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This report covers the work of a TVA team which visited Colombia during April of 1974. A team of TVA engineers had previously studied the FERTICOL facility at Barrancabermeja in 1970 and made recommendations for improvement of the operation. Specific objectives of this new study were to:

1. Review the expansion plans recommended by the 1970 TVA team.
2. Consider the feasibility of using domestic sources of phosphate rock to satisfy P_2O_5 demands.
3. Make recommendations concerning the increased use of domestic natural gas sources for nitrogen fertilizer production.

Section I provides general background information. Comments are given concerning use of the natural gas newly discovered in Guajira for producing ammonia and urea. Recommendations to improve the FERTICOL operations are discussed in Section II. Section III contains a discussion of the use of domestic phosphate rock. The technical questions posed by ABOCOL were answered by letter, a copy of which is included in the appendix.

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ENGINEERING EVALUATION OF SELECTED SEGMENTS OF THE COLOMBIAN FERTILIZER INDUSTRY

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RSSA NO. TVA 01-74

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INTRODUCTION

The Agency for International Development (AID) requested TVA to provide technical assistance to the FERTICOL nitrogen fertilizer complex. This report covers the work of a TVA team which visited Colombia during April of 1974. A team of TVA engineers had previously studied the FERTICOL facility at Barrancabermeja in 1970 and made recommendations for improvement of the operation. Specific objectives of this new study were to:

1. Review the expansion plans recommended by the 1970 TVA team.
2. Consider the feasibility of using domestic sources of phosphate rock to satisfy P_2O_5 demands.
3. Make recommendations concerning the increased use of domestic natural gas sources for nitrogen fertilizer production.

The study was conducted by a two man team consisting of George M. Spickard and Donald R. Waggoner, TVA engineers. The team arrived in Colombia on April 3, 1974, for a 3-week period. Included were visits to the Bogota offices of ABOCOL, Monomeros, Caja Agraria, Ministry of Agriculture and FERTICOL. In addition, the team visited sites of rock phosphate deposits at Pesca, Lake Tota and the Cascajera phosphate mine. Seven days were spent at Barrancabermeja working with the FERTICOL organization.

The period of time in Colombia was extended to 4 weeks to allow time for technical advice to ABOCOL at Cartagena. A report of discussions with ABOCOL is included in the appendix.

SUMMARY AND RECOMMENDATIONS

Section I provides general background information. Comments are given concerning use of the natural gas newly discovered in Guajira for producing ammonia and urea. Recommendations to improve the FERTICOL operations are discussed in Section II. Section III contains a discussion of the use of domestic phosphate rock. The technical questions posed by ABOCOL were answered by letter, a copy of which is included in the appendix. A summary of recommendations follows:

FERTICOL:

1. Installation of facilities for producing nitric phosphates is not recommended.
2. Modifications are recommended as follows:
   a. Installation of additional ammonia producing capacity of 65 mt/day minimum. The newer ammopac units range from 90 to 100 mt/day which may be the practical lower unit for additional capacity.
   b. Addition of 1000 mt of ammonia storage capacity.
   c. Installation of a new concrete cooling tower to replace the deteriorating wooden towers.
   d. Conversion of the urea unit to total recycle.
   e. Conversion of the ammonium nitrate granulation unit to NPK granulation. Increase the capacity from 175 mt/day to 300 mt/day.
   f. Install facilities for producing UAN solution.

The estimated cost of the above modifications is approximately U6.7 million. Details of the cost estimates are given in Section II.

3. Conversion of the granulation unit to use of the TVA pipe reactor process when phosphoric acid becomes available. See Section III.

4. Visit of key FERTICOL personnel to NPK producing facilities in the United States.

Use of Colombian Phosphate Rock:

1. Substitution of Colombian phosphate rock for imported phosphate rock is strongly recommended.

2. Construction of a wet-process phosphoric acid plant of 400 mt/day P_2O_5 capacity at Barrancabermeja is recommended.

3. Before (1) and (2) above can be accomplished it will be necessary to:

   a. Obtain full cooperation from all organizations and companies which have an interest in making use of the domestic rock. We feel that this can best be accomplished by formation of a task force or company composed of all interested parties and charged with the responsibility of developing the rock in the best possible manner for Colombia's use. In view of the current and predicted future P_2O_5 supply and cost situation in Colombia, it is imperative that this step be taken immediately.

   b. Immediately begin a research program to determine optimum methods for beneficiating the rock.

   c. Further explore and characterize all of the known deposits.

   d. Make a detailed study of the transportation system from the mines to the points of use.

e. Study the best ways to use the rock in addition to those already established; i.e., phosphate rock and phosphoric acid at ABOCOL and Monomeros. Production of electric-furnace acid from the Pesca rock is a distinct possibility since large coal reserves exist in the same area.

Use of Guajira Natural Gas:

1. Initiation of a project to use this source of natural gas for producing ammonia and urea is recommended.

SECTION I

GENERAL BACKGROUND

Present Fertilizer Situation

There are three basic nitrogen production units in operation in Colombia. They are the Monomeros plant at Barranquilla, ABOCOL at Cartagena, and FERTICOL at Barrancabermeja. The ABOCOL facility consists of units for providing ammonia, nitric acid, urea, and nitric phosphate (NPK).

Monomeros has a caprolactum facility which produces large quantities of ammonium sulfate as a byproduct. The ammonium sulfate is used in a modified Dutch State Mines nitric phosphate unit to produce NPK fertilizers. Nitric acid is produced on site but ammonia for the process is obtained from Venezuela.

FERTICOL has units at Barrancabermeja which use locally available natural gas to produce ammonia, nitric acid, urea, and granular ammonium nitrate (26% nitrogen). Some additional natural gas is available. The combined national production of fertilizer materials and the primary nutrients from these plants and several smaller plants is given in table 1. In addition to the national production cited in table 1, finished mixed fertilizers and urea are imported. These imports are shown in table 2 for 1972 and 1973. No estimate is available for 1974 because of uncertainty of supply.

Most of the P_2O_5 used in Colombia and shown as produced in table 1 is actually imported as raw material for the granulation plants. Types and amounts of phosphatic raw materials imported during the period

Table 1

National Production of Fertilizers*

Type Fertilizer	Metric Tons (thousands) 1970	1971	1972	1973	1974 (est.)
Compound Mixed	221	264	284	353	410
Nitrogen	102	109	112	110	114
Phosphates	54	58	42	70	70
Miscellaneous	2	3	3	3	5
Total	379	434	441	539	599

Production of Primary Nutrients

Nutrient	Metric Tons (thousands) 1970	1971	1972	1973	1974 (est.)
Nitrogen	61	69	77	86	102
Phosphate (P_2O_5)	48	62	52	72	81
Potassium (K_2O)	32	39	36	48	54

*Source: Martin Echavarria, Elementos Para un Diagnostico de la Situacion de los Fertilizantes Quimicas en Colombia.

Table 2

Imports of Mixed Fertilizers and Urea-Metric Tons*

	1972 Tons Met.	N	P	K	1973 Tons Met.	N	P	K
Urea	70,000	31,500	-	-	128,000	57,600	-	-
Mixed Fertilizers	27,000	2,465	7430	3165	76,000	8,478	13,748	12,198
Total Nutrients		33,965	7430	3165		66,078	13,748	12,198

*Source: Martin Echavarria - OPSA - Ministry of Agriculture

1970-1973 are shown in table 3. ABOCOL and Monomeros are producing at present maximum capacity of both P_2O_5 and nitrogen.

Monomeros is expected to increase production capacity by 1977. This will add approximately 30,000 mt of compound fertilizers to the national production shown in table 1 for 1974. All of the P_2O_5 contained in these fertilizers will be imported as either rock or phosphoric acid.

The Ministry of Agriculture has forecast a national shortage in 1974 of 20,000 mt of mixed fertilizers and 130,000 mt of urea (1). In addition, neither ABOCOL nor Monomeros is expected to meet the production forecast for 1974 because of shortage of raw materials in the world market. It is evident that Colombia must either develop some other means of obtaining urea and phosphatic materials or continue to face serious national shortages.

Fortunately, two recent developments place Colombia in a very enviable position for the future. First, several million tons of phosphate reserves have been proved and characterized during the past 4 years. Figure 1 is a map of the approximate location of the main deposits. Second, a large supply of natural gas has been located on the North Coast in Guajira close to Riohacha. There are no known potash deposits in Colombia. Serious search for potash should be undertaken immediately. However, according to a recent study by TVA, world potash supplies are expected to be adequate for the foreseeable future (2).

Studies at TVA have shown that good quality phosphoric acid can be produced from the domestic phosphate rock (3). All of the known deposits of rock contain excessive amounts of silica (4). The chemical composition of the four main deposits is shown in table 4. Investigation

Table 3

Phosphates Imported for Use as Raw Materials or Intermediates

Material	Metric Tons Imported (1000's)							
	1970		1971		1972		1973	
	Tons	P_2O_5	Tons	P_2O_5	Tons	P_2O_5	Tons	P_2O
DAP (18-46-0)	15.0	7.0	16.0	7.4	33.2	15.3	20.9	9.6
Phosphate Rock (33% P_2O_5)	12.3	4.1	20.5	6.8	37.2	12.3	45.5	15.0
TSP (46% P_2O_5)	12.6	5.8	30.4	14.0	19.9	9.2	40.0	18.4
Phosphoric Acid (54% P_2O_5)	19.5	10.5	29.9	16.2	20.8	11.2	23.5	12.7
TOTAL	59.4	27.4	96.8	44.4	111.1	48.0	129.9	55.7

Table 4

Chemical Composition of Selected Phosphate Rock Samples in Colombia

Deposit	A	B	C	D
P_2O_5	28.2	21.6	20.1	23.8
CaO	41.4	40.3	28.3	31.7
CO_2	2.7	8.5	1.2	1.6
F	3.2	2.4	2.2	2.3
Al_2O_3	1.9	1.9	1.6	-
Fe_2O_3	0.9	0.6	0.9	-
Acid Insoluble	16.6	19.6	44.0	31.8

A. Sardinata--average of many samples.

B. Azutrada--average of 44 samples.

C. Conejera--average of 25 samples.

D. Yaguara--average of 11 samples.

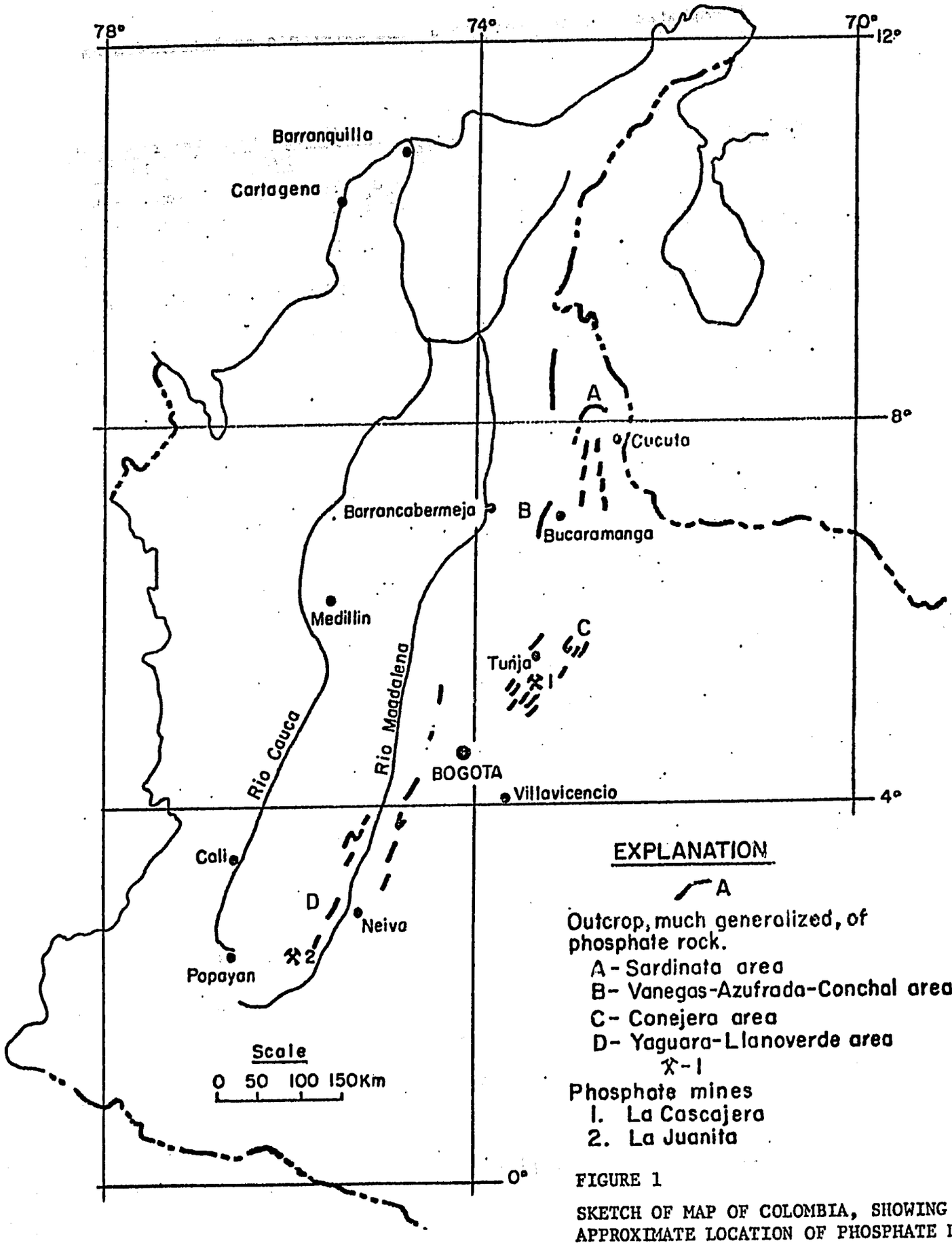

FIGURE 1

SKETCH OF MAP OF COLOMBIA, SHOWING APPROXIMATE LOCATION OF PHOSPHATE DEPOSI

by TVA has shown that the ore is composed of grains of phosphate and quartz embedded in a matrix of chert (amorphous silica) (5). Study of beneficiating the ore by flotation gave generally disappointing results (3). The tests were made using conditions favorable for Florida rock. It should be possible to develop methods for beneficiating the ore. However, beneficiation would not be necessary for producing phosphoric acid since the silica could be removed in the filtration step. Removal of the silica would be necessary before the rock could be used successfully at Monomeros and Abocol.

Further discussions for developing the phosphate industry in Colombia are included in Section III.

Ammonia and urea produced from low cost natural gas at or near coastal areas will always occupy a competitive position in the world market. In view of the serious shortage of urea already evident in Colombia and the expected increase in demand in Colombia and in world markets, planning for a large ammonia/urea complex based on the newly discovered natural gas should begin immediately. Time was not available for the TVA team to prepare a detailed preinvestment type study. It is safe to say that production of ammonia and urea in large modern type units from good quality, economically priced natural gas can be justified. Several local companies are interested in such a project. A prompt decision concerning the management of the project should be made so that actual implementation can begin.

SECTION II

FERTICOL

One week was spent at FERTICOL reevaluating the 1970 TVA recommendations, taking into consideration domestic sources of rock phosphate. The new supply and demand situation was also considered.

The FERTICOL facility is described in detail in the 1970 TVA report. Therefore, only a brief description will be given here. After major modification in 1966-1968, the plant now consists of a 65 mt/day ammonia unit, a 154 mt/day 54% nitric acid unit, a 60 mt/day urea unit and a 130 mt/day 26% ammonium nitrate granulation unit. In addition, electricity for the plant and a part of the city of Barrancabermeja is produced on the site. Storage consists of approximately 540 mt of ammonia, 600 mt of 54% nitric acid and a large bag storage warehouse.

The main problem that has faced the company for the past several years is that ammonia production is not sufficient for a balance of the end product units. The urea unit employs a partial recycle process which yields 0.254 tons of byproduct ammonia for each ton of urea produced. When the urea unit produces at full rate there is not enough ammonia left to produce sufficient nitric acid to neutralize the off-gas ammonia. Lack of demand for the granular 26% ammonium nitrate has been a serious problem in the past.

As a solution to these problems the 1970 TVA team recommended:

1. A scheme for closing the urea loop to greatly reduce the ammonia in the off-gas.
2. Conversion of the ammonium nitrate granulation unit to permit granulation of NPK products.
3. Diversion of a part of the ammonium nitrate to UAN solution.

One major change is that demand for granular 26% ammonium nitrate has greatly increased. The phosphate situation also is different. The earlier recommendations included use of imported triple superphosphate and/or monoammonium phosphate and diammonium phosphate as sources of P_2O_5. Since that time, large domestic reserves of good quality phosphate rock have been proven.

The following alternatives were considered:

Alternative I--Implementation of the 1970 TVA team recommendations including additional ammonia for satisfying the demand for ammonium nitrate.

Alternative II--Construction of a nitric phosphate unit sized to furnish the Caja Agraria's requirements for P_2O_5 (16,000 mt/yr).

Alternative III--Further modification at a future date of the ammonium nitrate granulation unit to produce NPK fertilizers using ammonium nitrate solution and domestically produced phosphoric acid.

A detailed discussion of each of these alternatives follows.

Alternative I

Since sufficient ammonia is not available to operate the complex at optimum capacity, additional ammonia production is necessary. It would be very difficult to justify installation of an economically sized ammonia unit. However, since all of the ammonia could be converted to solid products with minor changes in the existing unit, addition of a small ammonia plant can be justified. An estimate was made of capital requirements for accomplishing the following:

1. Construction of a 65 mt/day ammonia unit similar to the existing unit.

2. Conversion of the urea unit to total recycle to increase the production to 62 mt/day.

3. Modification of the existing ammonium nitrate granulation unit to allow production of granular ammonium nitrate, granular 5-20-12 and granular 8-24-8 at a rate of 300 mt/day.

4. Installation of facilities for producing and storing UAN solution.

5. Additional ammonia storage (1000 mt) and some offsites (water, cooling tower, etc.).

It is our opinion that these modifications can be accomplished with only minor interruption in the operating schedule. Individual items of equipment can be installed during regular short-term outages. A longer outage will be necessary for the final tie-in. If the additional ammonia storage and the urea modifications are completed first, the longer outage can be accomplished without significant production loss.

A summary of the estimated capital investment required for the above listed modifications is given in table 5. These investment costs were used to calculate production costs of the various end products. A comparison of these costs with actual production costs for 1973 is given in table 6.

Grade formulations and details of the variable costs are given in the appendix.

ECI and TSP costs were based on estimated f.o.b. prices Gulf Coast prices plus $30/mt for ocean freight, insurance, unloading and inland freight to Barrancabermeja. The f.o.b. prices used were $50/mt and $130/mt respectively for ECI and TSP.

Table 5

Alternative 1--Capital Investments

	$U.S.
NH_3 and offsites	
New 65 mt/day facility	5,200,000
Offsites 20%	1,100,000
Subtotal NH_3 and offsites	6,300,000
Urea	
High-pressure decomposer-separator	3,600
High-pressure cooler	24,400
Instrumentation	5,600
Piping	11,400
Carbonate pump	25,000
Cost of moving C-2 vessel	12,800
Subtotal Urea	88,800
Granulation	
Quotation received by PERFICOL from PERCO in 1971 for modification. Note: Costs escalated to 1975	165,000
Shipping and installation	165,000
Subtotal granulation	330,000
UAN Solutions	
Instrumentation and piping	7,500
Conversion of gas holder	5,000
Pump and motor	5,000
Contingency	2,500
Subtotal UAN solution	20,000
TOTAL INVESTMENT REQUIRED	$6,738,800

Table 6

Current Conditions vs. Alternative I Conditions PERTICOL

	Product	Ammonia	33% HNO_3	Prilled Urea Bagged	Granular AN 26% (Bagged)	95% AN Solution	5-20-12 Granular	8-24-8 Granular
Year 1973	Production, mt/yr	13,427	30,830	6,275	23,853			
	Costs, U.S./mt							
	Variable	27.70	13.28	48.48	38.06			
	Fixed	25.76	2.67	34.38	16.05	(100%		
	Total	53.46	15.95	82.86	54.11	Basis)		
	New Investment	6,300,000	-	88,800	330,000			
Cost after	Production, mt/yr	37,200	50,700	19,200	24,000	29,640	34,500	34,500
Alternative I	Costs, $U.S./mt							
Mid-1975	Variable	27.70	14.43	49.71	41.49	45.49	103.74	116.59
	Fixed	32.25	1.62	12.44	4.55	2.79	2.79	2.79
	Total	59.95	16.05	62.15	46.04	48.28	106.53	119.38

Since granular 5-20-12 and 8-24-8 are among the highest tonnage items sold by Caja Agraria, which also sells all of FERTICOL's product, these grades, along with granular 26% ammonium nitrate and urea, were chosen for the cost comparisons. Table 7 lists Caja Agraria's 1973 and projected 1974 demand for these materials. The tonnages to be produced at FERTICOL were based on 300 mt/day and balance of the liquid AN production.

Current selling prices of selected fertilizer materials f.o.b. Barrancabermeja, Bogota and Barranquilla are given in table 8. A comparison of these retail prices with the production costs shown in table 6 indicates that there is room for a good margin of profit for both the manufacturer and the retailer. Also, the costs of production are based on recently escalated prices for both TSP and KCl. If these prices continue, an increase in the retail price of 5-20-12 and 8-24-8 is likely, providing an even greater margin of profit.

Calculations were made to determine the economic feasibility of expanding the FERTICOL facility as outlined in Alternative 2. The results of these calculations are summarized in table 9. Using 1972 production costs and current selling prices as a basis, the net profit will increase from $US1.8 million in 1974 to $US6.0 million in 1976 after the expansion. This amounts to a 63.2% return on the additional investment of $6.7 million.

The modification and expansion outlined in Alternative 2 are strongly recommended.

We find that the FERTICOL organization has the technical competence necessary to implement this recommendation. However, it would be very helpful for the key personnel involved in the project to visit similar type installations in the United States.

Table 7

Caja Agraria's Demand for Selected Fertilizer Materials

Year	1973	1974
Material	mt/yr	mt/yr
5-20-12	52,700	70,000
10-30-10*	20,900	40,000
15-15-15	16,084	32,000

*Grade 8-24-8 is the highest 1-3-1 grade which can be produced at Fertisol using TSP as a P_2O_5 source.

Table 8

Current Retail Selling Prices of Selected Fertilizer Materials in Colombia

Location	Bogota	Barranquilla	Barrancabermeja
Material	$US/mt	$US/mt	$US/mt
5-20-12	278.50[b]	Not Sold	287.97
8-24-8*	232.66	213.96[b]	224.22
15-15-15	305.76	286.00[b]	292.26
Urea (45-0-0)	267.65	Not Shipped	258.13[b]
AN (26-0-0)	232.76	Not Shipped	222.29

*Based on 10-30-10 prices.

[b]Current price at point of production. Difference in price at other points represents freight charges.

Note: Conversion of Pesos to $US = 25.35/1

Table 9
FERTICOL--Alternative 1
Cost of Production and Value of Sales

Year	Product	mt/yr	Cost: $US/mt	Total	Sale Price	Total
1974	Urea	6,275	82.86	520,000	192.40	1,207,000
	Gran. AN (26% N)	24,000	54.11	1,290,000	100.00	2,400,000
			COST:	1,810,000	SALES:	3,607,000
	MARGIN: 1,797,000					
1976	Urea	19,200	62.15	1,193,000	192.40	2,694,000
	Gran. AN (26% N)	24,000	46.04	1,105,000	100.00	2,400,000
	5-20-12	34,500	106.53	3,680,000	125.20	4,319,000
	8-24-8	34,500	119.38	4,120,000	166.08	5,730,000
			COST:	10,098,000	SALES:	16,143,000

MARGIN: $6,045,000

INCREASE IN MARGIN: $4,248,000

NEW INVESTMENT: $6,748,000

ROI FOR NEW CAPITAL: 63.2%

Alternative II

Phosphate rock of suitable quality for use in a nitric phosphate plant at Barrancabermeja is available at Sardinata. Since the Caja Agraria will require approximately 16,000 mt/yr of P_2O_5 by 1976, calculations were made for a nitric phosphate plant of this size based on the modified Odda process. Calcium nitrate would be separated and converted to ammonium nitrate for use in the existing granulation unit. In addition to a nitric phosphate wet section, the following would be required:

Ammonia----------120 mt/day

Nitric Acid (100%)----------120 mt/day

Nitric Phosphate Granulation

Unit----------430 mt/day

A summary of the necessary capital investment is given in table 10. The total investment required is approximately $US24.6 million. This is an extremely high expenditure for providing 16,000 mt/yr of P_2O_5. Two very large nitric phosphate plants already exist in Colombia--ABOCOL at Cartagena and Monomeros at Barranquilla. Nitric phosphate processes inherently produce up to twice as many units of nitrogen as units of P_2O_5. The lower N/P_2O_5 ratio grades can only be produced by either adding a supplemental source of P_2O_5 or by separating either calcium nitrate or ammonium nitrate from the solution. FERTICOL would need to produce the lower N/P_2O_5 ratios since ABOCOL and Monomeros produce the higher ratios much cheaper than FERTICOL. This was the reason for choosing the modified Odda process.

It is evident without making detailed production cost calculations that an investment of the size required cannot be justified.

Therefore, production of the NPK grades at FERTICOL by the nitric phosphate route using domestically produced rock is not recommended.

Table 10

Capital Investment--Alternative II

NH_3 120 mt/day Facility	$US
1974 U. S. Battery Limit	$ 7,600,000
Support Facilities (15%)	1,100,000
TOTAL (U.S.)	$ 8,700,000
Colombia Cost (U.S. x 1.25)	10,900,000
Escalation	1,100,000
TOTAL-- COLOMBIA	$12,000,000
HNO_3 120 mt/day (100%)	
1977 U. S. Battery Limit	3,900,000
Support Facilities (15%)	600,000
TOTAL (U.S.)	4,500,000
Colombia Cost (U.S. x 1.25)	5,600,000
ODDA Nitric Phosphates 430 mt/day (Includes Granulation)	
1967 U.S. Cost	2,500,000*
1976 U.S. Cost 2.5 x 1.8	4,500,000
Support Facilities (25%)	1,100,000
TOTAL (U.S.)	5,600,000
Colombia Cost (U.S. x 1.25)	6,000,000
*Includes Handling for Rock and KCl.	
TOTAL CAPITAL INVESTMENT FOR COMPLEX	$24,600,000

Alternative III

If it is assumed that domestic sources of phosphate rock and phosphoric acid will become available, the FERTICOL facility could be converted to use of phosphoric acid. Actually, if the modifications outlined in Alternative I were already accomplished, a very modest additional investment of approximately $US133,000 would be required. The process could very easily be modified to use the TVA pipe reactor process. In the pipe reactor process, preheated, partially ammoniated phosphoric acid (54% P_2O_5) is reacted with preheated ammonia vapor in a pipe "tee." The heat evolved from the reactor is used to evaporate all of the free water and convert a portion of the P_2O_5 to polyphosphate forms. The resulting melt and evolved gases are separated in a vapor disengager. Ammonia in the evolved gases is recovered in a spray scrubber using the preheated feed phosphoric acid. The melt flows to a granulator where it is cooled and crystallized along with either urea or AN melt. The granulator product is cooled and screened. Crushed oversize, fines, and a portion of the product size from the screens are returned for recycle. Potassium chloride is added with the recycle. Since essentially anhydrous melts are used, no dryer is required.

Capital in addition to that required for Alternative I is given in table 11. The use of phosphoric acid would permit production of higher analysis grades, i.e., 17-17-17, 11-22-22, and 12-36-12. Approximate production costs of these grades have been calculated for a rate of 300 mt/day in the FERTICOL facility in 1976. These costs are summarized in table 12. The phosphoric acid cost has been taken as $US238.15/mt P_2O_5 based on Section III, Use of Colombian Phosphate Rock. A comparison of these costs with costs of production given for Alternative I in table 12 indicates that conversion to use of domestically produced

Table 11

Alternative III Investment Costs

Equipment	$US
Pipe reactor	2,000
Vapor disengager	8,000
Ammonia vaporizer	5,000
Spray reactor and blower	10,000
Spray reactor pumps	5,000
Phosphoric acid pumps	5,000
Phosphoric acid heater	4,500
Instrumentation	13,700
TOTAL (U.S.)	53,200
Colombia Cost (U.S. x 1.25)	66,500
Labor and engineering	66,500
TOTAL	133,000

Table 12

Alternative III Production Costs
Using Domestically Produced Phosphoric Acid

Grade		17-17-17	11-22-22	12-36-12
Production Rate:	mt/day	300	300	300
	mt/yr*	45,000	24,000	24,000
Production Costs, $US/mt				
Variable		102.18	109.73	114.90
Fixed		3.32	3.32	3.32

*Annual production tonnages as required to produce 300 mt/day and use all of the AN solution.

phosphoric acid could be justified. Grade formulation and details of the variable costs are given in the appendix.

SECTION III

USE OF COLOMBIAN PHOSPHATE ROCK

Introduction

As previously noted, Colombia is importing large quantities of phosphate as phosphate rock, phosphoric acid and finished products. The 1973 consumption of P_2O_5 was approximately 85,000 mt. The largest importers of P_2O_5 are Monomeros at Barranquilla and ABOCOL at Cartagena. By 1977, these two producers are expected to be using 288,000 mt of phosphate rock (28% P_2O_5) and 101,940 mt of phosphoric acid (54% P_2O_5). Additionally, ABOCOL is planning an expansion of 20% to 40% of its NPK production.

Calculations of projected consumption of P_2O_5 were made for 12% and 15% growth rates using the 1973 consumption of 85,000 mt as a basis. The resulting data have been plotted in figure 2. By 1977, Colombia could be using as much as 150,000 mt/yr of P_2O_5. If the P_2O_5 equivalent of the rock consumed by Monomeros and ABOCOL is subtracted, the P_2O_5 from phosphoric acid and phosphoric acid derivatives would be 70,000 mt/yr. By 1980, Colombia will be using the entire output of a 400 mt/day of P_2O_5 phosphoric acid plant in addition to phosphate rock.

If the current c.i.f. prices of $66/mt for phosphate rock (28% P_2O_5) and $184/mt for 54% P_2O_5 phosphoric acid are applied to 1977 demand projections, Colombia will be spending $37,600,000 foreign exchange for phosphates. Also, it is likely that the prices for phosphate rock and phosphoric acid will stabilize at levels higher than the above prices. In addition to higher prices, serious shortages of P_2O_5 have been predicted for Latin America through 1980 (2).

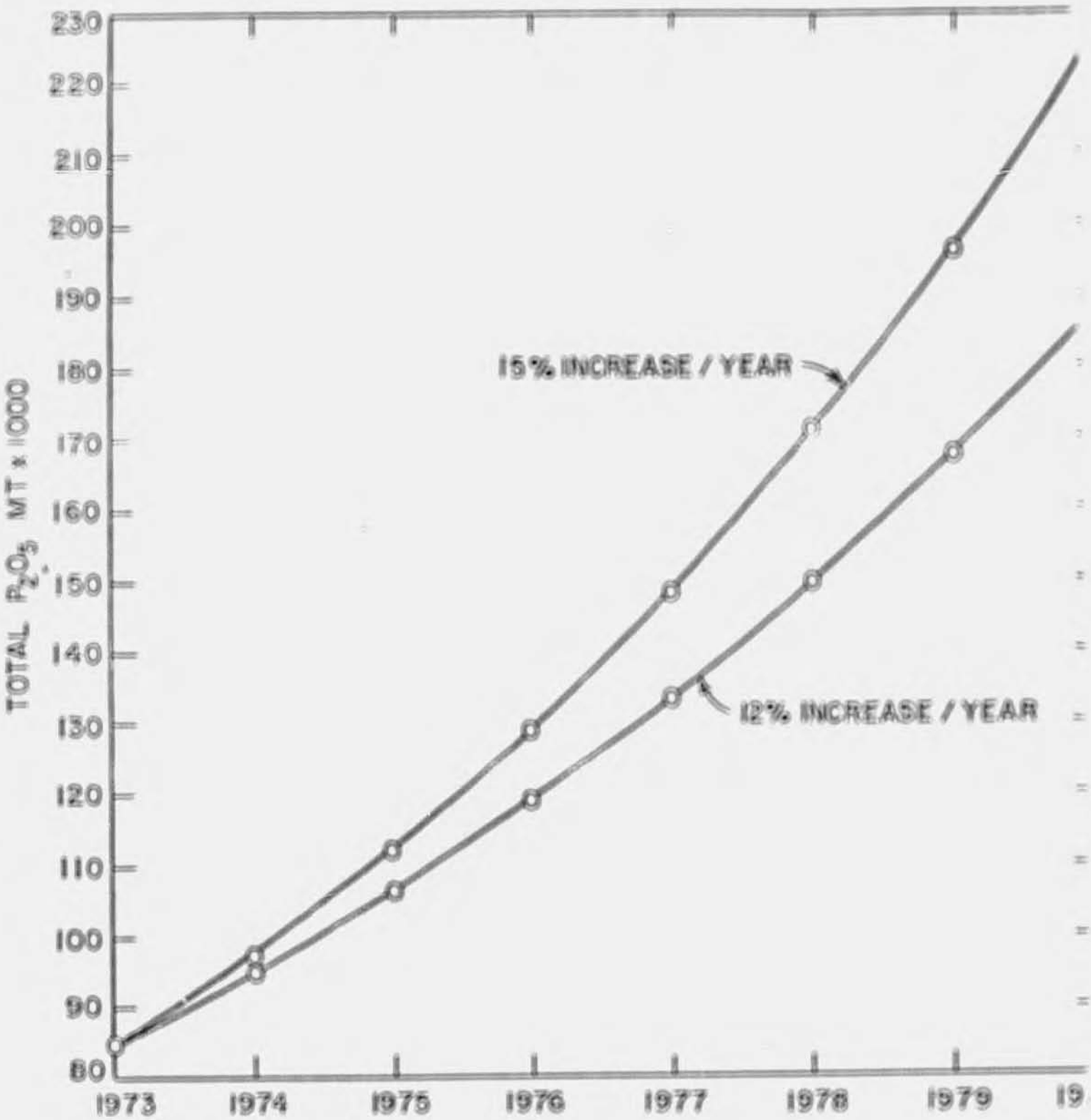

FIGURE 2

PROJECTED P_2O_5 REQUIREMENTS

Unless Colombia develops and uses its domestic phosphate rock, there is little hope for supplying the future P_2O_5 requirement of the agricultural sector.

Fortunately, enough good quality phosphate rock exists in Colombia to supply the domestic needs for many years (see table 13).

Table 13

Phosphate Reserves
Selected Areas

Area	Proved Reserves--mt	Inferred Reserves--mt
Sardinata	9,000,000	-
Arufrada	1,000,000	5,000,000
Conejera	12,000,000	40,000,000
Yaguara	-	30,000,000

The most important deposits are at Sardinata and Conejera. The chemical composition of the deposits is given in table 4. Rock from these deposits should be suitable for direct use in a wet-process phosphoric acid plant. However, some beneficiation to remove the silica would improve its suitability. It is doubtful that either of the rocks can be used as feed to the nitric phosphate processes at ABOCOL and Monomeros without removal of most of the silica or significant modification to the processes. Transportation of the rock from the mining area to the point of use will also present problems.

Since it is extremely important that Colombia begin as soon as possible to exploit the domestic rock, research of methods of beneficiating the rock should be given highest priority. Since transportation costs are likely to be high, beneficiation near the deposit could result in substantial savings.

As pointed out previously, plants using large quantities of phosphate rock and phosphoric acid are already in operation in Colombia. First use of the domestic rock should be aimed at this well-established market.

The following gaps need to be filled before Colombia can successfully exploit the rock:

1. Research to determine optimum methods of beneficiating the rock.
2. Further exploration and characterization of the known deposits.
3. Detailed study of the transportation system from the mines to the points of use.
4. Study of the best ways to use the rock in addition to the uses already established.

Accomplishment of these above listed objectives cannot be realized without close cooperation of all concerned. It has been our observation that this close working relationship does not now exist. For this reason, we recommend early establishment, if possible, of a task force or a new company composed of representatives of all of the interested parties. This organization should have full authority and responsibility for developing the phosphate rock into a usable material at the point of use. This would include mining, beneficiation and transportation. It should include representation from at least the following:

Ingeominas	Ecominas
Colminas	ANOCOL
Monomeros	IFI
FERTICOL	Caja Agraria

The project could be implemented more quickly if a joint venture were entered with a company possessing the desired technical competence. Those with experience in developing Western U.S. phosphate deposits are one possibility.

Production of Wet-Process Phosphoric Acid in Colombia

In addition to the large quantities of wet-process phosphoric acid imported by Colombia most other P_2O_5 sources are derivatives of wet-process phosphoric acid. Since Colombia possesses rock that can be used for producing wet-process phosphoric acid, candidate steps should begin to implement a project for production. This project can be carried out concurrently with the project for developing the rock.

Considering the fact that most of the phosphate rock and phosphoric acid will be used on the North Coast, the Sardinata deposit appears to be the best starting place for development. The Sardinata rock is chemically superior to the Cerejera rock, but development of a transportation system is likely to be more difficult for it than for the Cerejera rock. However, the Sardinata is much closer to the use area and can probably be supplied more economically after a transportation system is worked out. Eventually, both deposits will be required to satisfy the needs for rock and phosphoric acid.

Although time was not available for detailed study, it is our opinion that the Sardinata rock could be brought by pipeline or aluminoway to a point on the Magdalena river, beneficiated there, and shipped to the North Coast and to a phosphoric acid plant located in the Barrancabermeja area.

The site of a phosphoric acid plant should meet several criteria, such as:

1. Reasonable accessibility to the rock source.
2. Accessibility to all modes of transportation--rail, barge, and highway.
3. Electricity.
4. Cooling water.
5. Steam.
6. Land for the plant and for gypsum disposal.
7. Capability for expansion.
8. Skilled and semiskilled labor.
9. Experienced chemical plant management.
10. Easy access to use area.

Since FERTICOL already has a chemical plant in Barrancabermeja which meets all the above listed criteria, it is our opinion that a phosphoric acid facility should be constructed there. The rock could be brought to the Magdalena river and some shipped to ASOCOL and Monomeros via barge and some to FERTICOL. The acid produced at FERTICOL could be barged to Cartagena and Barranquilla and some could be upgraded to 52% product at FERTICOL. The barges carrying rock and acid north could backhaul fertilizer and sulfur to the interior of the country.

Investments costs were calculated for 200, 300, 400, 500, and 600 mt/day of P_2O_5 wet-process phosphoric acid plants using the Prayon process. A description of this process is given later. A typical investment for a 300 mt/day P_2O_5 battery limits phosphoric acid plant is given in table 14. Similar calculations were made for the other sizes as well as the equivalent sulfuric plant required. Tables 15 and 16 are

Table 14

Typical Capital Investment for Phosphoric Acid Production

in United States or European Location

300 mt/day P_2O_5

Battery Limits Cost

Section	Cost, $US * 1,000
Rock Storage	300
Rock Grinding	1,200
Reactor and Filtration	3,500
Acid Concentration	1,100
Clarification	530
Gypsum disposal and scrubber pond	760
TOTAL	7,400

Table 15

Capital Investment and Production Costs for Sulfuric Acid Plants in Colombia Based on Given Size of Phosphoric Acid Plant

Capacity, P_2O_5	200	300	400	500	600
Plant Investment	6.4	8.6	9.9	11.6	13.1
Capacity, tons H_2SO_4/day	584	876	1168	1460	1752
Capacity, tons H_2SO_4/year	192,720	289,080	385,440	481,800	578,160

	$US/ton H_2SO_4				
Sulfur, 0.344 tons @ $45	15.48	15.48	15.48	15.48	15.48
Cooling H_2O, 24,000 gal. * 0.02	0.48	0.48	0.48	0.48	0.48
Boiler feed H_2O, 1,100 gal. * 0.50	0.55	0.55	0.55	0.55	0.55
Electricity, 30 kWh * 0.01	0.30	0.30	0.30	0.30	0.30
Labor, ($144,500/yr)	0.75	0.50	0.38	0.30	0.25
Maintenance, 5% of Investment	1.66	1.49	1.29	1.20	1.13
Taxes and Insurance, 2% of Investment	.66	.60	.52	.48	.45
Depreciation, 6.67% of Investment	2.21	1.98	1.72	1.60	1.50
Analysis, 20% of Labor	0.15	0.10	0.08	0.06	0.05
Interest, 8% of ½ Investment	1.33	1.19	1.03	0.96	0.90
Overhead, 100% of Labor	0.75	0.50	0.38	0.30	0.25
Production Cost	24.32	23.17	22.21	21.66	21.34
Plus 10% ROI	3.32	2.98	2.57	2.41	2.27
Price of H_2SO_4	27.64	26.15	24.78	24.07	23.61

Table 16

Capital Investments Required for Producing Phosphoric Acid in Colombia

Capacity, tons P_2O_5/day	200	300	400	500	600
Phosphoric acid plant,					
U.S. Battery Limits	6.3	7.4	8.4	9.4	10.4
Auxiliary and Support Facilities	1.6	1.9	2.1	2.4	2.6
Total U.S. Investment	7.9	9.3	10.5	11.8	13.0
Developing Country Investment	9.9*	11.6	13.1	14.8	16.3
Sulfuric Acid Plant,					
U.S. Battery Limits	4.1	5.3	6.3	7.4	8.4
Auxiliary and Support Facilities	1.0	1.3	1.6	1.9	2.1
Total Plant Investment, U.S.	5.1	6.9	7.9	9.3	10.5
Developing Country Investment	6.4	8.6	9.9	11.6	13.1
Total Phosphoric and Sulfuric, US	13.0	16.2	18.4	21.1	23.5
Total for Colombia	16.3	20.2	23.0	26.4	29.4

*Based on U.S. cost x 1.25

Construction of these facilities in a location without any existing auxiliary and support facilities will add approximately 25% to the investment cost shown above.

summaries of these calculations. It should be pointed out that these represent capital required for a plant at Barrancabermeja taking advantage of existing offsites and other services. The investment would be considerably higher at less developed locations. Calculations of the working capital are given in the appendix. Calculations of the cost of producing phosphoric acid in each of the plants were made using rock at $30/mt and sulfur at $45/mt. It is our opinion that the phosphate rock can eventually be produced for less than $US30/mt. For each dollar reduction in rock cost, there is a corresponding $4 reduction in the cost of phosphoric acid (100% P_2O_5 basis).

The investment costs shown in tables 15 and 16 were used to calculate production costs for a 10% return on investment (ROI). These have been summarized in table 17 and also plotted in figure 3. The effect of rock and prices on production costs are shown in figures 4 and 5, respectively. The effect of ROI is shown in figure 6.

The cost of production increases very rapidly below 300 mt/day of P_2O_5, see figures 3 and 6. For this reason, the minimum size phosphoric acid plant should be 300 mt/day. This is equivalent to 93,000 mt/yr of P_2O_5, which will not be enough P_2O_5 to satisfy Colombia's demands through 1980, see figure 2. A 400 mt/day plant will produce enough to satisfy the 1980 demand. If it is assumed that a 400 mt/day plant is built, the cost of production when operating at only 300 mt/day will be approximately the same as a 300 mt/day plant operating at full rate, see figure 7.

A 400 mt/day P_2O_5 phosphoric acid plant at Barrancabermeja using Sardinata rock is recommended.

Table 17

Phosphoric Acid Production Costs for Plants of Various Sizes in Colombia

Capacity, P_2O_5	200	300	400	500	600
Mt P_2O_5 per year	66,000	99,000	132,000	165,000	198,000
Plant Investment Cost	9.9	11.6	13.1	14.8	16.3
Working Capital	2.7	3.3	4.0	4.7	5.5
Total Investment	12.6	14.9	17.1	19.5	21.8
Phosphate rock, 4.0[a] tons x $30 (78% P_2O_5)	120.00	120.00	120.00	120.00	120.00
Sulfuric acid[b] 2.92 tons	80.70	76.36	72.35	70.28	68.94
SUBTOTAL	200.70	196.36	192.35	190.28	188.94
Water[c]	0.20	0.20	0.20	0.20	0.20
Steam (none--free from H_2SO_4)	-	-	-	-	-
Electricity, 200 kWh @ 0.010	1.00	1.00	1.00	1.00	1.00
Operating Supplies[d]	1.50	1.50	1.50	1.50	1.50
Operating Labor (181,000/yr)[e]	2.73	1.83	1.37	1.11	0.91
Maintenance, 5% of Investment	7.50	5.86	4.96	4.48	4.12
Taxes and Insurance, 2% of Investment	3.00	2.34	1.98	1.79	1.65
Depreciation, 6.67% of Investment	9.98	7.79	6.60	5.96	5.48
Analysis, 20% of Labor	0.55	0.37	0.27	0.22	0.18
Interest, 8% of ½ of Investment	6.00	4.69	3.97	3.58	3.30
Overhead, 100% of Labor	2.73	1.83	1.37	1.11	0.91
Subtotal	235.89	223.77	215.57	211.23	708.19
Interest on Working Capital, 8%	3.27	2.67	2.43	2.28	2.22
Production Cost	239.16	226.44	217.99	213.51	210.41
10% ROI	15.00	11.71	9.92	8.97	8.23
TOTAL PRICE, $/ton P_2O_5	254.16	238.15	227.91	222.48	218.64

[a] Based on 28% P_2O_5 in rock and 90% recovery.
[b] Based on all CaO as pure apatite.
[c] Includes cooling water and recirculated water
[d] Includes chemicals and miscellaneous
[e] 63,000 man-hours/yr at approximately $3/man-hour.
[f] Working capital based on following assumptions: (1) 15,000 mt minimum sulfur inventory at $45/mt. (2) Rock inventory, 15 days supply or 20,000 mt minimum @ $30/mt. (3) 30 days inventory of product phosphoric acid (54% P_2O_5).

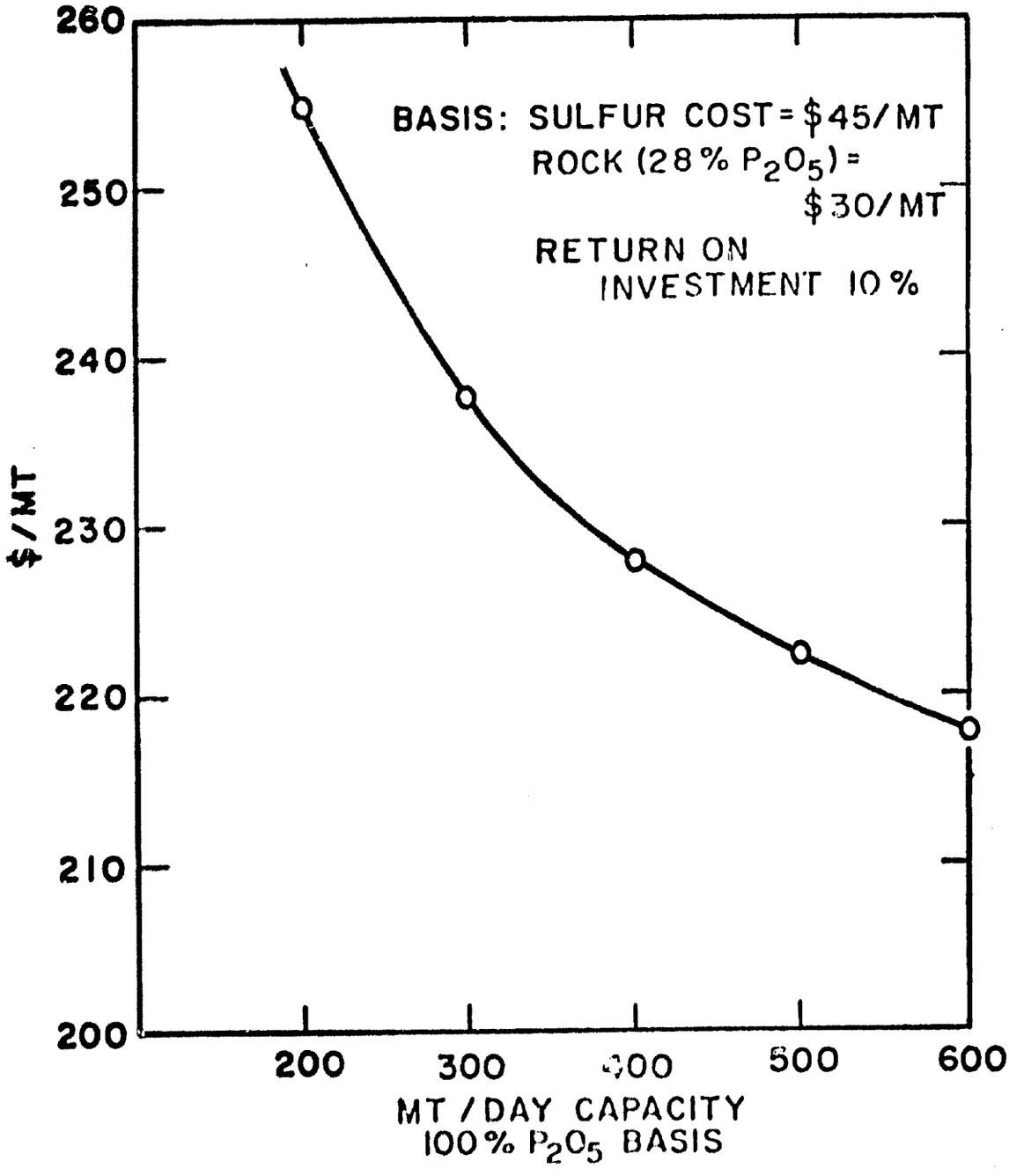

FIGURE 3

OVERALL PRODUCTION COST OF P_2O_5 IN U.S. DOLLARS

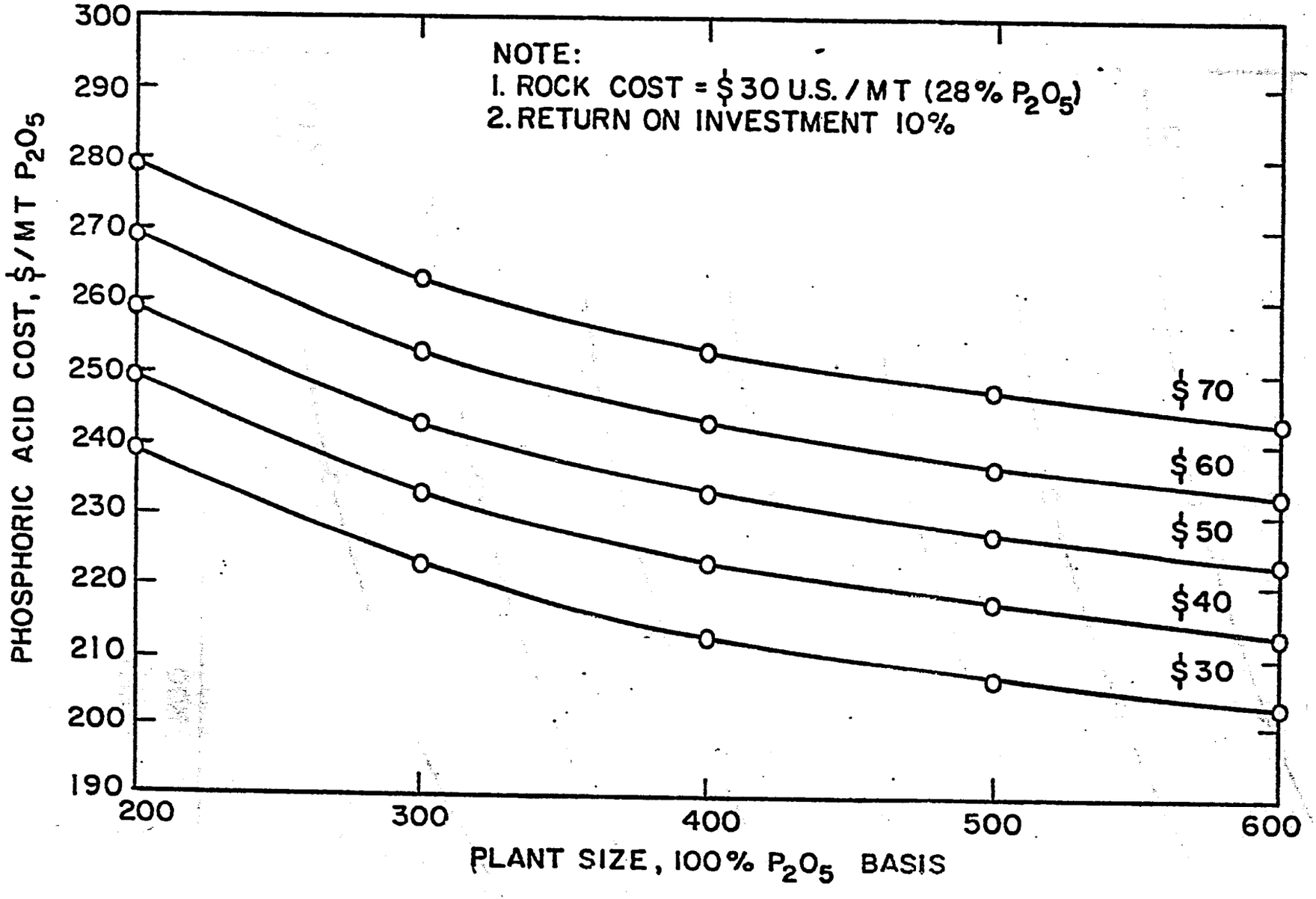

FIGURE 4

P_2O_5 COST AS A FUNCTION OF SULFUR COST AND PLANT SIZE

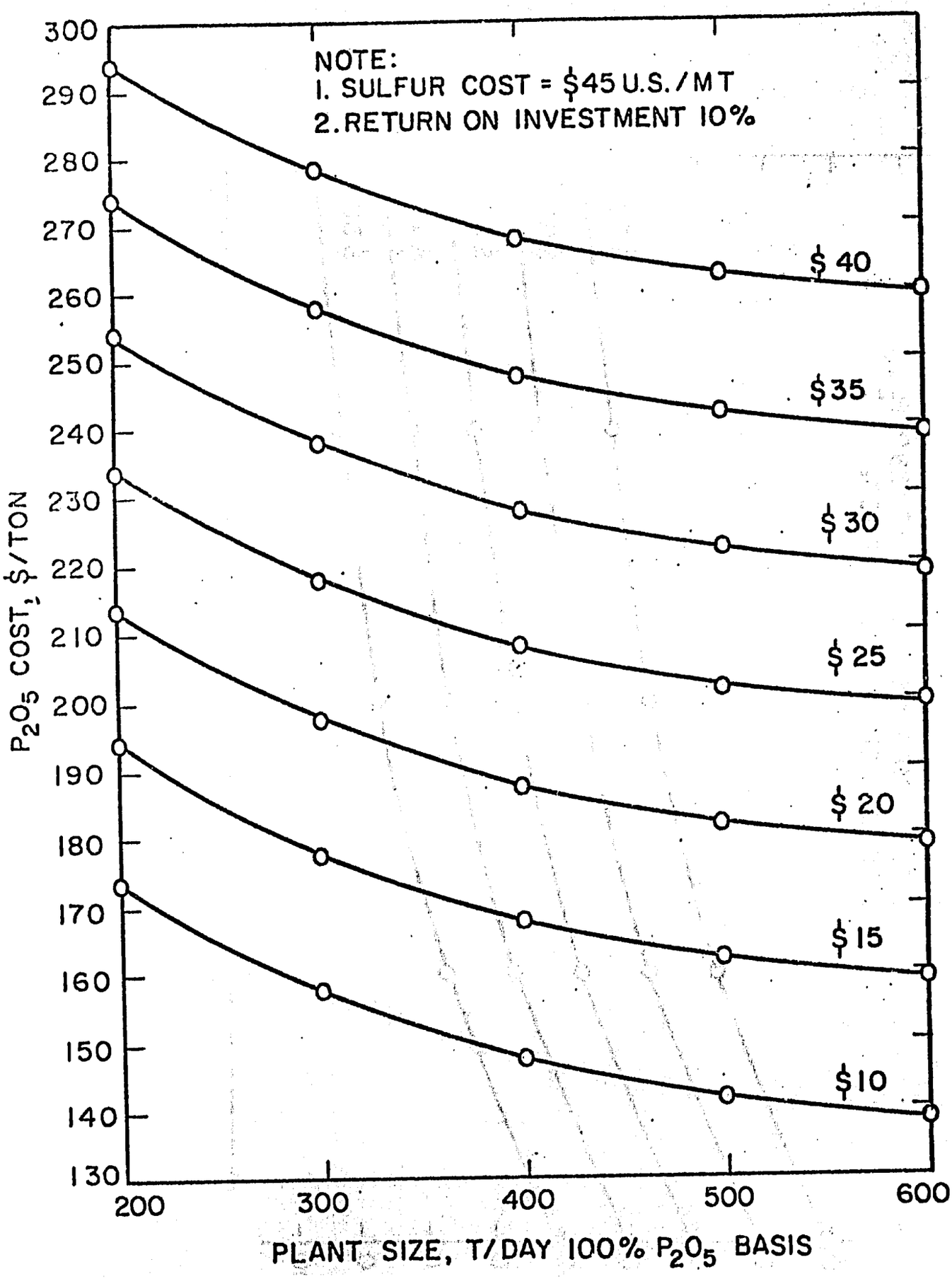

FIGURE 5

P_2O_5 COST AS A FUNCTION OF ROCK COST AND PLANT SIZE

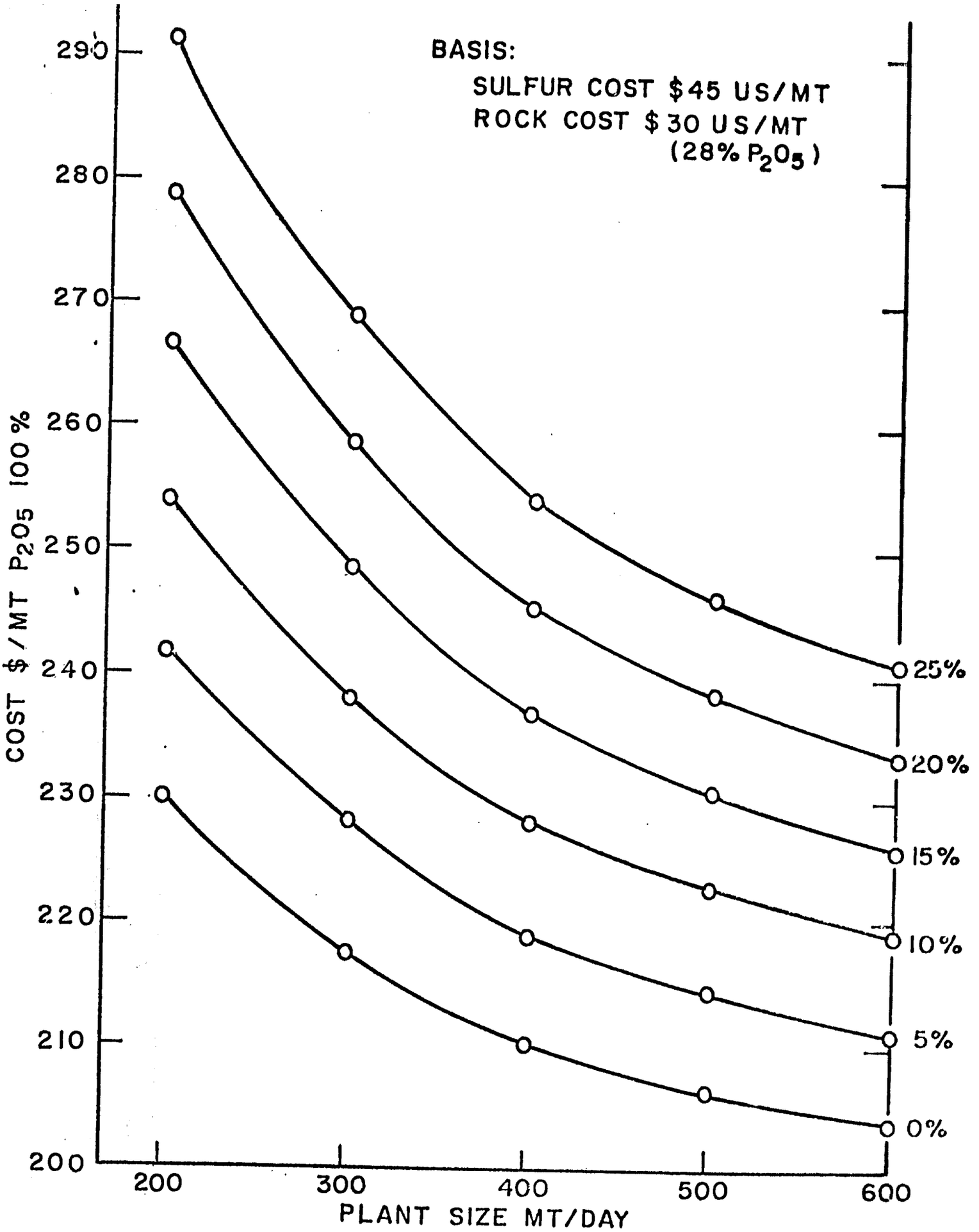

FIGURE 6

P_2O_5 COST AS A FUNCTION OF RETURN ON INVESTMENT AND PLANT SIZE

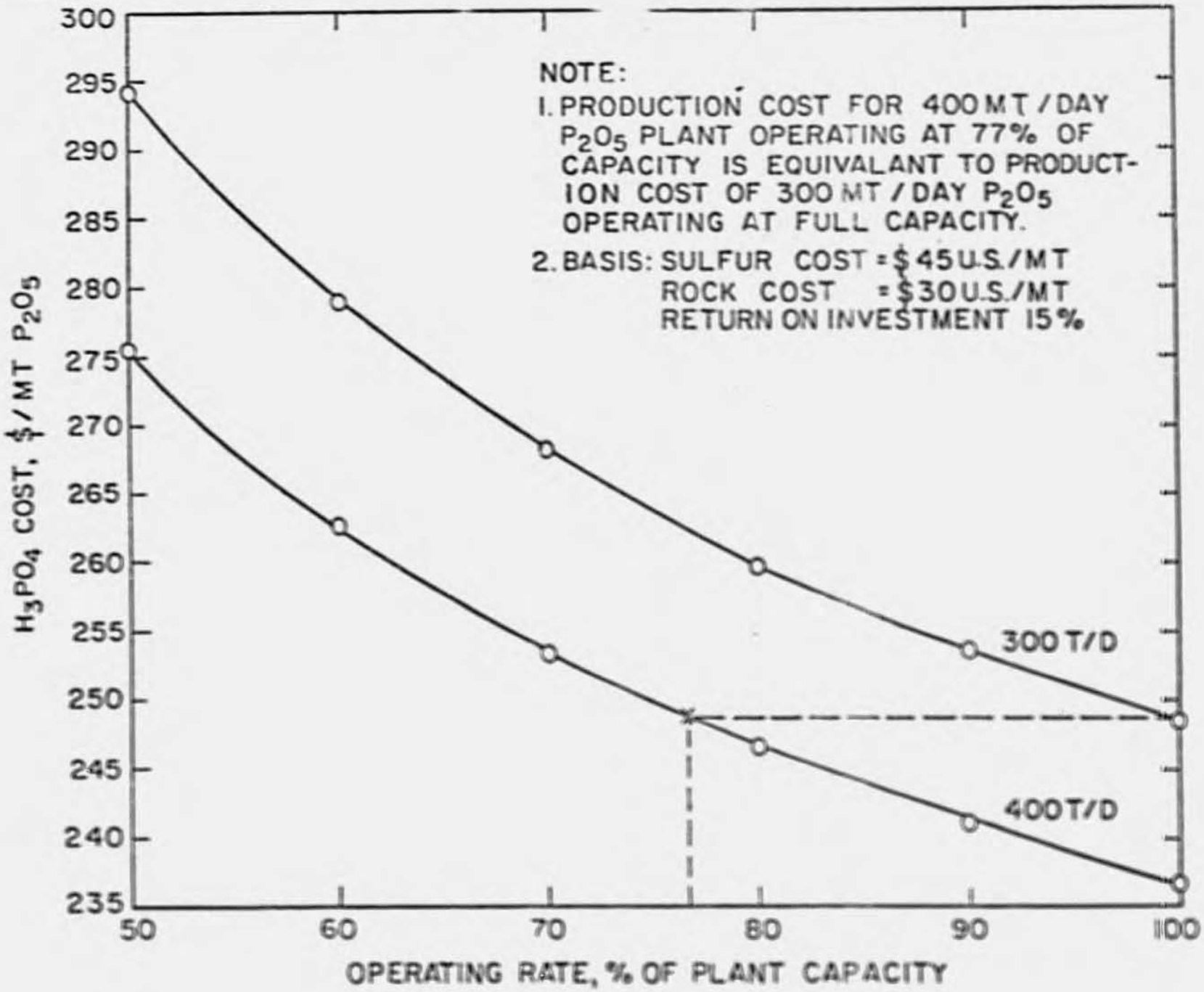

FIGURE 7

EFFECT OF THROUGHPUT [illegible] ON COST OF PRODUCING PHOSPHORIC ACID

Several commercially proven processes are available for manufacture of phosphoric acid. The most commonly used process is the dihydrate process, which is also called the Prayon process. Several engineering contractors offer this process. Names and addresses of the contractors are listed in the appendix. The process consists of: (1) reacting phosphate rock and strong sulfuric acid (98%) to form a slurry of weak phosphoric acid and gypsum ($CaSO_4 \cdot 2H_2O$), (2) filtering of the gypsum from the phosphoric acid, and (3) concentrating the phosphoric acid. The feed sulfuric acid is premixed in a tank with weak recycle phosphoric acid from the filter. The mixture of acids flows to the reactor for reaction with ground phosphate rock. The reaction is exothermic. Therefore, cooling is required to keep the slurry in the range of 75°-80°C. for gypsum formation. The rock contains fluorine, some of which is evolved from the reactor. The fumes are scrubbed with water to avoid air pollution. After the slurry is filtered to remove gypsum, the product contains about 30% P_2O_5. The gypsum filter is washed counter-currently with water to provide the weak acid used in the first step. The 30% P_2O_5 product can be used as is in a granulation facility or can be concentrated (usually in a vacuum concentrator) to the desired P_2O_5 level.

If the acid is to be shipped, the concentration is usually 54% P_2O_5. Also, the acid must be clarified before shipping because of postprecipitation of solids on standing.

The large quantities of byproduct gypsum are usually disposed of by settling in large ponds. Water from the ponds is recycled to the process.

Strong sulfuric acid (98%) for the process would be produced on site from imported sulfur. The capital cost estimates given earlier include sulfuric acid manufacturing and sulfur handling equipment. Figure 8 is a flow diagram of a sulfuric acid plant and figure 9 is a flow diagram of a wetprocess phosphoric acid plant.

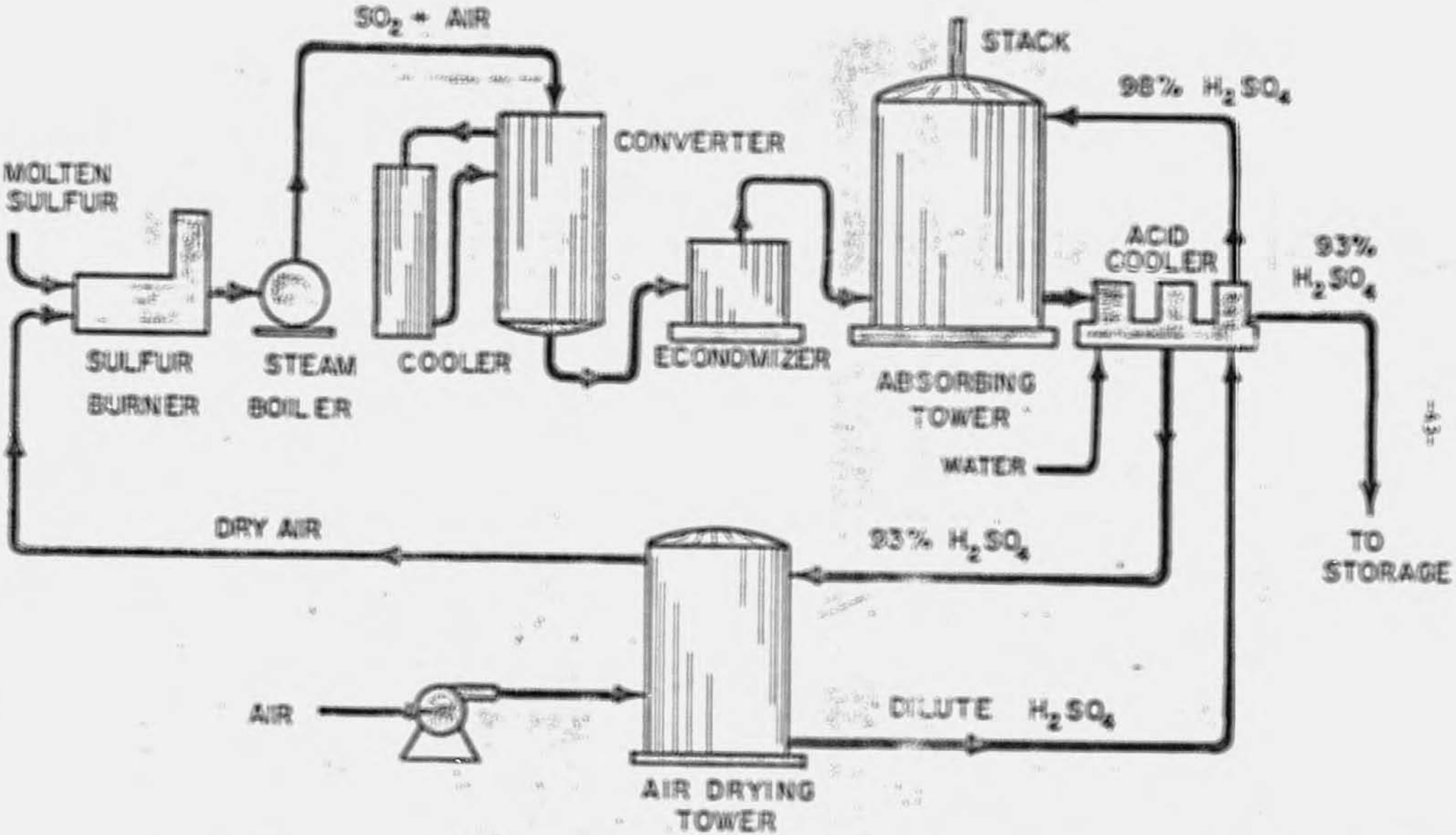

FIGURE 8

FLOW DIAGRAM OF CONTACT SULFURIC ACID PLANT

APPENDIX

List of Potential Contractors for Phosphoric Acid Plant

Davy Powergas Inc.
P.O. Box 2436
Lakeland, Florida 33803
Telephone: (813) 646-7100
Telex: 0522412

Davy-Oliver Incorporated
International Headquarters
Stamford, Connecticut 06904
Telephone: (203) 348-5811

Gulf Design Company
1052 East Memorial Boulevard
Lakeland, Florida 33801

M. W. Kellogg Company
Division of Pullman Standard
1300 Three Greenway Plaza East
Houston, Texas 77046

Swenson
Division of Whiting Corporation
Harvey, Illinois 60426

Singmaster and Breyer
235 East 42 Street
New York, New York 10017

Nissan Chemical Industries, Ltd.
Kowa-Mitsubashi Building
7-1, 3-Chome, Kanda-Mishiki-cho
Chiyoda-ku, Tokyo
JAPAN

Fisons Limited
Fertilizer Division
Harvest House, Felixstowe
Suffolk IP11 7CP
ENGLAND

Grade Formulations and Details of Variable Costs for FERTICOL

Material	$US/mt	Grade 5.20.12 T/T	Grade 5.20.12 $US/mt	Grade 6.24.8 T/T	Grade 6.24.8 $US/mt
TSP	160.00	0.458	73.28	0.549	87.84
KCl	86.00	0.211	18.15	0.140	12.04
AN	48.28	0.126	6.08	0.217	10.48
NH_3	59.95	0.010	0.60	0.010	0.60
Natural gas			0.13		0.13
Electricity			0.31		0.31
Lubricants			0.04		0.04
Bags and bagging			5.15		5.15
Total variable costs			103.74		116.59

APPENDIX

TENNESSEE VALLEY AUTHORITY
MUSCLE SHOALS, ALABAMA
35660

TVA 40 ANNIVERSARY OF PEOPLE IN PARTNERSHIP

May 31, 1974

Mr. Manuel Martinez
Abonos Colombianos, S.A.
Cartagena
COLOMBIA

Dear Mr. Martinez:

We certainly enjoyed our short visit to your facilities in Cartagena. Your staff asked us many technical questions to which we have replied in the enclosure. They also indicated that they would send a package of drawings of your nitric acid plant.

We were given samples of the Colombian phosphate rock and the residue removed daily from the reactor tanks which we lost or misplaced. Would you please send us another set of samples?

We hope the comments on the technical questions will be helpful to you.

Very truly yours,

Donald R. Waggoner
Senior Project Leader
Process Engineering Branch
Division of Chemical Development

George M. Spickard
Civil Engineer
Design Branch
Division of Chemical Development

Enclosure

COMMENTS ON QUESTIONS BY THE ABOCOL STAFF

I. General

1. Now receiving run-of-mine Colombian phosphate rock which is considerably larger than rock previously received. Must shut down once per shift to clean the unreacted rock from the reactors. What can be done to improve?

   Since the laboratory analysis shows that the unreacted rock has the same P_2O_5 content as the feed rock, the unreacted rock probably is residue from the larger particles in the feed. The only way we know to improve the situation is size reduction of the feed. This can be done with a rod mill, ball mill, or hammer mill. A rod mill or ball mill installation would probably be very expensive for your throughput requirements. We recommend purchase of a hammer mill to reduce the size to minus 5 mesh.

2. Can anything be done on a temporary basis to improve the fume scrubbers for the complex fertilizer unit? A permanent solution has been included in the expansion plans.

   Messrs. Young and Kelso made some recommendations on this in their report. We also recommend that you (1) try in-line condensation in the takeoff ducts on each side of the reaction train, and (2) replace the hollow-cone nozzles in the scrubbers with full cone nozzles.

3. Can contaminated wash water be stored in a pond or something similar? What are some recommendations?

Contaminated wash water from the various production units should be pumped to a lagoon for storage and evaporative disposal. The lagoon should be located above ground or a dike constructed to prevent entrance of surface water. A lining impervious to water must be furnished. This may consist of a layer of clay 6 inches (150 mm) thick if a deposit of impervious clay is reasonably accessible. If clay is not available, a liner of synthetic rubber or plastic specified to be resistant to the contaminants is recommended.

Size of lagoon depends on the quantity of material to be disposed of, annual rainfall, and rate of evaporation. This information should be available in Cartagena and calculation of lagoon size and depth made locally. Since the quantity is known to be relatively small, it is recommended that a somewhat larger than calculated lagoon be constructed to allow for errors in estimation of parameters and for future expansion.

II. Ammonia Unit

1. What about corrosion inhibitors for MEA?

Corrosion inhibitors for use in MEA are a fairly recent development. Several plants are using them and are pleased with the results. Some are using arsenate compounds and maintain a concentration of 25 ppm of arsenic. However, there are safety hazards involved with the use of arsenic and most companies use the inhibitor marketed by Union Carbide. This requires entering into a secrecy agreement with Union Carbide. We suggest that you contact them for details.

2. What are the advantages of preheating air to the secondary reformer and how can it best be done?

Preheating of the air to the secondary reformer allows shifting of some of the load from the primary reformer to the secondary reformer, thereby increasing the capacity of the primary reformer. The upper limit to prevent overheating of the top portion of the secondary reforming catalyst is about 900° F. You could install heating surface in the convection section of the primary furnace just upstream of the ID fan. This would heat the air to around 400° F. The furnace previously used to preheat natural gas for desulfurization could be used to finish preheating of the air.

Also some of the lower level heat wasted to the stack could be recovered by preheating the feed gas and/or boiler feed water.

3. What can be done to recover activity from the dust-covered catalyst in the high-temperature shift converter?

Some activity can be temporarily recovered by back blowing the bed with gas. However, the catalyst will still require changing. Also we recommend that you consider changing the second stage from high temperature to low temperature shift catalyst. You probably can get Girdler Catalyst, Inc., to help with the evaluation of such a change. Some of the changes required in the heat balance were discussed with the staff. We also discussed a method of keeping cost data on the LTS catalyst and deciding when to change.

4. How can the synthesis compressor capacity be increased?

If there are limiting factors in the compressors and not the drives, extensive changes such as liners, new cylinders, etc., could be required. The compressor manufacturer would be in the best position to advise. However, if the drives are the limiting factor, an additional 10 to 15% capacity can be obtained by cooling the motor windings. Use of an enclosed hood equipped with cooling coils over each driver is recommended. As a side result, clean air will be in contact with the windings which will greatly reduce the frequency of cleaning. Absorption-type refrigeration units using a waste source of low-pressure steam usually work well in this application.

5. Please send information on the continuous on-stream analyzers in the TVA ammonia unit.

The TVA ammonia unit has the following continuous analyzers:

Model 200 Lira analyzer, analyzes 0-50 ppm CO exit methanator

Model 200 Lira analyzer, analyzes 0-50 ppm CO_2 exit methanator

Model 300 Lira analyzer, analyzes 0-4.0% CO exit contactor

Model 300 Lira analyzer, analyzes 0-1.5% CO_2 exit contactor.

Model 300 Lira analyzer, analyzes methane. This is a dual-range instrument 0-1.5% methane content exit primary reformer 0-1.5% methane content exit secondary reformer.

They are MSA Lira infrared analyzers. You can obtain information by writing to: Mine Safety Appliance Company

Technical Products Division

201 North Braddock Avenue

Pittsburgh, Pennsylvania 15208

6. What are the possibilities of using ammonia recovery unit tail gases in the primary reformer for fuel?

This is standard practice in most ammonia plants. A method should be provided for venting the gas in case of upsets in the ammonia recovery system. If the ammonia concentration exceeds 500 ppm, carbamate will form in the control valves and give problems.

III. Nitric Acid Unit

1. An expansion of the nitric acid unit will be required when the complex fertilizer unit is expanded. How can this best be done?

Assuming that there are no other bottlenecks, an increase in air capacity will provide a substantial increase. This can be done by obtaining bleaching air from some other source and putting all of the Brown-Bavari discharge across the gauze. It may be necessary to add additional gauze. Also, you could change to "Random Pack" gauze and even reduce gauze requirements. Those using Random Pack have reported up to one-third reduction in requirements. Your gauze supplier should be able to give you the required information.

Another way to obtain additional air is to raise the suction pressure by installing a blower in the suction line. Of course, you will need to obtain recommendations on this from the compressor manufacturer.

We are aware of a similar nitric acid unit operating at 112 pounds compressor discharge pressure with an absorber 10 feet 6 inches which is producing 360 short tons per day of 100% nitric acid. The tower contains 34 absorption trays and 2 bleacher trays. Perhaps you can use these data for judging the capacity of your absorber.

2. How can the overall efficiency of the unit be improved?

One way is to minimize the frequency of shutdowns required because of lack of demand for nitric acid. In our opinion, it would be better to run at reduced rates than to run at high rates and have frequent shutdowns. Thermal shock to equipment is severe during startup and shutdown of nitric acid plants. This is particularly true in the converter-reheater section. Judging from the stack losses, there is probably a leak now in the reheater tube bundle. This can be tested by running samples of the tail gas before and after the reheater.

Mr. Homer Graham of TVA talked to some of your staff members when they visited here concerning the airlift for refluxing weak acid. It is possible that the airlift is not working properly which would flood weak acid into the strong acid. As a natural reaction, absorption water would be reduced thereby decreasing absorption and increasing losses. Installation of a recycle pump to replace the airlift is recommended.

3. After pickling the gauze, conversion is good for a few days and then falls off rapidly. Why?

The first point to check is the pickling procedure. Carefully follow the procedure recommended by C and I/Girdler. After determining that the pickling procedure is correct (it probably is since conversion is good immediately following pickle), look for sources of poison. These could be iron oxide in the air and NH_3 streams and/or oil in the ammonia stream. Primary ammonia (oil free) only should be used in the acid plant. Oil filters usually do not do an acceptable job in removing oil to the level required. Magnetic separators are available for removing iron oxide from the ammonia and air streams. The March 1974 issue of Chemical Engineering Progress (Vol. 70, No. 3) contains a discussion of the use of magnetic separators. One of the authors is Dr. G. R. Gillespie with Englehard Industries, Maury Hill, New Jersey. We suggest that you write directly to Dr. Gillespie concerning magnetic separators and Random Pack gauze.

If you wash your air intake filters regularly, do not use standard detergents. Phosphates in the detergent can be a serious source of poison to the platinum gauge.

In addition to these questions, several other items were discussed. Among them was a test for determining the bottlenecks in the unit and the benefit of additional air. Since the ammonia plant is not using all the air available, air could be sent to the acid unit through the line already available. This possibility was suggested by Mr. Van Zelm. We suggest that the air first be submitted for the bleaching air.

We also discussed the necessity for being extremely careful not to lose platinum when removing the reheater bundle or any equipment from the waste heat boiler upstream to the gauze. The piece of equipment should be encapsulated with polyethylene during remo and cleaned thoroughly with brushes and a vacuum cleaner. Waste heat boilers usually are loaded with platinum particularly after long periods of service. The tubes should be rodded out and all the residue saved for platinum recovery.

4. What about recent developments in stack cleanup devices?

We are sending a copy of a paper entitled "Control of Nitrogen Oxide Emission from Nitric Acid Plants" by J. C. Barber and H. L. Faucett.

IV. Urea Unit

1. Pressures are higher than design in the low-pressure decomposition and absorption sections. Also, ammonia losses are high. Why?

After looking at chemical analyses of the recycle solution and at process conditions, it is evident that the carbamate system contains excessive amounts of carbamate. This means that the conversion in the reactor is low. Returning the reactor to design pressure and the $NH_3:CO_2$ mole ratio to at least 3.5 (preferably 3.7) should increase the conversion, lower the carbamate in the recycle system, lower pressures in the gas systems, and reduce ammonia losses. Also, the only benefit from operating the first-stage high-pressure decomposer at 350 psig is shifting of some of the decomposition from the second stage to the first stage. Since the heat exchanger on the second stage has been repaired, we recommend going back to 500 psig

on the first stage. In our opinion, the problems in the low-pressure section and the absorbent tank are a direct result of imbalance in the process. Although more CO_2 can be pushed through the compressors at lower reactor pressure, conversion is lower and ammonia consumption is higher. Process conditions must be balanced against both production rate and losses.

Consideration should be given to increasing CO_2 compression by raising the suction pressure. This can be accomplished by raising stripper back pressure in the ammonia unit or installing a blower in the suction line.

2. Corrosion rates are high in the high-pressure decomposers including the rupture disks and instrumentation diaphragms. The decomposers and rupture disks are 316L stainless steel and the instrumentation diaphragms are titanium. Does TVA have any experience with these problems?

   Materials of construction in the TVA urea plant are the same and corrosion has not been a problem. However, we do inject air into the bottom of the high-pressure decomposer and the CO_2 suction line for oxygen passivation of the metal surfaces. Also the diaphragms are flushed with condensate.

3. Lifting of relief valves on the discharge of the high-pressure NH_3 and carbamate pumps is a problem.

   Installation of a dip tube in the reactor will provide a gas cushion at the top and help to dampen pulsations. Also most plants have pulsation dampeners on the pump discharges.

4. What can be done to prevent buildup of urea on the hopper section at the bottom of the prill tower?

The hopper surfaces can be coated with spray-on Teflon which will minimize the buildup but will not prevent it. A very simple and effective method is to fabricate the tower hopper from rubber conveyor belting and then use a wooden mallet occasionally to hit the belt and flex it so the buildup will fall off.

5. What would be the best way to install additional spray heads in urea prill tower.

This is a piping change which we feel can best be worked out there. One possible method is to enlarge the diameter of the bottom of the head tank to allow room for additional sprays to be installed.

6. There is a problem of mist carryover from the urea evaporator. The present mist eliminator is a baffled pipe arrangement. How can this be improved?

One method would be to install a Chevron-type eliminator in the offtake pipe. The offtake pipe should be sloped upward and the eliminator installed on a slant to provide for drainage back into the evaporator. The eliminator should be sized such that the velocity is no less than 5 feet per second and no more than 10 feet per second. The angles should be 90-degree sharp bends and the vanes should be spaced 1-1/2 inches apart.

If you decide to install a Chevron mist eliminator, write to us and we will try to contact vendors who could do the fabrication.

7. What do you recommend for vari-drive units for the carbamate and ammonia pumps? Do you recommend constant speed with pressure kickback valves?

We do not recommend constant speed pumps with pressure kickback. This is a very severe service and the kickback valves are a constant source of maintenance problems. Our vari-drive units are the eddy current clutch type. They are watercooled. They have given excellent service.

In addition to attempting to answer your questions, we would like to offer a suggestion concerning the urea finishing operation. We question the need for the very low biuret content that is produced by the crystallisation and remelt route. It has been our observation that urea with acceptable levels of biuret can be produced by simply concentrating to a melt and prilling the melt. Therefore, it is recommended that you give serious consideration to modifications to permit direct prilling without crystallisation and remelt. Such a modification would greatly simplify the finishing operation and could also reduce the amount of water recycled to the reactor.