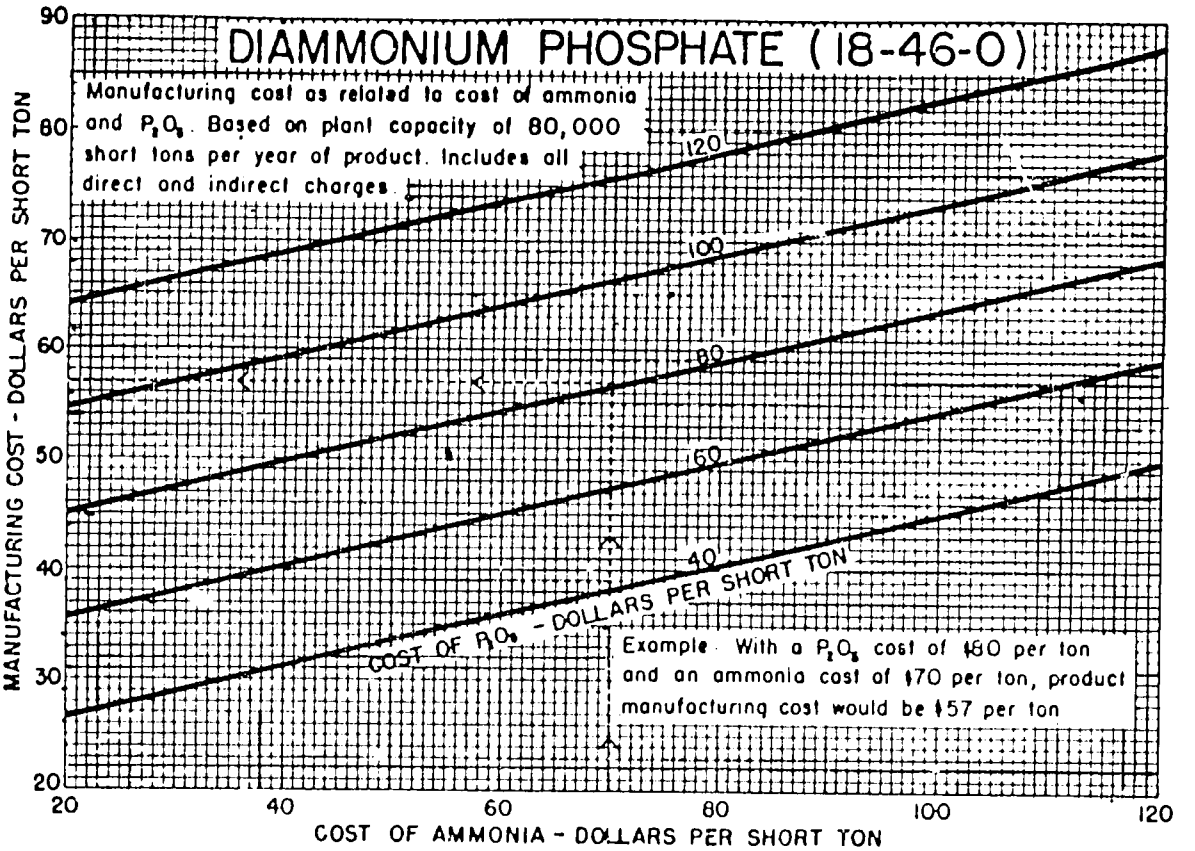
Table A-12. Estimated production cost of diammonium phosphate (18-46-0)

Assumptions:

Plant capacity - 80,000 short tons per year of 18-46-0 (37,500 tons of P_2O_5 equivalent assuming 98% recovery).
Plant location - Florida, U.S.A., associated with wet process phosphoric acid facility.
Plant cost - $600,000, exclusive of storage. 1/
Process - T.V.A. 2/

Direct Costs: Raw Materials	Units	Units Per Ton	Units Per Year	U.S. Dollars Per Unit	U.S. Dollars Per Year	U.S. Dollars Per Ton Of Product 2/
Phosphoric acid (40% P_2O_5) 3/	Short tons	1.175	94,100	$30.80	$2,900,000	$36.30
Ammonia 4/	Short tons	0.23	18,400	84.40	1,550,000	19.40
Power	KwH	20.00	1,630,000	0.007	11,400	0.14
Fuel oil	Gallons	3.00	240,000	0.06	14,400	0.18
Total Raw Materials					$4,475,800	$56.02
Operating and supervisory labor 5/					50,000	0.63
Maintenance and supplies					40,000	0.50
Total Direct Costs					$4,565,800	$57.15
Indirect Costs:						
Depreciation (at 10% per year of investment) 6/					60,000	0.75
Taxes and insurance (at 3% per year of investment) 6/					18,000	0.22
Interest on investment and working capital (at 4%) 7/					27,600	0.35
Overhead (at 50% of labor, maintenance and supplies)					45,000	0.56
Total Indirect Costs					$ 150,600	$ 1.88
Total Manufacturing Cost					$4,716,400	$59.03

1/ Plant is assumed to be a conventional ammoniation-granulation unit with a preneutralizer tank and ammonia scrubbing facilities.
2/ Stated in terms of dollars per ton of product (18-46-0).
3/ Cost of 40 percent P_2O_5 phosphoric acid assumed to be $2.50 per short ton less than that of standard 54 percent acid.
4/ Assumed to be 1 of 2 quoted market price, f.o.b. Tampa, Florida. Ammonia recovery assumed to be 95 percent.
5/ Assumes two men per shift, three shifts per day, 330 days per year, at $2.30 per hour times a factor of 1.8 allow for fringe benefits, overtime, vacations, etc.
6/ If storage facilities for 30,000 short tons of product were included, the added cost would be about $550,000. This would add about $1.00 per ton to the production cost.
7/ Working capital assumed to be about 15 percent of plant investment.



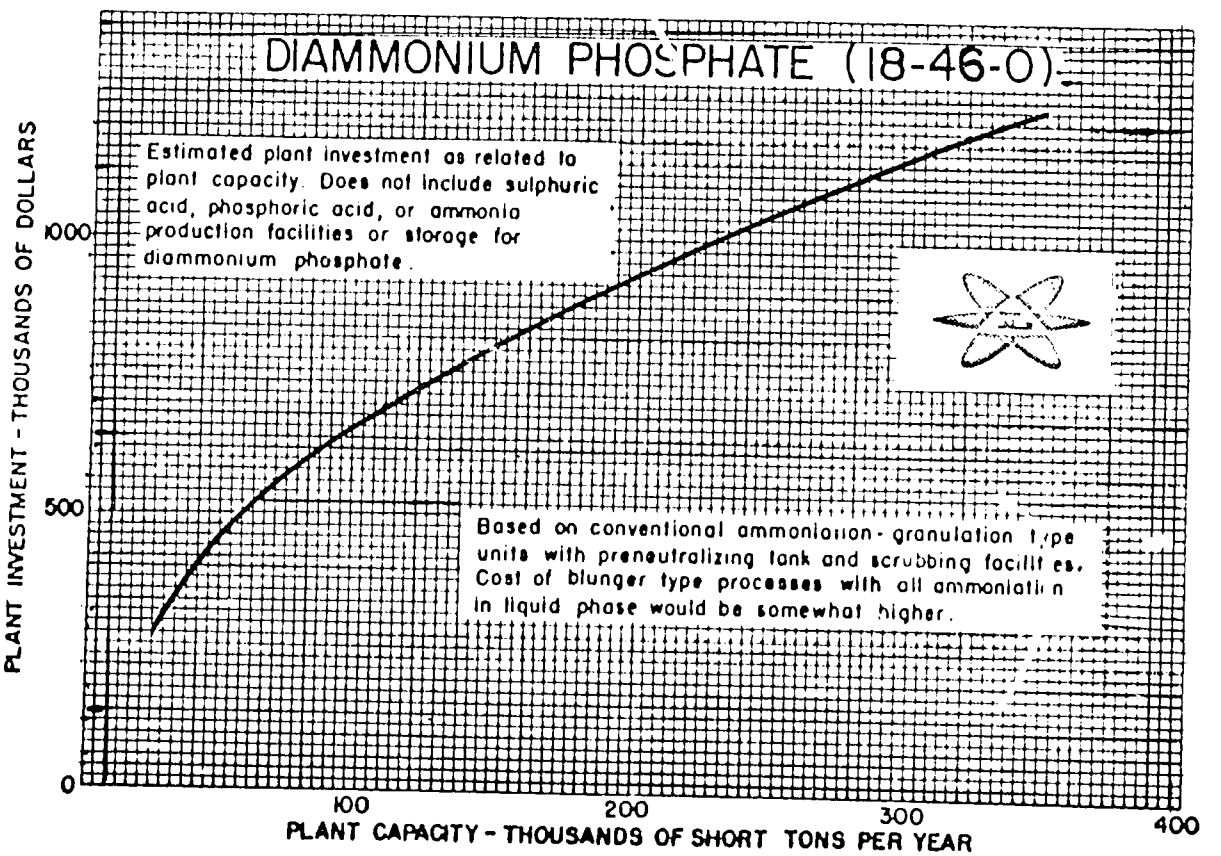


Figure A-24.

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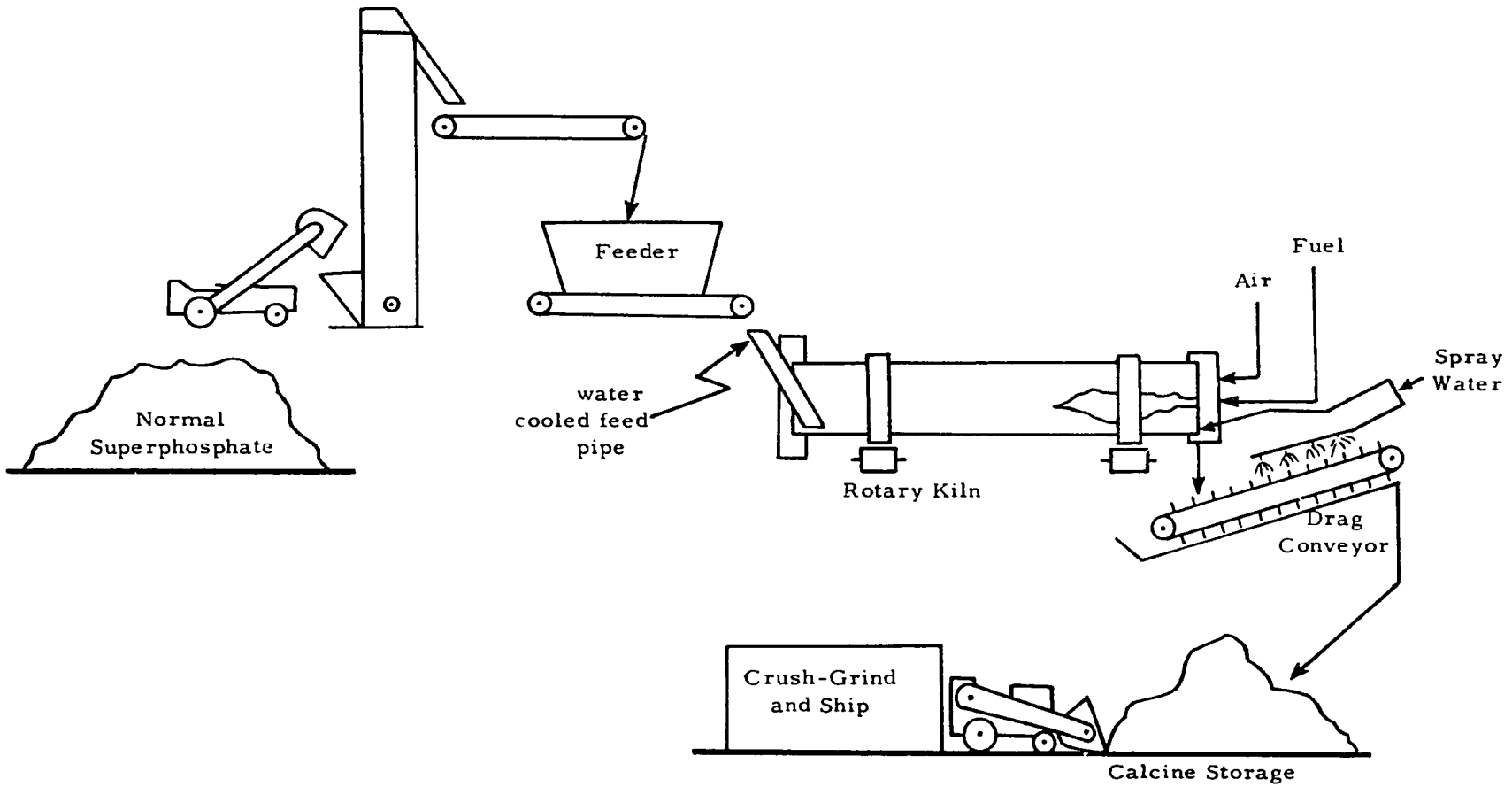
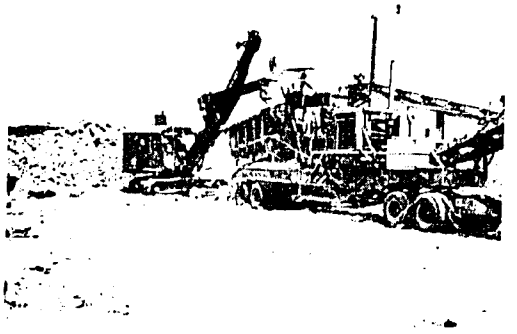
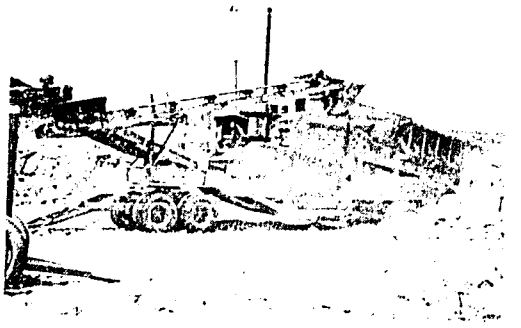


Figure A-25. Process flowsheet for the manufacture of defluorinated superphosphate.

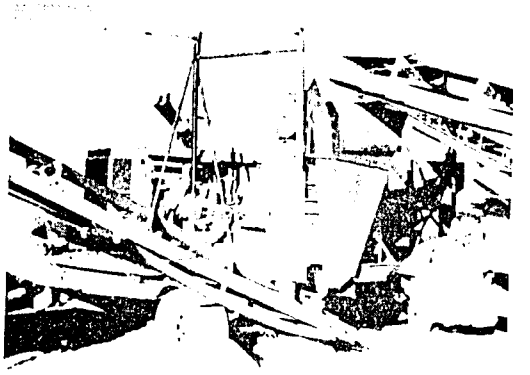


Primary crusher (impactor) and power shovel



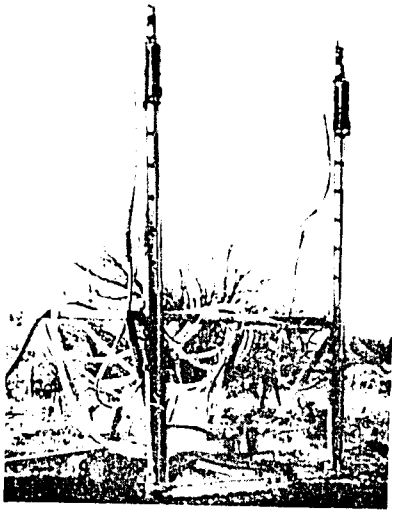
Primary crusher - opposite side

Screening unit



Hammermill

Trucks loading at conveyors



Pneumatic rock drill

Figure A-26. A modern, portable, U.S. agricultural limestone crushing plant

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